NETL Life Cycle Inventory Data
Process Documentation File

Process Name:	SOFC NG and Coal plant with CCUS
Reference Flow:	1 MWh of Electricity
Brief Description:	Coal integrated gasification solid oxide fuel cell (SOFC) and natural gas (NG) solid fuel cell power plants with and without carbon capture.

Section I: Meta Data

Geographical Coverage:	USA	**Region:**	Midwest
Year Data Best Represents:	2015		
Process Type:	Energy Conversion (EC)		
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	☐ Other
Releases to Water:	☐ Inorganic	☐ Organic Emissions	☐ Other
Water Usage:	☐ Water Consumption	☑ Water Demand (throughput)	
Releases to Soil:	☐ Inorganic Releases	☐ Organic Releases	☐ Other

Adjustable Process Parameters:

accep_deg	*[percent] Percent of fuel cell degradation allowed before replacement*
CO2_emissions	*[kg/MWhnet] kg CO2 released for every MWh plant output*
CO2_saline	*[kg/Mwhnet] mass of CO2 captured for every MWh plant output*

coal_flowrate	*[kg/MWhnet] mass of coal to generate one MWh electricity*
fc_degrade	*[FC/MWhnet] number of fuel cells that need replaced for every MWh*
HG_em	*[kg/Mwhnet] mercury emissions to air for every MWh electricity*
NG_flowrate	*[kg/MWhnet] mass of NG to generate one MWh electricity*
NOx_em	*[kg/Mwhnet] NOx emissions to air for every MWh electricity*
PM_em	*[kg/Mwhnet] PM emissions to air for every MWh electricity*
slag	*[kg/MWhnet] mass solid slag waste discarded for every one MWh electricity*
SO2_em	*[kg/Mwhnet] SO2 emissions to air for every MWh electricity*
wat_discharge	*[L/MWhnet] water returned to water table for every MWh output*
wat_withdrawal	*[L/MWhnet] water withdrawn from water table for every one MWh electricity*
stack_num	[count] number of stacks of SOFCs in plant
cap_factor	*[percent] Fraction of the year that the plant is assumed to operate*

Tracked Input Flows:

Illinois 6 Coal [Intermediate]	*[Technosphere]*
Solid Oxide Fuel Cells [Intermediate]	*[Technosphere]*
Natural Gas [Intermediate]	*[Technosphere]*

Tracked Output Flows:

Electricity [Energy]	*Reference flow*
Carbon dioxide [Intermediate]	*Intermediate product*
Waste (solid) [Waste for disposal]	*Solid waste*

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Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage3_O_SOFC_Power_2015.01.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 integrated gasification fuel cell (IGFC) systems and natural gas fuel cell (NGFC) systems. The first scenario is of an IGFC with catalytic coal gasification. The second is of an IGFC with traditional coal gasification. The third is of an NGFC. The fourth is of an IGFC with natural gas added to the syngas. All coal is assumed to be Illinois #6. The reference flow of this unit process is: 1 MWh of Electricity

Boundary and Description

Solid Oxide Fuel Cells (SOFC) are an energy conversion method that use oxidizers to convert fuel gas to electricity using a solid electrolyte. This technology can be combined with certain conventional power plants to create energy with fewer emissions. This National Energy Technology Laboratory (NETL) unit process is used to determine the energy and emissions associated with integrated gasification fuel cell (IGFC) systems and natural gas fuel cell (NGFC) systems. The scope and boundary of the unit process are illustrated in **Figure 1.**

IGFC systems are power plants that gasify coal to produce syngas, which in turn is used to power the SOFCs. Natural gas can also be injected into the syngas to produce more electricity. NGFC systems are those that use natural gas to produce fuel for the SOFCs. This unit process calculates the input and output flows for two IGFC using only Illinois #6 coal, one IGFC that uses Illinois #6 coal with natural gas injected into the syngas, and one NGFC.

The data for the fuel cell calculations were taken from two NETL reports: *Techno-Economic Analysis of Integrated Gasification Fuel Cell Systems Created by Energy Sector Planning and Analysis for SEAP & OPPB* (2014) and *Technoeconomic Analysis of Natural Gas Fuel Cell Plant Configurations* (2015). The two reports used the Aspen Plus® (Aspen) platform to develop system models based on published reports, technology vendor and user information, performance data, and/or best engineering judgment (NETL 2014).

The replacement rate of SOFCs depends on the degradation rate of the fuel cell, the hours of operation, and the percent degradation that is acceptable before replacing the cell. This unit process assumes a linear degradation rate (%/1000hrs) and an acceptable degradation rate of 10%. This results in a fuel cell lifetime of approximately 6.5yr for each of the scenarios. This differs slightly from the stack life (7.3yr) used in the NETL reports based on more complex degradation models, but allows for more parameterization.

Figure 1: Unit Process Scope and Boundary

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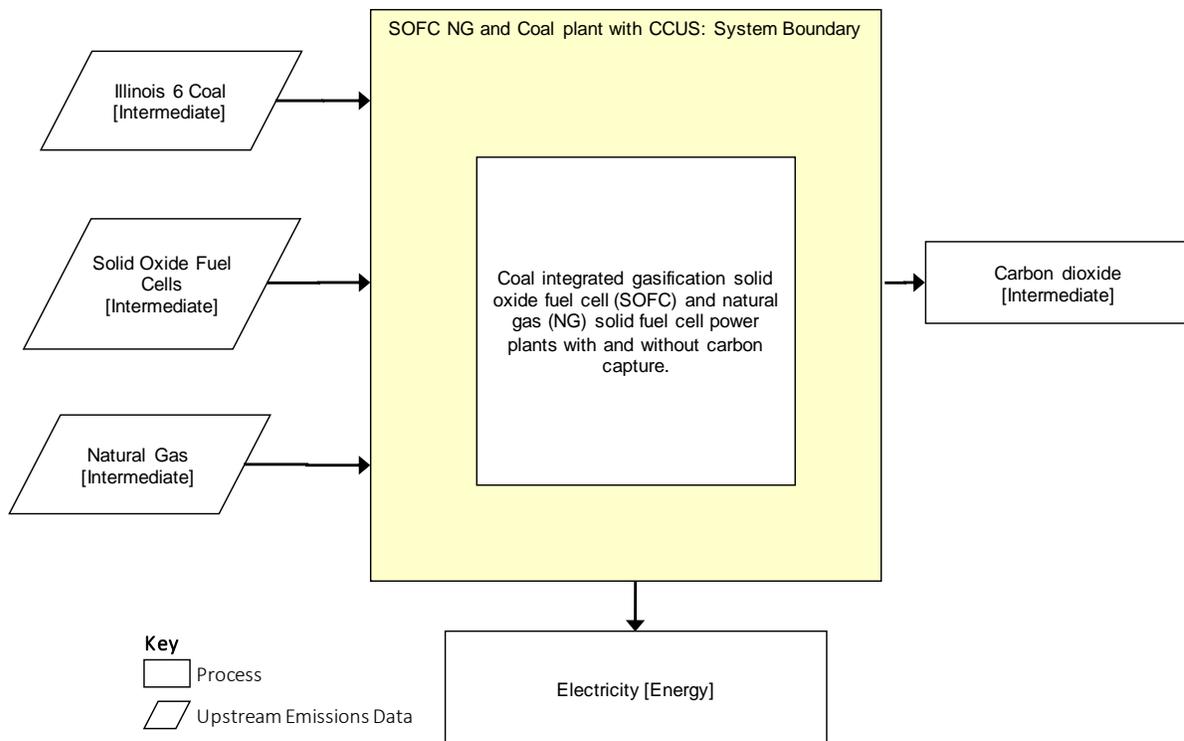
Table 1: Unit Process Input and Output Flows

Flow Name	Units (Per Reference Flow)	Scenario 1 Value	Scenario 2 Value	Scenario 3 Value	Scenario 4 Value	Scenario 5 Value
Inputs						
Illinois 6 Coal [Intermediate]	**kg**	**2.45E+02**	**2.88E+02**	**0**	**0.00E+00**	**1.69E+02**
Solid Oxide Fuel Cells [Intermediate]	**kW**	**1.68E-02**	**1.58E-02**	**1.83E-02**	**1.95E-02**	**1.67E-02**
Natural Gas [Intermediate]	**kg**	**0.00E+00**	**0.00E+00**	**1.06E+02**	**9.94E+01**	**4.48E+01**
Water (Unspecified) [Water]	L	6.39E+02	8.41E+02	4.62E+02	3.20E+02	6.54E+02
Outputs						
Electricity [Energy]	**MWh**	**1.00E+00**	**1.00E+00**	**1.00E+00**	**1.00E+00**	**1.00E+00**
Carbon dioxide [Inorganic emissions to air]	kg	9.66E+00	1.15E+01	5.90E+00	2.40E+02	9.62E+00
Carbon dioxide [Intermediate]	**kg**	**6.34E+02**	**8.08E+02**	**2.95E+02**	**0.00E+00**	**6.31E+02**
Mercury (+II) [Heavy metals to air]	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nitrogen oxides [Inorganic emissions to air]	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dust (unspecified) [Particles to air]	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Slag Waste (solid) [Waste for disposal]	**kg**	**3.47E+01**	**2.38E+01**	**0.00E+00**	**0.00E+00**	**1.39E+01**
Sulphur dioxide [Inorganic emissions to air]	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Water (wastewater) [Water]	L	1.54E+02	2.29E+02	1.52E+02	7.04E+01	1.91E+02
Stack Waste (solid) [Waste for disposal]	**Stacks**	**1.68E-02**	**1.58E-02**	**1.83E-02**	**1.95E-02**	**1.67E-02**

* **Bold face** clarifies that the value shown *does not* include upstream environmental flows.

Embedded Unit Processes

None.

References

NETL, 2014   National Energy Technology Laboratory, 2014. *Techno-Economic Analysis of Integrated Gasification Fuel Cell Systems Created by Energy Sector Planning and Analysis for SEAP & OPPB.*

NETL, 2015   National Energy Technology Laboratory, 2015. *Technoeconomic Analysis of Natural Gas Fuel Cell Plant Configurations.*

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Section III: Document Control Information

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