Kitty Hawk Wind

AVANGRID

Construction and Operations Plan

Appendix N - Air Emissions Calculations and Methodology

September 30, 2022

Submitted by
Kitty Hawk Wind, LLC
1125 NW Couch Street, Suite 600
Portland, Oregon 97209

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

Prepared by
Tetra Tech, Inc.
10 Post Office Square, 11th Floor
Boston, Massachusetts 02109

AVANGRID

Appendix N – Air Emissions Calculations and Methodology

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Prepared by:	Checked by:	Approved by:
TETRA TECH	Amanda Mayhew	Megan E. Higgins
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Construction and Operations Plan
Kitty Hawk North Wind Project
Lease Area OCS-A 0508

Appendix N
Air Emissions Calculations and Methodology

Prepared for:

Kitty Hawk Offshore

Kitty Hawk Wind, LLC
1125 NW Couch Street, Suite 600
Portland, Oregon 97209

Prepared by:

Tetra Tech

Tetra Tech, Inc.
10 Post Office Square, 11th Floor
Boston, Massachusetts 02109

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ACRONYMS AND ABBREVIATIONS

BOEM	Bureau of Ocean Energy Management
CFR	Code of Federal Regulations
CH_4	methane
CMV	commercial marine vessels
CO	carbon monoxide
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
EPA	United States Environmental Protection Agency
electrical service platform (ESP)	Offshore structure that connects the inter-array cables to the offshore export cables
g/kWh	grams per kilowatt-hour
GHG	greenhouse gases
GWP	Global Warming Potential
HAP	hazardous air pollutant
ICF	ICF International
km	kilometer
kW	kilowatt
landfall	The location where the export cables transition from offshore to onshore.
MARPOL	Convention for the Prevention of Pollution from Ships
Lease Area	The designated Renewable Energy Lease Area OCS-A 0508
MOVES	Motor Vehicle Emission Simulator
nm	nautical mile
NO_x	nitrogen oxides
N_2O	nitrous oxide
OCS	Outer Continental Shelf
OGV	ocean-going vessels
offshore export cables	Cables connecting the ESP to the transition bay at the landfall
onshore export cables	Cables connecting the ESP to the transition bay at the landfall
onshore substation site	A site located within the Corporate Landing Business Park in Virginia Beach, Virginia, which will contain the onshore substation, interconnection lines, and switching station
PM	particulate matter
PM_{10}	particulate matter less than 10 microns in diameter
$PM_{2.5}$	particulate matter less than 2.5 microns in diameter
Project	Kitty Hawk North Wind Project
SO_2	sulfur dioxide

VOC	volatile organic compounds
Wind Development Area	Approximately 40 percent of the Lease Area in the northwest corner closest to shore (19,441 hectares)
wind turbine generator	Wind turbine that will generate electricity

N.1 INTRODUCTION

Kitty Hawk Wind, LLC, a wholly owned subsidiary of Avangrid Renewables, LLC, proposes to construct, own, and operate the Kitty Hawk North Wind Project (Project). The Project will be located in the designated Renewable Energy Lease Area OCS-A 0508 (Lease Area). The Commercial Lease of Submerged Lands for Renewable Energy Development on the Outer Continental Shelf (OCS) was awarded through the Bureau of Ocean Energy Management (BOEM) competitive renewable energy lease auction of the Wind Energy Area offshore of North Carolina. The Lease Area covers 49,536 hectares and is located approximately 44 kilometers (km) offshore of Corolla, North Carolina (Figure N-1).

At this time, Kitty Hawk Wind, LLC proposes to develop approximately 40 percent of the Lease Area in the northwest corner closest to shore (19,441 hectares; the Wind Development Area). The Project will connect from the electrical service platform (ESP) through offshore export cables (within a designated corridor) and onshore export cables to the new onshore substation and switching station in the City of Virginia Beach, Virginia, where the renewable electricity generated will be transmitted to the electric grid.

This report describes the methodology applied to calculate the air emissions associated with the Project, as well as the results of the emissions calculations, which are detailed in Attachment N-1. There are six categories of sources for which emissions were calculated:

- Commercial marine vessels (CMVs);
- Helicopters;
- Stationary diesel generator engines;
- Gas-insulated switchgear;
- Nonroad engines; and
- On-road vehicles.

The specific air pollutants estimated from the above listed source categories consist of criteria air pollutants, hazardous air pollutants (HAPs), and greenhouse gases (GHGs). Specific pollutants in each group are as follows:

- Criteria Pollutants:
  - Nitrogen oxides (NO_X);
  - Volatile organic compounds (VOC);
  - Carbon monoxide (CO);
  - Total particulate matter (PM);
  - Particulate matter with aerodynamic diameter 10 micrometers or less (PM_{10});
  - Particulate matter with aerodynamic diameter 2.5 micrometers or less ($PM_{2.5}$); and
  - Sulfur dioxide (SO_2);
- HAPs, which include but are not limited to:
  - Formaldehyde;
  - Acetaldehyde;
  - Benzene;
  - Naphthalene;
  - Acrolein;
  - 1,3-Butadiene;
  - Ethylbenzene; and
  - Polycyclic Organic Matter; and

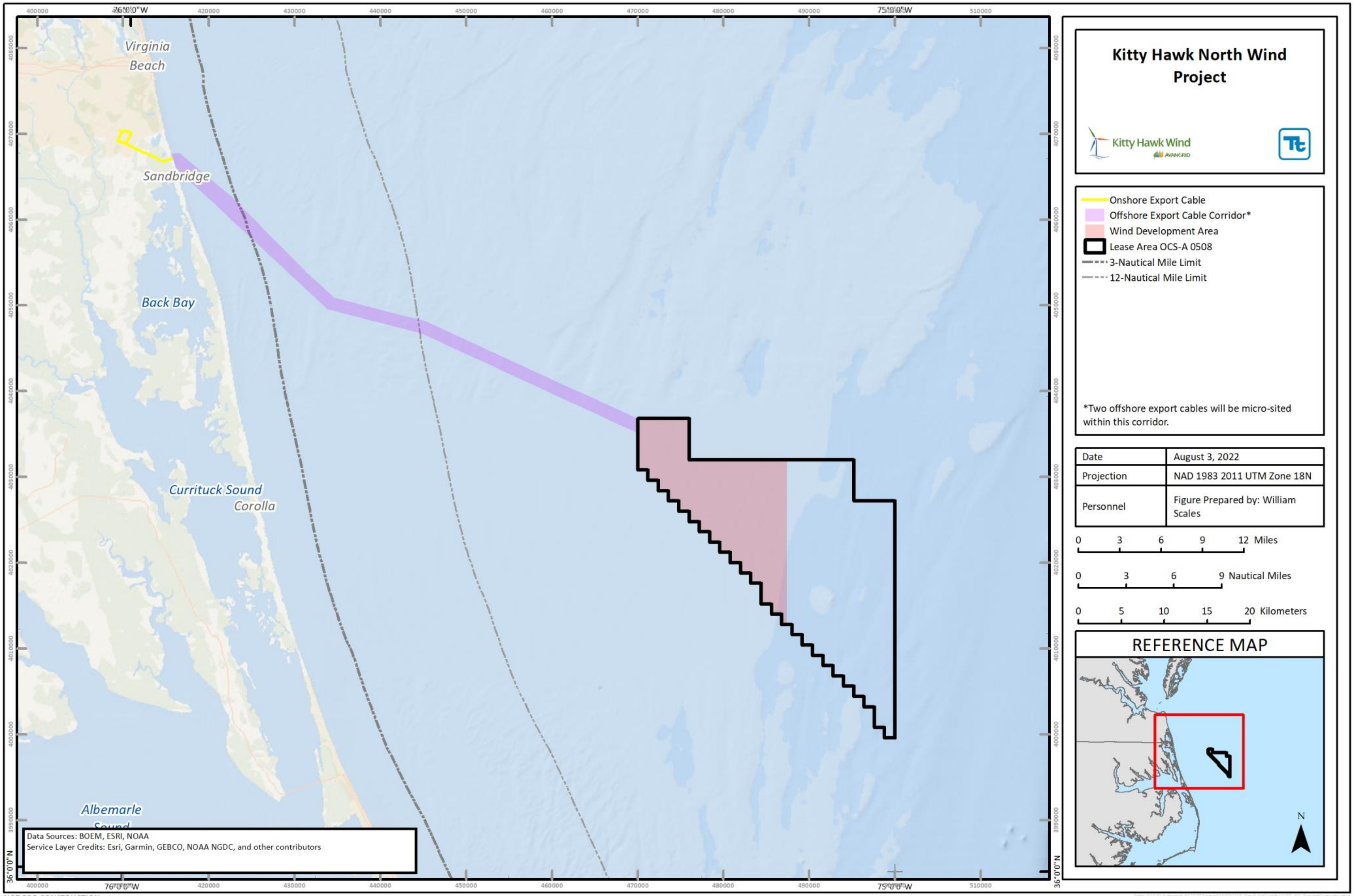

Figure N-1 Offshore Project Overview

- GHGs:
    - Carbon dioxide (CO_2);
    - Methane (CH_4);
    - Nitrous oxide (N_2O); and
    - Sulfur hexafluoride (SF_6).

For the purposes of this analysis, emissions of $PM_{2.5}$, PM_{10}, and PM are conservatively assumed to be the same.

N.2 EMISSION CALCULATION METHODS

Methods for calculating criteria pollutant emissions for the respective emission source categories are summarized in Section N.2.1 through Section N.2.5. Section N.2.7 discusses the methodology for estimating the total GHG emissions for each of the source categories. GHG emissions are presented as "carbon dioxide equivalent" (CO_2e), because the different GHG constituents have different heat absorption capacities.

N.2.1 Commercial Marine Vessels

The calculations presented in Attachment N-1 are based on an assumed typical vessel representative of the type, configuration, and size that the Project anticipates will be employed during the construction and operations phases of the Project. Any vessel names included are presented for illustrative purposes only, with each representing a reasonable worst-case scenario with respect to the potential emissions of the identified vessel category. Actual vessels to be employed during construction and operations activities are subject to change. Vessel operating durations are based on anticipated schedules provided by the Project and may also be subject to change, but, again, have been selected to represent a reasonable worst-case scenario with respect to potential emissions.

N.2.1.1 Emission Factors

ICF International (ICF) was contracted by the United States Environmental Protection Agency (EPA) to produce a guidance document for estimating CMV emissions, "Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories" (ICF 2009), which categorizes most vessels, including tugboats, crew boats, etc. as "harbor craft," and which categorizes ships with larger engines as "ocean-going vessels" (OGVs). The ICF factors selected for estimating emissions from harbor craft and OGVs are presented in Table N-1.

Vessel engines were classified as either Category 1, Category 2, or Category 3 engines based on the following size ranges:

- Category 1: Main or auxiliary engines rated at less than 1,000 kilowatts (kW);

- Category 2: Main or auxiliary engines rated at 1,000 kW or greater (but with a displacement of less than 30 liters per cylinder); and

- Category 3: Main or auxiliary engines with a displacement equal to or greater than 30 liters per cylinder.

Most of the marine vessels used for construction and operations of the Project are assumed to be equipped with either Category 1 or Category 2 engines and will qualify as harbor craft. These categories of engines will use only ultra-low sulfur diesel fuel, which has a sulfur content of 15 parts per million by weight. Some of the larger installation vessels will be equipped with Category 3 main engines, and these vessels have been assumed to use marine diesel oil with a sulfur content of 0.1 percent by weight.

Table N-1 Summary of Harbor Craft and OGV Emission Factors

Minimum Power (kW)		Emission Factor (g/kWh [grams per kilowatt hour])							
		NO_X	VOC	CO	$PM_{10}/PM_{2.5}$	SO_2	CO_2	CH_4	N_2O
Harbor Craft – Worst-Case Rate for Tier 1 and Tier 2 Engines									
Category 1	37 – 75 kW	9.8	0.27	5	0.77	0.0065	690	0.09	0.02
	75 – 130 kW	9.8	0.27	5	0.34	0.0065	690	0.09	0.02
	130 – 225 kW	9.8	0.27	5	0.34	0.0065	690	0.09	0.02
	225 – 450 kW	9.8	0.27	5	0.26	0.0065	690	0.09	0.02
	450 – 560 kW	9.8	0.27	5	0.26	0.0065	690	0.09	0.02
	560 – 1000 kW	9.8	0.27	5	0.26	0.0065	690	0.09	0.02
	1,000+ kW	9.8	0.27	5	0.26	0.0065	690	0.09	0.02
Category 2	All sizes	9.8	0.5	5	0.62	0.0065	690	0.09	0.02
Ocean-going Vessels									
Category 3	Main Engines	13.2	0.50	1.10	0.19	0.397	646.08	0.004	0.031
	Auxiliary Engines	13.9	0.40	1.10	0.18	0.424	690.71	0.004	0.031
MARPOL Tier 3 NOx Standard									
All Categories	All sizes	2.6	--	--	--	--	--	--	--

Notes:

1. Category 1 engines are main or auxiliary engines rated at less than 1,000 kW, Category 2 engines are those rated at 1,000 kW or greater with a displacement less than 30 liters per cylinder, and Category 3 engines are those with a displacement equal to or greater than 30 liters per cylinder.
2. The PM_{10} emission factors presented above for Category 1 and 2 engines have had an adjustment factor applied, as recommended in Section 3.4.2 of the ICF Report (ICF 2009), since the factors as presented in Table 3-8 of the ICF report are based on a fuel sulfur content of 1.5 percent. These factors were adjusted for the now-required 15 pounds per million by weight sulfur content in ultra-low sulfur diesel fuel, by multiplying the emission factors by 0.86.
3. The emission factors for the Category 3 engines were based on a medium-speed diesel vessel using marine diesel oil fuel. The PM_{10} emission factors for Category 3 engines are based on the formulas provided in Section 2.6 of the ICF report and assumed use of marine diesel oil (MDO) fuel with 0.1 percent sulfur content.

Several of the largest construction vessels were assumed to be equipped with Category 3 engines, including the main generator engines and/or main propulsion engines on the following vessels:

- Heavy lift vessels;
- Heavy transport vessels;
- Fall pipe vessels;
- Wind turbine generator installation vessel;
- Wind turbine generator supply vessel; and
- Offshore export and inter-array cable lay vessels.

For these Category 3 engines, the ICF emission factors for OGVs were used, as presented in Table 2-9 of the ICF report. The emission factors for OGVs are based on a 2002 analysis of emission data prepared by Entec (2002). For PM_{10}, the OGV emission factors originally presented in Table 2-9 of the ICF report are based on a fuel sulfur content of 1.0 percent. These factors were adjusted to comply with the International Maritime Organization's North America Sulfur Emissions Control Area requirements, which limit fuel sulfur content to 0.1 percent sulfur by weight. For these vessels, factors for PM_{10} were calculated using the formulas provided in Section 2.6 of the ICF report, assuming the use of marine diesel oil, and using the appropriate values for brake specific fuel consumption provided in Table 2-9 (main engines) and Table 2-16 (auxiliary engines).

The harbor craft emission factors for PM_{10} originally presented in Table 3-8 of the ICF report are based on a fuel sulfur content of 1.5 percent. To adjust these emission factors to reflect the now-required use of ultra-low sulfur diesel fuel, they were multiplied by an adjustment factor of 0.86, as recommended in Table 3-9 of the ICF report. For other criteria pollutants, the emission factors for harbor vessels are based on EPA marine engine emissions standards (i.e., Tier 0 to Tier 3 based on cylinder displacement) and their respective EPA engine categories for CMV main propulsion engines and auxiliary engines. EPA established a tier structure for the emission standards based on age of the engine and cylinder displacement. Tier 0 (baseline), Tier 1, or Tier 2 apply to engines built prior to 2009. Stricter Tier 3 emission standards apply to engines built starting in 2009; however, for the purpose of estimating the CMV emissions for the Project during which harbor craft with older engines might be utilized, the worst-case Tier 1 or Tier 2 emission factors were used providing a conservative estimate.

In addition to the NOx emission factors presented in the ICF report, emission rates were also developed for marine vessels that meet the international Convention for the Prevention of Pollution from Ships (MARPOL) Tier 3 NO_x emission standard, which applies to virtually all marine vessels worldwide that were built during or after 2016, regardless of where they operate. The MARPOL Tier 3 NO_x standard for marine engines is based on an equation that varies based on an engine's speed in rotations per minute. A conservative engine speed of 500 rotations per minute was assumed for use with the following equation:

$$\text{MARPOL Tier 3 } NO_x \text{ standard} = 9 * n^{(-0.2)} \text{ g/kWh} \quad (1)$$

Where:

n is more than 130 but less than 2,000 rotations per minute.

This formula results in a NOx emission rate of 2.6 grams per kilowatt-hour (g/kWh) for an engine speed of 500 rotations per minute. The service operations vessel (SOV) to be used during operations and maintenance of the Project is currently assumed to be a MARPOL Tier 3 vessel built during 2016 or later. As the Project refines its assumptions for construction and operations, other marine vessels meeting the MARPOL Tier 3 NOx standard may also be selected, in which case potential NO_x emissions will be revised as appropriate.

For all engine categories, SO_2 emission factors are based on a mass balance calculation for the appropriate fuel sulfur content of each fuel: 0.1 percent sulfur for MARPOL-compliant marine fuel, and 0.0015 percent for ultra-low sulfur diesel fuel. The fuel consumption rate for each engine type was converted to a mass of fuel using an assumed fuel density of 853 kilograms per cubic meter (7.11 pounds per gallon).

Emissions of HAPs for the marine vessel main engines and auxiliary generators were determined using the methodology identified by EPA for the 2017 National Emissions Inventory, which provides emission factors for each HAP compound as a percentage of the $PM_{2.5}$ or VOC emissions from CMVs. These are tabulated in Attachment N-1.

N.2.1.2 Load Factors

For marine vessel transit activities, main engines were assigned an average load factor of 83 percent, and auxiliary engines were assigned an average load factor of 17 percent, based on Table 3-4 in the ICF report. For marine vessel construction activities in the Wind Development Area or along the offshore export cable corridor, main and auxiliary engines were assigned differing load factors based on engineering judgment.

N.2.1.3 Calculation of Emissions

The basic equation used to estimate annual emissions from each CMV engine and activity is:

$$E = kW \times Act \times LF \times EF \quad (2)$$

Where:

E = emission, grams per year

kW = kilowatts (engine rating)

Act = activity, hours per year

LF = engine load factor (for the activity)

EF = emission factor, g/kWh

The calculated emissions were converted to tons per year by dividing the emissions by the conversion factor from grams to pounds (453.6 grams per pound) and by the conversion factor from pounds to tons (2,000 pounds per ton).

The CO_2e (GHG) emissions for the CMVs were calculated based on the methodology presented in Section N.2.7 below.

N.2.2 Stationary Engines

N.2.2.1 Electrical Service Platform and Onshore Generator Engines

The ESP is assumed to be equipped with two diesel generator engines each rated at 500 kW mechanical output. The onshore substation and switching station are each assumed to be equipped with one spark-ignition generator engine rated at 1,500 kW mechanical output. The ESP generator engines are assumed to be used for both emergency and non-emergency generation, while the onshore substation and switching station generator engines are assumed to be used only for emergency generation, as well as for readiness testing and maintenance purposes. For the ESP engines, potential emissions were estimated by conservatively assuming up to 1,000 operating hours per year for each engine, while potential emissions for the onshore engines assume up to 500 operating hours per year for each engine.

Emissions of NO_X, CO, VOC, and PM from the ESP generator engines were assumed to meet the corresponding EPA Tier 4 final emission standards in Table 1 of 40 Code of Federal Regulations (CFR) §

1039.101 for non-emergency engines of the appropriate size category. Emissions of SO_2 were based on a mass balance assuming a fuel sulfur content of 0.0015 percent by weight, and 100 percent conversion of fuel sulfur to SO_2. Emissions of HAPs for the ESP generator engines were based on factors presented in EPA's AP-42 Compilation of Air Pollutant Emission Factors Section 3.3 for small diesel engines (EPA 1996). Emissions for GHG pollutants (CO_2, CH_4, and N_2O) were based on the emission factors presented in 40 CFR § 98 Tables C-1 and C-2.

Emissions of NO_X, CO, VOC, and PM from the onshore substation and switching station generator engines were assumed to meet the EPA Tier 2 steady state emission standards for nonroad spark-ignition engines from 40 CFR § 1048.101(a). Emissions of PM_{10}, $PM_{2.5}$, SO_2, and HAPs are from AP-42, Table 3.2-3 for four-stroke rich-burn natural gas-fired engines. Emissions for GHG pollutants (CO_2, CH_4, and N_2O) were based on the emission factors presented in 40 CFR § 98 Tables C-1 and C-2.

Emission rates provided in g/kWh were multiplied by the engine's assumed power rating (kW) and by the total annual operating hours (assumed to be 1,000 hours per year for each ESP engine, and 500 hours per year for each onshore engine). The calculated emissions were converted to tons per year by dividing the emissions by the conversion factor from grams to pounds (453.6 grams per pound) and by the conversion factor from pounds to ton (2,000 pounds per ton).

Emissions calculated using EPA's AP-42 Compilation of Air Pollutant Emission Factors (pounds per million British thermal units) were multiplied by the heat input rate (million British thermal units per hour) (calculated from generator's fuel consumption [in gallons] and the diesel fuel's heat content [British thermal units per gallon]), and by the total annual operating hours, converting from pounds to ton (2,000 pounds per ton).

N.2.3 Non-road Engines

Emissions factors for mobile source, non-road engines to be used during the construction of the onshore substation, switching station, onshore export cables, and landfall (including cranes, forklifts, excavators, front end loaders, generators, horizontal directional drill rigs, and other construction equipment) were calculated using the EPA's Motor Vehicle Emission Simulator (MOVES 2014) emission factor modeling system (EPA 2014). To calculate emission factors for the Project, a run was conducted for an assumed construction start year of 2024, using the national database and inventory mode.

Emission factors from the EPA's MOVES (2014) emission model are provided for VOC, NO_X, CO, PM_{10}, $PM_{2.5}$, SO_2, CO_2, and CH_4 in units of grams per horsepower hour, so emissions were estimated by multiplying the emission factor by the non-road engine's assumed power rating (in horsepower), the total operating hours, and the load factor for each different type of machine. Typical load factors for various equipment types were based on Appendix A of EPA's "Median Life, Annual Activity, and Load Factor Values for Nonroad Engine Emissions Modeling" (EPA 2010). The calculated emissions were converted to tons per year by dividing the resultant emissions in grams per year by the conversion factor from grams to pounds (453.6 grams per pound) and by the conversion factor from pounds to ton (2,000 pounds per ton). Emission of HAPs are based on factors from ERG (2003, as cited in EPA 2005) Appendix D, Tables D-1 through D-3. Emissions for N_2O are based on EPA emission factors for construction equipment in Table B-8 of the EPA report on "Direct Emissions from Mobile Combustion Sources" (0.26 grams N_2O per gallon of fuel) (EPA 2016). Fuel consumption for each type of equipment was estimated based on CO_2 emission factor (grams per horsepower hour) generated from the EPA's MOVES (2014) model and the emission factor for the mass of CO_2 generated per gallon of diesel fuel (10.21 kilograms CO_2 per gallon of fuel), as presented in Table A-1 of the EPA (2016) report.

Therefore, CH_4 and N_2O emissions were calculated based on the following equation:

$$E = FC \times \rho \times EF \times 0.4536 \text{ (kilograms per pound)} \times \text{Eng. Rating} \times Act \times LF / 453.6 \text{ (grams per pound)} / 2{,}000 \text{ (pounds per ton)} \quad (3)$$

Where:

E = Emissions, tons per year

FC = Fuel consumption, gallons per horsepower-hour

ρ = Density, pounds per gallon

EF = Emission Factor, grams (CH_4 or N_2O) per kilogram of fuel

Eng. Rating = Engine Rating, horsepower

Act = Activity, hours per year

LF = Load Factor

The CO_2e (GHG) emissions were calculated based on the methodology presented in Section N.2.7.

N.2.4 On-road Vehicles

EPA's MOVES (2014) was used to estimate emissions associated with on-road engines used during construction of the onshore substation, switching station, onshore export cables, and landfall, for an assumed construction start year of 2024. This emission modeling system estimates emissions for a broad range of pollutants from mobile sources such as cars, trucks, and motorcycles, and allows multiple scale analysis.

Emission factors (in pounds per vehicle mile traveled) for VOC, NO_X, CO, PM, SO_2, and CO_2e were calculated for 2024 using the most current database files input into MOVES (2014). Input values were provided by the Virginia Department of Environmental Quality for Newport News, Portsmouth, and the City of Virginia Beach, and the City of Virginia Beach output values were used to estimate on-road vehicle emissions for the Project.

N.2.5 Helicopters

One helicopter is currently assumed to be used to perform crew transfers during the operations and maintenance phase of the Project. BOEM has produced a technical document, "BOEM Offshore Wind Energy Facilities Emission Estimating Tool - Technical Documentation" (BOEM 2017), to assist in estimating emissions for construction and operations of offshore wind energy facilities, including emission from helicopters. Table 4 of the BOEM document provides default emission factors for VOC, NO_x, CO, PM, SO_2, CO_2, CH_4, and N_2O, as well as default fuel consumption rates in gallons per hour, based on four categories of helicopter size. Table 9 of the BOEM document provides default airspeeds for each category of helicopter size. Emissions of HAPs for the helicopter engines were based on factors presented in EPA's AP-42 Compilation of Air Pollutant Emission Factors (AP-42) Section 3.4 for large diesel engines.

Emissions for helicopter crew transfers were estimated assuming a large twin-engine helicopter capable of carrying up to 15 passengers. The "Twin Heavy" helicopter category was selected from the BOEM document, with a default airspeed of 302.9 kilometers per hour. Although the airport for helicopter flights has not been selected, travel distances and durations were estimated using Virginia Beach Airport as the assumed departure location. Emissions were based on 600 round trips per year for the duration of the useful life of the Project, with a round trip duration of 60 minutes per flight.

N.2.6 Gas-Insulated Switchgear

The ESP, wind turbine generators, onshore substation, and switching station will all be equipped with high-voltage circuit breakers (switchgear) that use SF_6 as an insulating material. SF_6 is a GHG that slowly leaks from the sealed switchgear housings into the air. Emissions of SF_6 from the switchgear at the ESP, the wind turbine generators, and the onshore substation were estimated using the switchgear counts and storage quantities provided by the Project, and assuming an annual leakage rate of 0.5 percent by weight per year (IEC 2004, as cited in EPA 2017).

N.2.7 Global Warming Potentials

The GHG emissions from the Project are a result of the combustion of diesel fuel that produces emissions of CO_2, CH_4, and N_2O, as well as leakage of SF_6 from gas-insulated switchgear. GHGs (CO_2, CH_4, N_2O, and SF_6), are typically presented in CO_2 equivalent or "CO_2e," based on the specific Global Warming Potential (GWP) for each gas.

Each GHG constituent has a different heat trapping capability. The corresponding GWP has been calculated by EPA to reflect how long the gas remains in the atmosphere, on average, and how strongly it absorbs energy compared to CO_2. Gases with a higher GWP absorb more energy, per pound, than gases with a lower GWP.

Factors used to calculate CO_2e (GWP) were taken from Table A-1 of 40 CFR 98, Subpart A. The GWPs are 1 for CO_2, 25 for CH_4, 298 for N_2O, and 22,800 for SF_6. Therefore, the equation to calculate CO_2e for each of the sources is:

$$CO_2e = \left[CO_2 \frac{\text{tons}}{\text{yr}} \times CO_2\ \text{GWP}(1)\right] + \left[CH_4 \frac{\text{tons}}{\text{yr}} \times CH_4\ \text{GWP}(25)\right] + \left[N_2O \frac{\text{tons}}{\text{yr}} \times N_2O\ \text{GWP}(298)\right] + \left[SF_6 \frac{\text{tons}}{\text{yr}} \times SF_6\ \text{GWP}(22{,}800)\right] \quad (4)$$

N.3 GEOGRAPHIC ALLOCATION OF EMISSIONS

Some of the CMVs will make a number of round trips to and from shore during the construction and operations phases of the Project. Trips to and from shore will be made for multiple purposes, including loading of construction materials and equipment, refueling and restocking of supplies, crew transfers, and other purposes. Vessel transits will be made between the Wind Development Area and an onshore port location. Therefore, portions of the vessel emissions from each transit will occur in distinct geographic areas for the purposes of regulatory applicability.

For example, transit emissions within 46.3 km (25 nautical miles [nm]) of the Wind Development Area will be assigned to the OCS source potential emissions inventory. Transit emissions occurring in state waters will be assigned to the General Conformity potential emissions inventory for the specific nonattainment or maintenance area in which they occur, or to the attainment area potential emissions inventory for the purpose of addressing National Environmental Policy Act requirements. Those areas that are within 46.3 km (25 nm) of the Wind Development Area but also within state waters will only be considered for General Conformity. Those portions of the transit emissions that occur in waters located beyond 5.6 km (3 nm) from shore and also beyond 46.3 km (25 nm) from the Lease Area have not been included in either potential emissions inventory.

The Project has assumed that Norfolk, Virginia will be the local port and staging area for all purposes during construction and operations of the Project.

N.3.1 Vessel Transits to Shore

To determine the maximum potential transit emissions for General Conformity and National Environmental Policy Act purposes, the following one-way transit distances from Norfolk, Virginia to the Wind Development Area were used to allocate vessel transit emissions by geographic area:

- Norfolk, Virginia to the center of the Wind Development Area (each way):
  - Virginia state waters within the Hampton Roads Air Quality Control Region: 55.6 km (30.0 nm)
  - Federal waters outside OCS radius: 33.3 km (18.0 nm)

- Inside OCS radius: 59.3 km (32 nm)
- **TOTAL: 148.2 km (80.0 nm)**

An average transit speed of 18.5 kilometers per hour (10 knots) was assumed for all vessels. Emissions for all transits located within the 46.3-km (25-nm) OCS source perimeter are inventoried for the OCS air permit. Emissions for all transits located within state waters are inventoried either for the General Conformity assessments (if within a designated nonattainment or maintenance area) or for National Environmental Policy Act purposes (if located outside a designated nonattainment or maintenance area).

Emissions for those portions of transits that are outside the 46.3-km (25-nm) OCS source perimeter (and are also outside state waters) have not been inventoried. Generally, this results in exclusion of most of the ocean-crossing transit distance from overseas ports to the local port, or from overseas ports directly to the Wind Development Area.

N.3.2 All Other Vessel Activities

With the exception of transits to and from Norfolk, Virginia, and transits from overseas ports, emissions from all other vessel activities during construction and operations of the Project were assumed to occur within 46.3 km (25 nm) of the Wind Development Area and are, therefore, part of the OCS source potential to emit.

N.3.3 Helicopter Transits

For the purpose of allocating emissions to geographic areas, helicopter flights were treated in a similar manner to vessel transits, with all flights assumed to originate from Virginia Beach Airport. For the operations and maintenance phase of the Project, distances were based on a straight-line route to the center of the Wind Development Area:

- Virginia Beach Airport to the center of the Wind Development Area (each way):
  - City of Virginia Beach (overland and over state waters: 20.9 km (13 statute miles)
  - Inside OCS radius: 69.2 km (43 statute miles)
  - **TOTAL: 90.1 km (56.0 statute miles)**

N.3.4 Onshore Construction and Operations

Emissions from construction and operations of the onshore substation, switching station, onshore export cables, and landfall will occur the boundaries of City of Virginia Beach, Virginia.

N.4 SUMMARY OF EMISSIONS BY GEOGRAPHIC AREA

Table N-2 through Table N-4 present the potential emissions for each year of construction. Table N-5 presents the potential annual emissions during operations of the Project. Although partial O&M activities are expected to occur during the final year of construction activity in 2029, full-year O&M activities will commence in 2030 and therefore this year represents the maximum potential emissions for ongoing O&M.

Table N-2 Construction Emissions for Calendar Year 2027 (tons)

Geographic Area	VOC	NO_x	CO	PM/ PM_{10}	$PM_{2.5}$	SO_2	HAP	GHG (CO_2e)
Onshore (City of Virginia Beach)	1.40	22.74	6.59	0.85	0.83	0.06	0.30	8,911
State waters (Hampton Roads Air Quality Control Region)	4.62	104.26	41.48	4.71	4.57	0.88	0.47	6,836
Federal waters outside OCS radius	2.27	49.92	21.53	2.45	2.38	0.30	0.23	3,357
Inside OCS radius	269.40	6,683.28	1,158.79	159.52	154.73	159.45	25.02	362,288
TOTAL, ALL AREAS	**277.69**	**6,860.19**	**1,228.40**	**167.54**	**162.51**	**160.70**	**26.02**	**381,392**

Table N-3 Construction Emissions for Calendar Year 2028 (tons)

Geographic Area	VOC	NO_x	CO	PM / PM_{10}	$PM_{2.5}$	SO_2	HAPs	GHG (CO_2e)
Onshore (City of Virginia Beach)	0.56	8.62	2.44	0.37	0.36	0.03	0.12	3,866
State waters (Hampton Roads Air Quality Control Region)	1.19	28.22	11.28	1.19	1.15	0.23	0.12	1,853
Federal waters outside OCS radius	0.72	16.93	6.77	0.71	0.69	0.14	0.07	1,112
Inside OCS radius	61.71	1,523.18	278.34	37.42	36.29	35.44	5.73	83,306
TOTAL, ALL AREAS	**64.18**	**1,576.95**	**298.83**	**39.68**	**38.49**	**35.84**	**6.05**	**90,136**

Table N-4 Construction Emissions for Calendar Year 2029 (tons)

Geographic Area	VOC	NO_X	CO	PM / PM_{10}	$PM_{2.5}$	SO_2	HAPs	GHG (CO_2e)
Onshore (City of Virginia Beach)	0.06	4.41	7.28	0.07	0.07	4.14E-03	0.23	2,236
State waters (Hampton Roads Air Quality Control Region)	3.59	72.33	30.02	2.89	2.80	1.06	0.33	5,595
Federal waters outside OCS radius	0.98	20.48	10.99	0.96	0.93	0.17	0.10	1,731
Inside OCS radius	13.19	208.11	106.35	11.73	11.38	3.00	1.22	18,797
TOTAL, ALL AREAS	**17.82**	**305.33**	**154.64**	**15.64**	**15.18**	**4.24**	**1.88**	**28,358**

Table N-5 Operations and Maintenance Emissions for Calendar Year 2030 Onward (tons per year)

Geographic Area	VOC	NO_X	CO	PM / PM_{10}	$PM_{2.5}$	SO_2	HAPs	GHG (CO_2e)
Onshore (City of Virginia Beach)	0.06	4.41	7.28	0.07	0.07	4.14E-03	0.23	2,236
State waters (Hampton Roads Air Quality Control Region)	3.51	70.25	28.96	2.80	2.72	1.06	0.32	5,446
Federal waters outside OCS radius	0.94	19.23	10.35	0.91	0.88	0.17	0.09	1,642
Inside OCS radius	12.37	193.35	101.95	10.84	10.52	3.00	1.15	18,885
TOTAL, ALL AREAS	**16.88**	**287.24**	**148.53**	**14.62**	**14.18**	**4.23**	**1.80**	**28,209**

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Attachment N-1
Emission Calculations

KITTY HAWK OFFSHORE WIND PROJECT - OCS AIR EMISSION CALCULATIONS
Summary

Construction and Operating Emissions by Calendar Year

2024*

Emissions by geographic area	VOC	NO_X	CO	PM_{10}	$PM_{2.5}$	SO_2	HAPs	CO_2	CH_4	N_2O	CO_2e
Onshore (Virginia Beach)	1.31	20.91	6.02	0.82	0.79	0.06	0.28	8,454.12	0.16	0.20	8,517.79
State waters (Hampton Roads AQCR)	0	0	0	0	0	0	0	0	0	0	0
Federal waters outside OCS radius	0	0	0	0	0	0	0	0	0	0	0
Inside OCS radius	0	0	0	0	0	0	0	0	0	0	0
TOTAL, ALL AREAS	**1.31**	**20.91**	**6.02**	**0.82**	**0.79**	**0.06**	**0.28**	**8,454.12**	**0.16**	**0.20**	**8,517.79**

*Calendar year 2024 includes only onshore construction activities.

2025

Emissions by geographic area	VOC	NO_X	CO	PM_{10}	$PM_{2.5}$	SO_2	HAPs	CO_2	CH_4	N_2O	CO_2e
Onshore (Virginia Beach)	0.65	10.45	3.01	0.41	0.39	0.03	0.14	4,227.06	0.08	0.10	4,258.90
State waters (Hampton Roads AQCR)	3.34	76.73	28.55	3.25	3.15	0.78	0.34	4,869.80	0.48	0.16	4,930.85
Federal waters outside OCS radius	1.50	33.40	13.77	1.57	1.53	0.25	0.15	2,187.28	0.24	0.07	2,214.26
Inside OCS radius	93.77	2,214.39	557.66	71.54	69.40	40.87	9.04	127,145	8.43	4.93	128,825
TOTAL, ALL AREAS	**99.27**	**2,334.97**	**603.00**	**76.77**	**74.46**	**41.93**	**9.67**	**138,429**	**9.24**	**5.27**	**140,229**

2026

Emissions by geographic area	VOC	NO_X	CO	PM_{10}	$PM_{2.5}$	SO_2	HAPs	CO_2	CH_4	N_2O	CO_2e
Onshore (Virginia Beach)	0	0	0	0	0	0	0	0	0	0	0
State waters (Hampton Roads AQCR)	4.53	99.15	42.30	4.88	4.73	0.64	0.47	6,564.37	0.74	0.21	6,644.91
Federal waters outside OCS radius	2.49	53.67	24.84	2.84	2.75	0.21	0.26	3,650.96	0.44	0.11	3,695.14
Inside OCS radius	128.35	2,965.74	817.36	104.35	101.22	49.98	12.48	173,853	12.72	6.55	176,124
TOTAL, ALL AREAS	**135.37**	**3,118.56**	**884.50**	**112.06**	**108.70**	**50.83**	**13.20**	**184,069**	**13.90**	**6.87**	**186,464**

2027 onward

Emissions by geographic area	VOC	NO_X	CO	PM_{10}	$PM_{2.5}$	SO_2	HAPs	CO_2	CH_4	N_2O	CO_2e
Onshore (Virginia Beach)	0.06	4.41	7.28	0.07	0.07	4.14E-03	0.23	975.42	0.05	9.31E-03	2,235.98
State waters (Hampton Roads AQCR)	3.51	70.25	28.96	2.80	2.72	1.06	0.32	5,378	0.49	0.19	5,446
Federal waters outside OCS radius	0.94	19.23	10.35	0.91	0.88	0.17	0.09	1,622	0.18	0.05	1,642
Inside OCS radius	12.27	192.99	100.02	10.82	10.50	2.99	1.15	17,834	1.69	0.59	18,501
TOTAL, ALL AREAS	**16.77**	**286.87**	**146.60**	**14.60**	**14.17**	**4.23**	**1.79**	**25,810**	**2.40**	**0.84**	**27,825**

KITTY HAWK OFFSHORE WIND PROJECT - OCS AIR EMISSION CALCULATIONS
Foundation Construction Emissions (Monopile Option)

Vessels/Equipment	No. of Engines per vessel	1. DP 2.Anchored 3.Spuds	Dimensions (ft) length x width x depth (draft)	Emission Factor Used (see EFs worksheet)	Engine Rating (hp)	Fuel Type	Transit Round Trips	Transit Duration (hrs/round trip)	Non-OCS Operating Days	OCS Operating Days	Non-Transit Operating Hours (hrs/day)	Non-Transit Total Operating Hours (hrs)	Transit Average load (%)	Non-Transit Average load (%)	Transit Fuel Usage Gallons (per vessel)	Non-Transit Fuel Usage Gallons (per vessel)	Total Emissions (Non-Transit) VOC tons	NO$_X$ tons	CO tons	PM$_{10}$ tons	PM$_{2.5}$ tons	SO$_2$ tons	HAPs tons	CO$_2$ tons	CH$_4$ tons	N$_2$O tons	CO$_2$e tons
Heavy Lift Jack-up Vessel 1		3	456 x 164 x 36 (20)																								
-Main Engines	6			3	4,477	Diesel	1	6	0	428	24	10,272	83%	25%	6,139	3,165,737	28.36	748.80	62.40	10.51	10.20	22.51	2.51	36,650.17	0.23	1.76	37,179.89
-Emergency Generator	1			2	1,340	Diesel	0	0	0	0	0	0	0%	0%	0	0	0	0	0	0	0	0	0.00	0	0	0	0
Heavy Lift Jack-up Vessel 2		3	456 x 164 x 36 (20)																								
-Main Engines	6			3	4,477	Diesel	1	6	0	428	24	10,272	83%	25%	6,139	3,165,737	28.36	748.80	62.40	10.51	10.20	22.51	2.51	36,650.17	0.23	1.76	37,179.89
-Emergency Generator	1			2	1,340	Diesel	0	0	0	0	0	0	0%	0%	0	0	0	0	0	0	0	0	0.00	0	0	0	0
Scour Protection Vessel		1	520 x 118 x 44 (31)																								
-Main Generators	3			3	6,032	Diesel	8	16	0	360	24	8,640	83%	45%	88,227	3,228,807	28.93	763.71	63.64	10.72	10.40	22.96	2.55	37,380.34	0.23	1.79	37,920.61
-Aux. Generator	1			2	1,609	Diesel	8	16	0	360	24	8,640	17%	45%	1,765	315,305	2.57	50.40	25.71	3.18	3.09	0.03	0.27	3,548.57	0.46	0.10	3,590.79
-Emergency Generator	1			1	660	Diesel	0	0	0	0	0	0	0%	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
Tug 1		N/A	146 x 40 x 18																								
-Main Engines	2			2	5,600	Diesel	35	16	0	360	24	8,640	83%	45%	262,450	2,195,364	17.90	350.92	179.04	22.17	21.51	0.23	1.90	24,707.52	3.22	0.72	25,001.50
-Aux. Generators	2			1	134	Diesel	35	16	0	360	24	8,640	17%	45%	1,287	52,551	0.23	8.40	4.29	0.22	0.21	5.60E-03	0.02	591.43	0.08	0.02	598.47
Tug 2		N/A	146 x 40 x 18																								
-Main Engines	2			2	5,600	Diesel	35	16	0	360	24	8,640	83%	45%	262,450	2,195,364	17.90	350.92	179.04	22.17	21.51	0.23	1.90	24,707.52	3.22	0.72	25,001.50
-Aux. Generators	2			1	134	Diesel	35	16	0	360	24	8,640	17%	45%	1,287	52,551	0.23	8.40	4.29	0.22	0.21	5.60E-03	0.02	591.43	0.08	0.02	598.47
Tug 3		N/A	146 x 40 x 18																								
-Main Engines	2			2	5,600	Diesel	35	16	0	360	24	8,640	83%	45%	262,450	2,195,364	17.90	350.92	179.04	22.17	21.51	0.23	1.90	24,707.52	3.22	0.72	25,001.50
-Aux. Generators	2			1	134	Diesel	35	16	0	360	24	8,640	17%	45%	1,287	52,551	0.23	8.40	4.29	0.22	0.21	5.60E-03	0.02	591.43	0.08	0.02	598.47
Tug 4		N/A	146 x 40 x 18																								
-Main Engines	2			2	5,600	Diesel	35	16	0	360	24	8,640	83%	45%	262,450	2,195,364	17.90	350.92	179.04	22.17	21.51	0.23	1.90	24,707.52	3.22	0.72	25,001.50
-Aux. Generators	2			1	134	Diesel	35	16	0	360	24	8,640	17%	45%	1,287	52,551	0.23	8.40	4.29	0.22	0.21	5.60E-03	0.02	591.43	0.08	0.02	598.47
Barge 1 for Monopiles	N/A	N/A		N/A	N/A	N/A	35	16	0	360	24	8,640	N/A	N/A	N/A	N/A											
Barge 2 for Monopiles	N/A	N/A		N/A	N/A	N/A	35	16	0	360	24	8,640	N/A	N/A	N/A	N/A											
Barge 1 for Transition Pieces	N/A	N/A		N/A	N/A	N/A	35	16	0	360	24	8,640	N/A	N/A	N/A	N/A											
Barge 2 for Transition Pieces	N/A	N/A		N/A	N/A	N/A	35	16	0	360	24	8,640	N/A	N/A	N/A	N/A											
Bubble Curtain Support Vessel		N/A	150 x 36 x 10																								
_ Main Engines	2			1	750	Diesel	12	16	0	360	24	8,640	83%	10%	12,051	65,338	0.29	10.44	5.33	0.27	0.27	6.97E-03	0.03	735.34	0.10	0.02	744.09
-Aux. Generator	1			1	133	Diesel	12	16	0	360	24	8,640	17%	45%	219	26,070	0.11	4.17	2.13	0.11	0.11	2.78E-03	1.15E-02	293.40	0.04	8.50E-03	296.89
-Bow Thruster Engine	1			1	325	Diesel	12	16	0	360	24	8,640	0%	45%	0	63,705	0.28	10.18	5.20	0.27	0.26	6.79E-03	0.03	716.96	0.09	0.02	725.49
-Aux. Engine	1			1	133	Diesel	12	16	0	360	24	8,640	17%	45%	219	26,070	0.11	4.17	2.13	0.11	0.11	2.78E-03	1.15E-02	293.40	0.04	8.50E-03	296.89
Crew Transfer Vessel 1		N/A	114 x 24 x 7.4																								
-Main Engines	4			1	585	Diesel	52	16	0	52	8	416	83%	10%	81,467	4,908	0.02	0.78	0.40	0.02	0.02	5.23E-04	2.17E-03	55.23	7.20E-03	1.60E-03	55.89
-Aux. Generator	1			1	47	Diesel	52	16	0	52	8	416	17%	45%	335	444	1.95E-03	0.07	0.04	1.87E-03	1.81E-03	4.73E-05	1.96E-04	4.99	6.51E-04	1.45E-04	5.05
-Aux. Engine	1			1	47	Diesel	52	16	0	52	8	416	17%	45%	335	444	1.95E-03	0.07	0.04	1.87E-03	1.81E-03	4.73E-05	1.96E-04	4.99	6.51E-04	1.45E-04	5.05
Crew Transfer Vessel 2		N/A	114 x 24 x 7.4																								
-Main Engines	4			1	585	Diesel	52	16	0	52	8	416	83%	10%	81,467	4,908	0.02	0.78	0.40	0.02	0.02	5.23E-04	2.17E-03	55.23	7.20E-03	1.60E-03	55.89
-Aux. Generator	1			1	47	Diesel	52	16	0	52	8	416	17%	45%	335	444	1.95E-03	0.07	0.04	1.87E-03	1.81E-03	4.73E-05	1.96E-04	4.99	6.51E-04	1.45E-04	5.05
-Aux. Engine	1			1	47	Diesel	52	16	0	52	8	416	17%	45%	335	444	1.95E-03	0.07	0.04	1.87E-03	1.81E-03	4.73E-05	1.96E-04	4.99	6.51E-04	1.45E-04	5.05
Guard/MMO Vessel 1		N/A	41 x 13.5 x 4																								
-Main Engines	2			1	425	Diesel	12	16	0	360	24	8,640	83%	10%	6,829	37,025	0.16	5.92	3.02	0.16	0.15	3.95E-03	0.02	416.69	0.05	1.21E-02	421.65
Guard/MMO Vessel 2		N/A	41 x 13.5 x 4																								
-Main Engines	2			1	425	Diesel	12	16	0	360	24	8,640	83%	10%	6,829	37,025	0.16	5.92	3.02	0.16	0.15	3.95E-03	0.02	416.69	0.05	1.21E-02	421.65
														TOTALS	**1,347,638**	**19,134,066**	**161.94**	**3,791.63**	**969.22**	**125.62**	**121.86**	**68.99**	**15.66**	**218,428**	**14.74**	**8.43**	**221,310**

Notes:

1. Transit emissions are based on an assumed vessel speed of 10 knots for all vessel types, and the following one-way travel distances:
   Overseas port to center of Wind Development Area: 32 nm (only includes portion of transit within 25 nm of the Wind Development Area)
   Norfolk, VA (assumed local port) to center of Wind Development Area: 80 nm
2. The number of transits for each vessel are based on the following assumptions:
   1 round trip to/from overseas port for each heavy lift vessel.
   8 round trips to/from local port for the scour protection vessel (based on assumed capacity to install scour protection for 9 foundations per cargo).
   35 round trips to/from local port for each barge tug for 69 total positions.
   Weekly round trips to/from port for crew transfer vessels.
   Monthly round trips to/from port for construction support vessels and guard vessels.
3. The specific vessels for each operation have not been finalized at this time; however, the vessels identifed for each installation activity are typical sizes for performing this effort.
4. Emission factors for marine vessel engines are from ICF International report to the US EPA "Current Methodologies in Preparing Mobile Source Port-Related Emissions Inventories", April 2009.
5. HAP emission factors for commercial marine vessels were determined using the methodology identified by US EPA for the latest (2017) National Emissions Inventory (NEI); i.e., they are calculated as percentages of the PM$_{2.5}$ or VOC emissions from the CMVs.
6. Average load factors for vessel engines were estimated based on engineering estimates, and on Section 2.5 of the ICF International Report.
7. CO$_2$e emission rates use the following carbon equivalence factors: 25 for CH$_4$, and 298 for N$_2$O.

Foundation Construction Emissions (Monopile Option)

																	Total Emissions (Transit)										
Vessels/Equipment	No. of Engines per vessel	1. DP 2.Anchored 3.Spuds	Dimensions (ft) length x width x depth (draft)	Emission Factor Used (see EFs worksheet)	Engine Rating (hp)	Fuel Type	Transit Round Trips	Transit Duration (hrs/round trip)	Non-OCS Operating Days	OCS Operating Days	Non-Transit Operating Hours (hrs/day)	Non-Transit Total Operating Hours (hrs)	Transit Average load (%)	Non-Transit Average load (%)	Transit Fuel Usage Gallons (per vessel)	Non-Transit Fuel Usage Gallons (per vessel)	VOC tons	NO_X tons	CO tons	PM_{10} tons	$PM_{2.5}$ tons	SO_2 tons	HAPs tons	CO_2 tons	CH_4 tons	N_2O tons	CO_2e tons
Heavy Lift Jack-up Vessel 1		3	456 x 164 x 36 (20)																								
-Main Engines	6			3	4,477	Diesel	1	6	0	428	24	10,272	83%	25%	6,139	3,165,737	0.06	1.45	0.12	0.02	0.02	0.04	4.86E-03	71.07	4.40E-04	3.41E-03	72.10
-Emergency Generator	1			2	1,340	Diesel	0	0	0	0	0	0	0%	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
Heavy Lift Jack-up Vessel 2		3	456 x 164 x 36 (20)																								
-Main Engines	6			3	4,477	Diesel	1	6	0	428	24	10,272	83%	25%	6,139	3,165,737	0.06	1.45	0.12	0.02	0.02	0.04	4.86E-03	71.07	4.40E-04	3.41E-03	72.10
-Emergency Generator	1			2	1,340	Diesel	0	0	0	0	0	0	0%	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
Scour Protection Vessel		1	520 x 118 x 44 (31)																								
-Main Generators	3			3	6,032	Diesel	8	16	0	360	24	8,640	83%	45%	88,227	3,228,807	0.79	20.87	1.74	0.29	0.28	0.63	6.98E-02	1021.42	6.32E-03	0.05	1,036.18
-Aux. Generator	1			2	1,609	Diesel	8	16	0	360	24	8,640	17%	45%	1,765	315,305	1.44E-02	0.28	0.14	0.02	0.02	1.88E-04	1.53E-03	19.86	2.59E-03	5.76E-04	20.10
-Emergency Generator	1			1	660	Diesel	0	0	0	0	0	0	0%	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
Tug 1		N/A	146 x 40 x 18																								
-Main Engines	2			2	5,600	Diesel	35	16	0	360	24	8,640	83%	45%	262,450	2,195,364	2.14	41.95	21.40	2.65	2.57	0.03	0.23	2953.72	0.39	0.09	2,988.86
-Aux. Generators	2			1	134	Diesel	35	16	0	360	24	8,640	17%	45%	1,287	52,551	5.67E-03	0.21	0.10	5.41E-03	5.25E-03	1.37E-04	5.69E-04	14.48	1.89E-03	4.20E-04	14.65
Tug 2		N/A	146 x 40 x 18																								
-Main Engines	2			2	5,600	Diesel	35	16	0	360	24	8,640	83%	45%	262,450	2,195,364	2.14	41.95	21.40	2.65	2.57	0.03	0.23	2953.72	0.39	0.09	2,988.86
-Aux. Generators	2			1	134	Diesel	35	16	0	360	24	8,640	17%	45%	1,287	52,551	5.67E-03	0.21	0.10	5.41E-03	5.25E-03	1.37E-04	5.69E-04	14.48	1.89E-03	4.20E-04	14.65
Tug 3		N/A	146 x 40 x 18																								
-Main Engines	2			2	5,600	Diesel	35	16	0	360	24	8,640	83%	45%	262,450	2,195,364	2.14	41.95	21.40	2.65	2.57	0.03	0.23	2953.72	0.39	0.09	2,988.86
-Aux. Generators	2			1	134	Diesel	35	16	0	360	24	8,640	17%	45%	1,287	52,551	5.67E-03	0.21	0.10	5.41E-03	5.25E-03	1.37E-04	5.69E-04	14.48	1.89E-03	4.20E-04	14.65
Tug 4		N/A	146 x 40 x 18																								
-Main Engines	2			2	5,600	Diesel	35	16	0	360	24	8,640	83%	45%	262,450	2,195,364	2.14	41.95	21.40	2.65	2.57	0.03	0.23	2953.72	0.39	0.09	2,988.86
-Aux. Generators	2			1	134	Diesel	35	16	0	360	24	8,640	17%	45%	1,287	52,551	5.67E-03	0.21	0.10	5.41E-03	5.25E-03	1.37E-04	5.69E-04	14.48	1.89E-03	4.20E-04	14.65
Barge 1 for Monopiles	N/A	N/A		N/A	N/A	N/A	35	16	0	360	24	8,640	N/A	N/A	N/A	N/A											
Barge 2 for Monopiles	N/A	N/A		N/A	N/A	N/A	35	16	0	360	24	8,640	N/A	N/A	N/A	N/A											
Barge 1 for Transition Pieces	N/A	N/A		N/A	N/A	N/A	35	16	0	360	24	8,640	N/A	N/A	N/A	N/A											
Barge 2 for Transition Pieces	N/A	N/A		N/A	N/A	N/A	35	16	0	360	24	8,640	N/A	N/A	N/A	N/A											
Bubble Curtain Support Vessel		N/A	150 x 36 x 10																								
_ Main Engines	2			1	750	Diesel	12	16	0	360	24	8,640	83%	10%	12,051	65,338	0.05	1.93	0.98	0.05	0.05	1.29E-03	5.33E-03	135.63	0.02	3.93E-03	137.24
-Aux. Generator	1			1	133	Diesel	12	16	0	360	24	8,640	17%	45%	219	26,070	9.64E-04	0.03	0.02	9.21E-04	8.93E-04	2.33E-05	9.67E-05	2.46	3.21E-04	7.14E-05	2.49
-Bow Thruster Engine	1			1	325	Diesel	12	16	0	360	24	8,640	0%	45%	0	63,705	0	0	0	0	0	0	0	0	0	0	0
-Aux. Engine	1			1	133	Diesel	12	16	0	360	24	8,640	17%	45%	219	26,070	9.64E-04	0.03	0.02	9.21E-04	8.93E-04	2.33E-05	9.67E-05	2.46	3.21E-04	7.14E-05	2.49
Crew Transfer Vessel 1		N/A	114 x 24 x 7.4																								
-Main Engines	4			1	585	Diesel	52	16	0	52	8	416	83%	10%	81,467	4,908	0.36	13.02	6.64	0.34	0.33	8.69E-03	0.04	916.86	0.12	0.03	927.77
-Aux. Generator	1			1	47	Diesel	52	16	0	52	8	416	17%	45%	335	444	1.48E-03	0.05	0.03	1.41E-03	1.37E-03	3.57E-05	1.48E-04	3.77	4.92E-04	1.09E-04	3.82
-Aux. Engine	1			1	47	Diesel	52	16	0	52	8	416	17%	45%	335	444	1.48E-03	0.05	0.03	1.41E-03	1.37E-03	3.57E-05	1.48E-04	3.77	4.92E-04	1.09E-04	3.82
Crew Transfer Vessel 2		N/A	114 x 24 x 7.4																								
-Main Engines	4			1	585	Diesel	52	16	0	52	8	416	83%	10%	81,467	4,908	0.36	13.02	6.64	0.34	0.33	8.69E-03	0.04	916.86	0.12	0.03	927.77
-Aux. Generator	1			1	47	Diesel	52	16	0	52	8	416	17%	45%	335	444	1.48E-03	0.05	0.03	1.41E-03	1.37E-03	3.57E-05	1.48E-04	3.77	4.92E-04	1.09E-04	3.82
-Aux. Engine	1			1	47	Diesel	52	16	0	52	8	416	17%	45%	335	444	1.48E-03	0.05	0.03	1.41E-03	1.37E-03	3.57E-05	1.48E-04	3.77	4.92E-04	1.09E-04	3.82
Guard/MMO Vessel 1		N/A	41 x 13.5 x 4																								
-Main Engines	2			1	425	Diesel	12	16	0	360	24	8,640	83%	10%	6,829	37,025	0.03	1.09	0.56	0.03	0.03	7.28E-04	3.02E-03	76.86	1.00E-02	2.23E-03	77.77
Guard/MMO Vessel 2		N/A	41 x 13.5 x 4																								
-Main Engines	2			1	425	Diesel	12	16	0	360	24	8,640	83%	10%	6,829	37,025	0.03	1.09	0.56	0.03	0.03	7.28E-04	3.02E-03	76.86	1.00E-02	2.23E-03	77.77
														TOTALS	**1,347,638**	**19,134,066**	**10.34**	**223.12**	**103.69**	**11.78**	**11.42**	**0.85**	**1.08**	**15,199**	**1.84**	**0.46**	**15,383**

Notes:

1. Transit emissions are based on an assumed vessel speed of 10 knots for all vessel types, and the following one-way travel distances:
   Overseas port to center of Wind Development Area: 32 nm (only includes portion of transit within 25 nm of the Wind Development Area)
   Norfolk, VA (assumed local port) to center of Wind Development Area: 80 nm
2. The number of transits for each vessel are based on the following assumptions:
   1 round trip to/from overseas port for each heavy lift vessel.
   8 round trips to/from local port for the scour protection vessel (based on assumed capacity to install scour protection for 9 foundations per cargo).
   35 round trips to/from local port for each barge tug for 69 total positions.
   Weekly round trips to/from port for crew transfer vessels.
   Monthly round trips to/from port for construction support vessels and guard vessels.
3. The specific vessels for each operation have not been finalized at this time; however, the vessels identifed for each installation activity are typical sizes for performing this effort.
4. Emission factors for marine vessel engines are from ICF International report to the US EPA "Current Methodologies in Preparing Mobile Source Port-Related Emissions Inventories", April 2009.
5. HAP emission factors for commercial marine vessels were determined using the methodology identified by US EPA for the latest (2017) National Emissions Inventory (NEI); i.e., they are calculated as percentages of the $PM_{2.5}$ or VOC emissions from the CMVs.
6. Average load factors for vessel engines were estimated based on engineering estimates, and on Section 2.5 of the ICF International Report.
7. CO_2e emission rates use the following carbon equivalence factors: 25 for CH_4, and 298 for N_2O.

KITTY HAWK OFFSHORE WIND PROJECT - OCS AIR EMISSION CALCULATIONS
Foundation Construction Emissions (Jacket Pile Option)

																	Total Emissions (Non-Transit)										
Vessels/Equipment	No. of Engines per vessel	1. DP 2.Anchored 3.Spuds	Dimensions (ft) length x width x depth (draft)	Emission Factor Used (see EFs worksheet)	Engine Rating (hp)	Fuel Type	Transit Round Trips	Transit Duration (hrs/round trip)	Non-OCS Operating Days	OCS Operating Days	Non-Transit Operating Hours (hrs/day)	Non-Transit Total Operating Hours (hrs)	Transit Average load (%)	Non-Transit Average load (%)	Transit Fuel Usage Gallons (per vessel)	Non-Transit Fuel Usage Gallons (per vessel)	VOC tons	NO_X tons	CO tons	PM_{10} tons	$PM_{2.5}$ tons	SO_2 tons	HAPs tons	CO_2 tons	CH_4 tons	N_2O tons	CO_2e tons
Heavy Lift Jack-up Vessel 1		3	456 x 164 x 36 (20)																								
-Main Engines	6			3	4,477	Diesel	1	6	0	428	24	10,272	83%	25%	6,139	3,165,737	28.36	748.80	62.40	10.51	10.20	22.51	2.51	36,650.17	0.23	1.76	37,179.89
-Emergency Generator	1			2	1,340	Diesel	0	0	0	0	0	0	0%	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
Scour Protection Vessel		1	520 x 118 x 44 (31)																								
-Main Generators	3			3	6,032	Diesel	8	16	0	360	24	8,640	83%	45%	88,227	3,228,807	28.93	763.71	63.64	10.72	10.40	22.96	2.55	37,380.34	0.23	1.79	37,920.61
-Aux. Generator	1			2	1,609	Diesel	8	16	0	360	24	8,640	17%	45%	1,765	315,305	2.57	50.40	25.71	3.18	3.09	0.03	0.27	3,548.57	0.46	0.10	3,590.79
-Emergency Generator	1			1	660	Diesel	0	0	0	0	0	0	0%	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
Tug 1		N/A	146 x 40 x 18																								
-Main Engines	2			2	5,600	Diesel	35	16	0	360	24	8,640	83%	45%	262,450	2,195,364	17.90	350.92	179.04	22.17	21.51	0.23	1.90	24,707.52	3.22	0.72	25,001.50
-Aux. Generators	2			1	134	Diesel	35	16	0	360	24	8,640	17%	45%	1,287	52,551	0.23	8.40	4.29	0.22	0.21	5.60E-03	0.02	591.43	0.08	0.02	598.47
Tug 2		N/A	146 x 40 x 18																								
-Main Engines	2			2	5,600	Diesel	35	16	0	360	24	8,640	83%	45%	262,450	2,195,364	17.90	350.92	179.04	22.17	21.51	0.23	1.90	24,707.52	3.22	0.72	25,001.50
-Aux. Generators	2			1	134	Diesel	35	16	0	360	24	8,640	17%	45%	1,287	52,551	0.23	8.40	4.29	0.22	0.21	5.60E-03	0.02	591.43	0.08	0.02	598.47
Tug 3		N/A	146 x 40 x 18																								
-Main Engines	2			2	5,600	Diesel	35	16	0	360	24	8,640	83%	45%	262,450	2,195,364	17.90	350.92	179.04	22.17	21.51	0.23	1.90	24,707.52	3.22	0.72	25,001.50
-Aux. Generators	2			1	134	Diesel	35	16	0	360	24	8,640	17%	45%	1,287	52,551	0.23	8.40	4.29	0.22	0.21	5.60E-03	0.02	591.43	0.08	0.02	598.47
Tug 4		N/A	146 x 40 x 18																								
-Main Engines	2			2	5,600	Diesel	35	16	0	360	24	8,640	83%	45%	262,450	2,195,364	17.90	350.92	179.04	22.17	21.51	0.23	1.90	24,707.52	3.22	0.72	25,001.50
-Aux. Generators	2			1	134	Diesel	35	16	0	360	24	8,640	17%	45%	1,287	52,551	0.23	8.40	4.29	0.22	0.21	5.60E-03	0.02	591.43	0.08	0.02	598.47
Barge 1 for Foundations	N/A	N/A		N/A	N/A	N/A	35	16	0	360	24	8,640	N/A	N/A	N/A	N/A											
Barge 2 for Foundations	N/A	N/A		N/A	N/A	N/A	35	16	0	360	24	8,640	N/A	N/A	N/A	N/A											
Barge 1 for Pilings	N/A	N/A		N/A	N/A	N/A	35	16	0	360	24	8,640	N/A	N/A	N/A	N/A											
Barge 2 for Pilings	N/A	N/A		N/A	N/A	N/A	35	16	0	360	24	8,640	N/A	N/A	N/A	N/A											
Bubble Curtain Support Vessel		N/A	150 x 36 x 10																								
_ Main Engines	2			1	750	Diesel	12	16	0	360	24	8,640	83%	10%	12,051	65,338	0.29	10.44	5.33	0.27	0.27	6.97E-03	0.03	735.34	0.10	0.02	744.09
-Aux. Generator	1			1	133	Diesel	12	16	0	360	24	8,640	17%	45%	219	26,070	0.11	4.17	2.13	0.11	0.11	2.78E-03	1.15E-02	293.40	0.04	8.50E-03	296.89
-Bow Thruster Engine	1			1	325	Diesel	12	16	0	360	24	8,640	0%	45%	0	63,705	0.28	10.18	5.20	0.27	0.26	6.79E-03	0.03	716.96	0.09	0.02	725.49
-Aux. Engine	1			1	133	Diesel	12	16	0	360	24	8,640	17%	45%	219	26,070	0.11	4.17	2.13	0.11	0.11	2.78E-03	1.15E-02	293.40	0.04	8.50E-03	296.89
Crew Transfer Vessel 1		N/A	114 x 24 x 7.4																								
-Main Engines	4			1	585	Diesel	52	16	0	52	8	416	83%	10%	81,467	4,908	0.02	0.78	0.40	0.02	0.02	5.23E-04	2.17E-03	55.23	7.20E-03	1.60E-03	55.89
-Aux. Generator	1			1	47	Diesel	52	16	0	52	8	416	17%	45%	335	444	1.95E-03	0.07	0.04	1.87E-03	1.81E-03	4.73E-05	1.96E-04	4.99	6.51E-04	1.45E-04	5.05
-Aux. Engine	1			1	47	Diesel	52	16	0	52	8	416	17%	45%	335	444	1.95E-03	0.07	0.04	1.87E-03	1.81E-03	4.73E-05	1.96E-04	4.99	6.51E-04	1.45E-04	5.05
Crew Transfer Vessel 2		N/A	114 x 24 x 7.4																								
-Main Engines	4			1	585	Diesel	52	16	0	52	8	416	83%	10%	81,467	4,908	0.02	0.78	0.40	0.02	0.02	5.23E-04	2.17E-03	55.23	7.20E-03	1.60E-03	55.89
-Aux. Generator	1			1	47	Diesel	52	16	0	52	8	416	17%	45%	335	444	1.95E-03	0.07	0.04	1.87E-03	1.81E-03	4.73E-05	1.96E-04	4.99	6.51E-04	1.45E-04	5.05
-Aux. Engine	1			1	47	Diesel	52	16	0	52	8	416	17%	45%	335	444	1.95E-03	0.07	0.04	1.87E-03	1.81E-03	4.73E-05	1.96E-04	4.99	6.51E-04	1.45E-04	5.05
Guard/MMO Vessel 1		N/A	41 x 13.5 x 4																								
-Main Engines	2			1	425	Diesel	12	16	0	360	24	8,640	83%	10%	6,829	37,025	0.16	5.92	3.02	0.16	0.15	3.95E-03	0.02	416.69	0.05	1.21E-02	421.65
Guard/MMO Vessel 2		N/A	41 x 13.5 x 4																								
-Main Engines	2			1	425	Diesel	12	16	0	360	24	8,640	83%	10%	6,829	37,025	0.16	5.92	3.02	0.16	0.15	3.95E-03	0.02	416.69	0.05	1.21E-02	421.65
														TOTALS	**1,341,498**	**15,968,329**	**133.58**	**3,042.83**	**906.82**	**115.11**	**111.66**	**46.49**	**13.15**	**181,778**	**14.51**	**6.68**	**184,130**

Notes:

1. Transit emissions are based on an assumed vessel speed of 10 knots for all vessel types, and the following one-way travel distances:
   Overseas port to center of Wind Development Area: 32 nm (only includes portion of transit within 25 nm of the Wind Development Area)
   Norfolk, VA (assumed local port) to center of Wind Development Area: 80 nm
2. The number of transits for each vessel are based on the following assumptions:
   1 round trip to/from overseas port for each heavy lift vessel.
   8 round trips to/from local port for the scour protection vessel (based on assumed capacity to install scour protection for 9 foundations per cargo).
   35 round trips to/from local port for each barge tug for 69 total positions.
   Weekly round trips to/from port for crew transfer vessels.
   Monthly round trips to/from port for construction support vessels and guard vessels.
3. The specific vessels for each operation have not been finalized at this time; however, the vessels identifed for each installation activity are typical sizes for performing this effort.
4. Emission factors for marine vessel engines are from ICF International report to the US EPA "Current Methodologies in Preparing Mobile Source Port-Related Emissions Inventories", April 2009.
5. HAP emission factors for commercial marine vessels were determined using the methodology identified by US EPA for the latest (2017) National Emissions Inventory (NEI); i.e., they are calculated as percentages of the $PM_{2.5}$ or VOC emissions from the CMVs.
6. Average load factors for vessel engines were estimated based on engineering estimates, and on Section 2.5 of the ICF International Report.
7. CO_2e emission rates use the following carbon equivalence factors: 25 for CH_4, and 298 for N_2O.

KITTY HAWK OFFSHORE WIND PROJECT - OCS AIR EMISSION CALCULATIONS
Foundation Construction Emissions (Jacket Pile Option)

																	Total Emissions (Transit)										
Vessels/Equipment	No. of Engines per vessel	1. DP 2.Anchored 3.Spuds	Dimensions (ft) length x width x depth (draft)	Emission Factor Used (see EFs worksheet)	Engine Rating (hp)	Fuel Type	Transit Round Trips	Transit Duration (hrs/round trip)	Non-OCS Operating Days	OCS Operating Days	Non-Transit Operating Hours (hrs/day)	Non-Transit Total Operating Hours (hrs)	Transit Average load (%)	Non-Transit Average load (%)	Transit Fuel Usage Gallons (per vessel)	Non-Transit Fuel Usage Gallons (per vessel)	VOC tons	NO_X tons	CO tons	PM_{10} tons	$PM_{2.5}$ tons	SO_2 tons	HAPs tons	CO_2 tons	CH_4 tons	N_2O tons	CO_2e tons
Heavy Lift Jack-up Vessel 1		3	456 x 164 x 36 (20)																								
-Main Engines	6			3	4,477	Diesel	1	6	0	428	24	10,272	83%	25%	6,139	3,165,737	0.06	1.45	0.12	0.02	0.02	0.04	4.86E-03	71.07	4.40E-04	3.41E-03	72.10
-Emergency Generator	1			2	1,340	Diesel	0	0	0	0	0	0	0%	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
Scour Protection Vessel		1	520 x 118 x 44 (31)																								
-Main Generators	3			3	6,032	Diesel	8	16	0	360	24	8,640	83%	45%	88,227	3,228,807	0.79	20.87	1.74	0.29	0.28	0.63	0.07	1021.42	6.32E-03	0.05	1,036.18
-Aux. Generator	1			2	1,609	Diesel	8	16	0	360	24	8,640	17%	45%	1,765	315,305	1.44E-02	0.28	0.14	0.02	0.02	1.88E-04	1.53E-03	19.86	2.59E-03	5.76E-04	20.10
-Emergency Generator	1			1	660	Diesel	0	0	0	0	0	0	0%	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
Tug 1		N/A	146 x 40 x 18																								
-Main Engines	2			2	5,600	Diesel	35	16	0	360	24	8,640	83%	45%	262,450	2,195,364	2.14	41.95	21.40	2.65	2.57	0.03	0.23	2953.72	0.39	0.09	2,988.86
-Aux. Generators	2			1	134	Diesel	35	16	0	360	24	8,640	17%	45%	1,287	52,551	5.67E-03	0.21	0.10	5.41E-03	5.25E-03	1.37E-04	5.69E-04	14.48	1.89E-03	4.20E-04	14.65
Tug 2		N/A	146 x 40 x 18																								
-Main Engines	2			2	5,600	Diesel	35	16	0	360	24	8,640	83%	45%	262,450	2,195,364	2.14	41.95	21.40	2.65	2.57	0.03	0.23	2953.72	0.39	0.09	2,988.86
-Aux. Generators	2			1	134	Diesel	35	16	0	360	24	8,640	17%	45%	1,287	52,551	5.67E-03	0.21	0.10	5.41E-03	5.25E-03	1.37E-04	5.69E-04	14.48	1.89E-03	4.20E-04	14.65
Tug 3		N/A	146 x 40 x 18																								
-Main Engines	2			2	5,600	Diesel	35	16	0	360	24	8,640	83%	45%	262,450	2,195,364	2.14	41.95	21.40	2.65	2.57	0.03	0.23	2953.72	0.39	0.09	2,988.86
-Aux. Generators	2			1	134	Diesel	35	16	0	360	24	8,640	17%	45%	1,287	52,551	5.67E-03	0.21	0.10	5.41E-03	5.25E-03	1.37E-04	5.69E-04	14.48	1.89E-03	4.20E-04	14.65
Tug 4		N/A	146 x 40 x 18																								
-Main Engines	2			2	5,600	Diesel	35	16	0	360	24	8,640	83%	45%	262,450	2,195,364	2.14	41.95	21.40	2.65	2.57	0.03	0.23	2953.72	0.39	0.09	2,988.86
-Aux. Generators	2			1	134	Diesel	35	16	0	360	24	8,640	17%	45%	1,287	52,551	5.67E-03	0.21	0.10	5.41E-03	5.25E-03	1.37E-04	5.69E-04	14.48	1.89E-03	4.20E-04	14.65
Barge 1 for Foundations	N/A	N/A		N/A	N/A	N/A	35	16	0	360	24	8,640	N/A	N/A	N/A	N/A											
Barge 2 for Foundations	N/A	N/A		N/A	N/A	N/A	35	16	0	360	24	8,640	N/A	N/A	N/A	N/A											
Barge 1 for Pilings	N/A	N/A		N/A	N/A	N/A	35	16	0	360	24	8,640	N/A	N/A	N/A	N/A											
Barge 2 for Pilings	N/A	N/A		N/A	N/A	N/A	35	16	0	360	24	8,640	N/A	N/A	N/A	N/A											
Bubble Curtain Support Vessel		N/A	150 x 36 x 10																								
_ Main Engines	2			1	750	Diesel	12	16	0	360	24	8,640	83%	10%	12,051	65,338	0.05	1.93	0.98	0.05	0.05	1.29E-03	5.33E-03	135.63	0.02	3.93E-03	137.24
-Aux. Generator	1			1	133	Diesel	12	16	0	360	24	8,640	17%	45%	219	26,070	9.64E-04	0.03	0.02	9.21E-04	8.93E-04	2.33E-05	9.67E-05	2.46	3.21E-04	7.14E-05	2.49
-Bow Thruster Engine	1			1	325	Diesel	12	16	0	360	24	8,640	0%	45%	0	63,705	0	0	0	0	0	0	0	0	0	0	0
-Aux. Engine	1			1	133	Diesel	12	16	0	360	24	8,640	17%	45%	219	26,070	9.64E-04	0.03	0.02	9.21E-04	8.93E-04	2.33E-05	9.67E-05	2.46	3.21E-04	7.14E-05	2.49
Crew Transfer Vessel 1		N/A	114 x 24 x 7.4																								
-Main Engines	4			1	585	Diesel	52	16	0	52	8	416	83%	10%	81,467	4,908	0.36	13.02	6.64	0.34	0.33	8.69E-03	0.04	916.86	0.12	0.03	927.77
-Aux. Generator	1			1	47	Diesel	52	16	0	52	8	416	17%	45%	335	444	1.48E-03	0.05	0.03	1.41E-03	1.37E-03	3.57E-05	1.48E-04	3.77	4.92E-04	1.09E-04	3.82
-Aux. Engine	1			1	47	Diesel	52	16	0	52	8	416	17%	45%	335	444	1.48E-03	0.05	0.03	1.41E-03	1.37E-03	3.57E-05	1.48E-04	3.77	4.92E-04	1.09E-04	3.82
Crew Transfer Vessel 2		N/A	114 x 24 x 7.4																								
-Main Engines	4			1	585	Diesel	52	16	0	52	8	416	83%	10%	81,467	4,908	0.36	13.02	6.64	0.34	0.33	8.69E-03	0.04	916.86	0.12	0.03	927.77
-Aux. Generator	1			1	47	Diesel	52	16	0	52	8	416	17%	45%	335	444	1.48E-03	0.05	0.03	1.41E-03	1.37E-03	3.57E-05	1.48E-04	3.77	4.92E-04	1.09E-04	3.82
-Aux. Engine	1			1	47	Diesel	52	16	0	52	8	416	17%	45%	335	444	1.48E-03	0.05	0.03	1.41E-03	1.37E-03	3.57E-05	1.48E-04	3.77	4.92E-04	1.09E-04	3.82
Guard/MMO Vessel 1		N/A	41 x 13.5 x 4																								
-Main Engines	2			1	425	Diesel	12	16	0	360	24	8,640	83%	10%	6,829	37,025	0.03	1.09	0.56	0.03	0.03	7.28E-04	3.02E-03	76.86	1.00E-02	2.23E-03	77.77
Guard/MMO Vessel 2		N/A	41 x 13.5 x 4																								
-Main Engines	2			1	425	Diesel	12	16	0	360	24	8,640	83%	10%	6,829	37,025	0.03	1.09	0.56	0.03	0.03	7.28E-04	3.02E-03	76.86	1.00E-02	2.23E-03	77.77
														TOTALS	**1,341,498**	**15,968,329**	**10.28**	**221.67**	**103.57**	**11.76**	**11.40**	**0.80**	**1.07**	**15,128**	**1.84**	**0.46**	**15,311**

Notes:

1. Transit emissions are based on an assumed vessel speed of 10 knots for all vessel types, and the following one-way travel distances:
   Overseas port to center of Wind Development Area: 32 nm (only includes portion of transit within 25 nm of the Wind Development Area)
   Norfolk, VA (assumed local port) to center of Wind Development Area: 80 nm
2. The number of transits for each vessel are based on the following assumptions:
   1 round trip to/from overseas port for each heavy lift vessel.
   8 round trips to/from local port for the scour protection vessel (based on assumed capacity to install scour protection for 9 foundations per cargo).
   35 round trips to/from local port for each barge tug for 69 total positions.
   Weekly round trips to/from port for crew transfer vessels.
   Monthly round trips to/from port for construction support vessels and guard vessels.
3. The specific vessels for each operation have not been finalized at this time; however, the vessels identifed for each installation activity are typical sizes for performing this effort.
4. Emission factors for marine vessel engines are from ICF International report to the US EPA "Current Methodologies in Preparing Mobile Source Port-Related Emissions Inventories", April 2009.
5. HAP emission factors for commercial marine vessels were determined using the methodology identified by US EPA for the latest (2017) National Emissions Inventory (NEI); i.e., they are calculated as percentages of the $PM_{2.5}$ or VOC emissions from the CMVs.
6. Average load factors for vessel engines were estimated based on engineering estimates, and on Section 2.5 of the ICF International Report.
7. CO_2e emission rates use the following carbon equivalence factors: 25 for CH_4, and 298 for N_2O.

																	Total Emissions (Non-Transit)										
Vessels/Equipment	**No. of Engines per vessel**	**1. DP 2.Anchored 3.Spuds**	**Dimensions (ft) length x width x depth (draft)**	**Emission Factor Used (see EFs worksheet)**	**Engine Rating (hp)**	**Fuel Type**	**Transit Round Trips**	**Transit Duration (hrs/round trip)**	**Non-OCS Operating Days**	**OCS Operating Days**	**Non-Transit Operating Hours (hrs/day)**	**Non-Transit Total Operating Hours (hrs)**	**Transit Average load (%)**	**Non-Transit Average load (%)**	**Transit Fuel Usage Gallons (per vessel)**	**Non-Transit Fuel Usage Gallons (per vessel)**	**VOC tons**	**NO_X tons**	**CO tons**	**PM_{10} tons**	**$PM_{2.5}$ tons**	**SO_2 tons**	**HAPs tons**	**CO_2 tons**	**CH_4 tons**	**N_2O tons**	**CO_2e tons**
Heavy Lift Jack-up Vessel 1		3	456 x 164 x 36 (20)																								
-Main Engines	6			3	4,477	Diesel	1	6	0	428	24	10,272	83%	25%	6,139	3,165,737	28.36	748.80	62.40	10.51	10.20	22.51	2.51	36,650.17	0.23	1.76	37,179.89
-Emergency Generator	1			2	1,340	Diesel	0	0	0	0	0	0	0%	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
Scour Protection Vessel		1	520 x 118 x 44 (31)																								
-Main Generators	3			3	6,032	Diesel	8	16	0	360	24	8,640	83%	45%	88,227	3,228,807	28.93	763.71	63.64	10.72	10.40	22.96	2.55	37,380.34	0.23	1.79	37,920.61
-Aux. Generator	1			2	1,609	Diesel	8	16	0	360	24	8,640	17%	45%	1,765	315,305	2.57	50.40	25.71	3.18	3.09	0.03	0.27	3,548.57	0.46	0.10	3,590.79
-Emergency Generator	1			1	660	Diesel	0	0	0	0	0	0	0%	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
Tug 1		N/A	146 x 40 x 18																								
-Main Engines	2			2	5,600	Diesel	35	16	0	360	24	8,640	83%	45%	262,450	2,195,364	17.90	350.92	179.04	22.17	21.51	0.23	1.90	24,707.52	3.22	0.72	25,001.50
-Aux. Generators	2			1	134	Diesel	35	16	0	360	24	8,640	17%	45%	1,287	52,551	0.23	8.40	4.29	0.22	0.21	5.60E-03	0.02	591.43	0.08	0.02	598.47
Tug 2		N/A	146 x 40 x 18																								
-Main Engines	2			2	5,600	Diesel	35	16	0	360	24	8,640	83%	45%	262,450	2,195,364	17.90	350.92	179.04	22.17	21.51	0.23	1.90	24,707.52	3.22	0.72	25,001.50
-Aux. Generators	2			1	134	Diesel	35	16	0	360	24	8,640	17%	45%	1,287	52,551	0.23	8.40	4.29	0.22	0.21	5.60E-03	0.02	591.43	0.08	0.02	598.47
Barge 1 for Foundations	N/A	N/A																									
				N/A	N/A	N/A	35	16	0	360	24	8,640	N/A	N/A	N/A	N/A											
Barge 2 for Foundations	N/A	N/A																									
				N/A	N/A	N/A	35	16	0	360	24	8,640	N/A	N/A	N/A	N/A											
Crew Transfer Vessel 1		N/A	114 x 24 x 7.4																								
-Main Engines	4			1	585	Diesel	52	16	0	52	8	416	83%	10%	81,467	4,908	0.02	0.78	0.40	0.02	0.02	5.23E-04	2.17E-03	55.23	7.20E-03	1.60E-03	55.89
-Aux. Generator	1			1	47	Diesel	52	16	0	52	8	416	17%	45%	335	444	1.95E-03	0.07	0.04	1.87E-03	1.81E-03	4.73E-05	1.96E-04	4.99	6.51E-04	1.45E-04	5.05
-Aux. Engine	1			1	47	Diesel	52	16	0	52	8	416	17%	45%	335	444	1.95E-03	0.07	0.04	1.87E-03	1.81E-03	4.73E-05	1.96E-04	4.99	6.51E-04	1.45E-04	5.05
Crew Transfer Vessel 2		N/A	114 x 24 x 7.4																								
-Main Engines	4			1	585	Diesel	52	16	0	52	8	416	83%	10%	81,467	4,908	0.02	0.78	0.40	0.02	0.02	5.23E-04	2.17E-03	55.23	7.20E-03	1.60E-03	55.89
-Aux. Generator	1			1	47	Diesel	52	16	0	52	8	416	17%	45%	335	444	1.95E-03	0.07	0.04	1.87E-03	1.81E-03	4.73E-05	1.96E-04	4.99	6.51E-04	1.45E-04	5.05
-Aux. Engine	1			1	47	Diesel	52	16	0	52	8	416	17%	45%	335	444	1.95E-03	0.07	0.04	1.87E-03	1.81E-03	4.73E-05	1.96E-04	4.99	6.51E-04	1.45E-04	5.05
Guard/MMO Vessel 1		N/A	41 x 13.5 x 4																								
-Main Engines	2			1	425	Diesel	12	16	0	360	24	8,640	83%	10%	6,829	37,025	0.16	5.92	3.02	0.16	0.15	3.95E-03	0.02	416.69	0.05	1.21E-02	421.65
Guard/MMO Vessel 2		N/A	41 x 13.5 x 4																								
-Main Engines	2			1	425	Diesel	12	16	0	360	24	8,640	83%	10%	6,829	37,025	0.16	5.92	3.02	0.16	0.15	3.95E-03	0.02	416.69	0.05	1.21E-02	421.65
														TOTALS	**801,536**	**11,291,318**	**96.51**	**2,295.24**	**525.39**	**69.56**	**67.48**	**45.99**	**9.22**	**129,141**	**7.65**	**5.15**	**130,867**

Notes:

1. Transit emissions are based on an assumed vessel speed of 10 knots for all vessel types, and the following one-way travel distances:
   Overseas port to center of Wind Development Area: 32 nm (only includes portion of transit within 25 nm of the Wind Development Area)
   Norfolk, VA (assumed local port) to center of Wind Development Area: 80 nm
2. The number of transits for each vessel are based on the following assumptions:
   1 round trip to/from overseas port for each heavy lift vessel.
   8 round trips to/from local port for the scour protection vessel (based on assumed capacity to install scour protection for 9 foundations per cargo).
   35 round trips to/from local port for each barge tug for 69 total positions.
   Weekly round trips to/from port for crew transfer vessels.
   Monthly round trips to/from port for construction support vessels and guard vessels.
3. The specific vessels for each operation have not been finalized at this time; however, the vessels identifed for each installation activity are typical sizes for performing this effort.
4. Emission factors for marine vessel engines are from ICF International report to the US EPA "Current Methodologies in Preparing Mobile Source Port-Related Emissions Inventories", April 2009.
5. HAP emission factors for commercial marine vessels were determined using the methodology identified by US EPA for the latest (2017) National Emissions Inventory (NEI); i.e., they are calculated as percentages of the PM_{10} or VOC emissions from the CMVs.
6. Average load factors for vessel engines were estimated based on engineering estimates, and on Section 2.5 of the ICF International Report.
7. CO_2e emission rates use the following carbon equivalence factors: 25 for CH_4 and 298 for N_2O.

KITTY HAWK OFFSHORE WIND PROJECT - OCS AIR EMISSION CALCULATIONS
Foundation Construction Emissions (Jacket Caisson Option)

																	Total Emissions (Transit)											
Vessels/Equipment	No. of Engines per vessel	1. DP 2.Anchored 3.Spuds	Dimensions (ft) length x width x depth (draft)	Emission Factor Used (see EFs worksheet)	Engine Rating (hp)	Fuel Type	Transit Round Trips	Transit Duration (hrs/round trip)	Non-OCS Operating Days	OCS Operating Days	Non-Transit Operating Hours (hrs/day)	Non-Transit Total Operating Hours (hrs)	Transit Average load (%)	Non-Transit Average load (%)	Transit Fuel Usage Gallons (per vessel)	Non-Transit Fuel Usage Gallons (per vessel)	VOC tons	NO_X tons	CO tons	PM_{10} tons	$PM_{2.5}$ tons	SO_2 tons	HAPs tons	CO_2 tons	CH_4 tons	N_2O tons	CO_2e tons
Heavy Lift Jack-up Vessel 1		3	456 x 164 x 36 (20)																								
-Main Engines	6			3	4,477	Diesel	1	6	0	428	24	10,272	83%	25%	6,139	3,165,737	0.06	1.45	0.12	0.02	0.02	0.04	4.86E-03	71.07	4.40E-04	3.41E-03	72.10
-Emergency Generator	1			2	1,340	Diesel	0	0	0	0	0	0	0%	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
Scour Protection Vessel		1	520 x 118 x 44 (31)																								
-Main Generators	3			3	6,032	Diesel	8	16	0	360	24	8,640	83%	45%	88,227	3,228,807	0.79	20.87	1.74	0.29	0.28	0.63	0.07	1021.42	6.32E-03	0.05	1,036.18
-Aux. Generator	1			2	1,609	Diesel	8	16	0	360	24	8,640	17%	45%	1,765	315,305	1.44E-02	0.28	0.14	0.02	0.02	1.88E-04	1.53E-03	19.86	2.59E-03	5.76E-04	20.10
-Emergency Generator	1			1	660	Diesel	0	0	0	0	0	0	0%	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
Tug 1		N/A	146 x 40 x 18																								
-Main Engines	2			2	5,600	Diesel	35	16	0	360	24	8,640	83%	45%	262,450	2,195,364	2.14	41.95	21.40	2.65	2.57	0.03	0.23	2953.72	0.39	0.09	2,988.86
-Aux. Generators	2			1	134	Diesel	35	16	0	360	24	8,640	17%	45%	1,287	52,551	5.67E-03	0.21	0.10	5.41E-03	5.25E-03	1.37E-04	5.69E-04	14.48	1.89E-03	4.20E-04	14.65
Tug 2		N/A	146 x 40 x 18																								
-Main Engines	2			2	5,600	Diesel	35	16	0	360	24	8,640	83%	45%	262,450	2,195,364	2.14	41.95	21.40	2.65	2.57	0.03	0.23	2953.72	0.39	0.09	2,988.86
-Aux. Generators	2			1	134	Diesel	35	16	0	360	24	8,640	17%	45%	1,287	52,551	5.67E-03	0.21	0.10	5.41E-03	5.25E-03	1.37E-04	5.69E-04	14.48	1.89E-03	4.20E-04	14.65
Barge 1 for Foundations	N/A	N/A																									
				N/A	N/A	N/A	35	16	0	360	24	8,640	N/A	N/A	N/A	N/A											
Barge 2 for Foundations	N/A	N/A																									
				N/A	N/A	N/A	35	16	0	360	24	8,640	N/A	N/A	N/A	N/A											
Crew Transfer Vessel 1		N/A	114 x 24 x 7.4																								
-Main Engines	4			1	585	Diesel	52	16	0	52	8	416	83%	10%	81,467	4,908	0.36	13.02	6.64	0.34	0.33	8.69E-03	0.04	916.86	0.12	0.03	927.77
-Aux. Generator	1			1	47	Diesel	52	16	0	52	8	416	17%	45%	335	444	1.48E-03	0.05	0.03	1.41E-03	1.37E-03	3.57E-05	1.48E-04	3.77	4.92E-04	1.09E-04	3.82
-Aux. Engine	1			1	47	Diesel	52	16	0	52	8	416	17%	45%	335	444	1.48E-03	0.05	0.03	1.41E-03	1.37E-03	3.57E-05	1.48E-04	3.77	4.92E-04	1.09E-04	3.82
Crew Transfer Vessel 2		N/A	114 x 24 x 7.4																								
-Main Engines	4			1	585	Diesel	52	16	0	52	8	416	83%	10%	81,467	4,908	0.36	13.02	6.64	0.34	0.33	8.69E-03	0.04	916.86	0.12	0.03	927.77
-Aux. Generator	1			1	47	Diesel	52	16	0	52	8	416	17%	45%	335	444	1.48E-03	0.05	0.03	1.41E-03	1.37E-03	3.57E-05	1.48E-04	3.77	4.92E-04	1.09E-04	3.82
-Aux. Engine	1			1	47	Diesel	52	16	0	52	8	416	17%	45%	335	444	1.48E-03	0.05	0.03	1.41E-03	1.37E-03	3.57E-05	1.48E-04	3.77	4.92E-04	1.09E-04	3.82
Guard/MMO Vessel 1		N/A	41 x 13.5 x 4																								
-Main Engines	2			1	425	Diesel	12	16	0	360	24	8,640	83%	10%	6,829	37,025	0.03	1.09	0.56	0.03	0.03	7.28E-04	3.02E-03	76.86	1.00E-02	2.23E-03	77.77
Guard/MMO Vessel 2		N/A	41 x 13.5 x 4																								
-Main Engines	2			1	425	Diesel	12	16	0	360	24	8,640	83%	10%	6,829	37,025	0.03	1.09	0.56	0.03	0.03	7.28E-04	3.02E-03	76.86	1.00E-02	2.23E-03	77.77
														TOTALS	**801,536**	**11,291,318**	**5.94**	**135.36**	**59.53**	**6.39**	**6.20**	**0.75**	**0.61**	**9,051**	**1.04**	**0.28**	**9,162**

Notes:

1. Transit emissions are based on an assumed vessel speed of 10 knots for all vessel types, and the following one-way travel distances:
   Overseas port to center of Wind Development Area: 32 nm (only includes portion of transit within 25 nm of the Wind Development Area)
   Norfolk, VA (assumed local port) to center of Wind Development Area: 80 nm
2. The number of transits for each vessel are based on the following assumptions:
   1 round trip to/from overseas port for each heavy lift vessel.
   8 round trips to/from local port for the scour protection vessel (based on assumed capacity to install scour protection for 9 foundations per cargo).
   35 round trips to/from local port for each barge tug for 69 total positions.
   Weekly round trips to/from port for crew transfer vessels.
   Monthly round trips to/from port for construction support vessels and guard vessels.
3. The specific vessels for each operation have not been finalized at this time; however, the vessels identifed for each installation activity are typical sizes for performing this effort.
4. Emission factors for marine vessel engines are from ICF International report to the US EPA "Current Methodologies in Preparing Mobile Source Port-Related Emissions Inventories", April 2009.
5. HAP emission factors for commercial marine vessels were determined using the methodology identified by US EPA for the latest (2017) National Emissions Inventory (NEI); i.e., they are calculated as percentages of the PM_{10} or VOC emissions from the CMVs.
6. Average load factors for vessel engines were estimated based on engineering estimates, and on Section 2.5 of the ICF International Report.
7. CO_2e emission rates use the following carbon equivalence factors: 25 for CH_4 and 298 for N_2O.

KITTY HAWK OFFSHORE WIND PROJECT - OCS AIR EMISSION CALCULATIONS
WTG Installation Emissions

Vessels/Equipment	No. of Engines per vessel	1. DP 2.Anchored 3.Spuds	Dimensions (ft) length x width x depth (draft)	Emission Factor Used (see EFs worksheet)	Engine Rating (hp)	Fuel Type	Transit Round Trips	Transit Duration (hrs/round trip)	Non-OCS Operating Days	OCS Operating Days	Non-Transit Operating Hours (hrs/day)	Non-Transit Total Operating Hours (hrs)	Transit Average load (%)	Non-Transit Average load (%)	Transit Fuel Usage Gallons (per vessel)	Non-Transit Fuel Usage Gallons (per vessel)
Heavy Lift Jack-up Vessel 1		3	456 x 164 x 36 (20)													
-Main Engines	6			3	4,477	Diesel	1	6	0	230	24	5,520	83%	25%	6,139	1,701,214
-Emergency Generator	1			2	1,340	Diesel	0	0	0	0	0	0	0%	0%	0	0
WTG Supply Vessel		1	568 x 138 x 39 (18)													
-Main Generators	2			3	2,880	Diesel	24	6	0	0	0	0	83%	25%	31,592	0
-Main Generators	2			3	3,840	Diesel	24	6	0	0	0	0	17%	45%	8,628	0
-Aux. Generator	1			2	994	Diesel	24	6	0	0	0	0	17%	45%	1,227	0
-Emergency Generator	1			2	601	Diesel	0	0	0	0	0	0	0%	0%	0	0
Tug 1		N/A	146 x 40 x 18													
-Main Engines	2			2	5,600	Diesel	35	16	0	198	24	4,752	83%	45%	262,450	1,207,450
-Aux. Generators	2			1	134	Diesel	35	16	0	198	24	4,752	17%	45%	1,287	28,903
Tug 2		N/A	146 x 40 x 18													
-Main Engines	2			2	5,600	Diesel	35	16	0	198	24	4,752	83%	45%	262,450	1,207,450
-Aux. Generators	2			1	134	Diesel	35	16	0	198	24	4,752	17%	45%	1,287	28,903
Barge 1 for WTGs	N/A	N/A		N/A	N/A	N/A	35	16	0	198	24	4,752	N/A	N/A	N/A	N/A
Barge 2 for WTGs	N/A	N/A		N/A	N/A	N/A	35	16	0	198	24	4,752	N/A	N/A	N/A	N/A
														TOTALS	**575,059**	**4,173,920**

Vessels/Equipment	Total Emissions (Non-Transit)										
	VOC tons	NO_X tons	CO tons	PM_{10} tons	$PM_{2.5}$ tons	SO_2 tons	HAPs tons	CO_2 tons	CH_4 tons	N_2O tons	CO_2e tons
Heavy Lift Jack-up Vessel 1											
-Main Engines	15.24	402.39	33.53	5.65	5.48	12.10	1.35	19,695.18	0.12	0.95	19,979.85
-Emergency Generator	0	0	0	0	0	0	0	0	0	0	0
WTG Supply Vessel											
-Main Generators	0	0	0	0	0	0	0	0	0	0	0
-Main Generators	0	0	0	0	0	0	0	0	0	0	0
-Aux. Generator	0	0	0	0	0	0	0	0	0	0	0
-Emergency Generator	0	0	0	0	0	0	0	0	0	0	0
Tug 1											
-Main Engines	9.85	193.01	98.47	12.19	11.83	0.13	1.05	13,589.14	1.77	0.39	13,750.83
-Aux. Generators	0.13	4.62	2.36	0.12	0.12	3.08E-03	1.28E-02	325.29	0.04	9.43E-03	329.16
Tug 2											
-Main Engines	9.85	193.01	98.47	12.19	11.83	0.13	1.05	13,589.14	1.77	0.39	13,750.83
-Aux. Generators	0.13	4.62	2.36	0.12	0.12	3.08E-03	1.28E-02	325.29	0.04	9.43E-03	329.16
Barge 1 for WTGs											
Barge 2 for WTGs											
TOTALS	**35.19**	**797.64**	**235.19**	**30.28**	**29.37**	**12.36**	**3.46**	**47,524.03**	**3.75**	**1.75**	**48,139.81**

Notes:

1. Transit emissions are based on an assumed vessel speed of 10 knots for all vessel types, and the following one-way travel distances:
   Overseas port to center of Wind Development Area: 32 nm (only includes portion of transit within 25 nm of the Wind Development Area)
   Overseas port to Norfolk, VA (assumed local port: 30 nm (only includes portion of transit within the state seaward boundary)
   Norfolk, VA (assumed local port) to center of Wind Development Area: 80 nm
2. The number of transits for each vessel are based on the following assumptions:
   1 round trip to/from overseas port for each heavy lift vessel.
   24 round trips to/from overseas port to local staging area for the WTG supply vessel (based on assumed capacity to carry 3 WTG positions per cargo).
   35 round trips to/from local port for each barge tug for 69 total positions.
3. The specific vessels for each operation have not been finalized at this time; however, the vessels identifed for each installation activity are typical sizes for performing this effort.
4. Emission factors for marine vessel engines are from ICF International report to the US EPA "Current Methodologies in Preparing Mobile Source Port-Related Emissions Inventories", April 2009.
5. HAP emission factors for commercial marine vessels were determined using the methodology identified by US EPA for the latest (2017) National Emissions Inventory (NEI); i.e., they are calculated as percentages of the PM_{10} or VOC emissions from the CMVs.
6. Average load factors for vessel engines were estimated based on engineering estimates, and on Section 2.5 of the ICF International Report.
7. CO_2e emission rates use the following carbon equivalence factors: 25 for CH_4 and 298 for N_2O.

KITTY HAWK OFFSHORE WIND PROJECT - OCS AIR EMISSION CALCULATIONS
WTG Installation Emissions

Vessels/Equipment	No. of Engines per vessel	1. DP 2.Anchored 3.Spuds	Dimensions (ft) length x width x depth (draft)	Emission Factor Used (see EFs worksheet)	Engine Rating (hp)	Fuel Type	Transit Round Trips	Transit Duration (hrs/round trip)	Non-OCS Operating Days	OCS Operating Days	Non-Transit Operating Hours (hrs/day)	Non-Transit Total Operating Hours (hrs)	Transit Average load (%)	Non-Transit Average load (%)	Transit Fuel Usage Gallons (per vessel)	Non-Transit Fuel Usage Gallons (per vessel)
Heavy Lift Jack-up Vessel 1		3	456 x 164 x 36 (20)													
-Main Engines	6			3	4,477	Diesel	1	6	0	230	24	5,520	83%	25%	6,139	1,701,214
-Emergency Generator	1			2	1,340	Diesel	0	0	0	0	0	0	0%	0%	0	0
WTG Supply Vessel		1	568 x 138 x 39 (18)													
-Main Generators	2			3	2,880	Diesel	24	6	0	0	0	0	83%	25%	31,592	0
-Main Generators	2			3	3,840	Diesel	24	6	0	0	0	0	17%	45%	8,628	0
-Aux. Generator	1			2	994	Diesel	24	6	0	0	0	0	17%	45%	1,227	0
-Emergency Generator	1			2	601	Diesel	0	0	0	0	0	0	0%	0%	0	0
Tug 1		N/A	146 x 40 x 18													
-Main Engines	2			2	5,600	Diesel	35	16	0	198	24	4,752	83%	45%	262,450	1,207,450
-Aux. Generators	2			1	134	Diesel	35	16	0	198	24	4,752	17%	45%	1,287	28,903
Tug 2		N/A	146 x 40 x 18													
-Main Engines	2			2	5,600	Diesel	35	16	0	198	24	4,752	83%	45%	262,450	1,207,450
-Aux. Generators	2			1	134	Diesel	35	16	0	198	24	4,752	17%	45%	1,287	28,903
Barge 1 for WTGs	N/A	N/A		N/A	N/A	N/A	35	16	0	198	24	4,752	N/A	N/A	N/A	N/A
Barge 2 for WTGs	N/A	N/A		N/A	N/A	N/A	35	16	0	198	24	4,752	N/A	N/A	N/A	N/A
														TOTALS	**575,059**	**4,173,920**

Vessels/Equipment	Total Emissions (Transit)										
	VOC tons	NO_X tons	CO tons	PM_{10} tons	$PM_{2.5}$ tons	SO_2 tons	HAPs tons	CO_2 tons	CH_4 tons	N_2O tons	CO_2e tons
Heavy Lift Jack-up Vessel 1											
-Main Engines	0.06	1.45	0.12	0.02	0.02	0.04	4.86E-03	71.07	4.40E-04	3.41E-03	72.10
-Emergency Generator	0	0	0	0	0	0	0	0	0	0	0
WTG Supply Vessel											
-Main Generators	0.28	7.47	0.62	0.10	0.10	0.22	0.02	365.75	2.26E-03	1.75E-02	371.04
-Main Generators	0.08	2.04	0.17	0.03	0.03	0.06	6.83E-03	99.88	6.18E-04	4.79E-03	101.33
-Aux. Generator	1.00E-02	0.20	0.10	1.24E-02	1.20E-02	1.31E-04	1.06E-03	13.81	1.80E-03	4.00E-04	13.97
-Emergency Generator	0	0	0	0	0	0	0	0	0	0	0
Tug 1											
-Main Engines	2.14	41.95	21.40	2.65	2.57	0.03	0.23	2953.72	0.39	0.09	2,988.86
-Aux. Generators	5.67E-03	0.21	0.10	5.41E-03	5.25E-03	1.37E-04	5.69E-04	14.48	1.89E-03	4.20E-04	14.65
Tug 2											
-Main Engines	2.14	41.95	21.40	2.65	2.57	0.03	0.23	2953.72	0.39	0.09	2,988.86
-Aux. Generators	5.67E-03	0.21	0.10	5.41E-03	5.25E-03	1.37E-04	5.69E-04	14.48	1.89E-03	4.20E-04	14.65
Barge 1 for WTGs											
Barge 2 for WTGs											
TOTALS	**4.72**	**95.48**	**44.03**	**5.48**	**5.31**	**0.39**	**0.49**	**6,486.91**	**0.78**	**0.20**	**6,565.47**

Notes:

1. Transit emissions are based on an assumed vessel speed of 10 knots for all vessel types, and the following one-way travel distances:
   Overseas port to center of Wind Development Area: 32 nm (only includes portion of transit within 25 nm of the Wind Development Area)
   Overseas port to Norfolk, VA (assumed local port: 30 nm (only includes portion of transit within the state seaward boundary)
   Norfolk, VA (assumed local port) to center of Wind Development Area: 80 nm
2. The number of transits for each vessel are based on the following assumptions:
   1 round trip to/from overseas port for each heavy lift vessel.
   24 round trips to/from overseas port to local staging area for the WTG supply vessel (based on assumed capacity to carry 3 WTG positions per cargo).
   35 round trips to/from local port for each barge tug for 69 total positions.
3. The specific vessels for each operation have not been finalized at this time; however, the vessels identifed for each installation activity are typical sizes for performing this effort.
4. Emission factors for marine vessel engines are from ICF International report to the US EPA "Current Methodologies in Preparing Mobile Source Port-Related Emissions Inventories", April 2009.
5. HAP emission factors for commercial marine vessels were determined using the methodology identified by US EPA for the latest (2017) National Emissions Inventory (NEI); i.e., they are calculated as percentages of the PM_{10} or VOC emissions from the CMVs.
6. Average load factors for vessel engines were estimated based on engineering estimates, and on Section 2.5 of the ICF International Report.
7. CO_2e emission rates use the following carbon equivalence factors: 25 for CH_4 and 298 for N_2O.

KITTY HAWK OFFSHORE WIND PROJECT - OCS AIR EMISSION CALCULATIONS
OSS Topside Foundation Installation Emissions

																	Total Emissions (Non-Transit)										
Vessels/Equipment	No. of Engines per vessel	1. DP 2.Anchored 3.Spuds	Dimensions (ft) length x width x depth (draft)	Emission Factor Used (see EFs worksheet)	Engine Rating (hp)	Fuel Type	Transit Round Trips	Transit Duration (hrs/round trip)	Non-OCS Operating Days	OCS Operating Days	Non-Transit Operating Hours (hrs/day)	Non-Transit Total Operating Hours (hrs)	Transit Average load (%)	Non-Transit Average load (%)	Transit Fuel Usage Gallons (per vessel)	Non-Transit Fuel Usage Gallons (per vessel)	VOC tons	NO_X tons	CO tons	PM_{10} tons	$PM_{2.5}$ tons	SO_2 tons	HAPs tons	CO_2 tons	CH_4 tons	N_2O tons	CO_2e tons
Heavy Transport Vessel		1	568 x 138 x 39 (18)																								
-Main Generators	2			3	2,880	Diesel	1	6	0	30	24	720	83%	25%	1,316	47,579	0.43	11.25	0.94	0.16	0.15	0.34	0.04	550.83	3.41E-03	0.03	558.79
-Main Generators	2			3	3,840	Diesel	1	6	0	30	24	720	17%	45%	359	114,190	1.02	27.01	2.25	0.38	0.37	0.81	0.09	1,321.99	8.18E-03	0.06	1,341.10
-Aux. Generator	1			2	994	Diesel	1	6	0	30	24	720	17%	45%	51	16,237	0.13	2.60	1.32	0.16	0.16	1.73E-03	1.41E-02	182.73	0.02	5.30E-03	184.91
-Emergency Generator	1			2	601	Diesel	0	0	0	0	0	0	0%	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
Heavy Lift Vessel		1	600 x 154 x 60 (44)																								
-Main Engines	6			3	4,500	Diesel	1	6	0	30	24	720	83%	25%	6,170	223,027	2.00	52.75	4.40	0.74	0.72	1.59	0.18	2,582.01	0.02	0.12	2,619.33
														TOTALS	**7,897**	**401,032**	**3.58**	**93.61**	**8.91**	**1.44**	**1.40**	**2.74**	**0.32**	**4,637.57**	**0.05**	**0.22**	**4,704.13**

Notes:
1. Transit emissions are based on an assumed vessel speed of 10 knots for all vessel types, and the following one-way travel distances:
   Overseas port to center of Wind Development Area: 32 nm (only includes portion of transit within 25 nm of the Wind Development Area)
2. The number of transits for each vessel are based on the following assumptions:
   1 round trip to/from overseas port for each heavy transport and heavy lift vessel.
3. The specific vessels for each operation have not been finalized at this time; however, the vessels identifed for each installation activity are typical sizes for performing this effort.
4. Emission factors for marine vessel engines are from ICF International report to the US EPA "Current Methodologies in Preparing Mobile Source Port-Related Emissions Inventories", April 2009.
5. HAP emission factors for commercial marine vessels were determined using the methodology identified by US EPA for the latest (2017) National Emissions Inventory (NEI); i.e., they are calculated as percentages of the PM_{10} or VOC emissions from the CMVs.
6. Average load factors for vessel engines were estimated based on engineering estimates, and on Section 2.5 of the ICF International Report.
7. CO_2e emission rates use the following carbon equivalence factors: 25 for CH_4 and 298 for N_2O.

KITTY HAWK OFFSHORE WIND PROJECT - OCS AIR EMISSION CALCULATIONS
OSS Topside Foundation Installation Emissions

Vessels/Equipment	No. of Engines per vessel	1. DP 2.Anchored 3.Spuds	Dimensions (ft) length x width x depth (draft)	Emission Factor Used (see EFs worksheet)	Engine Rating (hp)	Fuel Type	Transit Round Trips	Transit Duration (hrs/round trip)	Non-OCS Operating Days	OCS Operating Days	Non-Transit Operating Hours (hrs/day)	Non-Transit Total Operating Hours (hrs)	Transit Average load (%)	Non-Transit Average load (%)	Transit Fuel Usage Gallons (per vessel)	Non-Transit Fuel Usage Gallons (per vessel)	Total Emissions (Transit)										
																	VOC tons	NO_x tons	CO tons	PM_{10} tons	$PM_{2.5}$ tons	SO_2 tons	HAPs tons	CO_2 tons	CH_4 tons	N_2O tons	CO_2e tons
Heavy Transport Vessel		1	568 x 138 x 39 (18)																								
-Main Generators	2			3	2,880	Diesel	1	6	0	30	24	720	83%	25%	1,316	47,579	1.18E-02	0.31	0.03	4.37E-03	4.24E-03	9.36E-03	1.04E-03	15.24	9.44E-05	7.31E-04	15.46
-Main Generators	2			3	3,840	Diesel	1	6	0	30	24	720	17%	45%	359	114,190	3.22E-03	0.09	7.09E-03	1.19E-03	1.16E-03	2.56E-03	2.84E-04	4.16	2.58E-05	2.00E-04	4.22
-Aux. Generator	1			2	994	Diesel	1	6	0	30	24	720	17%	45%	51	16,237	4.17E-04	8.17E-03	4.17E-03	5.16E-04	5.01E-04	5.45E-06	4.43E-05	0.58	7.50E-05	1.67E-05	0.58
-Emergency Generator	1			2	601	Diesel	0	0	0	0	0	0	0%	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
Heavy Lift Vessel		1	600 x 154 x 60 (44)																								
-Main Engines	6			3	4,500	Diesel	1	6	0	30	24	720	83%	25%	6,170	223,027	0.06	1.46	0.12	0.02	0.02	0.04	4.88E-03	71.44	4.42E-04	3.43E-03	72.47
														TOTALS	**7,897**	**401,032**	**0.07**	**1.86**	**0.16**	**0.03**	**0.03**	**0.06**	**6.25E-03**	**91.41**	**6.37E-04**	**4.38E-03**	**92.73**

Notes:

1. Transit emissions are based on an assumed vessel speed of 10 knots for all vessel types, and the following one-way travel distances:
   Overseas port to center of Wind Development Area: 32 nm (only includes portion of transit within 25 nm of the Wind Development Area)
2. The number of transits for each vessel are based on the following assumptions:
   1 round trip to/from overseas port for each heavy transport and heavy lift vessel.
3. The specific vessels for each operation have not been finalized at this time; however, the vessels identifed for each installation activity are typical sizes for performing this effort.
4. Emission factors for marine vessel engines are from ICF International report to the US EPA "Current Methodologies in Preparing Mobile Source Port-Related Emissions Inventories", April 2009.
5. HAP emission factors for commercial marine vessels were determined using the methodology identified by US EPA for the latest (2017) National Emissions Inventory (NEI); i.e., they are calculated as percentages of the PM_{10} or VOC emissions from the CMVs.
6. Average load factors for vessel engines were estimated based on engineering estimates, and on Section 2.5 of the ICF International Report.
7. CO_2e emission rates use the following carbon equivalence factors: 25 for CH_4 and 298 for N_2O.

KITTY HAWK OFFSHORE WIND PROJECT - OCS AIR EMISSION CALCULATIONS
Export Cable Installation Emissions

Vessels/Equipment	No. of Engines per vessel	1. DP 2.Anchored 3.Spuds	Dimensions (ft) length x width x depth (draft)	Emission Factor Used (see EFs worksheet)	Engine Rating (hp)	Fuel Type	Transit Round Trips	Transit Duration (hrs/round trip)	Non-OCS Operating Days	OCS Operating Days	Non-Transit Operating Hours (hrs/day)	Non-Transit Total Operating Hours (hrs)	Transit Average load (%)	Non-Transit Average load (%)	Transit Fuel Usage Gallons (per vessel)	Non-Transit Fuel Usage Gallons (per vessel)	Total Emissions (Non-Transit)										
																	VOC tons	NO_X tons	CO tons	PM_{10} tons	$PM_{2.5}$ tons	SO_2 tons	HAPs tons	CO_2 tons	CH_4 tons	N_2O tons	CO_2e tons
Cable Lay Vessel (Far Shore)		1	459 x 97 x 36 (24)																								
-Main Generators	6			3	3,003	Diesel	6	16	0	150	24	3,600	83%	10%	65,877	297,635	2.67	70.40	5.87	0.99	0.96	2.12	0.24	3,445.76	0.02	0.17	3,495.56
Cable Lay Vessel (Near Shore)			401 x 110 x 25 (18)																								
-Main Generators	4			2	1,332	Diesel	6	16	30	0	24	720	83%	10%	21,410	19,346	0.16	3.09	1.58	0.20	0.19	2.06E-03	0.02	217.73	0.03	6.31E-03	220.32
-Crane Engine	1			2	536	Diesel	6	16	30	0	24	720	17%	45%	441	8,758	0.07	1.40	0.71	0.09	0.09	9.34E-04	7.59E-03	98.57	1.29E-02	2.86E-03	99.74
-Emergency Generator	1			2	361	Diesel	0	0	0	0	0	0	17%	45%	0	0	0	0	0	0	0	0	0	0	0	0	0
Support Vessel		1	243 x 56 x 26 (21)																								
-Main Generators	2			2	2,466	Diesel	6	16	0	180	24	4,320	83%	10%	19,816	107,437	0.88	17.17	8.76	1.09	1.05	1.15E-02	0.09	1,209.14	0.16	0.04	1,223.53
-Main Generators	2			2	1,850	Diesel	6	16	0	180	24	4,320	83%	10%	14,862	80,578	0.66	12.88	6.57	0.81	0.79	8.59E-03	0.07	906.86	0.12	0.03	917.65
-Emergency Generator	1			1	382	Diesel	0	0	0	0	0	0	17%	45%	0	0	0	0	0	0	0	0	0	0	0	0	0
Survey Vessel		N/A	114 x 24 x 7.4																								
-Main Engines	4			1	585	Diesel	6	16	0	180	24	4,320	83%	10%	9,400	50,964	0.22	8.15	4.16	0.21	0.21	5.44E-03	0.02	573.57	0.07	0.02	580.39
-Aux. Generator	1			1	47	Diesel	6	16	0	180	24	4,320	17%	45%	39	4,606	0.02	0.74	0.38	0.02	0.02	4.91E-04	2.04E-03	51.84	6.76E-03	1.50E-03	52.46
-Aux. Engine	1			1	47	Diesel	6	16	0	180	24	4,320	17%	45%	39	4,606	0.02	0.74	0.38	0.02	0.02	4.91E-04	2.04E-03	51.84	6.76E-03	1.50E-03	52.46
Pre-Lay Grapnel Run Vessel			150 x 36 x 10																								
_ Main Engines	2			1	750	Diesel	1	16	0	30	24	720	83%	10%	1,004	5,445	0.02	0.87	0.44	0.02	0.02	5.81E-04	2.41E-03	61.28	7.99E-03	1.78E-03	62.01
-Aux. Generator	1			1	133	Diesel	1	16	0	30	24	720	17%	45%	18	2,172	9.57E-03	0.35	0.18	9.14E-03	8.87E-03	2.32E-04	9.60E-04	24.45	3.19E-03	7.09E-04	24.74
-Bow Thruster Engine	1			1	325	Diesel	1	16	0	30	24	720	0%	45%	0	5,309	0.02	0.85	0.43	0.02	0.02	5.66E-04	2.35E-03	59.75	7.79E-03	1.73E-03	60.46
-Aux. Engine	1			1	133	Diesel	1	16	0	30	24	720	17%	45%	18	2,172	9.57E-03	0.35	0.18	9.14E-03	8.87E-03	2.32E-04	9.60E-04	24.45	3.19E-03	7.09E-04	24.74
Guard/MMO Vessel 1		N/A	41 x 13.5 x 4																								
-Main Engines	2			1	425	Diesel	6	16	0	180	24	4,320	83%	10%	3,415	18,512	0.08	2.96	1.51	0.08	0.08	1.97E-03	8.18E-03	208.35	0.03	6.04E-03	210.83
Guard/MMO Vessel 2		N/A	41 x 13.5 x 4																								
-Main Engines	2			1	425	Diesel	6	16	0	180	24	4,320	83%	10%	3,415	18,512	0.08	2.96	1.51	0.08	0.08	1.97E-03	8.18E-03	208.35	0.03	6.04E-03	210.83
														TOTALS	**139,753**	**626,055**	**4.92**	**122.90**	**32.65**	**3.64**	**3.53**	**2.15**	**0.47**	**7,142**	**0.50**	**0.27**	**7,236**

Notes:

1. Transit emissions are based on an assumed vessel speed of 10 knots for all vessel types, and the following one-way travel distances:
   Norfolk, VA (assumed local port) to center of Wind Development Area: 80 nm
2. The number of transits for each vessel are based on the following assumptions:
   Monthly round trips to/from local port for each cable lay vessel, support vessel, and survey vessel.
   One round trip to/from local port for pre-lay grapnel run vessel
   Monthly round trips to/from port for guard vessels.
3. The specific vessels for each operation have not been finalized at this time; however, the vessels identifed for each installation activity are typical sizes for performing this effort.
4. Emission factors for marine vessel engines are from ICF International report to the US EPA "Current Methodologies in Preparing Mobile Source Port-Related Emissions Inventories", April 2009.
5. HAP emission factors for commercial marine vessels were determined using the methodology identified by US EPA for the latest (2017) National Emissions Inventory (NEI); i.e., they are calculated as percentages of the PM or VOC emissions from the CMVs.
6. Average load factors for vessel engines were estimated based on engineering estimates, and on Section 2.5 of the ICF International Report.
7. CO_2e emission rates use the following carbon equivalence factors: 25 for CH_4 and 298 for N_2O.

KITTY HAWK OFFSHORE WIND PROJECT - OCS AIR EMISSION CALCULATIONS
Export Cable Installation Emissions

																	Total Emissions (Transit)										
Vessels/Equipment	No. of Engines per vessel	1. DP 2.Anchored 3.Spuds	Dimensions (ft) length x width x depth (draft)	Emission Factor Used (see EFs worksheet)	Engine Rating (hp)	Fuel Type	Transit Round Trips	Transit Duration (hrs/round trip)	Non-OCS Operating Days	OCS Operating Days	Non-Transit Operating Hours (hrs/day)	Non-Transit Total Operating Hours (hrs)	Transit Average load (%)	Non-Transit Average load (%)	Transit Fuel Usage Gallons (per vessel)	Non-Transit Fuel Usage Gallons (per vessel)	VOC tons	NO_X tons	CO tons	PM_{10} tons	$PM_{2.5}$ tons	SO_2 tons	HAPs tons	CO_2 tons	CH_4 tons	N_2O tons	CO_2e tons
Cable Lay Vessel (Far Shore)		1	459 x 97 x 36 (24)																								
-Main Generators	6			3	3,003	Diesel	6	16	0	150	24	3,600	83%	10%	65,877	297,635	0.59	15.58	1.30	0.22	0.21	0.47	0.05	762.66	4.72E-03	0.04	773.68
Cable Lay Vessel (Near Shore)			401 x 110 x 25 (18)																								
-Main Generators	4			2	1,332	Diesel	6	16	30	0	24	720	83%	10%	21,410	19,346	0.17	3.42	1.75	0.22	0.21	2.28E-03	0.02	240.96	0.03	6.98E-03	243.83
-Crane Engine	1			2	536	Diesel	6	16	30	0	24	720	17%	45%	441	8,758	3.60E-03	0.07	0.04	4.46E-03	4.32E-03	4.71E-05	3.82E-04	4.97	6.48E-04	1.44E-04	5.02
-Emergency Generator	1			2	361	Diesel	0	0	0	0	0	0	17%	45%	0	0	0	0	0	0	0	0	0	0	0	0	0
Support Vessel		1	243 x 56 x 26 (21)																								
-Main Generators	2			2	2,466	Diesel	6	16	0	180	24	4,320	83%	10%	19,816	107,437	0.16	3.17	1.62	0.20	0.19	2.11E-03	0.02	223.02	0.03	6.46E-03	225.67
-Main Generators	2			2	1,850	Diesel	6	16	0	180	24	4,320	83%	10%	14,862	80,578	0.12	2.38	1.21	0.15	0.15	1.59E-03	1.29E-02	167.26	0.02	4.85E-03	169.25
-Emergency Generator	1			1	382	Diesel	0	0	0	0	0	0	17%	45%	0	0	0	0	0	0	0	0	0	0	0	0	0
Survey Vessel		N/A	114 x 24 x 7.4																								
-Main Engines	4			1	585	Diesel	6	16	0	180	24	4,320	83%	10%	9,400	50,964	0.04	1.50	0.77	0.04	0.04	1.00E-03	4.16E-03	105.79	1.38E-02	3.07E-03	107.05
-Aux. Generator	1			1	47	Diesel	6	16	0	180	24	4,320	17%	45%	39	4,606	1.70E-04	6.18E-03	3.15E-03	1.63E-04	1.58E-04	4.12E-06	1.71E-05	0.44	5.68E-05	1.26E-05	0.44
-Aux. Engine	1			1	47	Diesel	6	16	0	180	24	4,320	17%	45%	39	4,606	1.70E-04	6.18E-03	3.15E-03	1.63E-04	1.58E-04	4.12E-06	1.71E-05	0.44	5.68E-05	1.26E-05	0.44
Pre-Lay Grapnel Run Vessel			150 x 36 x 10																								
_ Main Engines	2			1	750	Diesel	1	16	0	30	24	720	83%	10%	1,004	5,445	4.42E-03	0.16	0.08	4.23E-03	4.10E-03	1.07E-04	4.44E-04	11.30	1.47E-03	3.28E-04	11.44
-Aux. Generator	1			1	133	Diesel	1	16	0	30	24	720	17%	45%	18	2,172	8.03E-05	2.92E-03	1.49E-03	7.67E-05	7.44E-05	1.95E-06	8.06E-06	0.21	2.68E-05	5.95E-06	0.21
-Bow Thruster Engine	1			1	325	Diesel	1	16	0	30	24	720	0%	45%	0	5,309	0	0	0	0	0	0	0	0	0	0	0
-Aux. Engine	1			1	133	Diesel	1	16	0	30	24	720	17%	45%	18	2,172	8.03E-05	2.92E-03	1.49E-03	7.67E-05	7.44E-05	1.95E-06	8.06E-06	0.21	2.68E-05	5.95E-06	0.21
Guard/MMO Vessel 1		N/A	41 x 13.5 x 4																								
-Main Engines	2			1	425	Diesel	6	16	0	180	24	4,320	83%	10%	3,415	18,512	0.02	0.55	0.28	1.44E-02	1.39E-02	3.64E-04	1.51E-03	38.43	5.01E-03	1.11E-03	38.89
Guard/MMO Vessel 2		N/A	41 x 13.5 x 4																								
-Main Engines	2			1	425	Diesel	6	16	0	180	24	4,320	83%	10%	3,415	18,512	0.02	0.55	0.28	1.44E-02	1.39E-02	3.64E-04	1.51E-03	38.43	5.01E-03	1.11E-03	38.89
														TOTALS	**139,753**	**626,055**	**1.13**	**27.39**	**7.32**	**0.86**	**0.84**	**0.48**	**0.11**	**1,594**	**0.11**	**0.06**	**1,615**

Notes:

1. Transit emissions are based on an assumed vessel speed of 10 knots for all vessel types, and the following one-way travel distances:
   Norfolk, VA (assumed local port) to center of Wind Development Area: 80 nm
2. The number of transits for each vessel are based on the following assumptions:
   Monthly round trips to/from local port for each cable lay vessel, support vessel, and survey vessel.
   One round trip to/from local port for pre-lay grapnel run vessel
   Monthly round trips to/from port for guard vessels.
3. The specific vessels for each operation have not been finalized at this time; however, the vessels identifed for each installation activity are typical sizes for performing this effort.
4. Emission factors for marine vessel engines are from ICF International report to the US EPA "Current Methodologies in Preparing Mobile Source Port-Related Emissions Inventories", April 2009.
5. HAP emission factors for commercial marine vessels were determined using the methodology identified by US EPA for the latest (2017) National Emissions Inventory (NEI); i.e., they are calculated as percentages of the PM or VOC emissions from the CMVs.
6. Average load factors for vessel engines were estimated based on engineering estimates, and on Section 2.5 of the ICF International Report.
7. CO_2e emission rates use the following carbon equivalence factors: 25 for CH_4 and 298 for N_2O.

KITTY HAWK OFFSHORE WIND PROJECT - OCS AIR EMISSION CALCULATIONS
Array Cable Installation Emissions

Vessels/Equipment	No. of Engines per vessel	1. DP 2.Anchored 3.Spuds	Dimensions (ft) length x width x depth (draft)	Emission Factor Used (see EFs worksheet)	Engine Rating (hp)	Fuel Type	Transit Round Trips	Transit Duration (hrs/round trip)	Non-OCS Operating Days	OCS Operating Days	Non-Transit Operating Hours (hrs/day)	Non-Transit Total Operating Hours (hrs)	Transit Average load (%)	Non-Transit Average load (%)	Transit Fuel Usage Gallons (per vessel)	Non-Transit Fuel Usage Gallons (per vessel)
Cable Lay Vessel		1	492 x 102 x 42 (29)													
-Main Generators	6			3	4625	Diesel	6	16	0	180	24	4,320	83%	10%	101,462	550,093
Support Vessel		1	243 x 56 x 26 (21)													
-Main Generators	2			2	2,466	Diesel	6	16	0	180	24	4,320	83%	10%	19,816	107,437
-Main Generators	2			2	1,850	Diesel	6	16	0	180	24	4,320	83%	10%	14,862	80,578
-Emergency Generator	1			1	382	Diesel	0	0	0	0	0	0	17%	45%	0	0
Survey Vessel		N/A	114 x 24 x 7.4													
-Main Engines	4			1	585	Diesel	8	16	0	240	24	5,760	83%	10%	12,533	67,952
-Aux. Generator	1			1	47	Diesel	8	16	0	240	24	5,760	17%	45%	52	6,142
-Aux. Engine	1			1	47	Diesel	8	16	0	240	24	5,760	17%	45%	52	6,142
Pre-Lay Grapnel Run Vessel			150 x 36 x 10													
, Main Engines	2			1	750	Diesel	1	16	0	30	24	720	83%	10%	1,004	5,445
-Aux. Generator	1			1	133	Diesel	1	16	0	30	24	720	17%	45%	18	2,172
-Bow Thruster Engine	1			1	325	Diesel	1	16	0	30	24	720	0%	45%	0	5,309
-Aux. Engine	1			1	133	Diesel	1	16	0	30	24	720	17%	45%	18	2,172
Guard/MMO Vessel 1		N/A	41 x 13.5 x 4													
-Main Engines	2			1	425	Diesel	6	16	0	180	24	4,320	83%	10%	3,415	18,512
Guard/MMO Vessel 2		N/A	41 x 13.5 x 4													
-Main Engines	2			1	425	Diesel	6	16	0	180	24	4,320	83%	10%	3,415	18,512
														TOTALS	**156,646**	**870,467**

Vessels/Equipment	Total Emissions (Non-Transit) VOC tons	NO_X tons	CO tons	PM_{10} tons	$PM_{2.5}$ tons	SO_2 tons	HAPs tons	CO_2 tons	CH_4 tons	N_2O tons	CO_2e tons
Cable Lay Vessel											
-Main Generators	4.93	130.11	10.84	1.83	1.77	3.91	0.44	6,368.50	0.04	0.31	6,460.55
Support Vessel											
-Main Generators	0.88	17.17	8.76	1.09	1.05	1.15E-02	0.09	1,209.14	0.16	0.04	1,223.53
-Main Generators	0.66	12.88	6.57	0.81	0.79	8.59E-03	0.07	906.86	0.12	0.03	917.65
-Emergency Generator	0	0	0	0	0	0	0	0	0	0	0
Survey Vessel											
-Main Engines	0.30	10.86	5.54	0.29	0.28	7.25E-03	0.03	764.76	0.10	0.02	773.86
-Aux. Generator	0.03	0.98	0.50	0.03	0.03	6.55E-04	2.72E-03	69.12	9.02E-03	2.00E-03	69.94
-Aux. Engine	0.03	0.98	0.50	0.03	0.03	6.55E-04	2.72E-03	69.12	9.02E-03	2.00E-03	69.94
Pre-Lay Grapnel Run Vessel											
, Main Engines	0.02	0.87	0.44	0.02	0.02	5.81E-04	2.41E-03	61.28	7.99E-03	1.78E-03	62.01
-Aux. Generator	9.57E-03	0.35	0.18	9.14E-03	8.87E-03	2.32E-04	9.60E-04	24.45	3.19E-03	7.09E-04	24.74
-Bow Thruster Engine	0.02	0.85	0.43	0.02	0.02	5.66E-04	2.35E-03	59.75	7.79E-03	1.73E-03	60.46
-Aux. Engine	9.57E-03	0.35	0.18	9.14E-03	8.87E-03	2.32E-04	9.60E-04	24.45	3.19E-03	7.09E-04	24.74
Guard/MMO Vessel 1											
-Main Engines	0.08	2.96	1.51	0.08	0.08	1.97E-03	8.18E-03	208.35	0.03	6.04E-03	210.83
Guard/MMO Vessel 2											
-Main Engines	0.08	2.96	1.51	0.08	0.08	1.97E-03	8.18E-03	208.35	0.03	6.04E-03	210.83
TOTALS	**7.04**	**181.32**	**36.97**	**4.28**	**4.15**	**3.95**	**0.66**	**9,974**	**0.51**	**0.41**	**10,109**

Notes:

1. Transit emissions are based on an assumed vessel speed of 10 knots for all vessel types, and the following one-way travel distances:
   Norfolk, VA (assumed local port) to center of Wind Development Area: 80 nm
2. The number of transits for each vessel are based on the following assumptions:
   Monthly round trips to/from local port for each cable lay vessel, support vessel, and survey vessel.
   One round trip to/from local port for pre-lay grapnel run vessel
   Monthly round trips to/from port for guard vessels.
3. The specific vessels for each operation have not been finalized at this time; however, the vessels identifed for each installation activity are typical sizes for performing this effort.
4. Emission factors for marine vessel engines are from ICF International report to the US EPA "Current Methodologies in Preparing Mobile Source Port-Related Emissions Inventories", April 2009.
5. HAP emission factors for commercial marine vessels were determined using the methodology identified by US EPA for the latest (2017) National Emissions Inventory (NEI); i.e., they are calculated as percentages of the PM_{10} or VOC emissions from the CMVs.
6. Average load factors for vessel engines were estimated based on engineering estimates, and on Section 2.5 of the ICF International Report.
7. CO_2e emission rates use the following carbon equivalence factors: 25 for CH_4 and 298 for N_2O.

KITTY HAWK OFFSHORE WIND PROJECT - OCS AIR EMISSION CALCULATIONS
Array Cable Installation Emissions

Vessels/Equipment	No. of Engines per vessel	1. DP 2.Anchored 3.Spuds	Dimensions (ft) length x width x depth (draft)	Emission Factor Used (see EFs worksheet)	Engine Rating (hp)	Fuel Type	Transit Round Trips	Transit Duration (hrs/round trip)	Non-OCS Operating Days	OCS Operating Days	Non-Transit Operating Hours (hrs/day)	Non-Transit Total Operating Hours (hrs)	Transit Average load (%)	Non-Transit Average load (%)	Transit Fuel Usage Gallons (per vessel)	Non-Transit Fuel Usage Gallons (per vessel)
Cable Lay Vessel		1	492 x 102 x 42 (29)													
-Main Generators	6			3	4625	Diesel	6	16	0	180	24	4,320	83%	10%	101,462	550,093
Support Vessel		1	243 x 56 x 26 (21)													
-Main Generators	2			2	2,466	Diesel	6	16	0	180	24	4,320	83%	10%	19,816	107,437
-Main Generators	2			2	1,850	Diesel	6	16	0	180	24	4,320	83%	10%	14,862	80,578
-Emergency Generator	1			1	382	Diesel	0	0	0	0	0	0	17%	45%	0	0
Survey Vessel		N/A	114 x 24 x 7.4													
-Main Engines	4			1	585	Diesel	8	16	0	240	24	5,760	83%	10%	12,533	67,952
-Aux. Generator	1			1	47	Diesel	8	16	0	240	24	5,760	17%	45%	52	6,142
-Aux. Engine	1			1	47	Diesel	8	16	0	240	24	5,760	17%	45%	52	6,142
Pre-Lay Grapnel Run Vessel			150 x 36 x 10													
, Main Engines	2			1	750	Diesel	1	16	0	30	24	720	83%	10%	1,004	5,445
-Aux. Generator	1			1	133	Diesel	1	16	0	30	24	720	17%	45%	18	2,172
-Bow Thruster Engine	1			1	325	Diesel	1	16	0	30	24	720	0%	45%	0	5,309
-Aux. Engine	1			1	133	Diesel	1	16	0	30	24	720	17%	45%	18	2,172
Guard/MMO Vessel 1		N/A	41 x 13.5 x 4													
-Main Engines	2			1	425	Diesel	6	16	0	180	24	4,320	83%	10%	3,415	18,512
Guard/MMO Vessel 2		N/A	41 x 13.5 x 4													
-Main Engines	2			1	425	Diesel	6	16	0	180	24	4,320	83%	10%	3,415	18,512
														TOTALS	**156,646**	**870,467**

Vessels/Equipment	Total Emissions (Transit)										
	VOC tons	NO_X tons	CO tons	PM_{10} tons	$PM_{2.5}$ tons	SO_2 tons	HAPs tons	CO_2 tons	CH_4 tons	N_2O tons	CO_2e tons
Cable Lay Vessel -Main Generators	0.91	24.00	2.00	0.34	0.33	0.72	0.08	1,174.63	7.27E-03	0.06	1,191.61
Support Vessel -Main Generators	0.16	3.17	1.62	0.20	0.19	2.11E-03	0.02	223.02	0.03	6.46E-03	225.67
-Main Generators	0.12	2.38	1.21	0.15	0.15	1.59E-03	1.29E-02	167.26	0.02	4.85E-03	169.25
-Emergency Generator	0	0	0	0	0	0	0	0	0	0	0
Survey Vessel -Main Engines	0.06	2.00	1.02	0.05	0.05	1.34E-03	5.54E-03	141.06	0.02	4.09E-03	142.73
-Aux. Generator	2.27E-04	8.24E-03	4.20E-03	2.17E-04	2.10E-04	5.50E-06	2.28E-05	0.58	7.57E-05	1.68E-05	0.59
-Aux. Engine	2.27E-04	8.24E-03	4.20E-03	2.17E-04	2.10E-04	5.50E-06	2.28E-05	0.58	7.57E-05	1.68E-05	0.59
Pre-Lay Grapnel Run Vessel , Main Engines	4.42E-03	0.16	0.08	4.23E-03	4.10E-03	1.07E-04	4.44E-04	11.30	1.47E-03	3.28E-04	11.44
-Aux. Generator	8.03E-05	2.92E-03	1.49E-03	7.67E-05	7.44E-05	1.95E-06	8.06E-06	0.21	2.68E-05	5.95E-06	0.21
-Bow Thruster Engine	0	0	0	0	0	0	0	0	0	0	0
-Aux. Engine	8.03E-05	2.92E-03	1.49E-03	7.67E-05	7.44E-05	1.95E-06	8.06E-06	0.21	2.68E-05	5.95E-06	0.21
Guard/MMO Vessel 1 -Main Engines	0.02	0.55	0.28	1.44E-02	1.39E-02	3.64E-04	1.51E-03	38.43	5.01E-03	1.11E-03	38.89
Guard/MMO Vessel 2 -Main Engines	0.02	0.55	0.28	1.44E-02	1.39E-02	3.64E-04	1.51E-03	38.43	5.01E-03	1.11E-03	38.89
TOTALS	**1.28**	**32.82**	**6.50**	**0.77**	**0.75**	**0.73**	**0.12**	**1,796**	**0.09**	**0.07**	**1,820**

Notes:

1. Transit emissions are based on an assumed vessel speed of 10 knots for all vessel types, and the following one-way travel distances:
   Norfolk, VA (assumed local port) to center of Wind Development Area: 80 nm
2. The number of transits for each vessel are based on the following assumptions:
   Monthly round trips to/from local port for each cable lay vessel, support vessel, and survey vessel.
   One round trip to/from local port for pre-lay grapnel run vessel
   Monthly round trips to/from port for guard vessels.
3. The specific vessels for each operation have not been finalized at this time; however, the vessels identifed for each installation activity are typical sizes for performing this effort.
4. Emission factors for marine vessel engines are from ICF International report to the US EPA "Current Methodologies in Preparing Mobile Source Port-Related Emissions Inventories", April 2009.
5. HAP emission factors for commercial marine vessels were determined using the methodology identified by US EPA for the latest (2017) National Emissions Inventory (NEI); i.e., they are calculated as percentages of the PM_{10} or VOC emissions from the CMVs.
6. Average load factors for vessel engines were estimated based on engineering estimates, and on Section 2.5 of the ICF International Report.
7. CO_2e emission rates use the following carbon equivalence factors: 25 for CH_4 and 298 for N_2O.

Vessels/Equipment	No. of Engines per vessel	1. DP 2.Anchored 3.Spuds	Dimensions (ft) length x width x depth (draft)	Emission Factor Used (see EFs worksheet)	Engine Rating (hp)	Fuel Type	Transit Round Trips	Transit Duration (hrs/round trip)	Non-OCS Operating Days	OCS Operating Days	Non-Transit Operating Hours (hrs/day)	Non-Transit Total Operating Hours (hrs)	Transit Average load (%)	Non-Transit Average load (%)	Transit Fuel Usage Gallons (per vessel)	Non-Transit Fuel Usage Gallons (per vessel)	Total Emissions (Non-Transit) VOC tons	NO_X tons	CO tons	PM_{10} tons	$PM_{2.5}$ tons	SO_2 tons	HAPs tons	CO_2 tons	CH_4 tons	N_2O tons	CO_2e tons
Service Operations Vessel 1		1	306 x 59 x 25 (18)																								
-Main Generators	2			2	2279	Diesel	6	16	0	180	24	4,320	83%	10%	18,308	99,263	0.81	15.87	8.10	1.00	0.97	1.06E-02	0.09	1,117.14	0.15	0.03	1,130.44
-Main Generators	2			2	1260	Diesel	6	16	0	180	24	4,320	83%	10%	10,123	54,886	0.45	8.77	4.48	0.55	0.54	5.85E-03	0.05	617.71	0.08	0.02	625.06
-Emergency Generator	1			1	268	Diesel	0	0	0	0	0	0	17%	45%	0	0	0	0	0	0	0	0	0	0	0	0	0
Service Operations Vessel 2		1	306 x 59 x 25 (18)																								
-Main Generators	2			2	2279	Diesel	6	16	0	180	24	4,320	83%	10%	18,308	99,263	0.81	15.87	8.10	1.00	0.97	1.06E-02	0.09	1,117.14	0.15	0.03	1,130.44
-Main Generators	2			2	1260	Diesel	6	16	0	180	24	4,320	83%	10%	10,123	54,886	0.45	8.77	4.48	0.55	0.54	5.85E-03	0.05	617.71	0.08	0.02	625.06
-Emergency Generator	1			1	268	Diesel	0	0	0	0	0	0	17%	45%	0	0	0	0	0	0	0	0	0	0	0	0	0
Crew Transfer Vessel 1		N/A	114 x 24 x 7.4																								
-Main Engines	4			1	585	Diesel	26	16	0	26	8	208	83%	10%	40,733	2,454	1.08E-02	0.39	0.20	1.03E-02	1.00E-02	2.62E-04	1.08E-03	27.62	3.60E-03	8.00E-04	27.94
-Aux. Generator	1			1	47	Diesel	26	16	0	26	8	208	17%	45%	168	222	9.77E-04	0.04	0.02	9.33E-04	9.05E-04	2.37E-05	9.80E-05	2.50	3.26E-04	7.24E-05	2.53
-Aux. Engine	1			1	47	Diesel	26	16	0	26	8	208	17%	45%	168	222	9.77E-04	0.04	0.02	9.33E-04	9.05E-04	2.37E-05	9.80E-05	2.50	3.26E-04	7.24E-05	2.53
Crew Transfer Vessel 2		N/A	114 x 24 x 7.4																								
-Main Engines	4			1	585	Diesel	26	16	0	26	8	208	83%	10%	40,733	2,454	1.08E-02	0.39	0.20	1.03E-02	1.00E-02	2.62E-04	1.08E-03	27.62	3.60E-03	8.00E-04	27.94
-Aux. Generator	1			1	47	Diesel	26	16	0	26	8	208	17%	45%	168	222	9.77E-04	0.04	0.02	9.33E-04	9.05E-04	2.37E-05	9.80E-05	2.50	3.26E-04	7.24E-05	2.53
-Aux. Engine	1			1	47	Diesel	26	16	0	26	8	208	17%	45%	168	222	9.77E-04	0.04	0.02	9.33E-04	9.05E-04	2.37E-05	9.80E-05	2.50	3.26E-04	7.24E-05	2.53
Temporary WTG Generator Engine		N/A	N/A																								
	1			254	54	Diesel	0	0	0	414	24	9,936	0%	100%	0	26,135	0.41	2.88	2.89	0.18	0.17	2.74E-03	7.12E-03	298.29	1.21E-02	2.42E-03	299.31
														TOTALS	**139,001**	**340,228**	**2.95**	**53.08**	**28.51**	**3.31**	**3.21**	**3.62E-02**	**0.28**	**3,833**	**0.47**	**0.10**	**3,876**

Notes:

1. Transit emissions are based on an assumed vessel speed of 10 knots for all vessel types, and the following one-way travel distances:
   Norfolk, VA (assumed local port) to center of Wind Development Area: 80 nm
2. The number of transits for each vessel are based on the following assumptions:
   Monthly round trips to/from local port for each SOV.
   Weekly round trips to/from port for crew transfer vessels.
3. The specific vessels for each operation have not been finalized at this time; however, the vessels identifed for each installation activity are typical sizes for performing this effort.
4. Emission factors for marine vessel engines are from ICF International report to the US EPA "Current Methodologies in Preparing Mobile Source Port-Related Emissions Inventories", April 2009.
5. HAP emission factors for commercial marine vessels were determined using the methodology identified by US EPA for the latest (2017) National Emissions Inventory (NEI); i.e., they are calculated as percentages of the PM_{10} or VOC emissions from the CMVs.
   HAP emissions for the temporary platform generator were based on EPA's AP-42 Volume 1, Chapter 3.3 for small diesel engines. (see HAP emission factor summary page)
6. Average load factors for vessel engines were estimated based on engineering estimates, and on Section 2.5 of the ICF International Report.
7. CO_2e emission rates use the following carbon equivalence factors: 25 for CH_4 and 298 for N_2O.

Commissioning Emissions

																	Total Emissions (Transit)										
Vessels/Equipment	No. of Engines per vessel	1. DP 2.Anchored 3.Spuds	Dimensions (ft) length x width x depth (draft)	Emission Factor Used (see EFs worksheet)	Engine Rating (hp)	Fuel Type	Transit Round Trips	Transit Duration (hrs/round trip)	Non-OCS Operating Days	OCS Operating Days	Non-Transit Operating Hours (hrs/day)	Non-Transit Total Operating Hours (hrs)	Transit Average load (%)	Non-Transit Average load (%)	Transit Fuel Usage Gallons (per vessel)	Non-Transit Fuel Usage Gallons (per vessel)	VOC tons	NO_X tons	CO tons	PM_{10} tons	$PM_{2.5}$ tons	SO_2 tons	HAPs tons	CO_2 tons	CH_4 tons	N_2O tons	CO_2e tons
Service Operations Vessel 1		1	306 x 59 x 25 (18)																								
-Main Generators	2			2	2279	Diesel	6	16	0	180	24	4,320	83%	10%	18,308	99,263	0.15	2.93	1.49	0.18	0.18	1.95E-03	0.02	206.05	0.03	5.97E-03	208.50
-Main Generators	2			2	1260	Diesel	6	16	0	180	24	4,320	83%	10%	10,123	54,886	0.08	1.62	0.83	0.10	0.10	1.08E-03	8.77E-03	113.93	1.49E-02	3.30E-03	115.29
-Emergency Generator	1			1	268	Diesel	0	0	0	0	0	0	17%	45%	0	0	0	0	0	0	0	0	0	0	0	0	0
Service Operations Vessel 2		1	306 x 59 x 25 (18)																								
-Main Generators	2			2	2279	Diesel	6	16	0	180	24	4,320	83%	10%	18,308	99,263	0.15	2.93	1.49	0.18	0.18	1.95E-03	0.02	206.05	0.03	5.97E-03	208.50
-Main Generators	2			2	1260	Diesel	6	16	0	180	24	4,320	83%	10%	10,123	54,886	0.08	1.62	0.83	0.10	0.10	1.08E-03	8.77E-03	113.93	1.49E-02	3.30E-03	115.29
-Emergency Generator	1			1	268	Diesel	0	0	0	0	0	0	17%	45%	0	0	0	0	0	0	0	0	0	0	0	0	0
Crew Transfer Vessel 1		N/A	114 x 24 x 7.4																								
-Main Engines	4			1	585	Diesel	26	16	0	26	8	208	83%	10%	40,733	2,454	0.18	6.51	3.32	0.17	0.17	4.34E-03	0.02	458.43	0.06	1.33E-02	463.88
-Aux. Generator	1			1	47	Diesel	26	16	0	26	8	208	17%	45%	168	222	7.38E-04	0.03	1.37E-02	7.05E-04	6.84E-04	1.79E-05	7.41E-05	1.89	2.46E-04	5.47E-05	1.91
-Aux. Engine	1			1	47	Diesel	26	16	0	26	8	208	17%	45%	168	222	7.38E-04	0.03	1.37E-02	7.05E-04	6.84E-04	1.79E-05	7.41E-05	1.89	2.46E-04	5.47E-05	1.91
Crew Transfer Vessel 2		N/A	114 x 24 x 7.4																								
-Main Engines	4			1	585	Diesel	26	16	0	26	8	208	83%	10%	40,733	2,454	0.18	6.51	3.32	0.17	0.17	4.34E-03	0.02	458.43	0.06	1.33E-02	463.88
-Aux. Generator	1			1	47	Diesel	26	16	0	26	8	208	17%	45%	168	222	7.38E-04	0.03	1.37E-02	7.05E-04	6.84E-04	1.79E-05	7.41E-05	1.89	2.46E-04	5.47E-05	1.91
-Aux. Engine	1			1	47	Diesel	26	16	0	26	8	208	17%	45%	168	222	7.38E-04	0.03	1.37E-02	7.05E-04	6.84E-04	1.79E-05	7.41E-05	1.89	2.46E-04	5.47E-05	1.91
Temporary WTG Generator Engine		N/A	N/A																								
	1			254	54	Diesel	0	0	0	414	24	9,936	0%	100%	0	26,135	0	0	0	0	0	0	0	0	0	0	0
														TOTALS	**139,001**	**340,228**	**0.83**	**22.22**	**11.34**	**0.92**	**0.89**	**1.48E-02**	**0.09**	**1,564.37**	**0.20**	**0.05**	**1,582.99**

Notes:

1. Transit emissions are based on an assumed vessel speed of 10 knots for all vessel types, and the following one-way travel distances:
   Norfolk, VA (assumed local port) to center of Wind Development Area: 80 nm
2. The number of transits for each vessel are based on the following assumptions:
   Monthly round trips to/from local port for each SOV.
   Weekly round trips to/from port for crew transfer vessels.
3. The specific vessels for each operation have not been finalized at this time; however, the vessels identifed for each installation activity are typical sizes for performing this effort.
4. Emission factors for marine vessel engines are from ICF International report to the US EPA "Current Methodologies in Preparing Mobile Source Port-Related Emissions Inventories", April 2009.
5. HAP emission factors for commercial marine vessels were determined using the methodology identified by US EPA for the latest (2017) National Emissions Inventory (NEI); i.e., they are calculated as percentages of the PM or VOC emissions from the CMVs.
   HAP emissions for the temporary platform generator were based on EPA's AP-42 Volume 1, Chapter 3.3 for small diesel engines. (see HAP emission factor summary page)
6. Average load factors for vessel engines were estimated based on engineering estimates, and on Section 2.5 of the ICF International Report.
7. CO_2e emission rates use the following carbon equivalence factors: 25 for CH_4 and 298 for N_2O.

Onshore Substation and Onshore Cable Route - Construction Emissions

								Fuel Use	Emissions										
Construction Equipment	**Source Category**	**HP per unit**	**Fuel Type**	**Emiss. Factor ID**	**hrs per day**	**Load Factor**	**Total Equip. Months**	**gal**	**VOC tons**	**NO_X tons**	**CO tons**	**PM_{10} tons**	**$PM_{2.5}$ tons**	**SO_2 tons**	**HAP Tons**	**CO_2 tons**	**CH_4 tons**	**N_2O tons**	**CO_2e tons**
Land-based Nonroad Equip.																			
Large Bulldozer	2270002069	800	diesel	115	8	59%	55	229,222	0.35	12.74	1.27	0.26	0.25	1.80E-02	0.09	2579.76	0.02	0.07	2599.88
All-Terrain Forklift	2270002057	150	diesel	113	8	59%	83	64,869	0.06	0.75	0.27	0.06	0.06	5.00E-03	1.48E-02	730.07	4.63E-03	0.02	735.72
Front End Loader	2270002060	200	diesel	114	8	59%	83	86,501	0.05	0.57	0.20	0.04	0.04	6.59E-03	1.17E-02	973.51	3.37E-03	0.02	980.98
Medium Crane	2270002045	400	diesel	112	8	43%	55	82,632	0.12	2.26	0.55	0.09	0.09	6.78E-03	0.03	929.98	7.31E-03	0.02	937.22
Medium Aerial Lift	2270003010	20	diesel	116	8	21%	55	2,635	0.04	0.20	0.16	0.02	0.02	2.73E-04	1.01E-02	29.65	1.43E-03	7.55E-04	29.91
Medium Excavator	2270002036	200	diesel	111	8	59%	69	71,915	0.02	0.29	0.08	0.02	0.02	5.38E-03	5.23E-03	809.36	1.40E-03	0.02	815.53
Piling Rig	2270002033	200	diesel	110	8	43%	14	10,502	0.07	0.93	0.20	0.04	0.04	1.05E-03	1.75E-02	118.19	3.80E-03	3.01E-03	119.19
Generator	2270006005	150	diesel	117	8	43%	83	46,730	0.19	2.32	0.67	0.15	0.14	4.06E-03	0.05	525.91	7.54E-03	1.34E-02	530.09
Landfall/Onshore HDD Drill Rig	2270002033	200	diesel	110	8	43%	60	45,009	0.31	3.99	0.87	0.19	0.18	4.50E-03	0.08	506.55	1.63E-02	1.29E-02	510.80
Landfall/Onshore HDD Compressor	2270006015	150	diesel	118	8	43%	60	33,807	0.04	0.63	0.15	0.04	0.04	2.67E-03	8.75E-03	380.48	2.95E-03	9.69E-03	383.44
Landfall/Onshore HDD Shaker	2270002081	100	diesel	115.2	8	59%	60	31,260	0.04	0.45	0.15	0.03	0.03	2.43E-03	9.08E-03	351.82	2.65E-03	8.96E-03	354.55
Landfall/Onshore HDD Excavator	2270002036	200	diesel	111	8	59%	60	62,535	0.02	0.25	0.07	1.68E-02	1.63E-02	4.68E-03	4.54E-03	703.79	1.22E-03	0.02	709.16
Landfall/Onshore HDD Tractor	2270002075	450	diesel	115.1	8	59%	60	140,683	0.12	2.21	0.80	0.12	0.12	1.11E-02	0.03	1583.30	8.34E-03	0.04	1595.52
Onshore Cable Route Excavator	2270002036	200	diesel	111	8	59%	69	71,915	0.02	0.29	0.08	1.93E-02	1.87E-02	5.38E-03	5.23E-03	809.36	1.40E-03	0.02	815.53
Onroad Vehicles																			
Semi-Truck		-	diesel	131	-	-	55	6,939	0.02	0.13	0.10	5.01E-03	4.61E-03	6.56E-04	2.87E-03	78.09	9.77E-03	2.90E-04	78.42
Work Truck		-	diesel	133	-	-	7	498	5.17E-03	1.27E-02	0.04	5.59E-04	5.14E-04	4.76E-05	5.45E-04	5.60	1.15E-03	2.59E-05	5.64
Refuse Truck		-	diesel	132	-	-	55	9,721	0.02	0.29	0.17	1.16E-02	1.07E-02	9.29E-04	2.21E-03	109.40	5.92E-03	1.66E-04	109.60
Dump Truck		-	diesel	131	-	-	345	43,526	0.14	0.81	0.61	0.03	0.03	4.11E-03	0.02	489.86	0.06	1.82E-03	491.93
Concrete Truck		-	diesel	131	-	-	55	6,939	0.02	0.13	0.10	5.01E-03	4.61E-03	6.56E-04	2.87E-03	78.09	9.77E-03	2.90E-04	78.42
Worker Commute																			
Light Commercial Truck		-	diesel	134	-	-	345	18,905	0.10	0.32	0.88	9.38E-03	8.63E-03	1.79E-03	1.38E-02	212.77	4.67E-02	9.63E-04	214.22
Passenger Truck		-	gasoline	135	-	-	207	8,418	0.08	0.08	1.10	2.04E-03	1.80E-03	1.66E-03	8.13E-03	81.47	3.49E-03	2.70E-03	82.36
							Total	**1,075,159**	**1.86**	**29.68**	**8.52**	**1.17**	**1.13**	**0.09**	**0.40**	**12,087**	**0.22**	**0.29**	**12,178**

Notes:

- Calculations assume equipment is used 5 days/wk - i.e., 21 days/month.
- Calculations conservatively assume that onroad vehicles travel approximately 50 miles per day, since emission factors from the MOVES2014 model for onroad vehicles are based on miles traveled.
- Calculations conservatively assume workers average daily round trip commute is approximately 40 miles per day, since emission factors from the MOVES2014 model for onroad vehicles are based on miles traveled.
- Calculations assume all onshore construction will occur within the boundaries of Virginia Beach.
- Calculations assume all onshore transmission cable will proceed at a rate of 100 feet per day.
- Area of soil disturbance for onshore substation construction is assumed to be 32.4 acres.

KITTY HAWK OFFSHORE WIND PROJECT - OCS AIR EMISSION CALCULATIONS
Onshore Switching Station - Construction Emissions

								Fuel Use	Emissions										
Construction Equipment	**Source Category**	**HP per unit**	**Fuel Type**	**Emiss. Factor ID**	**hrs per day**	**Load Factor**	**Total Equip. Months**	**gal**	**VOC tons**	**NO_X tons**	**CO tons**	**PM_{10} tons**	**$PM_{2.5}$ tons**	**SO_2 tons**	**HAP Tons**	**CO_2 tons**	**CH_4 tons**	**N_2O tons**	**CO_2e tons**
Land-based Nonroad Equip.																			
Large Bulldozer	2270002069	800	diesel	115	8	59%	4	16,671	0.03	0.93	0.09	0.02	0.02	1.31E-03	6.19E-03	187.62	1.56E-03	4.78E-03	189.08
All-Terrain Forklift	2270002057	150	diesel	113	8	59%	6	4,689	4.44E-03	0.05	0.02	4.26E-03	4.13E-03	3.62E-04	1.07E-03	52.78	3.35E-04	1.34E-03	53.18
Front End Loader	2270002060	200	diesel	114	8	59%	6	6,253	3.51E-03	0.04	1.43E-02	3.18E-03	3.09E-03	4.76E-04	8.46E-04	70.37	2.43E-04	1.79E-03	70.91
Medium Crane	2270002045	400	diesel	112	8	43%	4	6,010	8.47E-03	0.16	0.04	6.42E-03	6.22E-03	4.93E-04	2.04E-03	67.63	5.32E-04	1.72E-03	68.16
Medium Aerial Lift	2270003010	20	diesel	116	8	21%	4	192	3.07E-03	1.46E-02	1.20E-02	1.57E-03	1.52E-03	1.98E-05	7.37E-04	2.16	1.04E-04	5.49E-05	2.18
Medium Excavator	2270002036	200	diesel	111	8	59%	6	6,253	1.89E-03	0.03	6.86E-03	1.68E-03	1.63E-03	4.68E-04	4.54E-04	70.38	1.22E-04	1.79E-03	70.92
Piling Rig	2270002033	200	diesel	110	8	43%	2	1,500	1.04E-02	0.13	0.03	6.32E-03	6.13E-03	1.50E-04	2.50E-03	16.88	5.42E-04	4.30E-04	17.03
Generator	2270006005	150	diesel	117	8	43%	6	3,378	1.39E-02	0.17	0.05	1.06E-02	1.03E-02	2.93E-04	3.35E-03	38.02	5.45E-04	9.68E-04	38.32
Onroad Vehicles																			
Semi-Truck		-	diesel	131	-	-	4	505	1.61E-03	9.45E-03	7.08E-03	3.65E-04	3.36E-04	4.77E-05	2.09E-04	5.68	7.10E-04	2.11E-05	5.70
Work Truck		-	diesel	133	-	-	2	142	1.48E-03	3.63E-03	1.19E-02	1.60E-04	1.47E-04	1.36E-05	1.56E-04	1.60	3.29E-04	7.41E-06	1.61
Refuse Truck		-	diesel	132	-	-	4	707	1.57E-03	0.02	1.26E-02	8.45E-04	7.78E-04	6.76E-05	1.61E-04	7.96	4.30E-04	1.21E-05	7.97
Dump Truck		-	diesel	131	-	-	30	3,785	1.21E-02	0.07	0.05	2.74E-03	2.52E-03	3.58E-04	1.56E-03	42.60	5.33E-03	1.58E-04	42.78
Concrete Truck		-	diesel	131	-	-	4	505	1.61E-03	9.45E-03	7.08E-03	3.65E-04	3.36E-04	4.77E-05	2.09E-04	5.68	7.10E-04	2.11E-05	5.70
Worker Commute																			
Light Commercial Truck		-	diesel	134	-	-	30	1,644	8.92E-03	0.03	0.08	8.15E-04	7.50E-04	1.56E-04	1.20E-03	18.50	4.06E-03	8.37E-05	18.63
Passenger Truck		-	gasoline	135	-	-	16	651	6.45E-03	6.50E-03	0.08	1.58E-04	1.39E-04	1.28E-04	6.28E-04	6.30	2.70E-04	2.09E-04	6.37
							Total	**52,884**	**0.11**	**1.68**	**0.52**	**0.06**	**0.06**	**4.39E-03**	**0.02**	**594**	**0.02**	**1.34E-02**	**599**

Notes:

- Calculations assume equipment is used 5 days/wk - i.e., 21 days/month.
- Calculations conservatively assume that onroad vehicles travel approximately 50 miles per day, since emission factors from the MOVES2014 model for onroad vehicles are based on miles traveled.
- Calculations conservatively assume workers average daily round trip commute is approximately 40 miles per day, since emission factors from the MOVES2014 model for onroad vehicles are based on miles traveled.
- Calculations assume all onshore construction will occur within the boundaries of Virginia Beach.
- Area of soil disturbance for onshore switching station construction is assumed to be 2.5 acres.

KITTY HAWK OFFSHORE WIND PROJECT - OCS AIR EMISSION CALCULATIONS
Offshore Operations Emissions

Vessels/Equipment	No. of Engines per vessel	1. DP 2.Anchored 3.Spuds	Dimensions (ft) length x width x depth (draft)	Emission Factor Used (see EFs worksheet)	Engine Rating (hp)	Fuel Type	Transit Round Trips	Transit Duration (hrs/round trip)	Non-OCS Operating Days	OCS Operating Days	Non-Transit Operating Hours (hrs/day)	Non-Transit otal Operatin Hours (hrs)	Transit Average load (%)	Non-Transit Average load (%)	Transit Fuel Usage Gallons (per vessel)	Non-Transit Fuel Usage Gallons (per vessel)	Total Emissions (Non-Transit) VOC tons	NO_x tons	CO tons	PM_{10} tons	$PM_{2.5}$ tons	SO_2 tons	HAPs tons	CO_2 tons	CH_4 tons	N_2O tons	CO_2e tons
Helicopter - Twin-Engine Heavy		N/A																									
-Main Engines	2			163	1092	Jet fuel	600	1	0	0	0	0	100%	0%	69,954	0	0	0	0	0	0	0	0	0	0	0	0
Service Operations Vessel		1	269 x 56 x 24 (18)																								
-Main Engines	4			2.5	2788	Diesel	26	16	26	339	24	8,760	83%	10%	194,127	492,515	4.02	20.86	40.17	4.97	4.82	0.05	0.43	5,542.96	0.72	0.16	5,608.91
-Main Generators	1			2.5	2668	Diesel	26	16	26	339	24	8,760	17%	10%	9,512	117,829	0.96	4.99	9.61	1.19	1.15	1.26E-02	0.10	1,326.10	0.17	0.04	1,341.87
-Emergency Generator	1			1.5	302	Diesel	0	0	0	0	0	0	17%	45%	0	0	0	0	0	0	0	0	0	0	0	0	0
Crew Transfer Vessel 1		N/A	114 x 24 x 7.4																								
-Main Engines	4			1	585	Diesel	92	16	109	256	8	2,920	83%	10%	144,133	34,448	0.15	5.51	2.81	0.14	0.14	3.67E-03	0.02	387.69	0.05	1.12E-02	392.30
-Aux. Generator	1			1	47	Diesel	92	16	109	256	8	2,920	17%	45%	593	3,114	1.37E-02	0.50	0.25	1.31E-02	1.27E-02	3.32E-04	1.38E-03	35.04	4.57E-03	1.02E-03	35.46
-Aux. Engine	1			1	47	Diesel	92	16	109	256	8	2,920	17%	45%	593	3,114	1.37E-02	0.50	0.25	1.31E-02	1.27E-02	3.32E-04	1.38E-03	35.04	4.57E-03	1.02E-03	35.46
Crew Transfer Vessel 2		N/A	114 x 24 x 7.4																								
-Main Engines	4			1	585	Diesel	92	16	109	256	8	2,920	83%	10%	144,133	34,448	0.15	5.51	2.81	0.14	0.14	3.67E-03	0.02	387.69	0.05	1.12E-02	392.30
-Aux. Generator	1			1	47	Diesel	92	16	109	256	8	2,920	17%	45%	593	3,114	1.37E-02	0.50	0.25	1.31E-02	1.27E-02	3.32E-04	1.38E-03	35.04	4.57E-03	1.02E-03	35.46
-Aux. Engine	1			1	47	Diesel	92	16	109	256	8	2,920	17%	45%	593	3,114	1.37E-02	0.50	0.25	1.31E-02	1.27E-02	3.32E-04	1.38E-03	35.04	4.57E-03	1.02E-03	35.46
Daughter Craft 1		N/A	38 x 12 x 8 (2)																								
-Main Engines	2			1	330	Diesel	0	0	0	118	12	1,416	0%	83%	0	39,106	0.17	6.25	3.19	0.16	0.16	4.17E-03	0.02	440.12	0.06	1.28E-02	445.36
Daughter Craft 2		N/A	38 x 12 x 8 (2)																								
-Main Engines	2			1	330	Diesel	0	0	0	118	12	1,416	0%	83%	0	39,106	0.17	6.25	3.19	0.16	0.16	4.17E-03	0.02	440.12	0.06	1.28E-02	445.36
Environmental Monitoring Vessel 1		N/A	69 x 23 x 20 (7)																								
-Main Engines	2			2	1004	Diesel	1	16	1	6	24	168	83%	45%	1,344	7,653	0.06	1.22	0.62	0.08	0.07	8.16E-04	6.63E-03	86.13	1.12E-02	2.50E-03	87.16
-Aux. Engines	2			1	27	Diesel	1	16	1	6	24	168	17%	45%	7	204	9.00E-04	0.03	1.67E-02	8.60E-04	8.34E-04	2.18E-05	9.03E-05	2.30	3.00E-04	6.67E-05	2.33
Environmental Monitoring Vessel 2		N/A	69 x 23 x 20 (7)																								
-Main Engines	2			2	1004	Diesel	1	16	1	8	24	216	83%	45%	1,344	9,840	0.08	1.57	0.80	0.10	0.10	1.05E-03	8.52E-03	110.74	1.44E-02	3.21E-03	112.06
-Aux. Engines	2			1	27	Diesel	1	16	1	8	24	216	17%	45%	7	263	1.16E-03	0.04	0.02	1.11E-03	1.07E-03	2.80E-05	1.16E-04	2.96	3.86E-04	8.57E-05	2.99
WTG Supply Vessel			421 x 54 x 33 (23)																								
-Main Engine	1			3	4,020	Diesel	1	16	28	0	24	672	83%	25%	2,450	30,993	0.28	7.33	0.61	0.10	0.10	0.22	0.02	358.81	2.22E-03	1.72E-02	364.00
-Aux. Engines	2			1	434	Diesel	1	16	28	0	24	672	17%	45%	119	13,243	0.06	2.12	1.08	0.06	0.05	1.41E-03	5.85E-03	149.04	0.02	4.32E-03	150.81
WTG Repair Main Jack-up Vessel		3	433 x 148 x 29.5 (14)																								
-Main Generators	1			3	7,721	Diesel	6	16	11	51	24	1,488	83%	25%	28,233	131,810	1.18	31.18	2.60	0.44	0.42	0.94	0.10	1,525.98	9.45E-03	0.07	1,548.03
-Main Generators	2			3	5,670	Diesel	6	16	11	51	24	1,488	83%	25%	41,467	193,596	1.73	45.79	3.82	0.64	0.62	1.38	0.15	2,241.28	1.39E-02	0.11	2,273.68
-Main Generators	1			3	3,861	Diesel	6	16	11	51	24	1,488	83%	25%	14,116	65,905	0.59	15.59	1.30	0.22	0.21	0.47	0.05	762.99	4.72E-03	0.04	774.02
-Emergency Generator	1			2	1,877	Diesel	0	0	0	0	0	0	0%	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
WTG Repair Support Jack-up Vessel			184 x 135 x 15 (10)																								
-Main Generators	2			2	3,150	Diesel	6	16	11	51	24	1,488	83%	25%	25,309	118,158	0.96	18.89	9.64	1.19	1.16	1.26E-02	0.10	1,329.80	0.17	0.04	1,345.62
-Aux. Generators	2			2	1,340	Diesel	6	16	11	51	24	1,488	83%	25%	10,770	50,280	0.41	8.04	4.10	0.51	0.49	5.36E-03	0.04	565.87	0.07	1.64E-02	572.61
-Emergency Generator	1			1	212	Diesel	0	0	0	0	0	0	0%	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
Cable Scour Protection Repair Vessel		1	520 x 118 x 44 (31)																								
-Main Generators	3			3	6,032	Diesel	1	16	0	2	24	48	83%	45%	11,028	17,938	0.16	4.24	0.35	0.06	0.06	0.13	1.42E-02	207.67	1.29E-03	9.96E-03	210.67
-Aux. Generator	1			2	1,609	Diesel	1	16	0	2	24	48	17%	45%	221	1,752	1.43E-02	0.28	0.14	0.02	0.02	1.87E-04	1.52E-03	19.71	2.57E-03	5.71E-04	19.95
-Emergency Generator	1			1	660	Diesel	0	0	0	0	0	0	0%	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
Export + Array Cable Survey/Inspection Vessel		N/A	110 x 39 x 18 (9)																								
-Main Engines	2			1	526	Diesel	8	16	10	61	24	1,704	83%	25%	5,635	22,594	0.10	3.61	1.84	0.10	0.09	2.41E-03	9.99E-03	254.28	0.03	7.37E-03	257.30
-Main Generators	2			1	181	Diesel	8	16	10	61	24	1,704	17%	45%	397	13,992	0.06	2.24	1.14	0.06	0.06	1.49E-03	6.19E-03	157.47	0.02	4.56E-03	159.34
Export Cable Survey/Inspection Vessel		N/A	45 x 15 x 8 (3)																								
-Main Engines	2			1	715	Diesel	1	16	2	11	24	312	83%	25%	957	5,623	0.02	0.90	0.46	0.02	0.02	6.00E-04	2.49E-03	63.29	8.25E-03	1.83E-03	64.04
-Main Generators	2			1	16	Diesel	1	16	2	11	24	312	17%	45%	4	228	1.00E-03	0.04	0.02	9.58E-04	9.30E-04	2.43E-05	1.01E-04	2.56	3.34E-04	7.43E-05	2.59
														TOTALS	707,641	1,453,977	11.40	194.46	91.35	10.43	10.12	3.24	1.13	16,505.73	1.52	0.58	16,715.14

Notes:

1. Transit emissions are based on an assumed vessel speed of 10 knots for all vessel types, and the following one-way travel distances
   Overseas port to center of Wind Development Area: 32 nm (only includes portion of transit within 25 nm of the Wind Development Area
   Norfolk, VA (assumed local port) to center of Wind Development Area: 80 nm
2. The number of transits for each vessel are based on the following assumptions
   Bi-weekly round trips to/from local port for the SOV
   92 round trips per year to/from port for each crew transfer vesse
   One trip per year for each environmental monitoring vessel
   One trip per year for WTG supply vessel
   6 trips per year for each WTG repair jack-up vessel
   One trip per year for cable scour protection repair vesse
   9 trips per year for cable inspection/repair vessels
3. Helicopter transit emissions assume 600 round trips per year, with a duration of 60 minutes per round trip, based on travel from Virginia Beach Airport (56 mi one-way distance, 13 mi over Virginia Beach, and 43 mi inside OCS radius
4. The specific vessels for each operation have not been finalized at this time; however, the vessels identifed for each installation activity are typical sizes for performing this effort
5. Emission factors for marine vessel engines are from ICF International report to the US EPA "Current Methodologies in Preparing Mobile Source Port-Related Emissions Inventories", April 2009
6. NOx emission factors for the Service Operations Vessel are based on the MARPOL Tier 3 NOx standard for 2016 and newer marine engines, equivalent to 2.6 g/kWh for an engine speed of 500 rpm
7. HAP emission factors for commercial marine vessels were determined using the methodology identified by US EPA for the latest (2017) National Emissions Inventory (NEI); i.e., they are calculated as percentages of the $PM_{2.5}$ or VOC emissions from the CMVs.
8. Average load factors for vessel engines were estimated based on engineering estimates, and on Section 2.5 of the ICF International Report
9. CO_2e emission rates use the following carbon equivalence factors: 25 for CH_4, and 298 for N_2O.

KITTY HAWK OFFSHORE WIND PROJECT - OCS AIR EMISSION CALCULATIONS
Offshore Operations Emissions

																	Total Emissions (Transit)										
Vessels/Equipment	No. of Engines per vessel	1. DP 2.Anchored 3.Spuds	Dimensions (ft) length x width x depth (draft)	Emission Factor Used (see EFs worksheet)	Engine Rating (hp)	Fuel Type	Transit Round Trips	Transit Duration (hrs/round trip)	Non-OCS Operating Days	OCS Operating Days	Non-Transit Operating Hours (hrs/day)	Non-Transit Total Operating Hours (hrs)	Transit Average load (%)	Non-Transit Average load (%)	Transit Fuel Usage Gallons (per vessel)	Non-Transit Fuel Usage Gallons (per vessel)	VOC tons	NO_X tons	CO tons	PM_{10} tons	$PM_{2.5}$ tons	SO_2 tons	HAPs tons	CO_2 tons	CH_4 tons	N_2O tons	CO_2e tons
Helicopter - Twin-Engine Heavy		N/A																									
-Main Engines	2			163	1092	Jet fuel	600	1	0	0	0	0	100%	0%	69,954	0	1.04	2.17	0.06	0.06	0.06	0.23	7.69E-03	737.98	0.02	0.02	745.65
Service Operations Vessel		1	269 x 56 x 24 (18)																								
-Main Engines	4			2.5	2788	Diesel	26	16	26	339	24	8,760	83%	10%	194,127	492,515	1.58	8.22	15.83	1.96	1.90	0.02	0.17	2,184.79	0.28	0.06	2,210.78
-Main Generators	1			2.5	2668	Diesel	26	16	26	339	24	8,760	17%	10%	9,512	117,829	0.08	0.40	0.78	0.10	0.09	1.01E-03	8.24E-03	107.06	1.40E-02	3.10E-03	108.33
-Emergency Generator	1			1.5	302	Diesel	0	0	0	0	0	0	17%	45%	0	0	0	0	0	0	0	0	0	0	0	0	0
Crew Transfer Vessel 1		N/A	114 x 24 x 7.4																								
-Main Engines	4			1	585	Diesel	92	16	109	256	8	2,920	83%	10%	144,133	34,448	0.63	23.04	11.75	0.61	0.59	0.02	0.06	1,622.13	0.21	0.05	1,641.43
-Aux. Generator	1			1	47	Diesel	92	16	109	256	8	2,920	17%	45%	593	3,114	2.61E-03	0.09	0.05	2.50E-03	2.42E-03	6.32E-05	2.62E-04	6.67	8.70E-04	1.93E-04	6.75
-Aux. Engine	1			1	47	Diesel	92	16	109	256	8	2,920	17%	45%	593	3,114	2.61E-03	0.09	0.05	2.50E-03	2.42E-03	6.32E-05	2.62E-04	6.67	8.70E-04	1.93E-04	6.75
Crew Transfer Vessel 2		N/A	114 x 24 x 7.4																								
-Main Engines	4			1	585	Diesel	92	16	109	256	8	2,920	83%	10%	144,133	34,448	0.63	23.04	11.75	0.61	0.59	0.02	0.06	1,622.13	0.21	0.05	1,641.43
-Aux. Generator	1			1	47	Diesel	92	16	109	256	8	2,920	17%	45%	593	3,114	2.61E-03	0.09	0.05	2.50E-03	2.42E-03	6.32E-05	2.62E-04	6.67	8.70E-04	1.93E-04	6.75
-Aux. Engine	1			1	47	Diesel	92	16	109	256	8	2,920	17%	45%	593	3,114	2.61E-03	0.09	0.05	2.50E-03	2.42E-03	6.32E-05	2.62E-04	6.67	8.70E-04	1.93E-04	6.75
Daughter Craft 1		N/A	38 x 12 x 8 (2)																								
-Main Engines	2			1	330	Diesel	0	0	0	118	12	1,416	0%	83%	0	39,106	0	0	0	0	0	0	0	0	0	0	0
Daughter Craft 2		N/A	38 x 12 x 8 (2)																								
-Main Engines	2			1	330	Diesel	0	0	0	118	12	1,416	0%	83%	0	39,106	0	0	0	0	0	0	0	0	0	0	0
Environmental Monitoring Vessel 1		N/A	69 x 23 x 20 (7)																								
-Main Engines	2			2	1004	Diesel	1	16	1	6	24	168	83%	45%	1,344	7,653	1.10E-02	0.21	0.11	1.36E-02	1.32E-02	1.43E-04	1.16E-03	15.13	1.97E-03	4.39E-04	15.31
-Aux. Engines	2			1	27	Diesel	1	16	1	6	24	168	17%	45%	7	204	3.24E-05	1.18E-03	6.00E-04	3.09E-05	3.00E-05	7.84E-07	3.25E-06	0.08	1.08E-05	2.40E-06	0.08
Environmental Monitoring Vessel 2		N/A	69 x 23 x 20 (7)																								
-Main Engines	2			2	1004	Diesel	1	16	1	8	24	216	83%	45%	1,344	9,840	1.10E-02	0.21	0.11	1.36E-02	1.32E-02	1.43E-04	1.16E-03	15.13	1.97E-03	4.39E-04	15.31
-Aux. Engines	2			1	27	Diesel	1	16	1	8	24	216	17%	45%	7	263	3.24E-05	1.18E-03	6.00E-04	3.09E-05	3.00E-05	7.84E-07	3.25E-06	0.08	1.08E-05	2.40E-06	0.08
WTG Supply Vessel			421 x 54 x 33 (23)																								
-Main Engine	1			3	4,020	Diesel	1	16	28	0	24	672	83%	25%	2,450	30,993	0.02	0.58	0.05	8.13E-03	7.89E-03	0.02	1.94E-03	28.36	1.76E-04	1.36E-03	28.77
-Aux. Engines	2			1	434	Diesel	1	16	28	0	24	672	17%	45%	119	13,243	5.25E-04	0.02	9.71E-03	5.01E-04	4.86E-04	1.27E-05	5.27E-05	1.34	1.75E-04	3.89E-05	1.36
WTG Repair Main Jack-up Vessel		3	433 x 148 x 29.5 (14)																								
-Main Generators	1			3	7,721	Diesel	6	16	11	51	24	1,488	83%	25%	28,233	131,810	0.25	6.68	0.56	0.09	0.09	0.20	0.02	326.85	2.02E-03	1.57E-02	331.58
-Main Generators	2			3	5,670	Diesel	6	16	11	51	24	1,488	83%	25%	41,467	193,596	0.37	9.81	0.82	0.14	0.13	0.29	0.03	480.07	2.97E-03	0.02	487.01
-Main Generators	1			3	3,861	Diesel	6	16	11	51	24	1,488	83%	25%	14,116	65,905	0.13	3.34	0.28	0.05	0.05	0.10	1.12E-02	163.43	1.01E-03	7.84E-03	165.79
-Emergency Generator	1			2	1,877	Diesel	0	0	0	0	0	0	0%	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
WTG Repair Support Jack-up Vessel			184 x 135 x 15 (10)																								
-Main Generators	2			2	3,150	Diesel	6	16	11	51	24	1,488	83%	25%	25,309	118,158	0.21	4.05	2.06	0.26	0.25	2.70E-03	0.02	284.83	0.04	8.26E-03	288.22
-Aux. Generators	2			2	1,340	Diesel	6	16	11	51	24	1,488	83%	25%	10,770	50,280	0.09	1.72	0.88	0.11	0.11	1.15E-03	9.33E-03	121.21	1.58E-02	3.51E-03	122.65
-Emergency Generator	1			1	212	Diesel	0	0	0	0	0	0	0%	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
Cable Scour Protection Repair Vessel		1	520 x 118 x 44 (31)																								
-Main Generators	3			3	6,032	Diesel	1	16	0	2	24	48	83%	45%	11,028	17,938	0.10	2.61	0.22	0.04	0.04	0.08	8.73E-03	127.68	7.90E-04	6.13E-03	129.52
-Aux. Generator	1			2	1,609	Diesel	1	16	0	2	24	48	17%	45%	221	1,752	1.80E-03	0.04	0.02	2.23E-03	2.16E-03	2.35E-05	1.91E-04	2.48	3.24E-04	7.20E-05	2.51
-Emergency Generator	1			1	660	Diesel	0	0	0	0	0	0	0%	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
Export + Array Cable Survey/Inspection Vessel		N/A	110 x 39 x 18 (9)																								
-Main Engines	2			1	526	Diesel	8	16	10	61	24	1,704	83%	25%	5,635	22,594	0.02	0.90	0.46	0.02	0.02	6.01E-04	2.49E-03	63.41	8.27E-03	1.84E-03	64.17
-Main Generators	2			1	181	Diesel	8	16	10	61	24	1,704	17%	45%	397	13,992	1.75E-03	0.06	0.03	1.67E-03	1.62E-03	4.23E-05	1.76E-04	4.47	5.83E-04	1.30E-04	4.52
Export Cable Survey/Inspection Vessel		N/A	45 x 15 x 8 (3)																								
-Main Engines	2			1	715	Diesel	1	16	2	11	24	312	83%	25%	957	5,623	4.22E-03	0.15	0.08	4.03E-03	3.91E-03	1.02E-04	4.23E-04	10.78	1.41E-03	3.12E-04	10.90
-Main Generators	2			1	16	Diesel	1	16	2	11	24	312	17%	45%	4	228	1.94E-05	7.05E-04	3.60E-04	1.86E-05	1.80E-05	4.71E-07	1.95E-06	0.05	6.48E-06	1.44E-06	0.05
														TOTALS	**707,641**	**1,453,977**	**5.21**	**87.63**	**46.05**	**4.09**	**3.97**	**0.98**	**0.43**	**7,946.17**	**0.82**	**0.25**	**8,042.49**

Notes:

1. Transit emissions are based on an assumed vessel speed of 10 knots for all vessel types, and the following one-way travel distances
   Overseas port to center of Wind Development Area: 32 nm (only includes portion of transit within 25 nm of the Wind Development Area
   Norfolk, VA (assumed local port) to center of Wind Development Area: 80 nm
2. The number of transits for each vessel are based on the following assumptions
   Bi-weekly round trips to/from local port for the SOV
   92 round trips per year to/from port for each crew transfer vesse
   One trip per year for each environmental monitoring vessel
   One trip per year for WTG supply vessel
   6 trips per year for each WTG repair jack-up vessel
   One trip per year for cable scour protection repair vesse
   9 trips per year for cable inspection/repair vessels
3. Helicopter transit emissions assume 600 round trips per year, with a duration of 60 minutes per round trip, based on travel from Virginia Beach Airport (56 mi one-way distance, 13 mi over Virginia Beach, and 43 mi inside OCS radius
4. The specific vessels for each operation have not been finalized at this time; however, the vessels identifed for each installation activity are typical sizes for performing this effort
5. Emission factors for marine vessel engines are from ICF International report to the US EPA "Current Methodologies in Preparing Mobile Source Port-Related Emissions Inventories", April 2009
6. NOx emission factors for the Service Operations Vessel are based on the MARPOL Tier 3 NOx standard for 2016 and newer marine engines, equivalent to 2.6 g/kWh for an engine speed of 500 rpm
7. HAP emission factors for commercial marine vessels were determined using the methodology identified by US EPA for the latest (2017) National Emissions Inventory (NEI); i.e., they are calculated as percentages of the $PM_{2.5}$ or VOC emissions from the CMVs.
8. Average load factors for vessel engines were estimated based on engineering estimates, and on Section 2.5 of the ICF International Report
9. CO_2e emission rates use the following carbon equivalence factors: 25 for CH_4, and 298 for N_2O.

KITTY HAWK OFFSHORE WIND PROJECT - OCS AIR EMISSION CALCULATIONS
ESP Generator Emissions

Generator Engine Data

Generator Manufacturer	TBD	
Model	TBD	
Engine Type	TBD	
Rated engine output	kW	500
Rated engine output	bhp	670
Engine speed	rpm	1800
Fuel consumption at 100% load	gal/hr	33.5
Number of generators	engines	2
Annual operating hours per generator	hr/yr	500
Annual Fuel Usage per generator	gal/yr	16,756

Fuel Data

Fuel type	Ultra low sulfur diesel	
Fuel heat content	Btu/lb (LHV)	18,360
Fuel heat content	Btu/lb (HHV)	19,326
Fuel density	lb/gal	7.01
Fuel sulfur content	% weight	0.0015
Conversion factor	LHV/HHV	0.95

Tetra Tech assumptions/calculations

Engine load	%	100
Heat input rate	MMBtu/hr (HHV)	4.69

Engine Emission Factors

NOx	g/kWh	0.67
CO	g/kWh	3.5
HC (VOC)	g/kWh	0.19
PM/PM10	g/kWh	0.03
PM2.5	g/kWh	0.03
SO2	lb/MMBtu (HHV)	0.0016
HAP	lb/MMBtu (HHV)	0.0016
CO2	lb/MMBtu (HHV)	163.1
CH4	lb/MMBtu (HHV)	0.007
N2O	lb/MMBtu (HHV)	0.001

Engine Emission Estimates

NOx	lb/hr (per engine)	0.7
CO	lb/hr (per engine)	3.9
VOC	lb/hr (per engine)	0.21
PM10	lb/hr (per engine)	0.03
PM2.5	lb/hr (per engine)	0.03
SO2	lb/hr (per engine)	7.28E-03
HAP	lb/hr (per engine)	7.47E-03
CO2	lb/hr (per engine)	765.0
CH4	lb/hr (per engine)	3.10E-02
N2O	lb/hr (per engine)	6.21E-03
CO2e	lb/hr (per engine)	767.6

	Short Term Emissions (lb/hr per engine)	Annual Emissions (tons/yr total)
NOx	0.74	0.37
CO	3.86	1.93
VOC	0.21	0.10
PM10	0.03	0.02
PM2.5	0.03	0.02
SO2	7.28E-03	3.64E-03
HAP	0.01	3.73E-03
CO2	765.0	382.5
CH4	0.03	0.02
N2O	6.21E-03	3.10E-03
CO2e	767.6	383.8

Notes:

1. Engine power rating is based on project assumption.
2. It is assumed that each engine may be used for both emergency and non-emergency purposes, limited to no more than 500 hours per year to include maintenance and testing.
3. Emission factors for NOx, CO, VOC, and PM are based on EPA Tier 4 final standards from Table 1 of 40 CFR 1039.101.
4. All particulate (PM) is assumed to be ≤ to 10 µm (PM10) and 97% of the PM is assumed to be smaller than 2.5 µm (PM2.5) based on US EPA Report Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling - Compression-Ignition, No. NR-0009d, July 2010.
5. SO2 emission factor calculated from mass balance for 0.0015% by weight ULSD, assuming 100% conversion of fuel sulfur to SO2.
6. HAP emission factor based on EPA's AP-42 Volume 1, Chapter 3.3 for small diesel engines.
7. Emission factors used to calculate emission rates for CO2 (73.96 kg/MMBtu), CH4 (0.003 kg/MMBtu) and N2O (0.0006 kg/MMBtu) were based on Tables C-1 and C-2 of 40 CFR Part 98 - Mandatory Greenhouse Gas Reporting, Subpart C - General Stationary Fuel Combustion Sources.

KITTY HAWK OFFSHORE WIND PROJECT - OCS AIR EMISSION CALCULATIONS
Onshore Substation Generator Emissions

Generator Engine Data

Generator Manufacturer	TBD	
Model	TBD	
Engine Type	TBD	
Rated engine output	kW	1,500
Rated engine output	bhp	2,011
Engine speed	rpm	1800
Number of generators	engines	1
Annual operating hours per generator	hr/yr	500

Fuel Data and Assumptions

Fuel type	Propane	
Fuel consumption rate (assumed)	Btu/hp-hr	7,000
Heat input rate	MMBtu/hr (HHV)	14.08

Engine Emission Factors

NOx	g/kWh	2.66
CO	g/kWh	4.4
HC (VOC)	g/kWh	0.036
PM/PM10	lb/MMBtu (HHV)	9.50E-03
PM2.5	lb/MMBtu (HHV)	9.50E-03
SO2	lb/MMBtu (HHV)	5.88E-04
HAP	lb/MMBtu (HHV)	3.24E-02
CO2	lb/MMBtu (HHV)	138.6
CH4	lb/MMBtu (HHV)	6.61E-03
N2O	lb/MMBtu (HHV)	1.32E-03

Engine Emission Estimates

NOx	lb/hr (per engine)	8.8
CO	lb/hr (per engine)	14.6
VOC	lb/hr (per engine)	0.12
PM10	lb/hr (per engine)	0.13
PM2.5	lb/hr (per engine)	0.13
SO2	lb/hr (per engine)	8.28E-03
HAP	lb/hr (per engine)	0.46
CO2	lb/hr (per engine)	1,950.8
CH4	lb/hr (per engine)	0.09
N2O	lb/hr (per engine)	0.02
CO2e	lb/hr (per engine)	1,958.7

	Short Term Emissions (lb/hr)	Annual Emissions (tons/yr)
NOx	8.8	2.20
CO	14.6	3.64
VOC	0.12	0.03
PM10	0.13	0.03
PM2.5	0.13	0.03
SO2	8.28E-03	2.07E-03
HAP	0.46	0.11
CO2	1,950.8	487.7
CH4	0.09	0.02
N2O	0.02	4.65E-03
CO2e	1,958.7	489.7

Notes:

1. Engine power rating is based on project assumption.
2. It is assumed that the engine will only be used for emergency purposes and limited to no more than 500 hours per year to include maintenance and testing.
3. Emission factors for NOx, CO, and VOC are based on Tier 2 standards in 40 CFR 1048.101, paragraph (a)(2).
4. NOx+NMHC limit is 2.7 g/kWh; split into NOx and VOC based on NOx and VOC fractions in AP-42 Table 3.2-3 for four-stroke rich-burn natural gas-fired engines.
5. Emission factors for PM10, PM2.5, SO2, and HAP are from AP-42, Table 3.2-3 for four-stroke rich-burn natural gas-fired engines.
6. Emission factors used to calculate emission rates for CO2 (62.87 kg/MMBtu), CH4 (0.003 kg/MMBtu) and N2O (0.0006 kg/MMBtu) were based on Tables C-1 and C-2 of 40 CFR Part 98 - Mandatory Greenhouse Gas Reporting, Subpart C - General Stationary Fuel Combustion Sources.
7. CO2e emission rates use the following carbon equivalence factors: 25 for CH4, and 298 for N2O.

KITTY HAWK OFFSHORE WIND PROJECT - OCS AIR EMISSION CALCULATIONS
Onshore Switching Station Generator Emissions

Generator Engine Data

Generator Manufacturer	TBD	
Model	TBD	
Engine Type	TBD	
Rated engine output	kW	1,500
Rated engine output	bhp	2,011
Engine speed	rpm	1800
Number of generators	engines	1
Annual operating hours per generator	hr/yr	500

Fuel Data and Assumptions

Fuel type	Propane	
Fuel consumption rate (assumed)	Btu/hp-hr	7,000
Heat input rate	MMBtu/hr (HHV)	14.08

Engine Emission Factors

NOx	g/kWh	2.66
CO	g/kWh	4.4
HC (VOC)	g/kWh	0.036
PM/PM10	lb/MMBtu (HHV)	9.50E-03
PM2.5	lb/MMBtu (HHV)	9.50E-03
SO2	lb/MMBtu (HHV)	5.88E-04
HAP	lb/MMBtu (HHV)	3.24E-02
CO2	lb/MMBtu (HHV)	138.6
CH4	lb/MMBtu (HHV)	6.61E-03
N2O	lb/MMBtu (HHV)	1.32E-03

Engine Emission Estimates

NOx	lb/hr (per engine)	8.8
CO	lb/hr (per engine)	14.6
VOC	lb/hr (per engine)	0.12
PM10	lb/hr (per engine)	0.13
PM2.5	lb/hr (per engine)	0.13
SO2	lb/hr (per engine)	8.28E-03
HAP	lb/hr (per engine)	0.46
CO2	lb/hr (per engine)	1,950.8
CH4	lb/hr (per engine)	0.09
N2O	lb/hr (per engine)	0.02
CO2e	lb/hr (per engine)	1,958.7

	Short Term Emissions (lb/hr)	Annual Emissions (tons/yr)
NOx	8.8	2.20
CO	14.6	3.64
VOC	0.12	0.03
PM10	0.13	0.03
PM2.5	0.13	0.03
SO2	8.28E-03	2.07E-03
HAP	0.46	0.11
CO2	1,950.8	487.7
CH4	0.09	0.02
N2O	0.02	4.65E-03
CO2e	1,958.7	489.7

Notes:

1. Engine power rating is based on project assumption.
2. It is assumed that the engine will only be used for emergency purposes and limited to no more than 500 hours per year to include maintenance and testing.
3. Emission factors for NOx, CO, and VOC are based on Tier 2 standards in 40 CFR 1048.101, paragraph (a)(2).
4. NOx+NMHC limit is 2.7 g/kWh; split into NOx and VOC based on NOx and VOC fractions in AP-42 Table 3.2-3 for four-stroke rich-burn natural gas-fired engines.
5. Emission factors for PM10, PM2.5, SO2, and HAP are from AP-42, Table 3.2-3 for four-stroke rich-burn natural gas-fired engines.
6. Emission factors used to calculate emission rates for CO2 (62.87 kg/MMBtu), CH4 (0.003 kg/MMBtu) and N2O (0.0006 kg/MMBtu) were based on Tables C-1 and C-2 of 40 CFR Part 98 - Mandatory Greenhouse Gas Reporting, Subpart C - General Stationary Fuel Combustion Sources.
7. CO2e emission rates use the following carbon equivalence factors: 25 for CH4, and 298 for N2O.

KITTY HAWK OFFSHORE WIND PROJECT - OCS AIR EMISSION CALCULATIONS
ESP Switchgear SF6 Emissions

Circuit Breaker SF_6 [1] Fugitive Emissions

Total SF_6 Storage Capacity	lbs	5,115
Number of Switches	units	N/A
SF_6 Leak Rate (by weight) [2]	% per year	0.5%
SF_6 Emissions	lbs/year	25.57
SF_6 Emissions	tons/year	0.0128
Annual GHG emissions (CO_2e) [3]	tons/year	291.54

1. SF_6 = Sulfur Hexafluoride
2. Leak rate for the SF6 is based on the International Electrotechnical Commission Standard 62271-1, 2004, as presented in the U.S. EPA technical paper, "SF6 Leak Rates from High Voltage Circuit Breakers - U.S. EPA Investigates Potential Greenhouse Gas Emissions Source."
3. CO_2e emission rates use the following carbon equivalence factors based on Table A-1 to Subpart A of 40 CFR Part 98—Global Warming Potentials: 22,800 for SF6.

KITTY HAWK OFFSHORE WIND PROJECT - OCS AIR EMISSION CALCULATIONS
WTG Switchgear SF6 Emissions

Circuit Breaker SF_6 [1] Fugitive Emissions

SF_6 Storage Capacity per Switch	lbs	39.7
Number of Switches	units	69
SF_6 Leak Rate (by weight) [2]	% per year	0.5%
SF_6 Emissions	lbs/year	13.69
SF_6 Emissions	tons/year	0.0068
Annual GHG emissions (CO_2e) [3]	tons/year	156.07

1. SF_6 = Sulfur Hexafluoride
2. Leak rate for the SF6 is based on the International Electrotechnical Commission Standard 62271-1, 2004, as presented in the U.S. EPA technical paper, "SF6 Leak Rates from High Voltage Circuit Breakers - U.S. EPA Investigates Potential Greenhouse Gas Emissions Source."
3. CO_2e emission rates use the following carbon equivalence factors based on Table A-1 to Subpart A of 40 CFR Part 98—Global Warming Potentials: 22,800 for SF6.

KITTY HAWK OFFSHORE WIND PROJECT - OCS AIR EMISSION CALCULATIONS
Onshore Switchgear SF6 Emissions

Onshore Substation Circuit Breaker SF_6 [1] Fugitive Emissions

Total SF_6 Storage Capacity	lbs	11,023
Number of Switches	units	N/A
SF_6 Leak Rate (by weight) [2]	% per year	0.5%
SF_6 Emissions	lbs/year	55.12
SF_6 Emissions	tons/year	0.0276
Annual GHG emissions (CO_2e) [3]	tons/year	628.31

Onshore Switching Station Circuit Breaker SF_6 [1] Fugitive Emissions

Total SF_6 Storage Capacity	lbs	11,023
Number of Switches	units	N/A
SF_6 Leak Rate (by weight) [2]	% per year	0.5%
SF_6 Emissions	lbs/year	55.12
SF_6 Emissions	tons/year	0.0276
Annual GHG emissions (CO_2e) [3]	tons/year	628.31

1. SF_6 = Sulfur Hexafluoride
2. Leak rate for the SF6 is based on the International Electrotechnical Commission Standard 62271-1, 2004, as presented in the U.S. EPA technical paper, "SF6 Leak Rates from High Voltage Circuit Breakers - U.S. EPA Investigates Potential Greenhouse Gas Emissions Source."
3. CO_2e emission rates use the following carbon equivalence factors based on Table A-1 to Subpart A of 40 CFR Part 98—Global Warming Potentials: 22,800 for SF6.

KITTY HAWK OFFSHORE WIND PROJECT - OCS AIR EMISSION CALCULATIONS
Emission Factors

Commercial Marine Vessels (CMVs)

		Commercial Marine Vessel Emission Factors (g/hp-hr) /a									Fuel Cons.
	Engine Type	VOC	NO_x	CO	PM/ PM_{10} /b, /c	$PM_{2.5}$ /b	SO_2 /d	CO_2	CH_4	N_2O	(gal/hp-hr) /e
1	Category 1 engines < 1000 kW	0.20	7.3	3.73	0.19	0.19	0.0049	515	0.067	0.015	0.050
1.5	Category 1 engines < 1000 kW meeting MARPOL Tier 3	0.20	1.9	3.73	0.19	0.19	0.0049	515	0.067	0.015	0.050
2	Category 2 engines	0.37	7.3	3.73	0.46	0.45	0.0049	515	0.067	0.015	0.050
2.5	Category 2 engines meeting MARPOL Tier 3	0.37	1.9	3.73	0.46	0.45	0.0049	515	0.067	0.015	0.050
3	Category 3 engines (MSD using MDO) (>30L/cyl.)	0.37	9.8	0.82	0.14	0.13	0.296	482	0.003	0.023	0.046
3.5	Category 3 engines meeting MARPOL Tier 3	0.37	1.9	0.82	0.14	0.13	0.296	482	0.003	0.023	0.046
4	All Categories aux. engines (MSD using MDO)	0.30	10.4	0.82	0.14	0.13	0.316	515	0.003	0.023	0.049

/a Emission factors for Category 1 and 2 engines are from Table 3-8 and Category 3 engines are from Tables 2-9, 2-13, and 2-16 from ICF International report to the U.S. EPA, "Current Methodologies in Preparing Mobile Source Port-Related Emissions Inventories", April 2009 (converted from g/kW-hr to g/hp-hr by multiplying by 0.746 kW/hp). Assumed all Category 1 and 2 engines to be used for the Project are certified to meet EPA Tier 1 and 2 marine engine standards respectively (providing conservative estimate for Category 1 engines); therefore the Tier 1 and 2 emission factors in Table 3-8 from the ICF International report was used.

/b All PM is assumed to less than 10 µm in diameter; therefore, PM emission factor is equivalent to PM_{10} emission factor. $PM_{2.5}$ is estimated to be 97 % of PM_{10} per EPA guidance in "Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling - Compression-Ignition," EPA420-R-10-018/NR-009d, July 2010.

/c PM_{10} Emission factors for Category 1 and 2 engines presented in Table 3-8 of the ICF report (ICF International 2009) are based on a fuel sulfur content of 1.5 percent. These factors were adjusted for two potential fuel sulfur contents that could be used by marine vessels: 0.1 percent sulfur MARPOL-compliant marine fuel, and 0.0015 percent ultra-low sulfur distillate (ULSD) fuel oil. The ICF factors were adjusted for each fuel sulfur content following the approach used in Section 3.4.2 of the ICF Report. For 0.1 percent sulfur MARPOL-compliant marine fuel, the ICF factors were multiplied by 1.00 for PM10.
For 0.0015 percent sulfur ULSD fuel oil, the ICF factors were multiplied by 0.86 for PM10.

/d SO2 emission factors for all marine engine categories are based on a mass balance calculation for the appropriate fuel sulfur content of each fuel: 0.1 percent sulfur MARPOL-compliant marine fuel, and 0.0015 percent ultra-low sulfur distillate (ULSD) fuel oil. The fuel consumption rate for each engine type was converted to a mass of fuel using an assumed fuel density of 853 kg/m3 (7.11 lb/gal).

/e Fuel consuption rate for category 1 and 2 marine engines was estimated based on CO_2 emission factor (g/hp-hr) and the emission factor for the mass of CO_2 generated per gallon of fuel (10.21 kg CO_2/gal fuel) as presented in Table A-1 of the EPA report, "Direct Emissions from Mobile Combustion Sources, U.S. EPA Center for Corporate Leadership – Greenhouse Gas Inventory Guidance," EPA430-K-16-004, January 2016.
Fuel consumption for Category 3 marine engines was based on the BSFC (g/kW-hr) in the ICF International report.

Land-based Nonroad Engines and Other Equipment (Chesapeake and Portsmouth, VA)

	NONROAD Source Category			NONROAD Emission Factors (g/hp-hr) /a								Climate Leaders (g/kWh) /b	Fuel	NONROAD
	SCC	Description	Engine Size (hp)	Exhaust+ Crankcase VOC	Exhaust NO_x	Exhaust CO	Exhaust PM_{10}	Exhaust $PM_{2.5}$	Exhaust SO_2	Exhaust CO_2	Exhaust CH_4	Exhaust N_2O	Consumption gal/hp-hr/c	Default Load Factor
	Construction & Mining Subcategory (*002*)													
100	2270002033	Diesel Bore/Drill Rigs	175 < HP <= 300	0.23	2.01	0.48	0.10	0.10	0.003	530	0.014	0.014	0.052	43%
101	2270002036	Diesel Excavators	175 < HP <= 300	0.16	0.31	0.12	0.01	0.01	0.003	536	0.013	0.014	0.053	59%
102	2270002045	Diesel Cranes	300 < HP <= 600	0.17	1.09	0.29	0.04	0.04	0.003	531	0.014	0.014	0.052	43%
103	2270002057	Diesel Rough Terrain Forklifts	100 < hp <= 175	0.17	0.63	0.26	0.04	0.04	0.003	536	0.014	0.014	0.053	59%
104	2270002060	Diesel Rubber Tire Loaders	175 < hp <= 300	0.16	0.45	0.17	0.02	0.02	0.003	536	0.013	0.014	0.053	59%
105	2270002069	Diesel Crawler Tractor/Dozers	750 < hp <= 1000	0.20	2.59	0.45	0.06	0.06	0.003	536	0.016	0.014	0.053	59%
105.1	2270002075	Diesel Off-Highway Tractor	300 < HP <= 600	0.16	0.78	0.30	0.04	0.04	0.003	536	0.013	0.014	0.053	59%
105.2	2270002081	Diesel Other Construction Equip.	100 < hp <= 175	0.17	0.76	0.32	0.06	0.06	0.003	536	0.014	0.014	0.053	59%
	Industrial Equipment Subcategory (*003*)													
106	2270003010	Diesel Aerial Lifts	16 < hp <= 25	1.06	5.13	4.40	0.61	0.59	0.005	693	0.044	0.018	0.068	21%
	Commercial Equipment Subcategory (*006*)													
107	2270006005	Diesel Generator Sets	100 < HP <= 175	0.26	2.22	0.62	0.13	0.13	0.003	530	0.015	0.014	0.052	43%
108	2270006015	Diesel Air Compressors	100 < HP <= 175	0.17	0.78	0.22	0.04	0.04	0.003	531	0.014	0.014	0.052	43%

/a Emission factors for the land-based nonroad engines were estimated using EPA's MOVES2014b emission model for an assumed construction year of 2024.

/b Emission factors for N_2O are based on Table B-8 of the EPA report, "Direct Emissions from Mobile Combustion Sources, U.S. EPA Center for Corporate Leadership – Greenhouse Gas Inventory Guidance," EPA430-K-16-004, January 2016 (0.26 g N2O/gal fuel).

/c Fuel consumption for each type of equipment was estimated based on CO2 emission factor (g/hp-hr) generated from the MOVES2014a model and the emission factor for the mass of CO2 generated per gallon of fuel (10.21 kg CO_2/gal fuel) as presented in Table A-1 of the EPA report, "Direct Emissions from Mobile Combustion Sources, U.S. EPA Center for Corporate Leadership – Greenhouse Gas Inventory Guidance," EPA430-K-16-004, January 2016.

Land-based Nonroad Engines and Other Equipment (Newport News, Norfolk, and Virginia Beach, VA)

				NONROAD Emission Factors (g/hp-hr) /a								Climate Leaders (g/kWh) /b		NONROAD
	NONROAD Source Category			Exhaust+ Crankcase	Exhaust	Exhaust	Exhaust	Exhaust	Exhaust	Exhaust	Exhaust	Exhaust	Fuel Consumption	Default
	SCC	Description	Engine Size (hp)	VOC	NO_x	CO	PM_{10}	$PM_{2.5}$	SO_2	CO_2	CH_4	N_2O	gal/hp-hr/c	Load Factor
	Construction & Mining Subcategory (*002*)													
110	2270002033	Diesel Bore/Drill Rigs	175 < HP <= 300	0.33	4.17	0.91	0.20	0.19	0.005	530	0.017	0.013	0.052	43%
111	2270002036	Diesel Excavators	175 < HP <= 300	0.01	0.19	0.05	0.01	0.01	0.004	537	0.001	0.014	0.053	59%
112	2270002045	Diesel Cranes	300 < HP <= 600	0.07	1.29	0.31	0.05	0.05	0.004	531	0.004	0.014	0.052	43%
113	2270002057	Diesel Rough Terrain Forklifts	100 < hp <= 175	0.05	0.55	0.20	0.04	0.04	0.004	537	0.003	0.014	0.053	59%
114	2270002060	Diesel Rubber Tire Loaders	175 < hp <= 300	0.03	0.32	0.11	0.02	0.02	0.004	537	0.002	0.014	0.053	59%
115	2270002069	Diesel Crawler Tractor/Dozers	750 < hp <= 1000	0.07	2.65	0.26	0.05	0.05	0.004	537	0.004	0.014	0.053	59%
115.1	2270002075	Diesel Off-Highway Tractor	300 < HP <= 600	0.04	0.75	0.27	0.04	0.04	0.004	537	0.003	0.014	0.053	59%
115.2	2270002081	Diesel Other Construction Equip.	100 < hp <= 175	0.06	0.69	0.23	0.05	0.05	0.004	537	0.004	0.014	0.053	59%
	Industrial Equipment Subcategory (*003*)													
116	2270003010	Diesel Aerial Lifts	16 < hp <= 25	0.99	4.68	3.85	0.50	0.49	0.006	693	0.034	0.018	0.068	21%
	Commercial Equipment Subcategory (*006*)													
117	2270006005	Diesel Generator Sets	100 < HP <= 175	0.19	2.35	0.68	0.15	0.14	0.004	530	0.008	0.014	0.052	43%
118	2270006015	Diesel Air Compressors	100 < HP <= 175	0.05	0.89	0.21	0.05	0.05	0.004	531	0.004	0.014	0.052	43%

/a Emission factors for the land-based nonroad engines were estimated using EPA's MOVES2014b emission model for an assumed construction year of XXXX.

/b Emission factors for N_2O are based on Table B-8 of the EPA report, "Direct Emissions from Mobile Combustion Sources, U.S. EPA Center for Corporate Leadership – Greenhouse Gas Inventory Guidance," EPA430-K-16-004, January 2016. (0.57 g CH4/gal fuel and 0.26 g N2O/gal fuel, respectively)

/c Fuel consumption for each type of equipment was estimated based on CO2 emission factor (g/hp-hr) generated from the MOVES2014a model and the emission factor for the mass of CO2 generated per gallon of fuel (10.21 kg CO_2/gal fuel) as presented in Table A-1 of the EPA report, "Direct Emissions from Mobile Combustion Sources, U.S. EPA Center for Corporate Leadership – Greenhouse Gas Inventory Guidance," EPA430-K-16-004, January 2016.

On-road Vehicles (Virginia Beach, VA)

		MOVES2014a Emission factors in lb/VMT /a											
		VOC	NO_x	CO	PM_{10}	PM2.5	SO_2	HAP	CO_2	CH_4	N_2O	CO2e	mi/gal
131	Diesel Single Unit Short-haul Truck	0.00077	0.00450	0.00337	0.00017	0.00016	0.00002	0.00010	2.70454	0.00034	0.00001	2.71066	8.32
132	Diesel Refuse Truck	0.00075	0.01008	0.00599	0.00040	0.00037	0.00003	0.00008	3.78889	0.00020	0.00001	3.79252	5.94
133	Diesel Light Commercial Truck	0.00141	0.00345	0.01136	0.00015	0.00014	0.00001	0.00015	1.52405	0.00031	0.00001	1.52922	14.77
134	Diesel Passenger Truck	0.00071	0.00221	0.00608	0.00006	0.00006	0.00001	0.00010	1.46838	0.00032	0.00001	1.47325	15.33
135	Gasoline Passenger Truck	0.00096	0.00097	0.01261	0.00002	0.00002	0.00002	0.00009	0.93708	0.00004	0.00003	0.94560	20.66

/a Emission factors (lb/VMT) for VOC, NOx, CO, PM10, SO2, HAP and CO2e, were derived using the MOVES2014 model and inputs for calendar year 2024 using the latest input files for calendar year 2017 from the Virginia Department of Environmental Quality.

On-road Vehicles (Portsmouth, VA)

		MOVES2014a Emission factors in lb/VMT /a											
		VOC	NO_x	CO	PM_{10}	PM2.5	SO_2	HAP	CO_2	CH_4	N_2O	CO2e	mi/gal
141	Diesel Single Unit Short-haul Truck	0.00090	0.00469	0.00400	0.00018	0.00016	0.00002	0.00012	2.76545	0.00041	0.00001	2.77181	8.14
142	Diesel Refuse Truck	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	#VALUE!
143	Diesel Light Commercial Truck	0.00223	0.00535	0.01711	0.00027	0.00024	0.00001	0.00020	1.61253	0.00024	0.00001	1.61738	13.96
144	Diesel Passenger Truck	0.00101	0.00296	0.00869	0.00010	0.00009	0.00001	0.00012	1.58136	0.00030	0.00001	1.58647	14.23
145	Gasoline Passenger Truck	0.00136	0.00131	0.01596	0.00003	0.00003	0.00002	0.00014	1.04811	0.00005	0.00004	1.05821	18.47

/a Emission factors (lb/VMT) for VOC, NOx, CO, PM10, SO2, HAP and CO2e, were derived using the MOVES2014 model and inputs for calendar year 2024 using the latest input files for calendar year 2017 from the Virginia Department of Environmental Quality.

On-road Vehicles (Newport News, VA)

		MOVES2014a Emission factors in lb/VMT /a											
		VOC	NO_x	CO	PM_{10}	PM2.5	SO_2	HAP	CO_2	CH_4	N_2O	CO2e	mi/gal
151	Diesel Single Unit Short-haul Truck	0.00078	0.00363	0.00354	0.00012	0.00011	0.00002	0.00011	2.33546	0.00039	0.00001	2.34059	9.64
152	Diesel Refuse Truck	0.00050	0.01351	0.00666	0.00007	0.00007	0.00003	0.00008	4.04731	0.00042	0.00001	4.05159	5.56
153	Diesel Light Commercial Truck	0.00140	0.00296	0.01092	0.00013	0.00012	0.00001	0.00014	1.27740	0.00022	0.00000	1.28074	17.62
154	Diesel Passenger Truck	0.00068	0.00213	0.00678	0.00006	0.00006	0.00001	0.00009	1.37641	0.00026	0.00001	1.38046	16.35
155	Gasoline Passenger Truck	0.00105	0.00128	0.01525	0.00003	0.00003	0.00002	0.00010	0.91915	0.00004	0.00003	0.92730	21.06

/a Emission factors (lb/VMT) for VOC, NOx, CO, PM10, SO2, HAP and CO2e, were derived using the MOVES2014 model and inputs for calendar year 2024 using the latest input files for calendar year 2017 from the Virginia Department of Environmental Quality.

KITTY HAWK OFFSHORE WIND PROJECT
MOVES Emission Factor Summary

Virginia Beach, VA													
Input Year	Fuel	Vehicle Type	Emission Factor lbs/VMT										
			VOC	NOx	CO	PM10	PM2.5	SO2	HAPS	CO2	CH4	N2O	CO2e
2024	Diesel	Combination Long-haul Truck	2.95E-04	4.69E-03	1.32E-03	1.41E-04	1.29E-04	3.24E-05	2.78E-05	3.88	1.03E-04	4.43E-06	3.88
		Combination Short-haul Truck	3.34E-04	4.85E-03	1.94E-03	1.31E-04	1.21E-04	3.25E-05	3.53E-05	3.88	1.36E-04	4.81E-06	3.89
		Single Unit Long-haul Truck	5.62E-04	3.59E-03	3.17E-03	1.48E-04	1.36E-04	1.94E-05	7.23E-05	2.31	2.50E-04	7.59E-06	2.31
		Single Unit Short-haul Truck	7.66E-04	4.50E-03	3.37E-03	1.74E-04	1.60E-04	2.27E-05	9.93E-05	2.70	3.38E-04	1.00E-05	2.71
		Refuse Truck	7.48E-04	1.01E-02	5.99E-03	4.03E-04	3.70E-04	3.22E-05	7.65E-05	3.79	2.05E-04	5.74E-06	3.79
		Light Commercial Truck	1.41E-03	3.45E-03	1.14E-02	1.52E-04	1.40E-04	1.30E-05	1.48E-04	1.52	3.13E-04	7.06E-06	1.53
		Passenger Truck	7.08E-04	2.21E-03	6.08E-03	6.47E-05	5.95E-05	1.23E-05	9.52E-05	1.47	3.22E-04	6.65E-06	1.47
		Passenger Car	4.28E-04	2.84E-04	6.84E-03	1.04E-05	9.53E-06	5.55E-06	8.23E-05	0.66	3.85E-04	1.77E-06	0.67
	Gasoline	Combination Short-haul Truck	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		Single Unit Long-haul Truck	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		Single Unit Short-haul Truck	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		Refuse Truck	2.74E-03	2.65E-03	1.30E-02	7.93E-05	7.01E-05	6.77E-05	3.64E-04	3.33	6.10E-05	1.85E-05	3.33
		Light Commercial Truck	2.76E-03	2.50E-03	2.64E-02	4.58E-05	4.05E-05	2.15E-05	2.70E-04	1.05	8.85E-05	6.70E-05	1.07
		Passenger Truck	9.60E-04	9.67E-04	1.26E-02	2.35E-05	2.07E-05	1.91E-05	9.35E-05	0.94	4.02E-05	3.11E-05	0.95
		Passenger Car	9.23E-04	6.59E-04	9.60E-03	1.92E-05	1.70E-05	1.43E-05	9.33E-05	0.70	2.52E-05	2.33E-05	0.71

Note: Emission factors (lb/VMT) for VOC, NOx, CO, PM10, SO2, HAP and CO2e, were derived using the MOVES2014 model and inputs for calendar year 2024 using the latest input files for calendar year 2017 from the Virginia Department of Environmental Quality.

Portsmouth, VA													
Input Year	Fuel	Vehicle Type	Emission Factor lbs/VMT										
			VOC	NOx	CO	PM10	PM2.5	SO2	HAPS	CO2	CH4	N2O	CO2e
2024	Diesel	Combination Long-haul Truck	3.37E-04	5.08E-03	1.63E-03	1.61E-04	1.48E-04	3.51E-05	3.35E-05	4.20	1.26E-04	5.68E-06	4.20
		Combination Short-haul Truck	4.93E-04	6.63E-03	3.14E-03	2.15E-04	1.98E-04	3.58E-05	5.24E-05	4.27	1.77E-04	6.44E-06	4.27
		Single Unit Long-haul Truck	6.68E-04	3.96E-03	3.56E-03	1.64E-04	1.51E-04	2.12E-05	8.67E-05	2.53	3.01E-04	9.05E-06	2.54
		Single Unit Short-haul Truck	9.02E-04	4.69E-03	4.00E-03	1.79E-04	1.65E-04	2.32E-05	1.19E-04	2.77	4.11E-04	1.15E-05	2.77
		Refuse Truck	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		Light Commercial Truck	2.23E-03	5.35E-03	1.71E-02	2.66E-04	2.45E-04	1.38E-05	2.03E-04	1.61	2.42E-04	7.38E-06	1.62
		Passenger Truck	1.01E-03	2.96E-03	8.69E-03	9.57E-05	8.80E-05	1.34E-05	1.16E-04	1.58	2.99E-04	7.05E-06	1.59
		Passenger Car	3.91E-04	2.59E-04	6.21E-03	9.44E-06	8.69E-06	5.66E-06	7.24E-05	0.68	3.30E-04	1.84E-06	0.68
	Gasoline	Combination Short-haul Truck	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		Single Unit Long-haul Truck	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		Single Unit Short-haul Truck	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		Refuse Truck	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		Light Commercial Truck	3.64E-03	3.29E-03	3.25E-02	5.72E-05	5.06E-05	2.33E-05	3.71E-04	1.14	1.06E-04	8.02E-05	1.17
		Passenger Truck	1.36E-03	1.31E-03	1.60E-02	2.91E-05	2.57E-05	2.13E-05	1.40E-04	1.05	4.66E-05	3.60E-05	1.06
		Passenger Car	1.07E-03	7.52E-04	1.06E-02	2.21E-05	1.96E-05	1.57E-05	1.14E-04	0.77	2.58E-05	2.44E-05	0.78

Note: Emission factors (lb/VMT) for VOC, NOx, CO, PM10, SO2, HAP and CO2e, were derived using the MOVES2014 model and inputs for calendar year2024 using the latest input files for calendar year 2017 from the Virginia Department of Environmental Quality.

Newport News, VA													
Input Year	Fuel	Vehicle Type	Emission Factor lbs/VMT										
			VOC	NOx	CO	PM10	PM2.5	SO2	HAPS	CO2	CH4	N2O	CO2e
2024	Diesel	Combination Long-haul Truck	2.73E-04	4.59E-03	1.19E-03	1.30E-04	1.20E-04	3.18E-05	2.48E-05	3.80	9.16E-05	3.86E-06	3.81
		Combination Short-haul Truck	3.69E-04	6.07E-03	1.92E-03	1.69E-04	1.55E-04	3.21E-05	3.54E-05	3.83	1.14E-04	4.14E-06	3.83
		Single Unit Long-haul Truck	5.29E-04	2.86E-03	3.15E-03	1.10E-04	1.01E-04	1.79E-05	7.27E-05	2.14	2.72E-04	6.76E-06	2.14
		Single Unit Short-haul Truck	7.78E-04	3.63E-03	3.54E-03	1.25E-04	1.15E-04	1.96E-05	1.08E-04	2.34	3.94E-04	9.60E-06	2.34
		Refuse Truck	5.04E-04	1.35E-02	6.66E-03	7.33E-05	6.75E-05	3.37E-05	8.47E-05	4.05	4.20E-04	5.88E-06	4.05
		Light Commercial Truck	1.40E-03	2.96E-03	1.09E-02	1.33E-04	1.23E-04	1.09E-05	1.35E-04	1.28	2.15E-04	4.94E-06	1.28
		Passenger Truck	6.75E-04	2.13E-03	6.78E-03	6.32E-05	5.81E-05	1.16E-05	8.51E-05	1.38	2.64E-04	5.11E-06	1.38
		Passenger Car	3.33E-04	2.47E-04	6.07E-03	8.97E-06	8.25E-06	4.95E-06	6.26E-05	0.59	2.89E-04	1.33E-06	0.59
	Gasoline	Combination Short-haul Truck	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		Single Unit Long-haul Truck	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		Single Unit Short-haul Truck	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		Refuse Truck	4.55E-03	4.68E-03	3.00E-02	1.70E-04	1.50E-04	7.41E-05	5.62E-04	3.64	1.73E-04	1.25E-04	3.67
		Light Commercial Truck	2.16E-03	2.30E-03	2.18E-02	4.51E-05	3.99E-05	1.81E-05	2.10E-04	0.89	7.36E-05	5.12E-05	0.90
		Passenger Truck	1.05E-03	1.28E-03	1.52E-02	2.93E-05	2.59E-05	1.87E-05	1.03E-04	0.92	4.25E-05	2.80E-05	0.93
		Passenger Car	7.82E-04	6.41E-04	9.12E-03	1.91E-05	1.69E-05	1.33E-05	7.86E-05	0.65	2.30E-05	1.84E-05	0.66

Note: Emission factors (lb/VMT) for VOC, NOx, CO, PM10, SO2, HAP and CO2e, were derived using the MOVES2014 model and inputs for calendar year 2024 using the latest input files for calendar year 2017 from the Virginia Department of Environmental Quality.

KITTY HAWK OFFSHORE WIND PROJECT
EPA NEI HAP emission factors for Commercial Marine Vessels

HAP emission factors for commercial marine vessels were determined using the methodology identified by US EPA for the 2017 National Emissions Inventory (NEI); i.e., they are calculated as percentages of the PM2.5 or VOC emissions from the CMVs.

Pollutant	HAP?*	Fraction of	Fraction (All engines Cat 1/2/3, all fuel types, all operating modes)
Ammonia	No	PM2.5	0.019247
Antimony	Yes	PM2.5	6.15E-04
Arsenic	Yes	PM2.5	2.59E-05
Benz[a]Anthracene	Yes	PM2.5	8.82E-06
Benzo(g,h,i)Perylene	Yes	PM2.5	1.32E-04
Benzo[a]Pyrene	Yes	PM2.5	4.18E-06
Benzo[b]Fluoranthene	Yes	PM2.5	8.35E-06
Benzo[k]Fluoranthene	Yes	PM2.5	4.18E-06
Cadmium	Yes	PM2.5	2.36E-04
Chromium (VI)	Yes	PM2.5	7.24E-09
Chrysene	Yes	PM2.5	1.63E-05
Dibenzo[a,h]anthracene	Yes	PM2.5	8.65E-06
Fluoranthene	Yes	PM2.5	8.97E-05
Indeno[1,2,3-c,d]Pyrene	Yes	PM2.5	8.35E-06
Lead	Yes	PM2.5	1.25E-04
Manganese	Yes	PM2.5	3.22E-06
Mercury	Yes	PM2.5	4.18E-08
Nickel	Yes	PM2.5	6.87E-04
Polychlorinated Biphenyls	Yes	PM2.5	4.18E-07
Pyrene	Yes	PM2.5	3.37E-05
Selenium	Yes	PM2.5	4.38E-08
Total HAP (ratioed to PM2.5)			**0.0213**
1,3-Butadiene	Yes	VOC	0.001013
2,2,4-Trimethylpentane	Yes	VOC	7.12E-03
Acenaphthene	Yes	VOC	5.09E-05
Acenaphthylene	Yes	VOC	1.18E-04
Acetaldehyde	Yes	VOC	0.009783
Acrolein	Yes	VOC	0.001848
Anthracene	Yes	VOC	3.44E-04
Benzene	Yes	VOC	0.004739
Ethyl Benzene	Yes	VOC	4.39E-04
Fluorene	Yes	VOC	1.64E-04
Formaldehyde	Yes	VOC	0.042696
Hexane	Yes	VOC	2.79E-03
Naphthalene	Yes	VOC	2.73E-03
o-Xylene	Yes	VOC	5.13E-04
Phenanthrene	Yes	VOC	0.001356
Propionaldehyde	Yes	VOC	0.001517
Toluene	Yes	VOC	0.002035
Xylenes (Mixed Isomers)	Yes	VOC	0.001422
Total HAP (ratioed to VOC)			**0.0807**

*For completeness, all of the pollutants in EPA's database are shown, but not all are HAP as defined in Section 112 of the Clean Air Act and as updated in 40 CFR 63 Subpart C.

Reference: US EPA, "2017 National Emissions Inventory (NEI)," April 2020, available from https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-data.
HAP speciation profiles for Category 1 and 2 engines are from Table 8 of the 2017 NEI "Methodology Documentation for EPA's Commercial Marine Emissions Estimates" for Category 1 and 2 vessels. HAP speciation profiles for Category 3 and 2 engines are from Table 15 of the "Methodology Documentation for EPA's Commercial Marine Emissions Estimates" for Category 3 vessels. Both documents are available from https://www.epa.gov/sites/production/files/2019-11/cmv_methodology_documentation.zip.

KITTY HAWK OFFSHORE WIND PROJECT

HAP Emission Factor Calculation Sheet

Small Diesel Engines

Pollutant		Emission Factor (lb/MMBtu)[a]	Emission Factor Rating	Source (AP-42 Table)
Organic Compounds				
Benzene[b]		9.33E-04	E	3.3-2
Toluene[b]		4.09E-04	E	3.3-2
Xylene[b]		2.85E-04	E	3.3-2
1,3 Butadiene	<	3.91E-05	E	3.3-2
Propylene		2.58E-03	E	3.3-2
Formaldehyde[b]		1.18E-03	E	3.3-2
Acetaldehyde[b]		7.67E-04	E	3.3-2
Acrolein[b]	<	9.25E-05	E	3.3-2
PAH				
Naphthalene[b]		8.48E-05	E	3.3-2
Acenaphthylene[b]	<	5.06E-05	E	3.3-2
Acenaphthene[b]	<	1.42E-06	E	3.3-2
Fluorene[b]		2.92E-05	E	3.3-2
Phenanthrene[b]		2.94E-05	E	3.3-2
Anthracene[b]		1.87E-06	E	3.3-2
Fluoranthene[b]		7.61E-06	E	3.3-2
Pyrene[b]		4.78E-06	E	3.3-2
Benzo(a)anthracene[b]		1.68E-06	E	3.3-2
Chrysene[b]		3.53E-07	E	3.3-2
Benzo(b)fluoranthene[b]	<	9.91E-08	E	3.3-2
Benzo(k)fluoranthene[b]	<	1.55E-07	E	3.3-2
Benzo(a)pyrene[b]	<	1.88E-07	E	3.3-2
Indeno(1,2,3-cd)pyrene[b]	<	3.75E-07	E	3.3-2
Dibenz(a,h)anthracene[b]	<	5.83E-07	E	3.3-2
Benzo(g,h,i)perylene[b]	<	4.89E-07	E	3.3-2
TOTAL PAH		1.68E-04	E	3.3-2
Metals and inorganics[c]				
Arsenic[b]		4.62E-08		
Cadmium[b]		5.13E-09		
Chromium[b]		1.24E-05		
Chromium VI[b, d]		2.24E-06		
Lead[b]		7.69E-07		
Mercury[b]		1.03E-08		
Nickel[b]		1.48E-06		
Selenium[b]		2.56E-07		

Total for substances identified as HAP[e]	<	3.89E-03

[a] Values preceded by "<" are based on method detection limits.

[b] Specifically listed as a "Hazardous Air Pollutant" (HAP) in the Clean Air Act, or a component of Polycyclic Organic Matter, which is also listed as a HAP.

[c] Metal emissions are based on the paper *Survey of Ultra-Trace Metals in Gas Turbine Fuels,* 11th Annual International Petroleum Conference, Oct 12-15, 2004. Where trace metals were detected in any of 13 samples, the average result is used. Where no metals were detected in any of 13 samples, the detection limit is used.

[d] Hexavalent chrome was not detected in any fuel oil samples (in the note c reference study). However, to allow for potential hex chrome emissions formed during combustion, 18% of the total chrome emissions were assumed to be hex chrome (per EPA 453/R-98-004a)

[e] Total calculated using the TOTAL PAH emission factor instead of factors for individual PAH.

KITTY HAWK OFFSHORE WIND PROJECT

HAP Emission Factor Calculation Sheet

Large Stationary Diesel Engines

Pollutant		Emission Factor (lb/MMBtu)[a]	Emission Factor Rating	Source (AP-42 Table)
Organic Compounds				
Benzene[b]		7.76E-04	E	3.4-3
Toluene[b]		2.81E-04	E	3.4-3
Xylene[b]		1.93E-04	E	3.4-3
Propylene		2.79E-03	E	3.4-3
Formaldehyde[b]		7.89E-05	E	3.4-3
Acetaldehyde[b]		2.52E-05	E	3.4-3
Acrolein[b]		7.88E-06	E	3.4-3
PAH				
Naphthalene[b]		1.30E-04	E	3.4-4
Acenaphthylene[b]		9.23E-06	E	3.4-4
Acenaphthene[b]		4.68E-06	E	3.4-4
Fluorene[b]		1.28E-05	E	3.4-4
Phenanthrene[b]		4.08E-05	E	3.4-4
Anthracene[b]		1.23E-06	E	3.4-4
Fluoranthene[b]		4.03E-06	E	3.4-4
Pyrene[b]		3.71E-06	E	3.4-4
Benz(a)anthracene[b]		6.22E-07	E	3.4-4
Chrysene[b]		1.53E-06	E	3.4-4
Benzo(b)fluoranthene[b]		1.11E-06	E	3.4-4
Benzo(k)fluoranthene[b]	<	2.18E-07	E	3.4-4
Benzo(a)pyrene[b]	<	2.57E-07	E	3.4-4
Indeno(1,2,3-cd)pyrene[b]	<	4.14E-07	E	3.4-4
Dibenz(a,h)anthracene[b]	<	3.46E-07	E	3.4-4
Benzo(g,h,i)perylene[b]	<	5.56E-07	E	3.4-4
TOTAL PAH	<	2.12E-04	E	3.4-4
Metals and inorganics[c]				
Arsenic[b]		4.62E-08		
Cadmium[b]		5.13E-09		
Chromium[b]		1.24E-05		
Chromium VI[b, d]		2.24E-06		
Lead[b]		7.69E-07		
Mercury[b]		1.03E-08		
Nickel[b]		1.48E-06		
Selenium[b]		2.56E-07		

Total for substances identified as HAP[e]	<	1.59E-03

[a] Values preceded by "<" are based on method detection limits.

[b] Specifically listed as a "Hazardous Air Pollutant" (HAP) in the Clean Air Act, or a component of Polycyclic Organic Matter, which is also listed as a HAP.

[c] Metal emissions are based on the paper *Survey of Ultra-Trace Metals in Gas Turbine Fuels,* 11th Annual International Petroleum Conference, Oct 12-15, 2004. Where trace metals were detected in any of 13 samples, the average result is used. Where no metals were detected in any of 13 samples, the detection limit is used.

[d] Hexavalent chrome was not detected in any fuel oil samples (in the note f reference study). However, to allow for potential hex chrome emissions formed during combustion, 18% of the total chrome emissions were assumed to be hex chrome (per EPA 453/R-98-004a)

[e] Total calculated using the TOTAL PAH emission factor instead of factors for individual PAH.

KITTY HAWK OFFSHORE WIND PROJECT

HAP Emission Factor Calculation Sheet

Natural Gas-Fired Engines

Pollutant		Emission Factor (lb/MMBtu)[a]	Emission Factor Rating	Source (AP-42 Table)
1,1,2,2-Tetrachloroethane		2.53E-05	C	3.2-3
1,1,2-Trichloroethane	<	1.53E-05	E	3.2-3
1,3-Butadiene		6.63E-04	D	3.2-3
1,3-Dichloropropene	<	1.27E-05	E	3.2-3
Acetaldehyde		2.79E-03	C	3.2-3
Acrolein		2.63E-03	C	3.2-3
Benzene		1.58E-03	B	3.2-3
Carbon Tetrachloride	<	1.77E-05	E	3.2-3
Chlorobenzene	<	1.29E-05	E	3.2-3
Chloroform	<	1.37E-05	E	3.2-3
Ethylbenzene	<	2.48E-05	E	3.2-3
Ethylene Dibromide	<	2.13E-05	E	3.2-3
Formaldehyde		2.05E-02	A	3.2-3
Methanol		3.06E-03	D	3.2-3
Methylene Chloride		4.12E-05	C	3.2-3
Naphthalene	<	9.71E-05	E	3.2-3
PAH		1.41E-04	D	3.2-3
Styrene	<	1.19E-05	E	3.2-3
Toluene		5.58E-04	A	3.2-3
Vinyl Chloride	<	7.18E-06	E	3.2-3
Xylene		1.95E-04	A	3.2-3
Total for substances identified as HAP[e]	<	3.24E-02		

[a] Values preceded by "<" are based on method detection limits.

KITTY HAWK OFFSHORE WIND PROJECT
EPA NEI HAP emission factors for Nonroad Diesels

HAP emission factors for nonroad diesels (below) were obtained from ERG, "Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and Other Nonroad Components of the National Emissions Inventory," Volume I - Methodology, October 7, 2003 (available from http://www.epa.gov/ttn/chief/net/1999inventory.html#final3haps), Appendix D, Tables D-1 through D-3. This is the reference cited by EPA's National Inventory Model (NMIM), i.e., US EPA, "EPA's National Inventory Model (NMIM), A Consolidated Emissions Modeling System for MOBILE6 and NONROAD", EPA420-R-05-024, December 2005 (available from http://www.epa.gov/otaq/models/nmim/420r05024.pdf), pp. 19-21.

Pollutant	Fraction of	Emissions Factor %
1,3-butadiene	VOC - Exhaust	0.0018616
formaldehyde	VOC	0.11815
benzene	VOC	0.020344
acetaldehyde	VOC	0.05308
ethylbenzene	VOC - Exhaust	0.0031001
styrene	VOC - Exhaust	0.00059448
acrolein	VOC	0.00303
toluene	VOC	0.014967
hexane	VOC	0.0015913
propionaldehyde	VOC	0.011815
2,2,4-trimethylpentane	VOC	0.000719235
2,3,7,8-TCDD TEQ **	tons TEQ/gal	1.90705E-14
xylenes	VOC	0.010582
	Total HAP (ratioed to VOC)	**0.239834715**
PAH		
benz[a]anthracene	PM10	0.0000071
benzo[a]pyrene	PM10	0.00000035
benzo[b]fluoranthene	PM10	0.00000049
benzo[k]fluoranthene	PM10	0.00000035
chrysene	PM10	0.0000019
dibenzo[a,h]anthracene	PM10	2.9E-09
indeno[1,2,3-c,d]pyrene	PM10	0.000000079
acenaphthene	PM10	0.0001
acenaphthylene	PM10	0.000084
anthracene	PM10	0.00000043
benzo[g,h,i]perylene	PM10	0.00000019
fluoranthene	PM10	0.000017
fluorene	PM10	0.0001
naphthalene	PM10	0.00046
phenanthrene	PM10	0.00026
pyrene	PM10	0.0000029
	Total HAP (ratioed to PM10)	**0.001034792**
chromium	ug/bhp-hr	0.03
manganese	ug/bhp-hr	1.37
nickel	ug/bhp-hr	2.035
	Total HAP (Metals ug/bhp-hr)	**3.435**

** Note: the emission rate for 2,3,7,8-TCDD TEQ is significantly lower than any other HAP and therefore, was not factored into the total HAP emission factor.