NETL Life Cycle Inventory Data
Process Documentation File

Process Name: Transformer Construction

Reference Flow: 1 piece (pcs) of transformer, construction

Brief Description: The metal materials and mineral oil used for the construction of a padmount transformer with a rating from 1000 to 7500 kVA.

Section I: Meta Data

Geographical Coverage: US **Region:** Average

Year Data Best Represents: 2010

Process Type: Energy Conversion (EC)

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:

TURBINE_MW	*Turbine power rating (in MW); a range from 0.75 to 5 MW is representative of the source data for this unit process.*
share_steel	*Fraction of total transformer mass that is steel; default value of 0.50 indicates that 50% of transformer mass is steel.*
share_Al	*Fraction of total transformer mass that is aluminum; default value of 0.25 indicates that 50% of transformer mass is aluminum.*
share_Cu	*Fraction of total transformer mass that is copper; default value of 0.25 indicates that 50% of transformer mass is copper.*

RECYCLE	*Rate at which metal scrap is recycled; default value of 0.9 indicates that 90% of transformer manufacturing and transformer end-of-life metal scrap is recycled.*

Tracked Input Flows:

M_oil	*Mineral oil used by transformer*
Steel plate, BF	*Steel plate used for transformer construction; steel is made in a blast furnace (BF)*
Aluminum	*Aluminum used for transformer construction*
Coppersheet	*Copper sheet used for transformer construction*

Tracked Output Flows:

Construction	*Reference flow; construction of a single transformer to be used by a wind turbine*
Steel scrap [Waste for recovery]	*Mass of steel scrap that is recovered for recycling*
Aluminum scrap [Waste for recovery]	*Mass of aluminum scrap that is recovered for recycling*
Copper scrap [Waste for recovery]	*Mass of copper scrap that is recovered for recycling*
Unspecified scrap waste [Consumer waste]	*Mass of manufacturing 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_Transformer_Construction_2010.01.xls*, which provides additional details regarding relevant calculations, data quality, and references.

Goal and Scope

The scope of this unit process provides a summary of relevant materials used for the construction of a transformer with a rating of 1000 to 7500 kVA. The data are representative of a padmount transformer used for a wind turbine. A linear relationship between transformer construction materials and transformer rating is applied in order to scale material requirements to wind turbine rating (0.75 to 5 MW).

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 transformer construction (e.g., cold rolled steel) 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 transformer at the base of each wind turbine, known as a padmount transformer. Padmount transformers step up the voltage of the electricity generated by wind turbines and allow the distribution of the electricity to the central switchyard of the wind farm.

This analysis assumes that steel accounts for 50 percent, aluminum accounts for 25 percent, and copper accounts for 25 percent of the total mass of transformer metals. The total mass of metals used for the construction of a transformer used by a 0.75 MW wind turbine is 4,580 kg; the mass of a transformer used by a 2.5 MW turbine is 8,550 kg; the mass of a transformer used by a 5 MW wind turbine is 19,000 kg (Shafer 2001). The relationship between wind turbine rating (MW) and transformer mass (kg) is described by the following linear equation:

Transformer mass (kg) = 3,450 x Turbine rating (MW) + 1230

In addition to metals used for the construction of padmount transformers, mineral oil is also necessary. The total mass of mineral oil used by a 0.75 MW wind turbine is 1,730 kg; the total mass of mineral oil used by a 2.5 MW wind turbine is 2,730 kg; the mass of mineral oil used by a 5 MW wind turbine is 5,680 kg (Shafer 2001). This analysis uses kerosene as a surrogate for mineral oil. The relationship between wind turbine rating (MW) and the mass (kg) of mineral oil used by a transformer is described by the following linear equation:

Mineral oil mass (kg) = 948 x Turbine rating (MW) + 774

This unit process assumes that scrap material is generated by the end-of-life disposition of the transformer. The outputs of this unit process include the mass of metals that are recovered for recycling and the mass of metals that are landfilled. 90 percent of the metal in the transformer is recovered for recycling and 10 percent is landfilled (Nalukowe *et al* 2006).

Figure 1: Unit Process Scope and Boundary

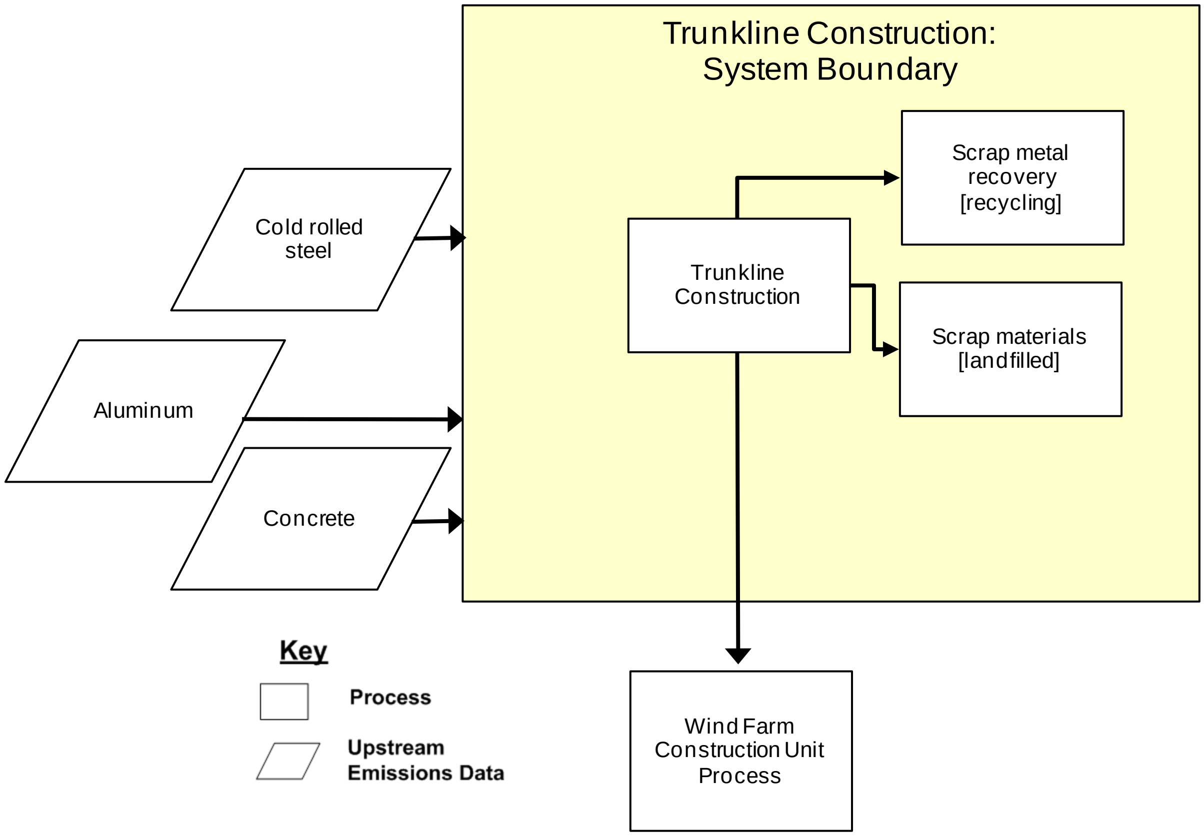

Table 1: Transformer Characteristics

Component	Value	Source
Transformer mass scaling equation: Metals	*Transformer mass (kg) = 3,450 x Turbine rating (MW) + 1230*	Shafer 2001
Transformer mass scaling equation: Mineral Oil	*Mineral oil mass (kg) = 948 x Turbine rating (MW) + 774*	Shafer 2001
Steel percent mass	50%	Study assumption
Aluminum percent mass	25%	Study assumption
Copper percent mass	25%	Study assumption

Table 2: Unit Process Input and Output Flows

Flow Name*	Conventional Turbine	Advanced Turbine	Units (Per Reference Flow)
Inputs			
Kerosene [Crude oil products]	2,196	6,462	kg
Steel plate, BF (85% Recovery Rate) [Metals]	3,203	10,965	kg
Aluminum [Metals]	1,601	5,483	kg
Coppersheet [Metals]	1,601	5,483	kg
Outputs			
transformer [construction]	1	1	pcs
Steel scrap [Waste for recovery]	3,042	10,417	kg
Aluminum scrap [Waste for recovery]	1,521	5,208	kg
Copper scrap [Waste for recovery]	1,521	5,208	kg
Unspecified scrap waste [Consumer waste]	320	1,097	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

Nalukowe *et al*. 2006	Nalukowe, B.B. Liu, J. Damien, W. Lukawski, T. 2006. *Life Cycle Assessment of a Wind Turbine*. May 22, 2006.
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 August 26, 2010)

Section III: Document Control Information

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