NETL Life Cycle Inventory Data
Process Documentation File

Process Name: Solid oxide fuel cell SOFC Manufacture

Reference Flow: 1 kW fuel cell capacity

Brief Description: Material and energy inputs for the construction of the NETL natural gas fuel cell (NGFC) plant with or without CCS

Section I: Meta Data

Geographical Coverage: USA **Region:** N/A

Year Data Best Represents: 2000

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	☐ 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:

en_input	*[kWh/kW] kilowatt-hour of electricity needed to build an SOFC unit with 1 kW capacity*
steel	*[kg/kW] kilogram of stainless steel needed to build an SOFC unit with 1 kW capacity*

Cr_alloy	*[kg/kW] kilogram of chrome alloy needed to build an SOFC unit with 1 kW capacity*
insulation	*[kg/kW] kilogram of insulation needed to build an SOFC unit with 1 kW capacity*
Ni_oxide	*[kg/kW] kilogram of nickel oxide needed to build an SOFC unit with 1 kW capacity*
LSM	*[kg/kW] kilogram of Lanthanum Strontium Manganite (LSM) needed to build an SOFC unit with 1 kW capacity*
YSZ	*[kg/kW] kilogram of Yttria-stabilized Zirconia (YSZ) needed to build an SOFC unit with 1 kW capacity*
binders	*[kg/kW] kilogram of binders needed to build an SOFC unit with 1 kW capacity*
solvents	*[kg/kW] kilogram of solvents needed to build an SOFC unit with 1 kW capacity*
copper	*[kg/kW] kilogram of copper needed to build an SOFC unit with 1 kW capacity*
scrap_ceramic	*[unitless] fraction of ceramic cell materials scrapped during manufacturing process*
scrap_metal	*[unitless] fraction of metals scrapped during manufacturing process*

Tracked Input Flows:

Energy input [electricity]	*[Technosphere]*
Chrome alloy input [material]	*[Technosphere]*
steel input [material]	*[Technosphere]*
insulation input [material]	*[Technosphere]*
nickel oxide input [material]	*[Technosphere]*
lanthanum strontium manganite input [material]	*[Technosphere]*
yttria-stabilized zirconia input [material]	*[Technosphere]*
binder input [material]	*[Technosphere]*
solvent input [material]	*[Technosphere]*
copper input [material]	*[Technosphere]*

Tracked Output Flows:

Fuel cells [material]	*Reference flow*
Scrapped materials [solid waste]	*[Technosphere]*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage3_M_SOFC_Manufacture_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 the manufacture of solid oxide fuel cells (SOFC). Inputs include electricity and a variety of materials. Outputs include a unit of fuel cells with a capacity of 1 kW and scrap materials. Items required for balance of plant are not included as part of the unit. This unit process does not include production of materials required, only energy and material input for the assembly process. The reference flow of this unit process is 1 kW of fuel cell capacity.

Boundary and Description

This solid oxide fuel cell (SOFC) manufacturing unit process accounts for only material and energy flows in the assembly of planar SOFCs. This assembly process consists of ball milling, tape casting, drying, sintering, preparation of the cathode and anode ink, and screen printing to manufacture the cells as well as metal forming for the interconnect (Karakoussis et al., 2000). Production of materials are not included in this unit process. The boundary is illustrated in **Figure 1.**

Data for this unit process is taken from Staffell et al. (2011) and adjusted to be compatible with the fuel cell systems used in the unit process DS_Stage3_SOFC_Power_2015.01. Those SOFC systems were tuned to have 42 stacks of planar SOFCs that provide 550kW of net power for either integrated gasification fuel cell plants or natural gas fuel cell plants. To achieve this, the power density of the cells changed for each scenario, but the size and number of cells remained the same (NETL 2015, NETL 2014). Equivalent capacities can be produced by holding the power density constant and changing the number of cells per stack, or stacks per plant. Thus, this unit process uses a kW of capacity as the functional unit. The outcome is a unit of fuel cells (cell, stack, set of stacks, etc.) that has 1 kW of capacity. This allows for this unit

process to be used more generally. Staffell et al. provide the energy and material inputs required for manufacturing planar SOFCs based on planar SOFCs built by Fuel Cells Scotland and merged with data from two other reports. The results are meant to represent the material and energy inputs for a general SOFC and were reported on a per kW electricity basis.

Figure 1: Unit Process Scope and Boundary

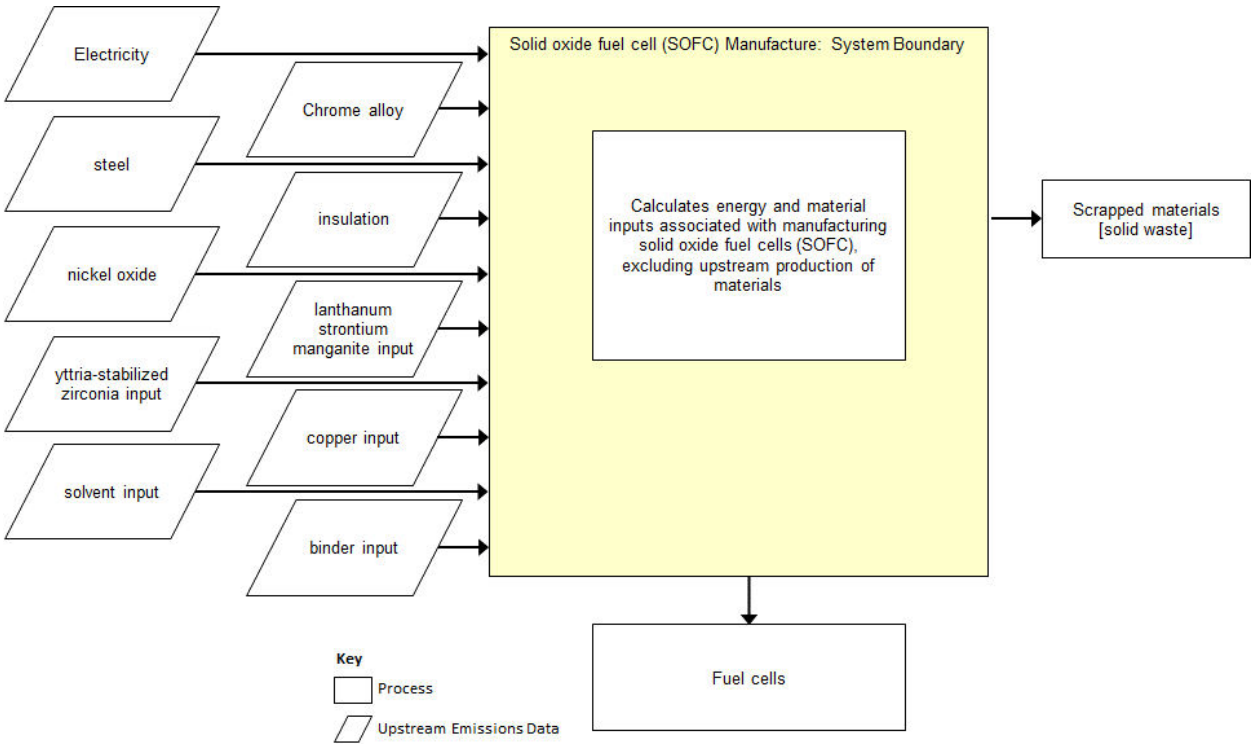

Table 1: Unit Process Input and Output Flows

Flow Name	Value	Units (Per Reference Flow)
Inputs		
Electricity	**3.23E+02**	**kWh**
Chrome alloy input [material]	**9.85E+00**	**kg**
Steel input [material]	**4.33E+00**	**kg**
Insulation input [material]	**1.30E+00**	**kg**
Nickel oxide input [material]	**1.95E-01**	**kg**
Lanthanum strontium manganite input [material]	**2.71E-01**	**kg**
Yttria-stabilized zirconia input [material]	**4.72E-01**	**kg**
Binder input [material]	**3.53E-01**	**kg**
Solvent input [material]	**7.50E-01**	**kg**
Copper input [material]	**1.20E-01**	**kg**
Outputs		
Fuel cells [material]	**1.00E+00**	**Reference flow**
Scrapped materials [solid waste]	**1.72E-01**	**kg**

* **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.

Staffel et al. 2011 — Staffell, Iain, Andrew Ingram and Kevin Kendall. 2011. Energy and Carbon Payback Times for Solid Oxide Fuel Cell Based Domestic CHP.Journal of Hydrogen Energy. Vol 37. pg 2509-2523

V. Karakoussis et al., 2000 — V. Karakoussis,et al. 2000. The Environmental Impact of Manufacturing Planar and Tubular Solid Oxide Fuel Cells.Journal of Power Sources. Vol 101. http://www.researchgate.net/profile/Matthew_Leach4/publication/223662684_The_environmental_impact_of_manufacturing_planar_and_tubular_solid_oxide_fuel_cells/links/5507fcb50cf2d7a28126d8e9.pdf (Accessed June 26, 2015)

Section III: Document Control Information

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