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Hydrogen technologies — Methodology for determining the greenhouse gas emissions associated with the production, conditioning and transport of hydrogen to consumption gate

Annex D

Hydrogen Production Pathway – Steam cracking

Contents

Annex D
(informative)

Hydrogen Production Pathway – Steam cracking

D.1 Process description and overview

D.1.1 Description

Steam cracking is a petrochemical process in which saturated hydrocarbons are broken down into smaller, often unsaturated, hydrocarbons. It is the principal industrial method for producing the lighter alkenes (or commonly olefins), including ethene (or ethylene) and propene (or propylene). Steam cracker units are facilities in which a feedstock such as naphtha, liquefied petroleum gas (LPG), ethane, propane or butane is thermally cracked using steam in cracking furnaces to produce olefins. Propane dehydrogenation process may be accomplished through alternative commercial technologies. The main differences between each of them concerns the catalyst employed, design of the reactor and strategies to achieve higher conversion rates.

Olefins are useful precursors to myriad products. Steam cracking is the core technology that supports the largest scale chemical processes, i.e., ethylene and propylene. Ethane, propane and butane from natural gas liquid (NGL) and naphtha from petroleum refineries are the dominant feedstock for steam crackers[i]. With ethane as feedstock, hydrogen share in products is high, about 4% by mass[ii].

Process description co-product hydrogen from naphtha steam cracking:

- Steam cracking of naphtha is used to generate olefin, mainly to produce plastics. First, naphtha is pre-heated to a temperature of 550-600°C while steam at a temperature of 180-200°C is added. Then, the naphtha is heated up to a temperature of 800-850°C where the hydrocarbon chains are cracked into ethylene and propylene as main products as well as various other compounds as co-products, thereof about 1% hydrogen by mass, or 2.63% by energy.

D.1.2 Overview

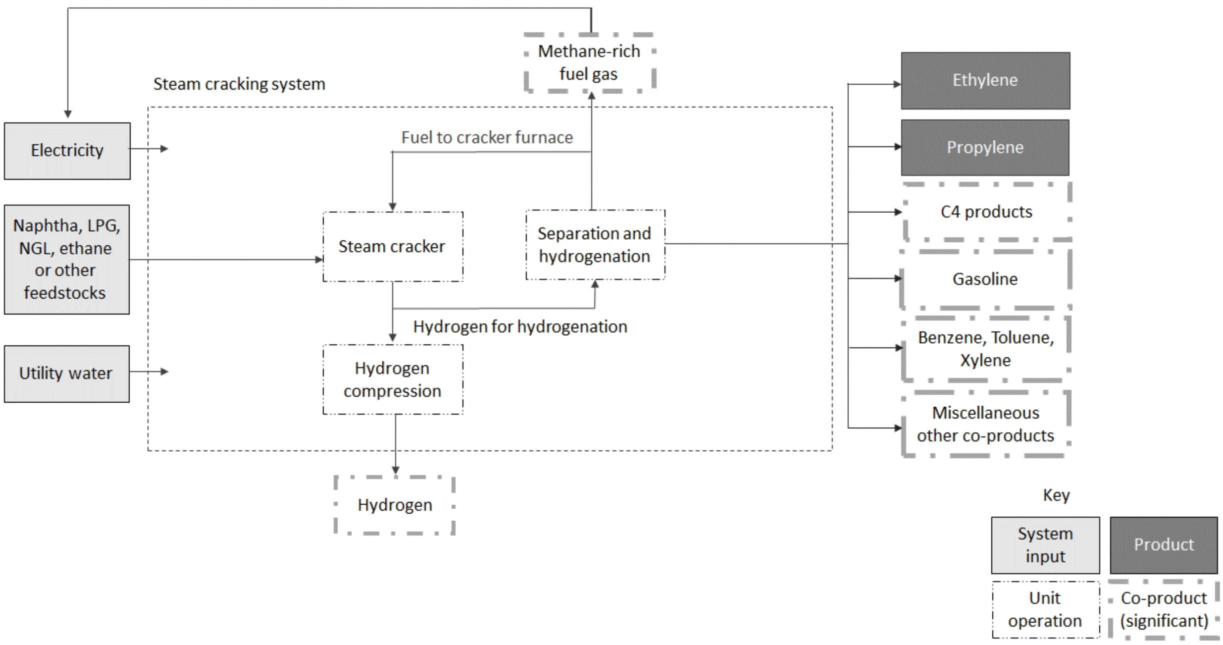

Figure D.1 — Example of process diagram for hydrogen co-product from steam cracking

Of importance is how the hydrogen is used in practice. In this example ~2/3 of hydrogen is used as part of the fuel gas for the furnace and 1/3 is part of fuel gas used to fire a boiler[iii]. Alternatively, hydrogen may be separated and purified (e.g., via pressure swing adsorption) and compressed for export to the merchant markets.

D.2 Emission sources and inventory

D.2.1 Emission sources

Emissions from steam cracking are related to the combustion of fuel gas generated from the cracking process, which is used to provide the required heat to the process. Combustion occurs at the furnace and boilers). The emissions depend on the feedstock used in the steam cracking process (naphtha, ethane, propane, butane, or gasoil).

D.2.2 Emission inventory

Key life cycle GHG emissions in sources in co-produced hydrogen from steam cracking process are described in Table D.1.

Table D.1 — Key life cycle GHG emission sources in hydrogen production for steam cracking

Process unit/stage	Key emissions sources	Other emissions sources
Feedstock (naphtha, LPG, NGL, etc) production	• Electricity and/or fuel combustion for producing feedstock	• Flaring and venting
Feedstock transport to steam cracking facility	• Electricity and/or fuel combustion for transport	
Electricity and heat generation for facilities with onsite combined heat and power generation unit	• Fuel combustion	
Hydrogen purification	• Electricity and/or heat for operation of the relevant purification units	
Hydrogen compression and storage	• Electricity for compression and storage maintenance	
Disposal of waste products (where not valorised)	• Electricity and fuel combustion for transport of waste products	

D.3 Emission Allocation

D.3.1 Emission inventory using Attributional Approach

Using an attributional approach, the energy use and emission burdens associated with the steam cracking process are allocated to unit products (i.e., olefin products and H_2) by their physical attributes. The olefin products can be valorised by their energy or mass. The appropriate physical attribute for emissions allocation can be decided by how the co-products are valorised. The formulas below provide example of emissions allocation to product *i* among all coproducts by their mass shares. Similar formulas can be used for emissions allocation by energy shares of coproducts. After proper allocation of process emissions to

the hydrogen coproduct, the additional emissions associated with purification and compression of hydrogen should be added to calculate the carbon intensity of hydrogen.

$$E_{Product\ i}(\frac{g}{kg}\ or\ \frac{mg}{kg}) = \frac{Emission_{unit\ process} \times MassAF_i}{Mass_i} \quad \text{(D1)}$$

Where,

$MassAF_i = \frac{Mass_i}{\sum Mass_i}$

D.3.2 Emission inventory using Consequential Approach

In a consequential approach, other considerations associated with valorising hydrogen as a coproduct can be accounted for. These include counterfactual scenarios for hydrogen use in a typical steam cracking plant, such as its internal use for heating and/or power generation as mentioned in D.1.2.

In a counterfactual scenario where hydrogen in the fuel gas is used within the steam cracking plant for its heating value (e.g., for process heat or as a fuel for CHP unit), diverting such hydrogen for export to the merchant market will require a substitute heat input (e.g., natural gas) to compensate for the heat deficit created by such diversion. The emissions associated with natural gas supply chain and combustion to substitute the same amount of heat lost due to hydrogen export would then be added to the exported hydrogen co-product. Emissions associated with purification and compression of hydrogen will be additional.[ii]

D.4 Information to be reported

Table D.2 —shows the information to be reported for hydrogen produced from steam cracking process.

Table D.2 — Information to Be Reported for Hydrogen production from steam cracking

Category	**Matters to be identified**
Facility details	• Facility identity • Facility location • Commencement of facility operation • Main climatic and meteorological data (Atmospheric pressure, average ambient temperature, average relative humidity)
Product specifications	• Production pathway • Hydrogen produced (kg) • Hydrogen temperature and pressure at the gate • Hydrogen purity level at the gate • Specification of contaminants
GHG emissions overview	• Emissions intensity of hydrogen batch [$kgCO_2e/kgH_2$]
Batch details	• Beginning and end of batch dates • Batch quantity [kg]
Electricity	Location based emissions accounting • Quantity of purchased grid electricity [kWh] • Location based emission factor used [gCO_2e/kWh] • Quantity of sold electricity [kWh]

	Market based emissions accounting • Quantity of purchased grid electricity [kWh] • Quantity of contracted electricity [kWh] and/or quantity of associated GOs or RECs • Residual electricity [kWh] • Residual mix emission factor [gCO_2e/kWh] • Type of GOs or RECs On-site electricity generation • Quantity of on-site generation [kWh] • Emission factor for on-site generation (as applicable) [gCO_2e/kWh]
Other utilities	• Source/s of water • Source/s of steam • Quantity of purchased water [kg] • Quantity of purchased steam [kg] • upstream emission factor for water [kgCO_2e/kg] • upstream emission factor for steam [kgCO_2e/kg]
Fuel use	• Types of fuels combusted • Quantities of fuel combusted [L, kg] • Relevant emissions calculation or factors used [kgCO_2e/relevant unit of fuel] • Emissions intensity of fuel used, including all emissions associated with fuel extraction, transporting to a processing plant, and processing [gCO2e/MJ]
Process	• Reactor type • Hydrogen purification technology and capacity • Quantity and type of vented GHG gases [kg] • Quantity and type of flared GHG gases [kg]
Hydrogen purification	• Electricity consumption [MWh]
Hydrogen compression	• Electricity consumption [MWh]
feedstock	• Type of feedstock • Feedstock composition • Quantity of feedstock used [kg or MJ] • Upstream emission factor for the feedstock [kgCO_2e/kg]
Waste and other Co-products	• Quantity of olefins produced [kg] • Emissions allocated to olefins [kgCO_2e/kg] • Quantity of steam sold [kg] • Emissions allocated to steam [kgCO_2e/kg] • Quantity of electricity sold (MWh) • Emissions allocated to electricity sold [gCO_2e/kWh]

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