NETL Life Cycle Inventory Data
Process Documentation File

Process Name: Biomass Torrefaction for Coal-Biomass Cofiring

Reference Flow: 1 kg of Torrefied Biomass

Brief Description: This unit process considers the mass/energy inputs, mass outputs, and air emissions for the torrefaction of biomass, which is the partial gasification of biomass (without oxygen), to enable cofiring at a pulverized coal power plant.

Section I: Meta Data

Geographical Coverage: United States **Region:** N/A

Year Data Best Represents: 2010

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:

N/A

Tracked Input Flows:

Ground Biomass [Intermediate product]	*Ground biomass generated, transported within the boundary of the study*
Power [Electric power]	*Electricity from the grid*

Tracked Output Flows:

Torrefied Biomass [Intermediate Product]	*Reference flow*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage3_O_Biomass_Torrefaction_2011.01.xls*, which provides additional details regarding relevant calculations, data quality, and references.

Goal and Scope

The scope of this unit process covers the torrefaction of biomass, in support of coal-biomass cofiring, as described in greater detail below. Biomass torrefaction is the process of heating biomass, under a reduced oxygen environment, such that the biomass becomes partially charred, prior to being combusted during the coal-biomass cofiring process. Torrefaction is applied to cofiring of biomass in a pulverized coal (PC) boiler, but is not required for stoker boilers. This unit process considers energy use (electricity) as well as carbon dioxide and particulate emissions associated with biomass torrefaction. The calculations presented for this unit process are based on the reference flow of 1 kg of torrefied biomass, 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 via coal-biomass cofiring.

Boundary and Description

During the torrefaction process, biomass that has been previously subject to size reduction is heated in a controlled oxygen environment. Torrefaction can be considered analogous to a low-level gasification or pyrolysis process, which drives off water contained in the biomass, and results in the production of a biochar. Heating rates vary, but generally range from 230 to 280 degrees C. For the purposes of this unit process, it is assumed that torrefaction occurs at a temperature of 250 degrees C for a period of 60 minutes. This moderate to light level of torrefaction is expected to generate torrefied biomass that is suitable for combustion in a PC boiler, but which has not been subject to excessive loss of mass or net energy content.

Torrefaction is applicable to PC boilers but not stoker boilers. Stoker boilers are capable of combusting chipped biomass directly, and do not require additional processing. Therefore, this unit process is not relevant to coal-biomass cofiring using stoker boilers.

During the torrefaction process, heating of the biomass in a controlled oxygen environment results in the generation of substantial amounts of volatile organic compounds, which are driven off from the biomass (Ciolkosz and Wallace 2011). These compounds contain sufficient energy that, when combusted, heat derived from their combustion is sufficient to provide process heat for torrefaction (Ciolkosz and Wallace 2011). Therefore, external sources of energy, such as natural gas, are not required for heating during the torrefaction process. Electricity use for auxiliary components, such as biomass handling and other processes was estimated assuming that it requires 5% of the total electricity required for biomass grinding (see **Table 1**).

Torrefaction has not yet been widely implemented in the energy production industry. As a result, only very limited data are available in support of quantifying airborne emissions from the torrefaction process. This unit process estimates carbon dioxide and particulate matter emissions from torrefaction based on bulk emission values disclosed by Ciolkosz and Wallace (2011). Herein, total gas released was shown to be approximately 1.4 percent by mass of the mass of incoming biomass. Presuming that gaseous emissions would be completely combusted prior to emission, as a part of the torrefaction/heating process, it was assumed that 99.5 percent of all emissions would be carbon dioxide, while the remaining 0.5 percent would be particulate matter. This estimate likely underestimates NO_x and other non-CO_2 emissions that would result from the torrefaction of biomass, and is noted as a data limitation, until more complete air emissions data become available for torrefaction.

Figure 1 provides an overview of the boundary of this unit process. As shown, biomass that is produced, transported, and ground within upstream unit processes is input to biomass torrefaction operations. Energy (electricity) consumption is then quantified for the torrefaction process, and air emissions (CO_2 and PM_{10}) are estimated. This unit process then feeds into a separate unit process for coal-biomass cofiring using a PC boiler for electricity production.

Figure 1: Unit Process Scope and Boundary

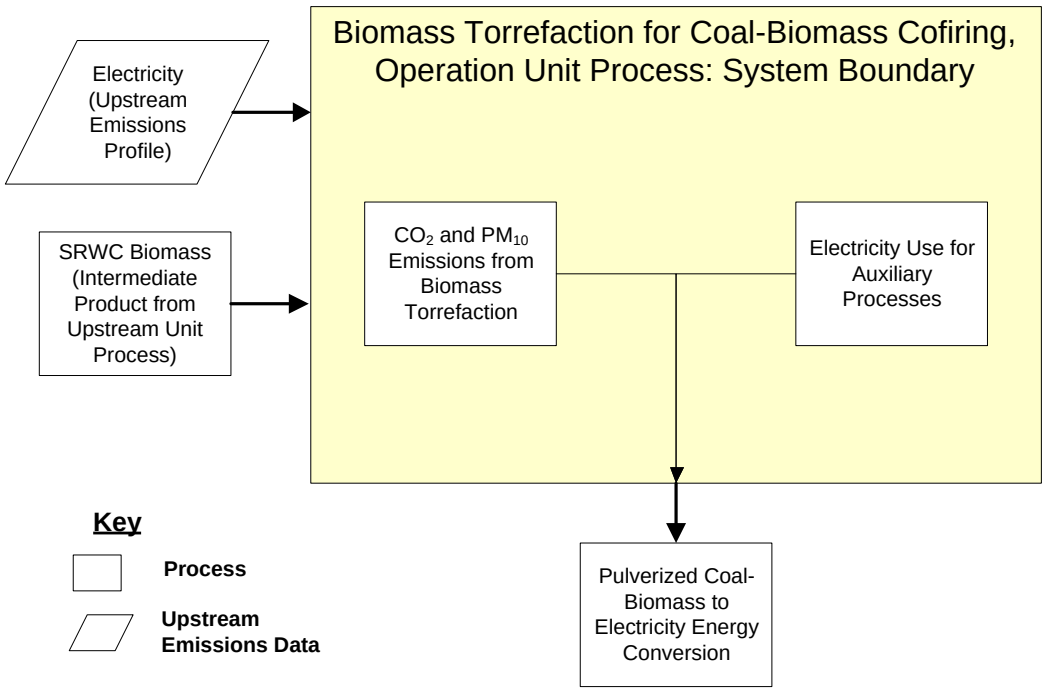

Table 1 summarizes airborne emissions factors and energy inputs and outputs that are applied within this unit process. **Table 2** provides a summary of modeled input and output flows. Additional detail regarding input and output flows, including calculation methods, is contained in the associated DS.

Table 1: Energy Requirements and Emission Factors

Flow Name	Value	Units (Per Reference Flow)	Reference
Electricity Use from Auxiliary Components	0.018	MJ/kg	NETL Engineering Calculation
Heat Energy Required for Torrefaction	Provided by Combustion Gaseous Torrefaction Products (VOCs)		Ciolkkosz and Wallace 2011
Total Gas Released from Torrefaction	1.4%	percent of incoming biomass mass	Ciolkkosz and Wallace 2011
Proportion of Total Gas as CO_2	0.995	[unitless]	NETL Engineering Judgment
Proportion of Total Gas as PM10	0.005	[unitless]	NETL Engineering Judgment

Table 2: Unit Process Input and Output Flows

Flow Name	Value	Units (Per Reference Flow)
Inputs		
Biomass [Intermediate Product]	1.152E+00	kg
Power [Electric power]	1.800E-02	MJ/kg
Outputs		
Ground Biomass [Intermediate product]	1.000E+00	kg
Carbon dioxide [Inorganic emissions to air]	1.548E-02	kg
Dust (PM10) [Particles to air]	7.776E-05	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

Ciolkosz and Wallace 2011 — Ciolkosz and Wallace. 2011. A review of torrefaction for bioenergy feedstock production. Biofuels, Bioproducts, and Biorefining 10.1002/bbb.275. Available at: http://onlinelibrary.wiley.com/doi/10.1002/bbb.275/full (Accessed on April 27, 2011).

Section III: Document Control Information

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