OCS-A 0501

MASS USA

VINEYARD WIND

Draft
Construction and Operations Plan

Volume III
Appendices

Vineyard Wind Project

October 22, 2018

Submitted by
Vineyard Wind LLC
700 Pleasant Street, Suite 510
New Bedford, Massachusetts 02740

Submitted to
Bureau of Ocean Energy Management
45600 Woodland Road
Sterling, Virginia 20166

Prepared by
Epsilon Associates, Inc.
3 Mill & Main Place, Suite 250
Maynard, Massachusetts 01754

Epsilon
ASSOCIATES INC.

Draft Construction and Operations Plan

Volume III

Appendices

Vineyard Wind Project

Submitted to:

BUREAU OF OCEAN ENERGY MANAGEMENT
45600 Woodland Rd
Sterling, VA 20166

Submitted by:

VINEYARD WIND LLC
700 Pleasant Street, Suite 510
New Bedford, MA 02740

Prepared by:

EPSILON ASSOCIATES, INC.
3 Mill & Main Place, Suite 250
Maynard, MA 01754

In Association with:

Biodiversity Research Institute
C2Wind
Capitol Air Space Group
Clarendon Hill Consulting
Ecology and Environment
Foley Hoag
Geo SubSea LLC
Gray & Pape
JASCO Applied Sciences
Morgan, Lewis & Bockius LLP
Public Archaeology Laboratory, Inc.
RPS
Saratoga Associates
Swanson Environmental Associates
Wood Thilsted Partners Ltd
WSP

October 22, 2018

Appendix III-B

Air Emissions Calculations and Methodology

Vineyard Wind

Air Emissions Calculations and Methodology

Prepared for:

Vineyard Wind, LLC
700 Pleasant Street, Suite 510
New Bedford, MA 02740

Prepared by:

Epsilon Associates, Inc.
3 Mill & Main Place, Suite 250
Maynard, MA 01754

May 2018

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

List of Figures

List of Tables

List of Tables (Continued)

List of Attachments

1.0 INTRODUCTION

The following document describes the methodology used to calculate air emissions from the ~800 megawatt (MW) Vineyard Wind Project. While the proposed wind turbines will not generate air emissions, there will be air emissions from construction, operations and maintenance, and decommissioning activities.

OCS Permit Emissions: Some air emissions from the Project are regulated through the Environmental Protection Agency's (EPA) Outer Continental Shelf (OCS) Air Permit process under the Outer Continental Shelf Air Regulations, 40 CFR Part 55. 40 CFR Part 55 establishes air pollution control requirements for OCS sources (i.e., stationary sources and vessels directly or indirectly attached to the seabed of the OCS) located within 25 miles of a state's seaward boundaries. Air emission estimates in the OCS Air Permit application must include emissions from OCS sources and vessels traveling in and around the Project Area when within 25 miles of an OCS source.[1]

Under the OCS Air Regulations, OCS sources located within the Offshore Project Area are subject to the federal, state, and local requirements of the Corresponding Onshore Area ("COA") set forth in 40 CFR Parts 55.13 and 55.14. Vineyard Wind submitted a Notice of Intent (NOI) for the Project to EPA Region 1 on December 11, 2017and identified Massachusetts as the nearest onshore area (NOA) to the project area (a copy of the NOI can be found at the end of Attachment B). EPA did not receive a request from any neighboring state air pollution control agencies to be designated as the COA within the 60-day period allotted in 40 CFR Part 55.5(b)(l). As a result, Massachusetts (the NOA) became the designated COA without further Agency action after 90 days (see 40 CFR Part 55.5(c)(l)). Therefore, the Project's OCS sources will be required to comply with the applicable Massachusetts air quality regulations, which include Best Available Control Technology ("BACT") and Lowest Achievable Emission Rate ("LAER") under 310 CMR § 7.00.

General Conformity Emissions: The General Conformity Rule, codified in 40 CFR Part 93 Subpart B and 40 CFR Part 51 Subpart W, ensures that federal actions do not interfere with states' plans to attain and maintain NAAQS in areas that are or have been out of attainment with those standards. Until the 2008 8-hour ozone National Ambient Air Quality Standard (NAAQS) is revoked, Dukes County (onshore and within three nautical miles offshore) will be considered an ozone nonattainment or maintenance area potentially subject to "General Conformity" requirements (EPA, 2017; EPA, 2015b). If the Project uses a port in Connecticut during the construction phase, vessels will pass through nonattainment and maintenance areas in Connecticut and New York, resulting in the need for a General Conformity evaluation. Before determining whether the General Conformity Rule is applicable, the Bureau of Ocean Energy Management (BOEM) must first estimate emissions from the Project. BOEM's estimate will not include emissions that are already accounted for in the OCS Air

---

[1] The Project's Outer Continental Shelf (OCS) Air Permit application, which was submitted to EPA on August 17, 2018, incorporates refinements to the Project Envelope that have been made since this air emissions analysis. Further minor refinements to the construction and O&M air emissions estimate are expected through the EPA review process.

Permit. General Conformity air emissions will only include direct and indirect emissions from the Project that occur beyond 25 miles from an OCS source *and* within a maintenance or nonattainment area. Figure 1-1 illustrates the regions where Project emissions are subject to the OCS Air Permit Process and potentially the General Conformity Process[2].

Total Project Emissions within the US: Emissions that occur further than 25 miles from an OCS source and are not within a maintenance or nonattainment area are not regulated through the OCS Air Permit or General Conformity processes. However, all emissions from the Project within the US (onshore and 200 NM out to sea) were estimated to assess regional impacts to air quality as part of Vineyard Wind's Construction and Operations Plan (COP) and for the National Environmental Policy Act (NEPA) process. The emission estimates provided represent the upper bound of Project emissions.

The estimate of the Project's potential construction phase air emissions was conducted assuming that 106 wind turbine generator (WTG) positions, four light-weight electrical service platforms (ESPs), and the maximum length of inter-array, inter-link, and export cables would be installed for the 800 MW Project, which represents a maximum design scenario. Based on the most aggressive construction schedule under consideration for the 800 MW project, it was conservatively estimated that half of the WTGs, three quarters of the inter-array cables, and all of the scour protection, offshore export and inter-link cables, ESPs, and foundations could be constructed in one year. It was also assumed that all onshore construction activities will occur in one year[3]. To account for the envelope of possible ports used during the construction phase, the emission estimate uses the combination of ports with the longest transit distances to and from the Offshore Project Area within US waters (all state and federal waters within the 200 NM US Exclusive Economic Zone). The emissions estimate also accounts for delays caused by inclement weather and possible time of year restrictions.

Operations and maintenance (O&M) phase emissions were calculated assuming a Project lifespan of 30 years. Vineyard Wind intends to use port facilities at both Vineyard Haven on Martha's Vineyard and the New Bedford Terminal to support O&M activities. Total O&M phase emissions within the US were estimated assuming all vessels use the New Bedford Marine Commerce Terminal (New Bedford Terminal), which represents the O&M port with the farthest transit distances to and from the

---

[2] The OCS Air Permit application accounts for the possibility of OCS sources existing along the portion of the OECC within federal waters (in Nantucket Sound) during construction. Consequently, the OCS Air Permit application includes emissions from vessels traveling to and from the OECC when within 25 miles of the OECC, which is not illustrated in the figures of this Appendix. The General Conformity construction phase emissions estimate contained in this Appendix may be overly-conservative because it includes emissions that are accounted for in the OCS Air Permit application.

[3] Several refinements to the Project Envelope and schedule have been made since conducting this estimate of the Project's potential emissions. For example, the Project will only construct up 100 WTGs and has eliminated the option to install light-weight ESPs. As a result, this estimate of Project air emissions during construction over-conservatively estimates the emissions resulting from the installation of the WTGs, ESPs, and their foundations.

Offshore Project Area. For the General Conformity O&M phase emissions estimate, it was assumed that some vessels use Vineyard Haven as a port, which provides the most conservative estimate of emissions that could occur within Duke's County.

Potential emissions from the decommissioning phase, which is expected to take place in approximately 30 years, are not included in the estimate of potential emissions. A separate OCS Air Permit and General Conformity analysis will be issued for the decommissioning phase, if needed.

Air pollution from the Project is associated with fuel combustion, construction dust, and some incidental solvent use associated with onshore and offshore construction, operation, and maintenance activities. There are seven primary categories of sources for which emissions were calculated:

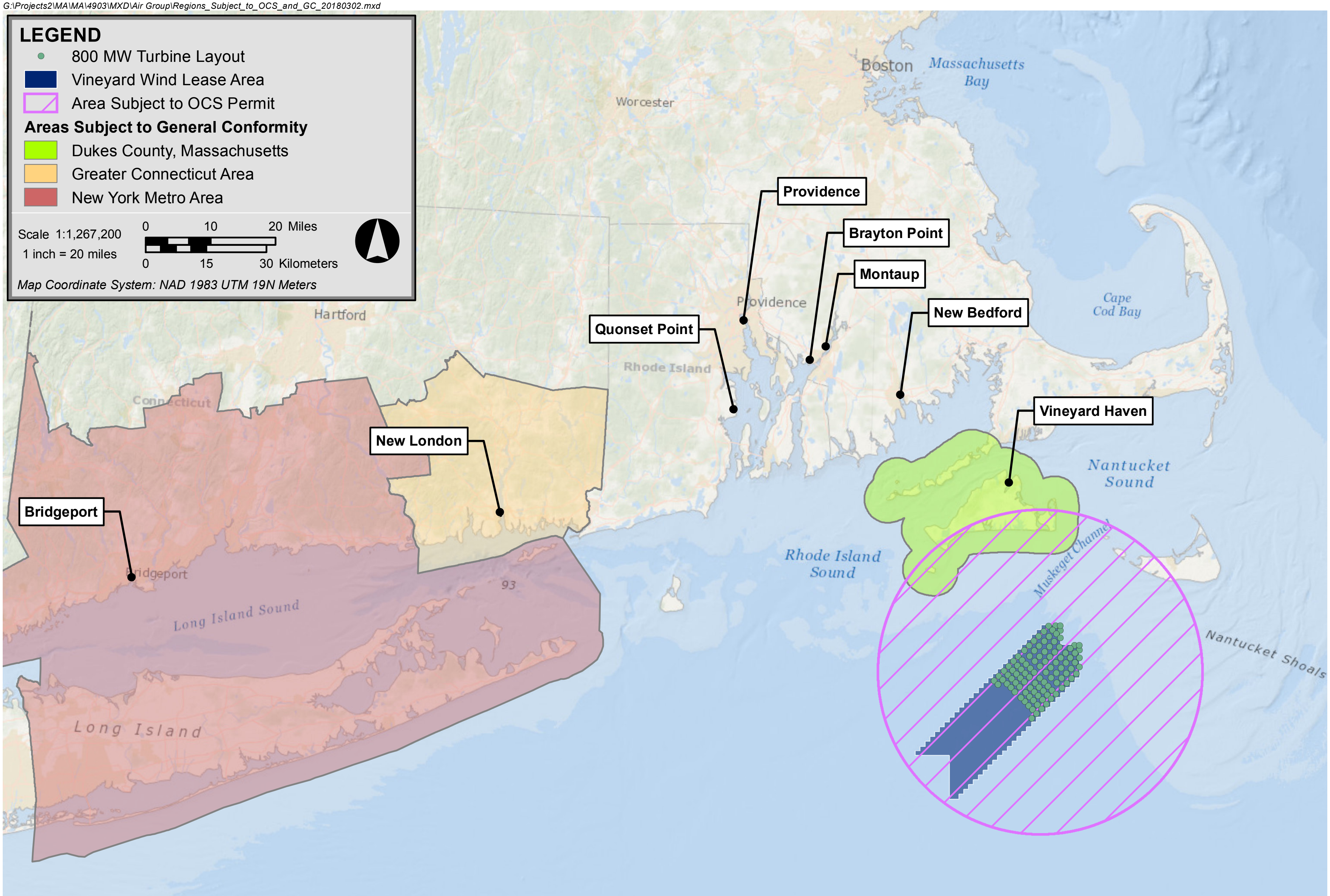
- Commercial marine vessels (CMVs),
- Helicopters,
- Generators,
- Non-road engines,
- On-road vehicles,
- Fugitive emissions, and
- Construction dust.

The following pollutants were included in the air emissions analysis:

- Nitrogen oxides (NOx),
- Volatile organic compounds (VOC),
- Carbon monoxide (CO),
- Particulate matter smaller than 10 microns (PM10),
- Particulate matter smaller than 2.5 microns (PM2.5, a subset of PM10),
- Sulfur dioxide (SO2),
- Sulfuric Acid Mist (H2SO4),
- Lead (Pb),
- Total hazardous air pollutants (HAPs, individual compounds are either VOC or particulate matter), and
- Greenhouse gas emissions as carbon dioxide equivalent (CO2e).

Emissions subject to the OCS Air Permit process are discussed in Section 2.0. Section 3.0 discusses emissions potentially subject to General Conformity. Section 4.0 discusses all emissions resulting from the construction and operational phases of the Project. Section 5.0 describes the method used to estimate the emissions from conventional power generation that will be avoided as a result of the Project. All air emissions associated with the Project are summarized in Attachment A.

G:\Projects2\MA\MA\4903\MXD\Air Group\Regions_Subject_to_OCS_and_GC_20180302.mxd



Service Layer Credits: Sources: Esri, GEBCO, NOAA, National Geographic, Garmin, HERE, Geonames.org, and other contributors

Vineyard Wind Project

VINEYARD WIND

Figure 1-1

Areas Subject to OCS Air Permit and General Conformity

2.0 OUTER CONTINENTAL SHELF (OCS) AIR PERMIT EMISSIONS

Air emission estimates in the OCS Air Permit application must include air emissions from OCS sources and vessels traveling to and from an OCS source when within 25 miles of the OCS source. An OCS source is defined in 40 CFR Part 55.2 as "any equipment, activity, or facility which:

1) Emits or has the potential to emit any air pollutant;
2) Is regulated or authorized under the Outer Continental Shelf Lands Act ("OCSLA") (43 U.S.C. §1331 et seq.); and
3) Is located on the OCS or in or on the waters above the OCS."

OCS Air Permit emissions, which only occur offshore, were calculated for the construction and operational phases. Since all ports that may be used during the Project's construction are beyond 25 miles from any of the Project's construction phase OCS sources and both O&M ports are beyond 25 miles from any OCS source during the Project's operational period, it was assumed that all vessels will travel 25 miles between the location of OCS source and the port. As such, the OCS Air Permit emissions estimate does not depend on the port(s) used during the Project. The following sections provide a description of the emission sources included in the OCS Air Permit and the methods used to quantify OCS Air Permit emissions.

2.1 Description of OCS Air Permit Emission Sources

The majority of OCS Air Permit emissions from the Project will come from the main engines, auxiliary engines, and auxiliary equipment on marine vessels used during construction activities. Additional construction-related emissions will come from helicopters used to transfer crew, diesel generators used to temporarily supply power to the WTGs and ESPs, engines used to power pile driving hammers, and air compressors used to supply compressed air to noise mitigation devices (e.g. bubble curtains) during pile-driving. All emission sources included in the OCS Air Permit during construction are described in the following table.

Table 2-1 Description of Emissions Points

Emission Source	Description of Source
Crew transfer/service vessels	Transport crew to the project site Potential transport of marine mammal observers Used to refuel WTGs and ESPs
Heavy lift crane vessels	Lift, support, and orient the components of each WTG and ESP during installation Used for foundation installation
Cable installation vessels	Lay and bury transmission cables in the seafloor
Scour protection installation vessels (fall pipe vessels)	Deposit a layer of stone around the WTG and ESP foundations to prevent the removal of sediment by hydrodynamic forces Place cable protection over limited sections of the offshore cable system
Multipurpose support vessels	Clear the seabed floor of debris prior to laying transmission cables Used to commission WTGs

Table 2-1 Description of Emissions Points (Continued)

Emission Source	**Description of Source**
Tugboats	Transport equipment and barges to the WDA
Anchor handling tug supply vessels	Install bubble curtains (underwater noise mitigation devices)
Jack-up vessels	Transport WTG components to the WDA Extend legs to the ocean floor to provide a safe, stable working platform Used for offshore accommodations
Dredging vessels	Used in certain areas prior to cable laying to remove the upper portions of sand waves
Survey vessels	Used to perform geophysical and geotechnical surveys
Pile driving hammer engine	Drive the foundations of the WTGs into the seafloor
Air compressors	Supply compressed air to noise mitigation devices
Temporary diesel generators	Temporarily supply power to the WTG prior to the turbine becoming operational
Helicopters	Transfer crew to the WDA
Fugitive emissions	Fugitive emissions from solvents, paints, coatings, and diesel fuel storage/transfer

Emissions during the Project's approximately 30-year-long operations and maintenance phase will come from vessels, generators, and helicopters used during routine maintenance and repair activities. Emission sources during the operational phase of the Project include:

- Crew transfer/service vessels,
- Scour protection installation vessels,
- Multipurpose support vessels,
- Tugboats,
- Jack-up vessels,
- Survey vessels,
- Emergency generators,
- Helicopters, and
- Fugitive emissions of solvents, paints, coatings, diesel fuel storage/transfer, and sulfur hexafluoride (SF6).

The number and type of vessels, helicopters, and other equipment along with anticipated hours of operation and number of round trips for each emission source was provided by Vineyard Wind's engineers. A complete description of all emission points associated with Vineyard Wind's 800MW Project that are subject to the OCS Air Permit can be found in Attachment B.

2.2 Emissions Calculation Methods

2.2.1 Commercial Marine Vessels (CMVs)

Emissions from commercial marine vessels were calculated according to the methodology used by the BOEM Offshore Wind Energy Facilities Emission Estimating Tool ("BOEM Emission Estimating Tool"). This emission estimating tool was released in early 2017 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 *Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories* ("EPA's Port-Related Emission Guidance") and EPA's *2014 National Emission Inventory Technical Support Document* ("2014 NEI").

2.2.1.1 Criteria Air Pollutants and Their Precursors

The Environmental Protection Agency ("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 sulfur dioxide (SO2); particulate matter (smaller than 10 microns as PM10, smaller than 2.5 microns as PM2.5); nitrogen dioxide (NO2); carbon monoxide (CO); ozone (O3); and lead (Pb). Typically, ozone is not emitted directly into the air; instead, ozone primarily forms from the reaction of volatile organic compounds (VOC) and nitrogen oxides (NOx) in sunlight. VOC and NOx, which are often emitted directly into the air, are commonly referred to as ozone precursors. Therefore, emissions of the precursors to ozone are quantified instead of ozone. Consistent with the BOEM Emission Estimating Tool, vessel air emissions were calculated based on vessels' hours of operation at the WDA or along the OECC, distance traveled, speed, total number of round trips, engine size, load factor, and emission factor. For each vessel, four calculations were made:

- Emissions from the main engines while in transit
- Emissions from the main engines while maneuvering at WDA or along OECC
- Emissions from the auxiliary engines while in transit
- Emissions from the auxiliary engines while maneuvering at the WDA or along OECC

Since no ports used by the Project are located within 25 miles of an OCS source, emissions from vessels while maneuvering and hoteling in port are not included in the OCS Air Permit. The basic equation used for each of the four calculations above is:

$$E = kW * Hours * LF * EF * 1.10231E\text{-}6$$

Where:

- E = total emissions, tons
- kW = total engine size, kW

- $Hours$ = hours for each activity
- LF = engine load factor (for the activity)
- EF = emission factor, g/kW-hr
- $1.10231E\text{-}6$ = g to ton conversion factor

Per the 2014 National Emissions Inventory (NEI) methodology (2016), the emission estimates did not include emissions associated with boilers used to generate steam. All installation vessels used within the WDA and along the OECC that are subject to the OCS Air Permit are expected to contain unfired boilers that will heat water using excess heat from the vessel's engines.

Engine Size

Vessel emission estimates are based on actual vessels that may be used for the Project or are closely representative of the type of vessel that is expected to be used for the Project. Engine sizes and vessel speeds are from equipment specification sheets for each representative vessel (see Attachment G). However, several vessel specification sheets did not specify the size of auxiliary engines or differentiate between auxiliary engines and main engines. 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.

Distance Traveled and Hours of Operation

For the OCS Air Permit emissions estimate, the distance traveled by each vessel was based on the number of round trips each vessel made to and from port. Each vessel was assumed to travel a distance of 25 statute miles (21.7 nautical miles) from port to the location of the vessel's construction or O&M activity. Any distance traveled beyond 25 miles from the potential location of an OCS source was excluded from the distance traveled. Consequently, the OCS Air Permit emissions estimate does not depend on the port(s) used during construction or O&M. For vessels that traveled extensively within the WDA or along the OECC rather than directly to and from port, the total distance traveled included distance traveled between WTGs, EPS, and along the offshore cable system. These distances in nautical miles (NM) are shown in Table 2-2 below.

Table 2-2 Distances Traveled by Vessels

Continuous path connecting 53 WTG positions	47 NM
Continuous path connecting 2 ESP positions	5.7 NM
Total export cable length for 3 cables (inside OCS Air Permit Boundary)	53 NM
Inter-link cable length (inside OCS Air Permit Boundary)	8.1 NM
Inter-array cable length	74 NM

For most vessels, the number of round trips to and from port was provided by Vineyard Wind's engineering team. For the scour protection installation vessels, the number of round trips was based on the cargo hold capacity of the vessel and the total volume of rock required for scour protection around the WTG and ESP foundations and over the offshore export cables (see Attachment F). For offshore construction, Vineyard Wind's engineering team initially provided the number of vessel trips and operating days required for the construction a 400 MW Project. As shown in Attachment B, the construction phase emissions estimate was first calculated for a 400 MW Project for each emission source. Then, the emissions estimate for most construction activities was doubled to derive the emissions estimate for an 800 MW Project[4]. For the O&M phase, the number of vessel trips and duration of each activity were provided for an 800 MW Project.

Hours of operation for main engines while in transit were calculated from the vessel's speed and total distance traveled by the vessel when within the 25 miles of an OCS source. It was assumed that main engines will provide power for maneuvering activities anytime the vessel is within the Project Area and not in transit (except for jack-up vessels whose main engines will not provide propulsion power while jacked-up). Auxiliary engines were assumed to always operate when the vessel is within 25 miles of an OCS source.

Load Factor

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

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

---

[4] The emissions estimate for offshore export cable laying for a 400 MW Project was multiplied by 1.25 to convert the estimate to an 800 MW Project. This is because the offshore export cable installation will be largely the same for a 400 MW and 800 MW Project; installation of the 800 MW simply requires the additional installation of an inter-link cable between the two ESP locations.

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. The BOEM Emissions Estimating Tool provides a default load factor of 0.82 for main engines in transit. Consistent with EPA guidance, the more conservative load factor of 0.83 was used in our emission estimates.

Consistent with the 2014 NEI (2016) and the BOEM Emission Estimating Tool, a load factor of 0.20 was used for most main (propulsion) engines while maneuvering onsite[5]. However, based on discussions with Vineyard Wind's engineers and vessel suppliers, a load factor of 0.2 underestimates the power required by vessels that use dynamic positioning to maintain a precise location within the WDA. Fuel consumption rates during dynamic positioning (DP) from vessel specification sheets were used to derive a more accurate load factor for vessel's main engines during DP. See the following example DP load factor calculation for the [redacted] [redacted] vessel.

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

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

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

---

[5] According to the 2014 NEI (2016), 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.

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 during DP operations. This load factor was used for vessels whose specification sheets suggested that the vessel had a dynamic positioning system (see Attachment G).

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, a load factor of zero was used for jack-up vessels' main engines while at the Offshore Project Area.

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 are simply placeholders for more accurate information. For example, the auxiliary engine load factor in the Tool is defaulted to 1. Consequently, the BOEM Emissions Estimating Tool's default auxiliary engine load factor was not used. Auxiliary engine load factors for vessels whose main engines are Category 3 engines (characterized by EPA as ocean-going vessels) were taken from *Table 2-7: Auxiliary Engine Load Factor Assumptions* of EPA's Port-Related Emission Guidance (2009), 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 2-3 EPA Auxiliary Engine Load Factors for Ocean-going Vessels

Ship Type	Cruise	RSZ	Maneuver	Hotel
Auto Carrier	0.15	0.3	0.45	0.26
Bulk Carrier	0.17	0.27	0.45	0.1
Container Ship	0.13	0.25	0.48	0.19
Cruise Ship	0.8	0.8	0.8	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	0.3	0.45	0.26
Reefer	0.2	0.34	0.67	0.32
Tanker	0.24	0.28	0.33	0.26

Auxiliary engine load factors from *Table 3-3: EPA Load Factors for Harbor Craft*[6] were used for harbor craft (vessels with Category 1 and 2 main engines) because more specific load factors were unavailable. According to EPA (2009), "pending better evidence to the contrary, best practices are to follow this guidance." The auxiliary engine load factors are shown in the table below.

Table 2-4 EPA Auxiliary Engine Load Factors for Harbor Craft

Engine Category	Engine Size	Load Factor
Category 1 Auxiliary	<805 Hp	0.56
	>805 Hp	0.65
Category 2 Auxiliary	All	0.85

Emission Factor

The BOEM Emission Estimating Tool contains default vessel characteristics for a variety of vessel and helicopter 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 (IHS) vessel population data, which takes into account typical vessels' country of registration, engine categories, and regulatory tiers (Eastern Research Group, 2017). These vessel profiles were then combined with tier level emission factors from USEPA's 2014 National Emissions Inventory, Version 1

---

[6] From EPA's Port-Related Emission Guidance (2009).

Technical Support Document (2016) to create weighted emission factors for each vessel type (Eastern Research Group, 2017). The BOEM default emission factors for main and auxiliary engines of each vessel type are listed in Tables 2-5 and 2-6 below.

Table 2-5 BOEM Default Emission Factors for Vessel Main Engines

	Vessel Main Engine Emission Factors (g/kW*hr)									
Vessel Type	**NOX**	**VOC**	**CO**	**PM10**	**PM2.5**	**SO2**	**CO2**	**CH4**	**N2O**	**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
Vessel Type	**NOX**	**VOC**	**CO**	**PM10**	**PM2.5**	**SO2**	**CO2**	**CH4**	**N2O**	**Pb**
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 2-6 BOEM Default Emission Factors for Vessel Auxiliary Engines

	Vessel Auxiliary Engine Emission Factors (g/kW*hr)									
Vessel Type	**NOX**	**VOC**	**CO**	**PM10**	**PM2.5**	**SO2**	**CO2**	**CH4**	**N2O**	**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 the Project was assigned to one of the eleven vessel types listed above and the corresponding emissions factors were used.

Table 2-7 Assigned Vessel Types

Project Vessel	BOEM Category
Crew transfer/service vessels	Crew
Heavy lift crane vessels	Barge (the most conservative emission factors)
Heavy cargo vessel	Supply ship
Cable installation vessels	Cable-laying
Scour protection installation vessels	Cable-laying
Multipurpose support vessels	Cable-laying
Tugboats	Tug
Anchor handling tug supply vessels	Anchor handling tugs
Jack-up vessels	Jack-up
Dredging vessel	Dredging
Survey vessel	Research/Survey

2.2.1.2 CO2e

Emissions of greenhouse gases from commercial marine vessels, which include carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O), were estimated using the methodology described above for criteria air pollutants and their precursors. See Tables 2-5 and 2-6 for greenhouse gas emission factors provided by the BOEM Emissions Estimating Tool. Greenhouse gas emissions as carbon dioxide equivalent (CO2e) were then calculated using global warming potential (GWP) factors provided by the BOEM Emission Estimating Tool. The BOEM Tool provides a GWP of 28 for CH4 and 265 for N2O. Total CO2e emissions were calculated using the following equation:

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

Where:

- E = total CO2e emissions, tons
- $CH4$ = total CH4 emissions, tons
- $N2O$ = total N2O emissions, tons
- $CO2$ = total CO2 emissions, tons
- GWP_{CH4} = GWP for CH4
- GWP_{N2O} = GWP for N2O

CO2e emissions were calculated separately for emissions from the main engines while in transit, from the main engines while maneuvering within the WDA, and from the auxiliary engines (both onsite and in transit).

2.2.1.3 HAPS

The BOEM tool does not provide emission factors for hazardous air pollutants (HAPs) emitted from commercial marine vessels. Consequently, HAP emissions were estimated according to the methodology provided in the most current 2014 NEI (2016, p. 4-179). HAPs 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 PM10, PM2.5, and VOC emissions from the vessels using the following equation:

$$E = VOC * SF_{VOC} + PM10 * SF_{PM10} + PM2.5 * SF_{PM2.5}$$

Where:

- E = total HAP emissions, tons
- VOC = total VOC emissions, tons
- $PM10$ = total PM10 emissions, tons
- $PM2.5$ = total PM2.5 emissions, tons
- SF_{VOC} = speciation factor for VOC
- SF_{PM10} = speciation factor for PM10
- $SF_{PM2.5}$ = speciation factor for PM2.5

Appendix F of EPA's 2014 NEI Commercial Marine Vessels (2015) document provides HAP profiles for Category 1 and 2 engines during maneuvering and while underway. For Category 3 engines, Appendix F provides HAP speciation profiles for hoteling, maneuvering, and while underway. Underway HAP profiles for the appropriate engine category were used to calculate HAP emissions for main engines while in transit. Maneuvering HAP profiles for the appropriate engine category were used to calculate HAP emissions from auxiliary engines and main engines while maneuvering within the WDA and along the OECC.

2.2.1.4 Fuel Use

EPA's Port-Related Emission Guidance (2009) provides brake specific fuel consumption (BSFC) rates for the main and auxiliary engines of ocean-going vessels (Category 3 engines) for various engine types and fuels. According to the 2014 NEI (2016), the dominant propulsion engine configuration for large category 3 vessels is the slow-speed diesel (SSD) engine. A BFSC of 185 g/kw-hr for SSD ocean-going vessel main engines was used for Category 3 main engines[7]. For Category 3 auxiliary engines, a BFSC of 217 g/kw-hr for was

---

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

used, assuming that these auxiliary engines will fire primarily marine diesel oil (MDO) or marine gas oil (MGO)[8]. 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 CO2 emission factor for Category 1 and 2 engines (648.20 g/kW-hr) provided in the BOEM Emission Estimating Tool Technical Documentation (Eastern Research Group, 2017). This emission factor was converted to gal/kW-hr using a Distillate Fuel No. 2 higher heating value of 0.138 MMBtu/gal and a CO2 emission factor of 73.96 kg CO2/MMBtu.[9] 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
- ♦ $Hours$ = hours for each activity
- ♦ LF = Engine load factor (for the activity)

Total fuel use was calculated separately for emissions from the main engines while in transit, from the main engines while maneuvering at the Project Area, and from the auxiliary engines (both onsite and in transit).

2.2.2 Helicopters

2.2.2.1 Criteria Air Pollutants

Air emissions from helicopters were also calculated using the BOEM Offshore Wind Energy Facilities Emission Estimating Tool. All helicopters for the project were assumed to be medium-sized twin-engine helicopters. Emissions from helicopters were calculated based on the following equation

$$E \; = \; Hours * EF * 0.0005$$

---

[8] From EPA's Port-Related Emission Inventories Guidance (2009), Table 2016: Auxiliary Engine Emission Factors

[9] Distillate Fuel Oil No. 2 HHV and CO2 Emission Factor are from 40 CFR Part 98 Table C-1: Default CO2 Emission Factors and High Heat Values for Various Types of Fuel.

Where:

- $E =$ total emissions, tons
- $Hours$ = total hours in flight while within 25 miles of an OCS source
- $EF =$ emission factor, lb/hr
- $0.0005 =$ lb to ton conversion factor

Total hours in flight were based on the total distance each helicopter is expected to travel while within 25 miles of an OCS source and the BOEM tool default speed (183 mph) for twin medium helicopters. It was estimated that helicopters out of Martha's Vineyard Airfield would travel 24 miles and helicopters out of Providence Airport would travel 25 miles while in the airspace subject to the OCS Air Permit. The emission estimates used the following emission factors for twin-medium helicopters from the BOEM tool.

Table 2-8 BOEM Default Emission Factors for Twin-Medium Helicopters

	Helicopter Emission Factors (lb/hr)									
Helicopter Type	**NOX**	**VOC**	**CO**	**PM10**	**PM2.5**	**SO2**	**CO2**	**CH4**	**N2O**	**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 tool does not provide emission factors for hazardous air pollutants (HAPs) emitted from helicopters. HAP emissions were estimated according to the same methodology used to estimate HAP emissions from vessels. HAPs emissions were estimated by applying speciation profiles to the VOC estimates for organic HAPs and PM estimates for metal HAPs using the following equation:

$$E = VOC * SF_{VOC} + PM10 * SF_{PM10} + PM2.5 * SF_{PM2.5}$$

Where:

- $E =$ total HAP emissions, tons
- VOC = total VOC emissions, tons
- $PM10$ = total PM10 emissions, tons
- $PM2.5$ = total PM2.5 emissions, tons
- $SF_{VOC} =$ speciation factor for VOC
- $SF_{PM10} =$ speciation factor for PM10
- $SF_{PM2.5} =$ speciation factor for PM2.5

However, Appendix F of the 2014 NEI Commercial Marine Vessels document (2015) does not provide HAP speciation profiles for helicopters. 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 CO2e

Greenhouse gas emissions as carbon dioxide equivalent (CO2e) for helicopters were calculated using global warming potential (GWP) emission factors provided by the BOEM Emission Estimating Tool using the same methodology as described for commercial marine vessels.

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 Generators

It was assumed that portable diesel generators on the WTGs would be used during the Project's construction phase in the following sequence:

1. One ~40 kW generator per WTG for 5 days, 24 hours per day during cold commissioning of the WTGs

2. Then, three ~40 kW generators per WTG for 5 days, 24 hours per day during hot commissioning if power from the electrical grid is not available

3. Then, one ~40 kW generator per WTG running on average at 28 kW for 30 days, 24 hours per day after completion of hot commissioning if power from the electrical grid is not available

During construction, a temporary ~800 kW diesel generator will be placed on each conventional ESP. These generators will be used for commissioning activities on the ESP until the ESPs can be connected to the electrical gird. These generators will operate for 60 days, approximately 25% of the time.

During the operations and maintenance phase, depending on the model of WTG selected, each WTG may contain a 6 kW diesel emergency generator to provide back-up power if connection to the electrical grid is lost. This emergency generator would operate no more than 100 hours per year. If the other model of WTGs is selected, portable 50 kW diesel generators would be used on each WTG in the event of an emergency for approximately 0.2% of the year (~18 hours). For the emissions estimate, it was assumed that each WTG would contain a 6 kW diesel emergency generator that operates for 100 hours per year, which yields higher emissions than the use of 50 kW generators for 18 hours each year. In addition, each ESP was assumed to contain two 400 kW emergency diesel engines that would operate for up to 100 hours per year.

Emissions from the 40 kW generators located on the WTGs were estimated based on a 50 kW Tier 3 non-road diesel engine firing ULSD. Emissions from the 6 kW generators located on the WTGs were estimated based on a 6 kW Tier 4 non-road diesel engine firing ULSD. Emissions from the temporary generators on the ESPs during construction were estimated based on an 800 kW Tier 2 non-road diesel engine firing ULSD. Emissions from the emergency generators on the ESPs during O&M were estimated based on a 400 kW Tier 2 non-road diesel engine firing ULSD. Engine size, applicable regulatory tier, and fuel usage for each type of generator was determined from equipment specification sheets for diesel generators that are representative of the type of generator that will be used for the Project (see Attachment G).

For the 6 kW, 40 kW, 400 kW, and 800 kW diesel generators, emission factors for NMHC + NOx, CO, and PM were based on the applicable EPA nonroad engine exhaust emission standards corresponding to the engine's regulatory tier. It was conservatively estimated that NOx is 100% and VOC is 1% of NMHC + NOx. For all generators, it was assumed that 100% of PM is PM10 and 97% of PM is PM2.5 (EPA, 2010).

SO2 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 SO2 to sulfur. Total tons of SO2 were calculated using the following equation:

$$SO_2(tons) = Fuel\,use\,(gal) * \frac{7.10\,lb\,diesel\,fuel}{gal\,diesel\,fuel} * \frac{1.5 * 10^{-6}\,lb\,S}{lb\,diesel\,fuel} * \frac{100\,\%\,conversion}{100}$$

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

CO2 emission factors were based on the default Distillate Fuel No. 2 CO2 emission factor (73.96 kg CO2/MMBtu) and higher heating value (HHV) (0.138 MMBtu/gal) from 40 CFR Part 98 Table C-1[10]. CH4 and N2O emission factors were based on default CH4 and N2O emission factors for petroleum from 40 CFR Part 98 Table C-2[11] and the default Distillate Fuel No. 2 HHV from 40 CFR Part 98.

Greenhouse gas emissions as carbon dioxide equivalent (CO2e) for the generators were calculated using global warming potential (GWP) emission factors provided by the BOEM Emission Estimating Tool following the same methodology as described for commercial marine vessels.

---

[10] From 40 CFR Part 98 Table C-1: Default CO2 Emission Factors and High Heat Values for Various Types of Fuel.

[11] From 40 CFR Part 98 Table C-2: Default CH4 and N2O Emission Factors for Various Types of Fuel.

Pb emission factors for the 6 kW, 40 kW, and 400 kW generators were based on the lead emission factor for small (<600 hp) uncontrolled stationary diesel engines from AP-42. For the 800 kW temporary generators, the Pb emission factor was based on the lead emission factor for large (>600 hp) uncontrolled stationary diesel engines from AP-42. For all generators, the lead emission factor in lb/MMBtu was converted to lb/gallon using the default HHV for Distillate No. 2 Fuel Oil from 40 CFR Part 98 Table C-1. This lb/gallon emission factor was multiplied by the total fuel use of each generator to determine total emissions of lead.

HAPs emissions for the 6 kW, 40 kW, and 400 kW generators were estimated using HAP emission factors for small (<600 hp)[12] uncontrolled stationary diesel engines from AP-42. For the 800 kW temporary generators, HAP emissions were estimated using AP-42 HAP emission factors for large (>600 hp) uncontrolled stationary diesel engines[13]. For both generators, the total HAP emission factor in lb/MMBtu was converted to lb/gallon using the default HHV for Distillate No. 2 Fuel Oil from 40 CFR Part 98 Table C-1.

2.2.4 Pile Driving Hammer Engines

For each foundation, pile driving is expected to take less than three hours to achieve the target penetration depth. Therefore, it was conservatively assumed that the pile driving hammer engines would operate for 3 hours at 100% load for each foundation pile. It was conservatively assumed that 50% of the 106 WTG foundations will be 4-pile jacket foundations instead of monopiles and two conventional ESPs will have 4-pile jacket foundations, which provides the maximum number of piles that may be driven for the Project[14].

Emissions from the engines used to power the hydraulic pile driving hammer were estimated based on a Tier 2 non-road diesel engine firing ULSD. Engine size, applicable regulatory tier, and fuel usage was determined from the equipment specification sheet of a diesel engine that is expected to be used for pile driving activities (see Attachment G). Air emissions for

---

[12] The HAPs emission factor is the sum of emission factors listed in AP-42 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.

[13] The HAPs emission factor is the sum of emission factors listed in AP-42, 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.

[14] As indicated previously, several refinements to the Project Envelope and schedule have been made since conducting this estimate of the Project's potential emissions. The Project will only install up to 100 WTGs and only up to ten of those WTGs will have jacket foundations. As a result, this estimate of air emissions from pile driving is likely over-conservative.

NMHC+ NOx, CO, and PM are based on emission factors for 560 ≤ kW < 900 Tier 2 non-road compression-ignition engines. It was conservatively estimated that NOx is 100% and VOC is 1% of NMHC+ NOx. Based on guidance from EPA's most recent Exhaust and Crankcase Emission Factor for Nonroad Engine Modeling – Compression Ignition report (2010), 100% of PM is PM10 and 97% of PM is PM2.5.

SO2 emission factors 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 SO2 to sulfur. Total tons of SO2 were calculated using the same equation as described for the generators.

CO2 emission factors were based on the default Distillate Fuel No. 2 CO2 emission factor (73.96 kg CO2/MMBtu) and higher heating value (HHV) (0.138 MMBtu/gal) from 40 CFR Part 98 Table C-1[15]. CH4 and N2O emission factors were based on default CH4 and N2O emission factors for petroleum from 40 CFR Part 98 Table C-2[16] and the default Distillate Fuel No. 2 HHV from 40 CFR Part 98. Greenhouse gas emissions as carbon dioxide equivalent (CO2e) for the air compressors were calculated using global warming potential (GWP) emission factors provided by the BOEM Emission Estimating Tool using the same methodology as described for commercial marine vessels.

The Pb emission factor for the hammer engine was based on the lead emission factor for large (>600 hp) uncontrolled stationary diesel engines from AP-42. The lead emission factor in lb/MMBtu was converted to lb/gallon using the default HHV for Distillate No. 2 Fuel Oil from 40 CFR Part 98 Table C-1. This lb/gallon emission factor was multiplied by the total fuel use of the pile driving hammer engines to determine total emissions of lead. HAPs emissions for the hammer engines were based on HAPs emission factors for large (>600 hp)[17] uncontrolled stationary diesel engines from AP-42 and the HHV for Distillate Fuel No. 2.

2.2.5 Air compressors

The air compressors used for noise mitigation devices (e.g. bubble curtains) were assumed to operate for four hours per pile driven. Emissions from the air compressors were estimated based on an interim Tier 4 non-road compression ignition engine firing ULSD. Engine size, applicable regulatory tier, and fuel usage was determined from the equipment specification

---

[15] Distillate Fuel Oil No. 2 HHV and CO2 Emission Factor are from 40 CFR Part 98 Table C-1: Default CO2 Emission Factors and High Heat Values for Various Types of Fuel.

[16] Default CH4 and N2O emission factors are from 40 CFR Part 98 Table C-2: Default CH4 and N2O Emission Factors for Various Types of Fuel

[17] The HAPs emission factor is the sum of emission factors listed in AP-42 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.

sheet of a diesel air compressor that is representative of the type of compressor typically used for noise mitigation in offshore wind projects[18] (see Attachment G). Air emissions for NOx, VOC, CO, and PM were based on emission factors for 130 ≤ kW < 560 Tier 4 non-road compression-ignition engines per 40 CFR Part 1039.102. Based on guidance from EPA's most recent Exhaust and Crankcase Emission Factor for Nonroad Engine Modeling – Compression Ignition report (2010), 100% of PM is PM10 and 97% of PM is PM2.5. It was also assumed that 100% of NHMC is VOC.

SO2 emission factors 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 SO2 to sulfur. Total tons of SO2 were calculated using the same equation as described for generators.

CO2 emission factors were based on the default Distillate Fuel No. 2 CO2 emission factor (73.96 kg CO2/MMBtu) and higher heating value (HHV) (0.138 MMBtu/gal) from 40 CFR Part 98 Table C-1[19]. CH4 and N2O emission factors were based on default CH4 and N2O emission factors for petroleum from 40 CFR Part 98 Table C-2[20] and the default Distillate Fuel No. 2 HHV from 40 CFR Part 98.

Greenhouse gas emissions as carbon dioxide equivalent (CO2e) for the air compressors were calculated using global warming potential (GWP) emission factors provided by the BOEM Emission Estimating Tool using the same methodology as described for commercial marine vessels.

The Pb emission factor for the air compressors was based on the lead emission factor for small (<600 hp) uncontrolled stationary diesel engines from AP-42. The lead emission factor in lb/MMBtu was converted to lb/gallon using the default HHV for Distillate No. 2 Fuel Oil from 40 CFR Part 98 Table C-1. This lb/gallon emission factor was multiplied by the total fuel use of the air compressors to determine total emissions of lead. HAPs emissions for the air compressors were based on HAPs emission factors for small (<600 hp)[21] uncontrolled stationary diesel engines from AP-42 and the HHV for Distillate Fuel No. 2.

---

[18] Based on 100% Oil-Free Air Compressors Protect Marine Life with Bubble Curtain. (2010). From https://www.atlascopco.com/en-us/Rental/news/Oil-free-air-compressors-protect-marine-life-with-bubble-curtain

[19] Distillate Fuel Oil No. 2 HHV and CO2 Emission Factor are from 40 CFR Part 98 Table C-1: Default CO2 Emission Factors and High Heat Values for Various Types of Fuel.

[20] Default CH4 and N2O emission factors are from 40 CFR Part 98 Table C-2: Default CH4 and N2O Emission Factors for Various Types of Fuel

[21] The HAPs emission factor is the sum of emission factors listed in AP-42 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.

2.2.6 Fugitive Emissions

During the construction phase, it was conservatively estimated that 1 ton of VOC would be emitted from fugitive emissions of solvents, paints, coatings, and diesel fuel storage/transfer. During the operational phase, it was assumed that there would be fugitive emissions from the use of 50 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[22].

Emissions of SF6 used to insulate electrical equipment (primarily switchgear) on the WTGs and ESPs were estimated based on the storage capacity of SF6 within the equipment and the maximum permissible annual leak rate of 1% per 310 CMR 7.72(5)(a)[23]. Vineyard Wind's engineers indicated that there would be approximately13 kg of SF6 on each WTG. They also indicated that, for the 800 MW project, there is expected to be a total of eighteen 220 kV gas insulated switchgear (GIS) and twenty-two 66 kV located on the ESPs. The 220 kV GIS are anticipated to contain 125 kg SF6. The 66kV GIS are expected to contain 85 kg SF6. Greenhouse gas emissions of SF6 as carbon dioxide equivalent (CO2e) were calculated using a global warming potential (GWP) of 23,500 from the most recent IPCC Fifth Assessment Report (2014). SF6 calculations are provided in Attachment F.

2.2.7 Total Sulfuric Acid Mist Emissions

To determine the applicability of Prevention of Significant Deterioration (PSD) review as part of the OCS Air Permit application, total sulfuric acid mist (H2SO4) emissions were estimated. In the overview of diesel combustion and pollutant formation, EPA's (2007) *Draft Regulatory Impact Analysis: Control of Emissions of Air Pollution from Locomotive Engines and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder* states that:

> "Sulfur dioxide (SO2) is formed via combustion of sulfur compounds from the fuel and lubricating oil burned during combustion. In the absence of post-combustion catalytic treatment of the exhaust, approximately 1 to 3 % of fuel sulfur is oxidized to ionic sulfate (SO3-) and upon further cooling is present primarily as a hydrated sulfuric acid aerosol. For example, sulfate PM currently accounts for approximately 0.03 to 0.04 g/bhp-hr over the line-haul cycle for locomotive engines using 3000 ppm sulfur nonroad diesel fuel."

---

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

[23] The maximum allowable SF6 emission rate beginning in the 2020 calendar year.

Almost all emission sources for the Project will be compression-ignition engines. To determine the potential emissions of sulfuric acid mist (H2SO4) it was assumed that 3% of fuel sulfur is oxidized to ionic sulfate and all fuel will be ULSD with a 15 ppm sulfur content. To calculate the tons of H2SO4 based on the quantity of fuel used for the project, the following equation was used:

$$H_2SO_4(tons) = \ gal\ diesel\ fuel * \frac{7.10\ lb\ diesel\ fuel}{gal\ diesel\ fuel} * \frac{1.5 * 10^{-6}\ lb\ S}{lb\ diesel\ fuel} * \frac{3\ \%\ conversion}{100}$$

$$* \frac{1\ lb\ mole\ S}{32\ lb\ S} * \frac{1\ lb\ mole\ H_2SO_4}{1\ lb\ mole\ S} * \frac{98.1\ lb\ H_2SO_4}{1\ lb\ mole\ H_2SO_4} * \frac{1\ ton\ SO_2}{2000\ lb\ SO_2}$$

H2SO4 emissions were not calculated for each engine individually. Rather, total H2SO4 emissions for the construction and O&M phases were calculated based on the anticipated total fuel use during each phase.

2.3 OCS Air Permit Emissions Summary

Air emissions from the 800 MW Project that are subject to the OCS Air Permit process during the construction phase are summarized in Table 2-9 below[24].

Table 2-9 Construction Phase Air Emissions Subject to OCS Air Permit

	Total Fuel Use (gal)	OCS Air Permit Emissions (tons)												
		NOx	VOC	CO	PM10	PM2.5	SO2	CO2	CH4	N2O	Pb	HAPs	CO2e	H2SO4
Year 1	17,812,147	3,269	87	699	109	104	32.1	203,220	1.70	9.48	0.012	7.3	205,780	0.09
Year 2	3,928,868	663	13	162	22	21	2.3	44,593	0.39	2.02	0.003	1.8	45,140	0.02
Total	21,741,015	3,932	100	862	131	125	34.4	247,813	2.09	11.50	0.015	9.1	250,919	0.11

---

[24] Due to refinements to the Project Envelope and schedule that have been made since conducting this estimate of the Project's potential emissions, the estimate of the Project's construction emissions contained in the OCS Air Permit application are slightly less than the estimate reported in Table 5.1-5 of Volume III and in Appendix III-B. The Project will only install up 100 WTGs and has eliminated the option to install light-weight ESPs. As a result, this estimate of Project air emissions during construction over-conservatively estimates the emissions resulting from the installation of the WTGs, ESPs, and their foundations.

Table 2-10 summarizes the air emissions from the 800 MW Project that are subject to the OCS Air Permit process during the operations and maintenance phase[25].

Table 2-10 Operations and Maintenance Phase Air Emissions Subject to OCS Air Permit

	Total Fuel Use (gal)	OCS Air Permit Emissions												
		NOX	VOC	CO	PM10	PM2.5	SO2	CO2	CH4	N2O	Pb	HAPs	CO2e	H2SO4
30-Year Lifespan (tons)	10,263,637	1,416	48.1	364.5	47.3	45.8	8.41	114,344	1.17	5.16	0.007	27.8	10,263,637	0.050
Annual (tpy)	342,121	47.2	1.6	12.2	1.6	1.5	0.28	3,811	0.04	0.17	0.000	0.9	342,121	0.002

---

[25] The Project's OCS Air Permit application, which was submitted after conducting this air emissions analysis, reflects refinements to the emission estimates based on minor updates to the planned vessel use during O&M activities. The estimate of the Project's O&M emissions contained in the OCS Air Permit application are slightly higher for some pollutants than the estimate reported in Table 5.1-5 and in Appendix III-B. This increase in O&M emissions is primarily due to anticipated vessel speed restrictions implemented to protect marine mammal species, which results in increased vessel usage.

3.0 GENERAL CONFORMITY EMISSIONS

Direct and indirect emissions that are beyond 25 miles from an OCS source, but are within a maintenance or nonattainment area must be counted for purposes of determining general conformity. For coastal areas, the nonattainment or maintenance area boundary extends to the state's seaward boundary, which is three nautical miles (NM) from the coastline (except in Florida and Texas where the boundary is three leagues, or approximately nine miles). Because the Long Island Sound is a juridical bay within the US coastline, the states (Connecticut and New York) have jurisdiction over the Long Island Sound waters. As a result, the nonattainment or maintenance area boundary for areas bordering the Long Island Sound are based on state and county lines rather than the 3 NM limit.

Attainment designations for all counties where Project emissions may occur are summarized in Table 3-1. All counties potentially affected by the Project's air emissions are in attainment with the NAAQS for Pb, SO2, and NO2, which are not included in the following table.

Table 3-1 Air Quality Designations for Areas Where Project-Related Emissions May Occur

Area/County	2015 Ozone Standard	2008 8-Hour Ozone Standard	1997 & 2006 $PM_{2.5}$	1987 PM10 standard	1971 CO Standard
Barnstable, MA	Attainment	Attainment	Attainment	Attainment	Attainment
Bristol, MA	Attainment	Attainment	Attainment	Attainment	Attainment
Nantucket, MA	Attainment	Attainment	Attainment	Attainment	Attainment
Dukes, MA	Attainment	Dukes County Marginal Nonattainment Area	Attainment	Attainment	Attainment
Suffolk, NY	EPA Intends to Designate as New York Metro Nonattainment Area	New York Metro Moderate Nonattainment Area	New York-N. New Jersey-Long Island, NY-NJ-CT Maintenance Area	Attainment	Attainment
Fairfield, CT				Attainment	New York-N. New Jersey-Long Island, NY-NJ-CT / New Haven-Meriden-Waterbury, CT Maintenance Area
New Haven, CT				New Haven Maintenance Area	New Haven-Meriden-Waterbury, CT Maintenance Area
Middlesex, CT			Attainment	Attainment	Hartford-New Britain-Middletown, CT Maintenance Area
New London, CT	EPA Intends to Designate as Greater CT Nonattainment Area	Greater CT Moderate Nonattainment Area	Attainment	Attainment	Attainment
All Rhode Island Counties	Attainment	Attainment	Attainment	Attainment	Attainment

A General Conformity Determination will likely be required for Duke's County since NOx emissions exceed the de minimis threshold during the most intense year of construction. If the Project uses a port in Connecticut during the construction phase, vessels will pass through nonattainment and maintenance areas in Connecticut and New York, resulting in the need for a General Conformity evaluation.

For the construction phase, the air emissions subject to General Conformity will depend on the combination of ports used. Three port scenarios were evaluated to determine the maximum emissions that could occur in each nonattainment/maintenance area where Project activities may occur. As described in Section 3.2.5 of Volume I, the Project plans to use New Bedford Marine Commerce Terminal (New Bedford Terminal) to stage construction activities. However, given the scale of the Project and the possibility that one or more other offshore wind projects may be using portions of the New Bedford Terminal at the same time, Vineyard Wind may need to stage certain activities from other Massachusetts or North Atlantic commercial seaports. The ports that may be used by the Project are listed in Table 3-2 below. Table 3-2 also indicates which counties within nonattainment or maintenance areas vessels must pass through to reach each port.

Table 3-2 Potential Ports and Nonattainment/Maintenance Areas Impacted

Port	Regions Subject to General Conformity Where Vessel Emissions May Occur	
	Nonattainment /Maintenance Areas	Counties Along Vessel Route
Massachusetts Ports		
New Bedford Marine Commerce Terminal or other area in New Bedford Port	Dukes County, MA	Dukes County, MA
Brayton Point	None	None
Montaup	None	None
Rhode Island Ports		
Providence	None	None
Quonset Point	None	None
Connecticut Ports		
New London	Greater Connecticut Area	New London County, CT
	New York Metro Area	Suffolk County, NY
Bridgeport	New York Metro Area	Suffolk County, NY Fairfield County, CT Middlesex County, CT (possibly) New Haven County, CT (possibly)
Canadian Ports		
One or more Canadian ports	None	None

Vessels must only pass through nonattainment/maintenance areas when traveling from the WDA to the New Bedford Terminal, New London, or Bridgeport. If needed, the ports in New London and Bridgeport would likely only be used to offload shipments of WTG components, prepare them for installation, and then load the components onto vessels for delivery to the

WDA. As a result, the following three conservative scenarios were evaluated to determine the maximum emissions that could occur in each nonattainment/maintenance area where Project activities may occur:

1. All vessels travel using a domestic port travel to New Bedford Terminal.
2. One heavy cargo vessel and two jack-up vessels travel to Bridgeport, CT. The remaining vessels using a domestic port travel to New Bedford Terminal.
3. One heavy cargo vessel and two jack-up vessels travel to New London, CT. The remaining vessels using a domestic port travel to New Bedford Terminal.

Vineyard Wind intends to support O&M activities from ports at Vineyard Haven and the New Bedford Terminal. Smaller vessels used for O&M activities will likely be based out of Vineyard Haven. Larger vessels used for major repairs during O&M (e.g. jack-up vessels, heavy cargo vessels, etc.) would likely use the New Bedford Terminal. The New Bedford Terminal is not located in a nonattainment area. Therefore, vessels traveling to New Bedford Terminal would only pass through the region subject to General Conformity (Dukes County waters). Vineyard Haven is located in a nonattainment/maintenance area. Therefore, vessels using Vineyard Haven would dock, maneuver, and travel through a maintenance/nonattainment area.

Vessels must travel slightly further through the Dukes County nonattainment/maintenance area (with their main propulsion engines operating at high loads) to reach the New Bedford Terminal than to reach Vineyard Haven. However, CTVs and smaller support vessels using Vineyard Haven would spend time maneuvering within the nonattainment/maintenance area. For the purposes of General Conformity, it is more conservative to assume that smaller vessels use Vineyard Haven as opposed to New Bedford.

The following sections provide a description of the emission sources included in the General Conformity emissions estimate and the methods used to quantify General Conformity emissions.

3.1 Description of General Conformity Air Emission Sources

Like in the OCS Air Permit emissions estimate, the majority of air emissions from the Project that are potentially subject to General Conformity will come from the engines on marine vessels used during construction activities.

Emission sources used during offshore construction and O&M, which must be accounted for in the General Conformity emissions estimate, include:

- Crew transfer/service vessels,
- Heavy cargo vessels,
- Cable installation vessels,
- Scour protection installation vessels,

- Multipurpose support vessels,
- Tugboats,
- Anchor handling tug supply vessels,
- Jack-up vessels,
- Dredging vessels,
- Survey vessels, and
- Helicopters.

No onshore construction will occur within Dukes County, so there are no onshore emissions subject to General Conformity within Dukes County. If a port in New London or Bridgeport is used, there will be some onshore emissions from non-road equipment (i.e. cranes) and on-road vehicles used during the unloading and loading of equipment at the construction staging area. 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 Vineyard Wind's engineers. A complete description of all of the offshore emission points associated with Vineyard Wind's Project that may be subject to General Conformity can be found in Attachment C. Calculations of onshore emissions that are subject to General Conformity are included in Attachment D.

3.2 Emission Calculation Methods

3.2.1 Commercial Marine Vessels (CMVs)

Commercial marine vessel emissions were calculated for General Conformity in the same manner as for the OCS Air Permit, with some differences due to the location of the emissions and activities in port. Consistent with the BOEM Offshore Wind Energy Facilities Emission Estimating Tool, vessel air emissions were calculated based on vessels' hours of operation onsite, distance traveled, speed, total number of round trips, engine size, load factor, and emission factor. When necessary, BOEM's emission calculation methodology was supplemented with guidance from EPA's Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories (2009) and EPA's 2014 National Emission Inventory Technical Support Document (2016).

For vessels using New Bedford Terminal, the General Conformity emission estimates only include emissions from vessels while in transit and do not include time that vessels spend maneuvering in port or while dockside (hoteling). For each vessel, two calculations were made:

- Emissions from the main engines while in transit
- Emissions from the auxiliary engines while in transit

For each vessel using New London, Bridgeport, or Vineyard Haven, General Conformity emission estimates must account for the time that vessels spend maneuvering in port and while hoteling. For each vessel, five calculations were made:

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

The following sections primarily discuss the differences between the methodologies used to estimate vessel emissions for the General Conformity process and OCS Air Permit process. Engine sizes, emission factors for all pollutants (NOx, VOC, CO, PM10, PM2.5, SO2, HAPs, Pb, and CO2e), and fuel usage were determined using the methods discussed in the OCS Air Permit Emission Calculation Methods in Section 2.2.1.

Additional and Excluded Vessels

The General Conformity emissions estimate includes some vessels that were not included in the OCS Air Permit emissions estimate. The OCS Air Permit estimate must only include vessels at the WDA and along the OECC when within 25 miles of an OCS source. Therefore, cargo vessels and barges traveling directly from other domestic and international ports to the Project's construction staging area(s) were not included in the OCS Air Permit emissions estimate. In contrast, the General Conformity emissions estimate includes emissions from ocean-going high-speed heavy cargo vessels used to transport the monopiles, transition pieces, WTGs, and ESPs to the construction staging area(s) while within nonattainment/maintenance areas. For these ocean-going cargo vessels, engine sizes and vessel speeds are from equipment specification sheets of representative vessels (see Attachment G). When only the size of the main engine or total propulsion power was provided for an ocean-going vessel (OGV), auxiliary engine size was determined using auxiliary engine power ratios from Table 2-4 of EPA's Port-Related Emission Guidance (2009).

Some vessels that are included in the OCS Air Permit emissions estimate are excluded from the General Conformity emissions estimate because those vessels do not enter nonattainment/maintenance areas. This includes large heavy lift and jack-up vessels used for foundation, ESP, and WTG installation because these vessels are expected to travel directly to and from a Canadian port (or other international port) to the WDA.

Distance Traveled and Hours of Operation

For General Conformity, the emissions estimate includes vessel emissions that occur beyond 25 miles form an OCS source *and* within a maintenance or nonattainment area. The distance traveled by each vessel while within the region subject to General Conformity was determined using Massachusetts Ocean Records Information System (MORIS): Massachusetts Ocean Management Plan Data and 2013 Automatic Identification System (AIS) data.

Using MORIS and AIS data, vessel routes from the New Bedford Terminal to the WDA were mapped out based on regions of concentrated commerce traffic. For the purposes of the General Conformity, it was assumed that most vessels would travel from New Bedford to the edge of the OCS Air Permit Boundary through Quicks Hole Channel (between Pasque and Nashawena Islands), resulting in 13.5-nautical mile route through Dukes County waters (see Figure 3-1). This is a conservative estimate because many larger, deep draft Project vessels will travel around the Elizabeth Islands to reach New Bedford; this route only crosses through 5 NM of Dukes County waters (see Figure 3-1). The distance traveled by cable installation vessels within Dukes County waters was based on the maximum length of offshore export cable in Dukes County Waters (13 NM for three cables). Cargo vessels traveling between New Bedford and Europe or Canada were assumed to follow shipping fairways lanes and traffic separation schemes. As shown in Figure 3-2, this vessel route passes through 5 NM of Dukes County waters.

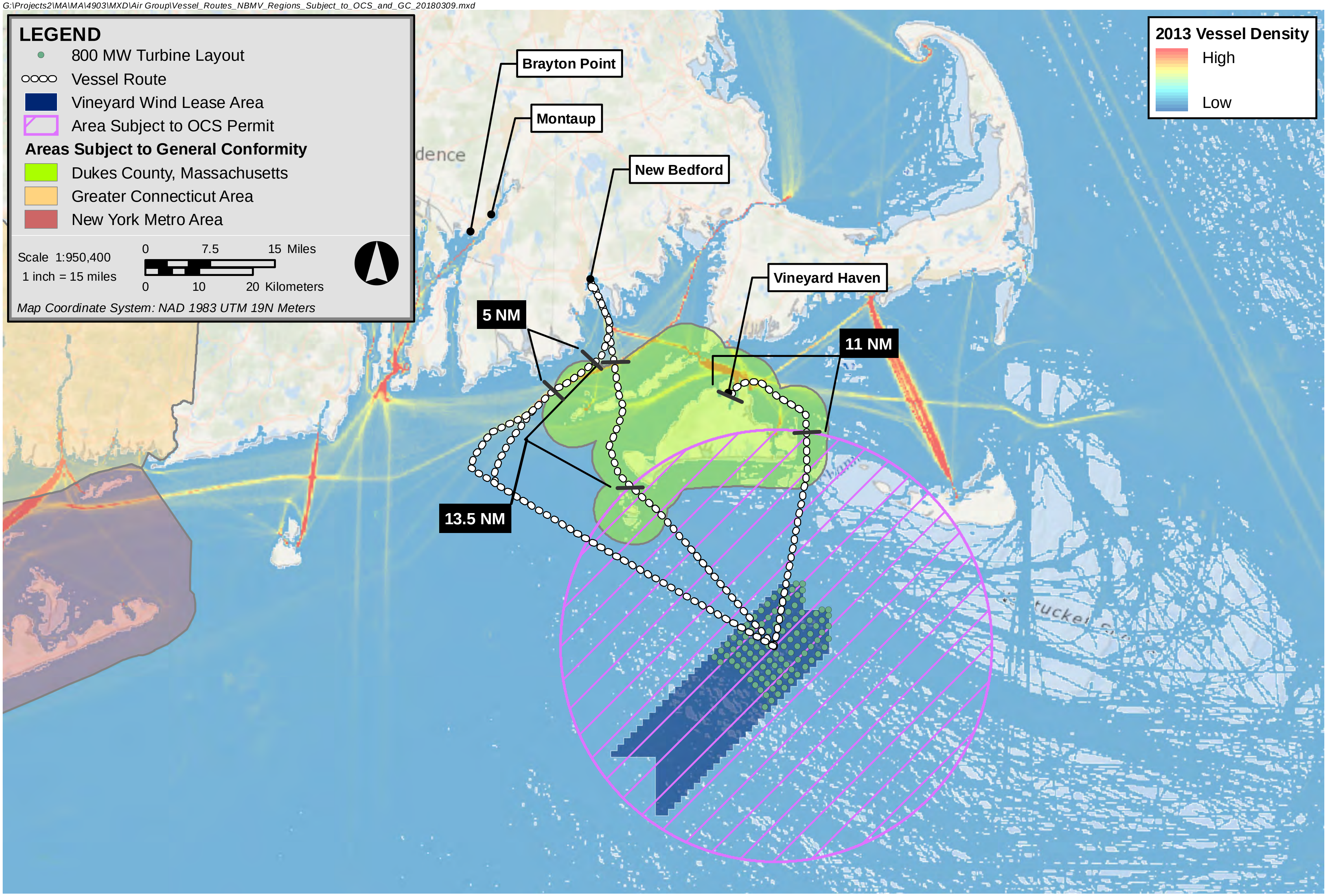
Most probable vessel routes from the center of the WDA to Bridgeport and New London were mapped out based on regions of concentrated commerce traffic using 2013 AIS data. It was assumed that vessels would not pass through Dukes County waters or other active renewable energy lease areas while enroute to New London or Bridgeport. It was estimated that vessels traveling to Bridgeport would travel 68 NM through the New York Metro Nonattainment Area. Vessels traveling to New London were estimated to travel 11 NM through the New York Metro Nonattainment Area and 5.7 NM though the Greater Connecticut Nonattainment Area (see Figure 3-3).

For offshore construction, Vineyard Wind's engineering team initially provided the number of vessel trips and operating days required for the construction a 400 MW Project. The construction phase emissions estimate was first calculated for a 400 MW Project and then the emissions estimate was doubled for most construction activities to derive the emissions estimate for an 800 MW Project[26]. For the O&M phase, the number of vessel trips and duration of each activity were provided for an 800 MW Project. For the General Conformity emissions estimate, one round trip was added to the number of round trips provided in the OCS Air Permit emissions estimate to account for the vessel's initial trip to the construction staging area from another port and final departure from the construction staging area to another port. This is a conservative estimate since the port of New Bedford will likely be the homeport of several harbor craft (e.g. tugs and crew transfer vessels) used for the Project.

---

[26] The emissions estimate for offshore export cable laying for a 400 MW Project was multiplied by 1.25 to convert the estimate to an 800 MW Project. This is because the offshore export cable installation will be largely the same for a 400 MW and 800 MW Project; installation of the 800 MW simply requires the additional installation of an inter-link cable between the two ESP locations.

G:\Projects2\MA\MA\4903\MXD\Air Group\Vessel_Routes_NBMV_Regions_Subject_to_OCS_and_GC_20180309.mxd



Service Layer Credits: Esri, Garmin, GEBCO, NOAA NGDC, and other contributors

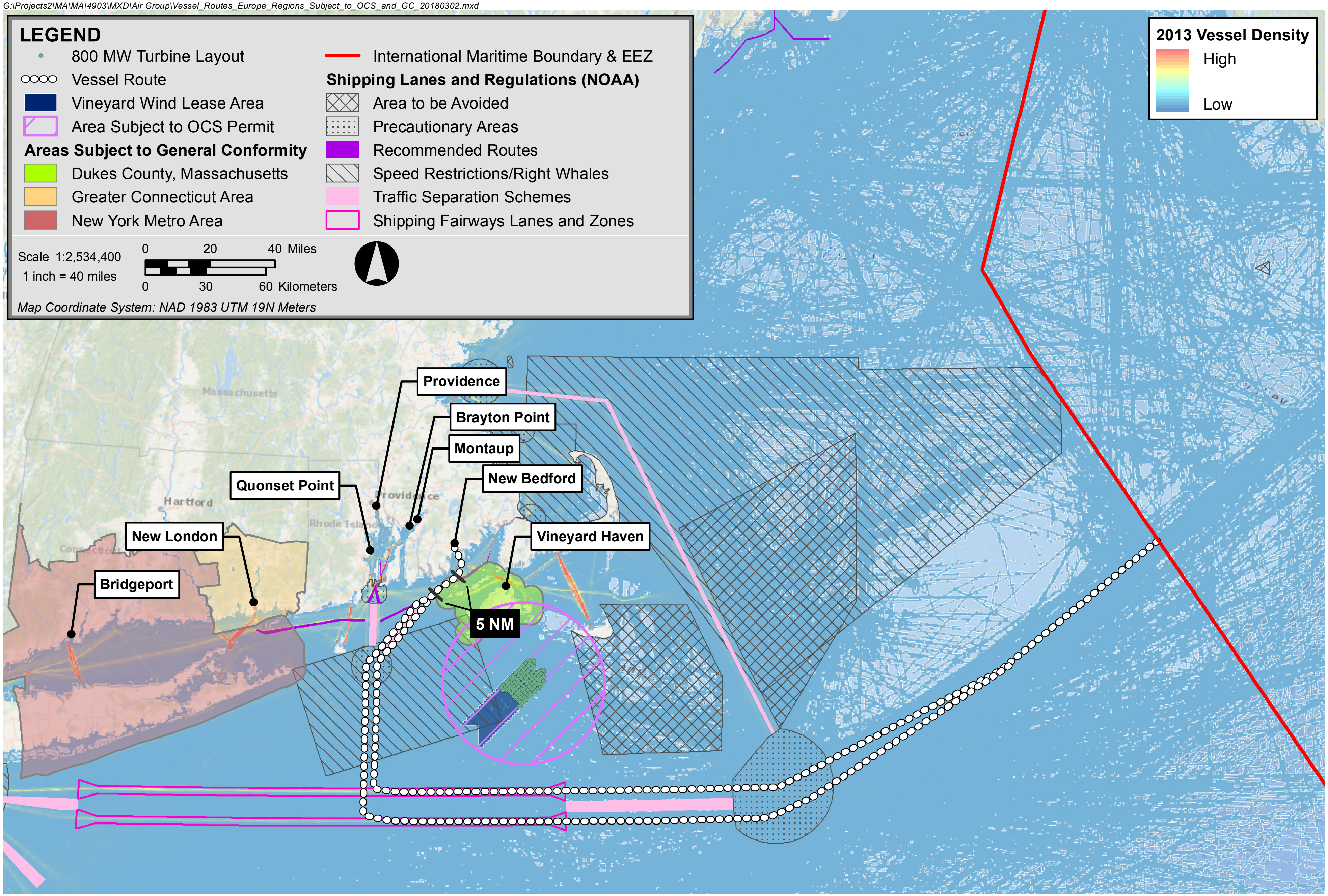
Vineyard Wind Project

VINEYARD WIND

Figure 3-1

New Bedford and Vineyard Haven Vessel Routes through General Conformity Areas

G:\Projects2\MA\MA\4903\MXD\Air Group\Vessel_Routes_Europe_Regions_Subject_to_OCS_and_GC_20180302.mxd



Service Layer Credits: Sources: Esri, GEBCO, NOAA, National Geographic, Garmin, HERE, Geonames.org, and other contributors

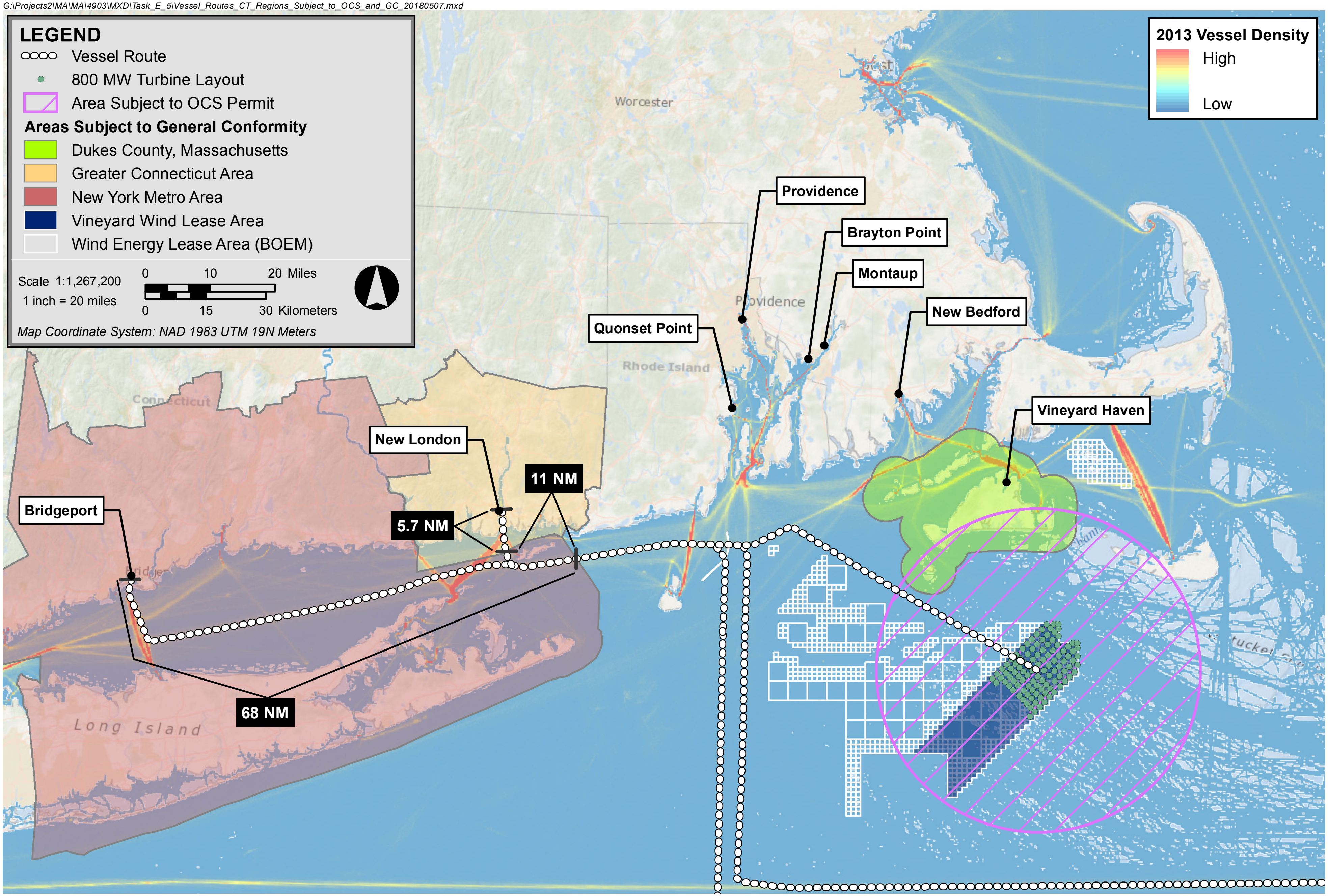
Vineyard Wind Project

VINEYARD WIND

Figure 3-2

Europe/Canada to New Bedford Vessel Routes through General Conformity Areas

G:\Projects2\MA\MA\4903\MXD\Task_E_5\Vessel_Routes_CT_Regions_Subject_to_OCS_and_GC_20180507.mxd



Vineyard Wind Project

VINEYARD WIND

Figure 3-3

Bridgeport and New London Vessel Routes through General Conformity Areas

Hours of operation for main engines and auxiliary engines while in transit were calculated from the vessel's speed and total distance traveled by the vessel when within 25 miles of an OCS source and within a nonattainment/maintenance area. Hours spent maneuvering in port were based on typical maneuvering times by vessel type provided in the 2014 NEI[27] (shown below) and the number of round trips.

Table 3-3 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
Misc.	1
Passenger	0.8
Reefer	1
RORO	1
Tanker	1
Tug	1.7
Vehicle Carrier	1

For all vessels, it was assumed that all main engines used for propulsion would not operate while the vessel is dockside per 2014 NEI (2016) guidance. For vessels equipped with Category 1 and 2 engines (except for some larger vessels such as jack-up vessels), it was assumed that neither the propulsion nor auxiliary engines would operate while the vessel was dockside to conserve fuel (EPA, 2016). For Category 3 and large Category 2 vessels, auxiliary engines were assumed to be hoteling any time the vessel is outside of the 25-mile OCS Air Permit Boundary and not in transit or maneuvering in port.

Load Factor

As described in Section 2.2.1, a load factor of 0.83 was used for main (propulsion) engines in transit. Consistent with the 2014 NEI (2016) and the BOEM Emission Estimating Tool, a load factor of 0.20 was used for most main (propulsion) engines while maneuvering in port. Since some export cable laying will be performed by vessels that use dynamic positioning

---

[27] From 2014 NEI (2016), Table 4-98: Estimated Maneuvering Time by Vessel Type. The maneuvering time includes time spent approaching the port and time spent departing from the port.

within Duke's county, a load factor of 0.4 was used for the maneuvering activities (both in port and along the export cable) of certain export cable laying vessels (see discussion of DP load factors in Section 2.2.1.1).

Auxiliary engine load factors for vessels whose main engines are Category 3 engines were taken from *Table 2-7: Auxiliary Engine Load Factor Assumptions* of EPA's Port-Related Emission Guidance (2009), shown in Table 2-3. For auxiliary engines in transit, the more conservative "RSZ" load factor was used, since vessels may operate at speeds slower than cruise speeds. For auxiliary engines on Category 3 vessels during hoteling, the "hotel" load factor was selected. Load factors from *Table 3-3: EPA Load Factors for Harbor Craft* (see Table 2-4) were used for auxiliary engines on Category 1 and 2 vessels while in transit and maneuvering in port. For large Category 2 vessels whose engines will not turn off in port, load factors from *Table 2-7: Auxiliary Engine Load Factor Assumptions* were used for auxiliary engines while hoteling.

3.2.2 Helicopters

General Conformity emission estimates for helicopters were determined for using the same method used in the OCS Air Permit emission calculations described in Section 2.2.2. However, the distance traveled by each helicopter only includes airspace over Dukes County (including waters three nautical miles from shore) that is beyond 25 miles from the potential location an OCS source. Emissions from helicopters traveling out of Martha's Vineyard Airfield were assumed to be entirely accounted for in the OCS Air Permit emissions estimate. It was estimated that helicopters out of Providence Airport would travel 14.5 miles while in the airspace subject to General Conformity.

3.2.3 Non-Road Engines

Emissions from non-road engines used at the construction staging area (i.e. cranes) were calculated using the latest version of EPA's Motor Vehicle Emission Simulator, MOVES2014a. This state-of-the-art emission estimating tool, last updated in November 2016, now incorporates NONROAD2008. Emissions factors from MOVES2014a were used to calculate emissions for each pollutant (NOx, VOC, CO, PM10, PM2.5, SO2, CO2, CH4, and HAPS[28]). To calculate emission factors and fuel consumption rates for this Project, a run was completed for a weekday in August, 2017. Air emissions from non-road engines were calculated based on engines' hours of operation, engine size, load factor, and emission factor using the following equation:

$$E = kW * Hours * LF * EF * 1.10231E\text{-}6$$

---

[28] MOVES2014a provides emission factors for individual HAPs, which were summed together.

Where:

- $E =$ total emissions, tons
- $kW =$ total engine size, kW
- $Hours$ = total hours of operation
- LF = engine load factor
- $EF =$ emission factor, g/kW-hr
- $1.10231E\text{-}6 =$ g to ton conversion factor

Load factors were from EPA's *Median Life, Annual Activity, and Load Factor Values for Nonroad Engine Emissions Modeling* (2010). The crane's engine size was largely based on onshore construction emission estimates from other U.S. offshore wind energy projects (Cape Wind, Virginia Offshore Wind Technology Advancement Project (VOWTAP), and Block Island Wind Farm)[29]. It was assumed that each WTG will take 6 hours to offload and load onto a vessel and that the crane will use ultra-low-sulfur diesel (ULSD). These calculations can be found in Attachment D.

3.2.4 On-road Vehicles

Emissions from vehicles used by port workers were also calculated using the latest version of EPA's Motor Vehicle Emission Simulator, MOVES2014a. To obtain passenger truck emission factors, one MOVES2014a run was performed for a July morning using Bristol County project-level inputs provided by MassDEP for the most current year available (2016). Emissions factors from MOVES2014a were used to calculate emissions for each pollutant (NOx, VOC, CO, PM10, PM2.5, SO2, and CO2e). HAPs emissions for on-road vehicles were not available via MOVES and were assumed to be negligible. It was assumed that there would be 25 port workers who will commute on average 15 miles each way.[30] Air emissions from on-road engines were calculated based on the distance each vehicle is expected to travel and MOVES2014a emission factors using the following equation:

$$E = Miles * EF * 1.10231E\text{-}6$$

---

[29] Onshore construction emission estimates were based on VOWTAP's Air Emission Calculation and Methodology (Tetra Tech, 2014), Block Island Wind Farm and Transmission System's Air Emission Analysis (Tetra Tech, 2012), and Cape Wind's OCS Air Permit Application (ESS Group, 2009).

[30] US Bureau of Transportation. (2003). From Home to Work, the Average Commute is 26.4 Minutes. *Omnistats*, Vol. 3 (Issue 4). From https://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/omnistats/volume_03_issue_04/pdf/entire.pdf

Where:

- $E =$ total emissions, tons
- $Miles =$ total distance traveled, miles
- $EF =$ emission factor, g/mile
- $1.10231E\text{-}6 =$ g to ton conversion factor

3.3 General Conformity Emissions Summary

Air emissions from the Project that may be subject to the General Conformity process during the construction phase are summarized in the table below for each port scenario discussed in Section 3.1.

Table 3-4 Construction Phase Air Emissions Subject to General Conformity (Exclusive Use of New Bedford Terminal)

	Total Fuel Use (gal)	Maximum General Conformity Emissions in Dukes County, MA (tons)											
		NOX	VOC	CO	PM10	PM2.5	SO2	CO2	CH4	N2O	Pb	HAPs	CO2e
Year 1	1,292,184	219	4	52	7	7	0.8	14,703	0.09	0.71	0.001	0.6	14,893
Year 2	275,734	48	1	11	2	1	0.1	3,106	0.02	0.15	0.000	0.1	3,146
Total	1,567,918	267	5	63	9	9	0.9	17,809	0.11	0.86	0.001	0.7	18,039

Table 3-5 Construction Phase Air Emissions Subject to General Conformity (Primary Use of New Bedford Terminal, Some Bridgeport Use)

	Total Fuel Use (gal)	Maximum General Conformity Emissions (tons)											
		NOX	VOC	CO	PM10	PM2.5	SO2	CO2	CH4	N2O	Pb	HAPs	CO2e
Dukes County, MA													
Year 1	1,208,946	204	3.9	48.9	6.9	6.7	0.8	13,768	0.09	0.66	0.001	0.53	13,946
Year 2	192,497	33	0.6	7.7	1.1	1.0	0.1	2,171	0.01	0.10	0.000	0.10	2,199
Total	1,401,442	236	4.4	56.6	8.0	7.7	0.9	15,938	0.10	0.77	0.001	0.63	16,144
New York Metro Area													
Year 1	566,391	98	1.5	23.6	3.0	2.9	0.1	6,457	0.05	0.29	0.000	0.27	6,534
Year 2	531,736	97	1.3	21.9	2.9	2.8	0.1	6,011	0.04	0.29	0.000	0.22	6,089
Total	1,098,127	196	2.9	45.5	5.9	5.7	0.2	12,468	0.08	0.58	0.001	0.49	12,623

Table 3-6 Construction Phase Air Emissions Subject to General Conformity (Primary Use of New Bedford Terminal, Some New London Use)

	Total Fuel Use (gal)	Maximum General Conformity Emissions (tons)											
		NOX	VOC	CO	PM10	PM2.5	SO2	CO2	CH4	N2O	Pb	HAPs	CO2e
Dukes County, MA													
Year 1	1,208,946	204	3.9	48.9	6.9	6.7	0.8	13,768	0.09	0.66	0.001	0.53	13,946
Year 2	192,497	33	0.6	7.7	1.1	1.0	0.1	2,171	0.01	0.10	0.000	0.10	2,199
Total	1,401,442	236	4.4	56.6	8.0	7.7	0.9	15,938	0.10	0.77	0.001	0.63	16,144
New York Metro Area													
Year 1	73,270	13	0.2	3.0	0.4	0.4	0.0	829	0.01	0.04	0.000	0.03	840
Year 2	73,270	13	0.2	3.0	0.4	0.4	0.0	829	0.01	0.04	0.000	0.03	840
Total	146,539	26	0.4	6.0	0.8	0.8	0.0	1,658	0.01	0.08	0.000	0.06	1,679
Greater Connecticut Area													
Year 1	186,146	30	0.5	8.2	0.9	0.9	0.0	2,153	0.02	0.08	0.000	0.11	2,175
Year 2	151,490	29	0.4	6.4	0.8	0.8	0.0	1,708	0.01	0.08	0.000	0.07	1,729
Total	337,636	60	0.9	14.6	1.7	1.7	0.0	3,861	0.03	0.16	0.000	0.18	3,905

Table 3-7 summarizes the air emissions from the Project that may be subject to the General Conformity process during the operations and maintenance phase.

Table 3-7 Operations and Maintenance Phase Air Emissions Subject to General Conformity

	Total Fuel Use (gal)	Maximum General Conformity Emissions											
		NOX	VOC	CO	PM10	PM2.5	SO2	CO2	CH4	N2O	Pb	HAPs	CO2e
30-Year Lifespan (tons)	1,451,226	232.8	3.5	58.1	7.9	7.6	0.2	16,349	0.10	0.78	0.001	0.6	16,559
Annual (tpy)	48,374	7.8	0.1	1.9	0.3	0.3	0.0	545	0.00	0.03	0.000	0.0	552

4.0 TOTAL PROJECT EMISSIONS WITHIN THE US

Emissions that occur beyond the 25 miles from an OCS source *and* outside a nonattainment/maintenance area are not regulated by the General Conformity or OCS Air Permit processes. Although these emissions are not regulated, they were quantified for the purposes of the Project's Construction and Operations Plan (COP) and the National Environmental Policy Act (NEPA) process. All emissions from the Project within the US (onshore and out to sea within the 200 NM Exclusive Economic Zone) were calculated by first determining the total emissions that occur outside of the OCS Air Permit Boundary, both onshore and offshore within US waters, and then adding the emissions subject to the OCS Air Permit. Emissions occurring outside the OCS Air Permit Boundary are referred to as "Non-OCS Air Permit" emissions.

Non-OCS Air Permit emissions were calculated for the construction phase and O&M phases. As discussed in Section 3, the quantity of construction phase air emissions will depend on the combination of ports used. Consequently, three scenarios are provided to account for the envelope of possible ports used during construction:

1. All vessels travel using a domestic port travel to New Bedford Terminal.
2. One heavy cargo vessel and two jack-up vessels travel to Bridgeport, CT. The remaining vessels using a domestic port travel to New Bedford Terminal.
3. One heavy cargo vessel and two jack-up vessels travel to New London, CT. The remaining vessels using a domestic port travel to New Bedford Terminal.

Although it is possible that some additional heavy cargo vessels (e.g. vessels used to transport WTG components) will travel to a Canadian port rather than New Bedford, this alternative scenario would reduce the amount of vessel traffic within US waters, and therefore reduce the emissions that would occur within US waters. Consequently, this scenario was not evaluated.

For the O&M phase, it was conservatively assumed that all vessels will travel to New Bedford Terminal, which represents the O&M port with the farthest transit distances to and from the Offshore Project Area. The following sections provide a description of the emission sources that occur beyond the 25 miles from the potential location of an OCS source and the methods used to quantify all "Non-OCS Air Permit" emissions. The emission estimates that are provided represent the upper bound of Project emissions.

4.1 Description of Non-OCS Air Permit Emission Sources

The majority of air emissions from the Project occurring beyond the 25 miles from an OCS source will come from the engines on marine vessels used during construction activities. Emissions from marine vessel engines will occur while vessels travel to and from port and while certain vessels are dockside. Emission sources used during offshore construction and O&M that are included in the Non-OCS Air Permit emissions estimate include:

- Crew transfer/service vessels,

- Heavy cargo vessels,
- Heavy lift crane vessels,
- Cable installation vessels,
- Scour protection installation vessels,
- Multipurpose offshore support vessels,
- Tugboats,
- Anchor handling tug supply vessels,
- Jack-up vessels,
- Dredging vessels,
- Survey vessels, and
- Helicopters.

Emission sources from onshore construction, operation, and maintenance activities will include non-road equipment and on-road vehicles used during the unloading and loading of equipment at the construction staging areas, during Horizontal Directional Drilling (HDD), during the installation of the onshore export cable, and during construction of the onshore substation. Onshore emission sources include:

- Non-road construction and mining equipment (backhoes, bore/drill rigs, compactors, concrete trucks, concrete saws, cranes, excavators, forklifts, graders, light plants off-highway trucks, and pavers);
- Non-road commercial equipment (generators, pumps, and welders);
- Non-road industrial equipment (AC units and aerial lifts);
- Worker vehicles;
- Delivery and heavy-duty vehicles;
- Fugitive emissions from incidental solvent release and SF6; and
- 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 Vineyard Wind's engineers. Engine sizes, activity types, and hours of operation for non-road equipment and vehicles were largely based on onshore construction emission estimates from other U.S. offshore wind energy projects (Cape Wind[31], Virginia Offshore Wind Technology Advancement Project (VOWTAP)[32], and Block Island Wind

---

[31] ESS Group. (2009). Revised Cape Wind Emissions Estimates –Methodology.

[32] Tetra Tech. (2014). Virginia Offshore Wind Technology Advancement Project Research Activities Plan, Appendix I: Air Emission Calculations and Methodology.

Farm[33]), replaced by project-specific information when possible. A complete description of all emission points associated with Vineyard Wind's 800 MW Project incorporated in the Non-OCS Air Permit calculations can be found in Attachment D.

4.2 Emission Calculation Methods

4.2.1 Commercial Marine Vessels (CMVs)

Commercial marine vessel emissions were calculated for Non-OCS Air Permit emissions in the same manner as for the OCS Air Permit, with some differences due to the location of the emissions and activities in port. Consistent with the BOEM Offshore Wind Energy Facilities Emission Estimating Tool, vessel air emissions were calculated based on vessels' hours of operation onsite, distance traveled, speed, total number of round trips, engine size, load factor, and emission factor. When necessary, BOEM's emission calculation methodology was supplemented with guidance from EPA's Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories (2009) and EPA's 2014 National Emission Inventory Technical Support Document (2016).

Unlike the OCS Air Permit emission calculations, Non-OCS Air Permit emission estimates must account for the time that vessels spend maneuvering in port and while dockside (hoteling). For each vessel, five calculations were made:

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

The following sections discuss the methodologies used to estimate vessel emissions that occur beyond the 25 miles from an OCS source. Engine sizes, emission factors for all pollutants (NOx, VOC, CO, PM10, PM2.5, SO2, HAPs, Pb, and CO2e), and fuel usage were determined using the methods discussed in the OCS Air Permit Emission Calculation Methods described in Section 2.2.1.

Additional and Excluded Vessels

The Non-OCS Air Permit emissions estimate includes emissions from any vessel used for the Project that will travel within US waters (all state and federal waters within the US Exclusive Economic Zone). As a result, the Non-OCS Air Permit emissions estimate includes several vessels that were not included in the OCS Air Permit emissions estimate. For example, the

---

[33] Tetra Tech EC. (2012). Block Island Wind Farm and Block Island Transmission System Environmental Report (ER)/Construction and Operations Plan (COP), Appendix K: Air Emissions Analysis.

Non-OCS Air Permit emissions estimate includes emissions from high-speed heavy cargo vessels used to transport the monopiles, transition pieces, WTGs, and ESPs to the construction staging area while within US waters.

Distance Traveled and Hours of Operation

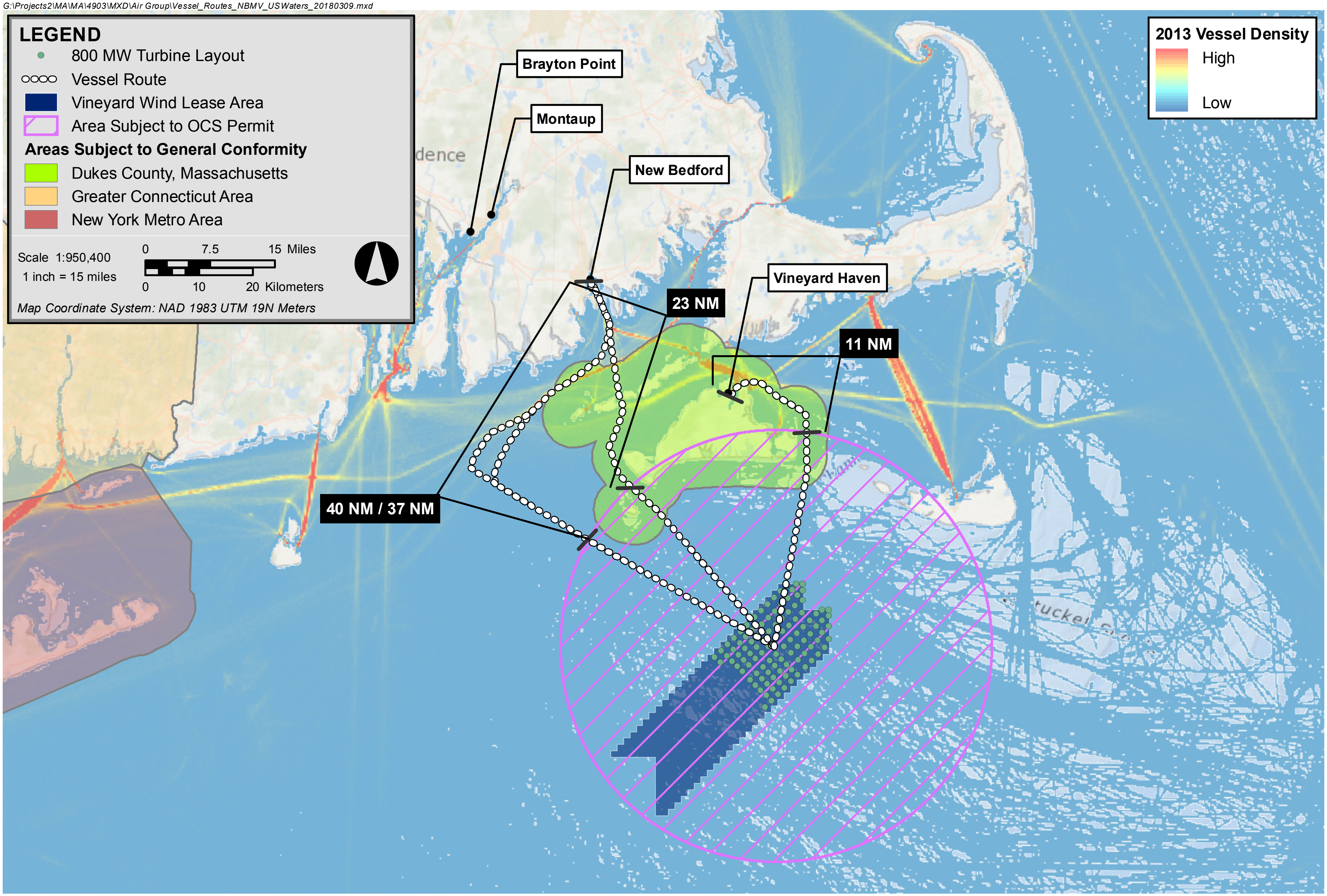
The Non-OCS Air Permit emissions estimate includes vessel emissions that are outside of the OCS Air Permit Boundary and within US waters. The distance traveled by each vessel while within US waters was determined using MORIS: Massachusetts Ocean Management Plan Data and 2013 Automatic Identification System (AIS) data. Using MORIS and 2013 AIS data, most probable vessel routes from the WDA to the New Bedford Terminal were mapped out based on regions of concentrated commerce traffic. It was conservatively assumed that most vessels would travel around the Elizabeth Islands to reach New Bedford, resulting in 37 to 40 nautical mile route from the New Bedford Terminal to the edge of the OCS Air Permit Boundary (see Figure 4-1). This is a conservative estimate, since many smaller vessels will travel along a 23 NM route through Quicks Hole Channel (between Nashawena and Pasque Islands) to reach New Bedford from the WDA. The distance traveled by cable installation vessels outside the OCS Air Permit boundary was based on the maximum length of offshore export cable outside the boundary (68 NM for 3 cables).

Cargo vessels traveling between New Bedford and Europe or Canada were assumed to follow shipping fairways lanes and traffic separation schemes. As shown in Figure 4-2, this vessel route is about 306 - 322 NM long within US waters. Large heavy lift and jack-up vessels used for foundation, ESP, and WTG installation are expected to travel directly to and from a Canadian port (or other international port) to the WDA. Most probable vessel routes between the WDA and Canadian ports were mapped out using AIS data, taking into account marine transportation areas to avoid. As shown in Figure 4-3, this vessel route is approximately 177 -188 NM long within US waters outside the OCS Air Permit Boundary.

Most probable vessel routes from the center of the WDA to Bridgeport and New London were mapped out based on regions of concentrated commerce traffic using 2013 AIS data. It was estimated that vessels traveling between Bridgeport and the WDA would travel 114 NM in US waters outside of the OCS Air Permit Boundary. Vessels traveling between New London and the WDA were estimated 63 NM in US waters outside of the OCS Air Permit Boundary (see Figure 4-4). Cargo vessels traveling between Europe or Canada to Bridgeport would follow shipping lanes and traffic separation schemes, resulting in a 366 - 377 NM route within US waters. International vessels traveling to New London would follow a 315 – 325 NM route within US waters (see Figure 4-5).

For offshore construction, Vineyard Wind's engineering team initially provided the number of vessel trips and operating days required for the construction a 400 MW Project. The construction phase emissions estimate was first calculated for a 400 MW Project and then the

G:\Projects2\MA\MA\4903\MXD\Air Group\Vessel_Routes_NBMV_USWaters_20180309.mxd



Service Layer Credits: Esri, Garmin, GEBCO, NOAA NGDC, and other contributors

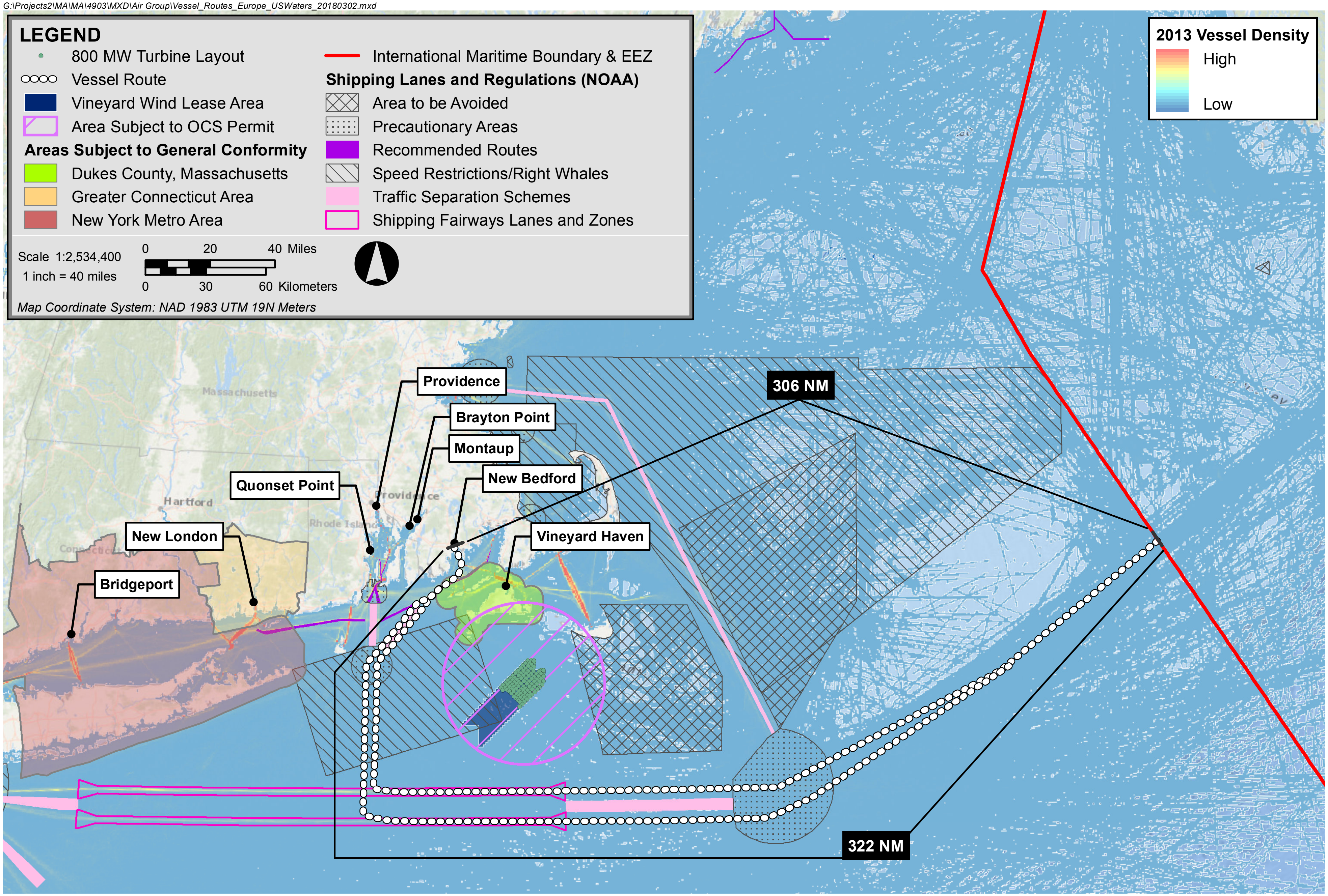
Vineyard Wind Project

VINEYARD WIND

Figure 4-1

New Bedford and Vineyard Haven Vessel Routes through US Waters

G:\Projects2\MA\MA\4903\MXD\Air Group\Vessel_Routes_Europe_USWaters_20180302.mxd



Service Layer Credits: Sources: Esri, GEBCO, NOAA, National Geographic, Garmin, HERE, Geonames.org, and other contributors

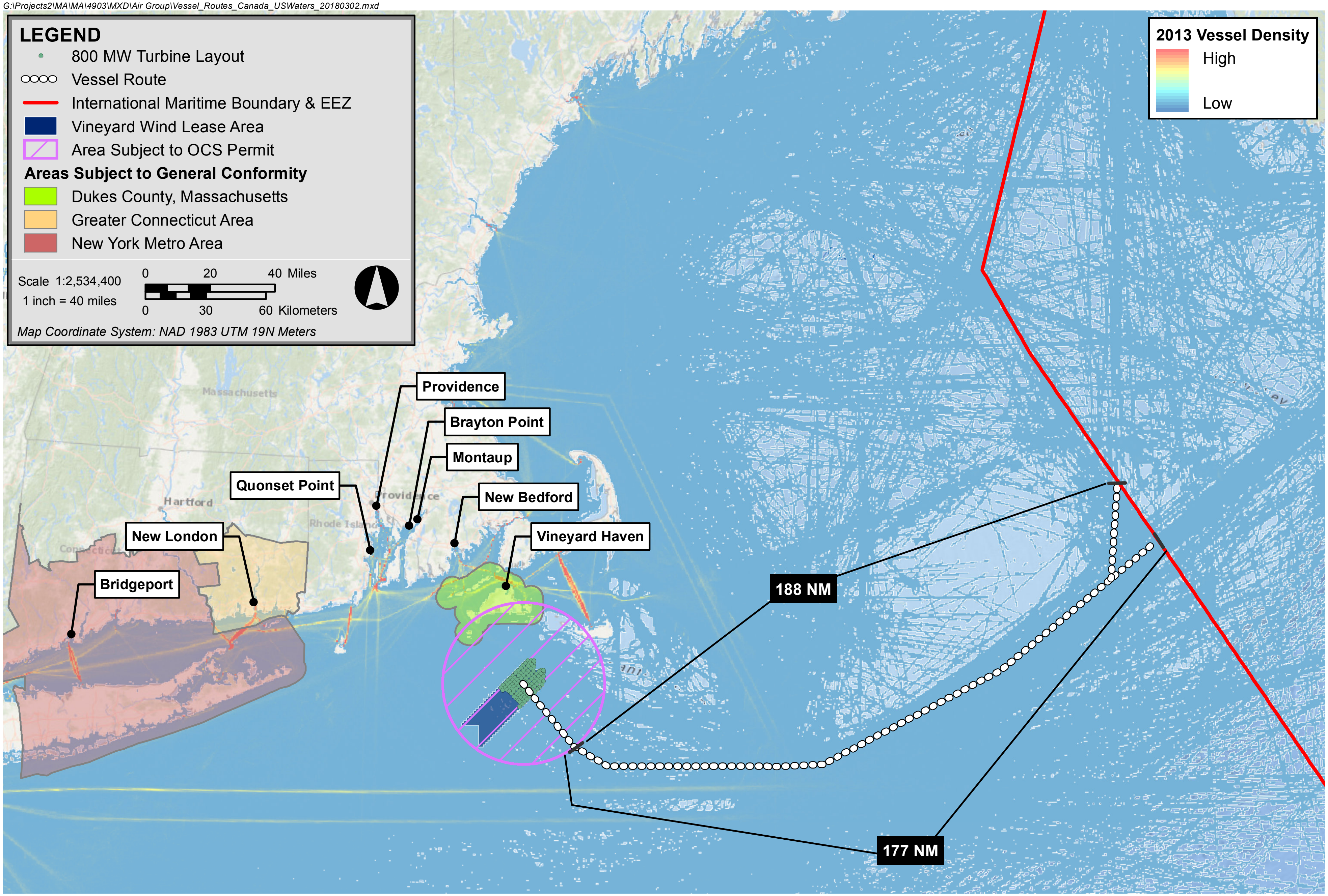
Vineyard Wind Project

VINEYARD WIND

Figure 4-2

Europe/Canada to New Bedford Vessel Routes through US Waters

G:\Projects2\MA\MA\4903\MXD\Air Group\Vessel_Routes_Canada_USWaters_20180302.mxd



Service Layer Credits: Sources: Esri, GEBCO, NOAA, National Geographic, Garmin, HERE, Geonames.org, and other contributors

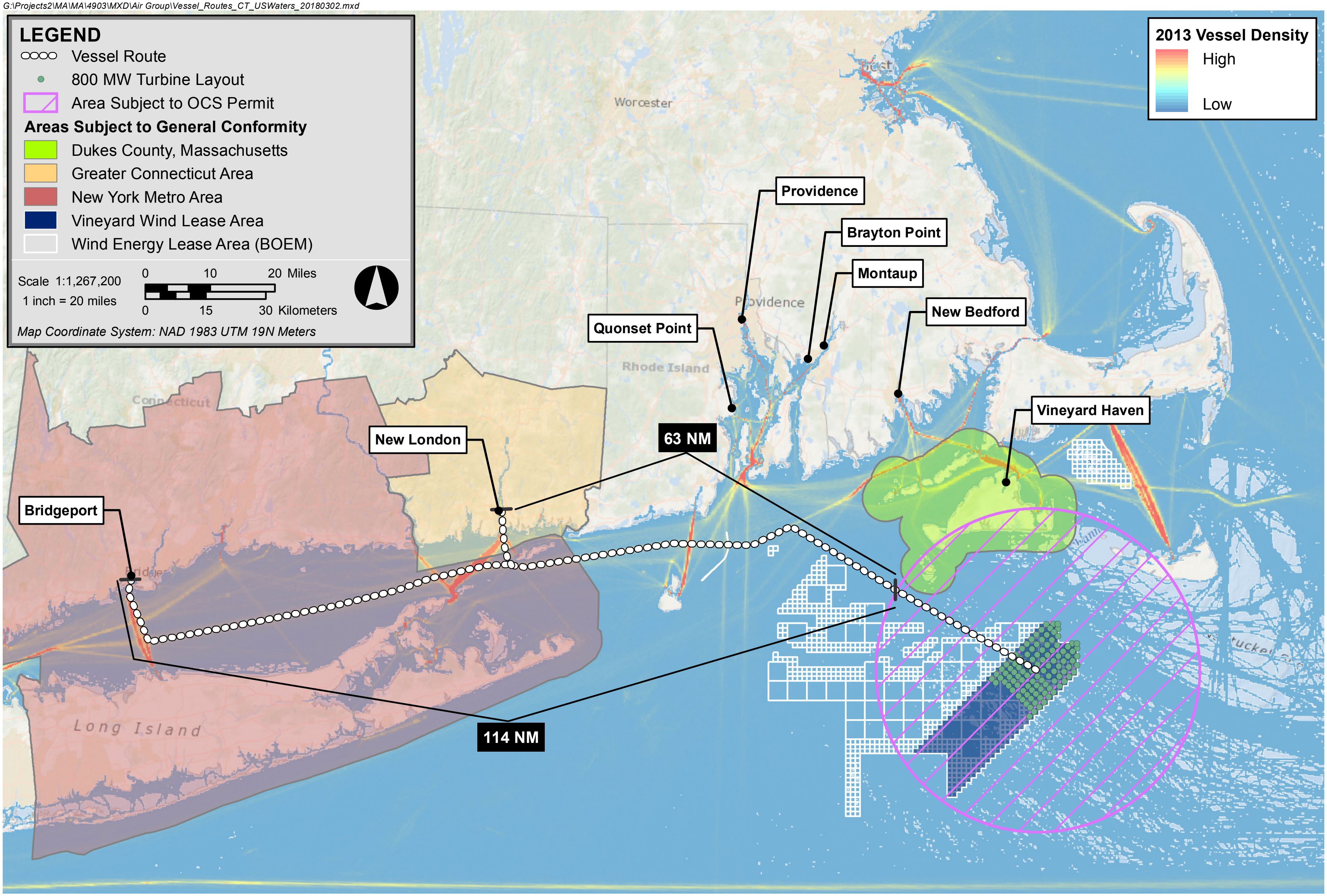
Vineyard Wind Project

VINEYARD WIND

Figure 4-3

Canadian Port to WDA Vessel Route through US Waters

G:\Projects2\MA\MA\4903\MXD\Air Group\Vessel_Routes_CT_USWaters_20180302.mxd



Service Layer Credits: Sources: Esri, GEBCO, NOAA, National Geographic, Garmin, HERE, Geonames.org, and other contributors

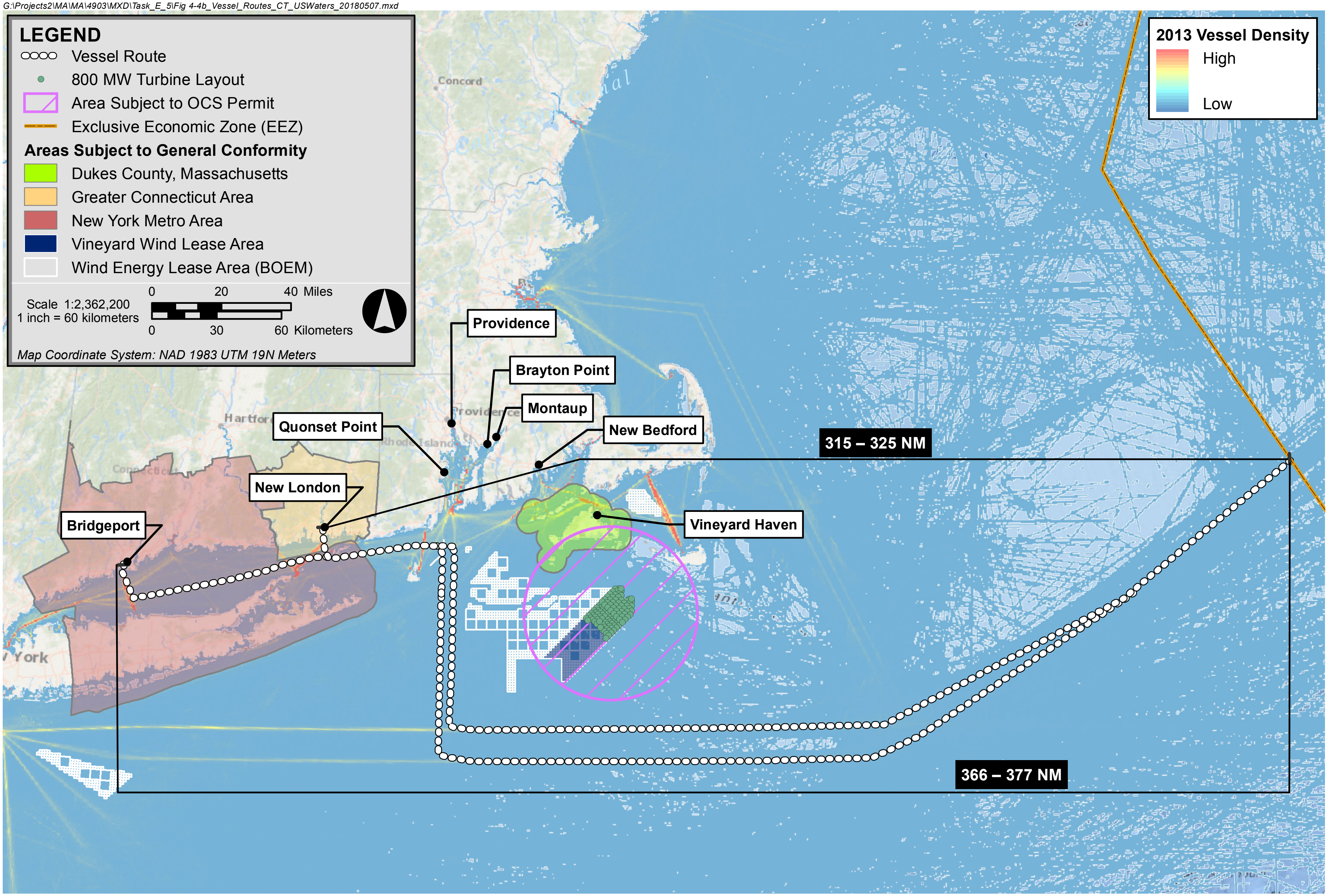
Vineyard Wind Project

VINEYARD WIND

Figure 4-4

Bridgeport and New London Vessel Routes through US Waters

G:\Projects2\MA\MA\4903\MXD\Task_E_5\Fig 4-4b_Vessel_Routes_CT_USWaters_20180507.mxd



Service Layer Credits: Esri, Garmin, GEBCO, NOAA NGDC, and other contributors

Figure 4-5

Europe/Canada to Bridgeport and New London Vessel Routes through US Waters emissions estimate was doubled for most construction activities to derive the emissions estimate for an 800 MW Project[34]. For the O&M phase, the number of vessel trips and duration of each activity were provided for an 800 MW Project.

For the Non-OCS Air Permit emissions estimate, one round trip was added to the number of round trips provided in the OCS Air Permit emissions estimate to account for the vessel's initial trip to the construction staging area from another port and final departure from the construction staging area to another port. This is a conservative estimate since the port of New Bedford will likely be the homeport of several harbor craft (e.g. tugs and crew transfer vessels) used for the Project.

Hours of operation for main engines while in transit were calculated from the vessel's speed and total distance traveled by the vessel when outside the 25-mile OCS Air Permit Boundary and within US waters. Hours spent maneuvering in port were based on typical maneuvering times by vessel type provided in the 2014 NEI[35] (see Table 3-3) and the number of round trips.

For all vessels, it was assumed that all main engines used for propulsion would not operate while the vessel is dockside per 2014 NEI (2016) guidance. For vessels equipped with Category 1 and 2 engines (except for some larger vessels such as jack-up vessels), it was assumed that neither the propulsion nor auxiliary engines would operate while the vessel was dockside to conserve fuel (EPA, 2016). For Category 3 and large Category 2 vessels, auxiliary engines were assumed to be hoteling any time the vessel is outside of the OCS Air Permit Boundary and not in transit or maneuvering in port.

Load Factor

As described in Section 2.2.1, a load factor of 0.83 was used for main (propulsion) engines in transit. Consistent with the 2014 NEI (2016) and the BOEM Emission Estimating Tool, a load factor of 0.20 was used for main (propulsion) engines while maneuvering in port. Since some export cable laying will be performed by vessels that use dynamic positioning outside the OCS Air Permit Boundary, a load factor of 0.4 was used for the maneuvering activities (both in port and along the export cable) of certain export cable laying vessels (see discussion of DP load factors in Section 2.2.1.1).

---

[34] The emissions estimate for offshore export cable laying for a 400 MW Project was multiplied by 1.25 to convert the estimate to an 800 MW Project. This is because the offshore export cable installation will be largely the same for a 400 MW and 800 MW Project; installation of the 800 MW simply requires the additional installation of an inter-link cable between the two ESP locations.

[35] From 2014 NEI (2016), Table 4-98: Estimated Maneuvering Time by Vessel Type. The maneuvering time includes time spent approaching the port and time spent departing from the port.

Auxiliary engine load factors for vessels whose main engines are Category 3 engines were taken from *Table 2-7: Auxiliary Engine Load Factor Assumptions* of EPA's Port-Related Emission Guidance (2009), shown in Table 2-3. 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. For auxiliary engines during hoteling, the "hotel" load factor was selected.

Load factors from *Table 3-3: EPA Load Factors for Harbor Craft*[36] (shown in Table 2-4) were used for auxiliary engines on Category 1 and 2 vessels while in transit and maneuvering in port. For large Category 2 vessels whose engines will not turn off in port, load factors from *Table 2-7: Auxiliary Engine Load Factor Assumptions* were used for auxiliary engines while hoteling.

4.2.2 Helicopters

Non-OCS Air Permit emission estimates for helicopters were determined for using the same method used in the Section 2.2.2. However, the distance traveled by each helicopter was only includes airspace outside of the 25-mile OCS Air Permit Boundary. Emissions from helicopters traveling out of Martha's Vineyard Airfield were assumed to be entirely accounted for in the OCS Air Permit emissions estimate. It was estimated that helicopters out of Providence Airport would travel 44 miles while in the airspace outside the OCS Air Permit Boundary.

4.2.3 Non-road Engines

Emissions from non-road engines such as cranes, excavators, and drilling rigs were calculated using the latest version of EPA's Motor Vehicle Emission Simulator, MOVES2014a which now incorporates NONROAD2008. Emissions factors from MOVES2014a were used to calculate emissions for each pollutant (NOx, VOC, CO, PM10, PM2.5, SO2, CO2, CH4, and HAPS[37]). To calculate emission factors and fuel consumption rates for this Project, a run was completed for a weekday in August, 2017. Air emissions from non-road engines were calculated based on engines' hours of operation, engine size, load factor, and emission factor using the following equation:

$$E = kW * Hours * LF * EF * 1.10231E\text{-}6$$

---

[36] From EPA's Port-Related Emission Guidance (2009).

[37] MOVES2014a provides emission factors for individual HAPs, which were summed together.

Where:

- $E =$ total emissions, tons
- $kW =$ total engine size, kW
- $Hours =$ total hours of operation
- $LF =$ engine load factor
- $EF =$ emission factor, g/kW-hr
- $1.10231E\text{-}6 =$ g to ton conversion factor

Load factors were from EPA's *Median Life, Annual Activity, and Load Factor Values for Nonroad Engine Emissions Modeling* (2010). Engine sizes, activity types, and hours of operation were largely based on onshore construction emission estimates from other U.S. offshore wind energy projects (Cape Wind, Virginia Offshore Wind Technology Advancement Project (VOWTAP), and Block Island Wind Farm)[38], replaced by project-specific information when possible.

Key assumptions used to generate non-road construction are listed in the table below for each onshore construction activity. These calculations can be found in Attachment F.

Table 4-1 Key Assumptions for Non-road Engine Onshore Construction Activities

All Onshore Construction	• Typical work hours for onshore construction will be 7 am to 5 pm (10-hour days) • All equipment will use ultra-low-sulfur diesel (ULSD)
Construction Staging Activities	• Each monopile and transition piece will take 2 hours to offload and load onto a vessel • Each WTG and ESP will take 6 hours to offload and load onto a vessel • Loading of rock onto the scour protection vessel will take 2 days per round trip • Offloading and loading of export cables, inter-link cables, and inter-array cables onto vessels will take one day per vessel round trip
Trench, Conduit, Duct bank, and Splice Vault Installation	• The maximum length of onshore export cable will be 6 miles. • Maximum trench dimensions are 11ft wide by 8ft deep • Maximum duct bank cross sectional area is 12ft^2 (4′ x 3′ or 6′ x 2′) • Trenching, duct bank installation, concrete pouring occurs will occur a rate of 150 ft per day • There will be one splice vault every 1500ft • Each splice vault will take 1 hour to place by crane
Cable Pulling	• Three of nine cables can be pulled per day per splice vault

---

[38] Onshore construction emission estimates were based on VOWTAP's Air Emission Calculation and Methodology (Tetra Tech, 2014), Block Island Wind Farm and Transmission System's Air Emission Analysis (Tetra Tech, 2012), and Cape Wind's OCS Air Permit Application (ESS Group, 2009).

Table 4-1 Key Assumptions for Non-road Engine Onshore Construction Activities (Continued)

HDD	• Set up of the Horizontal Directional Drilling (HDD) rig will take 4 weeks • HDD will require one week of continuous (24/7) operation per each of the three bore holes • Dismantling the HDD rig will take 2 weeks
Onshore Substation Construction	• The GIS substation will be 3 acres, with a concrete pad 0.66 m thick • Clearing/grading the land for the substation and pouring the foundation will take 1 month • Building the substation will take at most 8 months

4.2.4 Generators

Generators used offshore (on the ESPs and WTGs), were not included in the Non-OCS Air Permit emissions estimate since they are already accounted for in the OCS Air Permit emissions estimate. Generators used during onshore construction (cable pulling) were assumed to be 100 hp generators, and their emissions were estimated using the methodology for non-road engines described above.

4.2.5 On-road Vehicles

Emissions from on-road engines such passenger trucks, flatbed trucks, and dump trucks were also calculated using the latest version of EPA's Motor Vehicle Emission Simulator, MOVES2014a. One MOVES2014a 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 project-level inputs provided by MassDEP for the most current year available (2016). 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 MOVES2014a were used to calculate emissions for each pollutant (NOx, VOC, CO, PM10, PM2.5, SO2, and CO2e). HAPs emissions for on-road vehicles were not available via MOVES and were assumed to be negligible. When not available, PM10 was estimated from PM2.5, assuming 97% of PM10 is PM2.5[39]. Air emissions from on-road engines were calculated based on the distance each vehicle is expected to travel and MOVES2014a emission factors using the following equation:

$$E = Miles * EF * 1.10231E\text{-}6$$

---

[39] PM10 was not provided in MOVES2014a for light commercial trucks. It was assumed that light commercial trucks use diesel fuel. EPA's most recent Exhaust and Crankcase Emission Factor for Nonroad Engine Modeling –Compression Ignition report (2010) states that 97% of PM10 is PM2.5 for diesel engines.

Where:

- $E =$ total emissions, tons
- $Miles =$ total distance traveled, miles
- $EF =$ emission factor, g/mile
- $1.10231E\text{-}6 =$ g to ton conversion factor

As shown in the following table, each type on on-road vehicle used for the Project was assigned to one of 13 vehicle types used in MOVES2014a.

Table 4-2 Assigned Vehicle Types

Vehicle	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: concrete, winch, and boom trucks were characterized as non-road "off highway trucks"

The number of round trips taken by worker's personal vehicles and crew transfer vehicles was based on the duration of each construction 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 F. Key assumptions used to generate on-road construction emission estimates are listed in the table below for each onshore construction activity.

Table 4-3 Key Assumptions for On-road Engine Onshore Construction Activities

All Onshore Construction	• Workers will commute on average 15 miles each way[40] • Vehicles will not idle while at the project
Construction Staging Activities	• There will be 25 port workers

---

[40] US Bureau of Transportation. (2003). From Home to Work, the Average Commute is 26.4 Minutes. *Omnistats*, Vol. 3 (Issue 4). From https://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/omnistats/volume_03_issue_04/pdf/entire.pdf

Table 4-3 Key Assumptions for On-road Engine Onshore Construction Activities (Continued)

Trench, Conduit, Duct bank, and Splice Vault Installation	• Dump trucks have a capacity of 20 cubic yards and travel 30 miles each way • Concrete trucks have a capacity of 9.5 yards and take 2 hours per load, including travel • All dirt and pavement will be hauled away as it is excavated • All backfill will be delivered by dump truck • Plastic duct work will be delivered on one flatbed truck per day • Installation of the onshore export cable will require a 20-man crew
Cable Pulling	• Three of nine cables can be pulled per day per splice vault • Cable pulling will require 2 heavy-duty support trucks and 2 crew trucks
HDD	• HDD will require a 20-person crew
Onshore Substation Construction	• GIS substation construction will require one truck delivery per day • GIS substation construction will require a 20-person crew

4.2.6 Fugitive Emissions

It is possible that electrical equipment at the onshore substation (primarily switchgear) will contain sulfur hexafluoride (SF6). Emissions of SF6 used to insulate electrical equipment at the onshore substation were estimated using the same method used to estimate SF6 emissions on the WTGs and ESPs in Section 2.2.5. It was assumed that the onshore substation will contain the approximately same amount of SF6 as the ESPs. SF6 emissions were based on the storage capacity of SF6 within the equipment and the maximum permissible annual leak rate of 1% per 310 CMR Part 7.72(5)(a)[41].

4.2.7 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. PM10 emissions from onshore export cable installation, HDD, and onshore substation construction were estimated using the following equation:

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

---

[41] The maximum allowable SF6 emission rate beginning in the 2020 calendar year.

Where:

- $E =$ total PM10 emissions, tons
- $Months =$ duration of activity, months
- $Acres =$ area of construction, acres

For the emission estimates, it was assumed that each 150ft section of trench will be an active construction site for two days, the substation construction area will be 3 acres, and the HDD construction staging area will be 1 acre.

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 PM10 and "may result in too high an estimate for PM10 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 the Project. Without any direction from the Chapter 13.2.3 on PM2.5 emissions, it was also conservatively estimated that 100% of PM10 is PM2.5.

4.3 Total Project Emissions within the US

The total air emissions from the Project (within the US) are summarized below. For the construction phase, the total air emissions will depend on the combination of ports used. Three port scenarios were evaluated to determine the maximum total emissions that may occur during the Project's construction phase within the US (see Tables 4-4 through 4-6).

Table 4-4 Total Construction Phase Air Emissions (Exclusive Use of New Bedford Terminal)

	Total Fuel Use (gal)	Total Emissions (tons)											
		NOX	VOC	CO	PM10	PM2.5	SO2	CO2	CH4	N2O	Pb	HAPs	CO2e
Year 1	22,710,363	4,070	105	899	143	138	35.6	259,396	2.19	11.95	0.016	10.0	262,461
Year 2	4,936,817	842	15	204	28	27	2.6	55,968	0.46	2.57	0.004	2.3	56,661
Total	27,647,179	4,912	121	1,103	171	164	38.3	315,364	2.65	14.52	0.020	12.3	319,121

Table 4-5 Total Construction Phase Air Emissions (Primary Use of New Bedford Terminal, Some Bridgeport Use)

	Total Fuel Use (gal)	Total Emissions (tons)											
		NOX	VOC	CO	PM10	PM2.5	SO2	CO2	CH4	N2O	Pb	HAPs	CO2e
Year 1	23,148,435	4,146	106.4	918.1	145.7	139.9	35.7	264,372	2.22	12.18	0.016	10.15	267,498
Year 2	5,362,949	918	16.5	220.9	29.8	28.8	2.7	60,755	0.49	2.80	0.004	2.53	61,510
Total	28,511,384	5,064	122.9	1,139.0	175.5	168.7	38.5	325,128	2.7	15.0	0.020	12.68	329,008

Table 4-6 Total Construction Phase Air Emissions (Primary Use of New Bedford Terminal, Some New London Use)

	Total Fuel Use (gal)	Total Emissions (tons)											
		NOX	VOC	CO	PM10	PM2.5	SO2	CO2	CH4	N2O	Pb	HAPs	CO2e
Year 1	22,860,583	4,095	105.7	906.5	144.1	138.4	35.7	261,138	2.20	12.03	0.016	10.02	264,223
Year 2	5,075,098	867	15.8	209.2	28.2	27.3	2.7	57,521	0.47	2.64	0.004	2.41	58,234
Total	27,935,681	4,961	121.5	1,115.7	172.4	165.7	38.3	318,660	2.67	14.67	0.020	12.43	322,457

As shown above, the use of a secondary port in Bridgeport in addition to New Bedford results in the highest total air emissions estimate.

Vineyard Wind intends to use ports at Vineyard Haven and the New Bedford Terminal to support O&M activities. Since vessels will travel further to reach New Bedford Terminal than Vineyard Haven, and most vessels using Vineyard Haven are unlikely to hotel in port, it is more conservative to assume all vessels travel to New Bedford for the purposes of total O&M phase emissions estimate. This estimate is presented in Table 4-7 below.

Table 4-7 Total Operations and Maintenance Phase Air Emissions

	Total Fuel Use (gal)	Total Emissions											
		NOX	VOC	CO	PM10	PM2.5	SO2	CO2	CH4	N2O	Pb	HAPs	CO2e
30-Year Lifespan (tons)	14,714,970	2,122.6	59.2	542.4	71.1	68.9	9.08	164,623	1.49	7.52	0.010	29.7	241,402
Annual (tpy)	490,499	70.8	2.0	18.1	2.4	2.3	0.30	5,487	0.05	0.25	0.000	1.1	8,047

5.0 AVOIDED EMISSIONS

To quantity the CO2, NOx, and SO2 emissions associated with conventional power generation that would be avoided as a result of the 800 MW Vineyard Wind Project, the following equation was used:

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

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 NPCC New England annual non-baseload output emission rates from EPA's Emissions & Generation Resource Integrated Database (eGRID)[42] shown in Table 5-1.

Table 5-1 eGRID Avoided Emission Factors (g/MW-hr)

Pollutant	CO2	NOx	SO2
eGRID Avoided Emission Factor (g/MW-hr)	483,535	309.8	253.1

The analysis assumes an annual capacity factor of 45%. 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 the Project will be 220 kV three-core high-voltage alternating-current (HVAC) cables encased in cross-linked polyethylene (XPLE) insulation. 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 gives average transmission loss factors for an 800 MW windfarm using three 220 kV three-core HVAC cables with XPLE insulation at 50 km and 100 km for various windspeeds. These values were interpolated to determine an average TLF of 2.9% for the Project's approximately 70-80 km-long export cable (see Attachment E). Table 5-2 quantifies the emissions associated with

---

[42] The displacement analysis uses subregion annual non-baseload output emission rates from eGRID2014(v2) released 2/27/2017 https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid

conventional power generation that would be avoided by using electricity generated from the 800 MW Project over the Project's up to 30-year lifespan. Additional avoided emission calculation details can be found in Attachment E.

Table 5-2 Annual Avoided Air Emissions in New England

Pollutant	CO2	NOx	SO2
Annual Avoided Emissions (tons/year)	1,632,822	1,046	855
Avoided Emissions over Project Lifespan (tons)	48,984,670	31,385	25,641

6.0 REFERENCES

Eastern Research Group. (2017). BOEM Offshore Wind Facilities Emission Estimating Tool Technical Documentation. Retrieved from https://www.boem.gov/Technical-Documentation-stakeholder/

ESS Group. (2009). Revised Cape Wind Emissions Estimates – Methodology.

Lazaridis, L., P. (2005). Economic comparison of HVAC and HVDC solutions for large offshore wind farms under special consideration of reliability. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.66.4595&rep=rep1&type=pdf

Tetra Tech. (2014). Virginia Offshore Wind Technology Advancement Project Research Activities Plan, Appendix I: Air Emission Calculations and Methodology. Retrieved from https://www.boem.gov/Renewable-Energy-Program/State-Activities/VA/2013-12-06_Appendix-I_VOWTAP_Air-Emissions-Calculations_FINAL.aspx

Tetra Tech. (2012). Block Island Wind Farm and Block Island Transmission System Environmental Report (ER)/Construction and Operations Plan (COP), Appendix K: Air Emissions Analysis. Retrieved from http://dwwind.com/wp-content/uploads/2014/08/Environmental-Report-Exec-Summary.pdf

US Environmental Protection Agency (EPA). (2007). Draft regulatory impact analysis: control of emissions of air pollution from locomotive engines and marine compression-ignition engines less than 30 liters per cylinder states. Retrieved from https://nepis.epa.gov/Exe/ZyPDF.cgi/P10023S4.PDF?Dockey=P10023S4.PDF

US Environmental Protection Agency (EPA). (2009). Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories: Final Report. Retrieved from https://archive.epa.gov/sectors/web/pdf/ports-emission-inv-april09.pdf

US Environmental Protection Agency (EPA). (2010). Exhaust and Crankcase Emission Factor for Nonroad Engine Modeling –Compression Ignition report. Retrieved from https://nepis.epa.gov

US Environmental Protection Agency (EPA). (2015a). Commercial Marine Vessels – 2014 NEI Commercial Marine Vessels Final. Retrieved from https://www.epa.gov/sites/production/files/2015-12/documents/2014_nei_commercial_marine_vessels_reviewdraft20151217_cleaned.pdf

US Environmental Protection Agency (EPA). (2015b). Memorandum: Implementing the 2015 ozone National Ambient Air Quality Standards. Retrieved from https://www.epa.gov/sites/production/files/2015-10/documents/implementation_memo.pdf

US Environmental Protection Agency (EPA). (2016). 2014 National Emission Inventory, Version 1 Technical Support Document. Retrieved from https://www.epa.gov/sites/production/files/2016-12/documents/nei2014v1_tsd.pdf

US Environmental Protection Agency (EPA). (2017). Nonattainment areas for criteria pollutants (Green Book). Retrieved from https://www.epa.gov/green-book

Attachment A

Air Emissions Summary

Vineyard Wind Air Emissions Summary for 800 MW Construction (New Bedford Terminal)

Construction Phase	Total Fuel Consumption (gal)	Emissions (tons)											
		NOX	VOC	CO	PM10	PM2.5	SO2	CO2	CH4	N2O	Pb	HAPs	CO2e
OCS Air Permit Emissions													
Year 1	17,812,147	3,269	87	699	109	104	32.1	203,220	1.70	9.48	0.012	7.3	205,780
Year 2	3,928,868	663	13	162	22	21	2.3	44,593	0.39	2.02	0.003	1.8	45,140
Total	21,741,015	3,932	100	862	131	125	34.4	247,813	2.09	11.50	0.015	9.1	250,919
General Conformity Emissions (Dukes County, MA)													
Year 1	1,292,184	219	4	52	7	7	0.8	14,703	0.09	0.71	0.001	0.6	14,893
Year 2	275,734	48	1	11	2	1	0.1	3,106	0.02	0.15	0.000	0.1	3,146
Total	1,567,918	267	5	63	9	9	0.9	17,809	0.11	0.86	0.001	0.7	18,039
Non-OCS Emissions Offshore (includes Conformity Emissions)													
Year 1	4,498,646	780	15	181	26	25	3.5	51,227	0.32	2.47	0.003	1.9	51,891
Year 2	1,007,948	179	3	41	6	5	0.3	11,375	0.07	0.54	0.001	0.5	11,521
Total	5,506,594	959	18	222	32	31	3.8	62,602	0.39	3.02	0.004	2.4	63,412
Onshore Emissions (New Bedford/Barnstable, MA)													
Year 1	399,570	21	3	19	9	9	0.0	4,949	0.16	0.00	0.000	0.8	4,790
Year 2	0	0	0	0	0	0	0.0	0	0.00	0.00	0.000	0.0	0
Total	399,570	21	3	19	9	9	0.0	4,949	0.16	0.00	0.000	0.8	4,790
Total Construction Phase Emissions													
Year 1	22,710,363	4,070	105	899	143	138	35.6	259,396	2.19	11.95	0.016	10.0	262,461
Year 2	4,936,817	842	15	204	28	27	2.6	55,968	0.46	2.57	0.004	2.3	56,661
Total Construction Phase Emissions	27,647,179	4,912	121	1,103	171	164	38.3	315,364	2.65	14.52	0.020	12.3	319,121

Vineyard Wind Air Emissions Summary for 800 MW O&M (New Bedford Terminal/Vineyard Haven)

Operations and Maintenance Phase	Total Fuel Consumption (gal)	Emissions (tons)											
		NOX	VOC	CO	PM10	PM2.5	SO2	CO2	CH4	N2O	Pb	HAPs	CO2e
OCS Air Permit Emissions													
30-Year Lifespan	10,263,637	1,416.3	48.1	364.5	47.3	45.8	8.41	114,344	1.17	5.16	0.007	27.8	158,470
Annual	342,121	47.2	1.6	12.2	1.6	1.5	0.28	3,811	0.04	0.17	0.000	0.9	5,282
General Conformity Emissions													
30-Year Lifespan	1,451,226	232.8	3.5	58.1	7.9	7.6	0.2	16,349	0.10	0.78	0.001	0.6	16,559
Annual	48,374	7.8	0.1	1.9	0.3	0.3	0.0	545	0.00	0.03	0.000	0.0	552
Non-OCS Emissions Offshore (includes Conformity Emissions)													
30-Year Lifespan	4,372,737	703.2	10.7	175.3	23.7	23.0	0.7	49,327	0.30	2.36	0.004	1.8	49,961
Annual	145,758	23.4	0.4	5.8	0.8	0.8	0.0	1,644	0.01	0.08	0.000	0.1	1,665
Onshore Emissions (New Bedford/Barnstable, MA)													
30-Year Lifespan	78,597	3.1	0.4	2.5	0.1	0.1	0.01	953	0.02	0.00	0.000	0.1	32,972
Annual	2,620	0.1	0.0	0.1	0.0	0.0	0.00	32	0.00	0.00	0.000	0.2	1,099
Total Operations and Maintenance Phase Emissions													
30-Year Lifespan	14,714,970	2,122.6	59.2	542.4	71.1	68.9	9.08	164,623	1.49	7.52	0.010	29.7	241,402
Annual	490,499	70.8	2.0	18.1	2.4	2.3	0.30	5,487	0.05	0.25	0.000	1.1	8,047

Vineyard Wind Air Emissions Summary for 800 MW Construction (New Bedford Terminal + New London)

		Emissions (tons)											
Construction Phase	**Total Fuel Consumption (gal)**	**NOX**	**VOC**	**CO**	**PM10**	**PM2.5**	**SO2**	**CO2**	**CH4**	**N2O**	**Pb**	**HAPs**	**CO2e**
OCS Air Permit Emissions													
Year 1	17,812,147	3,269	86.8	699.5	108.6	103.8	32.1	203,220	1.70	9.48	0.012	7.26	205,780
Year 2	3,928,868	663	12.7	162.5	22.0	21.2	2.3	44,593	0.39	2.02	0.003	1.85	45,140
Total	21,741,015	3,932	99.5	861.9	130.5	125.0	34.4	247,813	2.09	11.50	0.015	9.11	250,919
General Conformity Emissions (Dukes County, MA)													
Year 1	1,208,946	204	3.9	48.9	6.9	6.7	0.8	13,768	0.09	0.66	0.001	0.53	13,946
Year 2	192,497	33	0.6	7.7	1.1	1.0	0.1	2,171	0.01	0.10	0.000	0.10	2,199
Total	1,401,442	236	4.4	56.6	8.0	7.7	0.9	15,938	0.10	0.77	0.001	0.63	16,144
General Conformity Emissions (Greater CT)													
Offshore Year 1	151,490	29	0.4	6.4	0.8	0.8	0.0	1,708	0.01	0.08	0.000	0.07	1,729
Offshore Year 2	151,490	29	0.4	6.4	0.8	0.8	0.0	1,708	0.01	0.08	0.000	0.07	1,729
Onshore Year 1	34,655	1	0.2	1.7	0.1	0.0	0.0	445	0.01	0.00	0.000	0.05	446
Onshore Year 2	0	0	0.0	0.0	0.0	0.0	0.0	0	0.00	0.00	0.000	0.00	0
General Conformity Year 1	186,146	30	0.5	8.2	0.9	0.9	0.0	2,153	0.02	0.08	0.000	0.11	2,175
General Conformity Year 2	151,490	29	0.4	6.4	0.8	0.8	0.0	1,708	0.01	0.08	0.000	0.07	1,729
General Conformity Total	337,636	60	0.9	14.6	1.7	1.7	0.0	3,861	0.03	0.16	0.000	0.18	3,905
General Conformity Emissions (New York Metro Area NY-NJ-CT)													
Year 1	73,270	13	0.2	3.0	0.4	0.4	0.0	829	0.01	0.04	0.000	0.03	840
Year 2	73,270	13	0.2	3.0	0.4	0.4	0.0	829	0.01	0.04	0.000	0.03	840
Total	146,539	26	0.4	6.0	0.8	0.8	0.0	1,658	0.01	0.08	0.000	0.06	1,679
Non-OCS Emissions Offshore (includes Conformity Emissions)													
Year 1	4,636,927	804	15.6	186.8	26.8	25.9	3.5	52,781	0.33	2.55	0.004	1.95	53,465
Year 2	1,146,230	204	3.1	46.8	6.3	6.1	0.3	12,928	0.08	0.62	0.001	0.56	13,095
Total	5,783,157	1,008	18.6	233.5	33.1	32.0	3.8	65,709	0.41	3.17	0.004	2.51	66,560
Onshore Emissions (New Bedford/Barnstable, MA)													
Year 1	376,854	20	3.1	18.5	8.7	8.6	0.0	4,692	0.16	0.00	0.000	0.77	4,532
Year 2	0	0	0.0	0.0	0.0	0.0	0.0	0	0.00	0.00	0.000	0.00	0
Total	376,854	20	3.1	18.5	8.7	8.6	0.0	4,692	0.16	0.00	0.000	0.77	4,532
Total Construction Phase Emissions													
Year 1	22,860,583	4,095	105.7	906.5	144.1	138.4	35.7	261,138	2.20	12.03	0.016	10.02	264,223
Year 2	5,075,098	867	15.8	209.2	28.2	27.3	2.7	57,521	0.47	2.64	0.004	2.41	58,234
Total Construction Phase Emissions	27,935,681	4,961	121.5	1,115.7	172.4	165.7	38.3	318,660	2.67	14.67	0.020	12.43	322,457

Vineyard Wind Air Emissions Summary for 800 MW Construction (New Bedford Terminal + Bridgeport)

Construction Phase	Total Fuel Consumption (gal)	Emissions (tons)											
		NOX	VOC	CO	PM10	PM2.5	SO2	CO2	CH4	N2O	Pb	HAPs	CO2e
OCS Air Permit Emissions													
Year 1	17,812,147	3,269	86.8	699.5	108.6	103.8	32.1	203,220	1.70	9.48	0.01	7.26	205,780
Year 2	3,928,868	663	12.7	162.5	22.0	21.2	2.3	44,593	0.39	2.02	0.00	1.85	45,140
Total	21,741,015	3,932	99.5	861.9	130.5	125.0	34.4	247,813	2.09	11.50	0.02	9.11	250,919
General Conformity Emissions (Dukes County, MA)													
Year 1	1,208,946	204	3.9	48.9	6.9	6.7	0.8	13,768	0.09	0.66	0.001	0.53	13,946
Year 2	192,497	33	0.6	7.7	1.1	1.0	0.1	2,171	0.01	0.10	0.000	0.10	2,199
Total	1,401,442	236	4.4	56.6	8.0	7.7	0.9	15,938	0.10	0.77	0.001	0.63	16,144
General Conformity Emissions (New York Metro Area NY-NJ-CT)													
Offshore Year 1	531,736	97	1.3	21.9	2.9	2.8	0.1	6,011	0.04	0.29	0.000	0.22	6,089
Offshore Year 2	531,736	97	1.3	21.9	2.9	2.8	0.1	6,011	0.04	0.29	0.000	0.22	6,089
Onshore Year 1	34,655	1	0.2	1.7	0.1	0.0	0.0	445	0.01	0.00	0.000	0.05	446
Onshore Year 2		0	0.0	0.0	0.0	0.0	0.0	0	0.00	0.00	0.000	0.00	0
General Conformity Year 1	566,391	98	1.5	23.6	3.0	2.9	0.1	6,457	0.05	0.29	0.000	0.27	6,534
General Conformity Year 2	531,736	97	1.3	21.9	2.9	2.8	0.1	6,011	0.04	0.29	0.000	0.22	6,089
General Conformity Total	1,098,127	196	2.9	45.5	5.9	5.7	0.2	12,468	0.08	0.58	0.001	0.49	12,623
Non-OCS Emissions Offshore (includes Conformity Emissions)													
Year 1	4,924,779	856	16.3	198.4	28.4	27.4	3.6	56,015	0.35	2.70	0.00	2.07	56,740
Year 2	1,434,081	255	3.8	58.4	7.8	7.6	0.4	16,162	0.10	0.77	0.00	0.68	16,370
Total	6,358,860	1,111	20.1	256.8	36.2	35.0	4.0	72,177	0.45	3.48	0.00	2.76	73,111
Onshore Emissions (New Bedford/Barnstable, MA)													
Year 1	376,854	20	3.1	18.5	8.7	8.6	0.0	4,692	0.16	0.00	0.00	0.77	4,532
Year 2	0	0	0.0	0.0	0.0	0.0	0.0	0	0.00	0.00	0.00	0.00	0
Total	376,854	20	3.1	18.5	8.7	8.6	0.0	4,692	0.16	0.00	0.00	0.77	4,532
Total Construction Phase Emissions													
Year 1	23,148,435	4,146	106.4	918.1	145.7	139.9	35.7	264,372	2.22	12.18	0.016	10.15	267,498
Year 2	5,362,949	918	16.5	220.9	29.8	28.8	2.7	60,755	0.49	2.80	0.004	2.53	61,510
Total Construction Phase E	28,511,384	5,064	122.9	1,139.0	175.5	168.7	38.5	325,128	2.7	15.0	0.020	12.68	329,008

Attachment B

OCS Air Permit Emissions (Includes Notice of Intent)

Attachment B is partially redacted.

Epsilon
ASSOCIATES INC.
20TH
ANNIVERSARY

December 11, 2017

3 Mill & Main Place, Suite 250
Maynard, MA 01754
www.epsilonassociates.com

978 897 7100
FAX 978 897 0099

Donald Dahl
EPA New England Headquarters
5 Post Office Square - Suite 100
Boston, MA 02109-3912
via email at dahl.donald@epa.gov

Subject: Vineyard Wind Notice of Intent per 40 C.F.R. § 55.4

Dear Mr. Dahl:

On behalf of Vineyard Wind, LLC, this letter constitutes a Notice Of Intent (NOI) as required prior to submitting an application for a preconstruction permit for the Vineyard Wind Project under the Outer Continental Shelf (OCS) Air Regulations pursuant to 40 C.F.R. Part 55.

This NOI addresses the requirements in 40 C.F.R. Part 55.4. Each provision of that regulation is restated in boxes below, followed by the information necessary to demonstrate that this NOI satisfies the regulatory requirement.

> 40 C.F.R. 55.4 (a) Prior to performing any physical change or change in method of operation that results in an increase in emissions, and not more than 18 months prior to submitting an application for a preconstruction permit, the applicant shall submit a Notice of Intent ("NOI") to the Administrator through the EPA Regional Office…

Vineyard Wind will be submitting an application for an OCS preconstruction permit within 18 months of this NOI.

> 40 C.F.R. 55.4 (a) [cont'd] …and at the same time shall submit copies of the NOI to the air pollution control agencies of the [Nearest Onshore Area] NOA and onshore areas adjacent to the NOA. This section applies only to sources located within 25 miles of States' seaward boundaries.

As shown in Figure 1, the Nearest Onshore Area (NOA) is Massachusetts. A copy of this NOI is being submitted to the air pollution control agencies of Massachusetts as follows:

Yi Tian
Massachusetts Department of Environmental Protection
1 Winter Street
Boston, Massachusetts 02108

Tom Cushing, Permit Chief
Massachusetts Department of Environmental Protection –Southeast Region
20 Riverside Drive
Lakeville, MA 02347

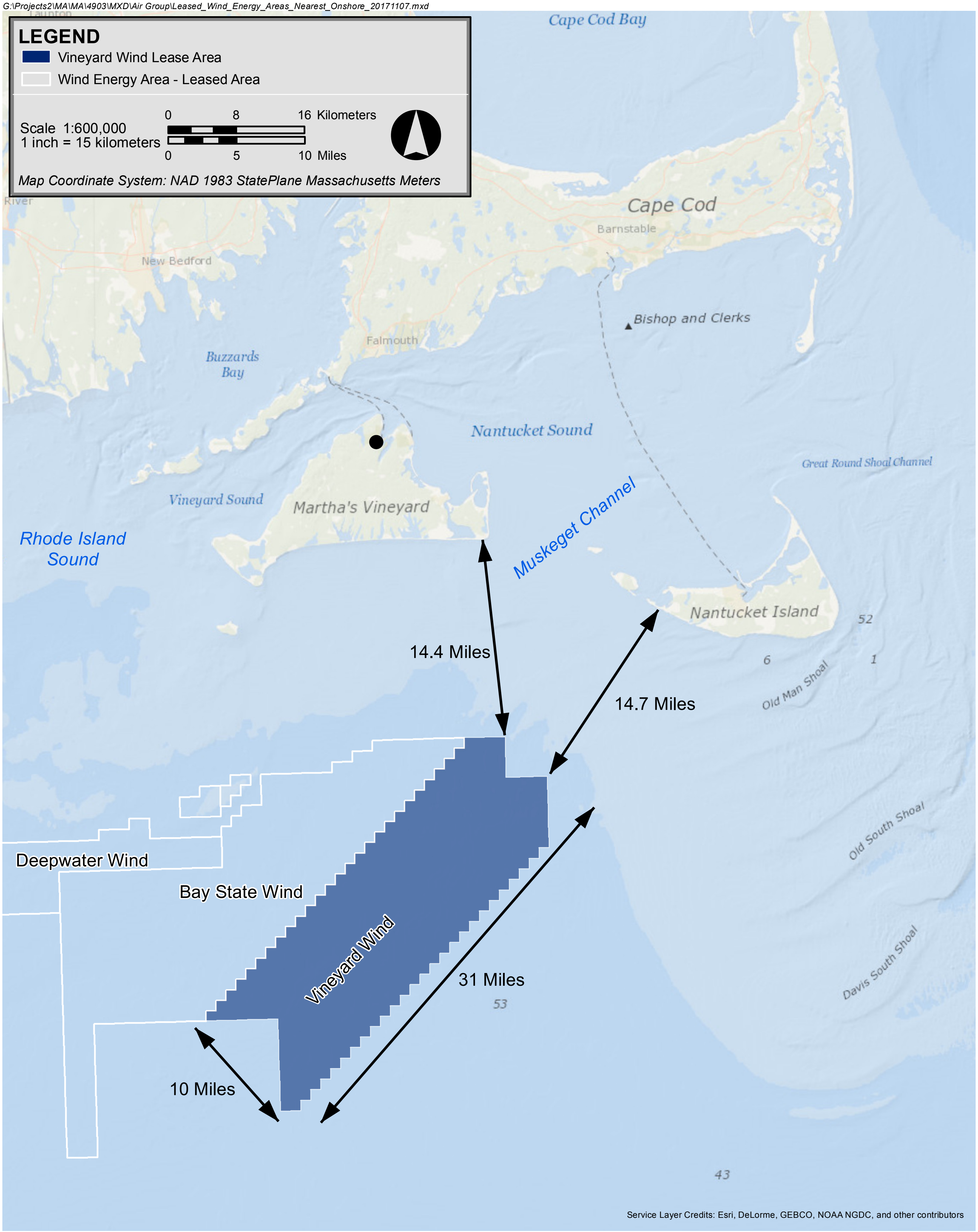
The onshore areas adjacent to the NOA are Rhode Island and New Hampshire. A copy of this NOI is being submitted to the air pollution control agencies of Rhode Island and New Hampshire as follows:

Laurie Grandchamp, Chief
RI DEM Office of Air Resources
235 Promenade Street
Providence, RI 02908

Craig A. Wright, Director
NHDES Air Resources Division
29 Hazen Drive
P.O. Box 95
Concord, NH 03302-0095

40 C.F.R. 55.4 (b) The NOI shall include the following: (1) General company information, including company name and address, owner's name and agent, and facility site contact.

Company Name:	Vineyard Wind, LLC
Company Mailing Address:	700 Pleasant Street, Suite 510 New Bedford, MA 02740
Facility Address:	Lease Area OCS-A-0501
Facility Site Contact:	Rachel Pachter, V.P. Permitting Affairs, Vineyard Wind
Contact Number:	508-640-5136
Contact E-mail Address:	Rpachter@vineyardwind.com



Service Layer Credits: Esri, DeLorme, GEBCO, NOAA NGDC, and other contributors

Vineyard Wind Project

VINEYARD WIND

Figure 1

Vineyard Wind Lease Area - Nearest Onshore Area

40 C.F.R. 55.4 (b) (2) Facility description in terms of the proposed process and products, including identification by Standard Industrial Classification Code.

Vineyard Wind, LLC is developing an ~800 MW offshore wind project (the "Project") for the BOEM Lease Area OCS-A 0501. The Lease Area is approximately 23 kilometers (14 miles) from the southeast corner of Martha's Vineyard as shown in Figure 1. The Project will utilize offshore wind energy as its renewable fuel to generate electric energy for sale. The Standard Industrial Code (SIC) for the Project is 4911. The Project's offshore facilities will include offshore wind turbine generators (WTGs), electrical service platforms (ESPs), and an offshore cable system.

The WTGs for this Project will be amongst the largest, most efficient machines currently demonstrated for offshore use. Power generated by the WTGs will be transmitted via an offshore cable system. Inter-array cables will connect strings WTGs to an ESP. The ESPs include step-up transformers and other electrical gear. A range of export cable routes and substation locations are being considered.

The Project may be constructed in one continuous construction cycle lasting approximately 2 ½ to three years for the onshore and offshore components. Onshore work is expected begin in late 2019 or early 2020. Offshore work will likely commence in 2021. Construction is expected to be completed in Q2, 2022. The project may also be built out in stages of 200 MW or 400 MW.

Heavy lift vessels, tugboats, barges, and jack-up vessels will be used to transport the WTG, MP, TP, and ESP components to the Offshore Project Area. Installation of the WTGs, monopiles, transition pieces, and ESPs will be performed using a combination of "jack-up" vessels and dynamically positioned (DP) vessels. Scour protection will be installed around the WTG and ESP foundations and cable protection will be placed over limited sections of the offshore cable system. Cable-laying will be performed by specialized cable-laying vessels. Prior to cable-laying, a pre-lay "grapnel run" will be made by multipurpose offshore support vessels to locate and clear obstructions such as abandoned fishing gear and other marine debris from the Offshore Export Cable Corridor. To achieve proper cable burial depth, a specialized dredging vessel may also be used in certain areas prior to cable laying to remove the upper portions of sand waves. Crew transfer vessels and helicopters are expected to be used to transport personnel to and from the Offshore Project Area and for marine mammal observations. Descriptions of each vessel type can be found in Table 4.

During the Project's operations and maintenance phase, crew transfer vessels and helicopters will transport crew to the Offshore Project Area for inspections, routine maintenance, and repairs. Jack-up vessels, multipurpose offshore support vessels, and rock-dumping vessels will travel to the Offshore Project Area infrequently for maintenance and repairs.

40 C.F.R. 55.4 (b) (3) Estimate of the proposed project's potential emissions of any air pollutant, expressed in total tons per year and in such other terms as may be necessary to determine the applicability of requirements of this part. Potential emissions for the project must include all vessel emissions associated with the proposed project in accordance with the definition of potential emissions in §55.2 of this part.

The *preliminary* estimate of the Project's potential emissions in terms of tons per year is shown in Table 1, below. The preliminary estimate of the Project's potential air emissions was conducted assuming that all WTG positions, all lightweight ESPs, and the maximum length of inter-array, inter-link, and offshore export cables would be installed for the 800 MW Project, which represents a maximum design scenario. Based on the most aggressive construction schedule under consideration for the 800 MW Project, it was conservatively estimated that half of the WTGs, three quarters of the inter-array cables, and all of the scour protection, offshore export cables, ESPs, and foundations could be constructed in one year. This estimate will be updated in the OCS Air Permit Application to reflect refinements in the Project design and possibly to reflect updated guidance for the OCS Air Permit emission calculations.

The air pollutants are associated with fuel combustion and some incidental solvent use associated with offshore construction and maintenance activities. This includes emissions from vessels servicing or associated with an OCS source while at the source, and while enroute to or from the source when within 25 miles of the source, in accordance with the definition of potential emissions in 40 C.F.R. § 55.2. During the construction phase, emissions will primarily come from engines on vessels and equipment used to transport and install WTGs, monopiles, transition pieces, ESPs, scour protection, and the offshore cable system. Crew transfer vessels and helicopters used to transport personnel to and from the Offshore Project Area will also emit air pollutants during the construction phase. During the Project's operations and maintenance phase, operation of the WTGs will not generate air emissions. However, there will be emissions from vessels and helicopters used to transport crew and equipment to the Offshore Project Area for routine maintenance and infrequent repairs.

The air pollutants emitted during the Project's construction and operational phases include: nitrogen oxides (NOx); volatile organic compounds (VOC); carbon monoxide (CO); particulate matter smaller than 10 microns (PM10); particulate matter smaller than 2.5 microns (PM2.5, a subset of PM10); greenhouse gas emissions as carbon dioxide equivalent (CO2e); sulfur dioxide (SO2); and total hazardous air pollutants (HAPs, individual compounds are either VOC or particulate matter). Potential emissions are listed separately for the construction phase and the operational phase. Emissions from the decommissioning phase are not included in this estimate of potential emission; a separate OCS Air Permit will likely be sought for the decommissioning phase.

Table 1: PRELIMINARY Potential to Emit

Activity	CO2e	NOx	SO2	VOC	CO	PM_{10}	$PM_{2.5}$	HAPs
Construction, worst single year (tons/year)	126,223	1,980	15.3	47.2	441	65.7	63.0	5.0
Operation and Maintenance (tons/year)	3,225	35.7	0.24	1.3	9.2	1.14	1.11	0.83

In context, the maximum projected single-year NOx emissions are approximately 0.22% of the total NOx emissions from commercial marine vessel activity in U.S. waters[1].

During the operational phase, the Vineyard Wind Project would provide up to 800 MW of zero-carbon electric power. Table 2 quantifies the emissions associated with conventional power generation that would be avoided by using electricity generated from the 800 MW Project. The displacement analysis uses NPCC New England air emissions data from EPA's Emissions & Generation Resource Integrated

---

[1] Based on USEPA's *2014 National Emissions Inventory, Version 1 Technical Support Document* (December 2016). According to Table 4-115, commercial marine vessels in the waters of the 50 states, Puerto Rico, and US Virgin Isles (out to 200 nautical miles from the US coastline) emitted 1,215,718 tons of NOx in 2014.

Database (eGRID)[2]. The constituents included in the analysis are nitrogen oxides (NOx), sulfur dioxide (SO2), and carbon dioxide (CO2).

Table 2: Annual Avoided Air Emissions in New England

Pollutant	CO2	NOx	SO2
Avoided Emissions (tons/year)	1,676,913	1,030	880

Table 3 summarizes the emissions of CO2, NOx, and SO2 that would be avoided as a result of the Vineyard Wind Project over the Project's estimated 30-year lifespan (taking into account construction and operational emissions).

Table 3: Avoided Air Emissions in New England over Project Lifespan

Pollutant	CO2	NOx	SO2
Avoided Emissions (tons)	50,108,292	27,819	26,369

As shown in this analysis, the Project would result in vastly lower emissions in the New England region. In addition, the Vineyard Wind Project would decrease the regional reliance on fossil fuels and enhance the reliability and diversity of the energy mix on Cape Cod and in the Commonwealth of Massachusetts. This is particularly important given that several base load/cycling plants have already retired, are slated for retirement, or are approaching the end of life.

40 C.F.R. 55.4 (b)(4) Description of all emissions points including associated vessels.

The majority of air emissions from the Project will come from the main engines, auxiliary engines, and auxiliary equipment on marine vessels used during construction activities. Additional construction-related emissions may come from diesel generators used to supply power to the WTGs and air compressors used to supply compressed air to bubble curtains (underwater noise mitigation devices) during pile-driving. All emission sources during construction are described in the following table.

---

[2] The displacement analysis uses subregion annual non-baseload output emission rates from eGRID2014(v2) released 2/27/2017 https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid

Table 4 Description of Emissions Points

Emission Source	Description of Source
Crew transfer/service vessels	Transport crew to the Offshore Project Area Transport marine mammal observers
Heavy lift crane vessels	Lift, support, and orient the components of each WTG and ESP Install the foundations of the WTGs
Cable installation vessels	Lay and bury transmission cables in the seafloor
Scour protection installation vessels	Deposit a layer of stone around the WTGs' foundations to prevent the removal of sediment by hydrodynamic forces
Multipurpose offshore support vessels	Clear the seabed floor of debris prior to laying transmission cables
Tugboats	Transport equipment and barges to the Offshore Project Area
Anchor handling tug supply vessels	Install bubble curtains (underwater noise mitigation devices)
Jack-up vessels	Transport WTG components to the Offshore Project Area Extend legs to the ocean floor to provide a safe, stable working platform
Dredging vessels	Used in certain areas prior to cable laying to remove the upper portions of sand waves
Air compressors	Supply compressed air to the bubble curtains
Temporary diesel generators	Temporarily supply power to the WTG prior to the turbine becoming operational
Helicopters	Transfer crew to the Offshore Project Area
Fugitive emissions of solvents, paints, and coatings	Fugitive emissions from solvents and paints/coatings

Emissions during the Project's operational phase will come from vessels, generators, air compressors, and helicopters used during routine maintenance and repair activities. Emission sources during the operational phase of the Project include:

- Crew transfer/service vessels
- Scour protection installation vessels

- Multipurpose offshore support vessels
- Tugboats
- Jack-up vessels
- Emergency generators
- Air Compressors
- Helicopters

A complete description of all of the emission points associated with Vineyard Wind's 800MW offshore wind project including engine sizes, hours of operation, load factors, emission factors, and fuel consumption rates will be provided in the OCS Air Permit application.

40 C.F.R. 55.4 (5) Estimate of quantity and type of fuels and raw materials to be used.

Fuel use, provided in Table 5, was calculated using the engine size, fuel consumption rate, load factor, and total operating hours of each emission source. All non-road equipment, emergency generators, jack-up vessels, crew transfer vessels, tugboats, and other smaller Category 1 and 2 vessels will use No. 2 fuel oil. Some larger vessels may use Heavy Fuel Oil (No. 5 and 6 fuel oil). Helicopters will use jet fuel (No. 1 fuel oil).

Table 5: PRELIMINARY Fuel Use, gallons per year

Activity	Fuel Type	Fuel Use
Construction, worst single year	Fuel oil	10,982,416
Operations and Maintenance	Fuel oil	286,476

During the construction phase, it is anticipated that approximately 50% of fuel used will be diesel fuel, about 50% will be Heavy Fuel Oil, and a small quantity of jet fuel will be used by helicopters. During the operational phase, approximately 77% of the fuel used is expected to be diesel fuel, 20% is expected to be jet fuel, and 3% is expected to be Heavy Fuel Oil.

40 C.F.R. 55.4 (6) Description of proposed air pollution control equipment.

The engines and generators used in this Project will be certified by the manufacturer to comply with applicable non-road or marine engine emission standards. For most engines, these standards will be met by optimizing the combustion process. Engine manufacturers will optimize the combustion process to avoid incomplete combustion and avoid "hot-spots" that can form NOx. Optimization steps will differ from engine to engine and can include changes to "fuel injection timing, pressure, and rate (rate shaping), fuel nozzle flow area, exhaust valve timing, and cylinder compression volume[3]." Controls can also include the use of water injection and exhaust gas recirculation to cool the combustion temperature, and on the newest engines can include selective catalytic reduction to reverse the NOx formation reaction.

40 C.F.R. 55.4 (7) Proposed limitations on source operations or any work practice standards affecting emissions.

Emissions from marine vessels will be minimized by the use of modern equipment that complies with domestic and international regulations. Under Annex VI of the MARPOL treaty, the International Maritime Organization (IMO) set global limits on the sulfur content of fuel oil used aboard U.S. and foreign vessels and on NOx emissions from any vessel built after 2000 with engine sizes greater than 130 kW. The emission standards are commonly referred to as Tier I, II, and III standards, and are based on the vessel's model year, engine size, and maximum engine speed. These emission limits are even more stringent within Emission Control Areas (ECAs). The Offshore Project Area is located within the waters of the North American ECA, which extends 200 nautical miles from most of the U.S. and Canadian coastline. Since the Offshore Project Area is located in an Emission Control Area (ECA), all applicable vessels operating within 25 miles of the Project area must comply with the following requirements at a minimum:

Table 6: MARPOL Annex VI NOx Emission Limits

Tier	Model Year	NOx Limit (g/kWh)			Maximum Fuel Sulfur Content (ppm)
		$n < 130$	$130 \leq n < 2000$	$n \geq 2000$	
Tier I	2000	17.0	$45 \cdot n^{-0.2}$	9.8	1000
Tier II	2011	14.4	$44 \cdot n^{-0.23}$	7.7	1000
Tier III	2016	3.4	$39 \cdot n^{-0.2}$	1.96	1000
n = engine maximum operating speed (rpm)					

---

[3] https://www.dieselnet.com/standards/inter/imo.php

Emission standards for U.S. vessels established by the EPA under 40 C.F.R. Parts 80, 89, 94, 1042, 1043, 1065, and 1068 are even more stringent for certain vessels. As of June 1, 2012, under 40 C.F.R. Part 80 Subpart I, all domestic non-road, locomotive, or marine (NRLM) diesel fuel must have a sulfur content of less than 15 ppm, with the exception of heavy fuel oils (HFO) used in Category 2 and Category 3 marine diesel engines and ECA marine fuel (defined by EPA as fuel oil used in Category 3 marine engines while operating in an ECA). Consequently, all domestic Category 1 engines and Category 2 engines (except those firing HFO) must use ULSD. All domestic Category 3 engines and Category 2 engines using HFO must use fuel oil with a sulfur content of less than 1000 ppm.

Although foreign vessels operating in an ECA can use any fuel oil with a sulfur content of up to 1000 ppm, the Project plans to use ULSD for all jack-up vessels and smaller Category 1 and 2 vessels (e.g. tugboats, crew vessels). It was conservatively assumed that all Category 3 marine vessels that do not possess jack-up capabilities will fire Heavy Fuel Oil (HFO) with a sulfur content of 1000 ppm. Consistent with 40 C.F.R. Part 80 Subpart I, all non-road equipment will use ULSD. Emergency generators located on the WTGs and ESPs will fire ULSD, and will operate for emergencies and reliability testing only.

To track emissions during the construction and operational phases, the hours of operation for each OCS stationary engine, non-stationary engine, and OCS vessel will be monitored and recorded. The sulfur content of all fuel used in all OCS engines will be monitored and documented. Using this information, OCS Source emissions, OCS vessel transit emissions, non-stationary engine emissions, and total OCS emissions of NOx will be calculated and recorded. Operation of the emergency generators on the ESPs will be restricted to 100 hours per year (outside of emergencies) for reliability testing.

40 C.F.R. 55.4 (8) Other information affecting emissions, including, where applicable, information related to stack parameters (including height, diameter, and plume temperature), flow rates, and equipment and facility dimensions.

When possible, the stack height of a vessel was determined from the vessel's specification sheet provided by the manufacturer. If this information was not available, an average stack height of 43 meters was used for ocean going vessels and an average stack height of 6 meters was used for commercial harbor craft[4]. Vessel stack heights are summarized in Table 7 below.

Table 7 Approximate Vessel Stack Heights

Emission Source	Stack Height (m)
Crew transfer/service vessels	6
Heavy lift crane vessels	38
Cable installation vessels	27 - 28
Scour protection installation vessels	30
Multipurpose offshore support vessels	6
Tugboats	6
Anchor handling tug supply vessels	6
Jack-up vessels	43
Dredging vessels	43

40 C.F.R. 55.4 (9) Such other information as may be necessary to determine the applicability of onshore requirements.

Massachusetts is the Nearest Onshore Area (NOA) for the Project. If the NOA becomes the designated Corresponding Onshore Area (COA) per 40 C.F.R. Part 55.5, the Project will be subject to the applicable requirements of the Massachusetts Air Regulations (310 CMR 6.00 - 8.00), which have been incorporated into 40 C.F.R. Part 55 by reference and have been listed in Appendix A of the OCS Air Regulations. If Massachusetts is designated as the COA, the following regulations will apply to the Project:

- 310 CMR 4.00 (Sections 4.01 – 4.04 and 4.10)
- 310 CMR 6.00 (Sections 6.01- 6.04)
- 310 CMR 7.00 (Sections 7.00 – 7.09, 7.11 – 7.15, 7,18,7.19, 7.21, 7.22, 7.24-26, 7.32, 7.60, 7.70, 7.71, and Appendices A-C)
- 310 CMR 8.00 (Sections 8.01 – 8.08, 8.15, and 8.30)

---

[4] Average vessel stack heights are from California EPA Air Resources Board's *Appendix G: Draft Diesel Particulate Matter Exposure Assessment Study for the Ports of Los Angeles and Long Beach* (2005).

However, the Massachusetts regulations have been revised since the last update to 40 C.F.R. Part 55. Per 40 C.F.R. Part 55.12, upon receipt of this NOI, EPA will conduct a consistency review of regulations in the onshore area and update 40 C.F.R. Part 55 to include all applicable federal, state, and local requirements.

40 C.F.R. 55.4 (10) Such other information as may be necessary to determine the source's impact in onshore areas.

Since the Offshore Project Area is approximately 14 miles offshore, to the southeast of the mainland, and prevailing winds are from the west, the Project is unlikely to have any effect on onshore areas. Further, construction emissions will be temporary, and operational emissions will be a small fraction of existing marine vessel emissions in the area. Finally, the Project's impacts will be minimized and mitigated through the OCS Air Permit process. If the NOA becomes the designated Corresponding Onshore Area (COA) per 40 C.F.R. Part 55.5, emissions from the construction-phase OCS sources will need to meet applicable Massachusetts Best Available Control Technology (BACT) and Lowest Achievable Emission Rate (LAER) limits, and will need to offset NOx emissions through the use of emission reduction credits.

Thank you for your attention. Questions or concerns regarding this NOI may be provided to Rachel Pachter, or to me at 978-897-7100 or ajablonowski@epsilonassociates.com.

Sincerely,
EPSILON ASSOCIATES, INC

A Jablonowski

A.J. Jablonowski
Principal

Attachment C

General Conformity Emissions

Attachment C is redacted in its entirety.

Attachment D

NON-OCS Air Permit Emissions

Attachment D is redacted in its entirety.

Attachment E

Avoided Emissions

Avoided Emissions for 800 MW

Inputs	
Total Capacity (MW)	800
Capacity Factor	0.45
Transmission Loss Factor[1]	2.9%
Hours per year	8,760
Power Generated (MW-hr)	3,063,423

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.

ISO NE Emissions[2]

	2015 ISO NE Emissions (kTons)	2015 ISO NE Emissions (Tons)
NOx	18.86	18,860
SO2	9.11	9,110
CO2	39,317.00	39,317,000

2) 2015 Emissions from ISO New England Electric Generator Air Emissions Report Air Emissions Report (2017) Table 1-1 2014 and 2015 New England System Emissions (ktons) and Emission Rates (lb/MWh) https://www.iso-ne.com/static-assets/documents/2017/01/2015_emissions_report.pdf

Avoided Emissions

Pollutant	Avoided Emission Factor (g/MWH)[3]	Avoided Emission Factor (lb/MWH)	Displaced Emissions from Conventional Power Generation (tons/year)	Displaced Emissions Over Project Lifespan (tons)	Fraction of ISO NE Region Emissions (%)[4]
NOx	309.8	0.68	1,046	31,385	6%
SO2	253.1	0.56	855	25,641	9%
CO2	483,535	1,066	1,632,822	48,984,670	4%

3) BOEM avoided emission factors use NPCC New England annual non-baseload output emission rates from EPA's eGRID2014(v2) released 2/27/2017

4) Based on 2015 Emissions from ISO New England Electric Generator Air Emissions Report Air Emissions Report (2017) Table 1-1 2014 and 2015 New England System Emissions (ktons) and Emission Rates (lb/MWh)

Transmission Loss Factors

Maximum length per offshore export cable (km)	75
Maximum length per onshore export cable (km)	10
Total length per cable (km)	85
Average transmission loss factor @ 50 km (800 MW, 220 kV)	1.86
Average transmission loss factor @ 100 km (800 MW, 220 kV)	3.29
Average transmission loss factor for Project (800 MW, 220 kV)	2.9

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

400 MW

	132 kV				220 kV				400 kV			
Wind Speed / Cable Length	8 m/s	9 m/s	10 m/s	11m/s	8 m/s	9 m/s	10 m/s	11m/s	8 m/s	9 m/s	10 m/s	11m/s
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

	132 kV				220 kV				400 kV			
Wind Speed / Cable Length	8 m/s	9 m/s	10 m/s	11m/s	8 m/s	9 m/s	10 m/s	11m/s	8 m/s	9 m/s	10 m/s	11m/s
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

	132 kV				220 kV				400 kV			
Wind Speed / Cable Length	8 m/s	9 m/s	10 m/s	11m/s	8 m/s	9 m/s	10 m/s	11m/s	8 m/s	9 m/s	10 m/s	11m/s
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

	132 kV				220 kV				400 kV			
Wind Speed / Cable Length	8 m/s	9 m/s	10 m/s	11m/s	8 m/s	9 m/s	10 m/s	11m/s	8 m/s	9 m/s	10 m/s	11m/s
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

	132 kV				220 kV				400 kV			
Wind Speed / Cable Length	8 m/s	9 m/s	10 m/s	11m/s	8 m/s	9 m/s	10 m/s	11m/s	8 m/s	9 m/s	10 m/s	11m/s
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

	132 kV				220 kV				400 kV			
Wind Speed / Cable Length	8 m/s	9 m/s	10 m/s	11m/s	8 m/s	9 m/s	10 m/s	11m/s	8 m/s	9 m/s	10 m/s	11m/s
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

	132 kV				220 kV				400 kV			
Wind Speed / Cable Length	8 m/s	9 m/s	10 m/s	11m/s	8 m/s	9 m/s	10 m/s	11m/s	8 m/s	9 m/s	10 m/s	11m/s
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 cable used for the Project)

Attachment F

Supporting Tables

Attachment F is redacted in its entirety.

Attachment G

Vessel and Equipment Specification Sheets

Attachment G is redacted in its entirety.