BOEM Offshore Wind Energy Facilities Emission Estimating Tool — Version 2.0

User's Guide

U.S. Department of the Interior
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Management

BOEM Offshore Wind Energy Facilities Emission Estimating Tool — Version 2.0

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DISCLAIMER

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CITATION

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1.0   INTRODUCTION/BACKGROUND

The Bureau of Ocean Energy Management (BOEM) reviews Construction Operation Plans and prepares numerous Environmental Assessments as part of its National Environmental Policy Act (NEPA) responsibilities for proposed site characterization/geologic and geophysical activities and lease sales. To follow the White House Council on Environmental Quality regulations, BOEM developed an efficient, consistent approach to estimate emissions associated with proposed actions. This approach could by extension include the potential beneficial impacts of offshore wind energy facilities on climate change, such as the quantification of indirect impacts and reduction in emissions due to the displacement of grid-based, fossil-fuel-generated electricity.

BOEM developed the Offshore Wind Energy Facilities Emission Estimating Tool (Wind Tool) for BOEM's NEPA document authors (and possibly project applicants) to easily quantify emissions associated with proposed actions and assess the associated benefits of offshore wind energy facilities.

This User's Guide provides detailed information on the functionality of the Wind Tool, including instructions for installing and using it. The guide describes what data are required, how to enter data, and how to obtain various forms of output. The chapters in this guide are organized as follows:

- Installation
- Overview of process
- Starting a new or editing an existing project
- Calculating emissions

2.0   INSTALLATION

The Wind Tool requires a personal computer (PC) equipped with the Microsoft® Windows® 7, 8, or 10 operating systems with Microsoft Office Access®. To ensure future compatibility, the tool was developed in a Microsoft® Office 360 runtime format. For more information about runtime go to: https://support.microsoft.com/en-us/office/download-and-install-microsoft-365-access-runtime-185c5a32-8ba9-491e-ac76-91cbe3ea09c9. Alternatively, you can download you can download the runtime platform at https://support.microsoft.com/en-us/office/download-and-install-microsoft-365-access-runtime-185c5a32-8ba9-491e-ac76-91cbe3ea09c9.

The user should possess a modest familiarity with the Windows® operating environment and should understand a few of its common features, such as point and click, file management, menu-driven selection, and text boxes.

The Wind Tool is an Access-based file that can be downloaded as a compressed (zipped) file from (<website>). The compressed file includes this User's Guide, import templates, and the Wind Tool (WindEnergyTool_v1.0.accdb).

To install the Wind Tool, follow the steps below:

1. Download the compressed file to your PC.
2. Save the compressed file to an installation folder of your choice (e.g., C:\WindTool).
3. Navigate to the saved compressed file and unzip.

It is necessary to keep the directory structure intact, as moving the folder and files will affect the tool's ability to export data and open a copy of this document. Users may want to create a desktop shortcut to the Wind Tool for easier access.

The first time you open the Wind Tool, you will have to click the "Enable Content" button that appears at the top of the Access window (Figure 1). This will ensure all code is executed properly.
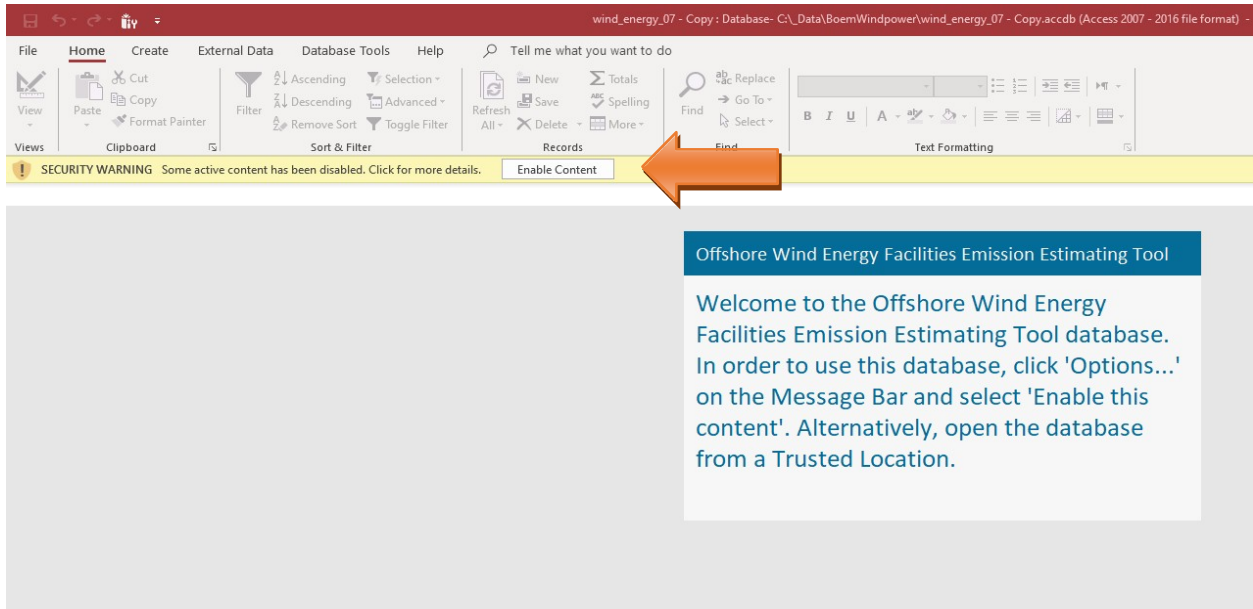
Figure 1. Prompt on Wind Tool's initial screen to "Enable Content"

3.0 OVERVIEW OF PROCESS

The Wind Tool walks users through the process of entering the input data needed to calculate the emissions from each phase of an offshore wind energy installation, from preconstruction through decommissioning. Combined with the information on the regional mix of energy sources for the location and calculated avoided emissions, the user can calculate the net emissions resulting from the project (i.e., the difference between the emissions that occur from the planning, installation, and maintenance of offshore equipment and the emissions avoided at conventional power-generating units as a result of the offshore wind energy facility).

The basic outline for data entry and calculations is as follows:

1. Enter project information, which includes project metadata such as company and contact information.
2. Enter equipment information, which includes offshore vessels, helicopters, and substation activity data.
3. Enter anticipated wind power electricity-generating information for avoided emission calculations.
4. Review emission estimates and export report.

Opening the software automatically opens the main screen, which has four main components (Figure 2); from here, the user can select from the following options:

- Project Setup: allows users to set up a project.

- Models: allows the user to populate necessary activity data and calculate emissions.

- Admin: location where this User's Guide is stored, and where users can view the static data files (e.g., vessel and helicopter emission factors, vessel and helicopter default attributes, AVoided Emissions and geneRation Tool [AVERT] emission factors).

- Exit Application: closes the Wind Tool.

Because all project information is stored locally in the database, the Wind Tool allows users to stop at any point and reopen projects for additional edits.

Figure 2. Wind Tool main screen

4.0 STARTING A NEW OR EDITING AN EXISTING PROJECT

The following section outlines the process to estimate the net emissions from a wind energy project, starting from scratch or editing data submitted earlier.

4.1 PROJECT INFORMATION

The first step is to click the "Projects" button on the Wind Tool main screen (Figure 2). This will open the project entry screen, which compiles various metadata for the project. The requested data are split between three tabs: Project Information, Company, and Contact Details.

To start a new project, the user will need to toggle the "Add Project" button; to edit previously submitted data, the user will need to toggle the "Edit Project" button.

The Project Information tab (Figure 3) gathers identifying and descriptive data about the project. These data include the name of the project, a project description, and a representative lease block that would represent the center of the wind farm activities. Data also include anticipated start dates for construction, operations, and decommissioning, as well as an approximate date for final closure. Note, for the date fields, a calendar is provided to facilitate date selection. Once a date is selected, the calendar will disappear (Figure 4).
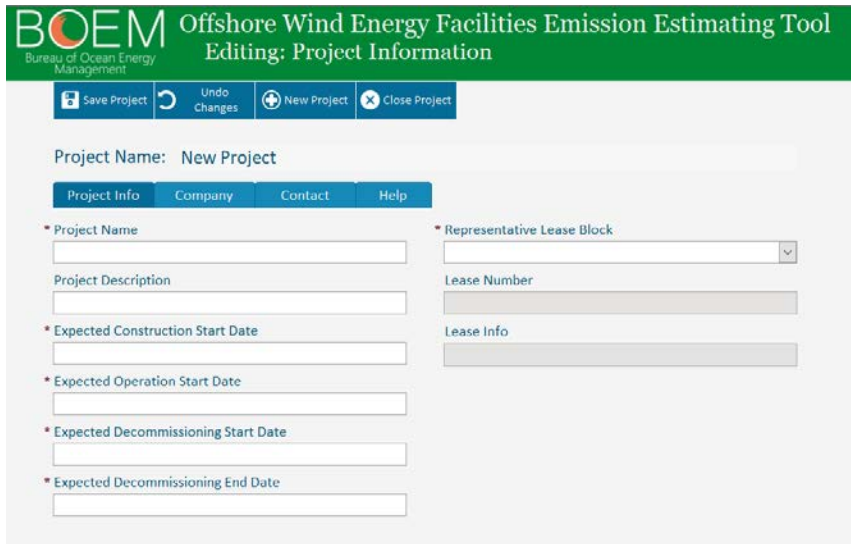
Figure 3. Project information entry screen

Figure 4. Date selection window

4.2 COMPANY DETAILS

The second tab in the project screen (Figure 5) stores the company information to simplify the data entry process. Users can select a previously populated company, or they can add a company by toggling the "Add a Company" button. Required data elements include the name and address of the company (Figure 6). After adding or editing the company data, the user should click the "Save" button before closing the company data screen.

Figure 5. Company selection screen

Figure 6. Company details entry screen

4.3 CONTACT DETAILS

The third tab in the project screen (Figure 7) stores previously entered or new contact information. For new contacts, toggle the "Add a Contact" button. The required data include the contact's name, role in the project, and contact information—such as email address and phone number (Figure 8). After adding or editing the contact data, the user should click "Save" before closing the contact data screen.

Figure 7. Contact screen

Figure 8. Contact details entry screen

Next, the user needs to save their project. In order to save the project the company and contact need to be selected then the user can select "Finish Editing" to return the project screen. From here, the user can select "Main" to return to the main screen of the tool.

4.4 CREATING A MODEL

After entering the project information, users should move on to the next step, entering or editing activity data inputs in the Models component of the Wind Tool (Figure 9). The first step is to provide a name and description for the model or to select a model that was previously developed.
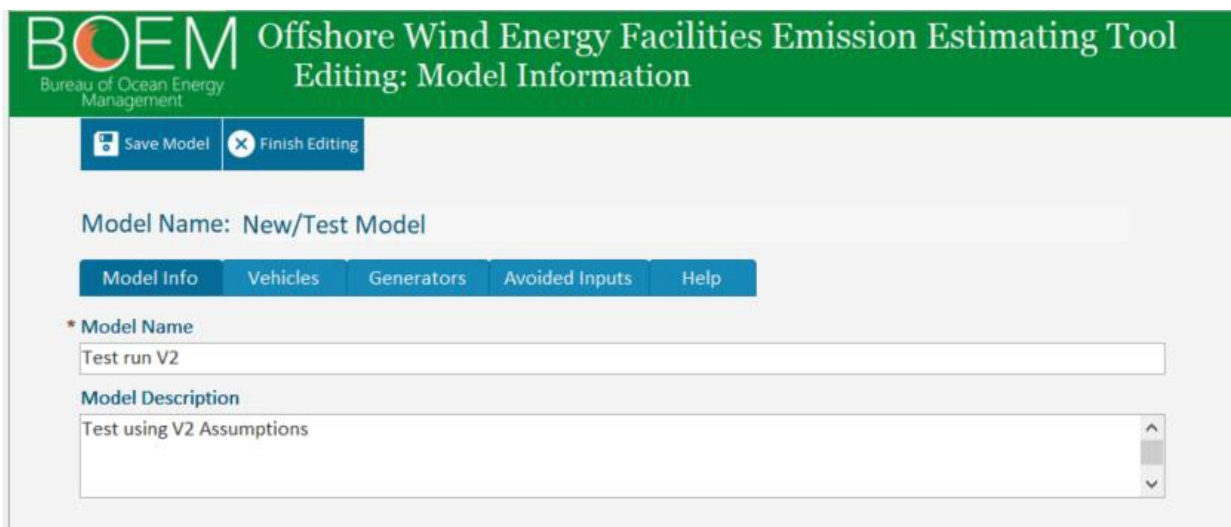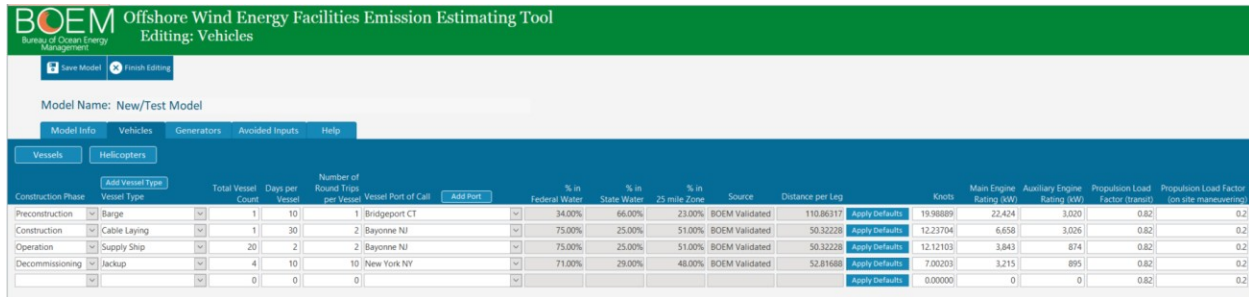

Figure 9. Initial model screen

4.4.1 Vessels

Next, the user needs to enter details about the vessels and helicopters to be used for this project. These data are disaggregated by construction phase (i.e., preconstruction, construction, operation, and decommissioning). Then, the user should add the vessels needed for each phase. The vessel data include the total number of vessels planned to be used for each phase of the project, the total number of days that a typical vessel use for the duration for each phase of the project, and an estimate of the total number of round trips for each phase of the project. Users will also need to provide data on the vessel's assumed transit speed, power rating of the main and auxiliary engines, engine operating load for main transit and onsite operations, and auxiliary operating load. Alternatively, they can use the defaults included in the model (Figure 10). The tool also allows users to create specialty vessels by toggling the "Add Vessel Type" button. Users can add the created vessel to the activity table. Note that users will need to add the vessel, propulsion, auxiliary power ratings, and typical transit speed.

To quantify transit emissions, users can select from a list of prepopulated ports that have been identified as being able to support offshore wind farms, or they can add their own port. If the user selects a prepopulated port, the software estimates the one-way trip length, as well as the fraction of the trip that occurs in federal waters, in state waters, and within 25 nautical miles of the representative lease block. To use a port that is not included in the prepopulated data, the user will need to input these data elements into the tool by selecting the "Add Port" button on the vessel activity screen.

The vessel's in-transit duration (in hours) is calculated by dividing the round-trip distance that the vessel travels by its speed. This value is subtracted from the total duration of the trip to estimate time spent on site.

Figure 10. Vessel activity screen

4.4.2 Helicopters

Users can follow similar steps to add their helicopter data. As with the vessel data, helicopter activity data are disaggregated by construction phase. The helicopter data include the total number of helicopters by type (i.e., twin light, medium, and heavy) that the user anticipates using, typical number of trips for each helicopter type, and typical speed; alternatively, users can use the default speeds provided in the tool (Figure 11).

To quantify transit emissions, the user can select one of the prepopulated ports developed for the vessel data that is closest to the supporting airport' this provides an estimate of the one-way trip length, as well as the fraction of the trip that occurs in federal waters, in state waters, and within 25 nautical miles of the representative lease block. Users can select a port that they added for marine vessels.

Figure 11. Helicopter activity screen

4.4.3 Generators

To estimate the emissions of offshore generators, the user will need to enter the number of generators, annual hours, maximum power rating, and operating load factors (Figure 12).
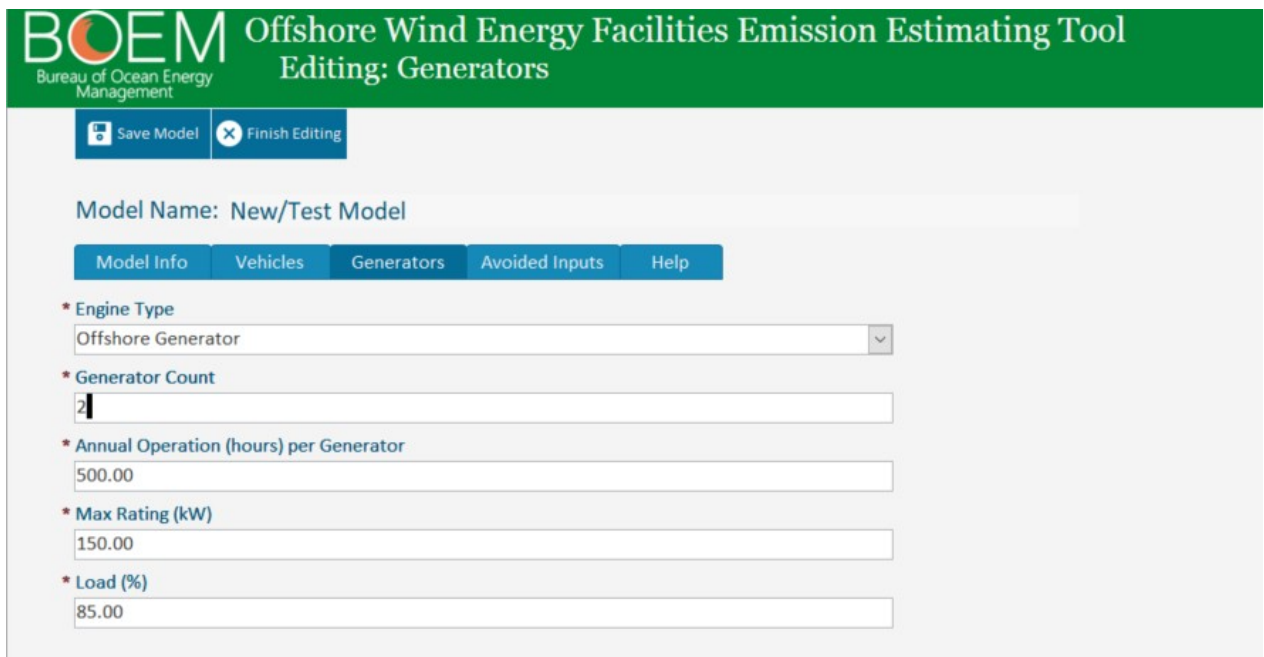
Figure 12. Generator activity screen

Once all of the model information, vessel, helicopter and generator data and avoided inputs, have been entered, the user should hit the "Finish Editing" button which

4.4.4 Avoided Emissions

After inputting the project activity data, users can enter the data needed to estimate the avoided emissions at landside power sources due to the use of offshore power. The landside emissions are calculated using the U.S. Environmental Protection Agency's (EPA's) AVERT data for specific regions. The user can use the AVERT regional code if they know it, use the map included in the tool (Figure 13), or search by the ZIP code where the power cable comes to shore. Note that the AVERT data account for line loss in transferring power to the grid (Figure 14).
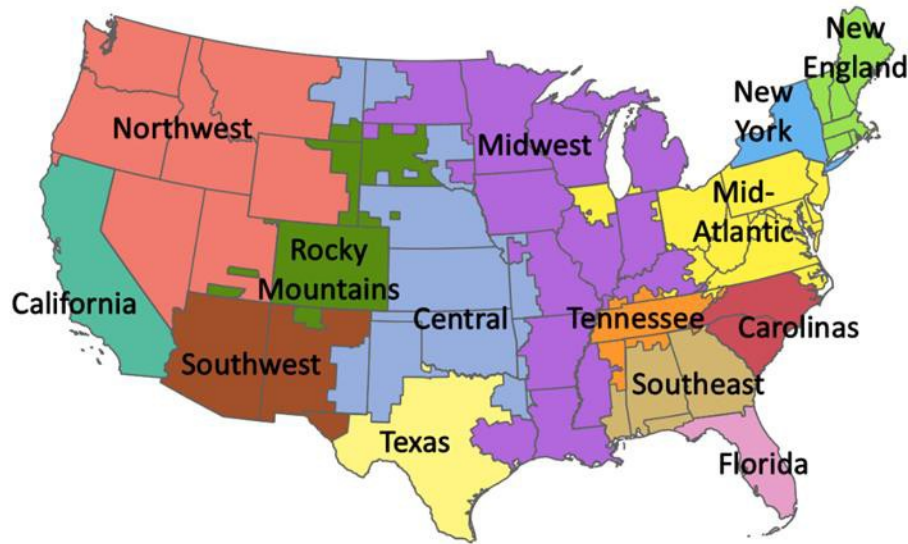
Figure 13. Map of AVERT regions

Additionally, the user will need to estimate a capacity factor, which is the ratio comparing the actual power delivered to the combined rated power of all the offshore wind farm's turbines.

Figure 14. Avoided emissions input screen

5.0   CALCULATING EMISSIONS

After entering or editing all the activity inputs, users should "save" their data and "Finish Editing": and then close the model to return to the main screen. From this screen, the user can select the Emissions tab. From the emissions screen, the user can see a summary of each pollutant; emissions in federal waters, in state waters, and within 25 miles of the representative lease block; and the avoided emissions and net emission reduction:

- Over the total life of the project (Figure 15).

- By operating phase (Figure 16).

- By source (i.e., vessel and helicopter) and operating phase (Figure 17).

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- By source, source type (e.g., barge, jack-up, support vessel, heavy twin helicopter), and operating phase (Figure 18).

If the user is only interested in emissions for a specific phase, source, type, or pollutant, they can filter the emissions data to only include those items for which they want a summary (Figure 19).
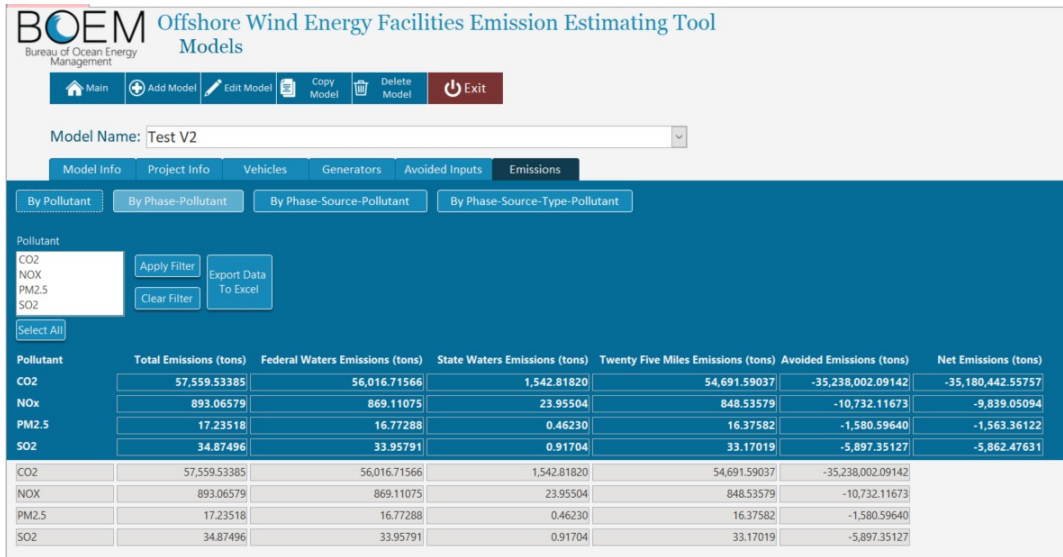
Figure 15. Emissions over the total life of the project
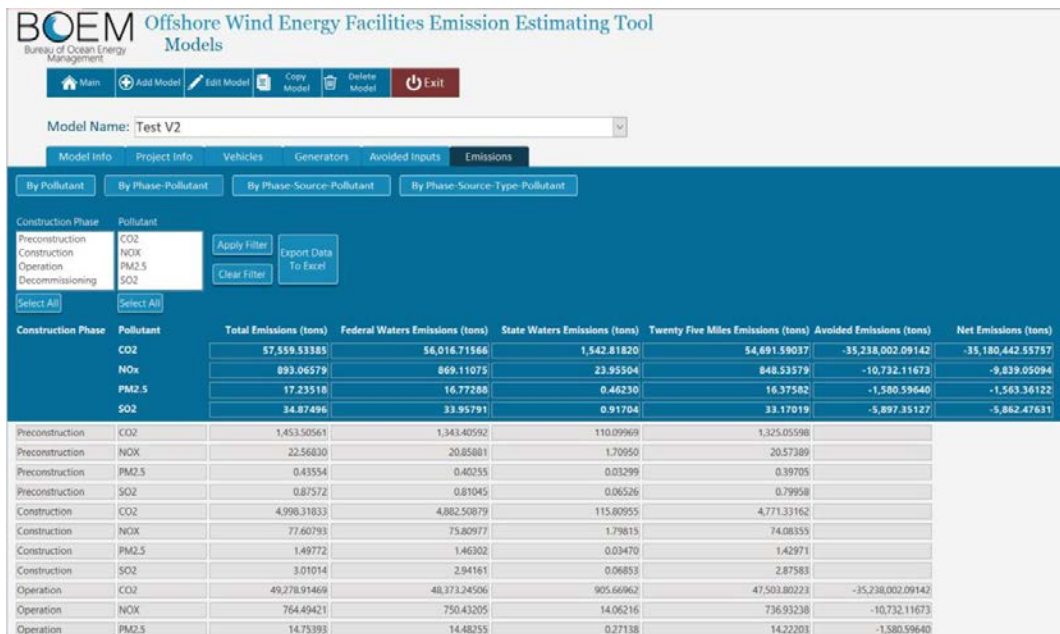
Figure 16. Emissions by operating phase
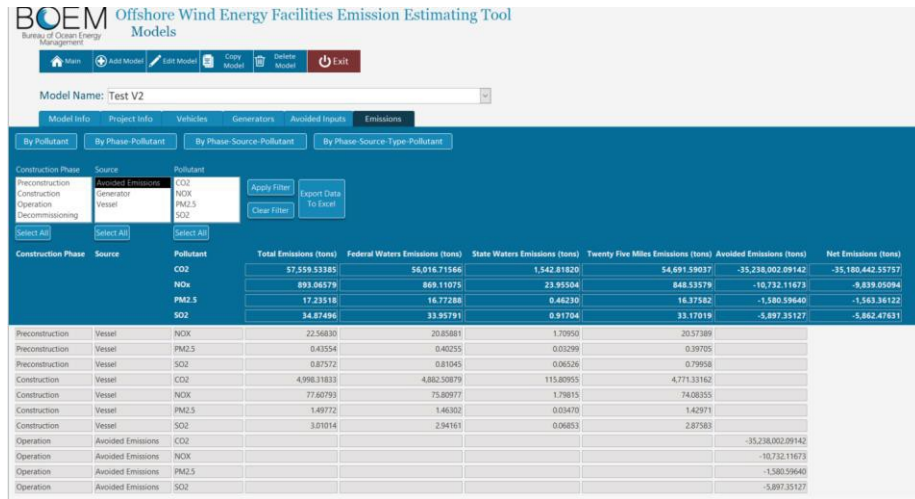
Figure 17. Emissions by source and operating phase
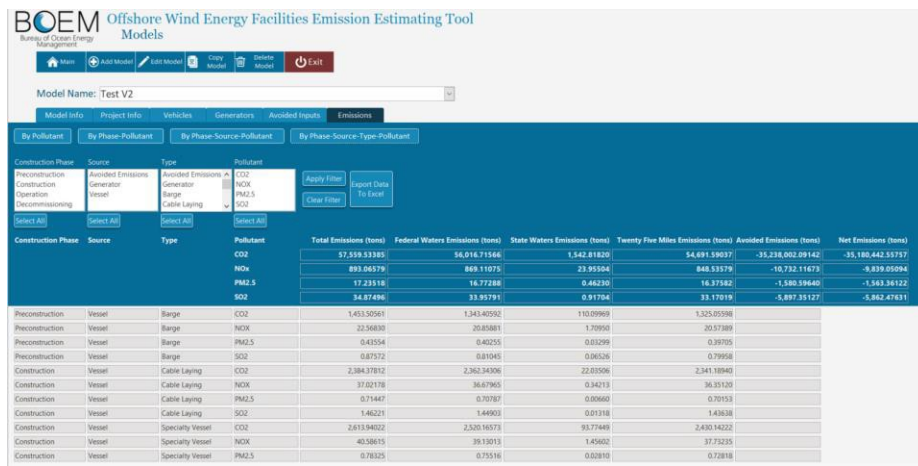
Figure 18. Emissions by source, type, and operating phase
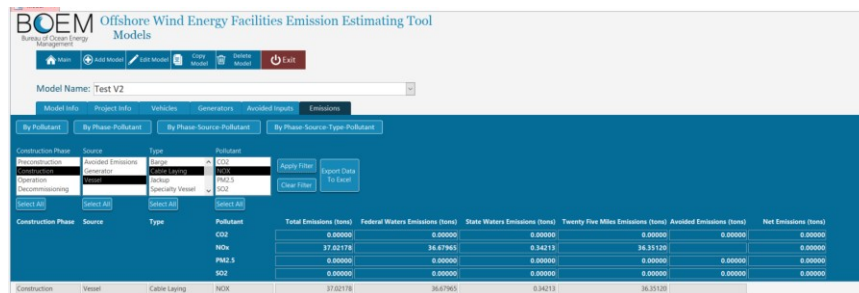
Figure 19. Emissions by specific source, type, phase, or pollutant

Users can also develop scenarios where specific data are excluded in the calculation by unchecking the "Included in Calculations" box in the vessel/helicopter activity tables (Figure 20).

From the emissions screen, the user can also export the results to a Microsoft Excel file (Figure 21).

Figure 20. Vessel activity noting the "Include in Calculations" check boxes
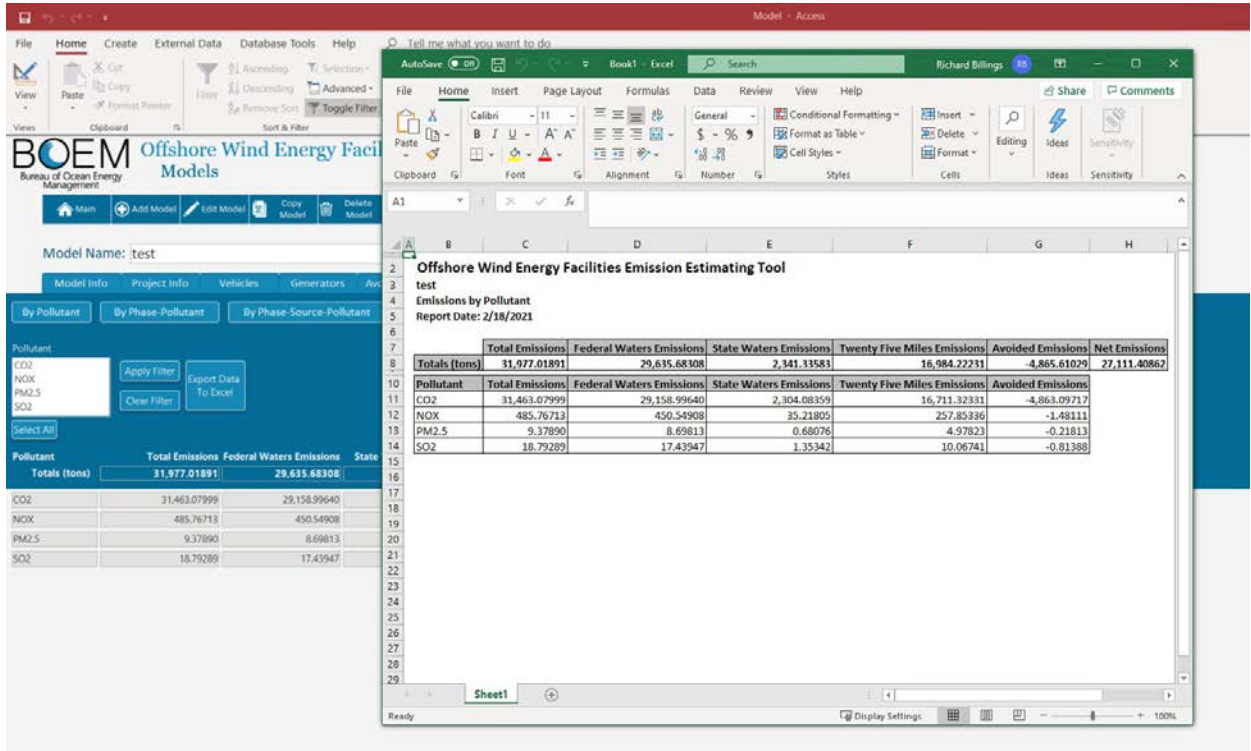
Figure 21. Exporting data to Excel

Appendix A

Technical Data

1.0 INTRODUCTION

1.1 MARINE VESSEL/ENGINES

In all phases of the wind power operation, marine vessels are required to ferry supplies and crew to and from offshore sites. BOEM's Wind Tool allows users to enter information about the fleet of vessels, as well as their anticipated activities. Information was compiled for a "typical" wind power installation to identify the expected marine vessel types that would be needed to support the offshore facilities throughout their useful life. Emergency generators used on offshore substations and wind turbines were also considered in this software tool. Section 3.1 presents the various vessel model defaults by vessel type.

To calculate emissions from marine vessels, the model requires the following data per phase:

- Vessel count
- Propulsion hours per vessel
- Auxiliary hours per vessel

The model calculates propulsion and auxiliary kilowatt-hours (kWh) of operation using the distance, speed, and total number of trips, as well as engine kilowatt (kW) ratings and load factors. Users can select the representative lease block of their project and the port that is providing support; the software includes preloaded route distances based on these selections. Alternatively, if the pulldown does not include the port, users must provide an estimate of the distance from the representative lease block to the port. Note, the software was developed to differentiate the use of different ports by different vessels. Additionally, the user must also provide an estimate of the number of trips by vessel type to generate the required activity (hours of operations). The software assumes that all trips are round trips. Users can use the model's default vessel and engine characteristics, or they can add their own vessel-specific data if known. Vessel emissions are calculated for propulsion and auxiliary engines using the following basic equations:

Main emissions (tons) = vessel count x main engine kW x main engine hours x load factor x emission factor (grams [g]/kWh) x 1.10231E-6 (g to ton)

Auxiliary emissions (tons) = vessel count x auxiliary kW x auxiliary hours x load factor x emission factor (g/kWh) x 1.10231E-6 (g to ton)

Emergency generators used on offshore substations and wind turbines were assumed to be EPA Category 1 engines with a power rating of 150 kW. Activity data required for these engines are annual hours of operation. Section 4 provides additional details about the equations the model uses for calculating emissions.

The model uses the latest EPA emission factors from the *Ports Emissions Inventory Guidance/Methodologies for Estimating Port-Related and Goods Movement Mobile Source Emissions Report* (EPA 420-B-20-046, September 2020). The factors in Table A-1 for carbon dioxide (CO_2), nitrogen oxides (NO_x), fine particulate matter ($PM_{2.5}$), and sulfur dioxide (SO_2) are applied to all marine vessel types and engines (main propulsion engines or auxiliary engines),

assuming that they are EPA Category 2/Tier 1 marine engines. Note that for the SO_2 factors, the model assumes that the auxiliary engines will use the same emission control area compliant fuel as the main propulsion engines. The emission factors for the emergency generators assume that they are Tier 4 engines using regulated nonroad fuel, as they will be part of the new construction.

Table A-1. Diesel Emission Factors

Source	Emission Factors g/kWh			
	CO_2	NO_x	$PM_{2.5}$	SO_2
Marine diesel engine	679.47	10.55	0.2036	0.400
Generator	679.47	1.3	0.0291	0.006246

1.2 HELICOPTER

Four typical support helicopter types were considered (i.e., single engine, twin light, twin medium, and twin heavy). A typical speed was assigned to each helicopter type, which users can adjust to more accurately represent the helicopters they plan to use. Users can use the same representative lease block and port nearest to their airport, or they can provide distance from the representative lease block to the closest support airport. The model assumes that all trips are round trips.

The helicopter speed and distance are used to calculate transit time for each round trip; transit time is multiplied by the number of trips to get total support helicopter hours by helicopter type. These activity data are applied to the compiled helicopter emission factors from the Swiss Federal Office of Civil Aviation, summarized in Table A-2.

Table A-2. Helicopter Emission Factors

Helicopter Type	Fuel Usage (gal/hr)	Emission Factors (lbs./hr)			
		CO_2	NO_x	SO_2	$PM_{2.5}$
Single	45.36	956.92	2.32	0.3	0.0663
Twin light	75.35	1,589.69	3.14	0.5	0.0943
Twin medium	116.59	2,459.92	7.22	0.78	0.198
Twin heavy	314.74	6,640.46	34.66	2.11	0.804

2.0   AVOIDED EMISSIONS

BOEM's Wind Tool estimates the emissions that will be avoided as electricity from new offshore wind farms displaces other sources of electric power generation, including fossil-fuel-fired electric generating units (EGUs). Specifically, this tool estimates the avoided emissions from fossil-fuel-fired EGUs that are most likely to be "turned off" or "turned down" as a result of the additional electricity that the new offshore wind farm contributes to the grid. That is, it characterizes the emissions of the *marginal* EGUs that are most likely to be displaced by a new renewable energy resource that is added to the grid. Marginal EGUs may include power plants that are relatively more expensive or less efficient to run (hence why they are only used when needed, and they are the first to "turn off"), or units that are relatively easy to ramp up and down in quick response to fluctuations of supply and demand. Which EGUs are "at the margin" can

vary by time of day and time of year. The marginal EGUs and their emission rates also vary by region, depending on which fuels dominate the power mix (and specifically the fuels used by non-baseload EGUs) in a given part of the United States. Thus, for a reasonably accurate estimation of emissions displaced by new wind power, it is helpful to use a source that provides region-specific marginal emission factors.

The Wind Tool uses marginal emission factors from EPA's AVERT (www.epa.gov/avert). AVERT is a freely available, open-source, peer-reviewed modeling tool that uses hourly historical generation and emissions data from every large (greater than 25-megawatt [MW]), stationary fossil-fired EGU in the contiguous United States (CONUS) to predict the avoided emissions associated with user-defined energy efficiency and renewable energy scenarios. Because AVERT has hourly source data, it can predict which EGUs are at the margin for each hour of the year. It can also account for hourly variations in the amount of electricity that a particular renewable resource will displace—for example, depending on the region, wind turbines may be more productive at certain times of day and during certain months of the year. This hourly historical approach gives AVERT an advantage over data sources that simply take average annual emission factors for all EGUs or large groups of EGUs in a given region. AVERT estimates avoided emissions of four pollutants: CO_2, NO_x, $PM_{2.5}$, and SO_2.

AVERT's user manual (www.epa.gov/avert/avert-user-manual) provides further documentation of the tool's theoretical basis, underlying data sources, methods, algorithms, and assumptions.

AVERT divides the CONUS into 14 regions for analysis, reflecting current electric grid operations and based on aggregations of one or more balancing authorities. Figure A-1 provides a map of the AVERT regions. While most grid regions import and export some degree of electricity from and to other regions, AVERT makes the important simplifying assumption (for modeling purposes) that an energy efficiency or renewable energy policy, program, or project in a particular region will displace another EGU within that same region. BOEM's tool calculates avoided emissions for the AVERT region where a user-defined offshore wind project will plug into the landside power grid.
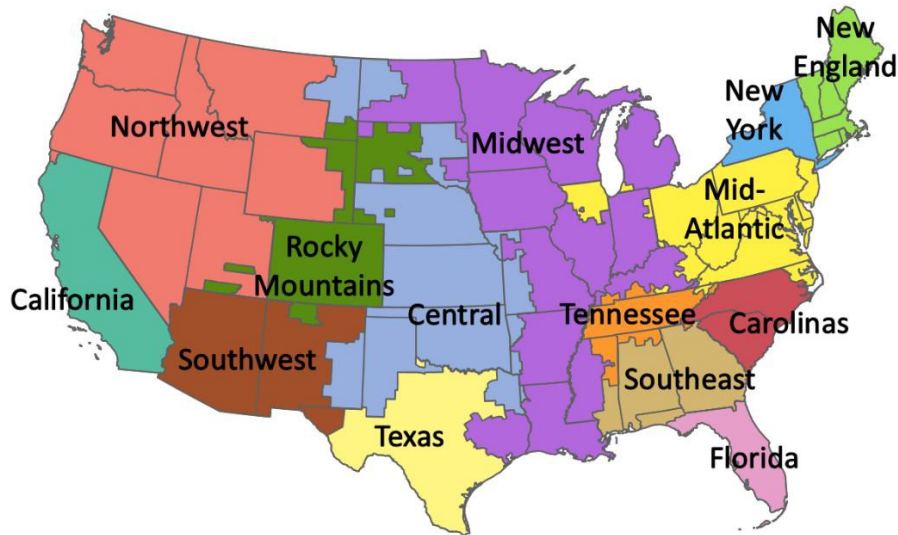
Figure A-1. AVERT regions

AVERT treats each type of energy efficiency and renewable energy resource uniquely, based on resource-specific characteristics. Offshore wind is its own category in AVERT, distinct from onshore wind or other renewables. AVERT incorporates assumptions about typical diurnal and seasonal variations in offshore wind capacity factors (i.e., productivity) to determine how much fossil-fired power will be displaced in each hour of the year. This enables a direct user of AVERT to input a nameplate capacity (e.g., a 250 MW project); AVERT will then determine how much electricity the project will actually produce (and therefore displace from the grid) in each hour of the year. AVERT's capacity factors are derived from BOEM's 2019 modeled hourly offshore wind speed dataset (www.boem.gov/Renewable-Energy-GIS-Data).

BOEM's Wind Tool uses a set of precalculated emission factors that EPA derived from AVERT. EPA publishes these factors for each type of energy efficiency and renewable energy resource (including offshore wind) by AVERT region at www.epa.gov/statelocalenergy/avoided-emission-factors-generated-avert-0. Using precalculated emission factors is more computationally efficient than embedding the full AVERT model into BOEM's tool and performing a custom run of AVERT for each user scenario. Moreover, it still has the benefit of providing numbers that were generated using AVERT's hourly algorithm—just rolled up into a convenient factor that represents marginal emission characteristics averaged over the entire year. EPA calculated these emission factors by assuming an average displacement of 0.5 percent of the existing demand in each AVERT region, though EPA has noted through sensitivity analyses that changing the default displacement level within a few percentage points does not appreciably change the resulting factors.

Table A-3 shows the specific AVERT offshore wind factors used in BOEM's Wind Tool. Key characteristics and considerations include the following:

- **Vintage:** BOEM's tool uses AVERT's 2019 emission factors, which are based on the generation patterns and emission characteristics of the electric power grid during calendar year 2019. That was the most recent year of data available at the time of this update. These factors came from AVERT version 3.0. AVERT does not predict how

the grid might change in the future (e.g., due to changing fuel costs, environmental regulations, or scheduled plant retirements), so it is understood that any application that uses AVERT emission factors will calculate displaced emissions with respect to the current power grid, not the composition or operation of the grid at some time far into the future.

- **Units of measure:** Emission factors are presented in pounds of each pollutant per megawatt-hour (MWh) of fossil-fired electricity displaced—not per MW of offshore wind nameplate capacity added to the grid. This means that assumptions about offshore wind capacity factors are *not* embedded directly into the emission factors. (Capacity factors were naturally factored in when EPA ran AVERT to generate the emission factors, but only to the extent that they helped establish the diurnal and seasonal patterns that allowed AVERT to calculate annual emission factors underlaid by hourly precision.) This means that a user of BOEM's tool must provide information about the actual amount of energy they expect their project to deliver to the grid—not just the nameplate generation capacity (i.e., rated power) of the devices they plan to install.

- **Line loss and parasitic load:** AVERT accounts for transmission and distribution line loss and parasitic load (additional electricity generated by an EGU and consumed on site) in its avoided emissions calculations, using data sources and methods described in the AVERT user manual cited above. With respect to where line loss occurs, the use of precalculated emission factors in BOEM's Wind Tool reflects the simplifying assumption that total line loss from the wind farm to the customer is roughly equal to line loss between the displaced fossil EGU and the customer. Grid line loss factors used by AVERT and other similar modeling tools are region-wide averages; further precision in line loss calculations is likely impractical. If BOEM tool users know that their wind farm is likely to incur a much larger line loss than the regional grid average—due to factors such as distance and undersea transmission voltage—they could account for this by lowering the user-defined capacity factor to reflect the actual amount of electricity that the project is expected to deliver at the point of connection to the landside grid. This would result in a lower estimate of displaced fossil EGU emissions.

- **Upstream emissions:** The AVERT emission factors are not full life cycle emission factors and thus do not account for activities upstream of power generation, such as fuel extraction and fuel delivery to EGUs. AVERT emission factors are limited to emissions produced at the point of electric power generation.

One challenge in using AVERT's offshore wind factors is that AVERT has 10 grid regions with ocean coastline (of which eight are included in the Atlantic and Gulf of Mexico covered by this version of BOEM's Wind Tool), yet EPA has only published offshore wind avoided emission factors for six of them (California, Carolinas, Mid-Atlantic, New England, New York, and Northwest). The other four regions (Florida, Midwest, Southeast, and Texas) do not have offshore wind factors because they are unable to run offshore wind scenarios in AVERT. This is because those four regions did not have any defined lease blocks or planning areas for offshore wind as of the 2020 release of AVERT version 3.0. AVERT's method for deriving offshore wind

capacity factors—which in turn is what allows AVERT to run and enables avoided emission factors to be generated—limits calculations to "likely offshore wind" areas so as to focus on wind speed data from the areas where offshore wind projects could actually be constructed.

To overcome this limitation, the BOEM tool substitutes EPA's onshore wind avoided emission factors for the four coastal regions that lack offshore wind data. This substitution is appropriate based on empirical observations. In all regions that do have offshore wind emission factors, these factors are identical or very close to the corresponding onshore wind factors. This result aligns with the observation that the biggest driver of the regional emission factors is "how dirty the regional EGU fleet is"—or, more specifically, "how dirty the marginal EGU are." Offshore and onshore wind will have some time-of-day and time-of-year differences, but the shape of the hourly curve is similar enough that it does not make a big difference in the resulting annual avoided emission factors.

A BOEM Wind Tool user must provide an estimate of the quantity of energy that the offshore wind farm will produce. The anticipated wind farm electricity generation is typically quantified in the design phase of the project, accounting for the power rating of the wind turbines and local wind conditions. The tool then applies AVERT emission factors to the user-supplied estimates of energy generation associated with the offshore wind farm to estimate emissions avoided, using the following equation:

$$EO_i = RP \times h \times CF \times EF_{ij}/2,000 \qquad \text{(Equation 1)}$$

Where:
EO_i	= Emissions avoided for pollutant i (tons)
RP	= Rated power (MW)
h	= Total number of hours of project operation
CF	= Capacity factor that accounts for fluctuations in wind speed (unitless)
EF_{ij}	= AVERT emission factor for pollutant i and region j (lbs./MWh)
2,000	= Conversion factor from lbs. to tons

Table A-3. Avoided Emission Factors from AVERT for Atlantic and Gulf of Mexico Offshore Wind

AVERT Region	Emission Factors (lbs./MWh)			
	CO_2	NO_X	$PM_{2.5}$	SO_2
Carolinas	1,537	0.94	0.11	0.58
Florida[*]	988	0.31	0.07	0.20
Mid-Atlantic	1,422	0.68	0.12	1.07
Midwest[*]	1,732	1.17	0.15	1.58
New England	1,023	0.18	0.03	0.08
New York	1,004	0.31	0.05	0.17
Southeast[*]	1,415	0.75	0.08	0.31
Texas[*]	1,199	0.45	0.06	0.63

[*]Onshore wind avoided emission factor substituted for offshore due to the absence of offshore wind-specific data in AVERT.

3.0 MODEL DEFAULTS

The model provides default values for marine vessels and helicopters if users do not have the vessel and helicopter data required to estimate emissions.

3.1 MARINE VESSEL DEFAULTS

Table A-4 summarizes the defaults for marine vessels.

Table A-4. Default Vessel Characteristics

Vessel Type	Default		
	Knots	Main kW	Aux kW
Anchor handling tugs	12.4	5,733	1,237
Barge	20.0	22,424	3,020
Cable laying	12.2	6,658	3,026
Crew	22.1	3,013	201
Dredging	10.9	3,234	964
Ice breaker	15.8	17,844	965
Jack-up	7.0	3,215	895
Research/survey	12.5	2,997	1,363
Shuttle tanker	14.8	17,484	30,769
Supply ship	12.1	3,843	874
Tug	11.5	2,053	238

The model also requires load factors for marine vessels. The default load factors are:

- 0.82 for transit propulsion

- 0.2 for maneuvering propulsion

- 1.00 for auxiliary power

3.2 HELICOPTER DEFAULTS

The model provides default helicopter speeds by helicopter type (Table A-5). Alternatively, users can use specific speeds associated with the helicopters they intend to use in their offshore project.

**Table A-5. Default Helicopter
Speeds by Helicopter Type**

Helicopter Type	Speed (mph)
Single	157.5
Twin light	177
Twin medium	182.6
Twin heavy	188.2

3.3 AVOIDED EMISSION DEFAULTS

For the Wind Tool to calculate the avoided emissions, the user will need to enter the total rated power of the planned offshore energy facility in MW, the forecasted capacity factor as a percentage (in aggregate), and the ZIP code of the location where the offshore wind energy facility will be connected to the shore-based grid.

4.0 CALCULATIONS

The Wind Tool calculates vessel emissions as two separate activities: 1) transit operations to and from the site and 2) onsite working operations, covering the duration that the vessel is on site supporting the construction maintenance or removal activities.

Vessel and helicopter transit emissions are based on the distances to port. To quantify the distance to port, the user can use one of the precalculated distances from a representative lease block of the proposed wind farm to a selection of ports that support offshore wind developments. Note, these distances assume that a vessel maneuvers to the closest shipping lanes and transits known shipping lanes to the port derived from GIS mapping of the routes. Alternatively, if the software does not include the port that the user intends to use, they can enter their estimate of the distance to port directly in the software.

As the tool differentiates emissions that occur in federal and state waters and within 25 nautical miles of the center of the project, the distance that vessels travel in federal waters was defined as the length of the vessel route that occurs outside of the federal/state boundary, while the distance that the vessel travels in state waters was estimated to be the difference between the total length and the distance traveled in federal waters. Note that state boundaries can occur along waterways, so it is left to the user to determine which state that the state emissions should be assigned to. The transit distance within 25 nautical miles was estimated to be the distance from the wind farm's representative lease block to the 25-nautical-mile boundary, as shown in Figure A-2.
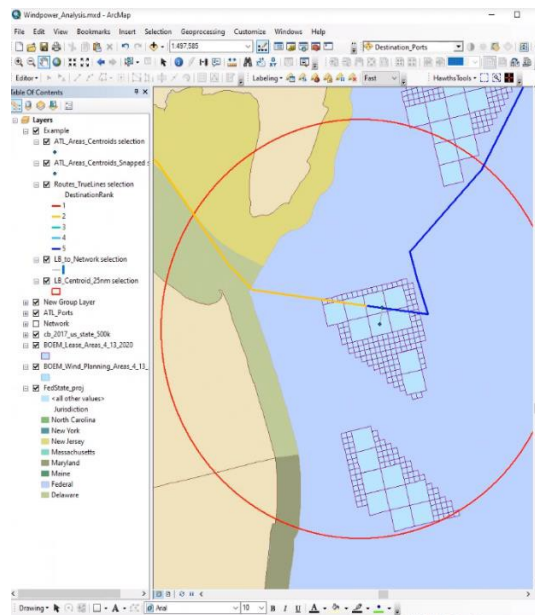

Figure A-2. Example vessel route

4.1 TRANSIT EMISSIONS

Transit emissions were estimated based on the total length in nautical miles between the representative lease block and the port. The time spent in transit is estimated using the following equation:

$$HR_t = \frac{(D*VC*TR*2)}{SP})$$ (Equation 2)

Where:

HR$_t$ = Total hours of transit
D = Distance from the representative lease block to the port
VC = Vessel count
TR = Trips
SP = Vessel speed (knots)

The vessel emissions from propulsion engines during transit for pollutant X are calculated as:

$$V_{Pt,X} = 1.1023E^{-6} \times EF_{Px} \times HR_t \times PR \times LF_{Pt}$$ (Equation 3)

Where:

V$_{Pt,X}$ = Propulsion transit emissions of pollutant X (tons)
EF$_{px}$ = Propulsion emission factor for pollutant X (g/kWh)
HR$_t$ = Total hours of transit between the representative lease block and the port (Equation 2)
PR = Main engine power rating (kW)
LF$_{Pt}$ = Load factor for propulsion engines during transit (default is 0.82)

The vessel emissions from auxiliary engines during transit for pollutant X are calculated as:

$$V_{At,X} = 1.1023E^{-6} \times EF_{Ax} \times HR_t \times APR \times LF_A$$ (Equation 4)

Where:

V$_{At,X}$ = Auxiliary emissions of pollutant X during transit (tons)
EF = Auxiliary emission factor for pollutant X (g/kWh)
HR$_t$ = Total hours of transit between the representative lease block and the port (Equation 2)
APR = Auxiliary engine power rating (kW)
LF$_A$ = Load factor for auxiliary engines during transit (default is 1)

The total transit emissions are then calculated by summing the calculated propulsion engine and auxiliary emissions:

$$Q_{t,X} = V_{At,X} + V_{Pt,X}$$ (Equation 5)

Where:

Q$_{t,X}$ = Total transit emissions tons
$V_{Pt,X}$ = Propulsion transit emissions (tons) (Equation 3)
$V_{At,X}$ = Auxiliary transit emissions (tons) (Equation 4)

For helicopters, emissions are estimated based on the number of hours in transit. The number of hours the helicopter is in transit are calculated as:

$$HR_{H,} = \left(\frac{(HC * HTR * D * 2)}{[HSP]} \right)$$

(Equation 6)

Where:

    HR   = Helicopter hours to and from the representative lease block
    HC   = Helicopter count
    HTR   = Helicopter trips
    D   = Distance from the representative lease block of the project to nearest heliport
              (miles)
    HSP   = Helicopter speed (miles per hour)

Helicopter emissions within 25 nautical miles of the installation are calculated as:

$$Q_H = \frac{EF_{Hx} \times HR_H}{2000 \left(\frac{lb}{ton} \right)}$$

(Equation 7)

Where:

    Q_H = Helicopter emissions (tons)
    EF_{Hx} = Helicopter emission factor for pollutant X (lbs. per hour)
    HR_H = Number of hours helicopter is in transit

4.1.1 Differentiating Federal, State, and Transit Emissions Occurring Within 25 Nautical Miles

The transit emissions in federal and state waters and within 25 nautical miles of the installation are apportioned using the following ratios:

Federal: Distance traveled in federal waters / total travel distance

State: Distance traveled in state waters / total travel distance

Within 25 nautical miles: Distance traveled within the 25-nautical-mile boundary / total travel distance

4.2 ONSITE EMISSIONS

Onsite emissions are calculated separately within the tool. These emissions are combined with the transit emissions to get total vessel emissions.

Hours on site are calculated as:

$$HR_o = (TD \times 24) - HRt$$

(Equation 8)

Where:

    HR_o = Hours on site
    TD   = Total days

24 = Hours per day

$HR_{,t}$ = Hours in transit

Propulsion engine emissions are calculated as:

$$V_{Po,X} = 1.1023E^{-6} \times EF_{Px} \times HR_o \times PR \times LF_{Po} \qquad \text{(Equation 9)}$$

Where:

$V_{Po,X}$ = Total propulsion emissions of pollutant X (tons)

EF_{px} = Propulsion emission factor for pollutant X (g/kWh)

HR_o = Hours on site (Equation 8)

PR = Main engine power rating (kW)

LF_{Po} = Load factor for propulsion engines during onsite maneuvering (default is 0.2)

Vessel emissions from onsite auxiliary engines for pollutant X are calculated as:

$$V_{A,X} = 1.1023E^{-6} \times EF_{Ax} \times HR_o \times APR \times LF_A \qquad \text{(Equation 10)}$$

Where:

$V_{A,X}$ = Auxiliary emissions of pollutant X (tons)

EF = Auxiliary emission factor for pollutant X (g/kWh)

HR_o = Hours of operation on site (Equation 8)

APR = Auxiliary engine power rating (kW)

LF_A = Load factor for auxiliary engines during transit (default is 1)

Total onsite emissions are then calculated as:

$$Q_{t,X} = V_{Ao,X} + V_{Po,X} \qquad \text{(Equation 11)}$$

Where:

$Q_{t,X}$ = Total onsite emissions (tons)

$V_{Po,X}$ = Propulsion emissions on site for pollutant X (Equation 9)

$V_{Ao,X}$ = Auxiliary emissions on site for pollutant X (Equation 10)

As all offshore lease blocks are in federal waters, it is assumed that all onsite emissions are within the 25 -nautical-mile boundary and only in federal waters.