NETL Life Cycle Inventory Data
Process Documentation File

Process Name: Horizontal Wind Turbine Farm, 1.5-6MW, Operation

Reference Flow: 1 MWh of Electricity

Brief Description: This unit process models the input flows and emissions required for operation of a wind farm, having variable total capacity, and based on variable sized wind turbines.

Section I: Meta Data

Geographical Coverage: US **Region:** United States

Year Data Best Represents: 2008

Process Type: Extraction Process (EP)

Process Scope: Cradle-to-Gate Process (CG)

Allocation Applied: No

Completeness: Individual Relevant Flows Captured

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:

WturbineCap	*Adjustable parameter. Enter capacity of a single turbine in the wind farm*
FarmCap	*Adjustable parameter. Enter total capacity of the entire wind farm, including all turbines. Maximum capacity is 200 MW*
CapFac	*Adjustable parameter. Enter the capacity factor for the wind farm. Default value is 30%*
ParasitLoad	*Power consumption of a wind turbine on standby, per MW of capacity*
MaintenanceDist	*Distance traveled per year for on-site maintenance*
Hours_yr	*Number of hours in one year*

DieselConsMi	*Amount of diesel consumed per mile*
Diesel_Density	*Density of diesel*
Repl_Oil	*Amount of oil per MW wind turbine capacity*
Oil_Repl_Freq	*Adjustable parameter; number of times per year that wind turbine oil is replaced*
EF_CO2	[kg CO2/L Diesel] *Emission factor per L of diesel combusted*
EF_CH4	[kg CH4/L Diesel] *Emission factor per L of diesel combusted*
EF_N2O	[kg N2O/L Diesel] *Emission factor per L of diesel combusted*
EF_NOx	[kg NOx/L Diesel] *Emission factor per L of diesel combusted*
EF_SO2	[kg SO2/L Diesel] *Emission factor per L of diesel combusted*
EF_CO	[kg CO/L Diesel] *Emission factor per L of diesel combusted*
EF_NMVOC	[kg NMVOC/L Diesel] *Emission factor per L of diesel combusted*
EF_Dust	[kg Dust/L Diesel] *Emission factor per L of diesel combusted*
EF_Ammonia	[kg Ammonia/L Diesel] *Emission factor per L of diesel combusted*
EF_RoadDust	*Road dust emissions per mile traveled, based on gravel roads and 4-short ton truck weight*
FarmLife	*Life span of a single turbine*

Tracked Input Flows:

Power [Electric power]	*Electricity used for wind farm operations*
Farm Construction [Construction]	*Construction per MWh of electricity produced*
Diesel [Crude oil products]	*Diesel used for wind farm operations*
Lubrication oil	*Lubrication oil used for wind farm operations*

Tracked Output Flows:

Electricity [Electric power]	*Generation of electricity by a multi-megawatt capacity horizontal wind turbine farm*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage3_O_Wind_Farm_Operation_2010.01.xls*, which provides additional details regarding relevant calculations, data quality, and references.

Goal and Scope

The scope of this unit process encompasses the material and energy inputs for the production of a single MWh of electricity by a horizontal wind turbine farm with capacities ranging from 1.5 MW to 6.0 MW. The unit process is based on the reference flow of 1 MWh of electricity. The relevant flows of this unit process are described below and shown in **Figure 1.**

This unit process calculates the number of turbines, parasitic electricity, and maintenance operations for a wind farm. The reference flow of this unit process is 1 MWh of electricity production. The inputs to this unit process include the electricity demands of parasitic power (which is the electricity necessary to keep turbines on standby and to support wind farm control operations), diesel used as fuel for maintenance equipment, lubrication oil used by turbines, and the share of the wind farm construction requirements apportioned to 1 MWh of production (the reference flow). The outputs of this unit process are air emissions due to the combustion of diesel and waste lubricating oil. The reference flow of this unit process is an input to the unit process for electricity transmission and distribution, which occurs in LC Stage #4 of this analysis.

Boundary and Description

This unit process accounts for the maintenance requirements and parasitic power of a wind farm. Adjustable parameters are used to allow scaling of the wind farm according to a chosen turbine size. Specifically, the total wind farm capacity (which has a default value of 200 MW) is divided by the power rating of the turbines (which can range from 1.5 to 6 MW) to determine the number of turbines required for the wind farm.

Based on personal communication with an engineer for a wind farm in the Altamont Pass (California), the parasitic load of a wind farm is 1.6 kW for a 2 MW turbine. A linear relationship between turbine size and parasitic load is assumed, which translates to 0.0008 kW per MW of installed capacity.

A 1.6 MW turbine has 250 liters of gearbox oil (Schaeffer Manufacturing Company 2010); the volume of gearbox oil is assumed to vary linearly with turbine rating. At a specific gravity of 0.88, the mass of gearbox oil is 144 kg/MW. This analysis assumes that the gearbox oil for a wind turbine is changed two times per year.

This analysis assumes that all maintenance vehicles are fueled by diesel and have a fuel economy of 8 miles per gallon. The total distance of onsite maintenance vehicles is assumed to be 1000 miles per year; no information is available for this activity, which is a data limitation. The combustion of diesel produces air emissions, which are calculated in this analysis by applying emission factors to total diesel consumption (DOE 2006). The dust from the use of maintenance vehicles on unpaved roads is assume to be particulate matter (PM10) and is estimated from EPA AP42 emission factors (EPA 2006).

The portion of wind farm construction that is apportion to 1 MWh of electricity generation is the reciprocal of the total MWh produced by the wind farm in its lifetime, which is a function of total installed turbine capacity (MW), capacity factor (30%), and a 30 year life.

Figure 1: Unit Process Scope and Boundary

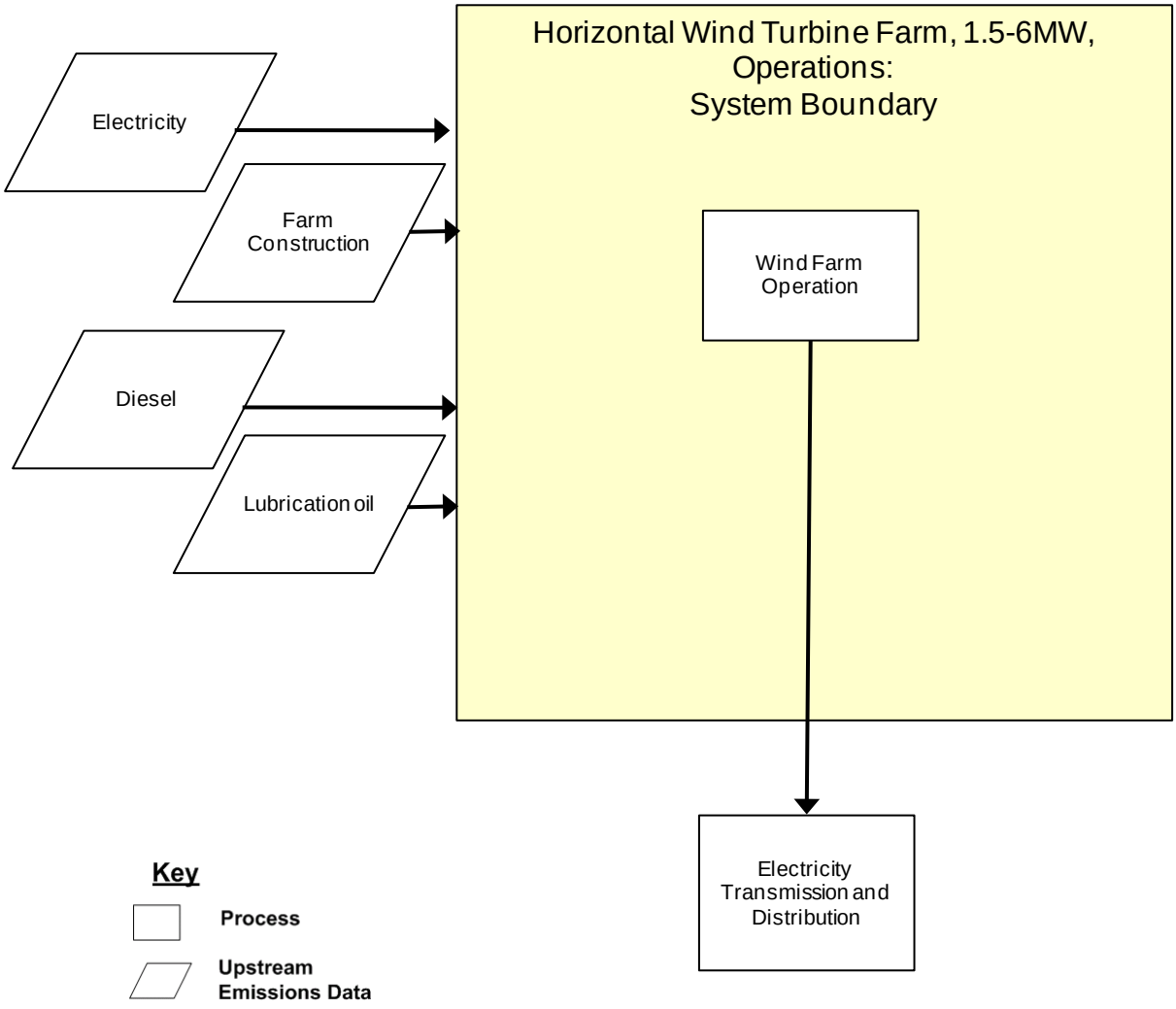

Table 1: Requirements for Wind Farm Operations

Variable	Value	Source
Parasitic electricity	0.0008 kWh/MW	Altamont Pass 2010
Gearbox oil	144 kg/MW	Schaeffer Manufacturing Company 2010
Maintenance vehicle	Fuel economy = 8 miles/gal Annual travel = 1,000 miles	Study assumption

Table 2: Unit Process Input and Output Flows

Flow Name*	Conventional Turbine	Advanced Turbine	Units (Per Reference Flow)
Inputs			
Power [Electric power]	1.87E-03	1.87E-03	MWh
Farm construction [Construction]	2.61E-05	2.61E-05	pcs
Diesel [Crude oil products]	7.59E-04	7.59E-04	kg
Lubrication oil	7.30E-02	7.30E-02	kg
Outputs			
Electricity [Electric power]	1.00	1.00	MWh
Carbon dioxide [Inorganic emissions to air]	2.39E-03	2.39E-03	kg
Methane [Organic emissions to air (group VOC)]	3.42E-07	3.42E-07	kg
Nitrous oxide (laughing gas) [Inorganic emissions to air]	6.18E-08	6.18E-08	kg
Nitrogen oxides [Inorganic emissions to air]	1.08E-06	1.08E-06	kg
Sulphur dioxide [Inorganic emissions to air]	2.27E-08	2.27E-08	kg
Carbon monoxide [Inorganic emissions to air]	1.33E-05	1.33E-05	kg
NMVOC (unspecified) [Group NMVOC to air]	5.04E-07	5.04E-07	kg
Dust (unspecified) [Particles to air]	2.53E-03	2.53E-03	kg
Waste oil	7.30E-02	7.30E-02	kg

* **Bold face** clarifies that the value shown *does not* include upstream environmental flows. Upstream environmental flows were added during the modeling process using GaBi modeling software, as shown in Figure 2.

Embedded Unit Processes

None.

References

Schaeffer 2010 — Schaeffer Manufacturing Company. 2010. *Technical Data: #203SW Wind Turbine Oil ISO 220, 320, 460, and 680.* (Accessed on November 1, 2010 from http://www.schaefferoil.com/datapdf/203SW%20Logo.pdf).

DOE 2006 — US Department of Energy. 2006. *Form EIA-1605 Long Form for Voluntary Reporting of Greenhouse Gases: Instructions. Appendix H: Fuel Emissions Factors*. March, 2006. OMB No. 1905-0194. (Accessed on June 13, 2009 from http://www.eia.doe.gov/oiaf/1605/excel/Fuel%20Emission%20Factors.xls).

EPA 2006 — United States Environmental Protection Agency. 2006. *AP-42: Dust Emissions from Unpaved Roads.* (Accessed on August 25, 2010 from http://www.epa.gov/ttn/chief/ap42/ch13/final/c13s0202.pdf)

Section III: Document Control Information

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