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In-Air Acoustic Assessments for Offshore Wind

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Senior Acoustic Engineer
Tetra Tech

January 17, 2024

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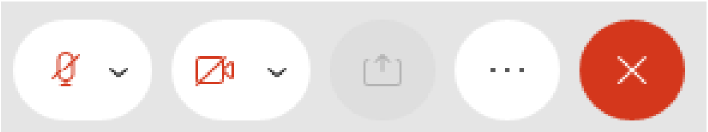
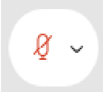


You'll see  **when your microphone is muted**

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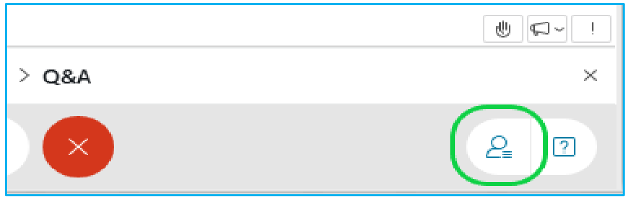

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Learning from the Experts

This webinar series is hosted by NYSERDA's offshore wind team and features experts in offshore wind technologies, development practices, and related research.

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In-Air Acoustic Assessments for Offshore Wind

Tricia Pellerin

January 17, 2024

TETRA TECH

Introduction

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- Tricia Pellerin, Acoustics Team Lead at Tetra Tech
- Located in Boston
- M.ESc. in Chemical/Biochemical Engineering from The University of Western Ontario
- 19 years of experience in environmental consulting specializing in acoustics
- Involvement in all areas of acoustics with a focus of renewable energy including offshore wind energy
- Proficient in both in-air and underwater acoustic analyses

Presentation Agenda

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1. Acoustic metrics and terminology
2. Noise regulations
3. Noise regulations in New York
4. Project activities during construction and operation
5. Qualitative versus quantitative
6. Ambient sound measurements
7. Acoustic modeling
8. Compliance assessment
9. Noise mitigation review
10. Final design considerations

Offshore Wind Energy Acoustic Analysis Requirements

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- Acoustic analyses are included as part of Construction and Operations Plan (COP) lessees submit to the Bureau of Ocean Energy Management (BOEM) for their review and approval.
- Underwater acoustic analysis
  - Modeling to predict potential noise impacts to marine species due to construction and operation, especially activities like pile driving.
  - Evaluation of impacts relative to National Oceanic and Atmospheric Administration National Marine Fisheries Service (NOAA NMFS) criteria.
- In-air acoustic analysis
  - Modeling to predict potential noise impacts to human receptors due to construction and operation.
  - Evaluation of impacts relative to applicable regulations at the state, county, and local levels.

Acoustic Metrics and Terminology

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- **Sound:** Vibration that propagates as an acoustic wave through a transmission medium.
- **Noise:** Sound that is considered excessive or loud.
- Sound levels are presented on a logarithmic scale and are expressed in units of decibels (dB).
- A-weighting (dBA) is an adjustment applied to a sound spectrum which reproduces how a noise is perceived by the human ear.
- Sound can be reported on a broadband basis or by octave band frequency, which is given in Hertz (Hz).

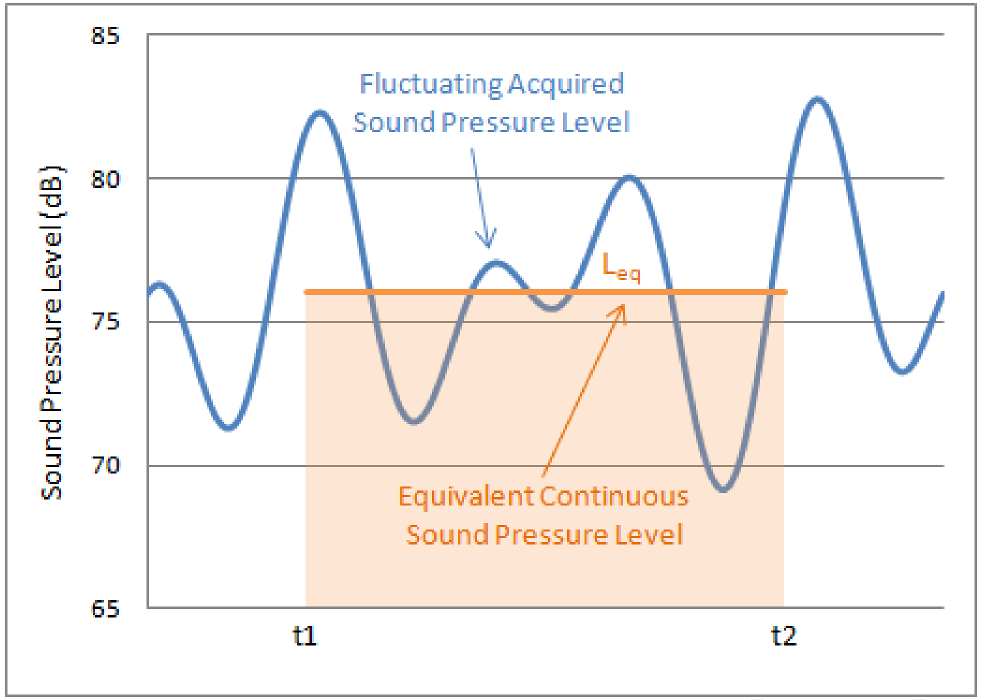
Acoustic Metrics and Terminology

- When analyzing sound sources, these two terms are commonly used:
  - **Sound Power Level**: A measure of the acoustic energy emitted from a source of sound. It cannot be measured. It is calculated from measurements of sound intensity or sound pressure at a given distance from the source.
  - **Sound Pressure Level**: A measure of sound pressure fluctuation at a given receiver location and can be obtained through the use of a microphone or calculated from information about the source sound power level and the surrounding environment.

Acoustic Metrics and Terminology

Sound metrics used to characterize sound power and/or sound pressure levels:

- **L_{eq}**: Conventionally expressed in dBA, the L_{eq} is the energy-averaged, A-weighted sound level for the complete time period.
- **L_n**: This is a statistical value, and it identifies the sound level that is exceeded "n" percent of the time over a measurement period .The sound level exceeded for a large percent of the time, L_{90}, closely corresponds to continuous, lower-level background noise (such as continuous noise from a distant industrial facility).
- **L_{max}**: The maximum sound level (L_{max}) can be used to quantify the maximum instantaneous sound pressure level over a given measurement period or maximum sound generated by a source.



Source: National Instruments

Noise Regulation Review

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Noise regulations can be presented in a qualitative manner; they also often prescribe numerical decibel limits, which can comprise an absolute limit or relative limit or a combination of the two.

- **Absolute limits** are specific decibel sound levels that are not to be exceeded at the point of compliance and can be given on a broadband basis or by octave band frequency sound level.
- **Relative limits** are those that are set as an allowable incremental increase in decibel level above existing sound levels, which means that existing sound levels would typically need to be established by way of a baseline sound survey to assess a project's compliance.

Noise Regulation Review

- Depending on location, while regulations must always be considered, precedent may be more controlling than limits prescribed by regulations.
- Studies and methodologies employed by previous applicants may set the expectations of the prevailing agency or authority; therefore, despite what the regulations require, the prevailing agency or authority might be anticipating a certain level of effort.

Noise Regulation Review – New York State

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- New York is particularly complex due to the multiple layers of requirements at the state, county, and local (city, town, village, etc.) levels.

State:

- New York State Department of Environmental Conservation (NYSDEC) “Assessing and Mitigating Noise Impacts” guidelines.
  - — 6 dBA incremental increase criterion
- New York State Department of Public Service (NYSDPS) “General Recommendations for Applications for Substations, Stations, and Converter Stations under Article VII”
  - — Absolute sound levels

City:

- New York City has regulations within its Noise Code and zoning regulations and include absolute octave band frequency limits at the facility property boundary and at offsite noise sensitive receptors (NSRs).
- Other jurisdictions within New York State have a variety of different regulations; therefore, conducting research to identify those that are applicable to your project is important.

Project Activities

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Construction

- Horizontal directional drilling
- Impact and vibratory pile driving
- Helicopters
- Support vessels
- General construction

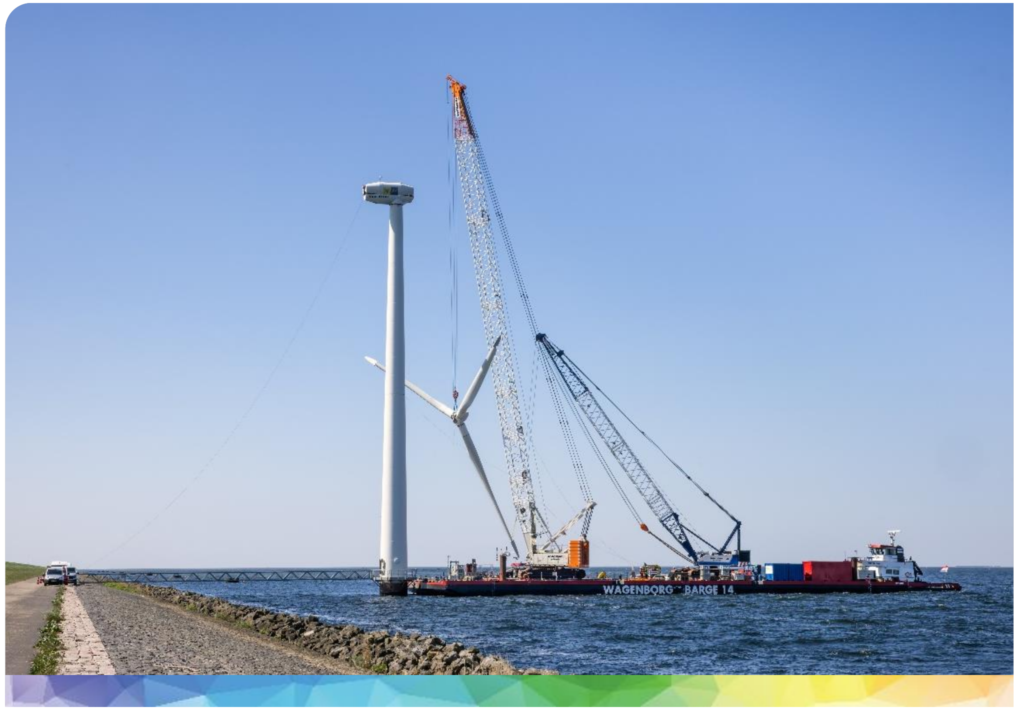
Operation

- Onshore substations and/or converter stations
- Offshore wind turbines and/or substations
- Sound signals

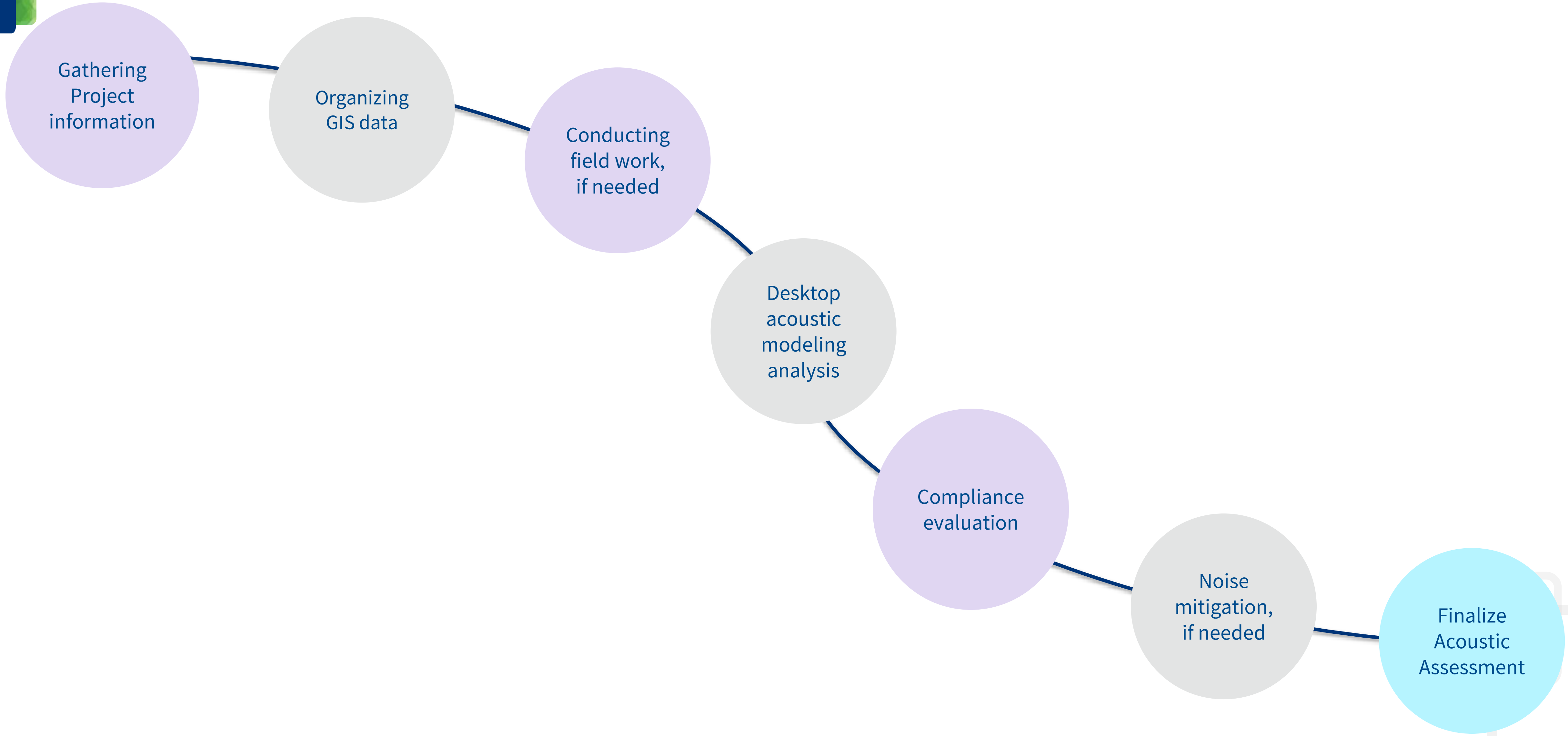
Qualitative versus Quantitative

Due to the stage of design at the time of the COP submittal some details may not be known; therefore, some activities must be addressed in in a qualitative manner while others would be evaluated quantitatively.

- **Qualitative**: Helicopter/airplane use, support vessels, general construction, wind turbine operation, and sound signals.
- **Quantitative:** HDD, pile driving, onshore substation and/or converter station operation.



Acoustic Assessment Process



Ambient Sound Surveys

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- In New York, ambient sound measurements are generally required to document the pre-construction acoustic environment.
- Depending on requirements and/or guidance from regulators measurements may be short-term (<24 hours) or long term (>24 hours).
- Measurements are typically conducted in the vicinity of the closest NSRs relative to project facilities.
- Measurements conducted based on ANSI standards.

Source: Larson Davis

Ambient Sound Surveys

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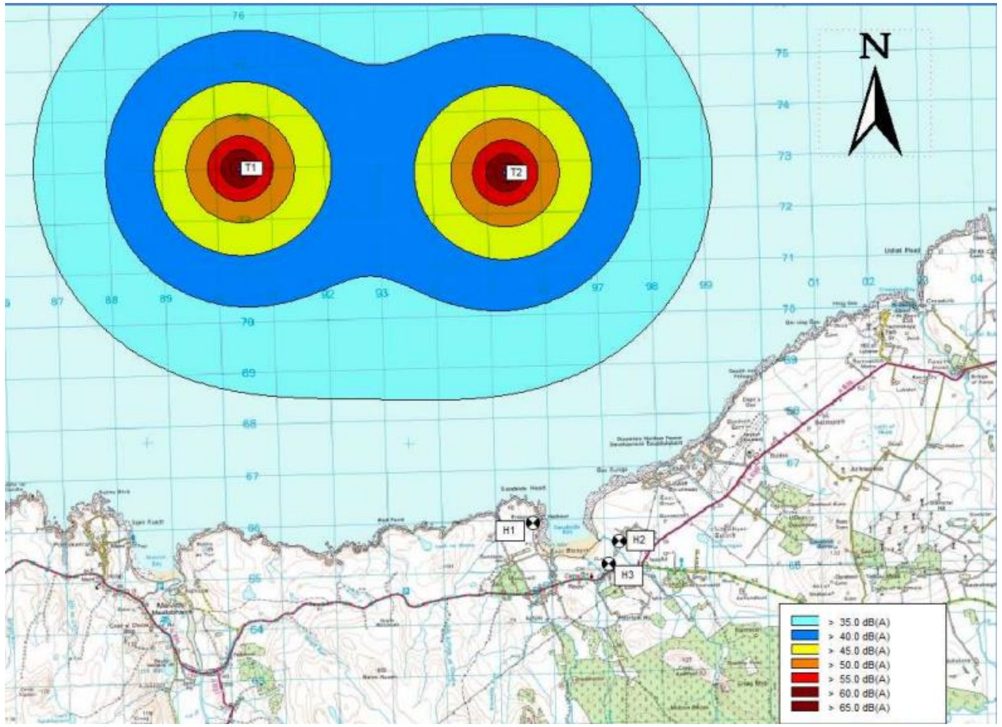
- Each sound analyzer is typically programmed to measure and log broadband A-weighted sound pressure levels for specific intervals (e.g., 1-second, 1-minute, 10-minute, etc.).
- A variety of sound metrics including the equivalent sound level (L_{eq}).
- Usually, several statistical sound levels (L_n) are also logged. Lastly data is collected in 1/1 and 1/3 octave bands spanning the frequency range of 8 Hz to 20 kilohertz.
- Upon completion of the survey, data are downloaded and analyzed with extraneous sound due to precipitation or other sound sources being eliminated from the dataset.

Acoustic Modeling

- DataKustik's CadnaA or similar program (e.g., SoundPlan).
- It conforms to International Organization for Standardization (ISO) 9613-2, "Attenuation of Sound during Propagation Outdoors."
- The algorithms incorporate geometric spreading due to:
  - Wave divergence,
  - Reflection from surfaces,
  - Atmospheric absorption,
  - Screening by topography and obstacles,
  - Ground effects,
  - Source directivity,
  - Heights of both sources and receptors,
  - Seasonal foliage effects, and
  - Meteorological conditions.

Acoustic Modeling

- Site-specific terrain data is incorporated into CadnaA.
- The ISO 9613-2 standard accounts for ground absorption rates by assigning a numerical coefficient of G=0 for acoustically hard, reflective surfaces and G=1 for absorptive surfaces and soft ground.
- If the ground is hard-packed dirt, the absorption coefficient is defined as G=0 to account for reduced sound attenuation and higher reflectivity.
- In contrast, ground covered in vegetation, including suburban lawns, and agricultural fields will be acoustically absorptive and aid in sound attenuation (i.e., G=1.0).
- For modeling , a semi-reflective ground absorption factor (G=0.5) is typically used except in areas with a ground absorption factor of 0 (e.g., waterbodies, pavement, etc.).



Source: Dounreay Offshore Wind Farm (https://marine.gov.scot/sites/default/files/appendix_29.1_-_noise_assessment.pdf)

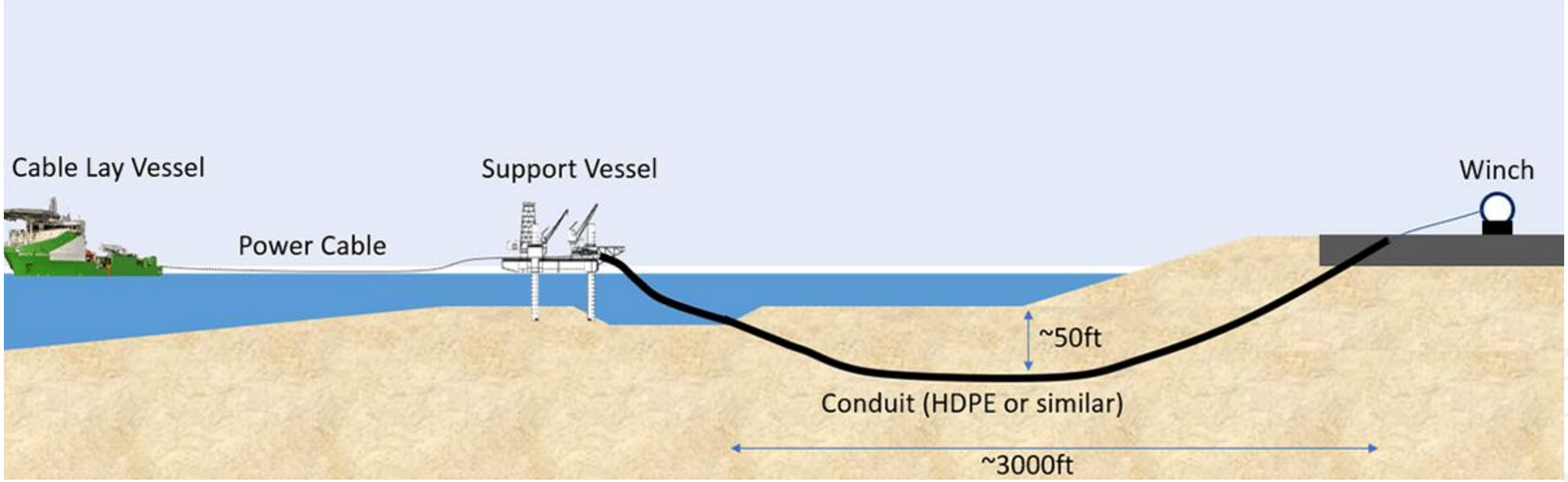
Acoustic Modeling Assumptions

Modeling incorporates conservative assumptions including:

- The ISO 9613-2 modeling method unrealistically assumes that downwind conditions exist in all directions, between each sound source and each receptor simultaneously, which is physically impossible. Therefore, lower levels are expected in the upwind direction.
- Essentially laminar atmospheric conditions are assumed in which neighboring layers of air do not mix. This conservative assumption does not take into consideration turbulent eddies and micrometeorological variations that may form when winds change speed or direction, which can interfere with the sound wave propagation path and increase attenuation effects.
- Assuming all sound sources are operating at full load simultaneously.
- Sound attenuation through foliage and diffraction around existing anthropogenic structures is conservatively ignored.

Horizontal Directional Drilling

- Horizontal directional drilling (HDD) is a trenchless construction method that minimizes impacts to key infrastructure and protected areas and is ideal for the installation of transmission cables at the interface between land and sea.
- The technique involves the drilling of a steered pilot hole on the desired trajectory; once completed, the hole is enlarged to enable the cable to be pulled through it.



Source: South Coast Wind 1 (https://southcoastwind.com/southcoast-wind-1/)

Horizontal Directional Drilling

Horizontal Directional Drilling

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- Equipment can vary at the entry and exit points and therefore the associated sound emission levels can vary too.

Equipment Component	Sound Power Level (dBA)
HDD Drill Rig and Power Unit	102
Drilling Mud Mixer/Recycling Unit	90
Mud Pumping Unit	102
Generator Set, 100 kilowatts	100
Generator Set, 200 kilowatts	102
Vertical Sump Pump	75
Total Sound Level	108

- Noise mitigation options:
  - Restricting hours of operation
  - Temporary acoustic enclosures and/or barriers
  - Exhaust silencers where applicable

Impact and Vibratory Pile Driving

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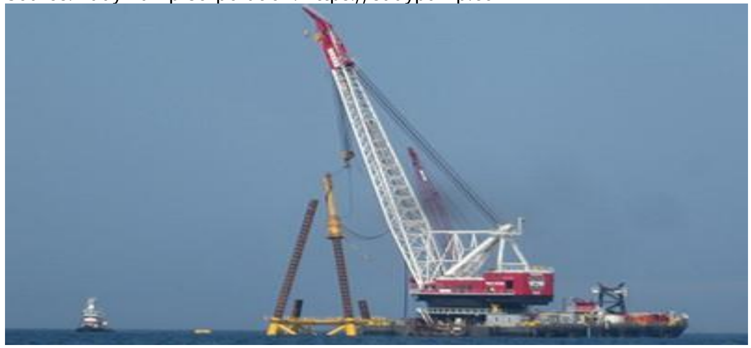
- Pile driving can be used for various activities including:
  - Offshore foundation installation
  - Cofferdam installation
  - Substation construction
  - Onshore cable routing
- Sound power levels associated with impact and vibratory pile drivers vary based on manufacturer/model, but examples of sound power levels are:
  - Vibratory pile driving: 127 dBA
  - Impact pile diving: 137 dBA

Source: Eddy Pump Corporation: https://eddypump.com



Source: DOSITS (https://dosits.org/animals/effects-of-sound/anthropogenic-sources/pile-driving/)

Impact and Vibratory Pile Driving

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- Like other construction activities, if pile driving is limited to daytime hours, it is often exempt from applicable noise regulations, but review of site-specific requirements is always necessary.
- For instance, the New York City Noise Control Code (§ 24-228), which imposes specific limits on construction activities including:
  - *Sound, other than impulsive sound, attributable to the source or sources, that exceeds 85 dB(A) as measured 50 or more feet from the source or sources at a point outside the property line where the source or sources are located or as measured 50 or more feet from the source or sources on a public right-of-way.*
  - *Impulsive sound, attributable to the source, that is 15 dB(A) or more above the ambient sound level as measured at any point within a receiving property or as measured at a distance of 15 feet or more from the source on a public right-of-way. Impulsive sound levels shall be measured in the A-weighting network with the sound level meter set to fast response. The ambient sound level shall be taken in the A-weighting network with the sound level meter set to slow response.*

Onshore Substation/Converter Station Operation

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- An electrical substation is a facility that serves as a junction point between electricity generation and electricity distribution.
- It includes many different onsite sound sources and since substations are operational (and semi-permanent) sound source acoustic modeling is required.
- Sound sources include:
  - Transformers
  - Shunt reactors
  - Harmonic filters
  - Capacitor banks
  - Coolers
  - Building exhaust/air handling units

Transformers

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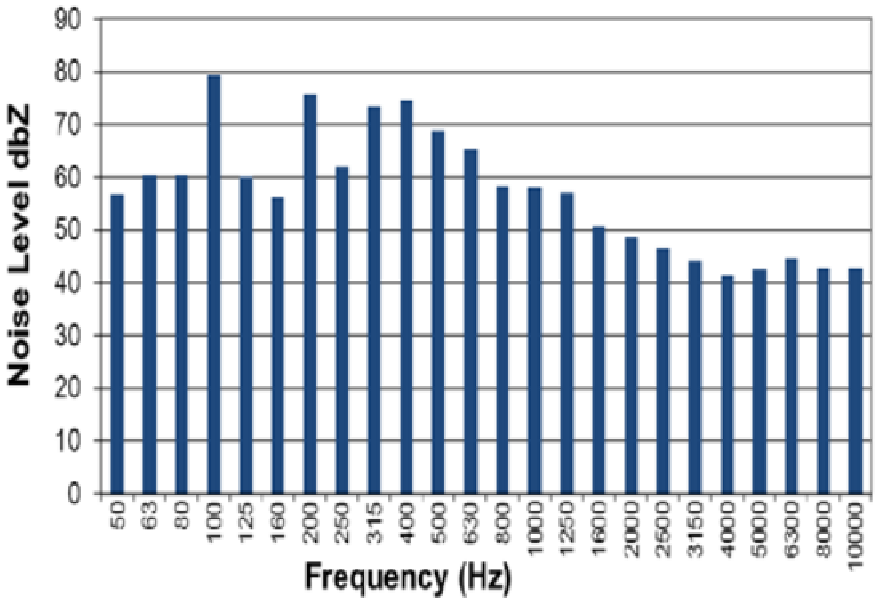
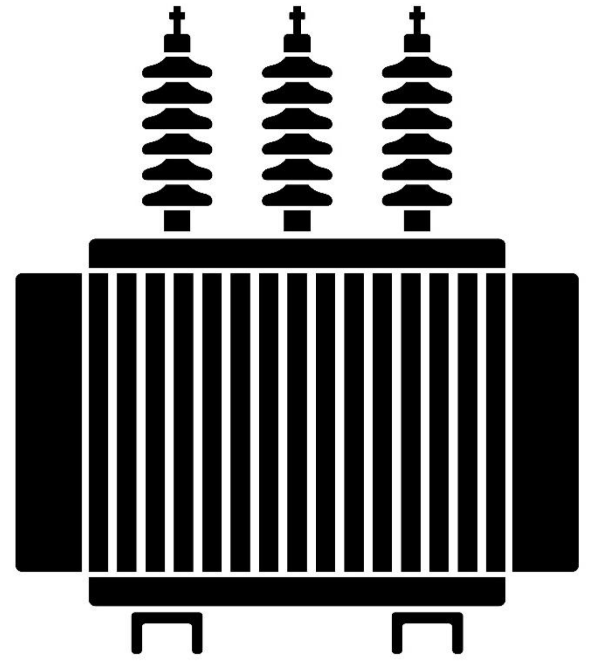
- There are three main sound sources associated with a transformer: core noise, load noise, and noise generated by the operation of the cooling equipment.
- The core vibrational noise is the principal noise source and does not vary significantly with electrical load.
- Transformer noise varies with transformer dimensions, voltage rating, and design, and attenuates with distance. The noise produced by substation transformers is primarily caused by the load current in the transformer's conducting coils (or windings) and consequently the main frequency of this sound is twice the supply frequency (60 Hz).
- The characteristic humming sound consists of tonal components generated at harmonics of 120 Hz.
- Most of the acoustical energy resides in the fundamental tone (120 Hz) and the first three or four harmonics (240, 360, 480, and 600 Hz).



Source: Gange, M. 2011. Low-frequency and Tonal Characteristics of Transformer Noise, Proceedings of ACOUSTICS 2011.

Transformers

- Information needed to understand transformer sound emissions:
  - Dimensions
  - MVA rating
  - NEMA rating
- If available, sound power and/or sound pressure level in octave band frequencies and overall dBA sound levels at a fixed distance.
- Depending on the stage of design specifications may not be available.
- In the past NYSDPS has accepted development of transformer sound profile using the Electric Power Plant Environmental Noise Guide calculation methodology.



Onshore Substation – Other Sound Sources

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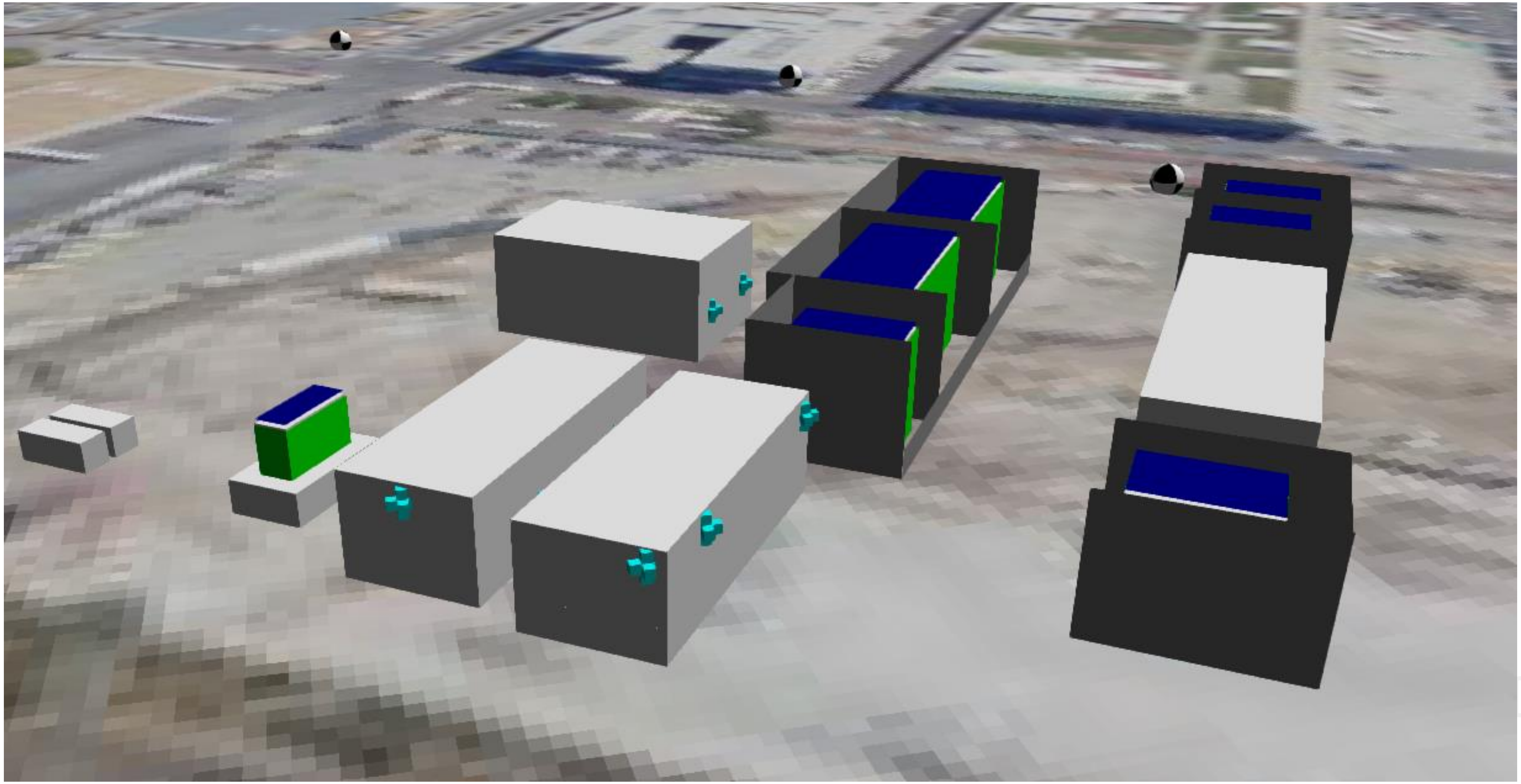
Substation Component	Representative Sound Power Level (dBA)
Main Power Transformer	98
Shunt Reactor	95
Harmonic Filter	75
Capacitor Bank	95
Circuit Breaker	60
SVC Converter	66
SVC Reactor	85
SVC Coolers	75
Aux Transformer	68
Exhaust Fan	64
Air Handling Units	74
Emergency Generator	105

Onshore Substation – Acoustic Model



Onshore Substation – Acoustic Model

Source: Empire Wind COP

Onshore Substation – Acoustic Model

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- Compliance is assessed relative to the applicable absolute or relative sound levels at residences and/or the Facility property line, as appropriate.
- In the event exceedances are identified, noise mitigation is reviewed, which could include measures such as the following:
  - Equipment placement/site layout design
  - Selection of lower noise equipment
  - Noise barrier walls
  - Enclosures
  - Silencers
  - Addition of absorptive materials

Qualitative - Construction

- General construction activities associated with installation of onshore export cables, substations, interconnection cables, and other onshore infrastructure.
- The noise levels resulting from construction activities vary greatly depending on factors such as the type of equipment, the specific equipment model, the operations being performed, and the overall condition of the equipment.
- The U.S. Environmental Protection Agency has published data on the L_{eq} sound levels for typical construction stages. Following the U.S. Environmental Protection Agency method, sound levels can be projected from the variety of construction equipment and vehicles planned.
- This calculation conservatively assumes that all equipment would be operating concurrently onsite for the specified construction stage and that there would be no sound attenuation for ground absorption or onsite shielding by the existing buildings or structures.

Qualitative – Support Vessels

- Vessels will transport crews and materials to the offshore lease area during construction, and to a lesser extent during ongoing operations and maintenance. The installation of the export cables, inter-array cables, foundations will require a number of different types of construction vessels, including heavy lift vessels, cable installation, and crew transport vessels.
- The International Maritime Organization (IMO) has established noise limits for vessels. In terms of sound generation limits of vessels, IMO resolution A.468 limits received noise levels to 70 dBA at designated listening stations located at the navigation bridge and windows during normal sail and operational conditions.
- In addition, the IMO further limits noise to 75 dBA at external areas and rescue stations.
- Nearshore, offshore export cables installation activities move along the cable laterally. Therefore, no shoreline receptors will be exposed to elevated noise levels for an extended period of time.

Qualitative – Helicopters

- Helicopters may be used for accessing and inspecting the wind turbines and/or emergency transportation.
- Helicopters will also be used for additional crew transfers during foundation construction activities and the O&M phase.
- The helicopter route plan will be developed to meet industry guidelines and best practices in accordance with FAA guidance. These types of helicopter operations will generate sound similar to aircraft already operating in the airspace.
- Helicopter sound is generated by a number of sources including the rotors as well as the blade vortex interaction.

Source: Vertical Magazine (https://verticalmag.com/features/the-science-behind-helicopter-noise-how-the-industry-is-working-to-reduce-it/)

Qualitative – Offshore Wind Turbine Operation

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- Wind facilities, in comparison to conventional energy projects, are somewhat unique in that the sound generated by each individual wind turbine will increase as the wind speed across the site increases.
- Wind turbine sound is negligible when the rotor is at rest, increases as the rotor tip speed increases, and is generally constant once rated power output and maximum rotational speed are achieved.
- It is important to recognize, as wind speeds increase, the background ambient sound level will likely increase as well, resulting in acoustic masking effects.
- The net result is that during periods of elevated wind when higher wind turbine sound emissions occur, the sound produced from a wind turbine operating at maximum rotational speed may well be largely or fully masked by wind generated sounds of foliage or by increased sound related to waves crashing on the shoreline. In practical terms, this means that a nearby receptor may hear these other sound sources (i.e., foliage, ocean waves) rather than the sound of a wind turbine.

Qualitative – Offshore Wind Turbine Operation

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- Offshore wind facility operations are unique due to reflective nature of sounds surrounded by water and the impact of the shoreline on sound attenuation.
- Sound propagation from offshore wind turbines is different than propagation from land-based wind turbines. Sound propagation over water at large distances involves a completely reflective surface and is dependent of the distance between the receiver and the sound source.
- Sound propagation over water is variable and dependent on a number of factors including:
  - The distance over water from the sound source to the receiver.
  - The height of the sound source above the completely reflective water surface.
  - The height of the atmospheric inversion layer trapping the sound waves below the height of the source, thus creating the cylindrical wave.
  - The atmospheric absorption coefficient due to the shoreline effect.
  - The attenuation due to the ground damping and the damping of sound.

Qualitative – Sound Signals

- Sound signals (i.e., fog horns) are typically installed on select wind turbines along the outer perimeter of the lease area.
- However, due to the large separation of distances of the sound signals to the nearshore environment, the sound level will be below the threshold of perception with the exception of vessels located in proximity.
- Requirements as detailed in 33 Code of Federal Regulations § 67, which calls for a foghorn to be installed less than 150 ft (46 m) above mean sea level with a sound signal audible to 0.5 nm (0.9 km). 33 Code of Federal Regulations § 67 also requires the foghorn emit a tone of 119.8 dB at a frequency of 822 Hz that will sound for a period of two seconds during a 20 second cycle (18 seconds silence).

Final Thoughts

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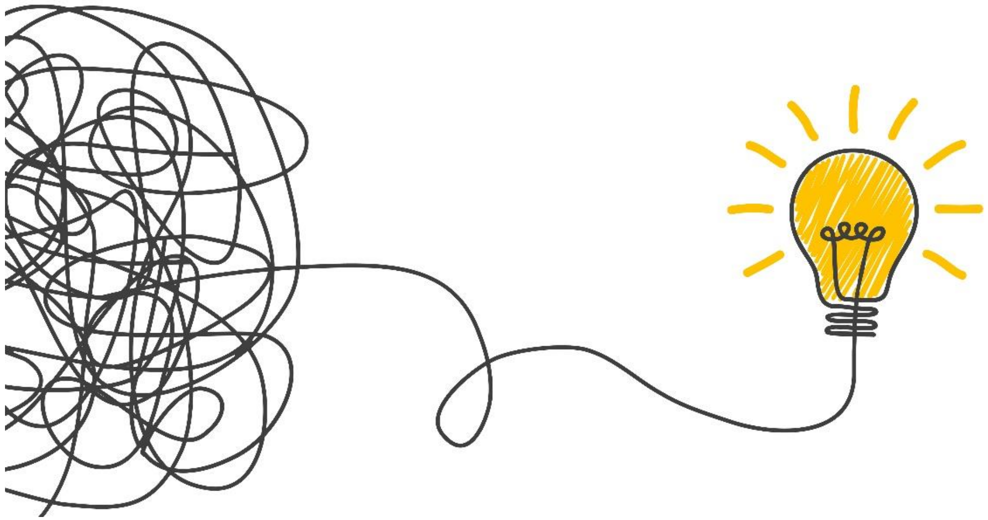
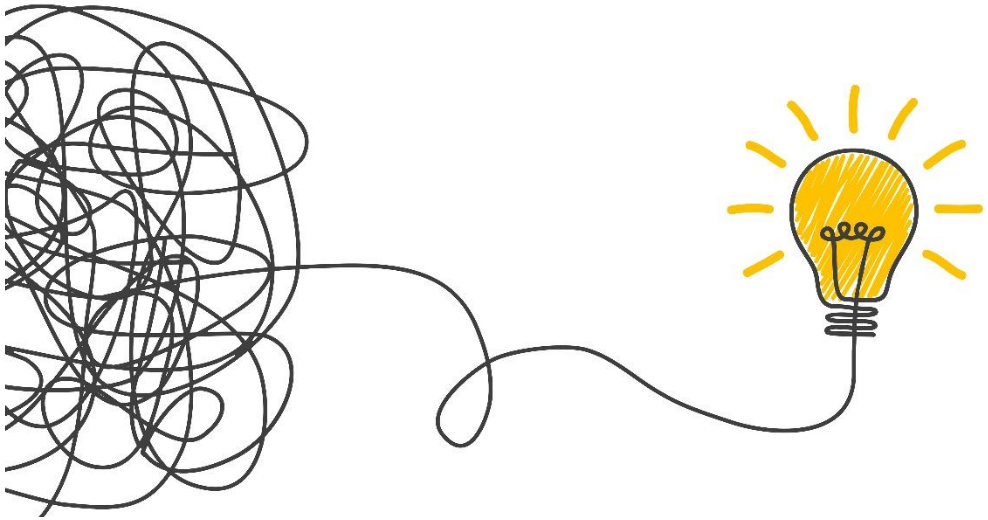
- Conduct a comprehensive review of noise regulations to make sure all your bases are covered. Consider reaching out to the applicable regulating agency if clarification is needed.
- Identify all Project-related sound sources/activities.
- Take time to organize site-specific inputs and assumptions to the extent possible to predict potential noise impacts as accurately as possible.



Final Thoughts

- The goal is to successfully demonstrate compliance with regulations/requirements. This may occur in time for the COP submittal or potentially closer to pre-construction.
- Furthermore, what noise regulations/requirements will be enforced and what waivers may be granted may not be decided until further along in the review process. For instance, in an order issued by the New York Public Service Commission.



Thank you for listening!

Contact: Tricia Pellerin
tricia.pellerin@tetratech.com

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