NETL Life Cycle Inventory Data
Process Documentation File

Process Name: H2 from Biomass and Coal Gasification w/ CSS

Reference Flow: 1kg Hydrogen, >99.90 vol%, 925 psig (6.48 MPa)

Brief Description: Energy use, feedstocks, and emissions associated with the co-gasification of coal and biomass coupled with a two-stage Selexol capture system (BG/CG + CCS) that converts coal and biomass to >99.90 vol-% hydrogen for generic industrial use.

Section I: Meta Data

Geographical Coverage: United States **Region:** Midwest

Year Data Best Represents: 2021

Process Type: Basic Process (BP)

Process Scope: Gate-to-Gate Process (GG)

Allocation Applied: No

Completeness: All 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:

groundwater_pct

[%] Percent of water supply sourced from groundwater

potw_pct

[%] Percent of water supply sourced from publicly-owned treatment works.

slag_credit_pct

[%] Percentage of slag produced that is credited as a coproduct. Customizable parameter for the user's specific system configuration. It should be set to one if and only if the plant designers have a confirmed use-case for all of its slag throughout the lifetime of the project.

Tracked Input Flows:

coal, at destination

[Technosphere] Mass flow rate of coal entering the facility. Coal is used as both feedstock and heat source. Mass flow rate is based on assumption of Illinois No.6 coal, with an as-received HHV of 27,113 kJ/kg.

Torrefied Biomass

[Technosphere] Mass flow rate of biomass (torrefied, woody biomass) into system. Biomass is used as both feedstock and heat source. Mass flow rate is based on assumption of torrefied, woody biomass, with an as-received HHV of 22.676 kJ/kg.

Water, purified

[Technosphere] Water filtered to acceptable purity by water treatment train.

Sodium hydroxide

[Technosphere] Sodium hydroxide input, scaled to the reference flow.

Sulfuric acid

[Technosphere] Sulfuric acid input, scaled to the reference flow.

Tracked Output Flows:

Hydrogen, >99.90 vol%, 925 psig (6.48 MPa)

[Reference flow]

Steam, medium pressure, 399°C

[Technosphere] Mass flow rate of the captured carbon dioxide, scaled to the reference flow.

Carbon dioxide, captured product

[Technosphere] Steam available for export, scaled to the reference flow. Default for coal gasification is zero.

Electricity

[Technosphere] Electricity co-product sold back to the grid.

Slag, produced

[Technosphere] Mass flow rate of co-product slag generated, scaled to the reference flow.

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_O_H2_from_Biomass_and_Coal_Gasification_with_CCS_2022.01.xlsx*, which provides additional details regarding relevant calculations, data quality, and references.

Goal and Scope

This unit process provides a summary of relevant input and output flows associated with a representative biomass and coal co-gasifier with CO_2 capture (BG/CG + CCS) that has been configured to primarily produce industrial-grade hydrogen. Gasification is a method to convert solid hydrocarbons into synthesis gas (CO and H_2). The syngas can then be shifted to mainly hydrogen and carbon dioxide via the water-gas shift reaction. This design utilizes two Shell dry feed, pressurized, up-flow, entrained, slagging gasifiers operating at 615 psia, for a feedstock comprising 43.5% biomass and 56.5% coal by mass. The design-specifications are based on the gasification of a torrefied, non-pelletized, short rotation, woody biomass (e.g., southern yellow pine) and Illinois No. 6 coal. The as-received higher heating values of the two feedstocks are 22,676 kJ/kg and 27,113 kJ/kg, respectively. A two-stage Selexol process is used to remove the 92.7% of the CO_2 from the flue gas. The facility requires supplemental electricity from the grid for auxiliary systems but does not require an external fuel source for the gasification reaction. The reference flow of this unit process is: 1 kg of >99.90 vol-% hydrogen at 925 psia.

Boundary and Description

This unit process provides a summary of relevant input and output flows associated with a co-gasification scenario of coal and biomass with integrated carbon capture (BG/CG + CCS). The plant configuration for BG/CG + CCS is nearly identical to that of coal gasification with CCS (CG w/ CCS), but with a biomass feedstock percentage that was set as a design specification to achieve a cradle-to-gate life cycle global warming potential (based on a preliminary emissions screening assessment with biomass, coal, and electricity impacts) of less than zero.

The material, energy, and emissions reported in this unit process are based on the NETL publication, Comparison of Commercial, State-of-the-Art, Fossil-Based Hydrogen Production Technologies (2022). The baseline model uses a combined feedstock that is 56.5 wt-% Illinois #6 sub-bituminous coal and 43.5 wt-% torrefied, non-pelletized, short rotation, woody biomass (e.g. southern yellow pine). The biomass modeled has a total moisture content of 11.12%, as-received, with a higher-heating value (HHV) of 22,676 kJ/kg. The Illinois #6 coal also has a moisture content of 11.12%, as-received, and an HHV of 27,113 kJ/kg.

The configuration of a coal and biomass co-gasification facility is nearly identical to that of a conventional coal gasification plant. The only major difference is the process by which biomass is received, stored, and prepared for gasification. These steps are included in the system boundaries of model. Like with CG w/ CCS, the crushed coal and biomass is dry-fed to a gasifier, which generates a stream of mostly H_2 and CO (syngas). The CO is converted to CO_2 by reacting with supplemental steam over a bed of catalyst in parallel fixed-bed reactors that are arranged in series to produce more hydrogen. Additional equipment is required to manage the higher contaminant levels that are caused by the solid feedstocks, including particulate removal, a syngas scrubber, mercury control, a Claus plant, and slag handling. Dual-stage Selexol carbon capture unit process was modeled, and the system has a slightly higher capture percentage than CG w/ CCS (92.7% vs. 92.5%). The overall yield is lower than for CG w/ CCS (75% vs. 85%), which accounts for the off-gas used to offset auxiliary electricity loads in the plant.

There are several byproducts of coal and biomass gasification that have been considered. Slag, a glass-like material formed from the mineral matter embedded in coal, is produced in significant quantities but is considered to be a waste product that is landfilled by default. Liquid sulfur is a byproduct of the Claus process, and it is commonly stored in a sulfur pit prior to transportation to end users. A complete life cycle assessment should model and include the impacts associated with disposal of the slag and sulfur.

Inputs and outputs have been scaled to a reference flow of 1 kg of gaseous hydrogen at 925 psia. The facility is assumed to be located at a generic, greenfield plant site in the Midwestern U.S.

Figure 1: Unit Process Scope and Boundary

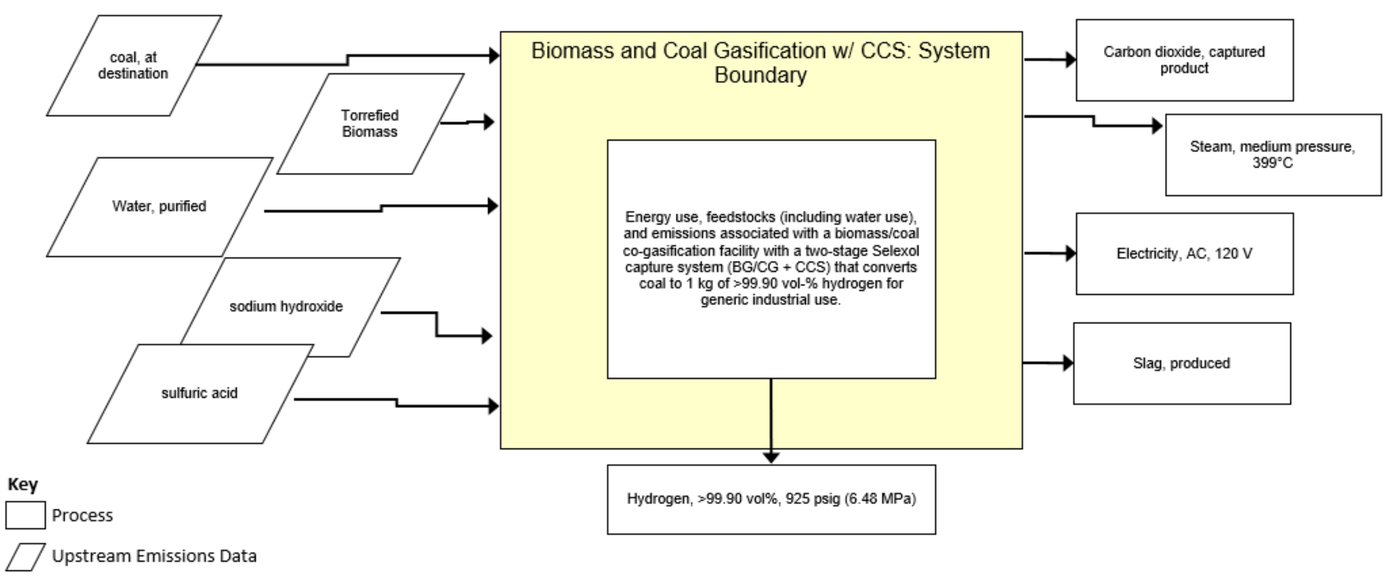

Table 1: Parameters

Parameter Name	Expected Value	Low	High	Units	Description
groundwater_pct	0.50	0	1	%	Percent of water supply sourced from groundwater. The sum of groundwater_pct and potw_pct must equal 1.
potw_pct	0.50	0	1	%	Percent of water supply sourced from publicly-owned treatment works. The sum of groundwater_pct and potw_pct must equal 1.
slag_credit_pct	1.00	0	1	%	Percent of slag produced that is credited as a coproduct. Customizable parameter for the user's specific system configuration. It should be set to one if and only if the plant designers have a confirmed use-case for all of its slag throughout the lifetime of the project.

Embedded Unit Processes

None.

References

Lewis et al. 2022

Lewis, E., McNaul, S., Jamieson, M., Henriksen, M. S., Matthews, H. S., Walsh, L., Grove, J., Shultz, T., Skone, T. J., and Stevens, R. 2022. Comparison Of Commercial, State-of-the-Art, Fossil-Based Hydrogen Production Technologies. DOE/NETL-2022/3241. U.S. Department of Energy, National Energy Technology Laboratory. April 12, 2022. Pittsburgh, PA.

Section III: Document Control Information

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None.

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