

BOEM Offshore Wind Energy Facilities Emission Estimating Tool Technical Summary

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TECHNICAL SUMMARY

1.0 OVERVIEW

Bureau of Ocean Energy Management (BOEM) developed a software tool to quantify emissions associated with developing (depicted in Figure 1), operating and decommissioning a proposed offshore wind farm, as well as quantifying the fossil fuel combustion emissions that the wind farm's generated energy would replace.

The software tool was developed by first evaluating the vessels needed to perform site characterization, construction, operation, and decommissioning activities. These vessel data along with U.S. Environmental Protection Agency (USEPA) emission factors were compiled into an Excel workbook (noted as red boxes in Figure 2). Next, an Excel workbook was developed that estimates fossil fuel emissions avoided by using wind power; noted as green boxes in Figure 2. To quantify net emission reductions from offshore power generation, the data from these two components are merged in the software tool retaining the input data fields and calculations. Output from the offshore vessels and helicopters were subtracted from the avoided emissions to get the net emissions for the project. Details related to these calculations are presented in the Technical Documentation. Additionally, a user's guide has been developed, providing step-by-step instructions on how to enter data into the software and generate output. An overview of the emission estimation approach for these two components are summarized below.

2.0 OFFSHORE WIND ENERGY EMISSIONS

To estimate emissions associated with offshore wind farms, an approach was developed that quantifies marine vessel, emergency generator, and helicopter emissions associated with the site assessment, construction, maintenance, and decommissioning of an offshore wind farm. The data were compiled to allow users to calculate emissions for vessel and helicopter operations of carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), CO₂ equivalents (CO₂e), black carbon, carbon monoxide (CO), nitrogen oxides (NO_x), particulate matter (PM₁₀ and PM_{2.5}), sulfur dioxide (SO₂), and volatile organic compounds (VOC).

2.1 Marine Engines

To estimate these emissions, a default fleet profile was developed that defines the type and range of vessel sizes typically used for preconstruction, construction, operation and maintenance, and decommissioning activities. A separate profile was developed for each activity phase and compiled into an Excel workbook.



Figure 1. Installation of Shaft, Turbine, and Blades. Source:

<https://www.offshorewind.biz/2015/07/06/royal-haskoningdhv-team-studies-ow-financing-side/>

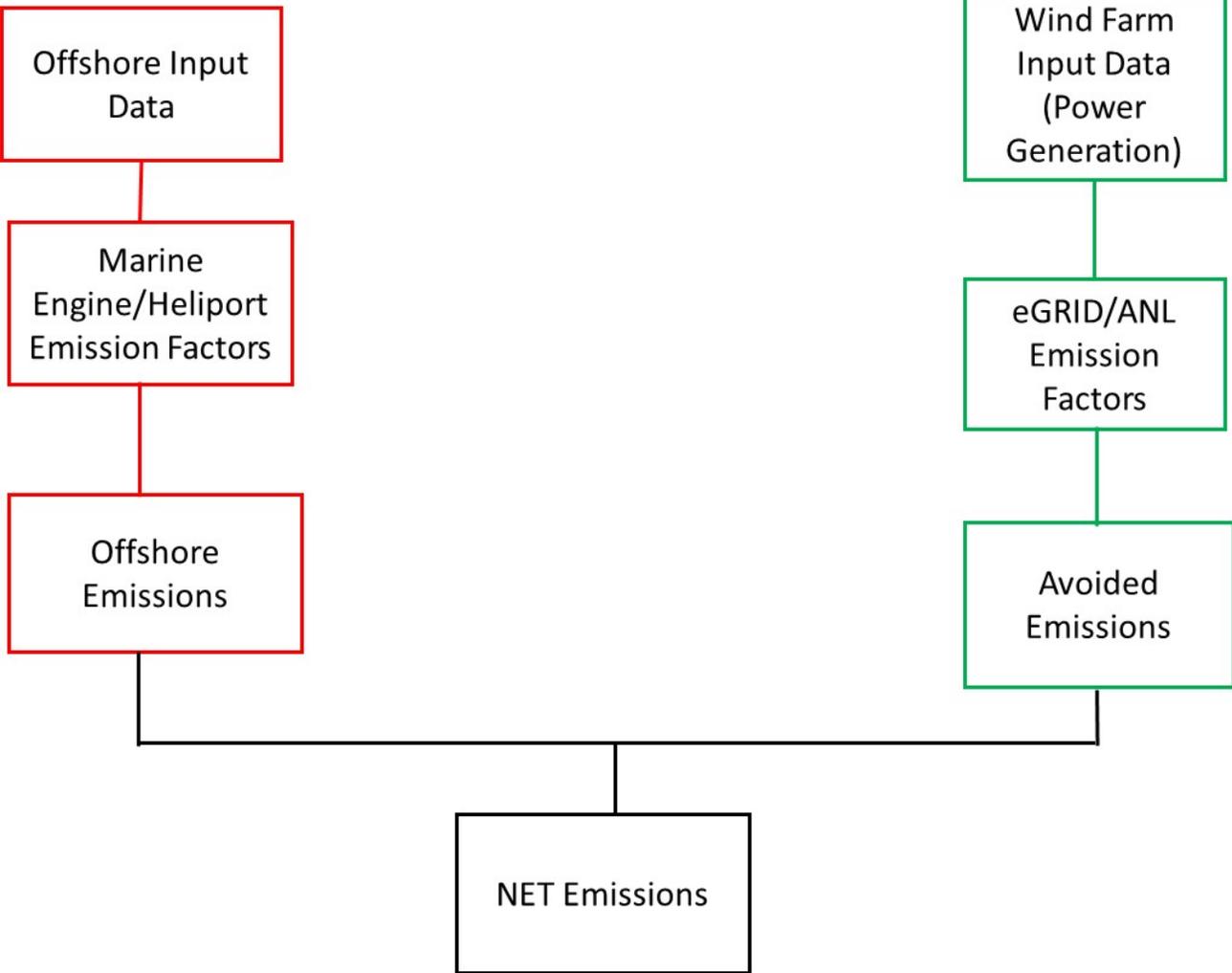


Figure 2. Offshore and Avoided Emission Data Compilation

The vessel characteristics data were compiled from IHS’s Register of Ships dataset for each vessel type included in each of the fleet profiles. The compiled vessel characteristics include:

- Propulsion engine power rating.
- Auxiliary engine power rating.
- Engine speed (i.e.; slow, medium, high speed).
- Cylinder diameter and stroke length to calculate USEPA engine category.
- Year of manufacture.
- Country of registration.
- Design speed.
- Gross registered and deadweight tonnage.
- Length.



Figure 3. Offshore Power Substation. Source: <https://www.jandenul.com/en/activities/offshore-services/offshore-wind-farms>

The compiled vessel characteristics data were aggregated by vessel type and USEPA engine category, domestic or foreign registration, engine speed, and year of manufacture to match the engines to current USEPA emission factors used in the USEPA 2014 National Emissions Inventory.

These data were used to develop appropriate vessel characteristics and emission factors for the vessels included in each fleet profile for each activity phase. These data were also used to develop the default vessel attributes that can be used if the user of the tool does not have vessel-specific data. If the user knows details of the vessels proposed for the project, the software is set up to accept user-provided data.

Emergency generators used on offshore substations (shown in Figure 3) and wind turbines were assumed to be Category 1 or 2 engines with a power rating of 150 kW.

To estimate emissions for all marine diesel engines, the software applies hours of operation provided by the user to the engine power ratings and load factors provided in the vessel fleet profile using the following equation:

$$E_{ab} = AH_{ab} \times kW_{ab} \times LF_{ab} \times EF/100 \times CF$$

Where:

- | | | |
|-----------|---|--|
| E_{ab} | = | Emissions for vessel type <i>a</i> and engine type <i>b</i> (tons) |
| AH_{ab} | = | Annual hours for vessel type <i>a</i> and engine type <i>b</i> |
| kW_{ab} | = | kW rating for vessel type <i>a</i> and engine type <i>b</i> |
| LF_{ab} | = | Engine load factor for vessel type <i>a</i> and engine type <i>b</i> (%) |
| EF | = | Emission factor for engine Category and Tier (g/kW-hr) |

- CF = Conversion factor ($g = 1.10231 \text{ E-6 ton}$)
- a = Vessel type (e.g., tug, support vessel, survey vessel)
- b = Engine type (e.g., main, auxiliary, or emergency generator)

2.2 Helicopters

For support helicopters, four typical 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. The user must estimate the distance to the closest support airport as well as the number of round trips anticipated for each phase of the project. The helicopter speed and distance to the local airport are used to calculate transit time for each round trip; transit time is multiplied by the number of trips provided by the user to yield total support helicopter hours by helicopter type. These activity data are then applied to the helicopter emission factors obtained from the Swiss Federal Office of Civil Aviation, which has the most complete data set of helicopter attributes.

3.0 AVOIDED EMISSIONS

The second element of this emission estimating tool quantifies the conventional power generation that offshore wind farms could replace, along with the associated avoided greenhouse gas (GHG) and criteria pollutant emissions. This will require the user to provide an estimate of the quantity of energy that the offshore wind farm is designed to generate. The anticipated wind power generation is typically quantified in the design phase of the project, accounting for the power rating of the wind turbines and local wind conditions.

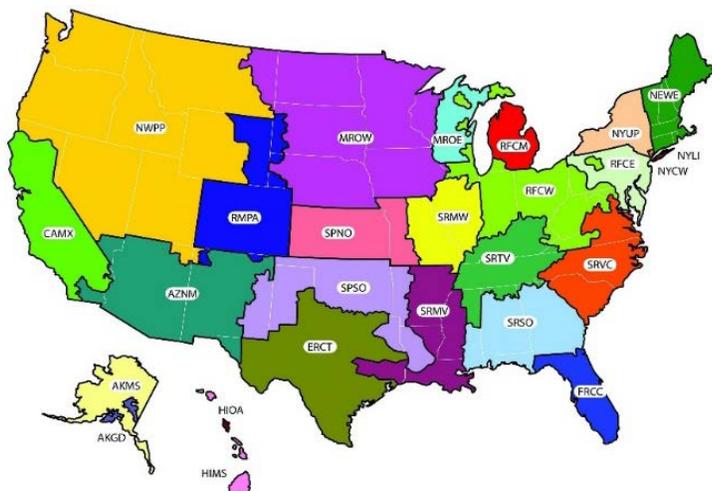


Figure 4. eGRID Subregions. Source: https://www.epa.gov/sites/production/files/2015-10/documents/egrid2012_summarytables_0.pdf

Estimating the amount of energy that is avoided by using electricity generated from the offshore wind farm requires accounting for the regional mix of energy sources used to generate grid-connected electric energy in the portion of the U.S. electric grid served by the planned offshore wind farm. The USEPA's Emissions & Generation Resource Integrated Database (eGRID) is a comprehensive database detailing emissions from electricity generating units in the United States.¹ The eGRID database includes emission factors in terms of energy usage accounting for regional mix of energy sources. Supplemental emission factors were obtained from

Argonne National Laboratory GREET project to gap fill pollutants not reported in the e-GRID system. The Figure 4 shows the eGRID/subregions.

¹ USEPA e-GRID web page <https://www.epa.gov/energy/egrid>.

The eGRID/ANL data are applied to the user supplied estimates of energy generation associated with the offshore wind farm to estimate emissions avoided, using the following equation:

$$EO_j = GP/1,000,000 \times EF_{ij}/2,000$$

Where:

EO_i	= Annual emissions avoided for pollutant i (tons)
GP	= Anticipated annual power generation (terawatt-hrs)
1,000,000	= Conversion from terawatt-hrs to megawatt-hrs
EF_{ij}	= Emission factor for pollutant i and region j (lbs/megawatt)
2,000	= Conversion factor lbs to tons

4.0 COMPILED SOFTWARE

To develop the software tool that combines the offshore vessel/helicopter activity and emissions data with the avoided emissions data to calculate the potential net emissions reduction (i.e., avoided emissions minus the vessel/helicopter emissions), an Access database was developed. Access provides a clean interface, streamlined method for calculation, simplified quality checks, and flexibility to update default profiles or add additional calculation methods, with little effort.

The tool is designed with an initial screen to allow users to start a new project or return to a previously entered project. While each option opens a separate series of windows for data entry or edits, the screens have similar features and options to make the user experience consistent. The first screens guide the user through the step of entering information to identify and define the scope of the proposed wind energy project. In the next phase, the user can either import offshore equipment information or manually enter data via buttons on the “Inputs” tab.

For data importation, users can populate the `facility_input_template` included in the template folder located in the software zip file. This template provides the input data structure associated with the software’s import function. The import button opens a window to browse to the file location, similar to opening a new file in any Windows program. Once the input file has been selected, the data can be automatically incorporated into the software. After all of the data are entered (either manually or as an input file), the user can review and edit the offshore data within the software.

Because the avoided emissions input data is relatively small it can only be entered through a screen on the Inputs tab.

Once all the inputs are entered, the program automatically moves to the “Calculation” tab. This tab contains a summary of which phases have had activity data entered. This allows the users to verify the data are complete prior to executing the calculations. Once satisfied with the inputs, the user clicks the “Calculate” button to start the calculations. The tool features a pop-up window to notify the user that the calculations are complete and to move on to the “Final” tab.

The tab for the final step gives the user the option to review a summary of the calculated emissions and a button to export the data. The user can use the emissions data summary as a preliminary quality check. The export file contains several tabs, including emission summaries

by phase, location, and equipment type as well as a summary of the inputs and emission factors used in calculations.

For more details concerning the steps needed to run the software, a separate user's guide is provided. Additionally, for more information about how the emissions are calculated and the original data files used in the software, a technical document is also provided.