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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 C

Hydrogen Production Pathway – Chlor-Alkali

Contents

Annex C
(informative)

Hydrogen Production Pathway – Chlor-alkali

C.1 Process description and overview

C.1.1 Description

The chlor-alkali industry produces chlorine (Cl_2), sodium hydroxide (NaOH) and hydrogen (H_2) through the electrolysis of brine. Electrolysis technologies in chlor-alkali plants include mercury, diaphragm, and membrane. Mercury technology is the oldest and mostly prevalent in Europe, while diaphragm is prevalent in the United States and membrane technology mostly used in Japan[i]. The key advantage of mercury technology is producing highly concentrated sodium hydroxide at 50% with lower brine quality requirement, but with higher electricity consumption and adverse environmental impact. The advantages of diaphragm technology are lower electricity consumption and lower quality of raw material required but requires higher energy for concentrating sodium hydroxide[i]. The processes of the three different technologies are shown in Figure C.1.[ii]

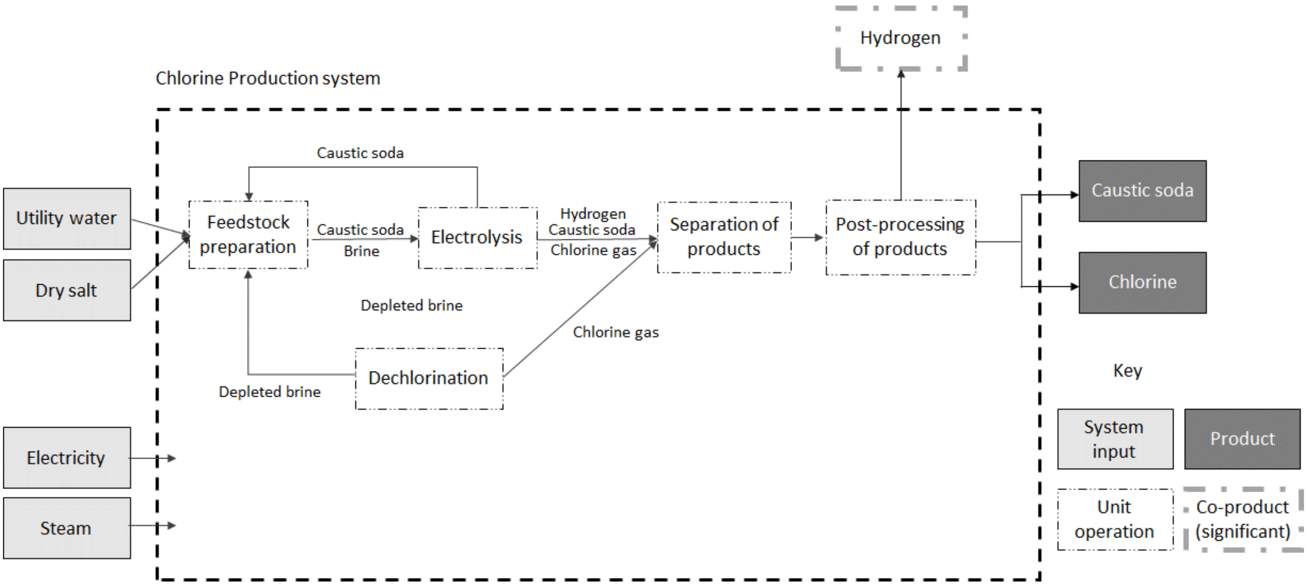

Figure C.1 — An example of process diagram for hydrogen co-produced from chlor-alkali process

The electrolysis of brine (sodium chloride or potassium chloride KCl) produces Cl_2, NaOH (or potassium hydroxide [KOH]), and H_2 as follow:

$$2\ NaCl + 2\ H_2O \rightarrow Cl_2 + H_2 + 2\ NaOH$$

Chlorine and sodium hydroxide are the main products from electrolysis with 46.4% and 52.3% mass share, respectively, while hydrogen's share is only 1.3%. The hydrogen from chlor-alkali plants has high purity (>99%)[iii]. The co-produced hydrogen may be sold in the merchant market, used internally for its heating value, or vented as a waste stream.

C.1.2 Overview

Chlor-alkali plants vary by their final products, which includes hydrochloride (HCl), sodium hypochlorite (NaClO), ethylene dichloride (EDC), vinyl chloride monomer (VCM) as shown in Figure C.2. Given the variability of the chlor-alkali processes, system boundaries and final products, it is important to assign the energy use and emissions to the various products using appropriate allocation methods.

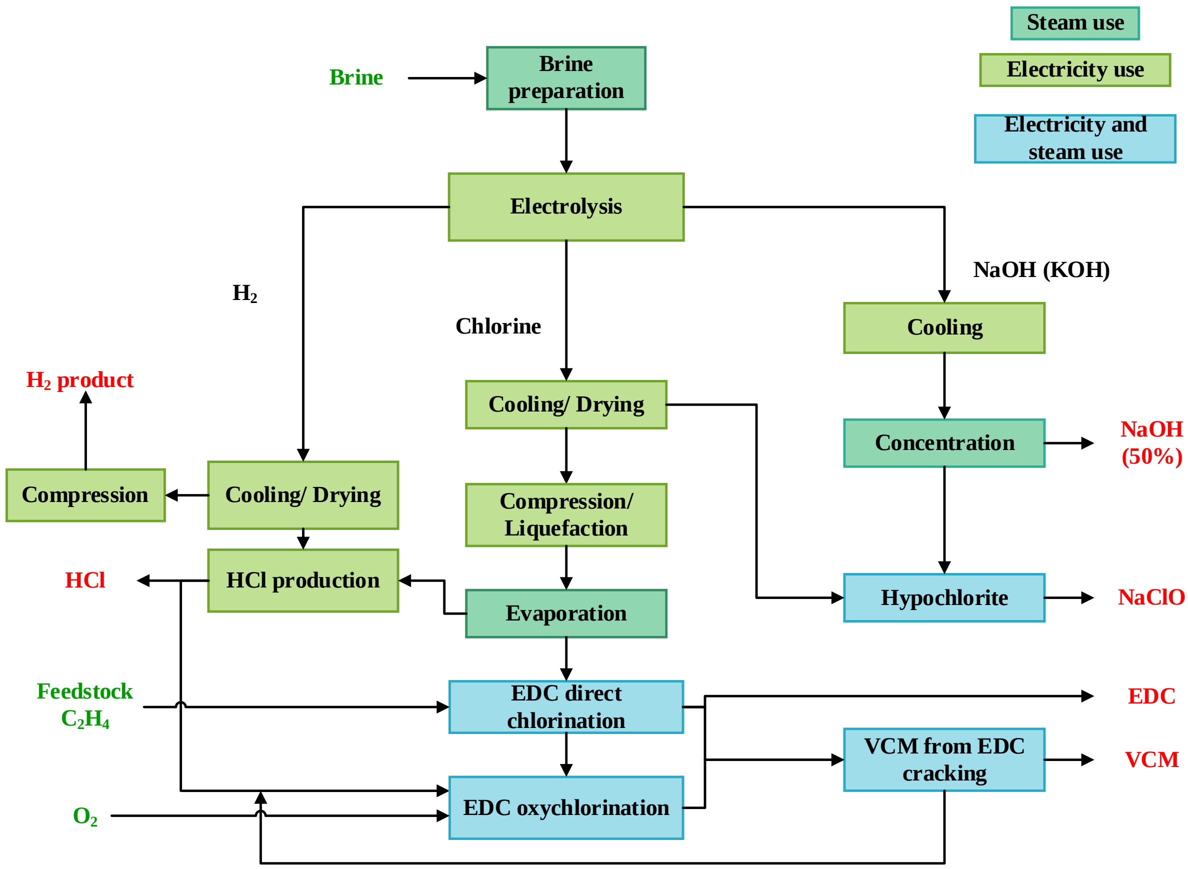

Figure C.2 — An example of the various possible products from chlor-alkali plant (adopted from Vyawahare et al)[ii]

C.2 Emission sources and inventory

Key life cycle GHG emissions in sources in co-produced hydrogen from chlor-alkali process are described in Table C.1.

Table C.1. Key life cycle GHG emission sources in co-produced hydrogen from chlor-alkali process

Process unit/stage	Key emissions sources	Other emissions sources
Brine supply and preparation	• Electricity and/or fuel combustion	
Electrolysis of brine	• Electricity for electrolyser unit	
Electricity and heat generation for facilities with onsite combined heat and power generation unit	• Fuel combustion	
Steam generation	• Fuel combustion	
Hydrogen cooling/drying	• Electricity and/or heat for relevant units	
Hydrogen compression and storage	• Electricity/Fuel for compression and storage	

C.3 Emission Allocation

C.3.1 Emission inventory using Attributional Approach

Using an attributional approach, the energy use and emission burdens associated with the chlor-alkali process are allocated to unit products (i.e., Cl_2, NaOH/KOH and H_2) by their physical attributes. Since Cl_2 and NaOH (or KOH) are not valorised by their energy, the appropriate physical attribute for emissions allocation among Cl_2, NaOH and H_2 is by their mass shares. The formulas below provide emissions allocation to product *i* among all coproducts. After proper allocation of process emissions to the hydrogen coproduct, the additional emissions associated with drying, cooling and compression of hydrogen should be added to calculate the carbon intensity of hydrogen.

$$E_{Product\ i}(\frac{g}{kg}\ or\ \frac{mg}{kg}) = \frac{Emission_{unit\ process} \times MassAF_i}{Mass_i} \quad \text{(C1)}$$

Where,

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

C.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 chlor-alkali plant, such as its internal use for heating and/or power generation or venting it as a waste as mentioned in C.1.1.

In a counterfactual scenario where hydrogen is vented, the only relevant processes for co-product hydrogen are related to hydrogen post-processing shown in Figure C.2 (i.e., drying, cooling and compression), which are needed to valorise hydrogen for export to the merchant market. In this case, the environmental burden is not assigned to the chlor-alkali process. Furthermore, credits associated with voided venting of hydrogen might be considered if its indirect effect on global warming is to be considered.

In a counterfactual scenario where hydrogen is used within the chlor-alkali 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 drying, cooling and compression of hydrogen will be additional.[iii]

C.4 Information to be reported

Table C.2 —shows the information to be reported for hydrogen produced from chlor-alkali process.

Table C.2. Information to be reported for hydrogen production from chlor-alkali process

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 technology • 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 [gCO_2e/MJ]
Hydrogen cooling	• Electricity consumption [MWh]
Hydrogen compression	• Electricity consumption [MWh]
Brine feedstock	• Type of brine • Brine composition • Quantity of brine used [kg] • Upstream emission factor for brine [kgCO_2e/kg]
Waste and other Co-products	• Quantity of chlorine produced [kg] • Emissions allocated to chlorine [kgCO_2e/kg] • Quantity of NaOH/KOH produced [kg] • Emissions allocated to NaOH/KOH [kgCO_2e/kg] • Quantity of electricity sold (MWh) • Emissions allocated to electricity sold [gCO_2e/kWh]

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