NETL Life Cycle Inventory Data
Process Documentation File

Process Name: Horizontal Wind Turbine Blades, 1.5-6 MW, Manufacturing

Reference Flow: 1 piece (pcs) of Horizontal Turbine Blades

Brief Description: Manufacture of turbine blades, based on NREL specifications for a horizontal axis multi capacity (1.5-6 MW) wind turbine. Assumes blades manufactured of CRP (advanced technology) or GRP (current technology) and Adhesive 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 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:

HT_CPTY	*Power production capacity of the wind turbine*
DIAMETER	*Diameter of the rotor*
BLADES	*Number of blades per turbine*
MNU_WSTE	*Percentage of manufacturing waste in this process*
CON_GRP_IN	*Percentage of Glass Reinforced Plastic (GRP) material used in conventional turbines' blade construction*
ADV_GRP_IN	*Percentage of Glass Reinforced Plastic (GRP) material used in advanced turbines' blade construction*

RECY_PER	*Recycling percentage of recyclable materials (steel, cast iron etc)*
ADH_PER	*Percentage of Adhesive material used in blade construction*
MJ_KG	*Amount of energy in the form of electricity used to manufacture per kg of blade*

Tracked Input Flows:

Glass fibers [Minerals]	*Glass fiber used for blade manufacture*
Carbon fibers [Plastics]	*Carbon fiber used for blade manufacture*
Resin glue [Operating materials]	*Glue used for blade manufacture*
Steel part [Metal parts]	*Steel used for blade manufacture*
Power [Electric power]	*Electricity used for blade manufacture*

Tracked Output Flows:

Horizontal Turbine Blades [Manufacturing]	*Manufacturing of a single blade 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*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage3_M_HTurbine_Blades_1.5-6MW_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 rotor blade for horizontal wind turbines with capacities ranging from 1.5 to 6.0 MW. The unit process is based on the reference flow of 1 pcs of blade. 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 component 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 blade mass are shown in **Table 1**.

The types of materials used for blade manufacture are based on estimated material profiles for wind turbine components (DOE 2008). Glass reinforced plastic (GRP) material is assumed to be 78 and 68 percent of the blade mass for conventional and advanced turbines, respectively (DOE 2008). This analysis assumes that carbon fiber is not used for conventional blades, but does comprise 10 percent of total blade mass for advanced turbine blades (DOE 2008). Resin adhesive is assumed to comprise 10 percent of the blade mass. The balance of the blade mass is assumed to be high-quality steel. The percentages for estimating the material compositions of conventional and advanced blades 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 blade. Of this manufacturing scrap, 95 percent is assumed to be landfilled and 5 percent is recovered for recycling (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 blade manufacture (e.g., glass fibers, resin glue, and steel) are calculated outside the boundary of this unit process and are based on profiles available within the life cycle inventory (LCI) databases.

Figure 1: Unit Process Scope and Boundary

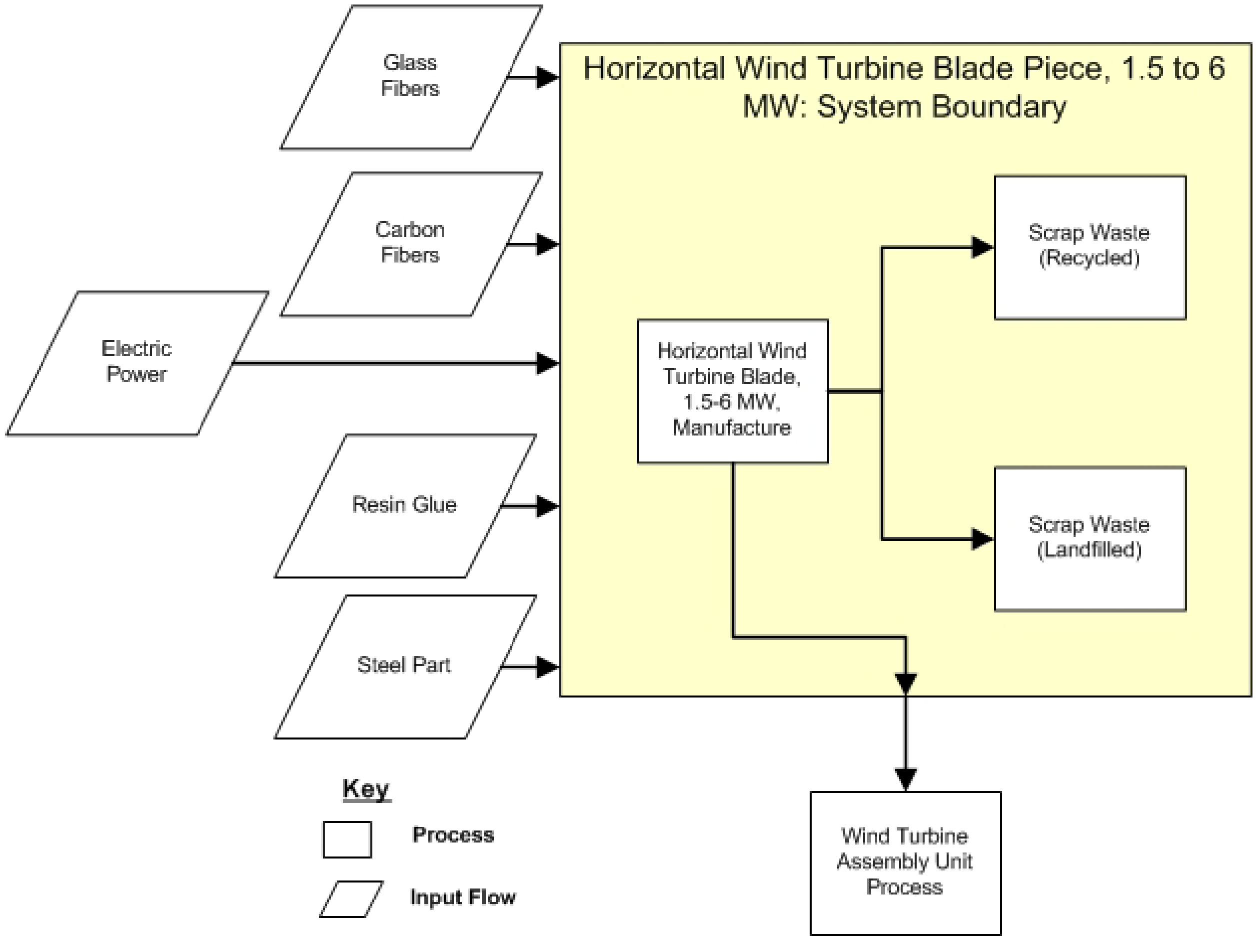

Table 1: Mass Scaling Equations for a Rotor Blade

Component	Conventional Turbine	Advanced Turbine	Notes	Source
Mass scaling equation	$0.1452 \times r^{2.92158}$	$0.495 \times r^{2.53}$	r = rotor radius in *m*	NREL 2006
Glass reinforced plastic	78%	68%	none	DOE 2008
Carbon fiber	0%	10%	none	DOE 2008
Resin glue	10%	10%	none	DOE 2008
Steel	12%	12%	none	DOE 2008

Table 2: Unit Process Input and Output Flows

Flow Name*	Value	Units (Per Reference Flow)
Inputs		
Glass fibers [Minerals]	**2,713**	**kg**
Carbon fibers [Plastics]	**399**	**kg**
Resin glue [Operating materials]	**598**	**kg**
Steel part [Metal parts]	**279**	**kg**
Power [Electric power]	**15,958**	**MJ**
Outputs		
Horizontal Turbine Blades, 1.5-6 MW Capacity [Manufacturing]	1.00	pcs
Unspecified scrap waste [Consumer waste]	3,778	kg
Scrap waste [Waste for recovery]	251	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

DOE 2008.	Department of Energy. 2008. 20% Wind Scenario: Wind Energy Provides 20% of U.S. Electricity Needs by 2030, DOE/GO-102008-2578.
Nalukowe *et al*. 2006	Nalukowe, B.B. Liu, J. Damien, W. Lukawski, T. 2006. *Life Cycle Assessment of a Wind Turbine*. May 22, 2006.
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).

Section III: Document Control Information

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