NETL Life Cycle Inventory Data
Process Documentation File

Process Name: Hydrogen Production

Reference Flow: 1 kg Hydrogen

Brief Description: Energy use, feedstock, and emissions from production of 1 kg of hydrogen at a hydrogen plant. Includes co-product steam, which is assumed to displace steam produced elsewhere.

Section I: Meta Data

Geographical Coverage: US **Region:** Not Applicable

Year Data Best Represents: 2004

Process Type: Energy Conversion (EC)

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

Allocation Applied: No

Completeness: Individual Relevant Flows Recorded

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:

None.

Tracked Input Flows:

Natural gas USA [Natural gas (resource)]	*Amount of natural gas used as both feed and fuel in the production of hydrogen*
Power [Electric power]	*Amount of electricity input to hydrogen production*

Tracked Output Flows:

Hydrogen	*1 kg reference flow*
Steam	*Co-product steam produced by the H2 plant, which displaces production from a dedicated steam process.*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage3_O_Hydrogen_Production_2010.01.xls*, which provides additional details regarding relevant, calculations, data quality, and references.

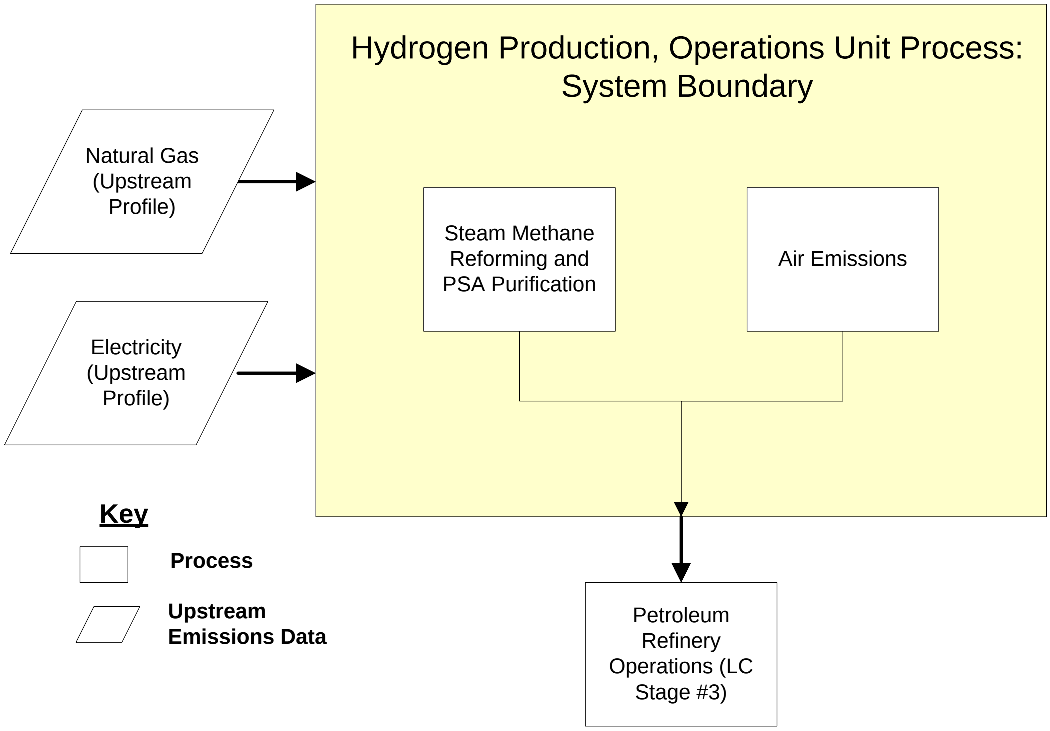
Goal and Scope

The scope of this unit process accounts for the feedstocks, fuels, and emissions associated with the production of hydrogen. Natural gas is input to the process both as food and as feedstock. Electricity and natural gas are considered to be the sole input flows for plant operation. Emissions from the extraction/ production of these inputs are calculated outside the boundaries of this process in proprietary GaBi data sets. Hydrogen and steam are co-products of the system.

Boundary and Description

Figure 1 provides an overview of the boundary of this unit process. The boundaries of this unit process start with the delivery of natural gas feedstock, natural gas fuel, and electricity to the hydrogen plant and end with the output of hydrogen. The reference flow of this unit process is the production of one kg of hydrogen gas. This unit process does not include the compression and transport of hydrogen to the consumer. As shown in Figure 1, the hydrogen produced in this unit process is incorporated into the Life Cycle (LC) Stage #3 of the petroleum LCA.

Figure 1: Unit Process Inputs, Outputs, and Boundaries



Three references were used to develop this unit process. Boyce et al (2004) provide the feedstock and utility requirements for old and modern hydrogen plants. The venting of carbon dioxide from hydrogen production (which is due to the reaction of steam with carbon in the feedstock) is based on emissions factors developed by API (URS 2004). The greenhouse gas and other air emissions associated with the combustion of natural gas for the generation on the site of the hydrogen plant were estimated using EPA AP42 emission factors (EPA 1998).

This unit process uses feedstock and utility data representative of a modern hydrogen plant. The key distinction between modern and old hydrogen plants is the method of purifying the product stream. Modern hydrogen plants use pressure swing absorption (PSA) to purify hydrogen gas, while older hydrogen plants use solutions of potassium carbonate or monethanolamine (MEA) to purify hydrogen gas (Boyce et al 2004). Hydrogen plants with PSA can produce hydrogen gas with a higher purity and are more efficient.

Steam is a co-product of hydrogen production. This unit process shows co-product steam as an output of the unit process. No allocation of inputs and emissions between the hydrogen and steam products is applied in this unit process. It is recommend that when this unit process is incorporated within a life cycle model, the co-product steam from hydrogen production is assumed to displace steam produced elsewhere, thus resulting in a reduction in emissions from the hydrogen plant.

Table 1 shows relevant properties and assumptions used to calculate the inputs and outputs for hydrogen production. **Table 2** provides a summary of modeled input and output flows. Additional detail regarding input and output flows, including calculation methods, are contained in the associated DS.

Table 1: Properties of the Hydrogen Production Facility Inputs and Outputs

Property	Value	Reference
Natural Gas HHV MJ/ m^3 (Btu/ft^3)	38 (1020)	URS 2004
Energy Content of Steam MJ/kg (Btu/lb)	2.745 (1180)	PE America
Steam Credit per Volume of Hydrogen Produced kg/m^3 (lb steam/ ft^3 hydrogen)	1.44 (0.09)	Boyce et al 2004

Table 2: Unit Process Input and Output Flows

Flow Name*	Value	Units (Per Reference Flow)
Inputs		
Natural gas USA [Natural gas (resource)]	**3.61**	**kg**
Power [Electric power]	**0.204**	**kWh**
Outputs		
Hydrogen	1	kg
Steam	44.0	MJ
Carbon dioxide [Inorganic emissions to air]	10.3	kg
Carbon monoxide [Inorganic emissions to air]	2.05E-03	kg
Methane [Organic emissions to air (group VOC)]	5.49E-05	kg
Nitrous oxide (laughing gas) [Inorganic emissions to air]	5.38E-05	kg
Nitrogen dioxide [Inorganic emissions to air]	6.84E-03	kg
Sulphur dioxide [Inorganic emissions to air]	1.47E-05	kg
Particulate Matter, unspecified [Other emissions to air]	1.86E-04	kg
NMVOC	1.34E-04	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

Boyce et al 2004 — Boyce, C.A., Crews, M.A., Ritter, R. 2004. "Time for a New Hydrogen Plant?" *Hydrocarbon Engineering*.

	February, 2004. http://www.cbi.com/about/articles/CBI_HydrocarbonEngineering_Feb04.pdf#search=%22%22refiners%20have%20a%20number%22%20tindall%22 (Accessed February 11, 2010).
EPA 1998	EPA. 1998. *AP-42, Fifth Edition, Volume I, Chapter 1.4: Natural Gas Combustion*. U.S. Environmental Protection Agency. http://www.epa.gov/ttnchie1/ap42/ch01/ (Accessed February 11, 2010).
URS 2004	URS Corporation. 2004. *Compendium of Greenhouse Gas Emissions Methodologies for the Oil and Gas Industry*. American Petroleum Institute. http://www.api.org/ehs/climate/new/upload/2004_COMPENDIUM.pdf (Accessed February 11, 2010).

Section III: Document Control Information

Date Created: February 12, 2010

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

Revision History: Original/no revisions

How to Cite This Document: This document should be cited as:

NETL (2009). *NETL Life Cycle Inventory Data – Unit Process: Hydrogen Production, Operation.* U.S. Department of Energy, National Energy Technology Laboratory. Last Updated: December 2009 (version 01). www.netl.doe.gov/energy-analyses (http://www.netl.doe.gov/energy-analyses)

Section IV: Disclaimer

Neither the U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL) nor any person acting on behalf of these organizations:

A. Makes any warranty or representation, express or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this document, or that the use of any information, apparatus, method, or process disclosed in this document may not infringe on privately owned rights; or

B. Assumes any liability with this report as to its use, or damages resulting from the use of any information. Apparatus, method, or process disclosed in this document.

Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by NETL. The views and opinions of the authors expressed herein do not necessarily state or reflect those of NETL.