MassCEC Acoustic Study Methodology for Wind Turbine Projects

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The Massachusetts Clean Energy Center (MassCEC) provides technical and financial support for the development of responsibly-sited wind generation projects. Toward this goal, MassCEC offers project proponents grants and loans to help in siting projects, including funding for acoustic studies. The purpose of this document is to establish a standardized methodology for conducting acoustic studies for projects that receive or request technical or financial support from MassCEC.

The methodology is intended to be compatible with the Massachusetts Department of Environmental Protection's (MassDEP) noise regulation. However, the methodology is not intended in any way to alter, substitute, create, or enforce any policy or regulation that is in force or may be developed by MassDEP or any other regulatory agency. While this methodology is intended to assist project developers anticipate whether a project will comply with MassDEP's noise regulation, following this methodology in itself **does not** constitute or guarantee compliance with MassDEP's noise regulation. MassCEC assumes no responsibility or liability arising from or related to a project's failure to meet MassDEP's noise regulation.

While use of this methodology is required for MassCEC acoustic studies initiated after the issue date of this document, MassCEC recognizes that studies conducted under other methodologies may be equally valid.

As explained on its Noise Policy Fact Sheet, MassDEP implements the requirements of 310 CMR 7.10 as follows:

- A violation of the noise regulation occurs when a source:
    - Increases the broadband sound level by more than 10 dB(A) above ambient, or
    - Produces a "pure tone" condition – when any octave band center frequency sound pressure level exceeds the two adjacent center frequency sound pressure levels by 3 decibels or more.
- Criteria are measured both at the property line and at the nearest inhabited residence. "Ambient" is defined as the background A-weighted sound level that is exceeded 90% of the time, measured during the equipment operating hours.[1]

A goal of a MassCEC-funded acoustic study is to make a conservative estimate whether a wind project will comply with MassDEP's noise policy. This methodology was developed to standardize data collection methods and interpretation of results to ensure quality and consistency of acoustic studies conducted with MassCEC funds. All acoustic studies funded by MassCEC or submitted in support of a funding application must comply with this methodology.

[1] Massachusetts Department of Environmental Protection (310 CMR 7.10) – Noise Policy Fact Sheet.

MASSACHUSETTS CLEAN ENERGY CENTER

Commonwealth Wind

This document provides guidance on:

1) determining the ambient sound levels,
2) calculating the hub height wind speeds, and
3) modeling the increase in ambient sound pressure level associated with selected turbine(s) operating at the proposed location(s).

In particular, the methodology addresses the importance of collecting sufficient measurements in a project area to firmly establish the ambient sound levels at wind speeds high enough for the turbine to generate power. For a wind energy project, this task is complicated by the fact that simply measuring the lowest L_{90} sound level in a given one- to two-day period is insufficient because winds may be too light during that time period for turbine operation.

This methodology incorporates the assumption that existing L_{90} sound levels generally vary with wind speed, and thus ambient levels will be different at the wind turbine cut-in wind speed (when a turbine first begins producing power) compared to the design wind speed (when a turbine first produces its maximum power). Typical values for the cut-in and design wind speeds, as measured at the turbine hub height, are 3-4 m/s (meters per second) and 9-10 m/s, respectively. Therefore, it is essential to establish the relationship between the near ground-level L_{90} sound pressure level and the range of hub height wind speeds when the proposed turbine could operate.

Prior to any data collection activities, consultants are required to submit a draft study design for review and approval by MassCEC, in consultation with an acoustic expert. Please refer to section 2.3 for details.

Acoustic studies must conform to the following specifications:

1. Equipment Standards

This section outlines the appropriate standards to which all sound level measurement equipment must comply.

1.1. Sound level meters used must be ANSI Type 1. ANSI Type 2 meters are not acceptable. Equipment meeting similar applicable ISO or IEC standards is also acceptable.

1.2. Consultants must provide the model and make of the sound level meter for the final report.

1.3. The sound level meter must have been field-calibrated using an ANSI Type I calibrator that has accuracy traceable to the National Institute of Standards and Technology (NIST).

1.4. The sound level meter must have been calibrated by a certified laboratory no more than 24 months prior to the date the acoustic study was conducted.

2. Study Design

The section outlines the steps to collect sufficient sound level data for the project area to document the L_{90} sound pressure level at different hub height wind speeds when the turbine could operate. The consultant must first identify the nearest residences or other sensitive receptors and the project's property lines. These receptors should be used to determine the locations where long-term and short-term monitoring will be conducted. Short-term monitoring locations may be useful in validating the general representativeness of selected long-term locations. Furthermore, short-term monitoring can help in quantifying acoustic impacts at additional receptors. The use of short-term monitoring is left to the professional judgment of the consultant. Careful monitoring of weather forecasts is required to choose a data collection period for sound monitoring with the objective of targeting the appropriate range of hub height wind speeds. Data can be collected at any time throughout the year but times with substantial insect or Tree Frog ("spring peepers") noise should be avoided.

2.1. Wind Speed Monitoring

On-site wind speed measurement must be taken using one of the following methods, listed in order of preference. Wind monitoring requirements are determined on a project-by-project basis according to a number of factors. An onsite meteorological (MET) tower is the preferred method to obtain wind resource data. However, when not available, an appropriate alternative will be determined in consultation with a wind resource assessment expert and MassCEC. Consultants are also advised to select an appropriate wind shear value that will lead to the most accurate estimate of the L_{90} ambient sound pressure level for each hub height wind speed bin. Wind speed data must be time-matched to coincide with acoustic monitoring data (including confirmation of clock accuracy, adjustments for daylight savings, etc.).

2.1.1. Preferably, an on-site MET tower with anemometers at or near hub height should be used. SODAR or LIDAR may also be used but should be located far enough away from the microphones to not impact ambient measurements.

2.1.2. If an on-site MET tower at hub height cannot be utilized, an on-site MET tower should be erected with an anemometer at approximately 10-meters and data extrapolated to hub height using the site's wind-shear profile.

2.1.3. If a 10-meter on-site MET tower cannot be erected at the site, the nearest, representative meteorological station with at least a 10-meter anemometer must be used and data extrapolated to hub height using the site's wind-shear profile.

2.2. Selection of Acoustic Monitoring Locations

2.2.1. Long-term monitoring locations

2.2.1.1. The consultant will need to select an appropriate number of long-term monitoring locations in order to establish the L_{90} ambient sound pressure level at sensitive receptor locations.

2.2.1.2. One of the long-term locations must represent the nearby residence with the lowest ambient sound levels.

2.2.2. Short-term monitoring locations

2.2.2.1. If short -term monitoring locations are utilized, they should be chosen to validate the general representativeness of selected long-term locations and to more accurately understand the existing L_{90} sound pressure level at sensitive receptors.

2.3. Draft Study Design

Prior to any data collection activities, consultants are required to submit a draft study design for review by MassCEC, in consultation with an acoustic expert. The draft study design must contain the following information:

2.3.1. An aerial image of the study area which identifies all proposed long and short-term monitoring locations.

2.3.2. An explanation and justification of the methods used to select each proposed long and short-term monitoring location.

2.3.3. The proposed method for determining hub-height wind speeds including the rationale for selection of the wind shear value.

2.3.4. A statement of qualifications for the acoustic consulting team, including relevant experience, training, memberships, and certifications. The statement should include a description of roles in the project, including designating the project manager.

3. Data Collection

This section provides detailed requirements for the data collection phase of the acoustic study.

3.1. Microphone Placement

3.1.1. Microphones must be mounted to a height between 1 and 2 meters above grade. Alternatives to the use of a tripod are acceptable provided that they adhere to sections 3.1.3 and 3.1.4.

3.1.2. Consultants must use appropriate wind screen to reduce wind noise according to applicable standards.

3.1.3. Microphones must be at least 7.5 meters from large reflecting surfaces including buildings.

3.1.4. Microphones must be at least 1.5 meters from small diameter objects such as trees and posts to the extent possible (see ANSI S12.9-1993/Part 3).

3.1.5. Consultants must provide a rationale for microphone placements if they differ from what is called for in sections 3.1.1. through 3.1.4.

3.1.6. The consultant must note the coordinates of all short and long-term monitoring locations for the final report.

3.2. Monitoring Conditions

3.2.1. For each long and short-term monitoring location the consultant must document the audible sound sources contributing to the background sound level and their apparent location including sound from Tree Frogs, insects, etc.

3.2.1.1. For long-term, un-attended monitoring, notes must be taken at the time the equipment is installed and at the conclusion of the monitoring period.

3.2.1.2. For short-term, attended monitoring, notes must be taken during the entire monitoring period.

3.2.2. For the duration of the long term monitoring, the consultant will monitor National Weather Service data for the location closest to the monitoring site and note any periods of adverse weather including rain, snow or thunder.

3.3. Acoustic and Wind Speed Data

3.3.1. The duration of acoustic monitoring at long-term sites must be 14 consecutive days during reasonable meteorological conditions. If fewer than 14 days of data are collected, or if any days of data are discarded, the consultant must provide appropriate documentation and justification in the final report.

3.3.2. During the 14 day monitoring period short term measurements must be taken at least once during the day (6 a.m. and 10 p.m.) and once between the hours of 1 a.m. and 4 a.m.

3.3.3. Measurements at short-term monitoring locations must be taken simultaneously with long-term measurements.

3.3.4. Measurements at short-term locations must be taken for the duration of one hour.

3.3.5. For all monitoring locations, L_{90} and L_{eq} must be determined in dB(A) for 10-minute intervals.

3.3.6. Establish the average hub-height wind speed for each 10-minute period of the sampling interval (see Section 2.1).

3.3.7. For each 10-minute period of data collected, retain and submit to MassCEC summary data including, as appropriate:

3.3.7.1. Time-stamped 10-minute L_{90} in dB(A).

3.3.7.2. Time-stamped 10-minute L_{eq} in dB(A).

3.3.7.3. Time-stamped un-weighted octave band sound pressure levels based on center octave bands (31.5 Hz to 16 kHz).

3.3.7.4. Hub height wind speed summarized in 10-minute intervals (time-matched to sound level data).

4. Data Preparation

This section provides detailed requirements for preparation and presentation of data, and calculation of ambient sound levels at all monitoring locations.

4.1. Data Clean-Up and Correlation with Wind Speeds.

The following steps should be conducted for data at each long-term monitoring location.

4.1.1. If tree frogs, insects, or other wildlife were present in the vicinity of the monitoring location, the noise emitted by those sources must be removed from the data. To correct for tree frog or insect noise, the following method must be used: Take the 2,000 Hz to 8,000 Hz un-weighted octave bands and lower them to fit a monotonically decreasing function from the 1,000 Hz to 16,000 Hz values of the un-weighted octave band sound pressure levels.

4.1.2. Hours with rain or snow, noted during data collections, must be excluded from the data.

4.1.3. Extrapolate wind speed data to hub-height using the appropriate wind shear value identified in section 2.1.

4.2. Data Presentation and Calculation of Ambient Sound Levels for Long-Term Monitoring Locations.

The following steps should be conducted for data at each long-term monitoring location.

4.2.1. Compile 10-minute L_{90} sound level measurements (dB(A)) and corresponding 10-minute average hub height wind speeds (m/s) into a spreadsheet.

4.2.2. Sort acoustic data from each location into wind speed bins centered on integer values of the hub height wind speed that cover the range from cut-in wind speed to design wind speed.[2]

4.2.3. Sufficient valid data are required for a range of hub height wind speeds from cut-in to turbine design wind speed. The consultant must note in the final report any areas where it may appear that less than sufficient data may have been gathered in key wind speed bins.

4.2.4. Plot all 10-minute L_{90} sound pressure levels as a function of their associated hub-height wind speed.

4.2.5. For each wind speed bin, the 10-minute L_{90} value that is exceeded 90 percent of the time by other 10-minute L_{90} values will be used to represent the L_{90} sound pressure level at a given wind speed. The rank of this data point is calculated by this equation:

$$Rank = \left({}^{1}\!/_{10}\right) \times n$$

[2] For example, for a turbine with a 4.2 m/s cut-in wind speed, and a 9.6 m/s design speed, there will be seven wind speed bins centered on the values 4, 5, 6, 7, 8, 9 and 10 m/s. The 4 m/s bin will include all hours with average wind speeds in the range 3.6 m/s through 4.5 m/s; the 5 m/s bin will contain all hours with wind speeds in the range 4.6 m/s through 5.5 m/s, and so forth, with the last bin similarly spanning 9.6 m/s through 10.5 m/s.

where *n* is the number of 10-minute L_{90} values in the wind speed bin. If necessary, round the rank to the nearest non-zero integer. Identify the 10-minute L_{90} value which corresponds to this ranked value, counting from the lowest value up. If the rank does not fall on a L_{90} value, then the next lowest value should be used. The resulting value represents the quietest 10% of the 10-minute L_{90} values in the wind speed bin. This is the 90^{th} percentile L_{90}.

4.2.6. Generate a linear regression line that is fit to the 90^{th} percentile L_{90} values from each wind speed bin. The equation and R^2 values must be provided.

4.2.7. Use values from the linear regression line to represent the L_{90} ambient sound pressure levels as a function of hub-height wind speed.

4.2.8. Create a table that shows (1) the series of hub height wind speeds (in m/s), (2) the corresponding wind turbine sound power levels (measured in accordance with IEC 61400-11 or similar, provided by the manufacturer) and (3) the ambient sound pressure levels for those wind speeds obtained from the regression line generated in Section 4.2.6. Repeat for each turbine model being considered.

4.3. Data Presentation and Calculation of Ambient Sound Levels for Short-Term Monitoring Locations; Comparison to Long-Term Locations.

Short-term monitoring locations are used to validate the general representativeness of selected long-term locations. Comparisons between short and long-term monitoring locations are based on the average difference between concurrent 10-minute L_{90s} measured during the 1 hour short-term monitoring period. If more than one long-term monitoring location is used, the consultant should select the one that is most representative of the existing ambient conditions for comparison. The following steps should be conducted for each short-term monitoring location.

4.3.1. Calculate the difference between each of the six short-term 10-minute L_{90s} and the concurrent 10-minute L_{90} from the representative long-term monitoring location.

4.3.2. Average the differences between each short-term 10-minute L_{90} and the concurrent 10-minute L_{90} from the representative long-term monitoring location calculated in 4.3.1.

4.3.3. If more than one hourly measurement was collected for both daytime and nighttime, average the differences for each part of the day.

4.3.4. Take the smaller of the daytime and nighttime average differences. This is the short-term offset value.

4.3.5. Using the linear regression determined for the long-term site in section 4.2, shift the ambient curve for all wind speeds by the short-term offset value. The resulting short-term ambient curve provides a representation of the ambient sound levels at the short-term site.

4.3.6. If the comparison of existing ambient to future ambient (Section 6.2) for the short-term site identifies a higher net increase than at the long-term site, it might be necessary to undertake additional monitoring at the short-term site, document a deficiency in the methodology, or conduct long-term monitoring at the site.

5. Sound Modeling

This section provides the requirements for modeling the sound output from the proposed wind turbine(s).

5.1. Software

5.1.1. Sound level predictions must be made with an acoustic model that conforms to ISO 9613, such as *CadnaA*, *SoundPlan*, or *WindPro*[3].

5.1.2. Identify and use a reliable source of digital terrain height such as MassGIS.

5.2. Model Parameters and Standards

5.2.1. For modeling purposes, use the sound power levels (L_w) provided by the manufacturer plus the uncertainty factor K. This provides a measure of conservatism. This Declared Sound Power Level [L_w + K] for each turbine must be used in the acoustic model.

5.2.2. The K Factor (a measure of the inherent uncertainty in establishing wind turbine sound power levels) for each turbine must be provided and utilized in the sound modeling. If no K factor was provided by manufacturer, a default K Factor of 2.0 dB(A) must be used.[4]

5.2.3. Atmospheric absorption must conform to ANSI S 1.26-1995.

5.2.4. All base turbine sound power levels (L_w) must correspond to the IEC 61400-11 levels.

5.2.5. The uncertainty factor K must correspond to IEC TS 61400-14.

5.2.6. Atmospheric absorption must conform to ANSI S 1.26-1995.

5.2.7. Use ISO 9613 conditions for sound propagation.

5.2.8. Spectral ground factor G must equal 0.0 for water and hard concrete or asphalt surfaces. G must equal 0.5 for all other surfaces, representing a semi-reflective ground as might occur during winter, frozen ground conditions.

5.2.9. The modeling must include no foliage attenuation or excess attenuation for wind shadow effects.

5.2.10. The consultant must identify all parameters used in the sound modeling for the final report.

5.2.11. If a proposed project consists of multiple turbines, modeling must represent all wind turbines operating simultaneously.

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[3] Some software has a preprogrammed library of octave band sound power levels for common turbine models; however, these values may not match a manufacturer's current specifications. Current octave band L_w data must always be used and manually entered into the selected acoustic model.

[4] The Consultant will need to make sure that the software being used for modeling properly addresses the K Factor. This is particularly important for those utilizing WindPro.

6. Predicting Future Sound Levels

This section provides the requirements for predicting the future sound levels at each receptor location with the wind turbine(s) operating under various wind conditions.

6.1. Future Ambient Calculation

Calculate the future ambient sound level as the sum of the model-predicted turbine sound pressure level and the existing L_{90} ambient sound pressure level for each hub height wind speed. Both the L_{90} ambient sound pressure level and the turbine sound vary with hub-height wind speed. Since it is not immediately obvious which wind speed value will produce the greatest incremental change in the ambient level, it is necessary to make these calculations at the full range of wind speeds.

6.2. Comparison of Future Ambient to Existing Ambient

The calculation of the increase in the broadband ambient sound pressure level requires a comparison of the future ambient sound pressure level with wind turbine(s) operating (calculated in section 6.1) to the existing L_{90} ambient sound pressure level at sensitive receptors.

6.3. Pure Tones

Under MassDEP Noise Policy, a "pure tone" condition occurs when any octave band center frequency sound pressure level exceeds the two adjacent octave band center frequency sound pressure levels by 3 dB or more. The consultant should examine the sound power spectrum for each proposed turbine to identify the existence of pure tone conditions as defined by MassDEP Sound Policy.

6.4. Organize Results

The calculated future ambient pressure sound pressure level (with wind turbine operating) should be provided in a clear format for each turbine model and each location. The following table shows an example of how this information can be provided. This information must be provided for each wind turbine model being considered. Present values for L_{90} sound pressure level to the nearest one-tenth decibel.

Hub height Wind speed (m/s)	Ambient L_{90} Level dB(A)	Maximum Project Sound dB(A)	Future Ambient Level dB(A)	Net Increase dB(A)

7. Final Report

This section outlines the information which is to be included in the final report.

7.1. Methods

7.1.1. A statement of qualifications for the acoustic consulting team, including relevant experience, training, memberships, and certifications (Section 2.3.4).

7.1.2. Model and make of the sound level meter (section 1.2).

7.1.3. Map of the study area which identifies all long and short-term monitoring locations (Section 2.3.2).

7.1.4. Explanation and justification of the methods used to select each long and short-term monitoring location (Section 2.3.3).

7.1.5. Rationale for microphone placements if other than what is called for in sections 3.1.1. through 3.1.4.

7.2. Results

7.2.1. Provide documentation of the audible sound sources contributing to the background sound level and their apparent location within the study area (Section 3.2.1).

7.2.2. Discuss if fewer than 14 days of data were collected or if any days of data were discarded (Section 3.3.1).

7.2.3. Comment on whether or not sufficient data was gathered in key wind speed bins (Section 4.2.2).

7.2.4. Provide linear regression line fit to the 90th percentile L_{90} values from each wind speed bin. The equation and R^2 values must also be provided (Section 4.2.5).

7.2.5. Include parameters used in the sound modeling (Section 5.2.10).

7.2.6. Provide data table(s) for each proposed turbine model outlined in Section 6.3.

7.2.7. Provide an aerial image showing contours of equal future ambient conditions.

7.3. Discussion

7.3.1. Discuss the net increase over ambient sound pressure level at all receptor locations.

7.3.2. Identify any receptors where the net increase over ambient exceeds 10 dB(A).

7.3.3. Discuss the general representativeness of long-term monitoring location(s) based on comparison to short-term monitoring locations (Section 4.3).

7.3.4. Provide a discussion of the potential acoustic impacts associated with all proposed turbines.

7.3.5. Discuss whether any of the proposed turbines are expected to produce pure tone conditions as described by the MassDEP Noise Policy.

7.4. Appendix

7.4.1. Summary data for each 10-minute period of data collected (Section 3.3.7):

- Time-stamped 10-minute L_{90} in dB(A).
- Time-stamped 10-minute L_{eq} in dB(A).

- Time-stamped un-weighted octave band sound pressure levels based on center octave bands (31.5 Hz to 16 kHz).
- Hub height wind speed summarized in 10-minute intervals (time-matched to sound level data).

7.4.2. Sound power levels for the wind turbine models analyzed.

7.4.3. The current MassDEP Noise Policy.