CertifHy Scheme

Subsidiary Document

CertifHy-SD Carbon footprint calculation

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Status of this document

This document, CertifHy-SD Carbon footprint calculation, is a subsidiary document to the 'CertifHy Scheme' of CertifHy.

Change history

Version	Date	Description
0.7	2022-06-08	Endorsed as CertifHy deliverable
1.0	2023-02-14	CertifHy Scheme subsidiary document, following endorsement by CertifHy SC Annex B.3: Switch to "CO_2 value adjusted value based allocation", following decision of CertifHy SC

1 Introduction

1.1 General

CertifHy's mission is to advance and facilitate the production, procurement, and use of hydrogen fulfilling ambitious environmental criteria in order to protect the climate and improve the living conditions of humankind.

CertifHy wants to contribute to and promote an environmentally, socially and economically sustainable production of hydrogen in all uses including energy, mobility, chemical conversion, etc.

1.2 CertifHy

CertifHy is a European Certification Scheme for hydrogen fulfilling specific criteria that sets out statements and principles regarding the operation of the scheme. It covers the entire upstream supply chain to the production device exit gate at defined quality. The scheme is continuously reviewed and improved by means of a multi-stakeholder dialogue.

The core features of the scheme are openness, reliability, integrity, quality and transparency. Those values are the fundamentals of CertifHy's relationship with its Stakeholders.

The scheme is complemented by Procedure Documents, which further provide detailed descriptions of the procedures.

1.3 Purpose

The purpose of this document is to specify the method used to calculate the carbon footprint within CertifHy. It is a subsidiary document to the CertifHy Scheme.

2 Definitions

This document relies on definitions provided in the CertifHy Scheme and the Hydrogen Criteria documents.

Definition of terms used in this document are provided in the table below.

Term	Definition
Carbon footprint of a product (CFP)	Sum of GHG emissions and GHG removals in a product system, expressed as CO_2 equivalents (CO_2e) and based on a life cycle assessment using the single impact category of climate change. The result of the quantification of the CFP is expressed in mass of CO_2e per functional unit.
Partial Carbon Footprint of a product	Sum of GHG emissions and GHG removals of one or more selected process(es) in a product system, expressed as CO_2 equivalents and based on the selected stages or processes within the life cycle, per unit amount of product.
Well-to-gate Carbon Footprint of an input	Partial carbon footprint of an input, considering all the processes in the product system associated to the supply of the input from extraction of raw materials to delivery to the input gate of the hydrogen production device, expressed in mass of CO_2e per unit amount of input. Also simply referred to as Carbon Footprint of the input
Emission Factor of an input	Sum of GHG emissions and GHG removals, considering all the processes in the product system associated to the supply of the input from extraction of raw materials to delivery to the input gate of the hydrogen production device, as well as oxidation of the carbon of which it is composed (if applicable), expressed in mass of CO_2e per unit amount of input.

3 Carbon footprint and emission factors of inputs

Notes:

- the Emission Factor of an input, a quantity that can be useful for calculating the Carbon Footprint of hydrogen produced from that input, is obtained by adding the GHG emissions from oxidation of the carbon of which it is composed to the input's Carbon Footprint at gate.
- For input that do not include carbon (e.g. electricity, steam), the Emission Factor and Carbon Footprint are identical quantities.

Annex A provides rules for the determination of the carbon footprint of specific inputs.

3.1 Data sources

The value of the carbon footprint and emission factors of substances constituting Inputs shall be derived from lifecycle emission data provided by a transparent database, scientific publication or legal sources in the country of hydrogen production, or disclosing process recognized by the CertifHy scheme.

3.2 Carbon Footprint of electricity from the grid

In locations where an electricity GO scheme is implemented and recognized by the CertifHy scheme, the Carbon Footprint of the electricity consumed shall be the GHG intensity of the electricity for which GOs were cancelled, or otherwise, the GHG intensity of the residual mix.

Where no GO scheme is implemented, the Carbon Footprint of the electricity consumed shall be the average GHG intensity of the electricity injected in the two preceding calendar years into the domain grid from which the electricity is obtained. If the electricity is obtained from a separate grid that is not taken into account in the calculation of a domain residual mix, the Carbon Footprint considered shall be the average GHG intensity of electricity injected into the separate grid.

As GHG emissions from capital goods are not considered, the Carbon Footprint of electricity is considered to be equal to zero if its Energy Source is wind, solar, or hydroelectric.

3.3 Carbon Footprint and Emission Factor of natural gas from the gas grid

In locations where a gas GO scheme is implemented, the Carbon Footprint of the natural gas consumed shall be calculated from the carbon footprint of the gas injected into the grid for which GOs were cancelled, or otherwise, the carbon footprint of the residual mix. GHG emissions from gas transport need to be added.

Where no GO scheme is implemented, the Carbon Footprint of the natural gas consumed shall be the average GHG intensity of the natural gas injected in the two preceding calendar years into the country grid from which the gas is obtained.

4 Calculation of the Carbon Footprint of hydrogen

The Carbon Footprint of the hydrogen is calculated following an attributional approach in accordance with ISO 14067.

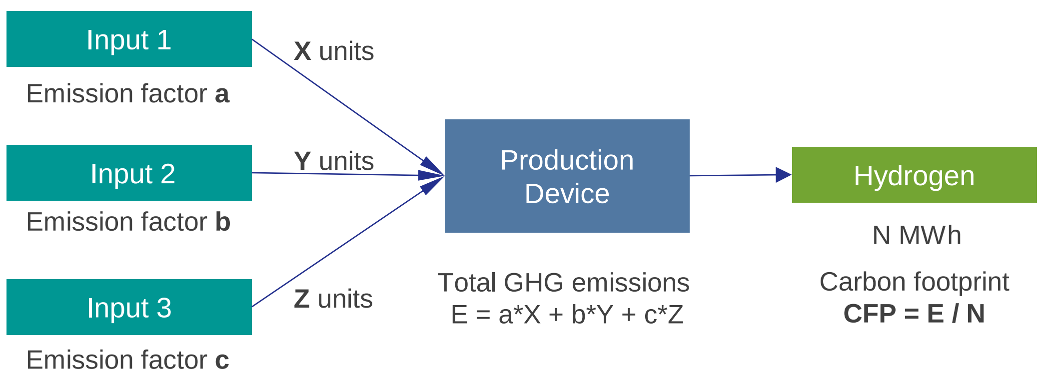
Annex B provides detailed indications for calculation of the Carbon Footprint for selected hydrogen production pathways.

When calculating the Carbon Footprint of the produced hydrogen from the Emission Factor of the inputs as indicated below, if the Production Device generates (non-CO_2) GHG emissions beyond those accounted for by the inputs' Emission Factors, these shall be added to the amount of emissions calculated from the Emission Factors as shown below for determining *Total GHG emissions*.

The amounts of Input, Output and waste are those measured for the production batch, or those assigned to the production batch on the basis of ratios determined from measured amounts over longer periods of time.

4.1 Hydrogen produced as a single output of the Production Device

When the Production Device has hydrogen as a single output, the Carbon Footprint of hydrogen of a given production batch shall be calculated as follows:



Emissions related to the required processing of waste and effluents from hydrogen production must be included as well.

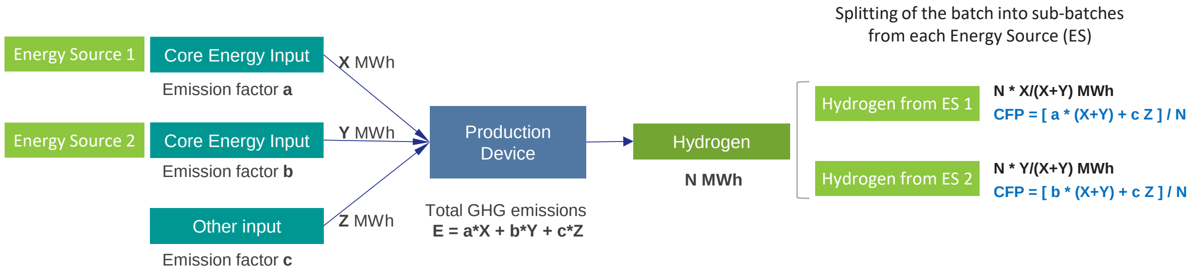
4.2 Production processes with a single Core Energy Input that may be produced from various Energy Sources

Note: Core Energy Input and Energy Source are defined in *CertifHy-SD Hydrogen Criteria*.

This section covers processes where the produced hydrogen derives from a single Core Energy Input, that may be produced from various Energy Sources. This is the case for instance for the production of hydrogen by water electrolysis using electricity from different primary energy sources, or the production of hydrogen from biomethane originating from a mixture of biomass feedstocks or from Natural Gas composed of Biomethane and fossil methane.

When part of the energy input consumed for a given hydrogen production batch is identified as generated from a specified energy source, a sub-batch is defined for the hydrogen produced from that specific energy source.

This sub-batch is assigned a specific Carbon Footprint, calculated considering the Emission Factor specific to energy input from that Energy Source, as shown below.



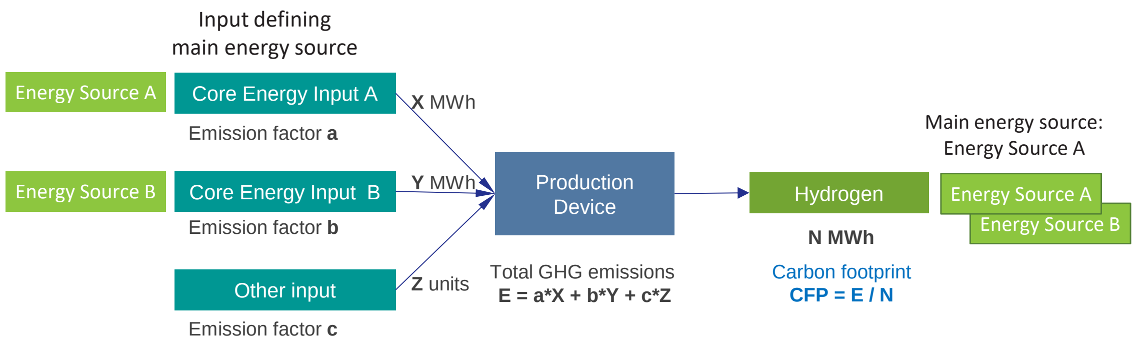
Emissions related to the required processing of waste and effluents from hydrogen production must be included as well, together with the emissions from "other inputs" for the purpose of the above calculation.

4.3 Production processes with multiple distinct Core Energy Inputs

This section covers the case where the hydrogen generation process requires the combination of different Core Energy Inputs. In this case, hydrogen production from one of the Energy Inputs only is not possible. and the production batch can therefore not be split into hydrogen from each of the Core Energy Inputs.

The main energy source of the production batch is the energy source from which the largest energy share of the hydrogen is derived. The CertifHy Certificate includes additional fields for indicating the other energy source(s) from which the energy content of the hydrogen is derived.

The Carbon Footprint of the batch is calculated as indicated for the case where hydrogen is a single output of the Production device as defined in section 4.1 above.



Emissions related to the required processing of waste and effluents from hydrogen production must be included as well as well, together with the emissions from "other inputs" for the purpose of the above calculation.

4.4 Hydrogen from a Production Device co-producing other products

This section covers the case of hydrogen produced as a product together with one or more other products.

In this case, the share of GHG emissions to be assigned to the produced hydrogen needs to be determined as described below, in application of ISO 14067.

The production process needs first to be subdivided into sub-processes, in order to identify which inputs and intermediate products contribute to hydrogen production, so that the attributes of the hydrogen may be correctly determined in accordance with the properties of the relevant inputs. These sub-processes may have either single or multiple outputs.

Following this subdivision step, a procedure, called allocation, needs to be applied to the sub-processes with multiple outputs contributing to hydrogen production, in order to divide the relevant emissions for the sub-process between all its useful outputs, starting with the sub-processes that are the most upstream. The relevant emissions are those reflected by the footprint at sub-process input gate of the sub-process' inputs plus the sub-process' own process emissions.

Allocation of the relevant emissions shall be performed following the prescriptions of ISO 14067.

Annex A: Carbon Footprint of specific inputs

A.1. Carbon Footprint of steam used as input

Used energy content of steam

The used energy content of steam used as heat input is considered to be the enthalpy of the steam minus enthalpy of water at 100°C and at atmospheric pressure, i.e. 0,419 MJ/kg.

If the steam is consumed as feedstock, the used energy content is considered to be the enthalpy of the steam.

Origin of the steam

When the heat used to generate the steam is created by inputs derived from various energy sources, the share of steam from a given source is the share of input derived from that energy source in the total energy input contributing to the enthalpy of the steam.

Calculation of the steam's Carbon Footprint (gCO2e/MJ)

Steam from a boiler	*Carbon Footprint of the steam = Emission Factor of fuel or electricity used as heat source* ***x*** *amount of energy consumed by the boiler per unit of used energy in the steam*
Steam from cogeneration of heat and electricity	The greenhouse gas emissions shall be divided between the electricity and heat output in proportion to exergy content. The exergy content of the electricity output is assumed to be its energy content. The exergy content of the heat is found by multiplying the used energy content of the steam with the Carnot efficiency, C_h, calculated as follows: $C_h = (T_h - T_0)/T_h$ with T_h *=Temperature in kelvin of the steam at point of delivery* T_0 *=Temperature of surroundings, set at 273,15 kelvin (equal to 0 °C)* *Emission factor of the steam =* *exergy in the heat* ***/*** *total exergy in electricity and heat* ***x*** *emission factor of the energy input to the cogeneration unit*

Steam from high grade process heat - temp. of heat carrying medium from which is generated ≥ **650 °C*** [Subject to amendment following adoption of RED II delegated act on quantification of emission savings from use of renewable fuels of non-biological origin]	*Carbon Footprint of the steam = emission factor of the input from which heat is generated in the process / 90%*
Steam from low or medium grade process heat – temp. of heat carrying medium from which is generated < **650 °C** [Subject to amendment following adoption of RED II delegated act on quantification of emission savings from use of renewable fuels of non-biological origin]	*Carbon Footprint of the steam = emission factor of the input from which heat is generated in the process / 90%* **x** *k* k, correction factor accounting for the lower usefulness of the heat compared to high grade heat, calculated as follows: $k = (T_h - T_0)/T_h / 0{,}703$ with T_h =*Temperature in kelvin of the steam at point of delivery* T_0 =*Temperature of surroundings, set at 273,15 kelvin (equal to 0 °C)* (0,703 is the Carnot efficiency for heat with a temperature of 650 °C)

* Temperature beyond which heat is qualified as high grade heat in an Interreg publication accessible through this link

Attributes of steam from a heat supply network

Heat injected into a steam network from a given source may be assigned to steam used from the same network for the purpose of defining the origin and emission factor of the steam, under the following conditions:

- The accumulated amount of heat injected into the steam network from designated sources is measured over each yearly quarter.
- The accumulated total amount of energy used from the steam network for any use where the steam used will be partly or wholly claimed to be energy from a designated source is measured over each yearly quarter.
- The accumulated amount of energy used from the steam network and claimed to be energy from any of the designated sources is measured over each yearly quarter.
- The accumulated amount over a yearly quarter of heat injected into the steam network from a designated source exceeds that required to balance the accumulated amount over that yearly quarter of energy claimed to be energy from that designated source for any use, taking into account a 10% heat loss in

each heat exchanger between the point of heat injection into the steam network and the point of steam delivery for use.

A.2. Carbon Footprint of waste used as input

Waste constituted of mixed non mechanically recyclable material that is required by law to be disposed of by incineration, if not disposed of in another legally acceptable way. Example: Refuse Derived Fuel	*Carbon Footprint of waste* = - *combustion emissions of the waste per unit of energy* + *emissions from waste transport beyond 50 km per unit of energy* Notes: - The above formula applies to any waste required by law to be incinerated, regardless of origin - The above formula is based on the premise that the reference end-of-life scenario of upstream products includes incineration of the mixed non-mechanically recyclable waste they generate, and that the upstream product's footprint is calculated accordingly, in application of ISO 14067.

Annex B: Renewable hydrogen share and hydrogen footprint calculation for specific processes

B.1. Alkaline or PEM water electrolysis

H_2 synthesis molar balance and required energy input	2 $H_2O(l)$ + electricity → 2 $H_2(g)$ + $O_2(g)$
Core energy input(s)	- Electricity for the electrolysis process
Other inputs or effluents of the production process contributing to the carbon footprint of the hydrogen	- Electricity for other uses than the electrolysis process - Make-up chemicals for electrolyte (KOH) - Water (when emissions related to water supply are not negligible)
Co-products	- Oxygen (if used)
Quantities to be measured for the production batch:	Inputs - Amount of electricity consumed by the production process, including ancillary functions (such as cooling) Output - Amount of H2 produced
Other quantities to be determined for the production batch:	- Consumption of chemicals - Water consumption when emissions related to water supply are not negligible
Additional information required	- Share of electricity consumption used for the electrolysis process
Part (%) of production batch from a designated energy source	Amount of electricity for the electrolysis process consumed from the designated energy source divided by the total amount electricity for the electrolysis process consumed for the production batch
Allocation to co-products	*Method of allocation of emissions to co-produced oxygen not yet adopted.*
Carbon Footprint of Hydrogen	Calculate the Carbon Footprint of Hydrogen from each Energy Source as indicated in section 4.2

B.2. Steam methane reforming (SMR) of natural gas or biomethane

This case does not consider the co-production of hydrogen and carbon monoxide.

H_2 synthesis molar balance and required energy input	Sum formula: $CH_4 + 2\ H_2O + Heat \rightarrow 4\ H_2 + CO_2$ Reforming $CH_4 + H_2O \rightarrow CO + 3\ H_2$ ΔH 206 kJ/mol WGS $CO + H_2O \rightarrow CO_2 + H_2$ ΔH -41 kJ/mol
Core energy input(s)	- Natural gas or biomethane used as feedstock - Natural gas, biomethane, or another energy carrier for heat
Other inputs or effluents of the production process contributing to the carbon footprint of the hydrogen	- Electricity - Water (when emissions related to water supply are not negligible)
Co-products	- Steam
Quantities to be measured for the production batch:	Inputs - Amount of natural gas consumed - Amount of electricity consumed Product Outputs - Amount of H_2 produced - Amount of useful heat generated in the form of steam (Enthalpy of produced steam - Enthalpy of corresponding condensed steam at 100°C) CO_2 emissions To be determined from the emission factors and measured quantities of the inputs minus the emission factors and measured quantities of the other outputs.
Other quantities to be determined for the production batch:	- Water consumption (when emissions related to water supply are not negligible)
Additional information required	- n/a
Part (%) of production batch from a designated renewable energy source	Amount of renewable gas consumed from the designated energy source divided by the total amount gas consumed for the production batch
Allocation to co-products	- Producer and consumers of steam shall apply the same allocation method. - If gas from multiple origins is used for the production batch, the amount of energy considered to be used for production of steam

	shall be allocated to each source proportionately to their contribution to the gas energy input
Carbon Footprint of Hydrogen	- Calculate Carbon Footprint of Hydrogen from each Energy Source as indicated in section 4.2, considering only gas consumption allocated to the hydrogen (see line above).

B.3. By-product hydrogen from chlor alkali electrolysis

H_2 synthesis molar balance and required energy input	2 NaCl + 2 H_2O + electricity → Cl_2 + 2 NaOH + H_2
Core energy input(s)	- Electricity
Other inputs or effluents of the production process contributing to the carbon footprint of the hydrogen	- Electricity for brine treatment - Heat for brine treatment - Vacuum salt (Sodium chloride – NaCl)
Co-products	- Hydrogen (H_2), Chlorine (Cl_2), Caustic soda (NaOH)
Quantities to be measured for the production batch:	Inputs - Amount of electricity consumed - Amount of heat consumed for brine treatment Product Outputs - Amount of H_2, Cl_2, and NaOH produced
Other quantities to be determined for the production batch:	- Consumption of vacuum salt based on stoichiometric ratio
Additional information required	- Share of electricity consumption used for the electrolysis process
Part (%) of production batch from a designated renewable energy source	Amount of electricity for the electrolysis process consumed from the designated energy source divided by the total amount electricity for the electrolysis process consumed for the production batch
Allocation to Hydrogen	- Emissions related to the consumed inputs shall be allocated to the hydrogen used in proportion to its economic value, with adjustment for value of CO2 emissions, by applying an allocation ratio *ah* calculated as follows: Calculation inputs: *vh*: market price per tonne of conventional hydrogen (3 year average based on latest Eurostat data) *vt*: total market value of all the co-produced chlor alkali products, including the hydrogen priced as conventional hydrogen assuming it is all used, per tonne of hydrogen generated (based on 3 year average prices using latest Eurostat data,

	considering co-production of 35,1 t of chlorine and 39,6 t caustic soda per tonne of generated hydrogen) *k*: proportion of price of EU CO_2 emissions allowance not reflected in market price of conventional hydrogen = 75% *q0*: GHG emissions of conventional hydrogen per tonne = 91 gCO2/MJ = 10,9 t CO2e/t *pc*: average spot price of European Emissions Allowances (EUA) in €/t CO_2 of latest year for which Eurostat price data for chlor alkali products is available *qe*: electrolyser GHG emissions in tonnes per tonne of hydrogen generated **Allocation ratio to the by-product hydrogen:** ***ah = (vh + k pc q0) / (vt + k pc qe)*** Note: This allocation results in the underlying by-product hydrogen value [*ah vt*] aligning with the value resulting from a lower assigned footprint vs natural gas based H2 [*vh* + *k (ah qe - q0) pc*] 3 year average price of chlor alkali products for 2019-2021 Hydrogen: 1560 €/t Chlorine: 192 €/t Caustic soda: 336 €/t Resulting total value of product output per tonne of hydrogen generated: *vt* = 21,63 k€ Average EUA spot price for 2021: 39,9 €/t Allocation ratio to the by-product hydrogen: *ah* = 8,4 %
Carbon Footprint of Hydrogen	*CFP = ah * GHG emissions from inputs in tonnes CO2e per tonne of hydrogen generated*