NETL Life Cycle Inventory Data
Process Documentation File

Process Name: Horizontal Turbine Generator, 1.5-6 MW, Manufacturing

Reference Flow: 1 piece (pcs) of Horizontal Turbine Generator, 1.5-6 MW

Brief Description: This unit process tracks materials and energy needed to manufacture high-speed and medium-speed permanent-magnet generators for horizontal 1.5 to 6 MW wind turbines, and manufacturing of direct drive with negligible amounts of other materials.

Section I: Meta Data

Geographical Coverage: US **Region:** Average

Year Data Best Represents: 2010

Process Type: Manufacturing Process (MP)

Process Scope: Gate-to-Gate (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:

HT_CPTY	*Machine power rating*
GEN_STEEL	*Percentage of stainless steel material used to manufacture one piece of generator*
GEN_CPPR	*Percentage of copper used to manufacture one new piece of generator*
MNU_WASTE	*Percentage of manufacturing waste in this process*
STL_RECPER	*Percentage of steel scraps recovery*
CU_RECPER	*Percentage of copper scraps recovery*

MJ_KG	*Required energy (electricity) to manufacture one piece of generator & direct drive of the turbine*
Draft_Amt	*Mass of steel required to manufacture one piece of Direct Drive*

Tracked Input Flows:

Steel cold rolled [Metals]	*Steel used for generator manufacture*
Copper parts [Metal parts]	*Copper used for generator manufacture*
Silicate [Minerals]	*Silicate used for generator manufacture*
Power [Electric power]	*Electricity used for generator manufacture*

Tracked Output Flows:

Generator [Manufacturing]	*Manufacturing of a single generator supporting multi-megawatt capacity horizontal wind turbines*
Unspecified scrap waste [Consumer waste]	*Mass of manufacturing waste that is landfilled*
Scrap waste [Waste for recovery]	*Mass of manufacturing waste that is recovered for recycling*
Copper scrap [Waste for recovery]	*Mass of copper waste that is recovered for recycling*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage3_M_HTurbine_Generator_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 manufacture a single generator for horizontal wind turbines, with capacities ranging from 1.5 MW to 6.0 MW. The unit process is based on the reference flow of 1 pcs of generator. The relevant flows of this unit process are described below and shown in **Figure 1.**

This unit process is combined with other wind turbine component unit processes in an assembly unit process for a single horizontal wind turbine:

DF_Stage3_M_Assembly_Turbine_2010.01.doc. The assembly unit process quantifies the number of each wind turbine components required to assemble a single horizontal wind turbine.

Boundary and Description

The mass relationships between turbine capacity and turbine components are based on equations developed using a wind turbine scaling model (NREL 2006). The conventional components are representative of 2002 technologies, while the advanced components represent pending designs. The equations for estimating conventional and advanced generator mass are shown in **Table 1**.

The types of materials used for generator manufacture are based on estimated material profiles for wind turbine components (NREL 2006). The generator is assumed to be manufactured from 3 percent stainless steel, 65 percent copper, and 32 percent silica (Martinez *et al.* 2009). The direct drive component is assumed to be made entirely of stainless steel (Martinez *et al.* 2009). The percentages for estimating the material compositions of conventional and advanced generators are shown in **Table 1**.

This unit process assumes that scrap material is generated by the manufacturing process at a rate of one percent of the weight of the finished generator. Of this manufacturing scrap, 90 percent of the steel and copper materials are recovered for recycling and 10 percent is landfilled (Nalukowe *et al* 2006).

Figure 1 provides an overview of the boundary of this unit process. The cradle-to-gate emissions for the production of materials used for generator manufacture (e.g., copper, silica, and steel) are calculated outside the boundary of this unit process and are based on profiles available in separate life cycle inventory (LCI) databases.

Figure 1: Unit Process Scope and Boundary

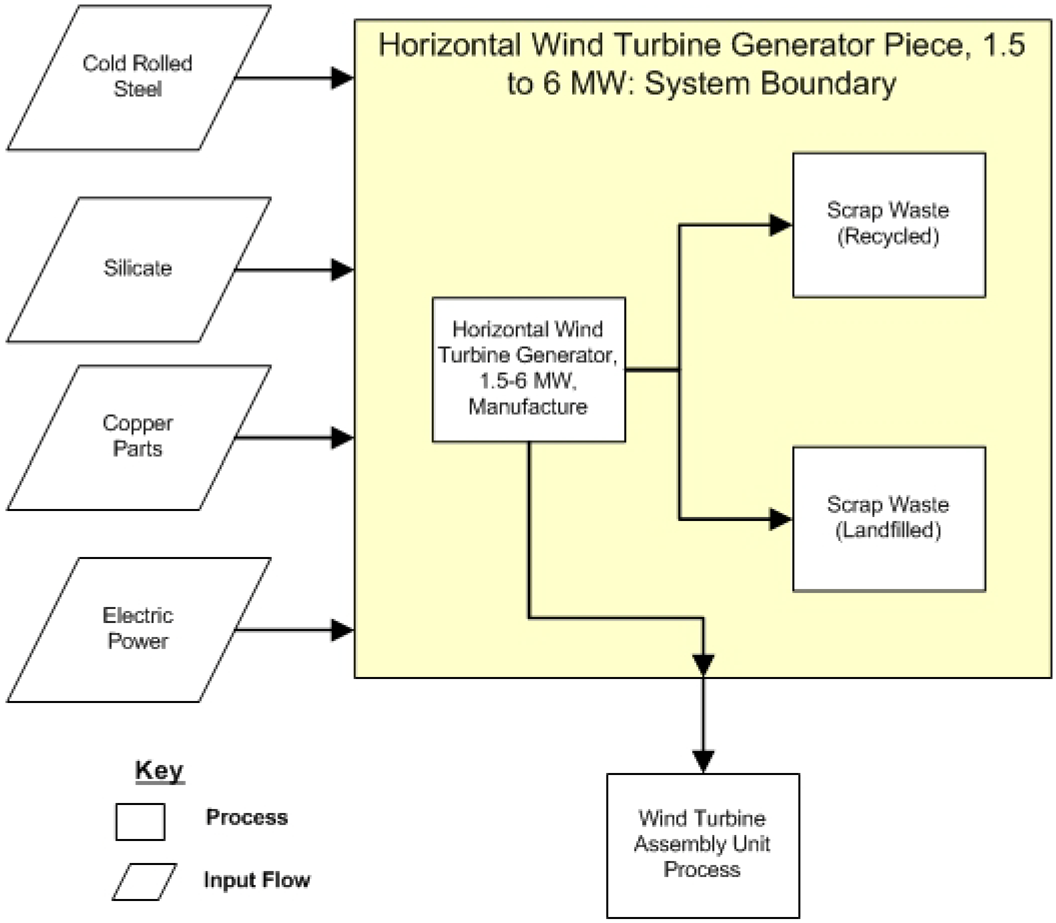

Table 1: Mass Scaling Equations for a Generator

Component	Conventional Turbine	Advanced Turbine	Notes	Source
Mass scaling equation	$10.51 \times \text{turbine rating}^{0.9223}$	$6.47 \times \text{turbine rating}^{0.9223}$	turbine rating is in *kW*	NREL 2006
Copper	65%	65%	none	Martinez *et al* 2009
Silica	32%	32%	none	Martinez *et al* 2009
Stainless steel	3%	3%	none	Martinez *et al* 2009

Table 2: Unit Process Input and Output Flows

Flow Name*	Conventional Turbine	Advanced Turbine	Units (Per Reference Flow)
Inputs			
Steel cold rolled [Metals]	665	1092	kg
Copper parts [Metal parts]	3574	12835	kg
Silicate [Minerals]	1759	6319	kg
Power [Electric power]	1361570	4595987	MJ
Outputs			
Generator [Manufacturing]	1.00	1.00	pcs
Unspecified scrap waste [Consumer waste]	2025	7141	kg
Scrap waste [Waste for recovery]	604	993	kg
Copper scrap [Waste for recovery]	3429	12315	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

NREL 2006	Fingersh, L. Hand, M. Laxson, A. 2006. *Wind Turbine Design Cost and Scaling Model.* National Renewable Energy Laboratory. NREL/TP-500-40566. Golden, Colorado. December 2006. (Accessed June 15, 2010).
Nalukowe *et al*. 2006	Nalukowe, B.B. Liu, J. Damien, W. Lukawski, T. 2006. *Life Cycle Assessment of a Wind Turbine*. May 22, 2006.
Martinez *et al*. 2009.	E. Martinez et al. 2009. *Life Cycle Assessment of a multi-megawatt wind turbine*. Renewable Energy, Vol. 34, pg 667-673.

Section III: Document Control Information

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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: Horizontal Turbine Generator, 1.5-6 MW Capacity, Manufacturing.* U.S. Department of Energy, National Energy Technology Laboratory. Last Updated: November 2010 (version 01). www.netl.doe.gov/energy-analyses (http://www.netl.doe.gov/energy-analyses)

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