New England Wind

AVANGRID RENEWABLES

Construction and Operations Plan

Lease Area OCS-A 0534

Volume III Appendices

June 2022

Submitted by
Park City Wind LLC

Submitted to
Bureau of Ocean Energy Management
45600 Woodland Rd
Sterling, VA 20166

Prepared by
Epsilon Associates, Inc.

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Submitted to:
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June 2022

Appendix III-B – Air Emissions Calculations and Methodology

On April 29, 2022, modifications were made to the Envelope that involved changing the maximum wind turbine generator (WTG) and electrical service platform (ESP) topside parameters for Phase 1 (Park City Wind) to match those of Phase 2 (Commonwealth Wind) (see Table 1). As a result of this change, the potential minimum footprint of Phase 1 decreased, and correspondingly the potential maximum footprint of Phase 2 increased (see Table 2). Additionally, the maximum capacity in megawatts for both phases was eliminated to accommodate the rapid advancement in commercially available wind turbine generator size and technology.

Table 1 Modifications to the Phase 1 WTG and ESP Parameters[1]

Maximum WTG Parameters	Previous Dimension	New Dimension[2]
Tip Height	319 m (1,047 ft)	357 (1,171 ft)
Top of the Nacelle Height	199 m (653 ft)	221 m (725 ft)
Hub Height	192 m (630 ft)	214 m (702 ft)
Rotor Diameter	255 m (837 ft)	285 m (935 ft)
Minimum Tip Clearance[3]	27 m (89 ft)	27 m (89 ft)
Blade Chord	8 m (26 ft)	9 m (30 ft)
Tower Diameter	9 m (30 ft)	10 m (33 ft)[4]
Maximum ESP Parameters	**Previous Dimension**	**New Dimension[2]**
Width	45 m (148 ft)	60 m (197 ft)
Length	70 m (230 ft)	100 m (328 ft)
Height	38 m (125 ft)	No change
Height of Topside (above MLLW[5])	70 m (230 ft)	No change

1. Maximum WTG dimensions are included in Table 3.2-1 and maximum ESP dimensions are included in Table 3.2-3 of COP Volume I
2. The new Phase 1 WTG and ESP maximum parameters were revised to match those of Phase 2
3. All parameters are maximum values except tip clearance, where the minimum tip clearance represents the maximum potential impact
4. To accommodate the slight increase in tower diameter, the maximum transition piece diameter/width for Phase 1 monopile foundations was also increased from 9 m (30 ft) to 10 m (33 ft) (see Table 3.2-2 of COP Volume I)
5. MLLW: Mean Lower Low Water

To accommodate the larger Phase 1 WTG dimensions and greater capacity range, the minimum footprint of Phase 1 decreased and the maximum footprint of Phase 2 increased, thus also adjusting the potential number of WTG/ESP positions within each Phase (see Table 2).

Table 2 Modifications to the Phase 1 and Phase 2 Layout and Size

		Previous Layout and Size	New Layout and Size
Phase 1	Number of WTGs	50-62	41-62
	Area	182-231 km^2 (44,973-57,081 acres)	150-231 km^2 (37,066-57,081 acres)
Phase 2	Number of WTGs	64-79	64-88
	Area	222-271 km^2 (54,857-66,966 acres)	222–303 km^2 (54,857–74,873 acres)

These revisions remain within the maximum design scenario considered for this report and the maximum potential impacts are still representative considering these modifications. Therefore, this report was not updated to reflect these minor modifications, as the findings are not affected.

The Proponent has also identified two variations of the Phase 2 Offshore Export Cable Corridor (OECC)— the Western Muskeget Variant and the South Coast Variant—in the event that technical, logistical, grid interconnection, or other unforeseen issues arise during the engineering and permitting processes that preclude one or more Phase 2 offshore export cables from being installed within all or a portion of the OECC (see Section 4.1.3 of COP Volume I). This Appendix considers the potential impacts associated with the Western Muskeget Variant; an assessment of the South Coast Variant in federal waters is provided separately in the COP Addendum.

New England Wind

Air Emissions Calculations and Methodology

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June 2022

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1.0 INTRODUCTION

The following document describes the methodology used to estimate air emissions from the construction and operation of New England Wind. New England Wind is the proposal to develop offshore renewable wind energy facilities in Bureau of Ocean Energy Management (BOEM) Lease Area OCS-A 0534 along with associated offshore and onshore cabling, onshore substations, and onshore operations and maintenance (O&M) facilities. New England Wind will be developed in two Phases with a maximum of 130 wind turbine generator (WTG) and electrical service platform (ESP) positions. Four or five offshore export cables installed within a shared Offshore Export Cable Corridor (OECC) will transmit electricity generated by the WTGs to onshore transmission systems in the Town of Barnstable, Massachusetts. Park City Wind LLC, a wholly owned subsidiary of Avangrid Renewables, LLC, is the Proponent of this Construction and Operations Plan (COP) and will be responsible for the construction, operation, and decommissioning of New England Wind.

New England Wind's offshore renewable wind energy facilities are located immediately southwest of Vineyard Wind 1, which is located in Lease Area OCS-A 0501. New England Wind will occupy all of Lease Area OCS-A 0534 and potentially a portion of Lease Area OCS-A 0501 in the event that Vineyard Wind 1 does not develop "spare" or extra positions included in Lease Area OCS-A 0501 and Vineyard Wind 1 assigns those positions to Lease Area OCS-A 0534. For the purposes of COP, the Southern Wind Development Area (SWDA) is defined as all of Lease Area OCS-A 0534 and the southwest portion of Lease Area OCS-A 0501.

Phase 1, also known as the 804 megawatt (MW) Park City Wind project, will be developed immediately southwest of Vineyard Wind 1. Phase 2, also known as Commonwealth Wind, will deliver 1,200 to 1,500 MW of power. When constructed, Phase 2 will be located southwest of Phase 1 and occupy the remainder of the SWDA. Each Phase of New England Wind will be developed and permitted using a Project Design Envelope (the "Envelope"). This allows the Proponent to properly define and bracket the characteristics of each Phase for the purposes of environmental review while maintaining a reasonable degree of flexibility with respect to the selection of key components, such as the WTGs, foundations, offshore cables, and ESPs. To assess potential impacts and benefits to air quality, a "maximum design scenario" (i.e. the design scenario with the maximum impacts anticipated for air quality) was established considering the Envelope parameters for each Phase that have the potential to cause the greatest effect.

New England Wind's WTGs will not generate air emissions. Rather, electricity generated by the WTGs will displace electricity produced by fossil fuel power plants and significantly reduce emissions from the ISO New England (ISO-NE) electric grid over the lifespan of New England Wind. However, there will be air emissions from vessels, construction equipment, helicopters, generators, on-road vehicles, and some fugitive emissions during the construction, operation, and decommissioning of New England Wind.

Air emissions from New England Wind are subject to regulatory programs and environmental impact reviews, which include the Environmental Protection Agency's (EPA's) Outer Continental Shelf (OCS) Air Permit process and BOEM's review under the National Environmental Policy Act (NEPA). This document details the methods used to estimate all air emissions from New England Wind within the United States

(US) (onshore and 370 kilometers [km] [200 nautical miles (NM)] out to sea[1]) in order to assess regional impacts to air quality as part of the New England Wind COP and for BOEM's NEPA process. To assess the air quality benefits of New England Wind, this document also describes the methods used to quantify emissions from the ISO-NE electric grid that are expected to be avoided as a result of the clean, renewable energy provided by New England Wind.

Air emissions from New England Wind will be associated with fuel combustion, construction dust, and some incidental solvent use associated with onshore and offshore construction as well as O&M activities. Air emissions are estimated by calculating the duration and intensity of emissions-generating activities and multiplying those estimates by appropriate emission factors. To the best of the Proponent's knowledge, the methods and emission factors (which are based on prior testing) used in this analysis are the most current and appropriate publicly available methods and factors for the specific activities that will be conducted by New England Wind (see the discussion of calculation methodologies in Section 2). There are eight primary categories of sources for which emissions were calculated:

1. Commercial marine vessels
2. Helicopters
3. Offshore generators
4. Other offshore construction equipment
5. Onshore non-road engines
6. On-road vehicles
7. Construction dust
8. Fugitive emissions

The following pollutants were included in the air emissions analysis:

- Nitrogen oxides (NOx)
- Volatile organic compounds (VOCs)
- Carbon monoxide (CO)
- Particulate matter smaller than 10 microns (PM_{10})
- Particulate matter smaller than 2.5 microns ($PM_{2.5}$, a subset of PM_{10})
- Sulfur dioxide (SO_2)
- Lead (Pb)
- Total hazardous air pollutants (HAPs, individual compounds are either VOC or particulate matter)
- Greenhouse gas emissions as carbon dioxide equivalent (CO_2e)

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[1] The air emission analysis for NEPA purposes includes New England Wind emissions onshore, in state waters, and in federal waters within the US Exclusive Economic Zone, which extends approximately 370 km (200 NM) offshore.

Potential air emissions were estimated for the construction and operation of New England Wind (Phases 1 and 2 combined), Phase 1 (individually), and Phase 2 (individually). Given the level of uncertainty regarding the types of vessels and equipment that will be available at the time of decommissioning, potential emissions from decommissioning are not quantified at this time.

As described in Section 1.1 below, the New England Wind air emissions estimate is based on the maximum design scenario allowed by New England Wind's Envelope of dimensions and installation methodologies. The types of emission sources, engine sizes, and durations of activities used in this air emissions estimate reflect the most current New England Wind logistical and operational plans to the best of the Proponent's knowledge at the time of submission, but because the Proponent is still selecting contractors and finalizing the design of New England Wind's facilities, the actual emissions associated with individual activities may be higher or lower than the estimate provided in the COP.

Section 2.0 describes the types of air emissions sources that may be used during construction and operation of New England Wind and discusses the methods used to calculate air emissions from those sources. Section 3.0 provides the preliminary estimate of air emissions from construction and operation of New England Wind (both Phases combined), Phase 1, and Phase 2. Section 4.0 describes the method used to quantify the emissions from conventional power generation that will be avoided as a result of New England Wind. Section 5.0 contains the references used to develop this Air Emissions Calculations and Methodology.

Attachment A contains a summary of construction and O&M emissions for New England Wind and each Phase separately. All anticipated air emission sources associated with New England Wind are itemized in Attachment B. Attachment C contains calculations used to quantify the CO_2e, NOx, and SO_2 emissions associated with conventional power generation that would be avoided as a result of New England Wind. Attachment D contains parameters of the New England Wind Envelope used to develop the emissions estimates along with typical vessel route distances. Attachment E contains emission factors, load factors, and other supporting calculations used to calculate potential emissions.

1.1 Maximum Design Scenario for the New England Wind Air Emissions Estimates

Air emissions from New England Wind were first estimated for the maximum design scenario of both Phases of New England Wind combined (i.e. for all 130 WTG/ESP positions). Then, based on the maximum design scenario for each Phase, the total air emissions of New England Wind were apportioned to develop an estimate of emissions for each Phase separately. As explained in Section 3 of COP Volume III, due to the range of buildout scenarios for Phases 1 and 2, summing the maximum emissions for Phase 1 and Phase 2 would overestimate the total construction emissions of New England Wind. The maximum design scenario for all of New England Wind, Phase 1 (individually), and Phase 2 (individually) are described below:

- **New England Wind Air Emissions (Phases 1 and 2):** Offshore emissions from both Phases of New England Wind combined were estimated assuming that 130 WTG/ESP positions would be occupied by one to five ESPs and the remainder would be occupied by WTGs (i.e. 125–129 WTGs).[2] The estimate also assumes the installation of the maximum length of offshore cables,[3] the maximum area of scour protection, and the maximum area of cable protection allowed by the New England Wind Envelope. The onshore emissions estimate was based on the maximum design scenario for each Phase's onshore facilities (e.g. the maximum length of onshore export cables and grid interconnection cables for each Phase). To account for the envelope of possible ports used during construction and operation, the emissions estimate uses the combination of ports with the longest transit distances to and from the Offshore Development Area[4] within US waters. [5]

- **Phase 1 Air Emissions:** The estimate of potential air emissions for Phase 1 is based on the installation of 62 WTGs and two ESPs, the maximum length of Phase 1 offshore cables, the maximum area of scour protection and cable protection for Phase 1, the maximum length of Phase 1 onshore cables, and the combination of ports with the longest transit distances to and from the Offshore Development Area. This represents the maximum design scenario for Phase 1.

- **Phase 2 Air Emissions:** The estimate of potential air emissions for Phase 2 is based on the installation of 79 total WTGs and ESPs,[6] the maximum length of Phase 2 offshore cables, the maximum area of scour protection and cable protection for Phase 2, the maximum length of Phase 2 onshore cables, and the combination of ports with the longest transit distances to and from the Offshore Development Area, which represents the maximum design scenario for Phase 2.

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2 For each emission source, the assumed combination of WTGs and ESPs (e.g. 129 WTGs/one ESP, 125 WTGs/five ESPs, etc.) varies depending on which combination yields the maximum air emissions estimate. The maximum design scenario also contemplates the use of ESPs that are co-located at the same position (see Sections 3.2.1.3 and 4.2.1.3 of COP Volume I).

3 The maximum length of the Phase 2 offshore export cables is based on the installation of three Phase 2 offshore export cables within the OECC that travels from the northwestern corner of the SWDA along the northwestern edge of Lease Area OCS-A 0501 (through Vineyard Wind 1) and then heads northward along the eastern side of Muskeget Channel toward landfall sites in the Town of Barnstable. While the Proponent intends to install all New England Wind offshore export cables within the OECC that travels through the eastern side of Muskeget Channel, the Proponent is reserving the fallback option to install one or two Phase 2 cables along the western side of Muskeget Channel, referred to as the Phase 2 OECC Western Muskeget Variant (see Section 4.1.3.2 of COP Volume I). Should any Phase 2 cables be installed within the Western Muskeget Variant, the total length of the Phase 2 offshore export cables would be less.

4 The Offshore Development Area is defined as the offshore area where New England Wind's offshore facilities are physically located, which includes the SWDA and the OECC.

5 The emissions estimate considers the farthest port that could be used for each individual vessel activity based on the best available information at the time of submission.

6 Phase 2 may include up to 88 WTG/ESP positions. The Proponent believes that these conservative Phase 2 emission estimates based on 79 positions also cover the scenario where more than 79 WTGs/ESPs are installed. For each emission source, the assumed combination of Phase 2 WTGs and ESPs varies depending on which combination yields the maximum air emissions estimate.

2.0 NEW ENGLAND WIND AIR EMISSIONS METHODOLOGY (PHASES 1 AND 2)

As described in Section 1.1, the air emissions analysis was first conducted for the maximum design scenario of both Phases of New England Wind combined (i.e. for all 130 WTG/ESP positions). Then, based on the maximum design scenario for each Phase, the total air emissions of New England Wind were apportioned to develop an estimate of emissions for each Phase separately. The following sections describe the emission sources included in the New England Wind air emissions estimate (for both Phases combined) and the methods used to quantify emissions from those sources.

2.1 Description of Air Emission Sources

Emissions from New England Wind will primarily come from the main engines, auxiliary engines, and auxiliary equipment on commercial marine vessels used during construction and O&M activities. Additional construction-related emissions are expected to come from helicopters used to transfer crew and diesel generators used to temporarily supply power to the WTGs and ESPs. There may also be emissions from other non-road construction equipment used aboard vessels including, but not limited to, engines used to power pile driving hammers, motion compensation system engines, and engines used for noise mitigation devices during pile driving (e.g. air compressors used to supply air to bubble curtains). Anticipated emission sources for offshore construction and O&M activities are described in the following table.

Table 2.1-1 Description of Offshore Emissions Sources

Emission Source[1]	Description of Source
Anchor handling tug supply (AHTS) vessels	Vessels that primarily handle and reposition the anchors of other vessels, which may be used during offshore cable installation. AHTS vessels may also be used to transport equipment or for other services.
Barges	Vessels with or without propulsion that may be used for transporting New England Wind components (e.g. monopiles, WTGs, etc.) or installation activities.
Bunkering vessels	Vessels used to supply fuel and other provisions to other vessels offshore.
Cable laying vessels	Specialized vessels/barges that lay and bury transmission cables in the seafloor.
Crew transfer vessels (CTVs)	Smaller vessels that transport crew, parts, and equipment to and from the Offshore Development Area during both construction and operations. These vessels may also transport marine mammal observers.
Dredging vessels	Specialized vessels that may be used in limited areas of the OECC prior to cable laying to remove the upper portions of sand waves.
Heavy lift vessels (HLVs)	Dynamic positioning (DP) or anchored vessels that may be used to lift, support, and orient the WTGs, ESP(s), and their foundations during installation.

Table 2.1-1 Description of Offshore Emissions Sources (Continued)

Emission Source[1]	Description of Source
Heavy transport vessels (HTVs)	Ocean-going vessels that may transport New England Wind components to port facilities or directly to the SWDA.
Jack-up vessels	Vessels that extend legs to the ocean floor to provide a safe, stable working platform. Jack-up vessels may be used to install foundations and/or WTGs, to transport WTG components to the Offshore Development Area, for offshore accommodations, and/or for cable splicing activities.
Scour/cable protection installation vessels (e.g. fallpipe vessels)	DP vessels that may be used to deposit a layer of rock around foundations or place cable protection over limited sections of the offshore cable system.
Service operation vessels (SOVs)	Larger vessels that provide offshore living accommodations and workspace, as well as transport crew to and from the Offshore Development Area.
Support vessels (e.g. work boats, supply boats, accommodation vessels)	Multipurpose vessels that may be used for a variety of activities, such as clearing the seabed floor of debris prior to laying offshore cables (i.e. a pre-lay grapnel run), supporting cable installation, commissioning WTGs, or transporting equipment.
Survey vessels	Specialized vessels used to perform geophysical and geotechnical surveys
Tugboats	Ocean-going vessels or smaller harbor craft used to transport equipment and barges to the Offshore Development Area.
Offshore generators	Diesel engines that temporarily supply power to the WTGs and ESPs during commissioning or provide backup power during O&M.
Other construction equipment	Non-road construction equipment used aboard vessels, on the WTGs, and/or on the ESPs (e.g. pile driving hammer engines, air compressors, motion compensation platform engines, forklifts, winches, etc.).
Helicopters	Helicopters capable of transporting crew to vessels or the ESPs.
Fugitive emissions	Emissions from solvents, paints, coatings, diesel fuel storage/transfer, and sulfur hexafluoride (SF_6).

Note:

1. Fishing vessels may be used for crew transfer or other miscellaneous activities described above.

Emission sources from onshore construction and O&M activities will include construction equipment and vehicles used during the unloading and loading of components at the port facilities, during construction at the landfall sites (e.g. horizontal directional drilling [HDD]), during installation of the onshore cables, and during construction of the onshore substations. Onshore emission sources include:

- Non-road construction and excavation equipment (e.g. backhoes, bore/drill rigs, compactors, concrete trucks, concrete saws, cranes, excavators, forklifts, graders, light plants, off-highway trucks, and pavers)
- Non-road commercial equipment (e.g. generators, pumps, and welders)
- Non-road industrial equipment (e.g. air conditioning units and aerial lifts)

- Worker vehicles
- Delivery and heavy-duty vehicles
- Fugitive emissions from incidental solvent release and sulfur hexafluoride (SF_6)
- Particulate emissions from construction dust

The number and types of vessels, helicopters, and other offshore equipment along with anticipated hours of operation and number of round trips for each offshore emission source was provided by the Proponent's engineers. Activity types and hours of operation for onshore non-road equipment and vehicles were largely based on inputs from the Proponent's engineers, supplemented by onshore construction emission estimates from other US offshore wind energy projects (Cape Wind,[7] Virginia Offshore Wind Technology Advancement Project [VOWTAP],[8] and Block Island Wind Farm[9]) where New England Wind-specific information was unavailable. A complete description of all anticipated emission points associated with New England Wind can be found in Attachment B.

2.2 Emissions Calculation Methods

2.2.1 Commercial Marine Vessels

Emissions from commercial marine vessels were calculated according to the methodology described in BOEM's *Offshore Wind Energy Facilities Emission Estimating Tool Technical Documentation,* referred to as "BOEM's Emission Estimating Tool" (Chang et al. 2017). BOEM's Emission Estimating Tool was developed to provide a consistent approach for estimating emissions associated with proposed offshore wind projects and to ensure consistency in BOEM's environmental review process. When necessary, BOEM's emission calculation methodology was supplemented with guidance from EPA's (2009) *Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories* ("EPA's Port-Related Emission Guidance"), EPA's *2014 National Emission Inventory Technical Support Document* ("2014 NEI"), and EPA's *2017 National Emission Inventory Technical Support Document* and supporting commercial marine vessel documentation ("2017 NEI").

2.2.1.1 Criteria Air Pollutants and Their Precursors

The EPA has developed National Ambient Air Quality Standards (NAAQS) for six air contaminants, known as criteria pollutants, for the protection of public health and welfare. The criteria pollutants are SO_2, particulate matter (smaller than 10 microns as PM_{10}, smaller than 2.5 microns as $PM_{2.5}$), nitrogen dioxide (NO_2), CO, ozone (O_3), and Pb. Typically, ozone is not emitted directly

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7 ESS Group. 2009.

8 Tetra Tech. 2014.

9 Tetra Tech. 2012.

into the air; instead, ozone primarily forms from the reaction of VOCs and NOx in sunlight. VOC and NOx, which are often emitted directly into the air, are commonly referred to as ozone precursors. Therefore, emissions of these ozone precursors are quantified instead of ozone.

Consistent with the BOEM Emission Estimating Tool, vessel air emissions were calculated based on vessels' hours of operation, distance traveled, speed, total number of round trips, engine size, load factor, and emission factor. For each vessel, five calculations were made:

- Emissions from the main engines while in transit
- Emissions from the main engines while maneuvering
- Emissions from the auxiliary engines while in transit
- Emissions from the auxiliary engines while maneuvering
- Emission from auxiliary engines while hoteling in port

The basic equation used for each of the five calculations above is:

$$E = kW * Hours * LF * EF * 1.10231 \; x \; 10^{-6}$$

Where:

- E = total emissions (US tons)
- kW = total engine size (kilowatt [kW])
- $Hours$ = duration of each activity (hours)
- LF = engine load factor (unitless)
- EF = emission factor (g/kW-hr)
- $1.10231 \; x \; 10^{-6}$ = grams to ton conversion factor

Per EPA's (2018a) 2014 NEI methodology, the emission estimates do not include activity or emissions associated with boilers used to generate steam. Any thermal energy needs (e.g. hot water) on vessels will typically be met using excess heat from the vessel's engines or electric heaters.

2.2.1.1.1 Engine Size

Vessel emission estimates are based on actual vessels that may be used for New England Wind or are closely representative of the types of vessels that are expected to be used for New England Wind. Engine sizes and vessel speeds[10] are from equipment specification sheets for each representative vessel. However, several vessel specification sheets did not specify the size of

[10] Vessel speeds, which are typically reported on specification sheets as maximum or cruising speeds, were adjusted in some instances to reflect possible vessel speed restrictions to protect marine species and operational restrictions (e.g. towing occurs at slower speeds).

auxiliary engines or differentiate between auxiliary engines and main engines. For some ocean-going vessels (OGVs), when only the size of the main engine or total propulsion power was provided, auxiliary engine size was determined using auxiliary engine power ratios from Table 2-4 of EPA's (2009) Port-Related Emission Guidance. In some instances, it was assumed that the smallest engine(s) supplied auxiliary power. For example, the scour protection installation vessel has three 4,500 kW engines, one 1,200 kW engine, and one 429 kW engine. It was assumed that the 1,200 kW and 429 kW engines provide auxiliary power. In diesel-electric vessels, the main engines are used to provide both auxiliary and propulsion power. In these vessels, at low loads, some engines can be shut down to allow others to operate more efficiently (EPA 2009). Consequently, for diesel-electric vessels, it was assumed that one of the main engines provides auxiliary power.

2.2.1.1.2 Distance Traveled

The emissions estimate for the COP includes all New England Wind-related vessel emissions within US waters.[11] To account for the envelope of possible ports used during construction and operations, the emissions estimate assumes the use of the port with the longest transit distances to and from the Offshore Development Area (within US waters) that may be used for each activity.[12] Approximate distances between New England Wind's ports, the SWDA, the OECC, and within the Offshore Development Area are summarized in Attachment D.

The distance traveled by each vessel while within US waters was estimated using preliminary vessel routes between the SWDA, OECC, and the ports included in the New England Wind Envelope. The preliminary vessel routes are illustrated in Figures D-1 through D-8 in Attachment D. These preliminary vessel routes were developed based on regions of concentrated commerce traffic (using vessels' Automatic Identification System [AIS] data), taking into consideration traffic separation schemes (TSS), recommended vessel routes, coastal maintained channels, and anchorage areas. These routes are *preliminary* vessel routes; for each transit, individual vessel captains will need to consider weather, water depths, tides, loading conditions, and visibility before selecting their route to port. Therefore, vessel captains may opt for a different route than those shown in Attachment D. It is expected that vessel traffic routes will continue to be developed through the construction planning process and that potentially significant refinements to the routes presented will occur.

For most vessels, the Proponent's engineering team provided the number of vessel trips and operating days required for the construction and operation of New England Wind (for both Phases 1 and 2 combined). However, the number of round trips for some vessels was derived from other parameters included in the Envelope. For example, the number of round trips for the vessels

11 Includes all state waters and federal waters within the US Exclusive Economic Zone, which extends approximately 370 km (200 NM) offshore.

12 Transit distances were measured to the centroid of the SWDA or OECC.

installing cable protection in the SWDA was based on the cargo hold capacity of the vessel and the total volume of rock that may be required for cable protection over the inter-array and inter-link cables (see Attachment D).

For several vessels, two round trips (one per Phase) were added to the number of round trips to/from the Offshore Development Area to account for the vessel's initial trip to a New England Wind port from another port (i.e. mobilization) and final departure from a New England Wind port to another port (i.e. demobilization). This is a conservative approach since the ports in the New England Wind Envelope will likely be the homeports of several harbor craft (e.g. tugs and crew transfer vessels) used for New England Wind.

2.2.1.1.3 Hours of Operation

Hours of operation for a vessel's engines while in transit were calculated from the vessel's speed and total distance traveled by the vessel within US waters. It was assumed that a vessel's engines will provide power for maneuvering activities anytime the vessel is within the Offshore Development Area (in the SWDA or along the OECC) and not in transit (except for jack-up vessels' main engines, which will not provide propulsion power while jacked-up[13]). Additional hours spent maneuvering in port were based on typical maneuvering times by vessel type provided in the 2014 NEI[14] (shown below) and the number of round trips.

Table 2.2-1 In-Port Maneuvering Time by Vessel

Vessel Type	Maneuvering Time (hours)
Bulk Carrier	1
Bulk Carrier, Laker	1
Buoy Tender	1.7
Container	1
Crude Oil Tanker	1.5
General Cargo	1
LNG Tanker	1
LPG Tanker	1
Miscellaneous	1
Passenger	0.8
Reefer	1
Roll-on/roll-off (RORO)	1
Tanker	1
Tug	1.7
Vehicle Carrier	1

13 In the case of jack-up vessels, which plant their legs on the seafloor to maintain their position, their main engines will not provide propulsion power while the vessel is jacked-up. Consequently, jack-up vessels' main engines were assumed to operate for zero hours per day while at the SWDA or OECC.

14 From EPA's (2018a) *2014 National Emissions Inventory, Version 2 Technical Support Document*, Table 4-111: Estimated Maneuvering Time by Vessel Type. The maneuvering time includes time spent approaching the port and time spent departing from the port.

For all vessels, it was assumed that all main engines used for propulsion would not operate while the vessel is dockside per 2014 NEI guidance (EPA 2018a). For vessels equipped with Category 1 and 2 engines (except for some larger Category 2 vessels), it was assumed that neither the propulsion nor auxiliary engines would operate while the vessel was dockside to conserve fuel (EPA 2018a). For vessels equipped with Category 3 and large Category 2 engines, auxiliary engines were assumed to be hoteling any time the vessel is within the US and not in transit or maneuvering.[15]

2.2.1.1.4 Load Factor

Load factors are expressed as a percent of the vessel's total propulsion or auxiliary power that is used for a given operational mode (EPA 2009). Load factors for propulsion power can be calculated from the Propeller Law, which is the theory that propulsion power varies by the cube of speed as illustrated by the following equation:

$$LF = \left(\frac{AS}{MS}\right)^3$$

Where:

- LF= Load factor
- AS = Actual speed (knots)
- MS = Maximum speed (knots)

Vessels in transit were assumed to operate at cruise speed, which is defined as approximately 94% of maximum speed (EPA 2009). Based on the Propeller Law, for the main (propulsion) engines of vessels operating at 94% of maximum speed, the load factor is 0.83. Consistent with EPA guidance, a load factor of 0.83 was used in the New England Wind emission estimates for main engines while in transit.

Consistent with the 2014 NEI and the BOEM Emission Estimating Tool, a load factor of 0.20 was used for most main (propulsion) engines while maneuvering onsite (EPA 2018a; Chang et al. 2017).[16] However, based on discussions with the Proponent's engineers and vessel suppliers, a

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[15] Depending on the federal regulation referenced, the definition of marine engine categories varies slightly. In 40 CFR Part 94, Category 1 marine compression ignition engines are defined as engines with a gross engine power ≥ 37 kW and a displacement <5 liters per cylinder (L/cyl). Category 2 marine compression ignition engines have a displacement greater ≥5 L/cyl and <30 L/cyl. In 40 CFR Part 1042, Category 1 marine compression ignition engines are defined as engines with a displacement of <7 L/cyl and Category 2 engines are those with displacement ≥7 L/cyl and <30 L/cyl. Both 40 CFR Part 94 and 40 CFR Part 1042 define Category 3 engines as marine engines with a displacement at or above 30 L/cyl.

[16] According to the 2014 NEI, the propulsion engine load factor of 0.20 is from Entec's European emission inventory (Entec UK Limited. 2002. *Quantification of emissions from ships associated with ship movements between ports in the European Community, European Commission Final Report*). EPA recommends that future National Emission Inventories consider reviewing port inventory data to derive more accurate maneuvering load factors.

load factor of 0.2 underestimates the power required by many vessels that use dynamic positioning (DP) to maintain a precise location within the SWDA or along the OECC. Fuel consumption rates during DP from vessel specification sheets were used to derive a more conservative load factor for vessel's main engines during DP. See the following example DP load factor calculation for a typical vessel:

Maximum speed: 13 knots
Fuel consumption at 12 knots: 14.5 metric tonne (MT)/day
Fuel consumption in DP mode: 7 MT/day

Using the Propeller Law to calculate the load factor at 12 knots:

$$LF = \left(\frac{AS}{MS}\right)^3 = \left(\frac{12}{13}\right)^3 = 0.79$$

Using the ratio of fuel consumption at different speeds to determine the load factor during DP:

$$\frac{LF\ during\ DP}{0.79} = \frac{7\,\frac{MT}{day}\,during\ DP}{14.5\,\frac{MT}{day}\,at\ 12\ kn}$$

$$LF\ during\ DP = 0.38$$

This calculation was repeated for several vessels to determine an approximate load factor of 0.4 for the main engines during DP operations. This load factor was used for most vessels whose specification sheets suggested that the vessel had a DP system.

According to BOEM, although it is appropriate to use the default vessel profiles provided in the BOEM Emissions Estimating Tool (which are based on national fleet data), some factors within the Tool are defaults that serve as placeholders for more accurate information. For example, the auxiliary engine load factor in the BOEM Emissions Estimating Tool is defaulted to 1. Consequently, the default auxiliary engine load factor was not used. Auxiliary engine load factors for ocean-going vessels (typically vessels whose main engines are Category 3 engines) were taken from *Table 2-7: Auxiliary Engine Load Factor Assumptions* of EPA's (2009) Port-Related Emission Guidance, which is shown below. For auxiliary engines maneuvering onsite, the "maneuver" load factor was selected. For auxiliary engines in transit, the more conservative "RSZ" load factor was used, since vessels may operate at speeds slower than cruise speeds. Reduced speed zone (RSZ) speed is the maximum safe speed the vessel uses to traverse distances within a waterway leading to a port (less than cruise speed and greater than maneuvering speed).

Table 2.2-2 EPA Auxiliary Engine Load Factors for Ocean-Going Vessels

Ship Type	Cruise	RSZ	Maneuver	Hotel
Auto Carrier	0.15	0.30	0.45	0.26
Bulk Carrier	0.17	0.27	0.45	0.10
Container Ship	0.13	0.25	0.48	0.19
Cruise Ship	0.80	0.80	0.80	0.64
General Cargo	0.17	0.27	0.45	0.22
Miscellaneous	0.17	0.27	0.45	0.22
OG Tug	0.17	0.27	0.45	0.22
RORO	0.15	0.30	0.45	0.26
Reefer	0.20	0.34	0.67	0.32
Tanker	0.24	0.28	0.33	0.26

Auxiliary engine load factors for harbor craft (typically vessels whose main engines are Category 1 or 2 engines) are from *Table 4 Auxiliary and Boiler Power Surrogates* of the 2017 NEI supporting documentation for vessels with Category 1 and 2 main engines (ERG 2019a). The auxiliary engine load factors are shown in the table below.

Table 2.2-3 2017 NEI Auxiliary Engine Load Factors for Harbor Craft

Vessel Group	Auxiliary Operating Load Factor
Bulk Carrier	0.1
Commercial Fishing	0.43
Container Ship	0.19
Ferry Excursion	0.43
General Cargo	0.22
Government	0.43
Miscellaneous	0.43
Offshore support	0.56
Reefer	0.32
RORO	0.26
Tanker	0.26
Tug	0.43
Work Boat	0.43

Specific to the service operation vessel (SOV) used during O&M, load factors were based on historical operational data provided directly from potential SOV suppliers. The assumed load factors are conservatively high compared to records of actual operation for similar projects.

2.2.1.1.5 Emission Factor

The BOEM Emission Estimating Tool contains default vessel characteristics for a variety of vessel types commonly used in offshore wind projects. For each vessel type, the BOEM tool provides default emission factors for main and auxiliary engines. These default emission factors were developed using Information Handling Service vessel population data, which takes into account typical vessels' country of registration, engine categories, and regulatory tiers (Chang et al. 2017). These vessel profiles were then combined with tier level emission factors from EPA's (2016) *2014 National Emissions Inventory, Version 1 Technical Support Document* to create weighted emission factors for each vessel type (Chang et al. 2017). The BOEM default emission factors for main and auxiliary engines of each vessel type are listed in Tables 2.2-4 and 2.2-5 below.

Table 2.2-4 BOEM Default Emission Factors for Vessel Main Engines

Vessel Type	Vessel Main Engine Emission Factors (g/kW*hr)									
	NOx	VOC	CO	PM_{10}	$PM_{2.5}$	SO_2	CO_2	CH_4	N_2O	Pb
Anchor Handling Tugs	9.26	0.24	2.16	0.34	0.33	0.08	636.09	0.004	0.03	4.0E-05
Barge	13.61	0.63	1.40	0.45	0.42	0.36	588.90	0.004	0.03	1.2E-05
Cable Laying	9.49	0.25	2.20	0.34	0.33	0.09	635.02	0.004	0.03	3.9E-05
Crew	9.15	0.14	2.30	0.31	0.30	0.01	648.16	0.004	0.03	4.6E-05
Dredging	9.60	0.28	2.13	0.36	0.34	0.11	630.62	0.004	0.03	3.7E-05
Ice Breaker	9.92	0.45	1.78	0.40	0.38	0.23	610.83	0.004	0.03	2.5E-05
Jack-up	10.03	0.14	2.30	0.31	0.30	0.01	647.08	0.004	0.03	4.5E-05
Research/ Survey	9.86	0.22	2.25	0.34	0.33	0.07	638.26	0.004	0.03	4.2E-05
Shuttle Tanker	9.05	0.63	1.40	0.45	0.42	0.36	588.90	0.004	0.03	1.2E-05
Supply Ship	9.44	0.17	2.29	0.32	0.31	0.03	644.58	0.004	0.03	4.5E-05
Tug	9.52	0.18	2.29	0.33	0.32	0.03	643.66	0.004	0.03	4.5E-05

Table 2.2-5 BOEM Default Emission Factors for Vessel Auxiliary Engines

Vessel Type	Vessel Main Engine Emission Factors (g/kW*hr)									
	NOx	VOC	CO	PM_{10}	$PM_{2.5}$	SO_2	CO_2	CH_4	N_2O	Pb
Anchor Handling Tugs	9.88	0.14	2.48	0.32	0.31	0.01	648.2	0.004	0.03	4.8E-05
Barge	12.57	0.14	2.48	0.32	0.31	0.01	648.2	0.004	0.03	4.8E-05
Cable Laying	9.89	0.14	2.48	0.32	0.31	0.01	648.2	0.004	0.03	4.8E-05
Crew	10.37	0.14	2.48	0.32	0.31	0.01	648.2	0.004	0.03	4.8E-05
Dredging	9.85	0.14	2.48	0.32	0.31	0.01	648.2	0.004	0.03	4.8E-05
Ice Breaker	10.09	0.14	2.48	0.32	0.31	0.01	648.2	0.004	0.03	4.8E-05
Jack-up	11.55	0.14	2.48	0.32	0.31	0.01	648.2	0.004	0.03	4.8E-05
Research/ Survey	10.21	0.14	2.48	0.32	0.31	0.01	648.2	0.004	0.03	4.8E-05
Shuttle Tanker	9.80	0.14	2.48	0.32	0.31	0.01	648.2	0.004	0.03	4.8E-05
Supply Ship	10.43	0.14	2.48	0.32	0.31	0.01	648.2	0.004	0.03	4.8E-05
Tug	10.10	0.14	2.48	0.32	0.31	0.01	648.2	0.004	0.03	4.8E-05

As shown in the following table, each representative vessel used for New England Wind was assigned to one of the eleven vessel types listed above and the corresponding emissions factors were used.

Table 2.2-6 Assigned Vessel Types

New England Wind Vessel Type	BOEM Category
AHTS vessel	Anchor handling tugs
Barge	Barge
Bunkering vessel	Shuttle tanker
Cable laying vessel	Cable laying
CTV	Crew
Dredging vessel	Dredging
HLV	Barge (the most conservative emission factors)
HTV	Supply ship
Jack-up vessels	Jack-up
Scour protection installation vessels	Cable laying (most similar in size and function)
SOV	Cable laying (most similar in size and function)
Support vessel	Cable laying (most similar in size and function)
Survey vessel	Research/Survey
Tugboats	Tug

2.2.1.2 CO_2e

Emissions of greenhouse gases from commercial marine vessels, which include carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), were estimated using the methodology described above for criteria air pollutants and their precursors. See Tables 2.2-4 and 2.2-5 for greenhouse gas emission factors provided by the BOEM Emissions Estimating Tool. Greenhouse gas emissions as CO_2e were then calculated using global warming potential (GWP) factors from the most recent Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (2021), which provides a GWP of 27.9 for CH_4 (for fossil fuels) and 273 for N_2O. Total CO_2e emissions were calculated using the following equation:

$$E = CH4 * GWP_{CH4} + N2O * GWP_{N20} + CO2$$

Where:

- E= total CO_2e emissions, tons
- $CH4$ = total CH_4 emissions, tons
- $N2O$ = total N_2O emissions, tons
- $CO2$ = total CO_2 emissions, tons
- GWP_{CH4} = GWP for CH_4
- GWP_{N2O} = GWP for N_2O

CO_2e emissions were calculated separately for emissions from the main engines while in transit, the main engines while maneuvering, the auxiliary engines while maneuvering, the auxiliary engines while in transit, and the auxiliary engines while hoteling.

2.2.1.3 HAPS

The BOEM Emissions Estimating Tool does not provide emission factors for HAPs emitted from commercial marine vessels. Consequently, HAP emissions were estimated according to the methodology provided in the 2017 NEI supporting documentation for commercial marine vessels (ERG 2019a, 2019b). HAP emissions were estimated by applying speciation profiles to VOC estimates for organic HAPs and PM estimates for metal HAPs. HAPs were calculated as percentages of the $PM_{2.5}$ and VOC emissions from the vessels using the following equation:

$$E = VOC * SF_{VOC} + PM2.5 * SF_{PM2.5}$$

Where:

- E= total HAP emissions, tons
- VOC = total VOC emissions, tons
- $PM2.5$ = total $PM_{2.5}$ emissions, tons
- SF_{VOC}= speciation factor for VOC
- $SF_{PM2.5}$= speciation factor for $PM_{2.5}$

The HAPs speciation profiles were obtained from the 2017 NEI supporting documentation for commercial marine vessels (ERG 2019a, 2019b).

2.2.1.4 Fuel Use

EPA's (2009) Port-Related Emission Guidance provides brake specific fuel consumption (BSFC) rates for the main and auxiliary engines of ocean-going vessels (typically having Category 3 propulsion engines) for various engine types and fuels. According to the 2014 NEI (EPA 2018a), the dominant propulsion engine configuration for large Category 3 vessels is the slow-speed diesel engine. A BSFC of 185 g/kw-hr for slow-speed diesel ocean-going vessel main engines was used for Category 3 main engines.[17] For Category 3 auxiliary engines, a BFSC of 217 g/kw-hr was used, assuming that these auxiliary engines will fire primarily marine diesel oil (MDO) or marine gas oil (MGO).[18] The BSFC was converted to gal/kW-hr using a diesel fuel density of 7.10 lb/gal.

A fuel consumption rate for Category 1 and 2 engines was calculated based on the CO_2 emission factor for Category 1 and 2 engines (648.20 g/kW-hr) provided in the BOEM Emission Estimating Tool Technical Documentation (Chang et al. 2017). This emission factor was converted to gal/kW-hr using a Distillate Fuel No. 2 higher heating value (HHV) of 0.138 MMBtu/gal and a CO_2 emission factor of 73.96 kg CO_2/MMBtu.[19] Fuel use was calculated using the following equation:

$$Fuel\ Use\ =\ Fuel\ Consumption\ Rate * \ kW * Hours * LF$$

Where:

- $Fuel\ Use$ = total fuel used (gallons)
- $Fuel\ Consumption\ Rate$ = engine-specific fuel consumption rate (gal/kW-hr)
- kW= total engine size (kW)
- $Hours$ = duration of each activity (hours)
- LF = engine load factor (unitless)

Total fuel use was calculated separately for emissions from the main engines while in transit, the main engines while maneuvering, the auxiliary engines while maneuvering, the auxiliary engines while in transit, and the auxiliary engines while hoteling.

17 From EPA's (2009) Port-Related Emission Guidance), Table 2-9: Emission Factors for OGV Main Engines

18 From EPA's (2009) Port-Related Emission Guidance, Table 2-16: Auxiliary Engine Emission Factors

19 Distillate Fuel Oil No. 2 HHV and CO_2 emission factors are from 40 CFR Part 98 Table C-1: Default CO_2 Emission Factors and High Heat Values for Various Types of Fuel.

2.2.2 Helicopters

2.2.2.1 Criteria Air Pollutants

Air emissions from helicopters were calculated using the BOEM Emission Estimating Tool methodology. All helicopters for New England Wind were assumed to be medium-sized twin-engine helicopters. Emissions from helicopters were calculated based on the following equation:

$$E = Hours * EF * 0.0005$$

Where:

- E= total emissions (US tons)
- $Hours$ = total hours in flight
- EF= emission factor (lb/hr)
- 0.0005= pounds to ton conversion factor

Total hours in flight were based on the total distance each helicopter is expected to travel to the SWDA and the BOEM Emission Estimating Tool default speed (183 miles per hour [mph]) for twin medium helicopters. Approximate distances traveled by the helicopters are provided in Attachment D. The emission estimates used the following emission factors for twin-medium helicopters from the BOEM Emission Estimating Tool.

Table 2.2-7 BOEM Default Emission Factors for Twin-Medium Helicopters

Helicopter Type	Helicopter Emission Factors (lb/hr)									
	NOx	VOC	CO	PM_{10}	$PM_{2.5}$	SO_2	CO_2	CH_4	N_2O	PB
Twin Medium	7.22	3.02	3.48	0.2031	0.1982	0.78	2459.9	0.07	0.08	0

2.2.2.2 HAPs

The BOEM Emission Estimating Tool does not provide emission factors for HAPs emitted from helicopters. HAP emissions for helicopters were estimated using a similar methodology used to estimate HAP emissions from vessels. HAP emissions were estimated by applying speciation profiles to the VOC estimates for organic HAPs and PM_{10} estimates for metal HAPs using the following equation:

$$E = VOC * SF_{VOC} + PM10 * SF_{PM10}$$

Where:

- E= total HAP emissions, tons
- VOC = total VOC emissions, tons
- $PM10$ = total PM_{10} emissions, tons
- SF_{VOC}= speciation factor for VOC

- SF_{PM10}= speciation factor for PM_{10}

The HAP speciation profile for helicopters was created using HAPs, VOC, and PM emission factors for distillate oil-fired stationary gas turbines found in AP-42 Chapter 3.1 Tables 3.1-2a, 3.1-4 and 3.1-5.

2.2.2.3 CO_2e

Greenhouse gas emissions as CO_2e for helicopters were calculated using the same methodology described for commercial marine vessels (see Section 2.2.1.2).

2.2.2.4 Fuel Use

Fuel use from helicopters was calculated using the default fuel consumption rate for twin medium helicopters provided in the BOEM Emission Estimating Tool. The default fuel usage rate (117 gal/hr) was multiplied by the total hours of flight to determine the total quantity of fuel used.

2.2.3 Offshore Generators

<u>**Generators on the WTGs**</u>

Depending on the model of WTG selected, each WTG may contain a small (~10 kW) diesel generator to provide back-up power to critical systems on the WTGs in the event of grid loss during O&M. These generators are anticipated to only operate for emergencies and reliability testing. It was conservatively assumed that the generators would operate for approximately 100 hours per year during O&M (excluding during emergencies). Given the unplanned and unpredictable nature of an emergency, it is impossible to predict with accuracy how long the WTGs' back-up generators would need to operate in an emergency.

In addition to any generators included in the design of the WTG, it was assumed that portable diesel generators would be used on the WTGs during construction in the following sequence:

1. One ~40 kW generator per WTG operates for five days (24 hours per day) for cold commissioning of the WTGs.

2. Then, three ~40 kW generators per WTG operate for five days (24 hours per day) during hot commissioning, if power from the electric grid is not available.

3. Then, one ~40 kW generator per WTG operates at partial load (~28 kW) for 30 days (24 hours per day) after completion of hot commissioning, if power from the electric grid is not available.

Portable diesel generators may also be temporarily placed on each WTG (or alternatively on a support vessel) during O&M to supply backup power during extended emergencies (i.e. grid loss). In the unlikely event that grid loss lasts longer than approximately two months, external portable generators may be placed on the WTGs to enable technicians to safely enter the nacelle of the WTG. Again, given the nature of an emergency, it is impossible to predict how long these generators would need to operate in an emergency.

Generators on the ESPs

For Phase 1, it was assumed that one or two ESPs will collectively require two ~450 kW generators to provide backup power to critical systems. For Phase 2, it was assumed that a total of up to three ~450 kW generators will be located on the ESP(s). These backup generators would operate for emergencies and reliability testing during O&M. Emergencies include unplanned loss of grid power or an unplanned failure of the offshore cable system that requires an ESP to be disconnected from external power (either from onshore or the WTGs). It was assumed that the ~450 kW back-up generators would operate for approximately 100 hours per year during O&M (excluding during emergencies).

In addition, the back-up generator(s) on the ESPs will likely be used to provide power for installation and commissioning activities on the ESPs until they can be connected to the electric gird. It was assumed that during construction, the generators on the ESPs will operate for about four months, approximately 50% of the time.

Based on the OCS Air Permit from EPA for Vineyard Wind 1, it is anticipated that the generators located on New England Wind's WTGs and ESPs will be required to meet or exceed EPA's highest applicable marine engine emission standards at 40 CFR Part 1042 and use ultra-low sulfur diesel (ULSD) with a maximum sulfur content of 15 parts per million (ppm) (see Section 5.1.2.1.2 of COP Volume III). Thus, emissions from the generators located on the New England Wind WTGs and ESPs were estimated based on the most stringent EPA marine engine emission standard applicable for each engine size (i.e. EPA Tier 3 marine engine emission standards for engines less than 600 kW and EPA Tier 4 marine engine emission standards for engines greater than or equal to 600 kW). It was assumed that the engines would fire ULSD with a maximum sulfur content of 15 ppm. The fuel usage rate for each generator was determined from equipment specification sheets for diesel generators that are representative of the type of generator that will be used for New England Wind.

The following hydrocarbon (HC) + NOx, CO, and PM emission factors were used to estimate emissions from the generators on the WTGs and ESPs.

Table 2.2-8 Assumed EPA Marine Engine Emission Standards

Generator	EPA Marine Engine Standard	Emission Factors (g/kW*hr)		
		HC + NOx	CO	PM
Permanent Generator on WTG (~10 kW)	EPA Tier 3 (for Category 1 Engines with disp. < 0.9)	7.5	6.6	0.40
Temporary Generator on WTG (~40 kW)	EPA Tier 3 (for Category 1 Engines with 0.9 ≤ disp. < 1.2 and power density ≤ 35 kW/L)	5.4	5.0	0.12
Permanent Generator on ESP (~450 kW)	EPA Tier 3 (for Category 1 Engines <600 kW with 3.5 ≤ disp. < 7.0 and power density ≤ 35 kW/L)	5.8	5.0	0.10

Note:

1. "Disp." = Displacement in liters per cylinder.

It was conservatively estimated that NOx is 100% and VOC is 1% of HC + NOx. For all generators, based on guidance from EPA's most recent *Exhaust and Crankcase Emission Factor for Nonroad Engine Modeling – Compression Ignition Report*, it was assumed that 100% of PM is PM_{10} and 97% of PM is $PM_{2.5}$ (EPA 2010).

SO_2 emission factors for the generators were developed using a mass balance based on the consumption of diesel fuel containing 15 ppm sulfur, a fuel density of 7.1 lb/gal, and a 2:1 ratio of SO_2 to sulfur. Total tons of SO_2 were calculated using the following equation:

$$SO_2(tons) = Fuel\ use\ (gal) * \frac{7.10\ lb\ diesel\ fuel}{gal\ diesel\ fuel} * \frac{15 * 10^{-6}\ lb\ S}{lb\ diesel\ fuel} * \frac{100\ \%\ conversion}{100}$$

$$* \frac{1\ lb\ mole\ S}{32\ lb\ S} * \frac{1\ lb\ mole\ SO_2}{1\ lb\ mole\ S} * \frac{64\ lb\ SO_2}{1\ lb\ mole\ SO_2} * \frac{1\ ton\ SO_2}{2000\ lb\ SO_2}$$

CO_2 emission factors were based on the default Distillate Fuel No. 2 CO_2 emission factor (73.96 kg CO_2/MMBtu) and HHV (0.138 MMBtu/gal) from 40 CFR Part 98 Table C-1.[20] CH_4 and N_2O emission factors were based on default CH_4 and N_2O emission factors for petroleum from 40 CFR Part 98 Table C-2[21] and the default Distillate Fuel No. 2 HHV from 40 CFR Part 98.

20 From 40 CFR Part 98 Table C-1: Default CO_2 Emission Factors and High Heat Values for Various Types of Fuel.

21 From 40 CFR Part 98 Table C-2: Default CH_4 and N_2O Emission Factors for Various Types of Fuel.

Greenhouse gas emissions as CO_2e for the generators were calculated using GWP emission factors provided in IPCC's Sixth Assessment Report (2021) following the same methodology described for commercial marine vessels (see Section 2.2.1.2).

Pb and HAP emission factors for generators smaller than 447 kW (600 horsepower [hp]) were based on the Pb and HAP emission factors for small uncontrolled stationary diesel engines from AP-42.[22] For generators larger than 447 kW (600 hp), the Pb and HAP emission factors were based on the emission factors for large uncontrolled stationary diesel engines from AP-42.[23] For all generators, the Pb and HAP emission factors in lb/MMBtu were converted to lb/gallon using the default HHV for Distillate No. 2 Fuel Oil from 40 CFR Part 98 Table C-1. These lb/gallon emission factors were multiplied by the total fuel use of each generator to determine total emissions of Pb and HAPs.

2.2.4 Other Offshore Construction Equipment

Various construction equipment may be used aboard vessels, on the WTGs, and on the ESPs during construction and operation of New England Wind. The assumptions used to estimate emissions from major offshore construction equipment (e.g. pile driving hammer engines, air compressors, motion compensation platform engines, winches, etc.) are described below, followed by a discussion of the emission factors used for the construction equipment.

Pile Driving Hammer Engines

It was conservatively assumed that five ESPs will have 12 jacket piles each and that 125 WTGs will have four jacket piles each, which provides the maximum number of piles that may be driven for New England Wind. For each foundation jacket pile, it was assumed that pile driving would take approximately six hours to achieve the target penetration depth (including time to power up and power down the hammer engines). It was conservatively assumed that the pile driving hammer engines would operate at 100% load.

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22 The HAP emission factor for small uncontrolled stationary diesel engines is the sum of emission factors listed in AP-42 from Table 3.3-2: Speciated Organic Compound Emission Factors for Uncontrolled Diesel Engines; Table 1.3-10: Emission Factors for Trace Elements from Distillate Fuel Oil Combustion Sources; and Table 3.1-5: Emission Factors for Metallic Hazardous Air Pollutants from Distillate Oil-Fired Stationary Gas Turbines. The Pb emission factor is from Table 3.1-5: Emission Factors for Metallic Hazardous Air Pollutants from Distillate Oil-Fired Stationary Gas Turbines.

23 The HAP emission factor for large uncontrolled stationary diesel engines is the sum of emission factors listed in AP-42 from Table 1.3-10: Emission Factors for Trace Elements from Distillate Fuel Oil Combustion Sources; Table 3.4-3: Speciated Organic Compound Emission Factors for Large Uncontrolled Stationary Diesel Engines; Table 3.4-4: PAH Emission Factors for Large Uncontrolled Stationary Diesel Engines; and Table 3.1-5: Emission Factors for Metallic Hazardous Air Pollutants from Distillate Oil-Fired Stationary Gas Turbines. The Pb emission factor is from Table 3.1-5: Emission Factors for Metallic Hazardous Air Pollutants from Distillate Oil-Fired Stationary Gas Turbines.

Engine size and fuel usage were determined from the equipment specification sheet of a diesel engine that is representative of the type of engine used for pile driving. Based on the specification sheet, it was assumed that three ~747 kW engines will power the pile driving hammer. As described below, emissions from the engines used to power the hydraulic pile driving hammer were estimated based on a Tier 2 marine diesel engine burning fuel with a sulfur content of 1,000 ppm.

Air Compressors

The air compressors that may be used for noise mitigation devices (e.g. bubble curtains) were assumed to operate for six hours per pile driven. Engine size and fuel usage were determined from the equipment specification sheet of a diesel air compressor that is representative of the type of compressor typically used for noise mitigation in offshore wind projects. As discussed further below, emissions from the air compressors were estimated based on a Tier 2 marine compression ignition engine burning fuel with a sulfur content of 1,000 ppm.

Motion Compensation Platform Engines

Depending on the contractor selected for foundation or WTG installation, foundations or WTG components may be fed to the SWDA on floating barges. If foundations or WTG components are transported from port to the SWDA on floating barges, the components may need to be held by a motion compensation platform during lifting operations. During the lift of the foundation or WTG, the motion compensation platform compensates vessels' roll, pitch, and heave motions.

For the air emissions estimate, it was assumed that transition pieces will be fed to the SWDA using vessels that employ a motion compensation platform. For each transition piece, it was conservatively estimated that the motion compensation platform's engines would operate for two hours at 100% load to hold the transition piece steady for lifting operations.

Engine size and fuel usage were determined from the equipment specification sheet of a typical diesel engine that could be used to power a motion compensation platform. It was assumed that three ~510 kW engines will power the motion compensation platform. Emissions from the engines used to power the motion compensation platform were estimated based on a Tier 2 marine engine burning fuel with a sulfur content of 1,000 ppm.

Winches

Winches will likely be used to pull offshore cables into the ESPs and WTGs. For winching operations, it was assumed that an ~4 kW generator would operate at 100% load for eight hours at each WTG and ESP foundation. Engine size and fuel usage were determined from the equipment specification sheet of a typical diesel engine that could be used to power a winch. As described further below, emissions were estimated based on a Tier 2 nonroad engine firing ULSD.

Cable Landing Tensioner

A cable tensioner may be used aboard a vessel to pull the offshore export cables through conduits installed at the landfall sites. It was assumed that a cable tensioner would operate for 45 hours at 100% load for each cable pull-in operation. Engine size and fuel usage were determined from the equipment specification sheet of a typical diesel engine that could be used to power a cable tensioner. As discussed below, emissions from the ~90 kW engine used to power the tensioner were estimated based on a Tier 2 marine engine burning fuel with a sulfur content of 1,000 ppm.

Cable Landing Excavator

Should HDD be used at the landfall sites, to facilitate offshore export cable pull-in and expose the conduit end, a shallow "pit" would likely be excavated at the HDD exit point possibly using an excavator aboard a vessel (other methods that may be used include controlled flow excavation, etc.). It was conservatively assumed that an ~258 kW excavator would operate at 100% load for 27 hours per cable. Engine size and fuel were determined from the equipment specification sheet of a typical excavator. As discussed below, emissions from the excavator's engines were estimated based on a Tier 2 marine engine burning fuel with a sulfur content of 1,000 ppm.

Cable Landing Generator

In addition to a tensioner and excavator, a generator may be used to perform cable pull-in operations at the landfall sites. It was assumed that an ~283 kW generator would operate for 72 hours at 100% load for each offshore export cable. Fuel usage was determined from the equipment specification sheet of representative diesel generator. As discussed below, emissions from the generator's engines were estimated based on a Tier 2 marine engine burning fuel with a sulfur content of 1,000 ppm.

Shallow Water Burial Tool

A specialty cable installation tool may be used to install the offshore export cables in shallow waters. It was assumed that a shallow water burial tool would operate for ~14 twelve-hour days per cable at 100% load. Based on the specification sheet of a representative shallow water burial tool, it was assumed that two ~410 kW engines would power the burial tool. Emissions from the burial tool's engines were estimated based on a Tier 2 marine engine burning fuel with a sulfur content of 1,000 ppm.

The HC + NOx, CO, and PM emission factors provided in Table 2.2-9 were used to estimate emissions from the offshore construction equipment.

Table 2.2-9 Assumed EPA Emission Standards

Engine	EPA Engine Standard	Emission Factors (g/kW*hr)		
		HC + NOx	CO	PM
Pile Driving Hammer Engine (~747 kW)	EPA Tier 2 Marine Engine (for Category 1 Engines with 2.5 ≤ disp. < 5.0)[1]	7.2	5.0	0.20
Air Compressor (~399 kW)	EPA Tier 2 Marine Engine (for Category 1 Engines with 2.5 ≤ disp. < 5.0)	7.2	5.0	0.20
Motion Compensation System Platform Engine (~510 kW)	EPA Tier 2 Marine Engine (for Category 1 Engines with 2.5 ≤ disp. < 5.0)	7.2	5.0	0.20
Winch Engine (~4 kW)	EPA Tier 2 Nonroad Engine (for kW < 8)	7.5[2]	8.0	0.80
Tensioner Engine (~90 kW)	EPA Tier 2 Marine Engine (for Category 1 Engines with 0.9 ≤ disp. < 1.2)	7.2	5.0	0.30
Excavator Engine (~258 kW)	EPA Tier 2 Marine Engine (for Category 1 Engines with 1.2 ≤ disp. < 2.5)	7.2	5.0	0.20
Cable Landing Generator	EPA Tier 2 Marine Engine (for Category 1 Engines with 1.2 ≤ disp. < 2.5)	7.2	5.0	0.20
Shallow Water Burial Tool Engine	EPA Tier 2 Marine Engine (for Category 1 Engines with 1.2 ≤ disp. < 2.5)	7.2	5.0	0.20

Notes:

1. "Disp." = Displacement in liters per cylinder.
2. NMHC + NOx emission standard.

It was conservatively estimated that NOx is 100% and VOC is 1% of HC + NOx or non-methane hydrocarbon (NMHC) + NOx. Based on guidance from EPA's most recent *Exhaust and Crankcase Emission Factor for Nonroad Engine Modeling – Compression Ignition Report*, it was assumed that 100% of PM is PM_{10} and 97% of PM is $PM_{2.5}$ (EPA 2010).

SO_2 emission factors were developed using a mass balance based on the consumption of diesel fuel containing 15 ppm or 1,000 ppm sulfur, a fuel density of 7.1 lb/gal, and a 2:1 ratio of SO_2 to sulfur. Total tons of SO_2 were calculated using the same equation as described for the generators (see Section 2.2.3).

CO_2 emission factors were based on the default Distillate Fuel No. 2 CO_2 emission factor (73.96 kg CO_2/MMBtu) and HHV (0.138 MMBtu/gal) from 40 CFR Part 98 Table C-1.[24] CH_4 and N_2O emission factors were based on default CH_4 and N_2O emission factors for petroleum from 40 CFR Part 98 Table C-2[25] and the default Distillate Fuel No. 2 HHV from 40 CFR Part 98. Greenhouse gas emissions as CO_2e were calculated using GWP emission factors using the same methodology as described for commercial marine vessels (see Section 2.2.1.2).

The Pb and HAP emission factors for the pile driving hammer engines and motion compensation platform engines were based on the Pb and HAP emission factors for large (greater than 600 hp) uncontrolled stationary diesel engines from AP-42.[26] The Pb and HAP emission factors for the remaining construction equipment were based on the Pb and HAP emission factors for small (less than 600 hp) uncontrolled stationary diesel engines from AP-42.[27] The Pb and HAP emission factors in lb/MMBtu were converted to lb/gallon using the default HHV for Distillate No. 2 Fuel Oil from 40 CFR Part 98 Table C-1. These lb/gallon emission factors were multiplied by the total fuel use of the offshore construction equipment to determine total emissions of Pb and HAPs.

2.2.5 Onshore Non-Road Engines

Emissions from non-road engines in onshore construction equipment (e.g. cranes, excavators, and drilling rigs) were calculated using EPA's Motor Vehicle Emission Simulator, MOVES2014b. This state-of-the-art emission estimating tool was updated in August 2018 to include significant improvements to estimate emissions from nonroad mobile sources (EPA 2018b). Emission factors from MOVES2014b were used to calculate emissions for each pollutant (NOx, VOC, CO, PM_{10},

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24 Distillate Fuel Oil No. 2 HHV and CO_2 Emission Factor are from 40 CFR Part 98 Table C-1: Default CO_2 Emission Factors and High Heat Values for Various Types of Fuel.

25 Default CH_4 and N_2O emission factors are from 40 CFR Part 98 Table C-2: Default CH_4 and N_2O Emission Factors for Various Types of Fuel

26 The HAP emission factor for large uncontrolled stationary diesel engines is the sum of emission factors listed in AP-42 from Table 1.3-10: Emission Factors for Trace Elements from Distillate Fuel Oil Combustion Sources; Table 3.4-3: Speciated Organic Compound Emission Factors for Large Uncontrolled Stationary Diesel Engines; Table 3.4-4: PAH Emission Factors for Large Uncontrolled Stationary Diesel Engines; and Table 3.1-5: Emission Factors for Metallic Hazardous Air Pollutants from Distillate Oil-Fired Stationary Gas Turbines. The Pb emission factor is from Table 3.1-5: Emission Factors for Metallic Hazardous Air Pollutants from Distillate Oil-Fired Stationary Gas Turbines.

27 The HAP emission factor for small uncontrolled stationary diesel engines is the sum of emission factors listed in AP-42 from Table 3.3-2: Speciated Organic Compound Emission Factors for Uncontrolled Diesel Engines; Table 1.3-10: Emission Factors for Trace Elements from Distillate Fuel Oil Combustion Sources; and Table 3.1-5: Emission Factors for Metallic Hazardous Air Pollutants from Distillate Oil-Fired Stationary Gas Turbines. The Pb emission factor is from Table 3.1-5: Emission Factors for Metallic Hazardous Air Pollutants from Distillate Oil-Fired Stationary Gas Turbines.

$PM_{2.5}$, SO_2, CO_2, CH_4, and HAPs[28]). To calculate emission factors and fuel consumption rates for onshore activities, a run was completed for a weekday in August 2022. Air emissions from non-road equipment were primarily calculated based on each equipment's hours of operation and emission factor using the following equation:

$$E = Hours * LF * EF * 1.10231\ x\ 10^{-6}$$

Where:

- E = total emissions (US tons)
- $Hours$ = duration of each activity (hours)
- LF = engine load factor (unitless)
- EF = emission factor (g/hr)
- $1.10231\ x\ 10^{-6}$ = grams to ton conversion factor

For some equipment, air emissions from non-road equipment were calculated based on hours of operation, engine size, load factor, and emission factor using the following equation:

$$E = kW * Hours * LF * EF * 1.10231\ x\ 10^{-6}$$

Where:

- E = total emissions (US tons)
- kW = total engine size (kW)
- $Hours$ = duration of each activity (hours)
- LF = engine load factor (unitless)
- EF = emission factor (g/kW-hr)
- $1.10231\ x\ 10^{-6}$ = grams to ton conversion factor

Load factors were from EPA's *Median Life, Annual Activity, and Load Factor Values for Nonroad Engine Emissions Modeling* (2010). Activity types and hours of operation were largely based on inputs from the Proponent's engineers, supplemented by onshore emission estimates from other US offshore wind energy projects where New England Wind-specific information was unavailable.

Key assumptions used to estimate non-road emissions for both Phases of New England Wind are listed in the table below for each onshore activity. These calculations can be found in Attachment D.

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[28] MOVES2014b provides emission factors for individual HAPs, which were summed together.

Table 2.2-10 Key Assumptions for Non-Road Engine Onshore Activities

Onshore Activity	Assumptions

Onshore Port Activities (Phases 1 and 2)	• During construction:
	  o Each monopile and transition piece will take approximately two hours of crane operations to offload and load onto a vessel.
	  o Each WTG will take approximately 14 hours of crane operations to offload and load onto a vessel.
	  o Offloading and loading of offshore cables onto vessels will take approximately two 24-hour days per vessel round trip.
	• During O&M:
	  o A crane will be used for approximately one 24-hour day each time the WTG repair support vessel transits to port.

All Onshore Construction (Phases 1 and 2)	• Typical work hours for installation of the onshore duct bank and cables will be 7:00 AM to 6:00 PM (11-hour days). Typical work hours at the landfall sites will be 7:00 AM to 7:00 PM (12-hour days). • All equipment will use ultra-low-sulfur diesel (ULSD). • Concrete trucks have a capacity of 7 m^3 (9.5 cubic yards) and take two hours per load, including travel.
Trench, Conduit, Duct bank, and Splice Vault Installation (Phases 1 and 2)	• The maximum length of the Phase 1 Onshore Export Cable and Grid Interconnection Routes will be ~13.4 km (~8.3 miles). The maximum total length of the Phase 2 Onshore Export Cable and Grid Interconnection Routes will be ~34 km (~21 miles). • The maximum cross-sectional area of the duct bank trench is approximately 8.1 square meters (m^2) (87 square feet [ft^2]), conservatively assuming the maximum Phase 2 trench dimensions. • The maximum duct bank cross sectional area is ~1.4 m^2 (~15 ft^2), conservatively assuming the maximum Phase 2 trench dimensions. • The maximum cross-sectional area of the pit excavated for splice vaults is ~22 m^2 (~240 ft^2). The maximum length is ~15 meters (m) (~50 feet [ft]). • On average, onshore construction (trenching, duct bank installation, concrete pouring, etc.) will occur a rate of ~35 m (~114 ft) per day.[1] • There will be splice vaults every ~457 m (~1,500 ft).[2] • Each splice vault will take approximately one hour to place by crane.
Cable Delivery, Pulling, Splicing, and Termination (Phases 1 and 2)	• Cable pulling will take approximately 360 days for both Phases combined. • Cable splicing and termination will take approximately 660 days for both Phases combined.

Table 2.2-10 Key Assumptions for Non-Road Engine Onshore Activities (Continued)

Onshore Activity	Assumptions
Construction at the Landfall Sites and other Trenchless Crossings (Phases 1 and 2)	• Set up of the drilling rigs will take approximately two weeks (six 12-hour workdays per week) per landfall site/trenchless crossing. • HDD at the landfall sites will require approximately six weeks (six 12-hour workdays per week) per offshore export cable. • A trenchless crossing of Centerville River for Phase 1 will take approximately four weeks per bore (six 12-hour workdays per week). • Each trenchless crossing of Route 6 will take approximately three weeks (six 12-hour workdays per week). • Dismantling the drilling rigs will take approximately one week (six 12-hour workdays per week) per landfall site/trenchless crossing.
Onshore Substation Construction (Phases 1 and 2)	• Clearing/grading each onshore substation site will take approximately two months. • Construction and commissioning of each onshore substation will take approximately 24 months. • Each onshore substation footprint will be ~1,200 m^2 (0.3 acres) covered by a concrete pad 0.2 m (0.7 ft) thick and each substation will have ~4,000 m^2 (1.0 acre) of internal gravel roadways of the same thickness.

Notes:

1. Onshore construction is expected to proceed at an average rate of approximately 24 to 61 m (80 to 200 ft) per day depending on a number of factors including existing utility density.
2. Splice vaults will be installed as two-piece preformed concrete chambers, and will be located approximately every 457—914 m (1,500—3,000 ft) or more along the Onshore Export Cable and Grid Interconnection Routes.

2.2.6 On-Road Vehicles

Emissions from on-road engines such passenger trucks, flatbed trucks, and dump trucks were also calculated using EPA's Motor Vehicle Emission Simulator, MOVES2014b. One MOVES2014b run was performed for each vehicle type (e.g. passenger truck, light commercial truck, etc.) to obtain emission factors specific to each vehicle type. Each run was performed for a July morning using Bristol County, Massachusetts project-level inputs provided by the Massachusetts Department of Environmental Protection (MassDEP) for 2022. Each MOVES vehicle type includes a mix of gasoline-fueled and diesel-fueled vehicles based on the project-level inputs provided by MassDEP. Emissions factors from MOVES2014b were used to calculate emissions for each pollutant (NOx, VOC, CO, PM_{10}, $PM_{2.5}$, SO_2, and CO_2e). HAP emissions for on-road vehicles were not available via MOVES and were assumed to be negligible. When not available, PM_{10} was estimated from $PM_{2.5}$, assuming 97% of PM_{10} is $PM_{2.5}$. Air emissions from on-road engines while in motion were calculated based on the distance each vehicle is expected to travel and MOVES2014b emission factors (for 30 mph) using the following equation:

$$E = Miles * EF * 1.10231 \, x \, 10^{-6}$$

Where:

- E= total emissions (US tons)
- $Miles$= total distance traveled (miles)
- EF= 30 mph emission factor (g/mile)
- $1.10231 \, x \, 10^{-6}$ = grams to ton conversion factor

As shown in the following table, each type on on-road vehicle used for New England Wind was assigned to one of 13 vehicle types used in MOVES2014b.

Table 2.2-11 Assigned Vehicle Types

Vehicle[1]	MOVES2014a Category	Description
Worker personal vehicle	Passenger truck	Light duty vehicles and light duty trucks
Inspection truck	Passenger truck	
Crew transport truck	Passenger truck	
Heavy duty support truck	Light commercial truck	Light duty trucks and class 2b trucks less than 10,000 lbs
Dump truck	Single unit short haul	Trucks greater than 10,000 lbs that travel less than 200 miles
Flatbed truck	Single unit short haul	

Note:

1. Concrete, winch, and boom trucks were characterized as non-road "off highway trucks." See Section 2.2.5.

The number of round trips taken by workers' personal vehicles was based on the duration of each activity. The number of round trips taken by delivery vehicles and dump trucks was based on the quantity of materials requiring transport. These calculations can be found in Attachment D. Key assumptions used to generate on-road emission estimates are listed in the table below for each onshore construction and O&M activity.

Table 2.2-12 Key Assumptions for On-Road Engine Onshore Activities

Onshore Activity	Assumptions
Onshore Port Activities (Phases 1 and 2)	• During construction and O&M, there will be 25 port workers who will commute on average 24 km (15 mi) each way.[1]
All Onshore Construction (Phases 1 and 2)	• Workers will commute on average 24 km (15 mi) each way. • Vehicles will not idle. • Dump trucks have a capacity of 15 m^3 (20 cubic yards) and travel 48 km (30 mi) each way.
Trench, Conduit, Duct bank, and Splice Vault Installation (Phases 1 and 2)	• All dirt and pavement will be hauled away as it is excavated. • All backfill will be delivered by dump truck. • Plastic conduits will be delivered on one flatbed truck per day. • Installation of the onshore export cable will require a 20-man crew.
Cable Delivery, Pulling, Splicing, and Termination (Phases 1 and 2)	• Cable pulling will take approximately 360 days for both Phases combined. • Cable splicing and termination will take approximately 660 days for both Phases combined. • Cable delivery, pulling, splicing, and termination will require two heavy-duty support trucks and two crew trucks.
Construction at the Landfall Sites and other Trenchless Crossings (Phases 1 and 2)	• Construction at the landfall sites, Centerville River Crossing (for Phase 1), and highway crossings will require a 20-person crew.
Onshore Substation Construction (Phases 1 and 2)	• Onshore substation construction will require one truck delivery per day. • Onshore substation construction will require a 20-person crew.
Onshore O&M (Phases 1 and 2)	• Each day, 20 O&M workers will commute to port on average 24 km (15 mi) each way. • Onshore substation inspections will be carried out weekly.

Note:

1. US Bureau of Transportation. 2003. From Home to Work, the Average Commute is 26.4 Minutes. Omnistats, Vol. 3 (Issue 4). https://www.nrc.gov/docs/ML1006/ML100621425.pdf.

2.2.7 Construction Dust

Particulate emissions estimates from onshore construction activities were calculated according to the methodology provided in EPA's *AP-42, Chapter 13.2.3: Heavy Construction Operation*. The amount of particulate emissions is proportional to the size of the construction area and level of construction activity. PM_{10} emissions from onshore cable installation, landfall site activities, and onshore substation construction were estimated using the following equation:

$$E = 1.2 \frac{tons}{acre * months} * Months * Acre$$

Where:

- E= total PM_{10} emissions (US tons)
- $Months$= duration of activity (months)
- $Acres$= area of construction (acres)

To estimate construction dust emissions from onshore construction, based on current engineering plans, it was assumed that each 35 m (114 ft) section of trench will be an active construction site for two days, the total onshore substation construction area will be ~0.19 km^2 (~46.5 acres), each landfall site construction staging area will be approximately 0.003 km^2 (0.8 acres), and the Centerville River crossing and highway crossing construction staging areas will each be approximately 0.003 km^2 (0.7 acres).

According to AP-42 Section 13.2.3.3, the emission factor of 1.2 tons/acre*month will result in conservatively high estimates of PM_{10} and "may result in too high an estimate for PM_{10} to be of much use for a specific site under consideration." While AP-42 Chapter 13.2.3 recommends estimating construction particulate emissions by breaking down the construction process into component operations using *Table 13.2.3-1: Recommended Emission Factors for Construction Operations* instead, the emission factors and equations provided in the table require specific information beyond what is currently available for New England Wind. Without any direction from the Chapter 13.2.3 on $PM_{2.5}$ emissions, it was also conservatively estimated that 100% of PM_{10} is $PM_{2.5}$.

2.2.8 Fugitive Emissions

During construction, it was conservatively estimated that 1 ton of VOCs per Phase would be emitted from fugitive emissions of solvents, paints, coatings, and diesel fuel storage/transfer. During O&M, it was assumed that there would be fugitive emissions from the use of 303 liters (80 gallons) of marine paint for touch-ups each year. The VOC emission rate was based on the product information sheet for White Ketamine Marine Primer, which had the highest VOC content from a selection of several marine coatings material sheets.[29]

[29] Cardinal White Ketamine Marine Primer from http://www.cardinalpaint.com/assets/TDS/7M90-10-tds.pdf.

Emissions of SF_6 used to insulate electrical equipment (primarily switchgear) on the WTGs, on the ESPs, and at the onshore substations were conservatively estimated based on the storage capacity of SF_6 within the equipment and the maximum permissible annual leak rate of 1% per 310 CMR 7.72(5)(a).[30] Greenhouse gas emissions of SF_6 as CO_2e were calculated using a GWP of 25,200 from IPCC's Sixth Assessment Report (2021). SF_6 calculations are provided in Attachment E.

The Proponent's engineers indicated that there would be up to approximately 16 kg (35 lb) of SF_6 on each Phase 1 WTG and 19 kg (42 pounds [lb]) of SF_6 on each Phase 2 WTG. The Phase 1 ESP(s) were assumed to contain a total of up to 4,120 kg (9,083 lb) of SF_6, whereas the Phase 2 ESPs were assumed to contain a total of up to 6,180 kg (13,625 lb) of SF_6.

At the Phase 1 onshore substation, SF_6 will be used in new circuit breakers, which are designed to be gas-tight and sealed for the life of the equipment. SF_6 quantities can vary between manufacturers, but it is estimated that the circuit breakers will contain 57–75 kg (125–165 lb) of SF_6 gas per breaker. The current Phase 1 onshore substation configuration has between 14 and 16 circuit breakers. Gas-insulated bus, located outdoors, will contain a similar amount of gas about every 1.5 linear meters (5 ft); the proposed layout utilizes approximately 457 linear meters (1,500 ft) of gas-insulated bus. It was assumed that the Phase 2 onshore substation(s) will contain, in total, double the amount of SF_6 as the Phase 1 onshore substation.

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30 The maximum allowable SF_6 emission rate beginning in the 2020 calendar year.

3.0 SUMMARY OF NEW ENGLAND WIND AIR EMISSIONS

3.1 New England Wind Air Emissions Estimate (Phases 1 and 2)

As described in Section 1, all air emissions from the construction and operation of New England Wind (both Phases 1 and 2) were estimated to assess regional impacts to air quality as part of the New England Wind COP and for BOEM's NEPA process. The estimates of New England Wind's air emissions were based on the maximum design scenario for both Phases of New England Wind combined (i.e. for all 130 WTG/ESP positions) and include all emissions within the US (onshore and offshore within the 370 km [200 NM] Exclusive Economic Zone). See Section 1.1 for a description of the maximum design scenario for both Phases.

The upper bound of construction emissions for New England Wind is presented in Table 3.1-1 below. Table 3.1-1 provides an estimate of total emissions for the entire construction period of both Phases, which would be distributed over several years. Fuel usage during construction of both Phases is also estimated in the following table.

Table 3.1-1 Maximum Air Emissions During Multi-Year New England Wind Construction (Phases 1 and 2)

Activity	Total Emissions (US tons)								Fuel Use (gal)
	NOx	VOCs	CO	PM_{10}	$PM_{2.5}$	SO_2	HAPs	CO_2e	
New England Wind Construction Emissions	12,834	272	3,052	549	533	89	40	862,756	74,619,739

Table 3.1-2 provides an estimate of air emissions from the O&M of both Phases of New England Wind, including an estimate of air emissions for a typical year of operation (for planned, routine O&M activities) as well as an estimate of the maximum annual operational air emissions (assuming several repair activities occur all within the same year). Fuel usage during O&M of both Phases is also estimated.

Table 3.1-2 Annual Air Emissions During New England Wind O&M (Phases 1 and 2)

Activity	Annual Emissions (US tons/year)								Fuel Use (gal)
	NOx	VOCs	CO	PM_{10}	$PM_{2.5}$	SO_2	HAPs	CO_2e	
New England Wind O&M Emissions, Typical Year	357	6.4	90	12	12	1.1	0.9	47,783	2,180,378
New England Wind O&M Emissions, Maximum Year	472	8.5	117	16	15	1.5	1.2	55,346	2,841,231

3.2 Phase 1 Air Emissions Estimate

Once the air emissions analysis was conducted for the full buildout of New England Wind, the total air emissions of New England Wind were apportioned to develop an estimate of emissions for each Phase separately. Emissions were apportioned for each individual vessel, equipment, or activity depending on the ratio of activity level required for the maximum design scenario of Phase 1 relative to the maximum design scenario for the full buildout of New England Wind. See Section 1.1 for a description of the maximum design scenario of Phase 1.

Table 3.2-1 provides an estimate of the maximum total emissions and fuel usage during the construction of Phase 1 (within the US), which is expected to be distributed over more than one year.

Table 3.2-1 Maximum Air Emissions During Phase 1 Construction

Activity	Total Emissions (US tons)								Fuel Use (gal)
	NOx	VOCs	CO	PM_{10}	$PM_{2.5}$	SO_2	HAPs	CO_2e	
Phase 1 Construction Emissions	5,917	124	1,406	238	230	41	18	393,627	34,096,155

Table 3.2-2 provides an estimate of air emissions (within the US) for a typical year of Phase 1 operation as well as an estimate of the maximum annual operational emissions (assuming several repair activities occur all within the same year). Fuel usage during Phase 1 O&M is also estimated.

Table 3.2-2 Annual Air Emissions During Phase 1 O&M

Activity	Annual Emissions (US tons/year)								Fuel Use (gal)
	NOx	VOCs	CO	PM_{10}	$PM_{2.5}$	SO_2	HAPs	CO_2e	
Phase 1 O&M Emissions, Typical Year	178	3.2	45	6.0	5.8	0.5	0.5	20,259	1,088,213
Phase 1 O&M Emissions, Maximum Year	266	4.8	65	8.9	8.6	0.8	0.7	26,039	1,595,288

3.3 Phase 2 Air Emissions Estimate

As with Phase 1, the total air emissions of New England Wind were apportioned to develop an estimate of emissions for Phase 2 separately. Emissions were apportioned for each individual vessel, equipment, or activity depending on the ratio of activity level required for the maximum design scenario of Phase 2 relative to the maximum design scenario for the full buildout of New England Wind. See Section 1.1 for a description of the maximum design scenario of Phase 2.

An estimate of the maximum air emissions from the construction of Phase 2 (within the US) is provided in the table below. The total Phase 2 construction emissions presented in Table 3.3-1 are anticipated to be distributed over more than one year of construction. Fuel usage during construction of Phase 2 is also estimated below.

Table 3.3-1 Maximum Air Emissions During Phase 2 Construction

Activity	Total Emissions (US tons)								Fuel Use (gal)
	NOx	VOCs	CO	PM_{10}	$PM_{2.5}$	SO_2	HAPs	CO_2e	
Phase 2 Construction Emissions	7,732	164	1,841	339	329	54	24	520,958	45,025,923

Table 3.3-2 quantifies typical and maximum annual air emissions that could occur within the US *specific* to the operation and maintenance of Phase 2. However, operational emissions from Phase 2 would occur simultaneously with Phase 1 for a significant portion of each Phase's operational period; emissions from concurrent operation of Phases 1 and 2 are presented in Table 3.1-2. Fuel usage specific to the O&M of Phase 2 is also estimated below.

Table 3.3-2 Annual Air Emissions During Phase 2 O&M

Activity	Annual Emissions (US tons/year)								Fuel Use (gal)
	NOx	VOCs	CO	PM_{10}	$PM_{2.5}$	SO_2	HAPs	CO_2e	
Phase 2 O&M Emissions, Typical Year	179	3.2	45	6.0	5.8	0.5	0.5	27,594	1,093,686
Phase 2 O&M Emissions, Maximum Year	270	4.9	67	9.0	8.7	0.9	0.7	33,606	1,621,450

4.0 AVOIDED EMISSIONS

Each Phase of New England Wind will produce clean, renewable offshore wind energy that is expected to displace electricity produced by fossil fuel power plants. To quantify the CO_2e, NOx, and SO_2 emissions associated with conventional power generation that would be avoided due to New England Wind, the following equation was used:

$$EO_i = EF_i * GP * 8760 \frac{hr}{year} * CF * (1 - TLF) * 1.10231E^{-6} \frac{ton}{g}$$

Where:

- EO_i= Annual Emissions Avoided for Pollutant i (tons)
- EF_i= eGRID Avoided Emission Factor for Pollutant i (g/MW-hr)
- GP= Total Rated Peak Power Generation (MW)
- CF= Capacity Factor
- TLF = Transmission Loss Factor

The displacement analysis uses the Northeast Power Coordinating Council (NPCC) New England annual non-baseload output emission rates from EPA's Emissions & Generation Resource Integrated Database (eGRID)[31] shown in Table 4-1.

Table 4-1 eGRID Avoided Emission Factors (lb/MW-hr)

Pollutant	CO_2e	NOx	SO_2
eGRID Avoided Emission Factor (lb/MW-hr)	936.5	0.501	0.266

The analysis assumes an annual capacity factor[32] of 50% for both Phases. The BOEM Emission Estimating Tool provides a default transmission loss factor (TLF) of 3%, which assumes the use of high voltage direct current (HVDC) transmission technology. However, the export cables used for New England Wind are expected to be three-core high-voltage alternating current (HVAC) cables encased in cross-linked polyethylene (XLPE) insulation; the Phase 1 export cables will be 220–275 kilovolt (kV) and the Phase 2 export cables will be 220–345 kV. Consequently, the TLF was determined from Lazaridis's (2005) *Economic Comparison of HVAC and HVDC Solutions for Large Offshore Wind Farms under Special Consideration of Reliability,* which provides the average power losses of HVAC transmission systems for different windfarm power ratings, average wind speeds, transmission distances, and transmission voltage levels. The study

31 The displacement analysis is based on NPCC New England subregion annual non-baseload output emission rates from EPA's Emissions & Generation Resource Integrated Database (eGRID2018(v2) released 3/9/2020 https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid

32 Capacity factor refers to the ratio of an offshore wind project's annual power production to the nameplate production potential.

gives average transmission loss factors for 400 to 1,000 MW offshore wind projects using 123 kV, 220 kV, and 400 kV three-core HVAC cables with XLPE insulation at 100 km (62 mi) and 150 km (93 mi) for various windspeeds. These values were interpolated to determine an average TLF of 3.8% for the Phase 1 HVAC export cables and 4.7% for the Phase 2 HVAC export cables (see Attachment C).

Table 4-2 quantifies the air emissions associated with conventional power generation that could be avoided by using electricity generated from both Phase 1 (804 MW) and Phase 2 (a minimum of 1,200 MW) during each Phase's operational period. Table 4-3 quantifies avoided emissions for Phase 1 assuming a 30-year operational period. Table 4-4 provides the avoided emissions for Phase 2 assuming a 30-year operational period and a minimum total capacity of 1,200 MW. Additional avoided emission calculation details can be found in Attachment C.

Table 4-2 Avoided Air Emissions Resulting from New England Wind (Phases 1 and 2)

	CO_2e	NOx	SO_2
New England Wind - Emissions Avoided Annually (US tons/year)	3,931,069	2,103	1,117
New England Wind - Emissions Avoided Over Operational Period (US tons)	117,932,071	63,089	33,497

Table 4-3 Avoided Air Emissions Resulting from Phase 1

	CO_2e	NOx	SO_2
Phase 1 - Emissions Avoided Annually (US tons/year)	1,585,878	848	450
Phase 1 - Emissions Avoided Over Operational Period (US tons)	47,576,348	25,452	13,513

Table 4-4 Avoided Air Emissions Resulting from Phase 2

	CO_2e	NOx	SO_2
Phase 2 - Emissions Avoided Annually (US tons/year)	2,345,191	1,255	666
Phase 2 - Emissions Avoided Over Operational Period (US tons)	70,355,723	37,638	19,983

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Attachment A

Air Emissions Summary

New England Wind Emissions Summary

Construction Emissions	Total Fuel Consumption (gal)	New England Wind Maximum Total Emissions in US (US Tons)							
		NOX	VOC	CO	PM10	PM2.5	SO2	HAPs	CO2e
Offshore Emissions	72,161,119	12,771	266	3,005	419	403	89	39	830,314
Onshore Emissions	2,458,620	63	5	47	131	131	0.1	1.9	32,442
Total Emissions	74,619,739	12,834	272	3,052	549	533	89	40	862,756

Annual O&M Emissions	Fuel Consumption per Year (gal)	New England Wind Maximum Total Emissions in US (US Tons per Year)							
		NOX	VOC	CO	PM10	PM2.5	SO2	HAPs	CO2e
Offshore Emissions, Routine O&M	2,166,290	357	6.4	89	12	12	1.1	0.9	27,966
Onshore Emissions, Routine O&M	14,088	0.1	0.0	0.6	0.0	0.0	0.0	0.0	19,816
Total Emissions, Routine O&M	2,180,378	357	6.4	90	12	12	1.1	0.9	47,783
Offshore Emissions, Maximum	2,827,142	472	8.4	116	16	15	1.5	1.2	35,530
Onshore Emissions, Maximum	14,088	0.1	0.0	0.6	0.0	0.0	0.0	0.0	19,816
Total Emissions, Maximum	2,841,231	472	8.5	117	16	15	1.5	1.2	55,346

New England Wind Emissions Summary

Construction Emissions	Total Fuel Consumption (gal)	Phase 1 Maximum Total Emissions in US (US Tons)							
		NOX	VOC	CO	PM10	PM2.5	SO2	HAPs	CO2e
Offshore Emissions	33,304,893	5,897	122	1,391	193	186	41	18	383,085
Onshore Emissions	791,262	20	1.8	15	45	44	0.0	0.6	10,542
Total Emissions	34,096,155	5,917	124	1,406	238	230	41	18	393,627

Annual O&M Emissions	Fuel Consumption per Year (gal)	Phase 1 Maximum Total Emissions in US (US Tons per Year)							
		NOX	VOC	CO	PM10	PM2.5	SO2	HAPs	CO2e
Offshore Emissions, Routine O&M	1,081,215	178	3.2	44	6.0	5.8	0.5	0.5	13,636
Onshore Emissions, Routine O&M	6,999	0.0	0.0	0.3	0.0	0.0	0.0	0.0	6,623
Total Emissions, Routine O&M	1,088,213	178	3.2	45	6.0	5.8	0.5	0.5	20,259
Offshore Emissions, Maximum	1,588,289	266	4.8	65	8.9	8.6	0.8	0.7	19,416
Onshore Emissions, Maximum	6,999	0.0	0.0	0.3	0.0	0.0	0.0	0.0	6,623
Total Emissions, Maximum	1,595,288	266	4.8	65	8.9	8.6	0.8	0.7	26,039

New England Wind Emissions Summary

Construction Emissions	Total Fuel Consumption (gal)	Phase 2 Maximum Total Emissions in US (US Tons)							
		NOX	VOC	CO	PM10	PM2.5	SO2	HAPs	CO2e
Offshore Emissions	43,481,089	7,693	161	1,810	252	243	54	23	500,430
Onshore Emissions	1,544,834	38	4	31	86	86	0.1	1.2	20,528
Total Emissions	45,025,923	7,732	164	1,841	339	329	54	24	520,958

Annual O&M Emissions	Fuel Consumption per Year (gal)	Phase 2 Maximum Total Emissions in US (US Tons per Year)							
		NOX	VOC	CO	PM10	PM2.5	SO2	HAPs	CO2e
Offshore Emissions, Routine O&M	1,086,597	179	3.2	45	6.0	5.8	0.5	0.5	14,400
Onshore Emissions, Routine O&M	7,090	0.0	0.0	0.3	0.0	0.0	0.0	0.0	13,193
Total Emissions, Routine O&M	1,093,686	179	3.2	45	6.0	5.8	0.5	0.5	27,594
Offshore Emissions, Maximum	1,614,360	270	4.9	66	9.0	8.7	0.9	0.7	20,413
Onshore Emissions, Maximum	7,090	0.0	0.0	0.3	0.0	0.0	0.0	0.0	13,193
Total Emissions, Maximum	1,621,450	270	4.9	67	9.0	8.7	0.9	0.7	33,606

Attachment B

Detailed Emissions Estimate for New England Wind (Phases 1 and 2)

Attachment B is redacted in its entirety.

Attachment C

Avoided Emissions

Avoided Emissions for New England Wind

Inputs	Phase 1	Minimum Phase 2	Minimum Total (Phase 1 + Phase 2)
Total Capacity (MW)	804	1,200	2,004
Capacity Factor	50%	50%	N/A
Transmission Loss Factor[1]	3.8%	4.7%	N/A
Hours per year	8,760	8,760	N/A
Annual Power Generated (MW-hr)	3,386,773	5,008,346	8,395,119

1) Lazaridis, L., P. (2005). Economic Comparison of HVAC and HVDC Solutions for Large Offshore Wind Farms under Special Consideration of Reliability. Tables 4.3 - 4.5: Average power losses in percent of the windfarm's average output power for different windfarm rated power, average wind speed, transmission distances and transmission voltage levels.

Operating Term (years)	30

Pollutant	Avoided Emission Factor (g/MWH)[2]	Avoided Emission Factor (lb/MWH)[2]	Displaced Emissions from Conventional Power Generation (US tons/year)	Displaced Emissions Over Project Lifespan (US tons)	Fraction of 2018 NPCC New England Region Emissions (%)[3]
Avoided Emissions - Phase 1 + Phase 2 (1,200 MW)					
NOx	227	0.501	2,103	63,089	10%
SO2	121	0.266	1,117	33,497	16%
CO2e	424,795	936.5	3,931,069	117,932,071	14%
Avoided Emissions - Phase 1					
NOx	227	0.501	848	25,452	4%
SO2	121	0.266	450	13,513	6%
CO2e	424,795	936.5	1,585,878	47,576,348	6%
Avoided Emissions - Phase 2 (1,200 MW)					
NOx	227	0.501	1,255	37,638	6%
SO2	121	0.266	666	19,983	9%
CO2e	424,795	936.5	2,345,191	70,355,723	8%

2) Avoided emission factors use NPCC New England annual non-baseload output emission rates from EPA's eGRID2018 revised 3/9/2020 https://www.epa.gov/sites/production/files/2020-01/documents/egrid2018_summary_tables.pdf

3) Based on eGRID2018 (revised 3/9/2020) subregion annual emissions.

Cars Removed Equivalency for New England Wind

Phase 1 (804 MW)	
1,585,878	US Tons
1.10231	Conversion Factor (US tons/metric ton)
1,438,686	metric tons
4.6	Metric tons CO2e per car per EPA[1]
312,758	Cars Removed from Road

1) Based on EPA Office of Transportation and Air Quality Report EPA-420-F-18-008
"Greenhouse Gas Emissions from a Typical Passenger Vehicle" (March 2018)

Phase 2 Mininum (1,200 MW)	
2,345,191	US Tons
1.10231	Conversion Factor (US tons/metric ton)
2,127,524	metric tons
4.6	Metric tons CO2e per car per EPA[1]
462,505	Cars Removed from Road

1) Based on EPA Office of Transportation and Air Quality Report EPA-420-F-18-008

Phase 1 + Phase 2 Minimum	
3,931,069	US Tons
1.10231	Conversion Factor (US tons/metric ton)
3,566,210	metric tons
4.6	Metric tons CO2e per car per EPA[1]
775,263	Cars Removed from Road

1) Based on EPA Office of Transportation and Air Quality Report EPA-420-F-18-008

Avoided Emissions for New England Wind

	Phase 1	Phase 2 (min MW)[2,3]
Maximum length per offshore export cable (km)	101	119
Maximum length per onshore export and grid interconnection cable (km)	13	17
Total length per cable (km)	114	136
Average transmission loss factor @ 100 km (assumed 220 kV Phase 1, 275 kV Phase	3.3	3.1
Average transmission loss factor @ 150 km (assumed 220 kV Phase 1, 275 kV Phase	5.2	5.3
Average transmission loss factor for VW South (assumed 220 kV Phase 1, 275 kV Phase 2)[1]	3.8	4.7

1) It was conservatively assumed that Phase 1 would use 220 kV HVAC cables to deliver 804 MW and Phase 2 would use 275 kV HVAC cables to deliver 1,200 MW.
2) Based on the transmission loss factors for the highest windfarm rated power provided in the table below (i.e. 1000 MW).
3) Given that HVAC export cables are expected to have greater transmission losses than HVDC export cables, the avoided emissions analysis conservatively assumed the use of HVAC cables for Phase 2. Values for the Phase 2 275 kV export cables are approximated based on regression equations relating Voltage to Average Transmission Loss Factor for 132 kV, 220 kV, and 400 kV cables at 1000 MW. Equations are as follows:
For 100 km cable length: $TLF = 302.49x^{-0.813}$ and for 150 km cable length: $TLF = 198.89x^{-0.644}$
where X = cable voltage in kW

Transmission Loss Factors (%) for HVAC Cables for Different Windfarm Rated Power, Average Wind Speed, Transmission Distances and Transmission Voltage Levels

Cable Length \ Wind Speed	132 kV 8 m/s	132 kV 9 m/s	132 kV 10 m/s	132 kV 11m/s	220 kV 8 m/s	220 kV 9 m/s	220 kV 10 m/s	220 kV 11m/s	400 kV 8 m/s	400 kV 9 m/s	400 kV 10 m/s	400 kV 11m/s
400 MW												
50 km	2.67	2.73	2.78	2.81	1.63	1.61	1.59	1.57	1.19	1.13	1.1	1.07
100 km	5.13	5.26	5.36	5.43	2.92	2.87	2.83	2.81	2.85	2.64	2.51	2.43
150 km	8.13	8.3	8.44	8.54	4.97	4.85	4.77	4.71	5.93	5.4	5.07	4.84
200 km	11.98	12.17	12.32	12.45	7.86	7.62	7.47	7.38	18.47	17.54	16.93	16.52
250 km	14.28	14.12	14.03	13.97	13.55	13.08	12.78	12.59	-	-	-	-
300 km	20.39	20.11	19.95	19.85	-	-	-	-	-	-	-	-
500 MW												
50 km	2.81	2.78	2.76	2.74	1.62	1.63	1.64	1.65	1.18	1.14	1.12	1.11
100 km	4.74	4.77	4.79	4.81	3.07	3.07	3.07	3.07	2.68	2.54	2.46	2.4
150 km	7.5	7.53	7.56	7.57	5.1	5.05	5.02	5.01	5.36	4.98	4.74	4.58
200 km	11.08	11.09	11.1	11.1	7.87	7.76	7.69	7.65	18.29	17.59	17.15	16.85
250 km	15.28	15.3	15.33	15.37	12.48	12.12	11.89	11.74	-	-	-	-
300 km	19.96	19.74	19.61	19.53	-	-	-	-	-	-	-	-
600 MW												
50 km	2.83	2.86	2.89	2.91	1.89	1.9	1.91	1.92	1.23	1.21	1.2	1.19
100 km	5.39	5.47	5.53	5.58	3.31	3.35	3.39	3.42	2.68	2.58	2.52	2.49
150 km	8.45	8.57	8.66	8.73	5.38	5.41	5.44	5.47	5.14	4.85	4.68	4.57
200 km	12.31	12.45	12.55	12.64	7.64	7.49	7.51	7.44	17.17	16.8	16.6	16.49
250 km	14.6	14.57	14.55	14.55	12.53	12.23	12.04	11.92	-	-	-	-
300 km	19.79	19.58	19.57	19.47	-	-	-	-	-	-	-	-
700 MW												
50 km	3.32	3.37	3.42	3.45	1.94	1.98	2.02	2.04	1.26	1.25	1.25	1.26
100 km	5.54	5.69	5.48	5.45	3.67	3.74	3.8	3.85	2.7	2.65	2.62	2.61
150 km	7.96	7.99	8	8.01	5.19	5.12	5.06	5.02	4.85	4.62	4.48	4.39
200 km	11.2	11.25	11.3	11.34	7.66	7.57	7.51	7.48	16.64	16.03	15.63	15.35
250 km	15.53	15.61	15.69	15.76	11.93	11.69	11.53	11.43	-	-	-	-
300 km	20.04	19.94	19.9	19.88	-	-	-	-	-	-	-	-
800 MW												
50 km	2.88	2.9	2.92	2.94	1.85	1.84	1.83	1.9	1.31	1.33	1.34	1.36
100 km	5.52	5.59	5.63	5.67	**3.17**	**3.34**	**3.33**	**3.32**	2.55	2.47	2.4	2.36
150 km	8.66	8.75	8.82	8.87	**5.16**	**5.15**	**5.15**	**5.15**	4.63	4.43	4.31	4.23
200 km	12.15	12.31	12.44	12.54	7.79	7.75	7.74	7.74	16.23	15.85	15.61	15.45
250 km	15.13	15.12	15.11	15.11	11.84	11.66	11.55	11.48	-	-	-	-
300 km	19.78	19.68	19.63	19.6	-	-	-	-	-	-	-	-
900 MW												
50 km	3.16	3.22	3.26	3.3	1.86	1.88	1.89	1.9	1.17	1.15	1.13	1.17
100 km	6.07	6.2	6.29	6.37	3.48	3.5	3.52	3.53	2.4	2.33	2.29	2.26
150 km	8.5	8.46	8.43	8.4	5.37	5.4	5.44	5.47	4.5	4.33	4.23	4.17
200 km	11.62	11.66	11.69	11.71	7.52	7.47	7.43	7.4	15.8	15.56	15.43	15.36
250 km	14.67	14.65	14.64	14.82	11.71	11.52	11.4	11.32	-	-	-	-
300 km	19.67	19.49	19.45	19.42	-	-	-	-	-	-	-	-
1000 MW												
50 km	3.17	3.15	3.14	3.12	1.93	1.96	1.98	2	1.17	1.14	1.13	1.12
100 km	**5.66**	**5.7**	**5.89**	**5.89**	**3.63**	**3.67**	**3.71**	**3.74**	**2.37**	**2.32**	**2.36**	**2.33**
150 km	**8.65**	**8.75**	**8.82**	**8.87**	**5.79**	**5.85**	**5.89**	**5.93**	**4.44**	**4.3**	**4.21**	**4.16**
200 km	12.18	12.36	12.49	12.59	7.62	7.58	7.57	7.56	15.51	15.14	14.89	14.72
250 km	15.36	15.38	15.41	15.44	11.62	11.48	11.39	11.3	-	-	-	-
300 km	19.54	19.53	19.47	19.43	-	-	-	-	-	-	-	-

Source: Lazaridis, L., P. (2005). Economic Comparison of HVAC and HVDC Solutions for Large Offshore Wind Farms under Special Consideration of Reliability. Tables 4.3 - 4.5: Average power losses in percent of the windfarm's average output power for different
windfarm rated power, average wind speed, transmission distances and transmission voltage levels.
Note: loss calculations were performed for 3 three-core HVAC cables with XPLE insulation (the type of HVAC cable expected to be used for New England Wind)

Attachment D

New England Wind Envelope Parameters and Vessel Routes

Attachment D is redacted in its entirety.

Attachment E

Supporting Tables

Attachment E is redacted in its entirety.