RSG INC.
ENVIRONMENT, ENERGY, & ACOUSTICS

Noise Modeling Study for Canton Wind Farm

Canton, Maine

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DATA ■ ANALYSIS ■ SOLUTIONS

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1. INTRODUCTION

Patriot Renewables is proposing to develop the Canton Mountain Wind project (CMW), a wind energy facility on Canton Mountain in Canton, Maine.

This report is an update to the December 2011, "Noise Impact Study for Canton Mountain Wind Farm," a March 2012 revision and a May 2012 Addendum "Siemens SWT 3.0 113 Sound Modeling Results for Canton Mountain, all prepared by RSG. The December 2011 report was based on a project consisting of seven GE 2.75-103 2.75 MW turbines and one GE 2.75-100, with 103 and 100-meter rotors respectively. The May 2012 Addendum was based on a project consisting of eight Siemens SWT 3.0-113 3.0 MW turbines.

This report is updated to show compliance with the wind power-specific noise regulations adopted in 2012 and contained in Chapter 375.10(I) of DEP rules. This report includes two turbine layouts – eight GE 2.85-103 2.85 MW turbines, and eight Siemens SWT 3.0-113 3.0 MW turbines.

To support these turbines, Patriot Renewables is also proposing the installation of a second 34.5/115 kV transformer at the substation approximately 1.5 miles to the southwest of the project area.[1] This noise modeling report predicts the wind turbine and transformer sound levels in the area surrounding the project.

With this revised report, we are assessing CMW's compliance with a 42 dBA nighttime sound limit at applicable protected locations, as ordered on March 5, 2013 by the Maine Supreme Court for the Saddleback Ridge Wind Project. The report also updates the list of participating properties.

The report includes:

1) A description of the project site
2) A noise primer
3) A discussion of noise issues specific to wind turbines
4) A discussion of applicable noise limits
5) The results of computer propagation modeling
6) A summary and conclusions

2. PROJECT AREA

The proposed turbines would be located in the Town of Canton in Oxford County, Maine (Figure 1). The area is mountainous and consists largely of forested areas. Canton Point Road runs 2,300 meters (7,550 feet) to the southwest of the project. Route 108 also runs to the southwest of the

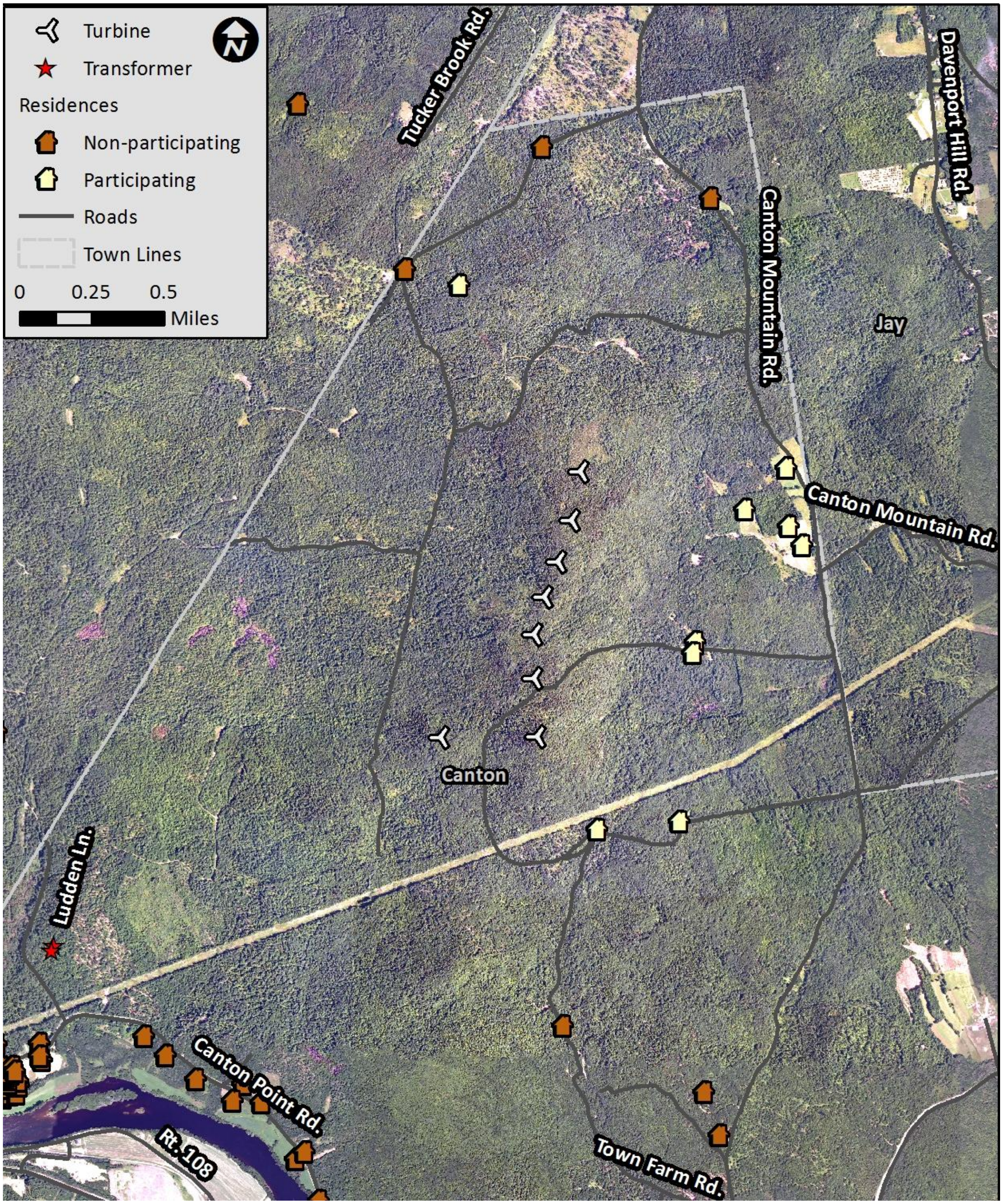
[1] This substation and one 34.5/115 kV transformer will be built for the Saddleback Ridge Wind project; however, the entire substation facility is modeled in this sound study in order to evaluate cumulative impacts.

project, 2,800 meters (9,200 feet) distant and across the Androscoggin River. Davenport Hill Road runs 2,300 meters (7,550 feet) to the northeast of the project. The proposed turbines are located along the Canton Mountain ridgeline, which runs roughly north to south through the project area.

The distance between the turbines and the closest non-participating residence to the south of the turbine array is approximately 1,600 meters (5,250 feet). The closest non-participating residence to the northwest is approximately 1,500 meters (4,900 feet).[2]

[2] Distances are from the residence to the nearest turbine base.

Figure 1: Project Area



3. A Noise Primer

3.1 What is Noise?

Noise is defined as "a sound of any kind, especially when loud, confused, indistinct, or disagreeable."[3] Passing vehicles, a noisy refrigerator, or an air conditioning system are sources of noise which may be bothersome or cause annoyance. These sounds are a part of generally accepted everyday life, and can be measured, modeled, and, if necessary, controlled.

3.2 How is Sound Described?

Sound is caused by variations in air pressure at a range of frequencies. Sound levels that are detectable by human hearing are defined in the decibel (dB) scale, with 0 dB being the approximate threshold of human hearing, and 135 dB causing pain and permanent damage to the ear. Figure 2 shows the sound levels of typical activities that generate noise.

The decibel scale can be weighted to mimic the human perception of certain frequencies. The most common of these weighting scales is the "A" weighting, and this scale is used most frequently in environmental noise analysis. Sound levels that are weighted by the "A" scale have units of dBA or dB(A).

To account for changes over time, a weighted average sound level called the "equivalent continuous" sound level (Leq) is often used. Leq averages sound pressure rather than decibels, and results in weighting the levels of loud and infrequent noises more heavily than quieter and more frequent noises. For example, a train passing by for one minute out of an hour could produce sound levels around 90 dBA while passing by, but the equivalent continuous sound level for the entire hour would be 72 dBA, if sound levels were 0 dBA for the rest of the hour. In comparison, the arithmetic decibel average for the hour would be 1.3 dB. This is due to the logarithmic relationship between sound pressure levels (in dB) and sound pressure fluctuations (in Pascals). Even though there is a 90 dB difference between 0 and 90 dBA, the sound pressure fluctuation at 90 dBA is 32,000 times greater than at 0 dBA. Consequently, averaging sound pressure fluctuations (as in an equivalent sound level) instead of the sound pressure level, weights loud infrequent sounds more heavily than continuous quieter sounds. The equivalent average sound level is often used in environmental noise analysis.

3.3 What is the Difference between Sound Pressure Levels and Sound Power Levels?

Both sound power and sound pressure levels are described in terms of decibels, but they are not the same thing. Sound power is a measure of the acoustic power emitted or radiated by a source. The sound power level of a source does not change with its surrounding conditions.

[3] "The American Heritage Dictionary of the English Language," Houghton Mifflin Company, 1981.

Figure 2: Basic Theory: Common Sounds in Decibels

Perception	Occupational Noise Measured at the ear	Everyday Noise	Transportation Noise	Decibels (dBA)
			Near a jet engine	140
Threshold of Pain				
				130
		Hard Rock Band		120
	Chainsaw			110
	Table saw Circular saw Bandsaw Impact Wrench		Auto horn at 10 feet	100
	Electric hand drill			
			Snowmobile	
		Riding lawn mower, at ear		90
			Street Sweeper	
		Shop-vac, at ear, outdoors	Truck passby, 60 mph at 50 feet	
			Inside car, windows open, 65 mph	80
			Truck passby, 30 mph, at 50 feet	
		Vacuum cleaner, at ear		
		Playground recess (avg)	Inside car, windows closed, 65 mph	70
			Car passby, 30 mph, at 50 feet	
Urban Area Conversational Speech		TV in quiet room		60
		Microwave oven at 2.5 feet	Car passby, 30 mph, at 100 feet	
		Field with Insects	Idling car at 50 feet	50
Suburban area	Office, with computer and HVAC			
		Refrigerator at 3 feet		40
		Library		
Quiet rural area, no wind, insects or traffic				30
Quiet winter night, wilderness area, no insects, traffic or wind				20
				10
Threshold of audibility at 1000 Hz				0

Range (dBA)	Description
110–140	Deafening
90–100	Very Loud
60–80	Loud
45–60	Moderate
25–45	Faint
0–25	Very Faint

Sound pressure level is observed at a specific location and is related to the difference in air pressure above or below atmospheric pressure. This fluctuation in air pressure is a result of the sound power of a source, the distance at which the sound pressure level is being observed, and the characteristics of the path and environment around the source and receiver. When one refers to sound level, they are generally speaking of the perceived level, or sound pressure level.

For example, a coffee grinder will have the same sound power whether or not it is grinding indoors or outdoors. The amount of sound the coffee grinder generates is always the same. However, if you are standing six feet away from the coffee grinder indoors, you would experience a higher sound pressure level than you would if you were six feet away from the coffee grinder outdoors in an open field. The reason for this is that the sound being emitted from the coffee grinder would bounce off walls and other surfaces indoors which would cause sound to build up and raise the sound pressure level.

Sound power cannot be directly measured. However, since sound pressure and sound power are related, sound power can be calculated by measurements of sound pressure and sound intensity. It can be helpful to note that over soft ground outside, the sound pressure level of a small source observed 50 feet away is roughly 33 dB lower than its sound power level.

3.4 How is Sound Modeled?

The decibel sound level is described on a logarithmic scale. One manifestation of this is that sound *power* increases by a factor of 10 for every 10 dB increase. However, for every 10 dB increase in sound pressure, we *perceive* an approximate doubling of loudness. Small changes in sound level, below 3 dB, are generally not perceptible.

For a point source, sound level diminishes or attenuates by 6 dB for every doubling of distance due to geometrical divergence. For example, if an idling truck is measured at 50 feet as 66 dBA, at 100 feet the level will decline to 60 dBA, and at 200 feet, 54 dBA, assuming no other influences. From a line source, like a gas pipeline or from closely spaced point sources, like a roadway or string of wind turbines, sound attenuates at approximately 3 dB per of doubling distance. These “line sources” transition to an attenuation of 6 dB per doubling at a distance of roughly a third of the length of the line source.

Other factors, such as intervening vegetation, terrain, walls, berms, buildings, and atmospheric absorption will also further reduce the sound level reaching the listener. In each of these, higher frequencies will attenuate faster than lower frequencies. Finally, the ground can also have an impact on sound levels. Harder ground generally increases and softer ground generally decreases the sound level at a receiver. Reflections off of buildings and walls can increase broadband sound levels by as much as 3 dB.

If we add two equal sources together, the resulting sound level will be 3 dB higher. For example, if one machine registers 76 dBA at 50 feet, two co-located machines would register 3 dB more, or 79 dBA at that distance. In a similar manner, at a distance of 50 feet, four machines, all operating at the same place and time, would register 82 dBA and eight machines would register 85 dBA. If the two sources differ in sound level then 0 to 3 dB will be added to the higher level as shown in Table 1.

Table 1: Decibel Addition

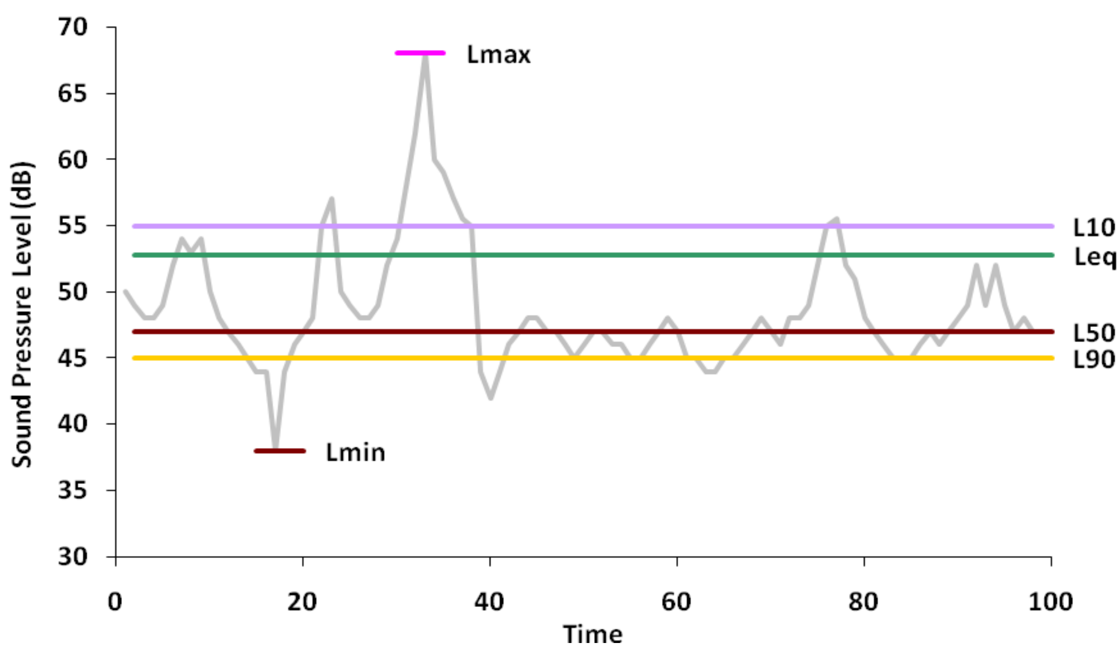
If Two Sources Differ By	Add
0-1 dB	3 dB
2-4 dB	2 dB
5-9 dB	1 dB
>9 dB	0 dB

3.5 Description of Terms

Sound can be measured in many different ways. Perhaps the simplest way is to take an instantaneous measurement, which gives the sound pressure level at an exact moment in time. The level reading could be 62 dB, but a second later it could 57 dB. Sound pressure levels are constantly changing. It is for this reason that it makes sense to describe noise and sound in terms of time.

The most common ways of describing noise over time is in terms of various levels. Take as an example, the sound levels measured over time shown in Figure 3. Instantaneous measurements are shown as a ragged grey line. The sound levels that occur over this time can be described verbally, but it is much easier to describe the recorded levels statistically. This is done using a variety of "levels" which are described below.

Figure 3: Example of Noise Measurement over Time and Descriptive Statistics



3.5.1 Equivalent Average Sound Level - Leq

One of the most common ways of describing noise levels is in terms of the continuous equivalent sound level (Leq). The Leq is the average of the sound pressure over an entire monitoring period and expressed as a decibel. The monitoring period could be for any amount of time. It could be one second ($Leq_{1\text{-sec}}$), one hour ($Leq_{(1)}$), or 24 hours ($Leq_{(24)}$). Because Leq describes the average pressure, loud and infrequent noises have a greater effect on the resulting level than quieter and more frequent noises. For example, in Figure 3, the median sound level is about 47 dBA, but the equivalent average sound level (Leq) is 53 dBA. Because it tends to weight the higher sound levels and is representative of sound that takes place over time, the Leq is the most commonly used descriptor in noise standards and regulations.

3.5.2 Percentile Sound Level - Ln

Ln is the sound level exceeded *n* percent of the time. This type of statistical sound level, also shown in Figure 3, gives us information about the distribution of sound levels over time. For example, the L10 is the sound level that is exceeded 10 percent of the time, while the L90 is the sound level exceeded 90% of the time. The L50 is exceeded half the time. The L90 is a residual base level which most of the sound exceeds, while the L10 is representative of the peaks and higher, but less frequent levels. When one is trying to measure a continuous sound, like a wind turbine, the L90 is often used to filter out other short-term environmental sounds that increase the level, such as dogs barking, vehicle passbys, wind gusts, and talking. That residual sound, or L90, is then the sound that is occurring in the absence of these noises.

3.5.3 Lmin and Lmax

Lmin and Lmax are simply the minimum and maximum sound level, respectively, monitored over a period of time.

4. NOISE STANDARDS

Canton Mountain Wind falls under the regulatory jurisdiction of the Maine Department of Environmental Protection (DEP), which has set out its regulations for noise in Control of Noise, Chapter 375.10. Generally speaking, commercial, industrial, and other non-residential areas are subject to hourly equivalent average $Leq_{(1)}$ sound level limits of 70 dBA in the daytime (7am to 7pm) and 60 dBA during the night (7pm to 7am).

Under the DEP standards that were in effect at the time the project applied for a permit from DEP, quiet areas were subject to hourly sound level limits of 55 dBA during the day (7am to 7pm) and 45 dBA during the night (7pm to 7am). A recent order from the Maine Supreme Court relating to the Saddleback Ridge Wind project lowered the nighttime standard applied to that permitted but unconstructed wind project to 42 dBA. Since the Canton Mountain Wind project is also permitted but not yet constructed, it is prudent to evaluate CMW against a limit of 55 dBA day and 42 dBA night $LAeq_{(1\text{-hour})}$.

The new DEP noise rules also changes the way various penalties are applied to the overall sound levels of wind power projects that emit certain tonal and short duration repetitive sounds.

5. SOUND LEVELS PRODUCED BY WIND TURBINES

5.1 Standards Used to Measure Wind Turbine Sound Emissions

A manufacturer of a wind turbine must test its turbines using two international standards:

1. International Electrotechnical Commission standard IEC 61400-11, "Wind Turbine Generator Systems – Part 11: Acoustic Noise Measurement Techniques"
2. International Electrotechnical Commission standard IEC 61400-14, "Wind Turbine Generator Systems – Part 14: Declaration of Apparent Sound Power Level and Tonality Values"

These standards provide sound power emission levels from a turbine, by wind speed and frequency. They also provide a confidence interval around the mean sound power level.

5.2 Manufacturer Sound Emissions Estimates

The project proposes to use eight GE 2.85-103 2.85 MW wind turbines with hub heights of 85 meters or eight Siemens SWT 3.0-113 3.0 MW turbines with hub heights of 79.5 meters. To support these turbines, a 34.5/115 kV transformer will also be installed in a substation located about 1.5 miles southwest of the project. This transformer will join an existing 34.5/115 kV transformer that will be built for the Saddleback Ridge Wind project. Sound emissions from both transformers were modeled to determine the cumulative impact.

Sound emissions from a wind turbine are measured as sound *power.* This is different from the sound *pressure* that one measures on a sound level meter. Sound *power* is the acoustical energy emitted by an object, and sound *pressure* is the measured change in pressure caused by acoustic waves at an observer location.

The sound *power* level from a GE 2.75/2.85-103 wind turbine[4] is 105 ± 2 dBA, with wind speeds of 7 m/s and greater (10-meter anemometer height) (Appendix C). The modeled levels in this report are 108 dBA, calculated by adding the manufacturer's sound power uncertainty of 2 dB and modeling uncertainty of 1 dB. The octave band sound power levels are shown in Table 2.

The sound *power* level from a Siemens SWT 3.0-113 3.0 MW wind turbine is 105.5 ± 1.5 dBA, with wind speeds of 7 m/s and greater (10-meter anemometer height). The modeled levels in this report are 108 dBA, calculated by adding the manufacturer's uncertainty factor of 1.5 dB to a 1 dB factor for modeling uncertainty. The octave band sound power levels are shown in Table 2.

[4] Although the CMW project proposes to use eight GE 2.85-103 turbines, the sound power levels are identical for the GE 2.75-103 and GE 2.85-103 wind turbines, so they are referred to collectively as GE 2.75/2.85-103 turbines for the purposes of sound modeling.

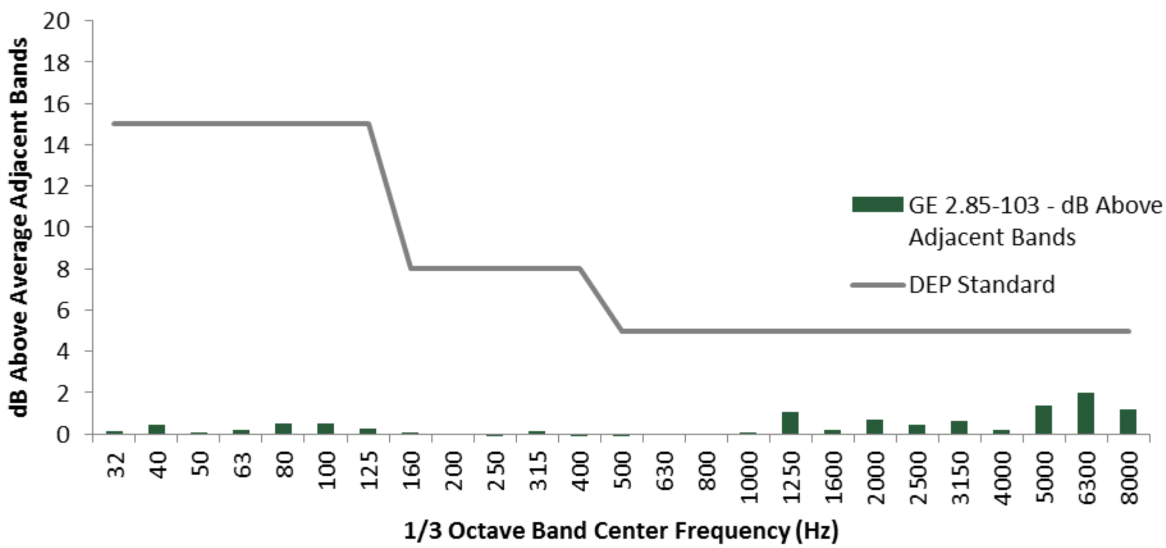
For the GE 2.75/2.85-103, no 1/3 octave band exceeds the Maine DEP definition of tonal noise (Figure 4). Siemens does not provide 1/3 octave band data above 160 Hz for the SWT 3.0-113 turbine. However, Siemens warrants that this turbine will not emit tonal sound according to Maine DEP definitions, irrespective of wind speed. Figure 5 shows the tonality of the Siemens turbine from 25 to 160 Hz.

Sound power for the modeled 34.5/115 kV transformer is taken from RSG's measurement of a similar transformer that is located at Vermont Electric Power Company, Inc.'s Vergennes substation. While the spectrum of the transformer sound power is tonal in the 125 Hz, 250 Hz, and 500 Hz 1/3 octave bands (which is a common trait of virtually all power transformers) (Figure 6), the combined spectrum from the turbines and transformers will not be tonal. Modeling shows that both when the wind turbines are operating along with the transformers and when only the transformers are operating alone sound levels at the closest residence to the substation (Residence 45) will be below 42 dBA, even with a 5 dB penalty for tonal sound (Figure 10, Figure 11, and Table A1). Furthermore the combined sound levels of the transformers and project turbines will not exceed the Maine DEP tonality definition in any 1/3 octave band (Table 3).[5] Note that Table 3 uses unweighted (dBZ) sound levels in accordance with the DEP tonality rules. The resulting analysis shows that no tonal penalty is warranted.

Table 2: Mean Spectral Sound Power Levels (dB)[6]

Sound Source	Nominal Sound Power (dBA)	Modeled Sound Power (dBA)	Octave Band Center Frequency								
			31.5 Hz	*63 Hz*	*125 Hz*	*250 Hz*	*500 Hz*	*1 kHz*	2 kHz	*4 kHz*	*8 kHz*
GE 2.75/2.85-103	105.0	108.0	81	90	95	95	96	100	100	91	72
Siemens SWT 3.0-113	105.5	108.0	79	92	94	98	98	99	99	95	86
34.5/115 kV Transformer	93.0	93.0	35	52	90	81	86	86	75	68	55

Figure 4: Comparison of 1/3 Octave Band Sound Power for the GE 2.75/2.85-103 with Maine DEP Tonal Noise Definition



6 Modeled sound power levels are shown in Table B1

Figure 5: Comparison of 1/3 Octave Band Sound Power for the Siemens SWT 3.0-113 with Maine DEP Tonal Noise Definition

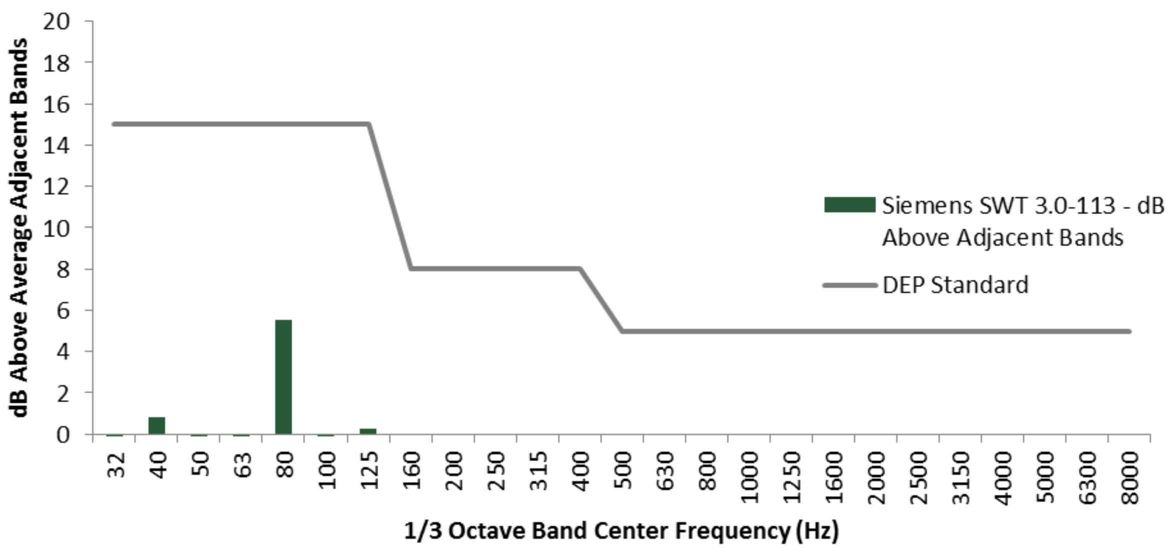


Figure 6: Comparison of 1/3 Octave Band Sound Power for the Transformer with Maine DEP Tonal Noise Definition

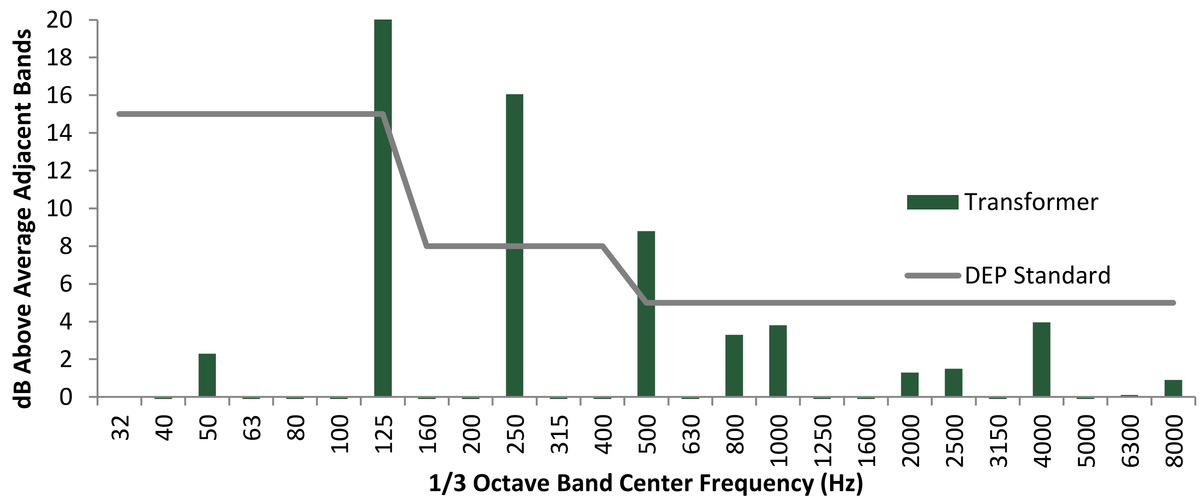


Table 3: Transformer Tonality Analysis Results at Closest Residence to Substation (520 meters or 1800 feet away) with the GE 2.75/2.85 – 103 Turbine[7]

1/3 Octave Band Center Frequency (Hz)	Residence 45					
	Transformers Only Sound Level (dBZ)	Turbines Only Sound Level - GE 2.75/2.85 (dBZ)	Combined Sound Level (dBZ)	Transformer Tonality (dB)	Combined Tonality (dB)	Tonal? (Combined)
50	6	46	46			N/A
63	5	45	45	-	0.1	No
80	7	44	44	-	2.8	No
100	20	37	37	-	-	No
125	39	34	40	23.9	6.8	No
160	11	30	30	-	-	No
200	5	28	28	-	-	No
250	24	25	27	16.1	2.2	No
315	10	22	22	-	-	No
400	17	21	22	-	-	No
500	25	19	26	8.8	5.0	No
630	15	18	20	-	-	No
800	19	16	21	2.9	1.5	No
1,000	18	15	19	3.8	2.0	No
1,250	8	12	14	-	2.0	No
1,600	2	0	4	-	-	No
2,000	2	0	4	1.3	0.8	No
2,500	0	0	3	-	-	No
3,150	0	0	3	-	-	No
4,000	0	0	3	0.1	0.0	No
5,000	0	0	3	-	-	No
6,300	0	0	3	-	-	No
8,000	0	0	3	0.2	0.1	No
10,000	0	0	3			N/A

[7] The table shows unweighted (dBZ) sound levels in accordance with DEP tonality rules. These cannot be directly compared with compliance standards that use an A-weighted sound level (dBA)

6. SOUND FROM WIND TURBINES – SPECIAL ISSUES

6.1 Wind Turbine Noise

Wind turbines generate two principle types of noise: aerodynamic noise, produced from the flow of air around the blades, and mechanical noise, produced from mechanical and electrical components within the nacelle.

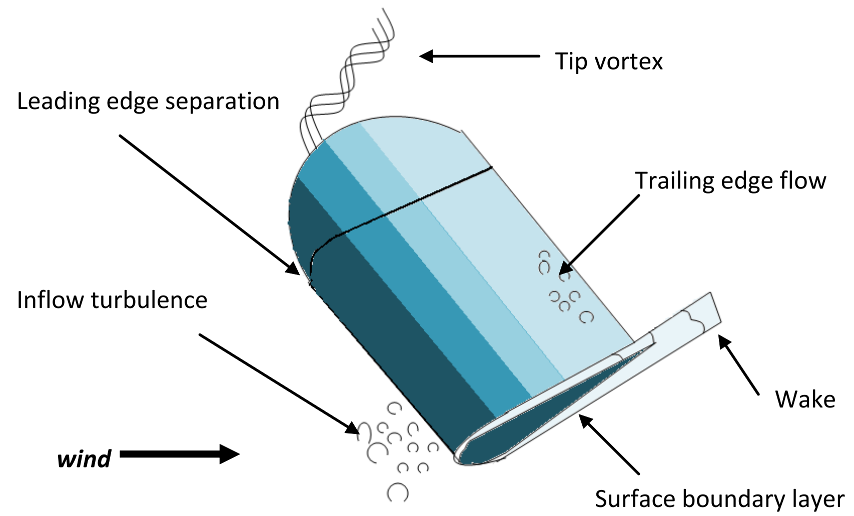
Aerodynamic noise is the primary source of noise associated with wind turbines. These acoustic emissions can be either tonal or broadband. Tonal noise occurs at discrete frequencies, whereas broadband noise is distributed with little peaking across the frequency spectrum.

While unusual, tonal noise can also originate from unstable air flows over holes, slits, or blunt trailing edges on blades. Most modern wind turbines have upwind rotors designed to prevent blade impulsive noise. Therefore, the majority of audible aerodynamic noise from wind turbines is broadband at the middle frequencies, roughly between 200 Hz and 1,000 Hz.

Wind turbines emit aerodynamic broadband noise as the spinning blades interact with atmospheric turbulence and as air flows along their surfaces. This produces a characteristic "whooshing" sound through several mechanisms (Figure 7):

- *Inflow turbulence noise* occurs when the rotor blades encounter atmospheric turbulence as they pass through the air. Uneven pressure on a rotor blade causes variations in the local angle of attack, which affects the lift and drag forces to cause aerodynamic loading fluctuations. This generates noise that varies across a wide range of frequencies but is most significant at levels below 500 Hz.
- *Trailing edge noise* is produced as boundary-layer turbulence around the airfoil passes into the wake, or trailing edge, of the blade. This noise is distributed across a wide frequency range but is most notable at high frequencies between 700 Hz and 2 kHz.
- *Tip vortex noise* occurs when tip turbulence interacts with the surface of the blade tip. While this is audible near the turbine, it tends to be a small component of the overall noise further away.
- *Stall* or *separation noise* occurs due to the interaction of turbulence with the blade surface.

Figure 7: Airflow around a Rotor Blade

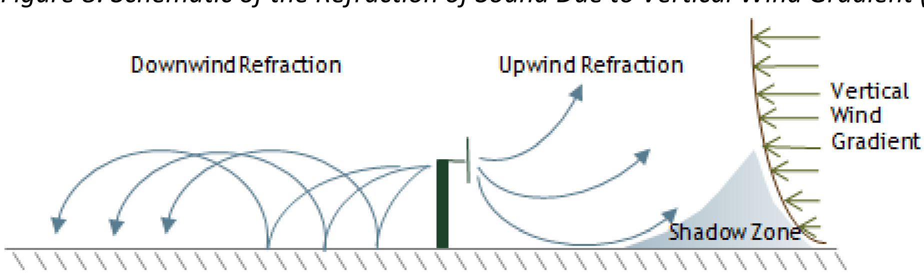


Mechanical noise from machinery inside the nacelle tends to be tonal in nature but can also have a broadband component. Potential sources of mechanical noise include the gearbox, generator, yaw drives, cooling fans, and auxiliary equipment. These components are housed within the nacelle, whose surfaces, if untreated, radiate the resulting noise. However modern wind turbines have nacelles that are designed to reduce internal noise, and rarely is the mechanical noise a significant portion of the total noise from a wind turbine.

6.2 Meteorology

Meteorological conditions can significantly affect sound propagation. The two most important conditions to consider are wind shear and temperature lapse. Wind shear is the difference in wind speeds by elevation and temperature lapse rate is the temperature gradient by elevation. In conditions with high wind shear (large wind speed gradient), sound levels upwind from the source tend to decrease and sound levels downwind tend to increase due to the refraction, or bending, of the sound (Figure 8).

Figure 8: Schematic of the Refraction of Sound Due to Vertical Wind Gradient (Wind Shear)



With temperature lapse, when ground surface temperatures are higher than those aloft, sound will tend to refract upwards, leading to lower sound levels near the ground. The opposite is true when ground temperatures are lower than those aloft (an inversion condition).

The term "Stability Class" is used to describe how stable the atmosphere is. Unstable atmospheres can be caused by high winds and/or high solar radiation. This creates turbulence and tends to break up and dissipate sound energy. Highly stable atmospheres, which tend to occur on clear nights with low ground-level wind speeds, tend to minimize atmospheric turbulence and are generally more favorable to down-wind propagation.

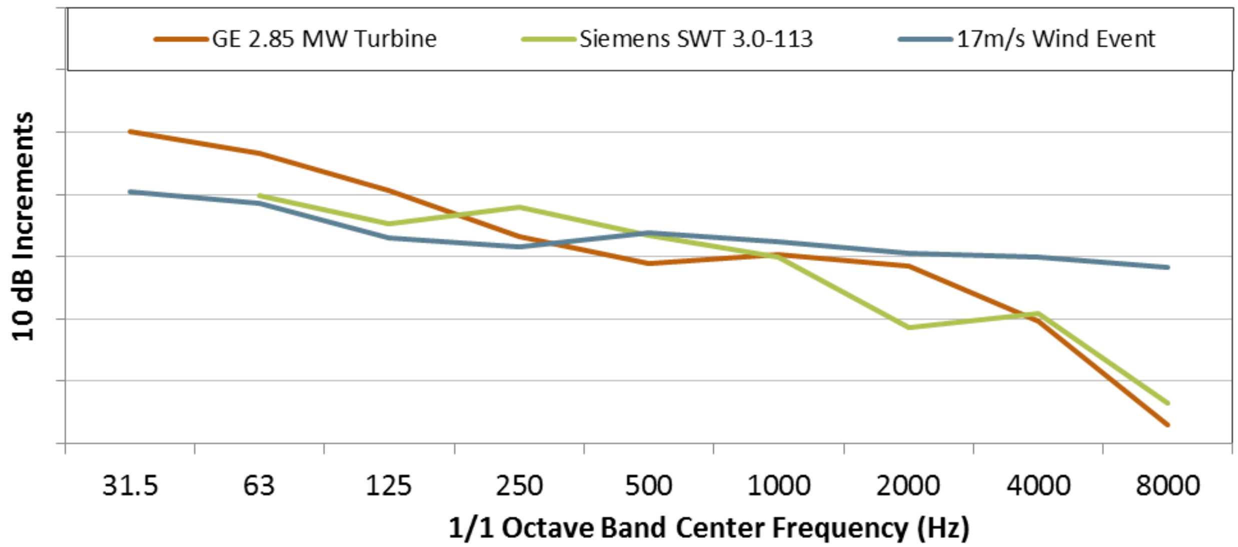
In general terms, sound propagates best under stable conditions with a strong temperature inversion. This tends to occur during the night and is characterized by low ground level winds.[8] As a result, worst-case conditions for wind turbines tend to occur under moderate nighttime temperature inversions. Therefore, this is the default condition for modeling wind turbine sound.

6.3 Masking

As mentioned above, sound levels from wind turbines are a function of wind speed. Background sound is also a function of wind speed, i.e., the stronger the winds, the louder the resulting background sound. This effect is amplified in areas covered by trees and other vegetation. The sound from a wind turbine can often be masked by wind noise at downwind receivers because the frequency spectrum from wind is very similar to the frequency spectrum from a wind turbine. Figure 9 compares the sound spectrum measured during a 17 m/s wind event to GE 2.75/2.85-103 and Siemens SWT 3.0-113 wind turbines. As shown, the shapes of the spectra are very similar at the lower frequencies. At higher frequencies, the sounds from the masking wind noise are higher than the wind turbine. As a result, the masking of turbine noise is possible at higher wind speeds.

[8] The amount of propagation is highly dependent on surface conditions and the frequency of the sound. Under some circumstances highly stable conditions can show lower sound levels.

Figure 9: Comparison of Normalized Frequency Spectra from Wind and the GE 2.75/2.85-103 and Siemens SWT 3.0-113 Wind Turbines



It is important to note that while winds may be blowing at turbine height, there may be little to no wind at ground level. This is especially true during strong wind gradients (high wind shear), which mostly occur at night. This can also occur on the leeward side of ridges where the ridge blocks the wind.

We would expect some masking of wind turbine sound, especially with residences on the eastern side of the project at higher wind speeds.

6.4 Infrasound and Low Frequency Sound

Low frequency aerodynamic tonal noise is typically associated with downwind rotors on horizontal axis wind turbines. In this configuration, the rotor plane is behind the tower relative to the oncoming wind. As the turbine blades rotate, each blade crosses behind the tower's aerodynamic wake and experiences brief load fluctuations. This causes short, low-frequency pulses or thumping sounds called *blade impulsive noise*. Large modern wind turbines are "upwind", where the rotor plane is upwind of the tower. As a result, this type of low frequency noise does not occur in all but the most swirling winds.

Infrasound is sound pressure fluctuations at frequencies below about 20 Hz. Sound below this frequency is generally not audible. Low frequency sound is in the audible range of human hearing, that is, above 20 Hz, but below 100 to 200 Hz depending on the definition.

At very high sound levels (greater than 110 dB), infrasound can cause health effects such as decreased alertness and sleepiness.[9] Infrasound can also rattle light-weight building partitions. However, modern wind turbines, with the hub upwind of the tower, do not create this level of infrasound. As a result, infrasound analysis is not necessary.

Low frequency sound is a component of the sound generated by wind turbines. It is absorbed less by the atmosphere and ground than higher frequency sound. As with infrasound, high levels of low frequency sound can induce rattling in light-weight partitions in buildings. The American National Standards Institute standard, ANSI S12.2, "Criteria for Evaluating Room Noise", recommends that levels be kept below 65 dB at 16 Hz, 65 dB at 31.5 Hz, and 70 dB at 70 Hz inside the building to prevent moderately perceptible vibration and rattles.

Low frequency sound is primarily generated by the generator and mechanical components. Much of the mechanical noise has been reduced in modern wind turbines through improved sound insulation at the hub. Low frequency sound can also be generated by the blades at higher wind speeds when the inflow air is very turbulent. However, at these wind speeds, low frequency sound from the wind turbine blades is often masked by wind noise at the downwind receivers.

Finally, low frequency sound is absorbed less by the atmosphere and ground than higher frequency sound. Our modeling took into account downward diffraction under a moderate nighttime temperature inversion and differing atmospheric absorption between low and high frequency sound.

7. Sound Modeling

7.1 Modeling Software

Modeling was completed for the project using Cadna A acoustical modeling software. Created by Datakustik GmbH, Cadna A is an internationally accepted acoustical model, used by many other noise control professionals in the United States and abroad. The software has a high level of reliability and follows methods specified by the International Standards Organization in their ISO 9613-2 standard, "Acoustics – Attenuation of sound during propagation outdoors, Part 2: General Method of Calculation." The ISO standard states,

> This part of ISO 9613 specifies an engineering method for calculating the attenuation of sound during propagation outdoors in order to predict the levels of environmental noise at a distance from a variety of sources. The method predicts the equivalent continuous A-weighted sound pressure level … under meteorological conditions favorable to propagation from sources of known sound emissions. These conditions are for downwind propagation … or, equivalently, propagation under a well-developed moderate ground-based temperature inversion, such as commonly occurs at night.

[9] Edge, Phillip and Mayes, William. "Description of Langley Low-Frequency Noise Facility and Study of Human Response to Noise Frequencies Below 50 CPS," National Aeronautics and Space Administration, January 1966.

The model takes into account source sound power levels, surface reflection and absorption, atmospheric absorption, geometric divergence, meteorological conditions, walls, barriers, berms, and terrain.

Standard modeling methodology takes into account moderate nighttime inversions and moderate wind speeds, but there may be meteorological conditions that result in higher levels of sound from the turbines. In particular, much higher wind speeds can account for greater downwind propagation. Adjustments can be made to take into account the more extreme conditions. For this study, we modeled the sound propagation in accordance with ISO 9613-2 for omnidirectional wind, using spectral ground attenuation and a ground absorption factor of 0.5 (to represent mixed ground). The wind turbine sound power used for modeling is shown in Table B1.

A 15-meter by 15-meter grid of receivers was set up in the model covering 32 square miles around the site. This accounts for a total of about 373,000 modeled receivers. A receiver is a point above the ground at which the computer model calculates a sound level. Separate discrete receivers were added to the model in addition to the grid to represent the 30 residences and camps located nearest to the proposed wind turbines and 30 residences and camps within 1 mile of the substation. Two receivers were placed to represent the worst case locations within a 500 foot radius of the two closest non-participating homes near the project. Grid receivers were modeled at a height of 1.5 meters, discrete receivers representing homes were modeled at a height of 4.0 meters, and discrete receivers representing other locations were modeled at a height of 1.5 meters. Given its extent, property boundaries were modeled using the receiver grid rather than at discrete points.

Eight GE 2.75/2.85-103 2.85 MW turbines with 103 meter diameter rotors and eight Siemens 3.0-113 3.0 MW turbines with 113 meter diameter rotors were modeled. In addition to the wind turbines, two 34.5/115 kV transformers were modeled. One transformer will support the proposed Canton Mountain Wind project and the other will support the already-permitted Saddleback Ridge Wind project.

8. Sound Propagation Modeling Results

8.1 Overall Results

Modeling results at full sound for GE 2.75/2.85-103 turbines are shown in Figure 10. The highest hourly Leq at a non-participating residence is 35.8 dBA and the highest sound level 500 feet from a non-participating residence is 35.8 dBA. 55 dBA is not exceeded at the property line of any protected location.

Modeling results at full sound for Siemens SWT 3.0-113 turbines are shown in Figure 11. The highest hourly Leq at a non-participating residence is 36.4 dBA and the highest sound level 500 feet from a non-participating residence is 36.1 dBA.[10] 55 dBA is not exceeded at the property line of any protected location.

8.2 Low Frequency Sound

A criterion for noise induced building vibration at the exterior of buildings can be found in ANSI S12.2-2008, "Criteria for evaluating room noise." The criteria for "moderately perceptible vibration and rattle likely" are 65 dB at 16 and 31.5 Hz, and 70 dB at 63 Hz. The sound level at the worst case non-participating residence is 58 dB in the 31.5 Hz 1/1 octave band and 54 dB in the 63 Hz 1/1 octave band for the GE turbine. For the Siemens turbine the sound level is 53 dB in both the 31.5 Hz and 63 Hz 1/1 octave bands.[11]

9. Short-Duration Repetitive Sounds

There are currently no ANSI, IEC, or other standards used to predict short-duration-repetitive-sounds (SDRS) from wind turbines. The cause of SDRS is debated, but it is likely a function of the different wind speeds at the top and bottom of the rotor (wind shear) and turbulence (Bowdler 2008, Dunbabin 1996, Oerlemans and Mendez, 2005, van den Berg 2005). The turbulence can be naturally occurring or created by wakes from upwind turbines.

9.1 Wind Shear

Several papers have studied the theoretical effect of wind shear on the "swishing" sound from wind turbines (Lee, et al. 2009, Oerlemans and Schepers, 2009). They found that much of this amplitude modulation can be explained simply by the difference in broadband blade noise created by higher wind speeds at the top versus the bottom of the rotor rotation. Higher wind shear would result in higher amplitude modulation. This amplitude modulation is broadband and not infrasonic.

Terrain breaks up the tendency to create stable wind layers. As a result, in turbine locations such as those found along Canton Mountain, there tend to be fewer instances of excessive wind shear.

To evaluate whether Canton Mountain is subject to very high wind shear, we reviewed a year of data from the Canton Mountain meteorological tower. The grey boxes in Figure 12 represent 90% of the 10-minute periods with hub-height wind speeds of 3 m/s or greater. In other words, of the periods where hub-height wind speeds were greater than 3 m/s, 90% exhibited wind shear amounts within the ranges that are represented by the grey boxes. Instances of high wind shear ($\alpha > 0.55$) occur 8% of the time for all hours.

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[10] The higher sound level further away from the turbines is due to the different heights assigned to buffers (1.5 meters) and the residences (4 meters).

[11] Note that these sound levels are unweighted. A brief primer on weightings is found in Section 3.2.

Figure 10: Sound Propagation Modeling Results with 8 GE 2.75/2.85-103 Turbines

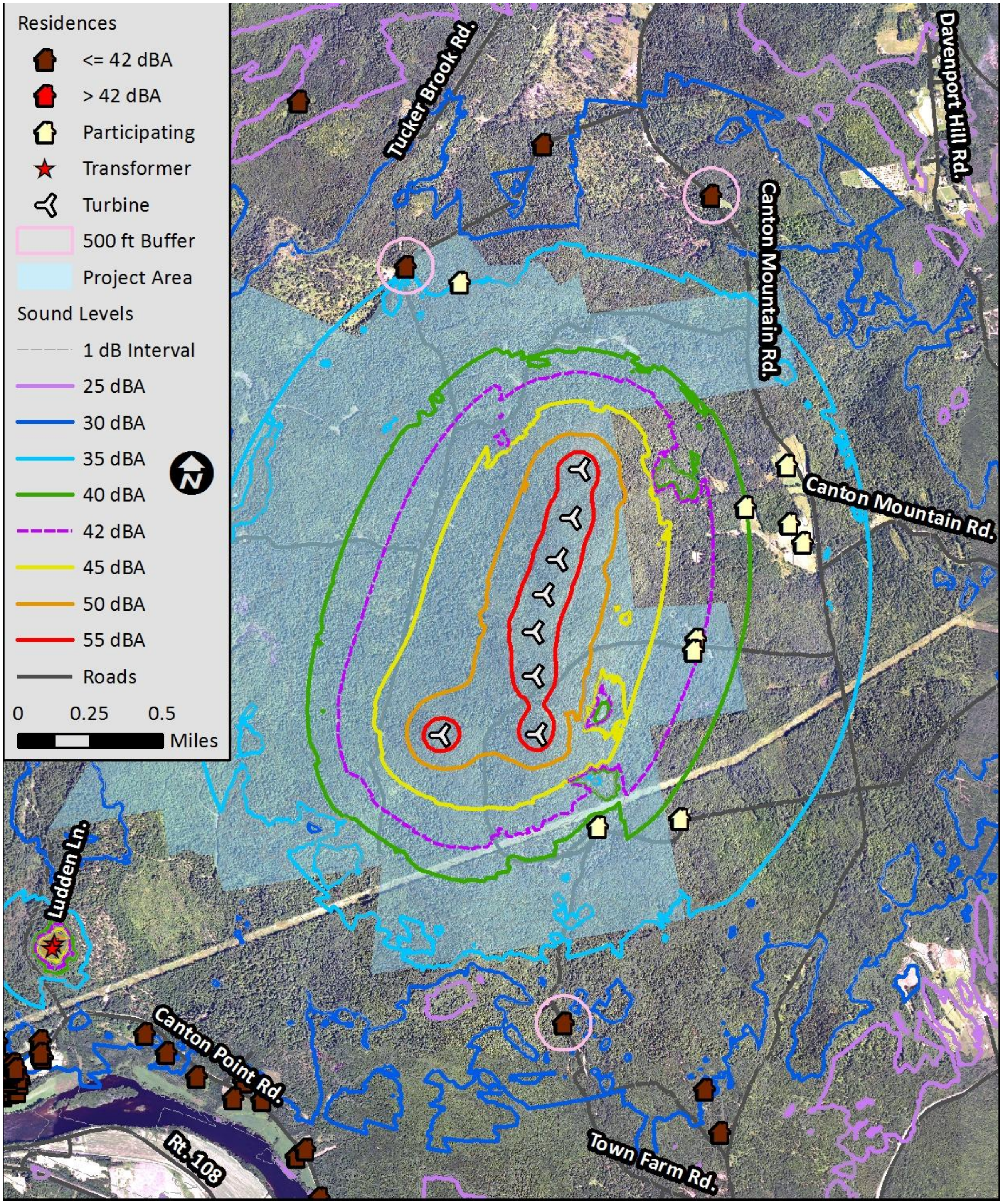


Figure 11: Sound Propagation Modeling Results with 8 Siemens SWT 3.0-113 Turbines

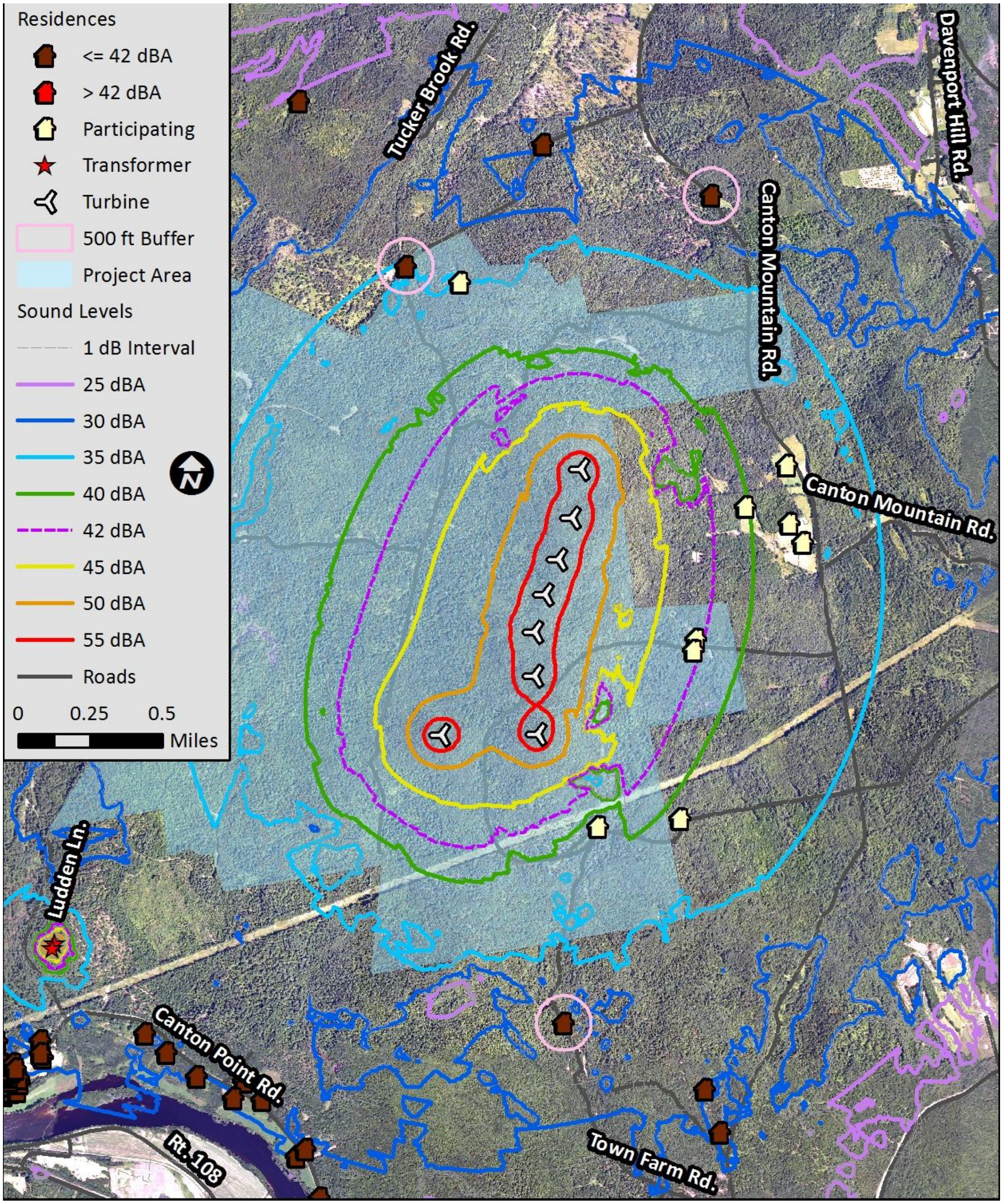
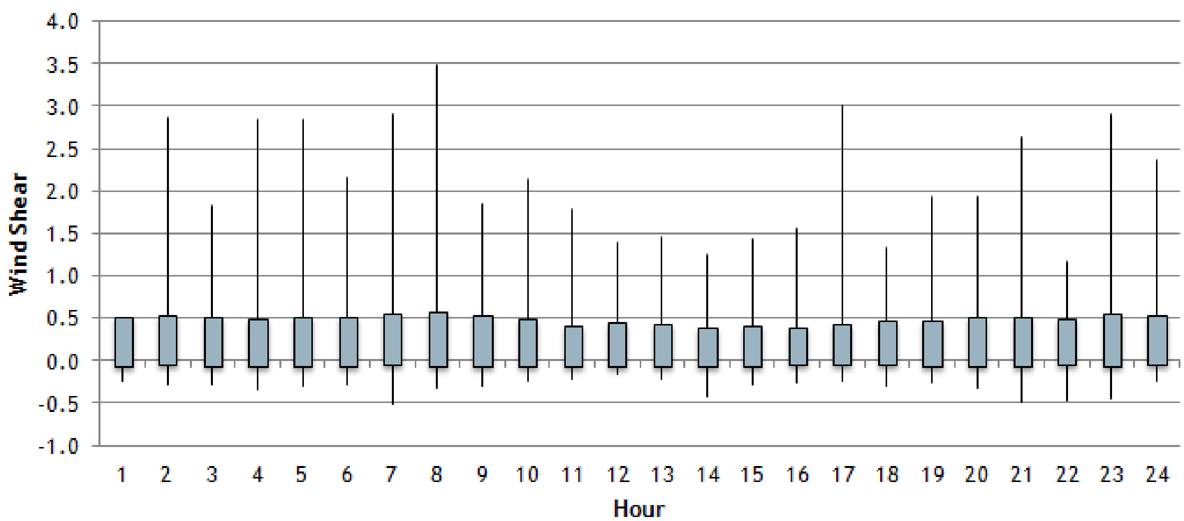


Figure 12: Wind profile power law exponent by time of day for hub height predicted wind speeds above 3 m/s.

Boxes show 90% of data and "whiskers" are the +5% and -5% outliers.



Excessive turbulence can increase the level of sound from a wind turbine and it may also contribute to SDRS. Turbulence may be naturally occurring, caused by thermal mixing and ground roughness, for example. Or, it can be caused by the wake from upwind turbines. To evaluate naturally occurring turbulence, we reviewed more than one year of meteorological data and plotted turbulence intensity for 60,815 10-minute data points. As shown on Figure 13, higher turbulence occurs during the day, due to higher solar radiation. Overall, 89% of the data points are below 0.20 turbulence intensity, with most of those periods above this figure occurring during the day.[12]

Turbulence intensity is highest at the lowest wind speeds, when sound output from the wind turbines is lower. Figure 14 shows turbulence intensity from the Canton Mountain met tower plotted against wind speed.

[12] Most wind turbines are tested in turbulence intensity environments below 0.2.

Figure 13: Turbulence intensity by time of day.

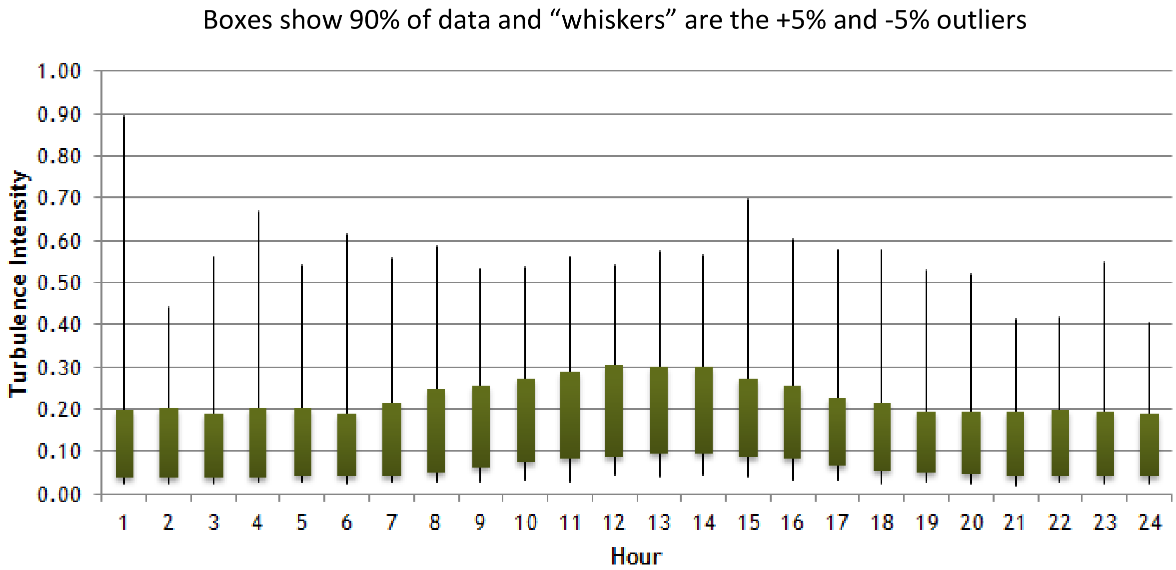
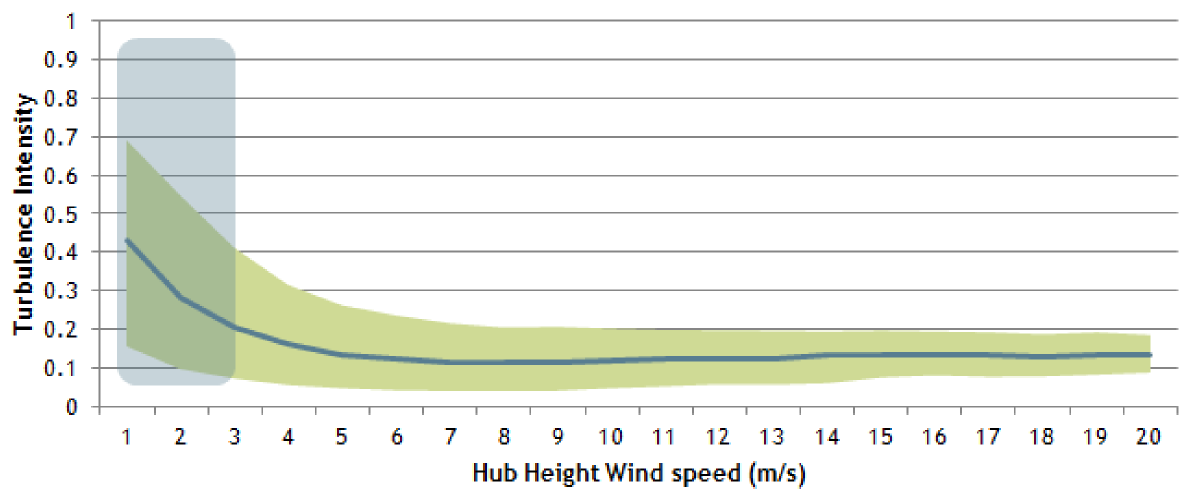


Figure 14: Turbulence Intensity by Wind Speed.

Green area bounds the 5th percentile and 95th percentile turbulence intensities by hub height wind speed. Shaded area shows wind speeds too low for turbine operation. Blue line shows the average.



While it is not possible to precisely calculate the extent of SDRS at wind projects prior to construction, the analysis shown above indicates that the site characteristics at Canton are not conducive to common occurences of SDRS.

Inflow turbulence between turbines in a turbine string can also affect noise from the wind farm. Proper turbine siting and operation minimizes this type of turbine wake impact.

Post-construction monitoring data will be collected to evaluate whether SDRS is occuring.

9.2 Comparison of Canton with Spruce Mountain Wind

In late March/early April 2012, RSG conducted compliance monitoring at Spruce Mountain Wind, an operating Patriot Renewables wind energy project in Woodstock, Maine. As part of that study, SDRS was monitored and reported. Given that the CMW project and Spruce Mountain Wind are within approximately 15 miles of each other, and they are both ridgeline projects situated along a similar axis, a review of the SDRS at Spruce Mountain Wind can inform us as to the potential for SDRS at CMW.

The Spruce Mountain Wind compliance report showed more than six potential SDRS events for each of the valid monitoring periods. However, since those events did not lead to violations of the sound standard, they were not reviewed at the time the study was conducted to determine whether the events were the result of wind turbines or other sources of sound, such as birds and insects. By definition under the DEP noise rules, in order for amplitude modulation to constitute SDRS it must be the result of wind turbine sound. For this study, we conducted a more detailed screening of that data to assess the actual number of SDRS events resulting from the Spruce Mountain Wind project during the Year 1 compliance period.

Results from the first year of compliance monitoring at Spruce Mountain Wind are shown in The level of turbine sound modulation is a dynamic process, dependent on instantaneous turbulence, shear, contribution from other turbines, and relative location of the listener, among other factors. As a result, computer models that can predict the precise number, duration, and level of short duration repetitive sounds from a wind project in any 10-minute period do not exist. Currently, the best way to estimate the extent to which SDRS may occur is to make comparisons with other similar sites and to evaluate specific site characteristics that contribute to amplitude modulation. In this case, based on comparisons with site characteristics and monitored sound emissions of the nearby Spruce Mountain Wind project, consideration of the monitored shear and turbulence at the Canton met tower, and our expectations of reduced amplitude modulation from independent pitch control turbines proposed to be used, we conclude that SDRS events are not expected to be a frequent occurrence at CMW, under the old or new Chapter 375.10 standard. Therefore, we have added no SDRS penalties into the results of our sound propagation modeling for CMW.. The SDRS analysis shown below was based on the 50 ms LA_f, in accordance with DEP Noise Regulations, Chapter 375.10(I)(4) and 375.10(I)(8)(f)(9). The results published in the 2012 compliance report were based on a 50 ms LA_{eq}, which has the effect of overstating the occurrence of SDRS (the results still indicated compliance under the old standard).

Table 4: Spruce Mountain Wind Year 1 Compliance Monitoring Results as Assessed using the New Chapter 375 Regulation[13]

Date/Time	Unadjusted Leq (dBA)	SDRS Seconds
3/30/2012 22:00	40.9	2
4/2/2012 8:20	40.6	5
4/2/2012 8:30	39.5	3
4/2/2012 8:40	36.9	1
4/2/2012 9:30	37.9	0
4/2/2012 23:20	39.9	1
4/3/2012 1:20	28.1	2
4/3/2012 2:20	29.5	0
4/3/2012 4:40	40.2	1
4/3/2012 6:20	39.1	0
4/3/2012 6:30	39.0	*
4/3/2012 6:50	39.0	*
4/3/2012 8:10	41.7	*

*Birds contaminated SDRS evaluation

The results show that, generally, SDRS events are not a frequent occurrence at Spruce Mountain Wind, with all periods containing fewer than six events per 10-minute period. Using the former Chapter 375 method, this would generally result in less than 0.1 dB of penalty for a single 10-minute period. Using the current method contained in Chapter 375.10(I)(4), this would result in no SDRS penalty.

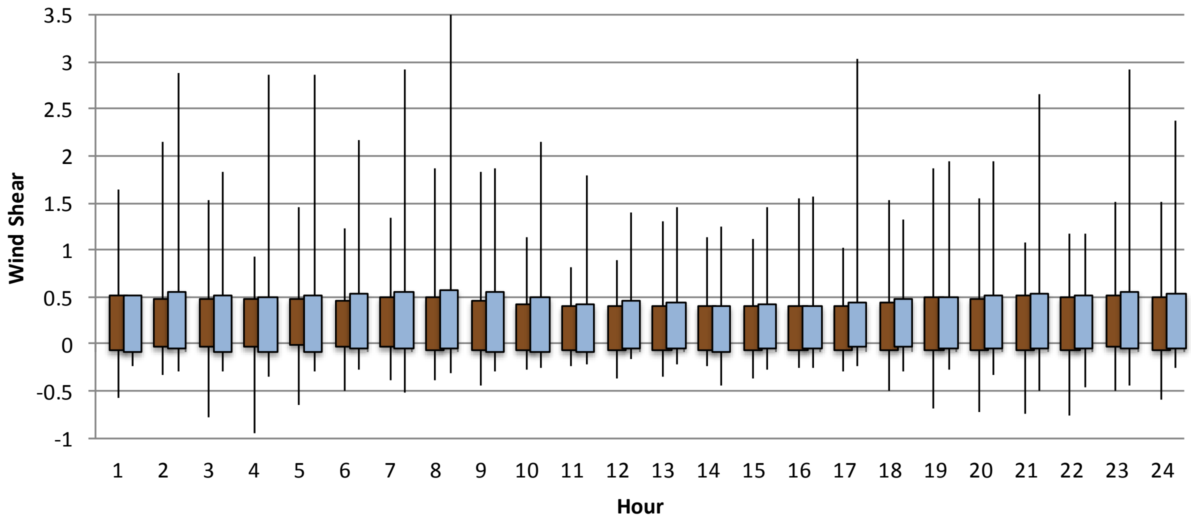
We note that the closest protected location to CMW is farther from the closest turbine than the monitoring location at Spruce Mountain Wind is to the closest turbine at that project. As one moves farther from a wind farm, the modulation of one turbine gets diminished as more turbines contribute to a greater degree to the overall sound level. In addition, as the distance increases, sound levels from the turbines are attenuated and the turbine sound level gets closer to the background sound level. Therefore, all else equal, we would expect the instances of SDRS events to be even fewer at the Canton Mountain Wind monitoring location than at the Spruce Mountain Wind monitoring location.

As noted in Section 9.1, SDRS will also be affected by turbulence and wind shear. Figure 15 compares the wind shear by time of day between the Spruce Mountain Wind and CMW projects. The "box and whiskers" have the same meaning as in Figure 12. The wind profiles between Spruce

[13] Other than the last three periods, SDRS periods were not reviewed to assess whether they were caused by the wind turbine generators (WTGs) or biogenic activity (birds and insects, in particular) at the time the Spruce Mountain Wind compliance report was released.

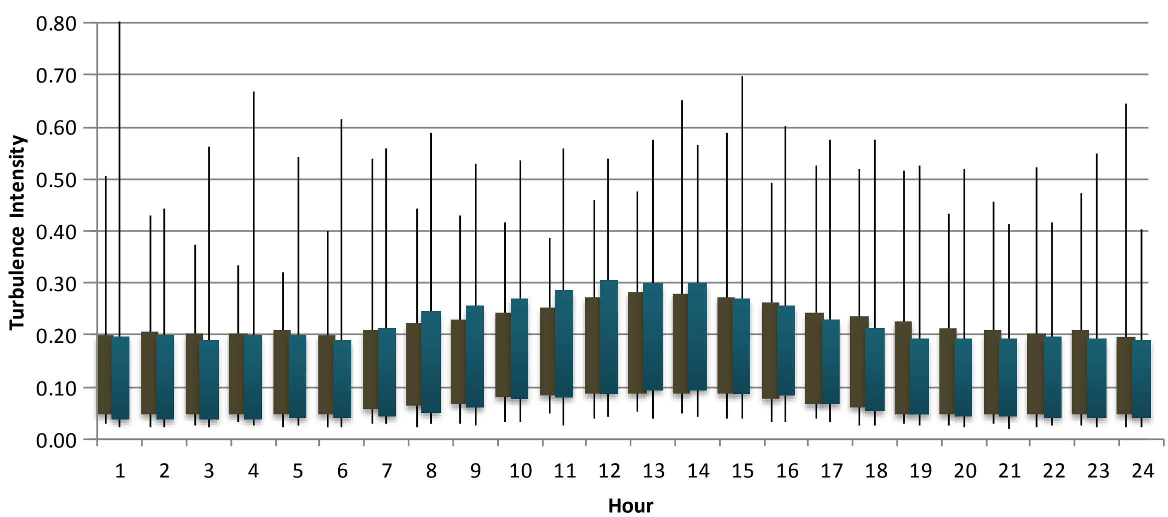
Mountain Wind and CMW show similar patterns and 90th percentile bounding boxes within each hour. CMW has slightly higher overall shear.

Figure 15: Comparison of shear exponents between Spruce Mountain Wind (brown) and CMW (blue)



A comparison of turbulence between Spruce Mountain Wind and CMW is shown in Figure 16. Like wind shear, the two projects show very similar patterns, with slightly lower nighttime and slightly higher daytime turbulence at CMW. The average turbulence intensity at CMW is 0.13 compared with 0.18 at Spruce Mountain Wind.

Figure 16: Comparison of 60 m turbulence intensity between Spruce Mountain Wind (brown) and CMW (teal) for winds greater than 4 m/s at hub height.



9.3 Turbine design

The GE turbines and Siemens turbines feature independent blade pitch control, a relatively new technology that allows the pitch of each blade to operate independently. In older designs, like the turbines installed at Spruce Mountain Wind, the blade pitch was optimized only for the wind speed at the hub and the angle of attack of each blade is identical. Using independent blade pitch control, each blade can react to changes in wind speed and turbulence intensity, and optimize its angle of attack to specific wind conditions, no matter where it is in the rotor path. Since noise increases with pitch error, we expect that this technology would result in lower occurrences of SDRS compared with other pitch control technologies (stall and standard pitch control).

9.4 Short duration repetitive sound penalty

We note that the new Chapter 375.10(I)(4) approach to SDRS is very strict, and that small, temporary, short-term deviations can lead to full 5 dB SDRS penalties for select 10-minute periods. If SDRS does become an issue that creates violations of the noise standard, both the GE and Siemens turbines have the capability of implementing "Noise Reduced Operations," which lowers the sound power and electric power output of selected turbines during specified periods.

Even though excessive SDRS is unlikely at CMW, if SDRS does occur, there is a 5.6 dB buffer between the highest modeled sound level and the 42 dBA nighttime standard for this project. Therefore, even assuming constant SDRS the project would still be in compliance with the 42 dBA standard with a 5 dB penalty under the new regulations.

The level of turbine sound modulation is a dynamic process, dependent on instantaneous turbulence, shear, contribution from other turbines, and relative location of the listener, among other factors. As a result, computer models that can predict the precise number, duration, and level of short duration repetitive sounds from a wind project in any 10-minute period do not exist. Currently, the best way to estimate the extent to which SDRS may occur is to make comparisons with other similar sites and to evaluate specific site characteristics that contribute to amplitude modulation. In this case, based on comparisons with site characteristics and monitored sound emissions of the nearby Spruce Mountain Wind project, consideration of the monitored shear and turbulence at the Canton met tower, and our expectations of reduced amplitude modulation from independent pitch control turbines proposed to be used, we conclude that SDRS events are not expected to be a frequent occurrence at CMW, under the old or new Chapter 375.10 standard. Therefore, we have added no SDRS penalties into the results of our sound propagation modeling for CMW.

10. Construction Impacts

The construction of the turbines will take place primarily on the ridge line. While there may be activity closer to residences for road construction and utility work, such work will be of a relatively short duration.

The equipment used for construction will be varied. Some of the louder pieces of equipment are shown in Table 5 along with the approximate maximum sound pressure levels at a reference distance of 50 feet (15.2 m) and 2,100 feet (640 m), which is the distance from the closest residence (Residence 2, participating) to the ridgeline, where the majority of construction activity will occur. Actual sound levels are likely to be lower than those shown in Table 5 due to the presence of dense vegetation between the construction areas and the nearest residences.

Blasting may be required. However, the amount of blasting will be limited. Blasts will be warned as per federal requirements. Blasts will be designed by a licensed blasting company and charges and delays will be set such that Chapter 375(10)(c)(4) rules, which reflect the Bureau of Mines standards for vibration and airblast, will be complied with.

Major construction work, such as clearing for the access roads, will occur primarily during the day; however, minor construction work may extend earlier or later.

Due to the setbacks involved and the limited duration of the activities, construction noise levels should comply with Chapter 375(10)(c)(2) rules.

Table 5: Maximum Sound Levels From Various Construction Equipment

Equipment	Sound Pressure Level at Reference Distance of 50 feet[14] (dBA)	Sound Pressure Level at 2,100 feet (dBA)[15]
M-250 Liftcrane	82.5	44
2250 S3 Liftcrane	78	40
Excavator	83	47
Dump truck being loaded	86	51
Dump truck at 25 mph accelerating	76	38
Tractor trailer at 25 mph accelerating	80	44
Concrete truck	81	43
Bulldozer	85	47
Rock drill	100	57
Loader	80	39
Backhoe	80	42
Chipper	96	61

[14] 50 feet is a reference distance at which sound levels of heavy equipment are often measured. It does not represent an actual distance between construction equipment and protected locations at CMW.

[15] Assumes hard ground around construction site, and ISO 9614-2 propagation with no vegetation reduction. Actual sound levels will likely be lower given the prevalence of dense vegetation and soft ground around the site.

11. CONCLUSIONS

Patriot Renewables proposes to construct and operate eight GE 2.85-103 2.85 MW wind turbines or eight Siemens SWT 3.0-113 3.0 MW wind turbines on Canton Mountain. These turbines have a nominal sound power rating of 105 dBA and 105.5 dBA, respectively. A 34.5/115 kV transformer will be installed at the substation about 1.5 miles southwest of the project, which has been included in the model; however, the transformer does not significantly affect protected locations.

This report evaluated the potential noise impacts of the project and concluded the following:

1) A recent court order has lowered the nighttime standard applied to unconstructed wind projects to 42 dBA. Therefore, the Canton Mountain Wind project was evaluated against a limit of 55 dBA day (7 am to 7 pm) and 42 dBA night LAeq(1-hour) within applicable protected locations, with both the old Chapter 375(10) and new Chapter 375(10)(I) wind turbine tonal and SDRS evaluation methodologies.
2) The proposed GE 2.85-103 wind turbines do not generate any tonal sound according the Maine DEP standard. Siemens warrants that the SWT 3.0-113 turbine will not generate tonal sound according to the Maine DEP definition. The proposed transformers at the nearby substation will be tonal, but the combined spectrum from the turbines and transformers will not be tonal. Both when the wind turbines are operating along with the transformers and when only the transformers are operating, sound levels at the nearest residence to the transformers (Residence 45) will be low enough that the project will meet the 42 dBA limit even with a 5 dB penalty for tonal sound during periods when the turbines are not operating.
3) Sound propagation modeling was conducted using conservative assumptions, including a ground absorption factor of 0.5 (to represent mixed ground), and adding in a margin to the model results to account for sound power and modeling uncertainty.
4) At maximum sound power levels, the highest modeled sound level at and within 500 feet of a non-participating residence was 35.8 and 35.8 dBA, respectively (Receivers 7 and 7B) for the GE 2.85-103 and 36.4 and 36.1 dBA, respectively (Receivers 7 and 7B) for the Siemens SWT 3.0-113 turbines.
5) 55 dBA is not exceeded at the property line of any protected location.
6) The modeled levels of low frequency sound will not create perceptible building vibration.
7) SDRS events are not expected to be a frequent occurrence at Canton Mountain Wind, under the old or new Chapter 375.10 standard, therefore SDRS penalties were not included in the model.

The modeled results described in this report indicate the Canton Mountain Wind project meets both the new and old noise standards set out by the Maine Department of Environmental Protection, Chapter 375(10) noise rules.

APPENDIX A: RECEIVER LOCATIONS AND RESULTS

Figure A1: Residence and Buffer Locations

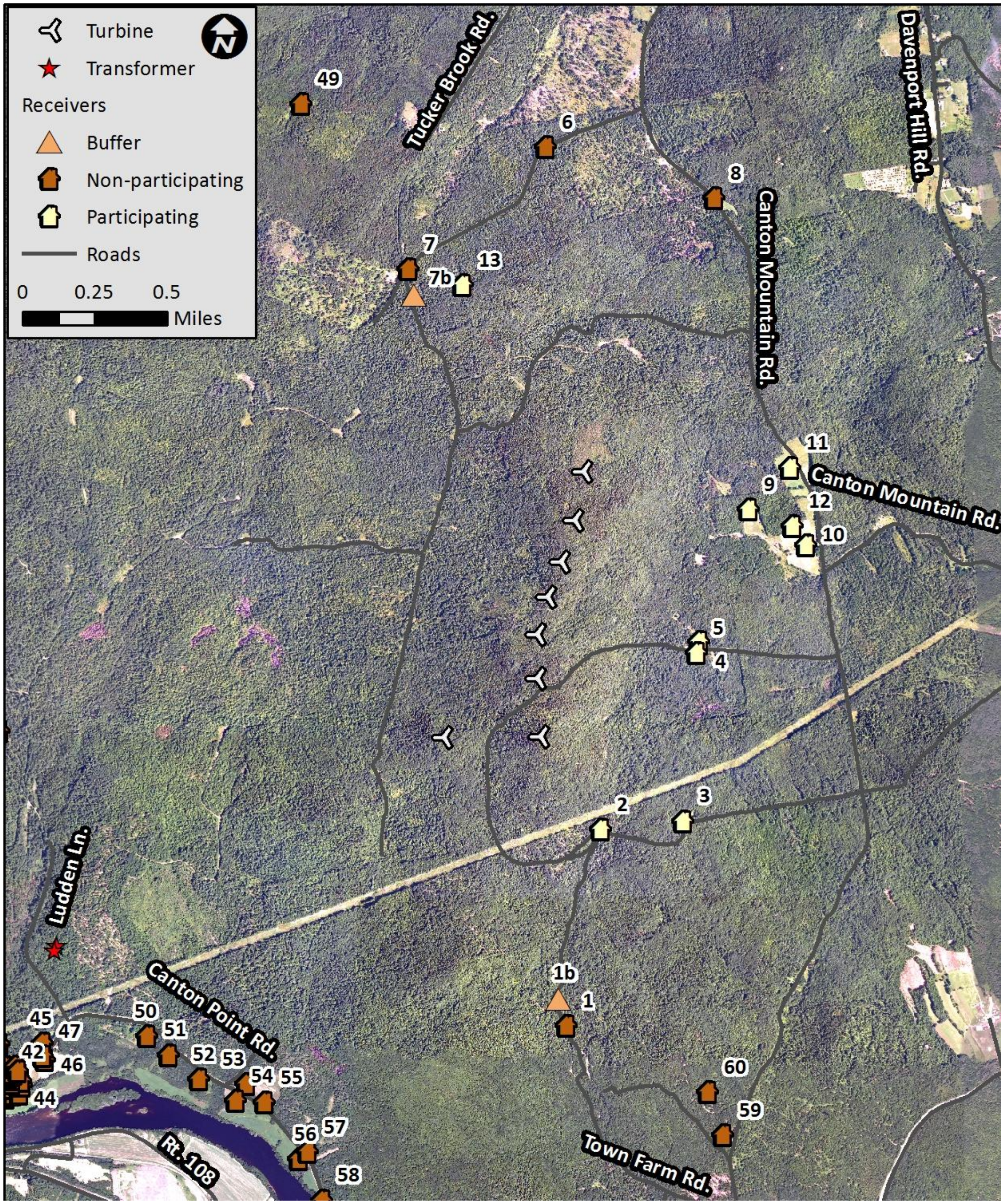


Table A 1: Discrete Receiver Results

Receiver ID	Status	Sound Pressure Levels (dBA)		Relative Height (m)	Coordinates (UTM NAD 83 Z19N)			Distance to Nearest Turbine (m)	Distance to Nearest Turbine (ft)
		GE 2.75/2.85-103	Siemens SWT 3.0-113		X (m)	Y (m)	Z (m)		
1	Non-participating	33	34	4	396535	4927470	192	1645	5396
2	Participating	40	40	4	396726	4928565	290	648	2127
3	Participating	40	40	4	397183	4928611	279	950	3117
4	Participating	43	44	4	397273	4929612	271	906	2971
5	Participating	43	44	4	397261	4929546	270	914	3000
6	Non-participating	30	31	4	396419	4932369	280	1833	6014
7	Non-participating	36	36	4	395653	4931689	350	1496	4909
8	Non-participating	33	34	4	397358	4932082	279	1702	5585
9	Participating	41	41	4	397547	4930349	241	970	3183
10	Participating	39	39	4	397867	4930150	226	1321	4333
11	Participating	39	39	4	397782	4930579	238	1178	3866
12	Participating	39	40	4	397793	4930254	230	1228	4028
13	Participating	36	36	4	395957	4931599	364	1242	4076
14	Non-participating	20	20	4	392501	4926924	146	3984	13069
16	Non-participating	27	28	4	392817	4927103	143	3623	11885
17	Non-participating	26	27	4	392918	4927107	141	3536	11602
18	Non-participating	28	29	4	393117	4927231	143	3302	10834
19	Non-participating	29	30	4	393238	4927258	139	3188	10460
20	Non-participating	27	28	4	393311	4927258	139	3129	10266
21	Non-participating	32	32	4	393377	4927368	144	3012	9881
22	Non-participating	31	31	4	393379	4927211	140	3102	10178
23	Non-participating	29	30	4	393338	4927199	139	3142	10307
24	Non-participating	30	31	4	393343	4927181	139	3149	10332
25	Non-participating	30	31	4	393381	4927185	139	3117	10225
26	Non-participating	30	31	4	393350	4927160	139	3157	10356
27	Non-participating	30	31	4	393397	4927143	139	3130	10268
28	Non-participating	30	31	4	393352	4927132	139	3172	10407
29	Non-participating	30	31	4	393418	4927105	137	3137	10293
30	Non-participating	29	30	4	393357	4927069	136	3207	10522
31	Non-participating	30	31	4	393414	4927068	135	3164	10379
32	Non-participating	29	30	4	393366	4927048	134	3214	10544
33	Non-participating	30	31	4	393455	4927087	135	3120	10237
34	Non-participating	30	31	4	393449	4927126	137	3100	10170

Receiver ID	Status	Sound Pressure Levels (dBA)		Relative Height (m)	Coordinates (UTM NAD 83 Z19N)			Distance to Nearest Turbine (m)	Distance to Nearest Turbine (ft)
		GE 2.75/2.85-103	Siemens SWT 3.0-113		X (m)	Y (m)	Z (m)		
35	Non-participating	30	30	4	393487	4927093	133	3092	10146
36	Non-participating	30	31	4	393503	4927139	136	3050	10006
37	Non-participating	30	31	4	393496	4927162	137	3041	9977
38	Non-participating	30	31	4	393446	4927149	138	3088	10131
39	Non-participating	31	31	4	393442	4927173	139	3076	10091
40	Non-participating	31	31	4	393432	4927191	139	3072	10080
41	Non-participating	31	31	4	393421	4927210	140	3069	10069
42	Non-participating	31	31	4	393411	4927239	141	3060	10038
43	Non-participating	31	32	4	393464	4927244	139	3015	9893
44	Non-participating	31	32	4	393479	4927218	139	3019	9905
45	Non-participating	31	32	4	393615	4927374	139	2817	9242
46	Non-participating	32	32	4	393630	4927281	137	2862	9390
47	Non-participating	32	32	4	393618	4927302	138	2859	9379
48	Non-participating	31	32	4	393376	4929110	159	2481	8139
49	Non-participating	25	25	4	395060	4932606	309	2584	8476
50	Non-participating	31	32	4	394198	4927414	131	2355	7726
51	Non-participating	31	32	4	394320	4927308	134	2349	7708
52	Non-participating	30	31	4	394490	4927171	134	2353	7718
53	Non-participating	31	31	4	394750	4927147	128	2235	7332
54	Non-participating	30	31	4	394693	4927051	126	2345	7694
55	Non-participating	31	32	4	394853	4927042	129	2279	7476
56	Non-participating	30	31	4	395044	4926729	126	2495	8184
57	Non-participating	30	31	4	395093	4926769	129	2441	8009
58	Non-participating	28	29	4	395172	4926499	127	2677	8784
59	Non-participating	30	31	4	397407	4926861	163	2467	8093
60	Non-participating	32	32	4	397324	4927102	192	2212	7257
1b	Buffer	33	33	1.5	396492	4927618	194	1495	4905
7b	Buffer	36	36	1.5	395684	4931539	355	1365	4477

APPENDIX B: TURBINE LOCATIONS

Figure B1: Turbine Locations

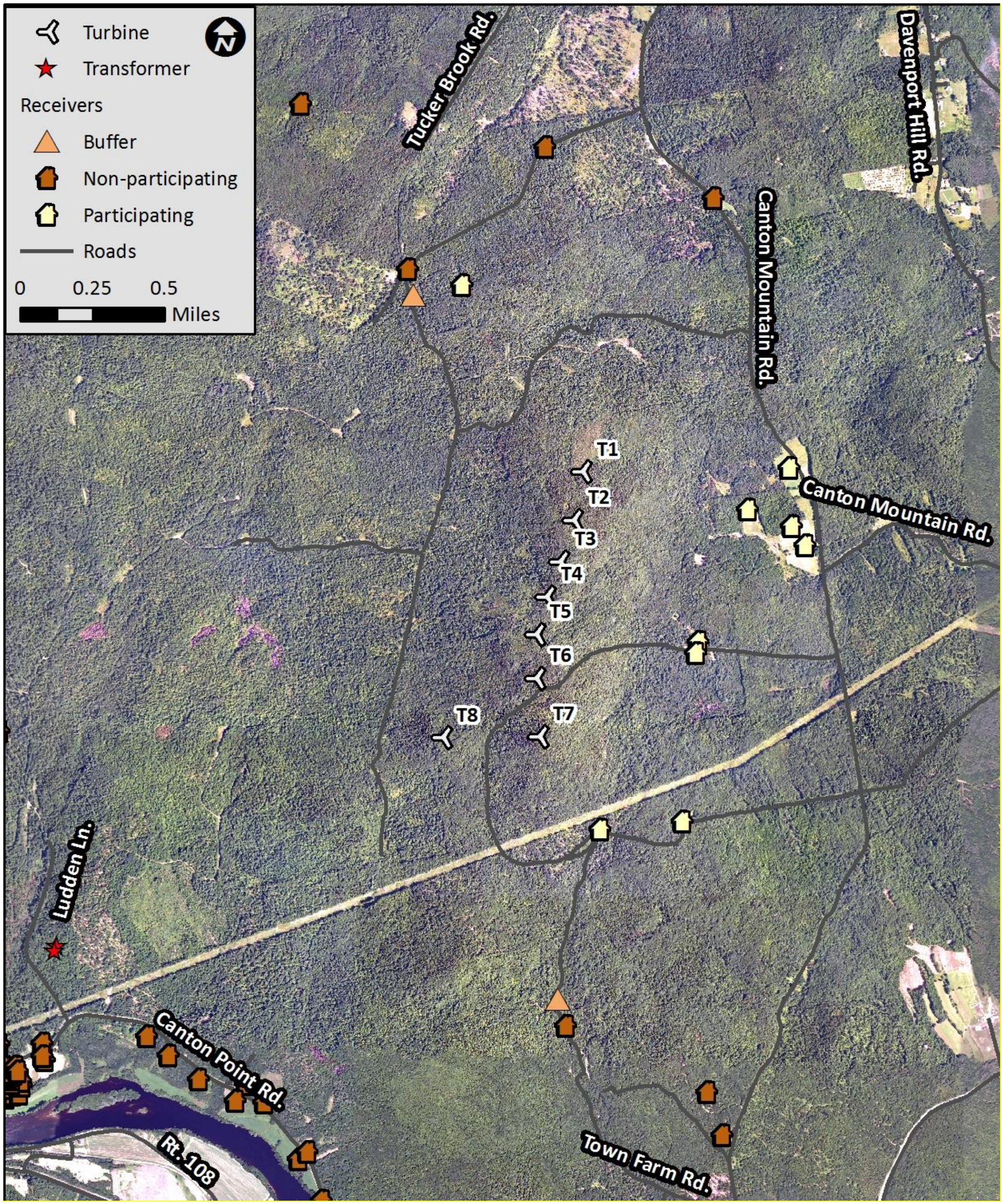


Table B 1: Turbine Information

Turbine ID	Turbine Model	Modeled Sound Power (dBA)	Sound Power (dBA)	Hub Height (m)	Coordinates (UTM NAD83 Z19N)		
					X (m)	Y (m)	Z (m)
T1	GE 2.75/2.85-103	108	105	85	396625	4930556	540
T2	GE 2.75/2.85-103	108	105	85	396576	4930287	546
T3	GE 2.75/2.85-103	108	105	85	396500	4930057	550
T4	GE 2.75/2.85-103	108	105	85	396425	4929860	550
T5	GE 2.75/2.85-103	108	105	85	396364	4929651	539
T6	GE 2.75/2.85-103	108	105	85	396365	4929406	545
T7	GE 2.75/2.85-103	108	105	85	396382	4929083	555
T8	GE 2.75/2.85-103	108	105	85	395844	4929075	490
T1	Siemens SWT 3.0-113	108	105.5	79.5	396625	4930556	535
T2	Siemens SWT 3.0-113	108	105.5	79.5	396576	4930287	541
T3	Siemens SWT 3.0-113	108	105.5	79.5	396500	4930057	545
T4	Siemens SWT 3.0-113	108	105.5	79.5	396425	4929860	545
T5	Siemens SWT 3.0-113	108	105.5	79.5	396364	4929651	534
T6	Siemens SWT 3.0-113	108	105.5	79.5	396365	4929406	539
T7	Siemens SWT 3.0-113	108	105.5	79.5	396382	4929083	550
T8	Siemens SWT 3.0-113	108	105.5	79.5	395844	4929075	485

Table B2: Transformer Information

Source ID	Sound Power Level (dBA)	Relative Height (m)	Coordinates (UTM NAD83 Z19N)		
			X (m)	Y (m)	Z (m)
Canton Transformer	93	3	393699	4927916	168
Saddleback Transformer	93	3	393683	4927887	166

Table B3: Modeling Parameters

Parameter	Setting
Ground Absorption	Spectral for all sources, G=0.5
Atmospheric Absorption	Based on 10 Degrees Celsius, 70 % Relative Humidity
Reflections	None
Receiver Height	4 m for residences, 1.5 meters for grid and 500 ft buffers

APPENDIX C: GE SOUND INFORMATION

GE Power & Water

– Original Instructions –

Technical Documentation Wind Turbine Generator Systems 2.75-103 and 2.85-103 - 60 Hz

Product Acoustic Specifications

Normal Operation according to IEC Incl. Octave Band Spectra and 1/3rd Octave Band Spectra

Patriot Renewables – Saddleback Ridge

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GE Power & Water

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Table of Contents

1 Introduction

This document summarizes acoustic emission characteristics of the 2.75-103 and 2.85-103 wind turbines for normal operation, including calculated apparent sound power levels $L_{WA,k}$, as well as uncertainty levels associated with apparent sound power levels, tonal audibility, and calculated 1/3rd octave band apparent sound power level.

All provided sound power levels are A-weighted.

Seller verifies specifications with measurements, including those performed by independent institutes. If a wind turbine noise performance test is carried out, it needs to be done in accordance with regulations of the international standard IEC 61400-11, ed. 2.1: 2006 and Machine Noise Performance Test document.

2 Normal Operation Calculated Apparent Sound Power Level and Octave Band Spectra

Calculated apparent sound power levels $L_{WA,k}$ and associated octave-band spectra are given in Table 1. Values are provided as mean levels for V_{85m} 14 m/s-cutout speed for Normal Operation (NO). Uncertainties for octave sound power levels are generally higher than for total sound power levels. Guidance is given in IEC 61400-11, Annex D.

Normal Operation Octave Band Spectra		
Hub height wind speed at 85 m [m/s]		14-Cutout
Frequency [Hz]	31.5	80.7
	63	90.3
	125	94.5
	250	94.6
	500	95.8
	1000	100.3
	2000	99.6
	4000	90.7
	8000	71.9
	16000	28.3
Total apparent sound power level L_{WA} [dB]		105.0

Table 1: Normal Operation Calculated Apparent Sound Power Level 2.75-103/2.85-103 with 85 m hub height

At hub height wind speeds above 14 m/s turbine has reached rated power and blade pitch regulation acts in a way that tends to decrease noise levels.

The highest normal operation calculated apparent sound power level for the 2.75-103 and 2.85-103 is $L_{WA,k}$ = 105.0 dB.

3 Uncertainty Levels

Apparent sound power levels in Table 1 are calculated mean levels. Uncertainty levels associated with measurements are described in IEC/TS 61400-14.

Per IEC/TS 61400-14, L_{WAd} is the maximum apparent sound power level for 95 % confidence level resulting from n measurements performed according to IEC 61400-11 standard: $L_{Wad} = L_{WA} + K$, where L_{WA} is the mean apparent sound power level from IEC 61400-11 testing reports and $K = 1.645\ \sigma_T$.

Testing standard deviation values σ_T, σ_R and σ_P for measured apparent sound power level are described by IEC/TS 61400-14, where σ_T is the total standard deviation, σ_P is the standard deviation for product variation and σ_R is the standard deviation for test reproducibility.

Assuming σ_R < 0.8 dB and σ_P < 0.8 dB as typical values leads to a calculated K < 2 dB for 95 % confidence level.

4 Tonal Audibility

At the reference measuring point R_0 the 2.75-103 and 2.85-103 wind turbines have a value for tonality of $\Delta L_{a,k} \leq$ **4 dB**.

5 IEC 61400-11 and IEC/TS 61400-14 Terminology

- $L_{WA,k}$ is wind turbine apparent sound power level (referenced to 10^{-12}W) measured with A-weighting as function of reference wind speed v_{10m}. Derived from multiple measurement reports per IEC 61400-11, it is considered as a mean value
- σ_P is the product variation i.e. 2.75-103 and 2.85-103 unit-to-unit product variation; typically < 0.8 dB
- σ_R is the overall measurement testing reproducibility as defined per IEC 61400-11; typically < 0.8 dB with adequate measurement conditions and sufficient amount of data samples
- σ_T is the total standard deviation combining both σ_P and σ_R
- $K = 1.645\ \sigma_T$ is defined per IEC/TS 61400-14 for 95 % confidence level
- R_0 is the ground measuring distance from the wind turbine tower axis per IEC 61400-11, which shall equal the hub height plus half the rotor diameter
- $\Delta L_{a,k}$ is the tonal audibility according to IEC 61400-11, described as potentially audible narrow band sound

6 1/3rd Octave Band Spectra

Table 2 shows the 1/3rd octave band values for 85m hub height for wind speeds 14 m/s – cut out.

Normal Operation 1/3rd Octave Band Spectra		
Hub height wind speed at 85 m [m/s]		**14-Cutout**
Frequency [Hz]	25	70.4
	32	74.8
	40	78.9
	50	82.1
	63	85.1
	80	87.7
	100	89.3
	125	89.9
	160	90.0
	200	89.9
	250	89.8
	315	89.9
	400	89.7
	500	90.7
	630	92.2
	800	93.8
	1000	95.4
	1250	96.8
	1600	96.1
	2000	95.0
	2500	92.5
	3150	89.1
	4000	84.5
	5000	79.5
	6300	71.7
	8000	59.9
	10000	45.7
	12500	28.3
	16000	3.3
	20000	-23.7
Total apparent sound power level L_{WA} [dB]		**105.0**

Table 2: Calculated Apparent 1/3rd Octave Band Sound Power Level (A-weighted) 2.75-103/2.85-103 with 85 m hub height for wind speeds 14 m/s-cut out