NETL Life Cycle Inventory Data
Process Documentation File

Process Name:	Switchyard Construction
Reference Flow:	1 pcs of switchyard
Brief Description:	The materials used for the construction of a switchyard for a 200 MW wind farm.

Section I: Meta Data

Geographical Coverage:	US	**Region:**	Average
Year Data Best Represents:	2010		
Process Type:	Transport Process (TP)		
Process Scope:	Gate-to-Gate Process (GG)		
Allocation Applied:	No		
Completeness:	All 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:

M_oil	*Mass of oil used for construction of a single transformer; based on linear relationship between turbine rating (MW) and transformer oil (kg).*
M_metal	*Mass of metal used for construction of a single transformer; based on linear relationship between turbine rating (MW) and transformer oil (kg)*
Share_steel	*Percent mass of steel in switchyard equipment.*
Share_Al	*Percent mass of aluminum in switchyard equipment.*
Share_Cu	*Percent mass of copper in switchyard equipment.*
RECYCLE	*Rate at which metals (from end-of-life disposition of switchyard) are recycled.*

Tracked Input Flows:

Kerosene [Crude oil products]	*Mineral oil used for switchyard transformers (kerosene is used as a surrogate for mineral oil)*
Steel cold rolled (St) [Metals]	*Steel used for switchyard construction*
Aluminum [Metals]	*Aluminum used for switchyard construction*
Coppersheet [Metals]	*Copper used for switchyard construction*
Concrete, ready mix, R-5-0 [Concrete_Cement]	*Concrete used for switchyard construction*

Tracked Output Flows:

construction	*Reference flow; 1 piece of a switchyard*
Steel scrap [Waste for recovery]	*Mass of steel scrap that is recovered for recycling during the end-of-life disposition of the switchyard.*
Aluminum scrap [Waste for recovery]	*Mass of aluminum scrap that is recovered for recycling during the end-of-life disposition of the switchyard.*
Copper scrap [Waste for recovery]	*Mass of copper scrap that is recovered for recycling during the end-of-life disposition of the switchyard.*
Unspecified scrap waste [Consumer waste]	*Mass of end-of-life waste that is landfilled*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage3_C_Switchyard_2010.01.xls*, which provides additional details regarding relevant calculations, data quality, and references.

Goal and Scope

This unit process provides a summary of relevant input and output flows associated with the construction of a switchyard for a wind farm. Materials include metals, mineral oil (for transformers), and concrete (for the foundation). Input metals (steel, aluminum, and copper) are recovered during decommissioning of the switchyard based on a parameterized recycling rate. The reference flow of this unit process is the construction of 1 switchyard.

This unit process is combined with other wind farm construction unit processes in the Wind Farm, Construction unit process: DF_Stage3_C_Wind_Farm _2010.01.doc.

Figure 1 provides an overview of the boundary of this unit process. The cradle-to-gate emissions for the production of materials used for switchyard construction (e.g., kerosene, cold rolled steel, aluminum, copper, and concrete) are calculated outside the boundary of this unit process and are based on profiles available within the life cycle inventory (LCI) databases.

Boundary and Description

Wind farms require a switchyard provides an interface between the generated electricity and the trunk line (which leads to the main electricity transmission grid). This unit process accounts for the materials required for the construction of a switchyard.

The total mass of switchyard equipment is assumed to be five times higher than the specifications for a 10 MW substation transformer as shown in a Department of Energy scaling study for wind farms (Shafer 2001). Transformers are not the only type of equipment used by a switchyard, but they are a heavy type of equipment and thus are assumed to represent the majority of total switchyard equipment mass. The total mass of transformers used by a single, 10 MW turbine is 46,500 lbs (Shafer 2001); increase this weight by a factor of five and converting to SI units results in an estimated switchyard mass of 105,000 kg. (This decision to scale a 10 MW substation is an approximation based on professional judgment. A 10 MW substation is not adequate to support a 200 MW wind farm, but it is likely that an economy of scale is realized when designing switchyards for larger systems.)

The mineral oil used by switchyards is also estimated from information in a Department of energy scaling study for wind farms (Shafer 2001). The volume of mineral oil for a transformer used by a 10 MW turbine is 1,600 gallons. When scaled upward by five times (the same scaling factor assumed for the switchyard transformers) and converted to SI units of mass (assuming that mineral oil has a specific gravity of 0.95), the total mass of mineral oil for switchyard construction is 28,800 kg. This analysis assumes that switchyard equipment is well-maintained and there are negligible mineral oil losses during the life of the switchyard. This analysis also assumes that the cradle-to-gate production of kerosene is a reasonable surrogate for the cradle-to-gate production of mineral oil.

This analysis also estimates the mass of metal used by circuit breakers in a wind farm switchyard. The mass of a circuit breaker is 4,785 kg (Mitsubishi Electric Power Products, Date Unknown). This analysis assumes that a switchyard has three circuit breakers (Shafer 2001). This analysis also assumes that the circuit breakers used by wind farms use mineral oil, not SF_6 (sulfur hexafluoride).

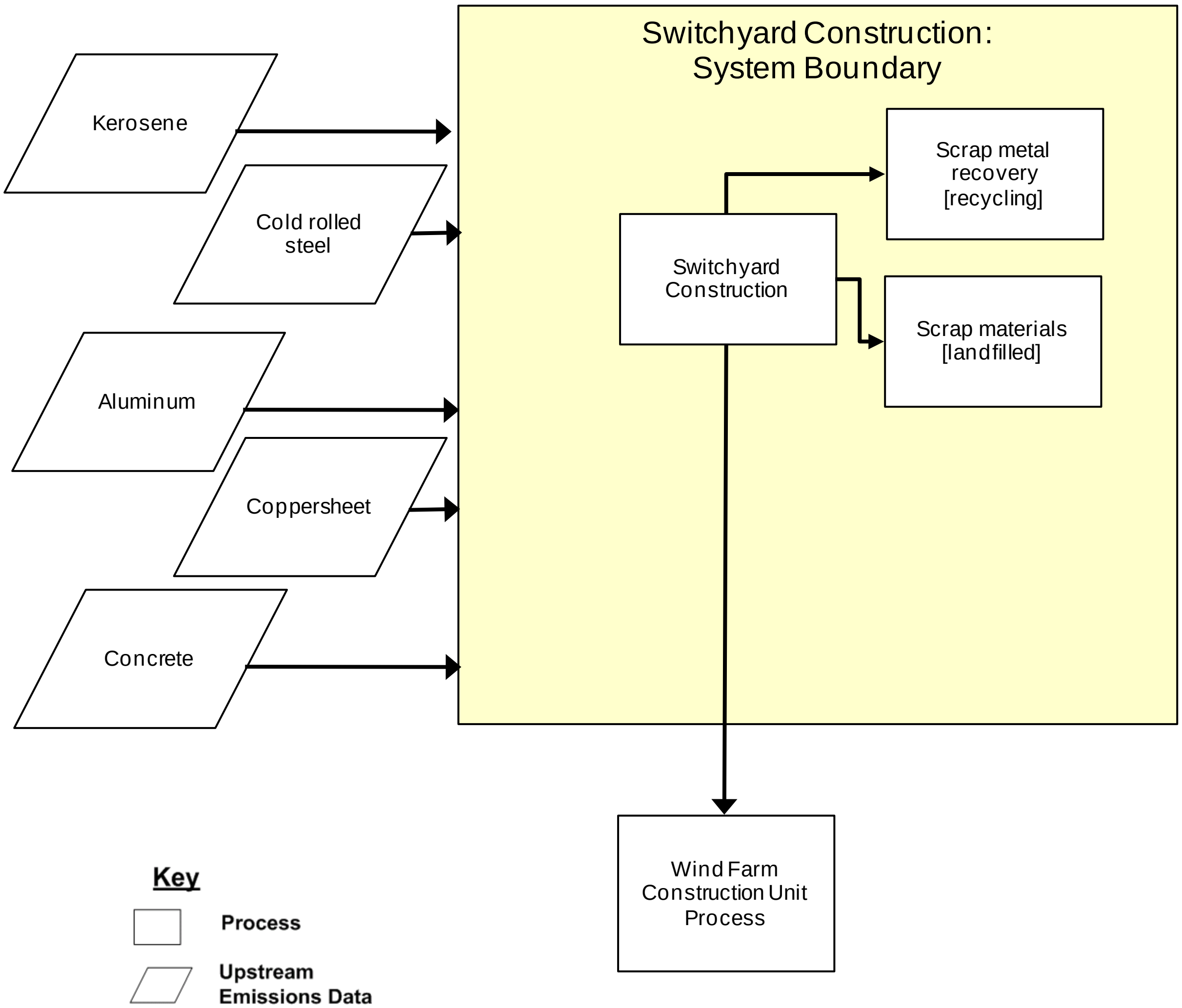
This analysis assumes that steel, aluminum, and copper each account for one third of total mass of metal materials used for switchyard construction. This assumption is parameterized in the unit process to allow sensitivity analysis if necessary.

This unit process assumes that scrap material is generated by the end-of-life disposition of the switchyard. The outputs of this unit process include the mass of metals that are recovered for recycling and the mass of metals that are landfilled. 95 percent of the metal in the switchyard is recovered for recycling and 5 percent is landfilled. The concrete used by the switchyard is not recovered for recycling and is assumed to be landfilled during the end-of-life disposition of the switchyard.

The concrete foundation of the switchyard has an estimated area of 1,000 square meters. Assuming a 0.3 meter thickness and a concrete density of 2,300 kg/m^3, this translates to 690,000 kg of concrete per switchyard.

This unit process is assumed to be representative of a 200 MW wind farm and is not scalable according to the turbine technologies used by the wind farm.

Figure 1: Unit Process Scope and Boundary



The properties of the wind farm switchyard are summarized in **Table 1.** The input and outputs of this unit process are shown in **Table 2.**

Table 1: Switchyard Characteristics

Property	Value	Source
Transformer mass	105,000 kg/switchyard	Shafer 2001; Study assumptions
Mineral oil mass	28,800 kg/switchyard	Shafer 2001; Study assumptions
Circuit breaker mass	14,400 kg/switchyard	Mitsubishi Electric Power Products
Concrete mass	690,000 kg/switchyard	Study assumption

Table 2: Unit Process Input and Output Flows

Flow Name*	Value	Units (Per Reference Flow)
Inputs		
Kerosene [Crude oil products]	2.88E+04	kg
Steel cold rolled (St) [Metals]	3.99E+04	kg
Aluminum [Metals]	3.99E+04	kg
Coppersheet [Metals]	3.99E+04	kg
Concrete, ready mix, R-5-0 [Concrete_Cement]	6.90E+05	kg
Outputs		
construction	1.00	pcs
Steel scrap [Waste for recovery]	3.79E+04	kg
Aluminum scrap [Waste for recovery]	3.79E+04	kg
Copper scrap [Waste for recovery]	3.79E+04	kg
Unspecified scrap waste [Consumer waste]	5.99E+03	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

Mitsubishi Electric Power Products, Inc. SF6 Circuit Breaker, Dead tank Type, Model: 200-SFMT-40SE. http://www.meppi.com/products/powercircuitbreakers/hvgcb/synchronous%20breaker%20brochures/3page200sfmt50se.pdf (Accessed September 1, 2010)

Shafer, D.A.. (2001). WindPACT Turbine Design Scaling Studies: Technical Area 4 -- Balance-of-Station Cost. http://www.nrel.gov/docs/fy01osti/29950.pdf (Accessed September 1, 2010)

Section III: Document Control Information

Date Created: November 1, 2010

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

Revision History:

Original/no revisions

How to Cite This Document: This document should be cited as:

NETL (2010). *NETL Life Cycle Inventory Data – Unit Process: Switchyard Construction.* U.S. Department of Energy, National Energy Technology Laboratory. Last Updated: October 2010 (version 01). www.netl.doe.gov/energy-analyses (http://www.netl.doe.gov/energy-analyses)

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