NETL Life Cycle Inventory Data
Process Documentation File

Process Name:	Coal Biomass Cofiring Pulverized Coal Boiler Facility
Reference Flow:	1 MWh of Electricity
Brief Description:	This unit process includes operation (input and emission flows) of a pulverized coal boiler, which has been repurposed in order to generate electricity from a combination of coal and biomass feedstocks.

Section I: Meta Data

Geographical Coverage:	United States	**Region:**	N/A
Year Data Best Represents:	2000		
Process Type:	Energy Conversion (EC)		
Process Scope:	Gate-to-Gate Process (GG)		
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:

Biom_Feed_Cofr	*Rate of biomass feed to the process; varies based on biomass type and energy density*

Tracked Input Flows:

Biomass [Intermediate product]	*Biomass generated, transported, and prepared within the boundary of the study*

Tracked Output Flows:

Electricity	*Reference flow*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage3_O_Cofiring_PC_Boiler _2011.02.xls*, which provides additional details regarding relevant calculations, data quality, and references.

Goal and Scope

The scope of this unit process covers the conversion of dried or torrefied biomass to electricity via a pulverized coal (PC) power plant that was originally designed for coal-fired power production. This unit process assumes that the facility has been modified so as to be able to handle ground and dried, or ground and torrefied biomass. The use of torrefied versus dried biomass is accounted for via alteration of the feed rate for biomass (in kg), assuming energy required must remain constant for cofiring, and that the mass of required biomass must be adjusted to maintain the required energy input. Heating values used for the calculation of feed rates account for moisture content of the incoming biomass.

This unit process considers biomass consumption, water use, wastewater production, and airborne emissions of carbon dioxide and criteria pollutants for which emissions data were available. Electricity produced within this unit process is presumed to be delivered to end users under subsequent life cycle stages or via other additional environmental modeling. The calculations presented for this unit process are based on the reference flow of 1 MWh of electricity, as described below and shown in **Figure 1**. This unit process is used under Life Cycle (LC) Stage #3 to assist in the conversion of biomass to electricity.

Boundary and Description

This unit process is applicable to the following types of biomass: short rotation woody crops (SRWC), corn stover, and switchgrass. Depending upon the type of biomass that is utilized and whether the biomass has been dried or torrefied, the user of this unit process must insert the appropriate biomass feed rate into the “Biom_Feed” parameter. Feed rates are determined based on the heating content of each type of biomass, such that an equivalent amount of energy is input into the process for each type of biomass utilized. Parameter values for each type of biomass are shown in **Table 1**.

Energy inputs within the scope of the unit process are limited to the consumption of biomass input to the PC boiler. Other energy requirements, such as electricity required for feedstock handling and other parasitic loads, are accounted for as reduced overall net generation capacity of the plant. Parasitic loads of the plant are not explicitly quantified within the unit process, but are instead considered within the biomass electricity production data source (EERE 1997) that serves as a basis for this unit process.

Table 1: Parameter Values for Biomass (NETL 2007, 2010b, c, d, 2012)

Biomass Type	Cultivation CO_2 Uptake (kg CO_2/kg biomass)	Heating Value (HHV) at 0% moisture (Btu/lb)	Moisture Content, as harvested (%)
Short Rotation Woody Crops	0.96	8438	50%
Switchgrass	1.33	7787	15%
Corn Stover	1.39	7528	15%

Air quality emissions resulting from combustion of biomass in the PC boiler are quantified using emission factors from an investigation of standalone biomass firing and coal-biomass cofiring, which was completed in 1997 (EERE, 1997). The data contained in this source was nearly 15 years old at the time of publication of this document. However, the analysis contained in EERE (1997) is comprehensive in that it provides feed rates and airborne emissions data for coal-biomass cofiring. Therefore, while EERE (1997) was selected as the best available data source for some of the calculations contained in this unit process, its vintage is a data limitation, and additional data development should be completed in the event that newer data become available.

Combustion stoichiometry was used to calculate the carbon dioxide (CO_2), sulfur dioxide (SO_2), and mercury (Hg) emissions associated with the coal firing at the facility (NETL 2010a). Utilizing this data allowed the process to be customized for the use of Illinois No. 6 (I6) coal. It was assumed that the facility was outfitted with flue gas desulfurization (FGD) and electrostatic precipitator (ESP) pollution control equipment. The FGD was assumed to have an SO_2 removal efficiency of 98 percent. The combination of the FGD and ESP was assumed to remove 42 percent of the mercury. The biogenic CO_2 emissions resulting from the combustion of biomass in the PC boiler were based on existing NETL unit processes that describe the uptake of CO_2 during the cultivation stage of the biomass (NETL 2010b, c, d). These values are adjusted according to the change in moisture content across the biomass dryer to ensure that the biogenic CO_2 balances between cultivation and combustion.

Figure 1 provides an overview of the boundary of this unit process. As shown, biomass that is produced, transported, and dried or torrefied within upstream unit processes is input to this energy conversion process. Within the boundary of the unit process, biomass feed rates that are needed to support energy conversion are identified, and air emissions, water use from groundwater and surface water, solid waste generation, and wastewater production are quantified. This unit process is aggregated with other life cycle stage #3 unit processes in order to evaluate total input and emission flows, prior to the distribution of electricity to the end user.

Figure 1: Unit Process Scope and Boundary

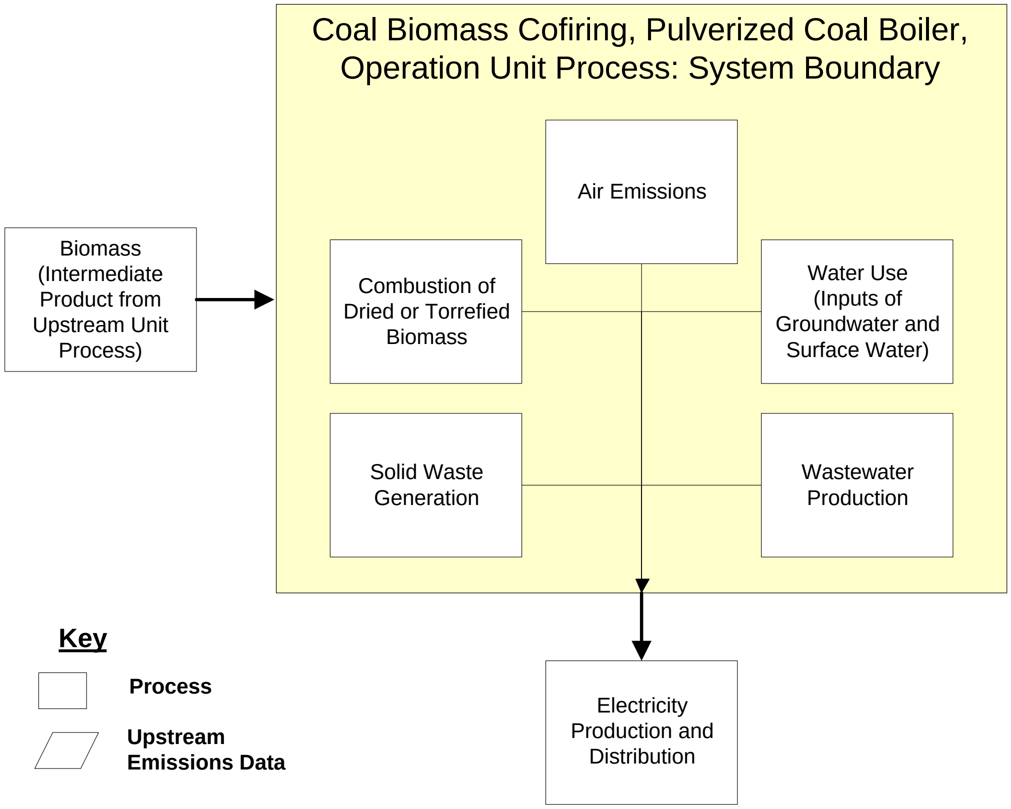

Table 2 provides a summary of modeled input and output flows. The data in **Table 2** are based on a 10 percent SWRC/90 percent I6 coal mixture, by energy. Additional detail regarding input and output flows, including calculation methods, is contained in the associated DS.

Table 2: Unit Process Input and Output Flows

Flow Name	Value	Units (Per Reference Flow)
Inputs		
Biomass [Intermediate Product]	6.18E+01	kg
Coal [Non-renewable resources]	3.62E+02	kg
Water (surface water) [Water]	1.26E+03	kg
Water (groundwater) [Water]	1.26E+03	kg
Outputs		
Electricity	1.00E+00	MWh
Carbon dioxide (biotic) [Inorganic emission to air]	9.89E+01	kg
Carbon dioxide [Inorganic emissions to air]	8.38E+02	kg
Nitrogen oxides [Inorganic emissions to air]	8.16E-01	kg
Sulphur oxides [Inorganic emissions to air]	3.47E-01	kg
Carbon monoxide [Inorganic emissions to air]	1.32E+00	kg
Dust (unspecified) [Particles to air]	2.21E-01	kg
Mercury (+II) [Heavy metals to air]	3.15E-05	kg
Solid Waste (unspecified) [Solid Waste]	3.40E+01	kg
Water (returned to receiving body) [Water]	5.66E+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 1.

Embedded Unit Processes

None.

References

EERE 1997 — United States Department of Energy, Energy Efficiency and Renewable Energy. 1997. Renewable Energy Technology Characterizations. Available at: http://www1.eere.energy.gov/ba/pba/pdfs/entire_document.pdf Accessed on May 1, 2011.

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NETL 2010c	NETL (2010c). *NETL Life Cycle Inventory Data – Unit Process: SRWC Cultivation, Operation.* U.S. Department of Energy, National Energy Technology Laboratory. Last Updated: June 2012 (version 02). www.netl.doe.gov/energy-analyses (http://www.netl.doe.gov/energy-analyses)
NETL 2010d	NETL (2010d). *NETL Life Cycle Inventory Data – Unit Process: Switchgrass Cultivation, Operation.* U.S. Department of Energy, National Energy Technology Laboratory. Last Updated: June 2012 (version 02). www.netl.doe.gov/energy-analyses (http://www.netl.doe.gov/energy-analyses
NETL 2012	NETL. (2012). *Greenhouse Gas Reductions in the Power Industry Using Domestic Coal and Biomass Volume 2: Pulverized Coal Plants*. (DOE/NETL-2012/1547). Pittsburgh, PA: National Energy Technology Laboratory, from http://www.netl.doe.gov/energy-analyses/refshelf/PubDetails.aspx?Action=View&SourSo=Main&PubId=426

Section III: Document Control Information

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

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13JUNE2012 Updated to revised parameter values.

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Section IV: Disclaimer

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