NETL Life Cycle Inventory Data
Process Documentation File

Process Name: Ocean Freighter Transport

Reference Flow: 1 pcs of water carrier transport

Brief Description: Transport of wind turbine components a distance of 15,000 km on a water carrier with a 20,000 tonne cargo capacity.

Section I: Meta Data

Geographical Coverage: US **Region:** N/A

Year Data Best Represents: 2014

Process Type: Transport Process (TP)

Process Scope: Gate-to-Gate Process (GG)

Allocation Applied: No

Completeness: All Relevant Flows Recorded

Flows Aggregated in Data Set:

☒ Process ☒ Energy Use ☐ Energy P&D ☐ Material P&D

Relevant Output Flows Included in Data Set:

Releases to Air:	☒ Greenhouse Gases	☒ Criteria Air Pollutants	☒ Other
Releases to Water:	☐ Inorganic Emissions	☐ Organic Emissions	☐ Other
Water Usage:	☐ Water Consumption	☐ Water Demand (throughput)	
Releases to Soil:	☐ Inorganic Releases	☐ Organic Releases	☐ Other

Adjustable Process Parameters:

Distance	*Round trip distance, in km*
Payload	*Mass of transported payload, in kg*
Diesel energy content	*Heating value of diesel, in MJ/liter of diesel*
Freighter power demand	*Diesel consumed by water carrier per kg-km of transport*

Tracked Input Flows:

Diesel [Crude oil products]	*Diesel from crude oil, for consumption during cargo transport (kg)*
Cargo [Other]	*Wind component input for transport (pcs)*

Tracked Output Flows:

Wind component, transported [Other]	*Reference flow (pcs)*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage2_O_Ocean_Freighter_Transport _2010.01.xls*, which provides additional details regarding relevant calculations, data quality, and references.

Goal and Scope

The scope of this unit process covers the round trip ocean freighter transportation of wind turbine components from the completion of foreign manufacturing processes to the U.S. port of entry. This unit process is contained within LC Stage #3 of the Wind Power LCA. This unit process is based on the reference flow of 1 piece of wind turbine component, as shown in **Figure 1**. Considered are the consumption of diesel and the resulting emissions from diesel combustion. An assumption is made that the cargo being transported will not have any emissions (i.e. fugitive dust particles) lost during transport.

Boundary and Description

Operational data for the ocean freighter is compiled from several sources, creating an emissions profile for criteria air pollutants and other pollutants of interest. The unit process is designed to transport a single wind turbine component of adjustable mass an adjustable distance. This unit process assumes that the component is loaded into the ocean freighter during a previous unit process. This unit process transports the component from one location to another.

Figure 1 provides an overview of the boundary of this unit process. As shown, upstream emissions associated with the production of diesel fuel, construction of an ocean vessel, and manufacture of wind turbine components are accounted for outside of the boundary of this unit process.

The user has the ability to vary certain parameters to tailor the dataset to fit the diesel production profile used. The parameters listed in the Adjustable Process Parameter section are the primary differentiators between diesel analyses. All of these adjustable

parameters help to determine the amount of diesel needed for transportation. These include the energy content of the diesel, the power demand of the ocean freighter, the roundtrip transport distance, and the mass of the transported payload (wind turbine component). The default values for these parameters are, respectively, 39 MJ/L, 1e-4 MJ/kg-km, 15,000 km, and 1.5e8 kg. These parameters may be varied based on updated information, or the specific values needed for a given investigation.

All emission factors for diesel combustion are provided in **Table 1**. It is assumed that the ocean freighter will be operating around or after the year 2014, and will therefore be in compliance with the US Environmental Protection Agency's (EPA) Tier 4 emissions standards, which will become effective in 2015. The Tier 4 standards include regulations for NO_X, PM, VOCs, and CO (US Federal Register 2008). Emission factors for CO_2, CH_4, and N_2O were taken from the documentation for the US Energy Information Administration's (EIA) form for the voluntary reporting of greenhouse gases (DOE 2006). Stiochiometric conversions determined the SO_2 emissions from diesel combustion. It was assumed that all sulfur contained in the diesel fuel would be converted to SO_2.

Figure 1. Unit Process Flow Diagram

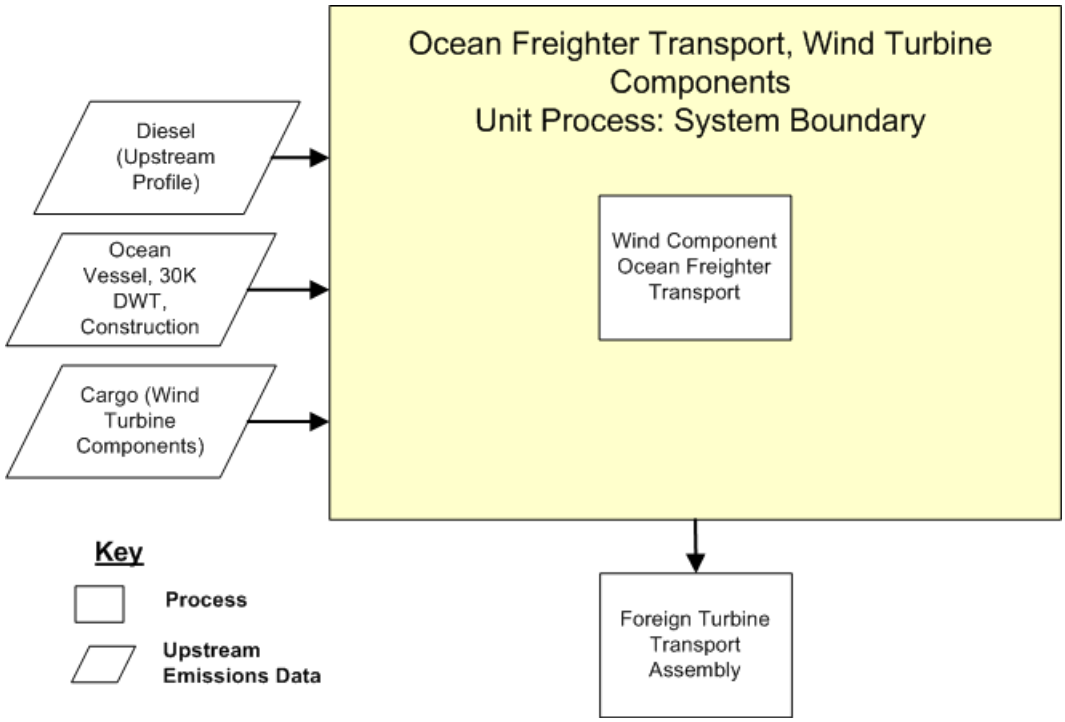

Table 1. Emission Factors for Ocean Freighter Transport

Emission	Value	Units (per kg cargo transported)	Reference
Carbon Dioxide	5.3666E-05 (1.1831E-04)	kg (lbs)	DOE 2006

Methane	1.9192E-06 (4.2312E-06)	kg (lbs)	DOE 2006
Nitrous Oxide	6.2375E-07 (1.3751E-06)	kg (lbs)	DOE 2006
Sulphur Oxide	1.1222E-09 (2.4741E-09)	kg (lbs)	NETL Engineering Calculation
Nitrogen Oxides	3.1187E-06 (6.8756E-06)	kg (lbs)	US Federal Register 2008
Particulate Matter, unspecified	2.1591E-07 (4.7601E-07)	kg (lbs)	US Federal Register 2008, Connell-Hatch 2008
VOCs, unspecified	3.3586E-07 (7.4045E-07)	kg (lbs)	US Federal Register 2008
Carbon Monoxide	8.8764E-06 (1.9569E-05)	kg (lbs)	US Federal Register 2008
Mercury (+II)	3.1632E-22 (6.9736E-22)	kg (lbs)	Conaway *et al*. 2005
Ammonia	2.6389E-10 (5.8178E-10)	kg (lbs)	Battye *et al*. 1994

Table 2: Unit Process Input and Output Flows

Flow Name*	Value	Units (Per Reference Flow)
Inputs		
Cargo	**1**	**pcs**
Diesel [Crude oil products]	**3.73E06**	**kg**
Outputs		
Wind component, transported	1	pcs
Carbon dioxide [Inorganic emissions to air]	1.20E+07	kg
Methane [Organic emissions to air (group VOC)]	9.45E+02	kg
Nitrous oxide (laughing gas) [Inorganic emissions to air]	3.07E+02	kg
Sulphur oxide [Inorganic emissions to air]	1.12E+02	kg
Nitrogen oxides [Inorganic emissions to air]	3.77E+04	kg
Particulate Matter, unspecified [Other emissions to air]	8.69E+02	kg
VOC (unspecified) [Organic emissions to air (group VOC)]	4.06E+03	kg
Carbon monoxide [Inorganic emissions to air]	4.35E+04	kg
Mercury (+II) [Heavy metals to air]	5.85E-10	kg
Ammonia [Inorganic emissions to air]	4.92E+02	kg

* **Bold face** clarifies that the value shown *does not* include upstream environmental flows.

Embedded Unit Processes

None.

References

Battye *et al*. 1994 — Battye, R., Battye, W., Overcash, C., Fudge, S. 1994. *Development and Selection of Ammonia Emissions*

Factors, Final Report. U.S. Environmental Protection Agency, Washington, D.C. http://www.epa.gov/ttn/chief/old/efdocs/ammonia.pdf (Accessed December 16, 2009).

Conaway *et al*. 2005 — Conaway, C.H., Mason, R.P., Steding, D.J., Flegal, A.R. 2005. "Estimate of mercury emission from gasoline and diesel consumption, San Francisco Bay area, California." *Atmospheric Environment* 39:101-105. http://www.sciencedirect.com/science?_ob=MImg&_imagekey=B6VH3-4DPC3KY-2-1&_cdi=6055&_user=2638189&_orig=search&_coverDate=01%2F01%2F2005&_sk=999609998&view=c&wchp=dGLbVzb-zSkWA&md5=08247b48f4834470afb239b4a93b0efd&ie=/sdarticle.pdf (Accessed December 16, 2009).

DOE 2006 — US DOE. 2006. *Form EIA-1605 Long Form for Voluntary Reporting of Greenhouse Gases: Instructions. Appendix H: Fuel Emissions Factors.* OMB No. 1905-0194. U.S. Department of Energy. March, 2006. http://www.eia.doe.gov/oiaf/1605/excel/Fuel%20Emission%20Factors.xls (Accessed December 16, 2009).

US Federal Register 2008 — National Archives and Records Administration. 2008. "Part IV: Environmental Protection Agency: 40 CFR Parts 9, 85, et al. Control of Emissions of Air Pollution from Locomotive Engines and Marine Compression-Ignition Engines Less Than 30 Liters per Cylinder, Republication, Final Rule." National Records and Archives Administration, Washington, D.C. *Federal Register* 73(126). June 30, 2008. http://www.epa.gov/fedrgstr/EPA-AIR/2008/June/Day-30/a7999a.pdf (Accessed December 16, 2009).

Section III: Document Control Information

Date Created: June 11, 2010

Point of Contact: Timothy Skone (NETL), Timothy.Skone@NETL.DOE.GOV

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