Wind Colebrook South Monthly

Noise Compliance Measurement Study

Colebrook, Connecticut

January, 2016

Prepared for:

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Executive Summary

A cold weather ("leaf off") noise monitoring study was completed for two 2.85 MW turbines installed at Wind Colebrook South in Colebrook CT during January 2016. In this report, we have reviewed applicable noise standards and criteria and described the measurements made at the location. **Given the data collected as a result of this study, it is our professional opinion that acoustic impacts from the wind turbines in Colebrook of 40-45 dBA are in compliance with and well below the maximum allowable noise levels of 61 dBA during the day and of 51 dBA during nighttime periods at all locations.** In fact, modeled background noise conditions were found to equal to or exceed the noise outputs of the turbines currently under consideration. Noise levels from the turbines were at or about the level of the wind in the trees background at two locations under windy operating conditions, and well below the background level from highway noise sources at another. The turbine noise levels were about 10 decibels below the levels from frequent plane overflights. Infrasound levels were not measurable with the equipment, but under typical operating conditions levels should be below levels normally detected by the human ear.

Based on this study, we conclude the following:

- L90 Operational levels from the turbines at maximum noise levels were below the appropriate Connecticut standards during both day and nighttime periods at all locations. Peak sound levels at the closest residence including traffic and tree noise were found to be about 1-5 dBA below the project noise limits, while peak levels from the turbines only were nearly 7-8 dBA below the project noise limits.

- The turbine noise levels of about 40-45 dBA were well below levels expected from aircraft flyovers in the area, about 50-55 dBA, and below the 45 dBA level usually considered to define turbine annoyance. Background levels under wind turbine operational conditions from wind and tree noise were between 30 and 50 dBA, but were often comparable to or exceeded turbine noise levels at 2 of 3 monitoring locations under operational conditions. These are nearly the same levels as those expected from the turbine itself at the monitoring locations, indicating that much of the turbine sound was masked by the background under typical operating conditions.

1 Introduction

Wind Colebrook South ("WCS"), located at 17 and 29 Flagg Hill Road in Colebrook, CT is an operational wind farm. This wind farm consists of two 2.85 MW wind turbines with 103 meter diameter blades and 98.3 meter hub heights which feed power into the Connecticut power grid. WCS began commercial operations on November 4, 2015. It is possible that a third wind turbine, located to the southwest of the two operational ones, may go up during 2017. In this case, additional monitoring near this turbine may be needed, which would be done at that time.

Dr. Howard Quin was contracted by BNE Energy to perform a cold weather noise study for the wind turbine installations. The study takes place over the months of January-March 2016. Each report summarizes noise measurements made during each of these months; this report summarizes the results for January 2016. Long-term monitoring will also be conducted at two locations over a one year period and the report will be filed in late 2016 when the study is completed. In this report, we review applicable noise standards and criteria, and summarize the measurement noise data at the site. Appendix A provides a description of various noise metrics.

2 Noise Standards and Criteria

Generally speaking, noise standards are usually defined as either absolute levels or amount over ambient background. Ambient is usually defined as the background A-weighted sound level that is exceeded 90 percent of the time (i.e. L90) measured during equipment operating hours, although in some cases is defined using the average level (the Leq). For the case where the turbines run continuously, as they did for many hours during the operational testing, the turbine sound is usually the ambient, depending on locations and other background sources. A wind turbine only operates when there is sufficient wind speed to run it, which is generally 4 meters per second (m/s) (9 mph) measured at a height of 10 meters (m), or about 5 m/sec at hub height. Therefore, it is appropriate to report sound levels when winds are blowing at speeds of 5 m/s or higher at hub height for purposes of comparison to the turbine noise emissions, if possible. Typically turbines would create peak sound levels near full production levels between 10 and 12 m/sec.

The noise monitoring program was conducted to demonstrate that the operation of the wind turbines at Colebrook South will meet the Connecticut Department of Energy and Environmental Protection's (DEEP) noise control regulations (Title 22a, §§ 22a-69-1 to 22a69-7), which are contained in the Regulations of Connecticut State Agencies. These regulations are:

Table 1

Noise Zone Standards, L90 (dBA)

Table 1				
Noise Zone Standards, L90 (dBA)				
	Class A Daytime	Class A Nighttime	Class B	Class C
Emitter Zone				
Class A (Residential)	55	45	55	62
Class B (Commercial)	55	45	62	62
Class C (Industrial)	61	51	66	70

Source: Control of Noise (Title 22a, Section 22a-69-1 to 22a-69-7.4), Regulations of Connecticut

The Emitter Zone for Colebrook South is Class C (Industrial) which shall not emit noise exceeding the levels stated in Table 1 at the adjacent noise zones. The relevant sound limits from the table are 61 dBA daytime and 51 dBA nighttime. In measuring compliance with Noise Zone Standards, the following short-term noise level excursions over the noise level standards established by these Regulations shall be allowed.

Allowable levels (dBA)	Time period of above standards such levels (minutes/hour)
3	15
6	7 ½
8	5

3 Measurement Program

A total of four sites were chosen for weekly sound measurements near the two turbines on Flagg Hill Road. Two of these sites were to have weekly monitors for one week intervals during the monthly monitoring program, while one other was to have seasonal monitors for one week each quarter as well as during the monthly program, while a final location was to have seasonal monitoring only. The monitoring locations were identified in the Colebrook South Post Construction Noise Monitoring Program approved by the Connecticut Siting Council on November 22, 2011. Figure 1 shows the turbines and monitoring locations. The two turbines are clearly visible on the map below inside the property line. The monitoring locations were as follows;

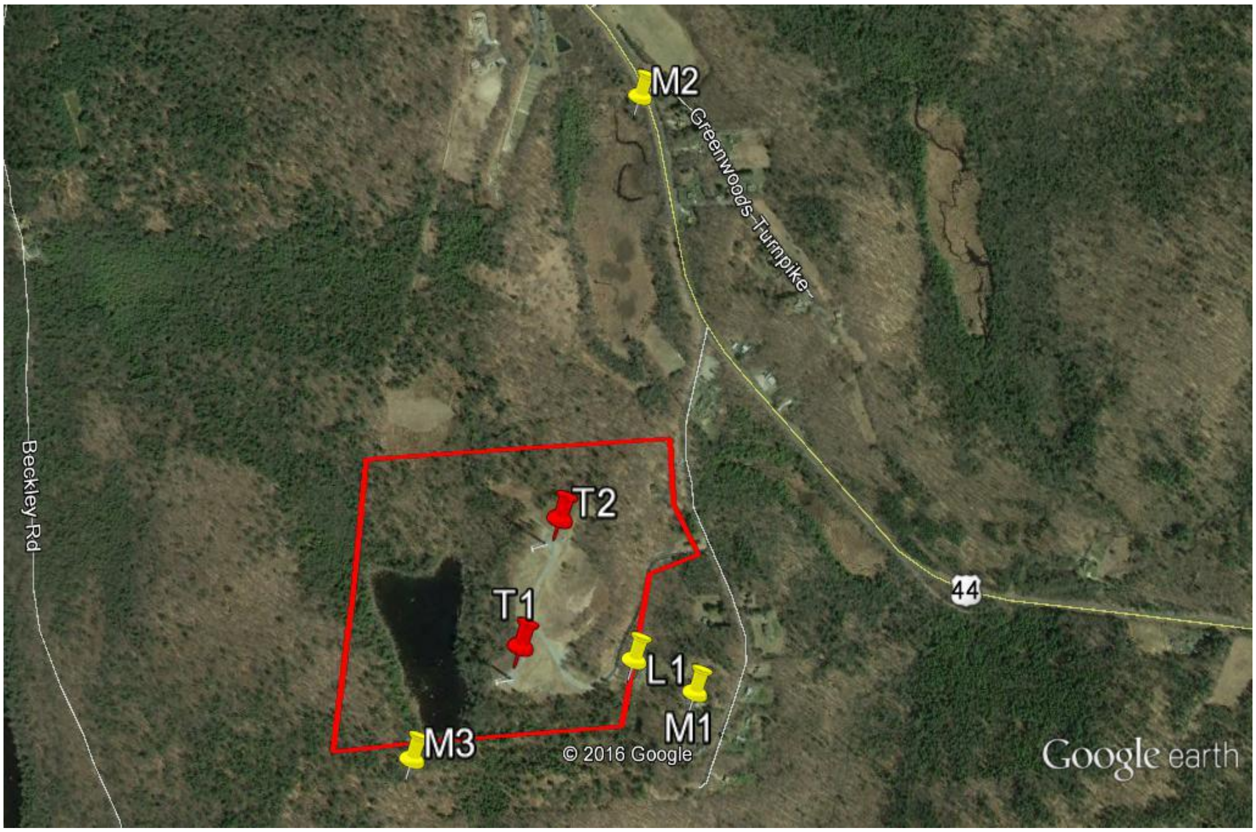


Figure 1.

Monitoring Sites and Property Line

Near Wind Colebrook South

M1 – Located near the Residence on 45 Flagg Hill Road. Identified as Receptor Location 5 (R5) in the Noise Report dated October 2010. The latitude and longitude coordinates are 41° 57.709'N Latitude, 73° 8.488'W Longitude. This location was also used for seasonal monitoring.

M2 – Located on the west side of the road near the Residences on Greenwoods Turnpike. Identified as Receptor Location 2 (R2) in the Noise Report. The latitude and longitude coordinates are 41° 58.363'N Latitude, 73° 8.569'W Longitude.

M3 – Located near the property line of the Residence on Beckley Road. Identified as Receptor Location 7 (R7) in the Noise Report. The latitude and longitude coordinates are 41° 57.641'N Latitude, 73° 8.910'W Longitude.

L1 – Located near the closest Residence to the turbines on 29 Flagg Hill Road, which has a Wind Farm Neighbor Agreement with Wind Colebrook South, and is the closest residence to Turbine 1. This is the seasonal monitoring location where measurement will be conducted for one week during each season. It was not monitored during this program; it was later examined in February.

Note that actual monitoring locations M1 and M2 were closer to the turbines than the closest nearby residents or property lines. Consequently, turbine sound levels measured at these locations are conservative; actual turbine sound levels at nearby relevant receptors would be lower.

At each location, long term data was collected in one hour intervals, in accordance with Connecticut DEEP requirements, with the meter on “slow” setting. As specified by DEEP requirements, the L90 metric was used to verify compliance with DEEP regulations. Since the DEEP regulations also contain standards for shorter time intervals, the L10, L15, and L25 metrics were recorded to approximate the L90s for shorter time periods. Note that this is a conservative estimate; typically one hour L10s would have higher levels than six minute L90s in ten high wind periods over the same hour. The hourly Leq (average) levels were also collected.

Noise measurements were conducted with Larson Davis 831 octave band sound level meters/noise analyzers for intervals of one hour, in order to comply with the Connecticut monitoring requirements. Field calibrations with acoustic calibrators were conducted for all of the measurements. All instrumentation components, including microphones, preamplifiers and field calibrators have current laboratory certified calibrations traceable to the National Institute of Standards and Technology.

Attended short term monitoring was also made on-site. This was done with a Quest Sound Pro Type I sound meter for periods of 30 minutes at each location with the meter on “slow” setting. The short term monitoring was done to ensure that a technician was on-site to verify the actual relative contributions of sound from various sources during typical wind turbine operating conditions. This is important, as it is not always readily evident from an examination of long term hourly measurements where sound sources come from.

The first measurement program was conducted by Dr. Howard Quin from January 11, 2016 to January 18, 2016. The sound levels measured are typical of those expected during dry winter conditions. Insect noise was absent during the winter. Meters were deployed for more than a week at each location. However, due to meter shutdown in very cold weather, somewhat more than 5 days of data was actually collected at each location. Since a substantial amount of this data was collected under turbine operational conditions, the data are sufficient to establish compliance at each location.

Weather varied significantly during the measurement period. Weather data were obtained from station KCTNORFO2, Great Mountain Forest, about 4 miles west near Tobey Pond; wind data was obtained on site from the turbine SCADA system. High temperatures ranged from about 20 degrees to 37 degrees Fahrenheit, while lows ranged from about 9 degrees to about 30 degrees. Leaves were off trees, and snow cover varied from no snow at the beginning, to about 2-3 inches in the middle, to no snow at the end. This is therefore typical of winter conditions in the study area. Wind conditions where peak operational wind conditions occurred on several days during the study, most noticeably on January 13 and January 19, where the wind was about 16-20 m/sec. Lower operational wind conditions occurred on most other days during the monitoring period; wind speeds at hub height varied from around 4 to 8 m/sec most days, typical of cut-in to average wind turbine speed.

Figure 2. Sound Monitoring Site Photos

Monitoring Location M1 At 47 Flagg Hill Road

Monitoring Location M2 Across From Greenwoods Turnpike

Monitoring Location M3 Near SW Property Line

4 Measurement Results

Figures 3, 4, and 5 represent graphs of the L90, L10 and Leq at sites M1, M2, and M3 for each one hour period. Wind speed is shown in blue, while sound level is in red. The established project limits are in green. The conservative nighttime is 51 dBA, while the 15 minute limit of 54 dBA which is 3 dBA above the Connecticut hourly limit is shown on the L10 graph. The graph shows that, typical L90s varied from approximately 21 to 45 dBA at Location M1, from 21 to 51 dBA at M2 which was dominated by traffic noise, and from 26 to 45 at M3, with high wind noise producing the peaks at both locations. Note that noise recorded includes all sound on site, not just the turbine noise, including noise from wind, trees, cars, trucks and planes. ***The data shows that the turbines were in compliance with the most stringent (nighttime) levels at all times during the study period even when including background noise caused by the wind, trees, cars, trucks and planes.***

In order to examine compliance with various metrics employed by DEEP, we have correlated the wind speed with SCADA data obtained from the wind turbine hub. For this analysis, we have used data from turbine T1, which is closest to the residences; similar data were obtained from turbine T2. The SCADA data is obtained in 10 minute windows, which makes for ready comparison with various metrics. We have plotted the L10 metric against the highest hourly 10 minute wind speed increment, the Leq metric against the average wind speed for each hour, and the L90 metric against the lowest hourly 10 minute wind speed, which is the exact interval used for Connecticut compliance evaluation. It should be noted that there is not an exact correlation here; the L10 and L90 are the highest and lowest 10% levels over an entire hour, whereas the 10 minute wind speed averages are only the highest and lowest separate 10 minute intervals. Nonetheless, they are closely correlated with the actual wind occurring during the highest and lowest 10 percent times at locations where wind noise and turbine noise predominate. Note that the L10 is also relevant, as it is above two other compliance metric levels, the 15 and 7 ½ minute levels; if the L10 is in compliance, those levels will be in compliance too.

An examination of the data indicates that there is some correlation between the hub wind speed and the sound levels at two of the locations, the meter near the residence on 47 Flagg Hill Road, and the meter near the pond to the southwest of the turbines. However, it should be noted that this is by no means a one-to-one correspondence. This is for two or three reasons. First, the wind direction varies somewhat, and turbines are most affected by sound from the upwind direction. This means that the peak sound levels from the turbine at 47 Flagg Hill Road are from winds from the west, while peak sound levels from the turbine at the pond area to the Southwest are from winds to the east and northeast.

Wind directionality had differing, but important effects, at each measurement location. This is due to differing orientations with regard to both sound and wind propagation, and differing background conditions. At location M1, sound was due to both wind turbine noise and background in the trees, with both being about equal in intensity depending on local gustiness. Sound levels were actually slightly higher when wind was from the south, as this allowed the wind to blow straight along the side of the hill without being blocked, as it would be when the wind was from the west. This caused the background levels from wind in the trees to be somewhat higher, compensating for the fact that sound from the turbine moved from downwind to sidewind.

This effect was also seen at location M3. The sound levels from sound in the trees when the wind was from the south were clearly higher. When the wind was from the west, sound levels were dominated almost entirely by the turbine, as the hill blocked most of the tree wind noise, and they were slightly lower overall as the local wind noise was lower. This shows that at both locations, wind in the trees contributes significant amounts to the total sound, and in many conditions actually masks the turbine sound, depending on wind direction.

In order to get the best examination of the sound from the turbines only, we examined data at locations M1 and M3 during a late night period when both turbines were continuously operational at nearly full power. Five hours of data between the hours of 3:00 AM and 8:00 AM on January 13 were examined, with winds from the NNW at about 13 m/sec Under these conditions, the turbine was operating at full, or almost full power (and maximum sound level) the entire time. **The L90 levels indicate that the sound levels from the turbines, which constituted most of the background, averaged 44.0 dBA and 43.8 dBA at M1 and M3, respectively.** At these wind speeds, it seems likely that there was some additional noise background from wind rustling in trees. **However, sound from the turbines only could not have exceeded these levels.**

At location M2, sound was actually mostly dominated by traffic noise. This was true through most of the day under normal turbine operating conditions, as the turbine noise levels were not particularly high in this area. This was confirmed by examining the L90 levels between 12 and 4 A.M. on January 13, when road noise would be minimal, with winds around 12 m/sec with the turbine operating, which show levels around 35 dBA. This means that there was little correlation of the L90 and L10 levels with the turbine operations on site. When the wind was higher, this area did experience higher sound levels; however, on-site observations indicated that this was largely due to background sound from the trees, not from the turbines. The highest sound levels occurred when wind from the west rustled the trees nearby, creating downwind sound. On site observations showed that this is not from the turbines. ***The data and on-site observations at location M2 both show that in this area, sound is dominated by either the road or tree noise; the turbines contribute relatively little to the overall sound environment in this area.***

Overall, all locations should experience similar levels from air flight flyovers, as this area is under the western flight path of Bradley International Airport. An on-site examination of sound sources indicates that the typical maximum level at location M3 (near the pond) would likely only occur during these flyovers, as there were no other high sound sources at this location except occasional gunfire from local hunting or shooting. An examination of the data at this location indicates precisely this; namely, Lmax levels were much lower during the late evening and early morning hours when there was no flyover activity. An examination of Lmax data from five hours of low turbine operation during the evening of January 13 from 8:00 P.M. to 1:00 A.M. when there would be no hunting or shooting activity and when planes would fly over indicates that the Lmax level was about 54 dBA. This indicates that sound from aircraft flyovers were between 5 and 10 dBA more than sound from the turbines.

TABLE 2.

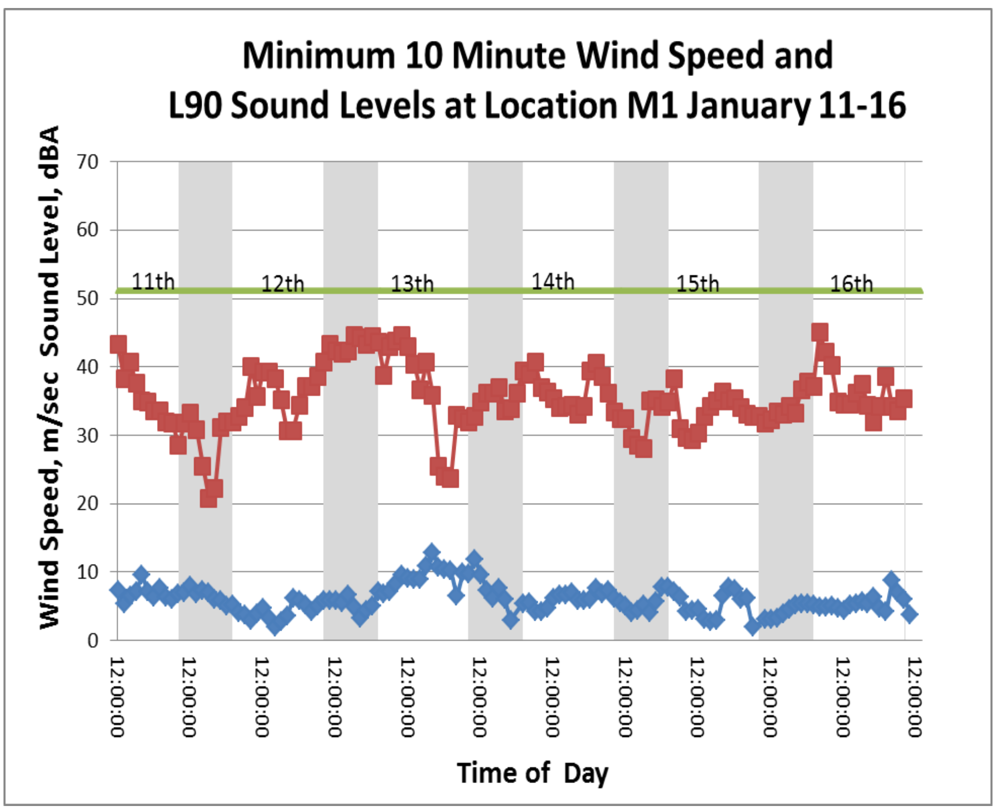
SHORT TERM MONITORING RESULTS

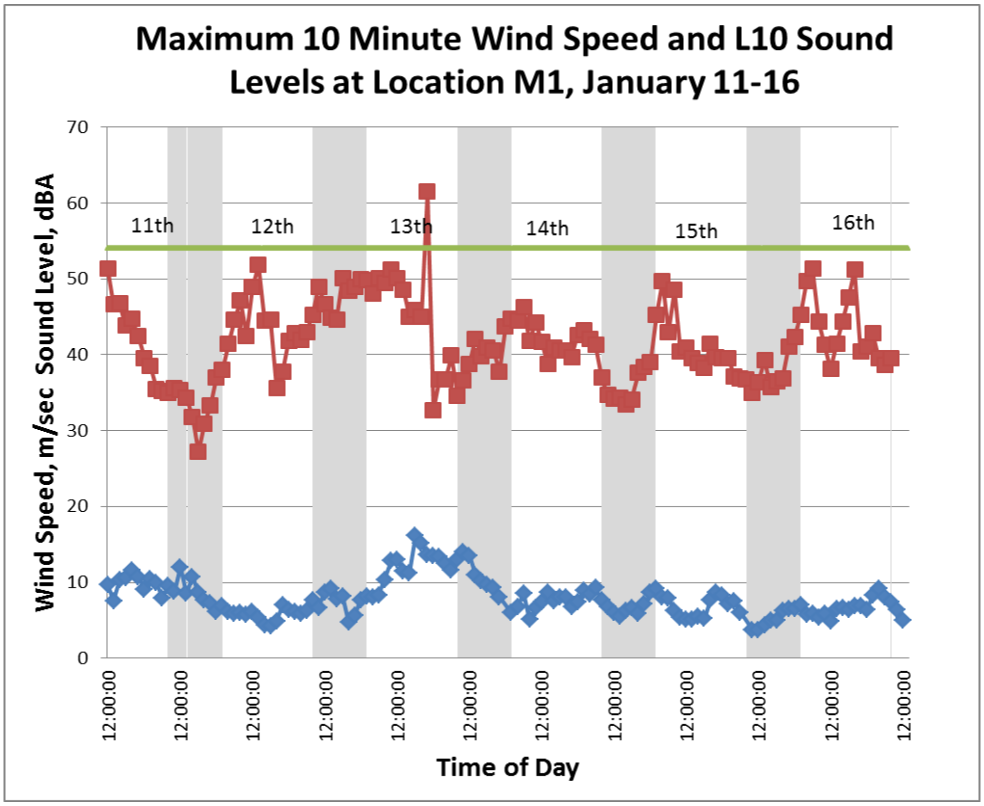
Location	Date	Time	Leq	L90	L50	L25	L15
M1	January 13	1:02 P.M.	46.7	40.3*	45.2	45.6	48.2
M2	January 13	1:52 P.M.	52.7	42.7*	51.0	54.0	55.3
M3	January 13	3:15 P.M.	46.8	40.9*	45.2	45.2	47.3
M1	January 18	10:27 P.M.	54.0	47.4	52	54.7	55.9
M2	January 18	11:25 P.M.	58.6	45.9*	53.6	57.8	60.3

Note: Nighttime measurements were not made at location M3 due to access and safety issues. It is assumed that daytime levels there were similar to nighttime, as there is no change in background conditions from day to night

*L90s obtained from adjacent hourly meter due to cold weather low level issues with Qwest meter

Figure 3.




Maximum 10 Minute Wind Speed and L10 Sound Levels at Location M1, January 11-16
Wind Speed, m/sec Sound Level, dBA
70
60
50
40
30
20
10
0
11th
12th
13th
14th
15th
16th
12:00:00
Time of Day

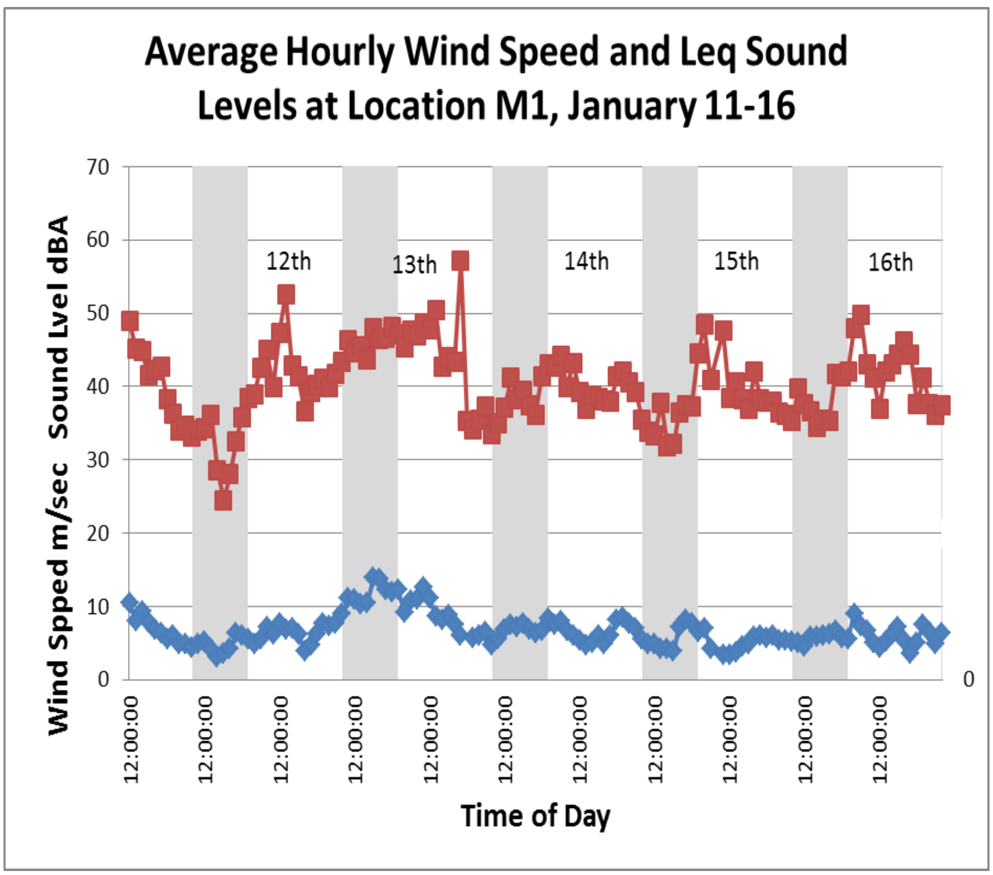
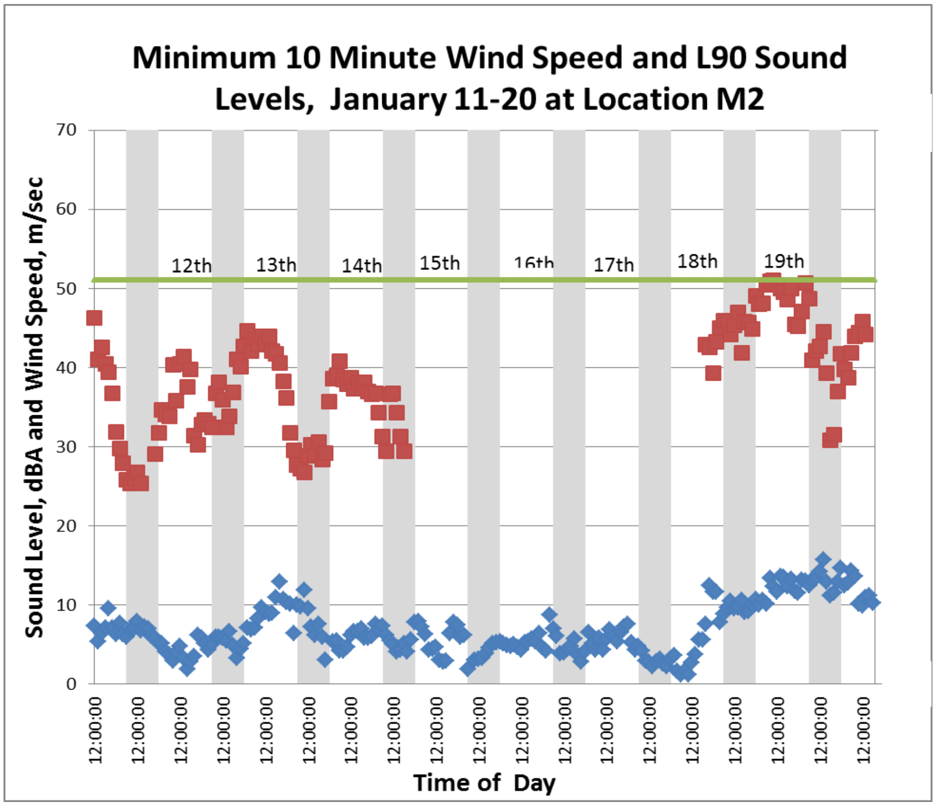

Average Hourly Wind Speed and Leq Sound Levels at Location M1, January 11-16
Wind Spped m/sec Sound Lvel dBA
70
60
50
40
30
20
10
0
12th
13th
14th
15th
16th
12:00:00
Time of Day

Figure 4.


Minimum 10 Minute Wind Speed and L90 Sound Levels, January 11-20 at Location M2
Sound Level, dBA and Wind Speed, m/sec
70
60
50
40
30
20
10
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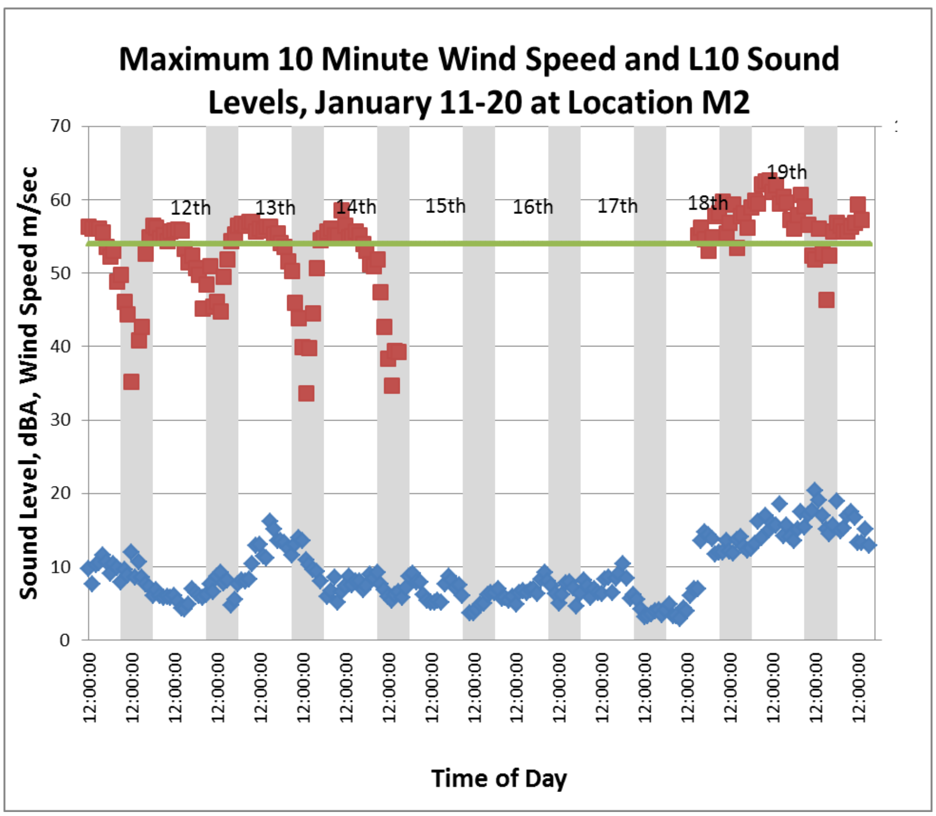
12th
13th
14th
15th
17th
18th
19th
12:00:00
Time of Day


Maximum 10 Minute Wind Speed and L10 Sound Levels, January 11-20 at Location M2
Sound Level, dBA, Wind Speed m/sec
70
60
50
40
30
20
10
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12th
13th
14th
15th
16th
17th
18th
19th
12:00:00
Time of Day

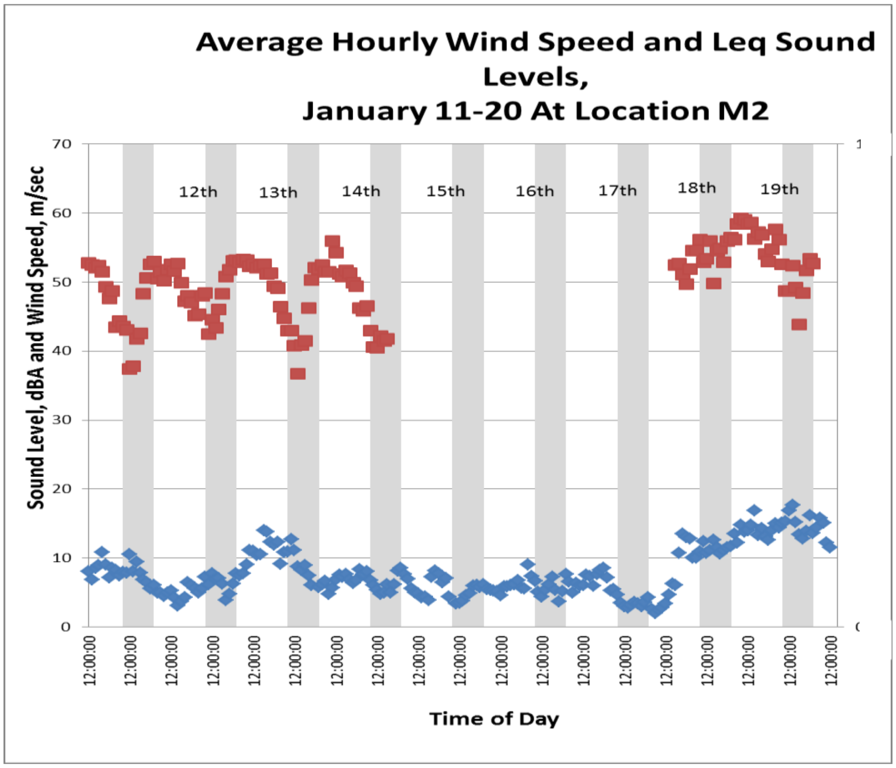
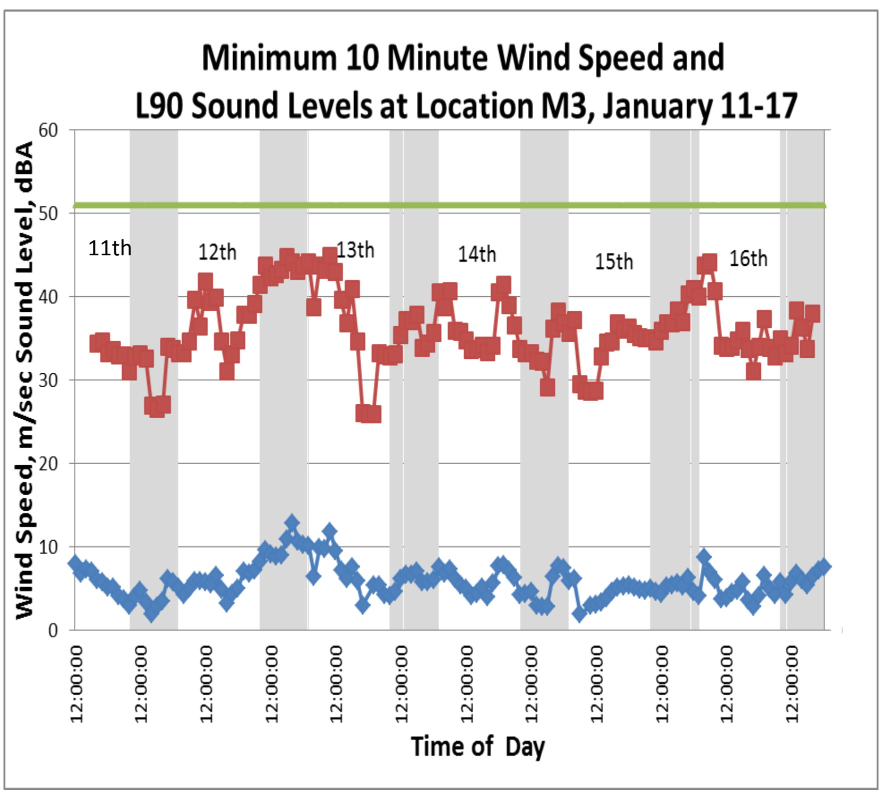
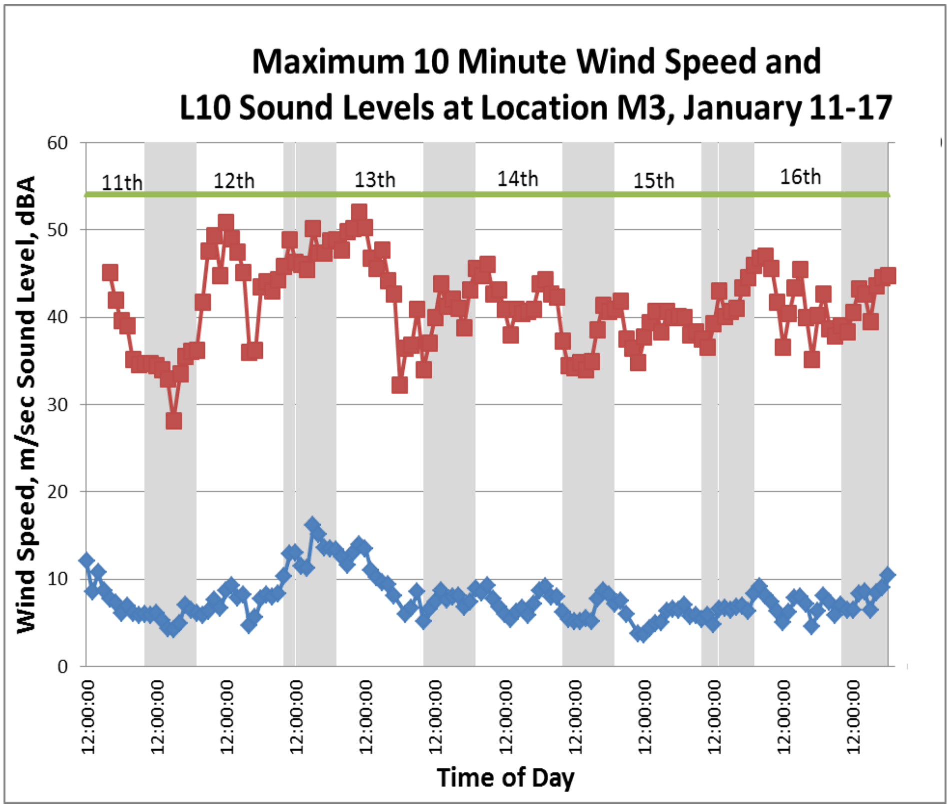

Average Hourly Wind Speed and Leq Sound Levels,
January 11-20 At Location M2
Sound Level, dBA and Wind Speed, m/sec
Time of Day
12th
13th
14th
15th
16th
17th
18th
19th
0
10
20
30
40
50
60
70
12:00:00

Figure 5.


Minimum 10 Minute Wind Speed and
L90 Sound Levels at Location M3, January 11-17
Wind Speed, m/sec Sound Level, dBA
Time of Day
11th
12th
13th
14th
15th
16th
0
10
20
30
40
50
60
12:00:00


Maximum 10 Minute Wind Speed and
L10 Sound Levels at Location M3, January 11-17
Wind Speed, m/sec Sound Level, dBA
0
10
20
30
40
50
60
11th
12th
13th
14th
15th
16th
12:00:00
Time of Day

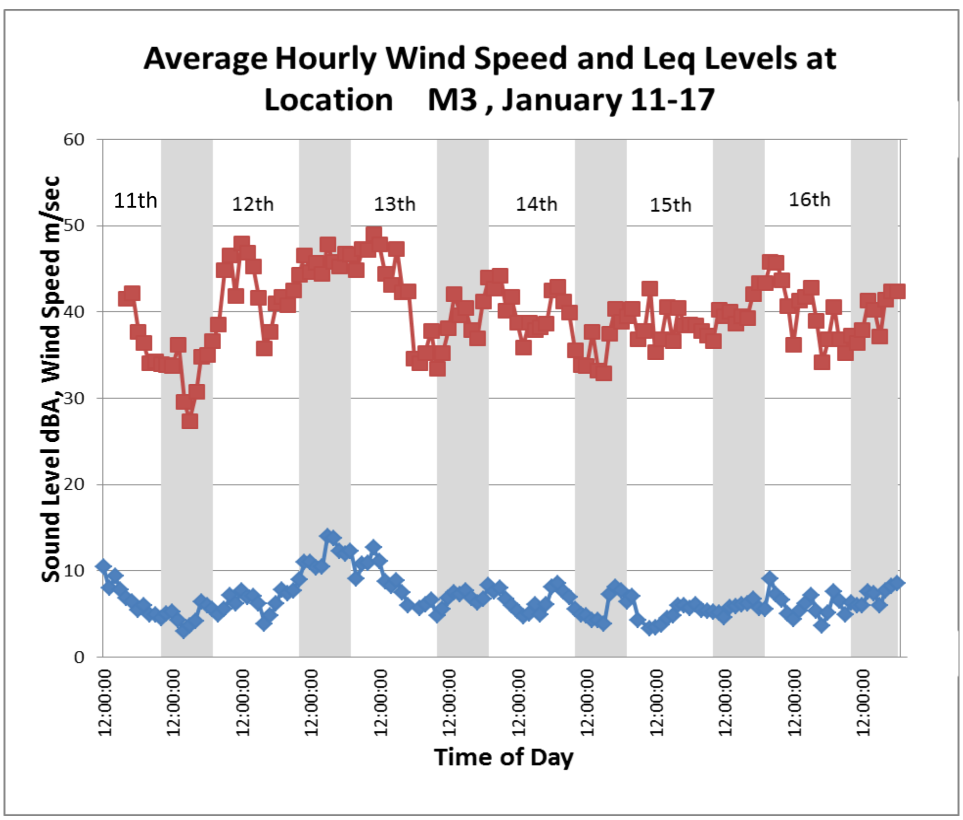
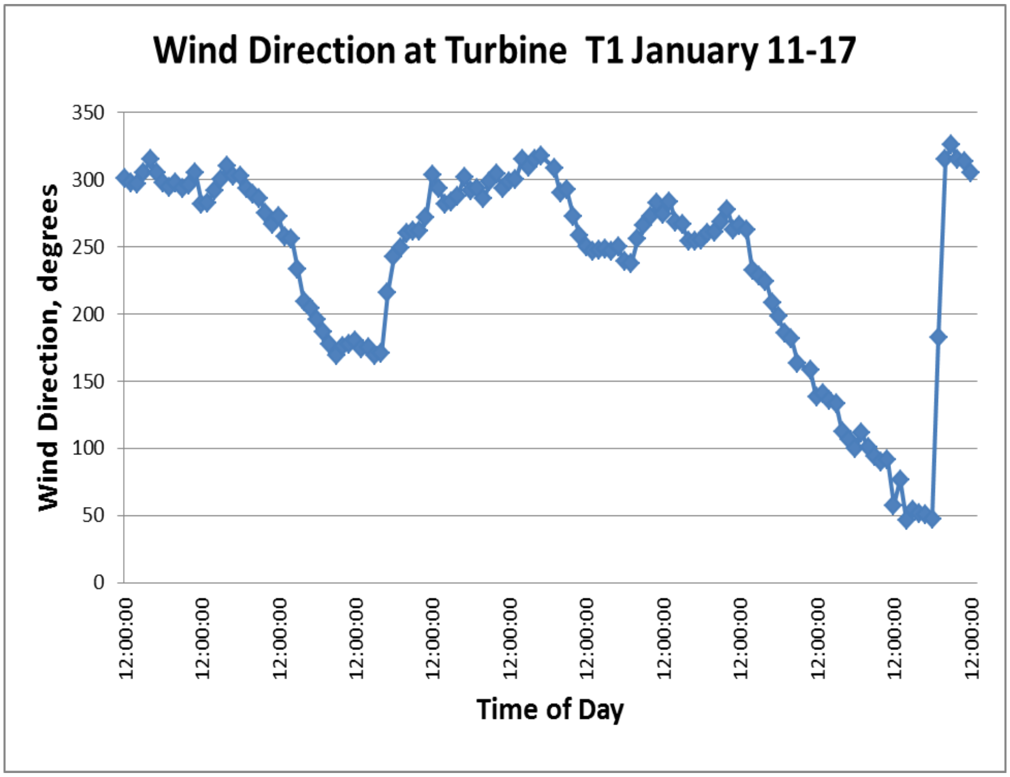

Average Hourly Wind Speed and Leq Levels at
Location M3 , January 11-17
Sound Level dBA, Wind Speed m/sec
0
10
20
30
40
50
60
11th
12th
13th
14th
15th
16th
12:00:00
Time of Day

Figure 6.


Wind Direction at Turbine T1 January 11-17
Wind Direction, degrees
350
300
250
200
150
100
50
0
12:00:00
12:00:00
12:00:00
12:00:00
12:00:00
12:00:00
12:00:00
12:00:00
12:00:00
12:00:00
12:00:00
12:00:00
Time of Day

Appendix A: Description of Noise Metrics

This Appendix describes the noise metrics used in this report.

1. A-weighted Sound Level, dBA

Loudness is a subjective quantity that enables a listener to order the magnitude of different sounds on a scale from soft to loud. Although the perceived loudness of a sound is based somewhat on its frequency and duration, chiefly it depends upon the sound pressure level. Sound pressure level is a measure of the sound pressure at a point relative to a standard reference value; sound pressure level is always expressed in decibels (dB), a logarithmic quantity.

Another important characteristic of sound is its frequency, or "pitch." This is the rate of repetition of sound pressure oscillations as they reach our ears. Frequency is expressed in units known as Hertz (abbreviated "Hz" and equivalent to one cycle per second). Sounds heard in the environment usually consist of a range of frequencies. The distribution of sound energy as a function of frequency is termed the "frequency spectrum."

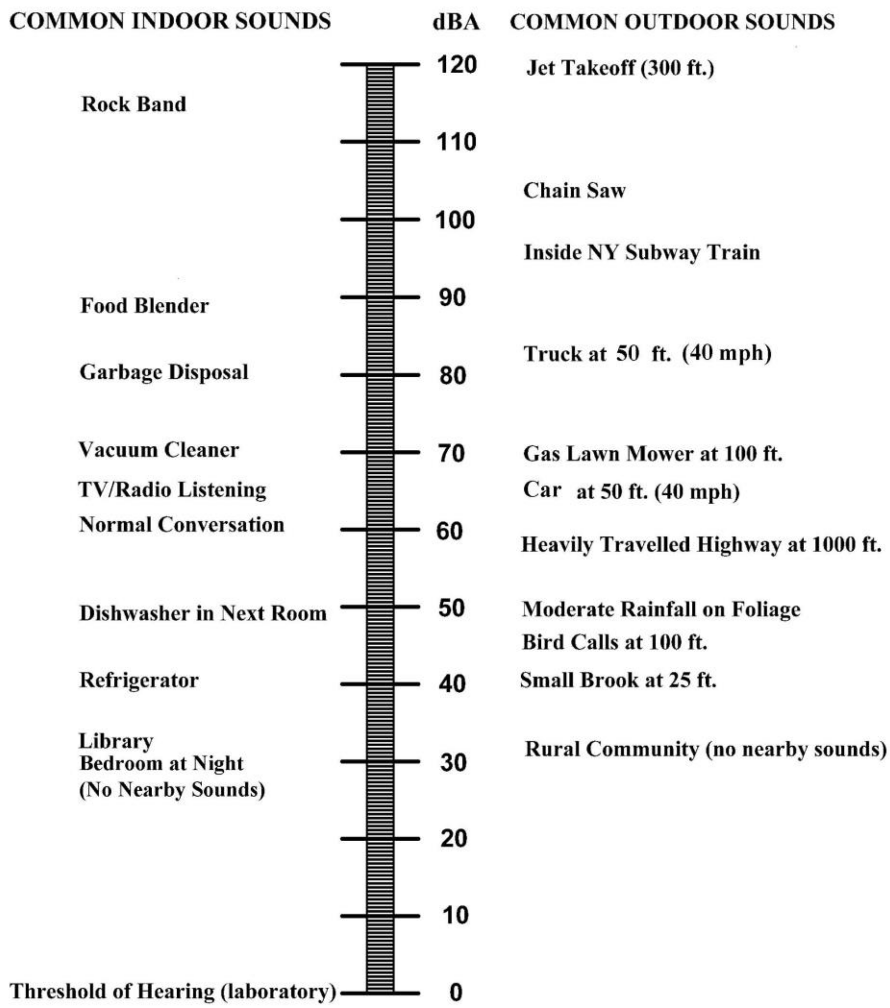
The human ear does not respond equally to identical noise levels at different frequencies. Although the normal frequency range of hearing for most people extends from a low of about 20 Hz to a high of 10,000 Hz to 20,000 Hz, people are most sensitive to sounds in the voice range, between about 500 Hz to 2,000 Hz. Therefore, to correlate the amplitude of a sound with its level as perceived by people, the sound energy spectrum is adjusted, or "weighted."

The weighting system most commonly used to correlate with people's response to noise is "A-weighting" (or the "A-filter") and the resultant noise level is called the "A-weighted noise level" (dBA). A-weighting significantly de-emphasizes those parts of the frequency spectrum from a noise source that occurs both at lower frequencies (those below about 500 Hz) and at very high frequencies (above 10,000 Hz) where we do not hear as well. The filter has very little effect, or is nearly "flat," in the middle range of frequencies between 500 and 10,000 Hz. A-weighted sound levels have been found to correlate better than other weighting networks, including C weighting, with human perception of "noisiness" from turbines, which is why C weighting is not usually used for wind turbine compliance analysis. One of the primary reasons for this is that the A-weighting network emphasizes the frequency range where human speech occurs, and noise in this range interferes with speech communication. The figure below shows common indoor and outdoor A-weighted sound levels and the environments or sources that produce them.

2. Equivalent Sound Level, Leq

The Equivalent Sound Level, abbreviated L_{eq}, is a measure of the total exposure resulting from the accumulation of A-weighted sound levels over a particular period of interest -- for example, an hour, an 8-hour school day, nighttime, or a full 24-hour day. However, because the length of the period can be different depending on the time frame of interest, the applicable period should always be identified or clearly understood when discussing the metric. Such durations are often identified through a subscript, for example L_{eq1h}, or $L_{eq(24)}$.

L_{eq} may be thought of as a constant sound level over the period of interest that contains as much sound energy as (is "equivalent" to) the actual time-varying sound level with its normal peaks and valleys. It is important to recognize, however, that the two signals (the constant one and the time-varying one) would sound very different from each other. Also, the "average" sound level suggested by L_{eq} is not an arithmetic value, but a logarithmic, or "energy-averaged" sound level. Thus, the loudest events may dominate the noise environment described by the metric, depending on the relative loudness of the events.



3. Statistical Sound Level Descriptors

Statistical descriptors of the time-varying sound level are often used instead of, or in addition to L_{eq} to provide more information about how the sound level varied during the time period of interest. The descriptor includes a subscript that indicates the percentage of time the sound level is exceeded during the period. The L_{50} is an example, which represents the sound level exceeded 50 percent of the time, and equals the median sound level. Another commonly used descriptor is the L_{10}, which represents the sound level exceeded 10 percent of the measurement period and describes the sound level during the louder portions of the period. The L_{90} is often used to describe the quieter background sound levels that occurred, since it represents the level exceeded 90 percent of the period.