MULTIPLHY

Multimegawatt high-temperature electrolyser to generate green hydrogen for production of high-quality biofuels

Assessment of Hydrogen Certification Deliverable D6.2

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (now Clean Hydrogen Partnership) under grant agreement No 875123. This Joint Undertaking receives support from the European Union’s Horizon 2020 research and innovation programme, Hydrogen Europe and Hydrogen Europe research.

Grant agreement number 875123
Start: 01/01/2020 – Duration: 60 months

Document Classification

Title	Assessment of hydrogen certification
Deliverable	D6.2
Reporting Period:	RP3 M25-M42
Date of Delivery foreseen	M30, shifted to M39
Draft delivery date	M39
Validation date	M39; 30 March 2023

Authors	Jan Freymann, Sunfire
Work package	WP6 - Regulatory framework & guarantee of origin for the hydrogen (CERTIFHY)
Dissemination	PU = Public
Nature	Report
Version	*V1*
Keywords	Plan of action; Report

Document Validation

Partner	Approval (Signature or e-mail reference)
WP Leader	Rose de Lannoy
Coordinator (PC/SC)	CEA, SF
Others (if applicable)	Neste

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Table of Acronyms

AIB	Association of Issuing Bodies
CFP	Carbon Footprint
CO2	Carbon Dioxide
CCS	Carbon Capture and Storage
GHG	Greenhouse Gas(es)
GO	Guarantee of Origin
H_2	Hydrogen
HPU	Hydrogen Processing Unit
HTE	High Temperature Electrolyser
HVO	Hydrogen Vegetable Oil
PPA	Power Purchase Agreement
RED II	Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the Promotion of the Use of Energy from Renewable Sources (recast)
RFNBO	Renewable Fuels of Non-Biological Origin
RES	Renewable Energy Sources
SF	Sunfire GmbH
SOEC	Solid Oxide Electrolyser
SMR	Steam Methane Reforming
WG2	Working Group 2

Abstract

This deliverable report D6.2 assesses the certification of green hydrogen produced with high-temperature steam electrolysers based on solid oxide technology (SOEC) through the CertifHy platform. While low-temperature water electrolyser technologies such as PEM and Alkaline solely use electricity as energy input to produce hydrogen, SOEC additionally uses thermal energy that is provided in the form of water steam. While a CertifHy methodology has been in place for assessing electricity input, CertifHy has so far lacked a methodology for steam/heat input.

In this context, Sunfire and Engie together with Hinicio, the managing entity of CertifHy, developed a methodology to determine the renewable content and associated GHG emission of steam. According to the developed methodology, three key aspects of the steam supply configuration need to be assessed to determine the eligibility for hydrogen certification under CertifHy (green or low-carbon hydrogen guarantees of origin (GOs)):

1. the energy source(s) used to produce the steam to determine whether the steam is renewable or not
2. the generation process to determine how greenhouse gases (GHG) emissions of the energy inputs are allocated to the steam, and
3. the supply system complexity from which an electrolyzers is sourcing the steam determining how GHG emissions are allocated in a network with multiple sources and off-takers.

The energy supply strategy for MultiPLHY, which is relevant for certification purposes, includes better biomass certified renewable steam, as well as the sourcing of renewable electricity through purchasing GOs. This energy supply strategy enables the production and certification of 100% green hydrogen according to CertifHy rules.

In the course of the project, the consortium was asked by the Project Officer to also evaluate the issuance of hydrogen guarantees of origin through the Dutch national certification authority Vertogas following the implementation of a Dutch national system on hydrogen GOs. As CertifHy will seek recognition as “Independent Certification Scheme”, it has declared it will not issue hydrogen GOs where there is a national issuing body doing so. Therefore, the consortium decided to investigate the Dutch GO certification scheme, which will mirror the methodology developed in CertifHy. In January 2023, Vertogas merged with VertiQ, the competent authority for electricity Guarantee of Origin, to VertiCer.

Introduction

Hydrogen produced from RES can contribute substantially to decarbonize energy-intensive industries, with refineries being one of these hard-to-abate industries. Hydrogen plays a crucial part in refinery processes, offering an important point of leverage in cutting CO_2 emissions when produced from renewable energy sources.

The MultiPLHY project is a green hydrogen pilot project aiming to validate the industrial production and use of green hydrogen in a renewable products refinery using high temperature electrolysers (HTE) based on Sunfire proprietary solid oxide electrolysis technology (SOEC). The green hydrogen shall replace a portion of the hydrogen which is currently produced from fossil resources via Steam Methane Reforming (SMR) – and which creates substantial carbon emissions.

In the scope of Work Package 6 the goal is to prepare and execute an action plan for the purchase of renewable energy, to assess the certification of 'green' hydrogen and to issue Guarantees of Origin (GOs) for the produced hydrogen. This deliverable report D6.2 focuses on the assessment of certification of green hydrogen through the CertifHy platform.

This report starts by giving an overview of the systems specifications of MultiPLHY and the corresponding energy input shares for electricity and heat (chapter 1). Chapter 2 outlines key aspects of the CertifHy scheme. In Chapter 3 the report shows the approach and result of developing a CertifHy methodology for classifying steam input for HTE's as amendment to the current CertifHy scheme. Chapter 4 describes how hydrogen GOs shall be issued in the scope of MultiPLHY project in collaboration with CertifHy and the Dutch certification body Vertogas.

1. Hydrogen Production in MultiPLHY

Picture 1 HVO refinery, Rotterdam (Neste)

MULTIPLHY aims to install, integrate, and operate the world's first high-temperature electrolyser (HTE) system in multi-megawatt-scale (~2.4 MW) in Rotterdam, the Netherlands, to produce hydrogen (≥ 60 kg/h) for the refinery's processes. With the HTE, MULTIPLHY's electrical efficiency (85 $\%_{el,LHV}$) shall be at least 20 % higher than efficiencies of low temperature electrolysers.

The plant consists of two main aggregates: The high-temperature electrolyser HyLink from Sunfire ("Sunfire-HyLink" is the proprietary trademark of the product) and a Hydrogen Processing Unit (HPU) designed by Paul Wurth, responsible for compression and purification.

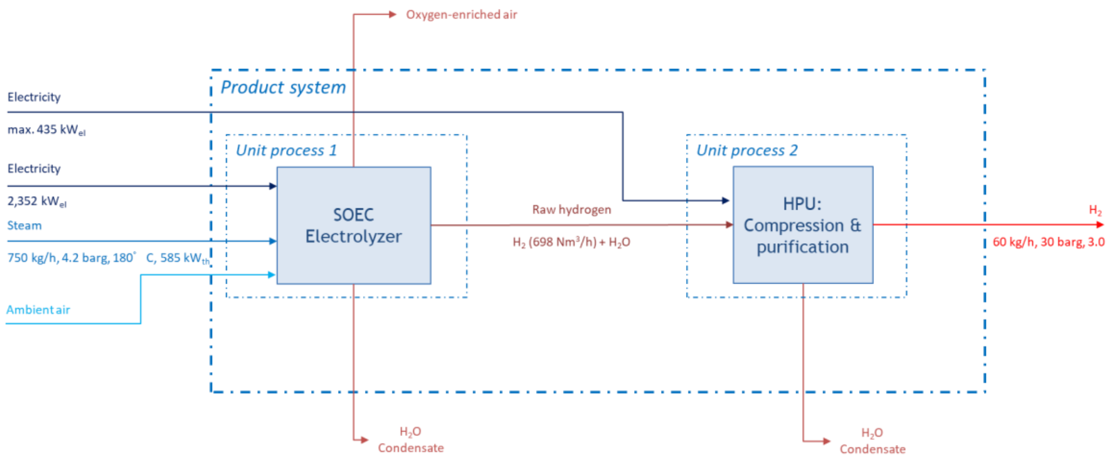

Figure 1 Energy flow diagram of the HTE plant of MultiPLHY

To produce the desired 60 kg/h of hydrogen, the HTE is supplied with 2,352 kW_{el} electricity and 585 kW_{th} steam. The hydrogen produced by HyLink is directed to the Hydrogen Processing Unit. The HPU compresses the hydrogen to approximately 30 bar(g), dries it and feeds it into the onsite hydrogen pipeline, with a total of max. 435 kW_{el} needed for this process. The injected hydrogen from the HTE plant is used in the downstream refinery processes. Based on the energy balance shown in Figure 1, the MultiPLHY system is supplied with electrical power of approximately 2,787 kW_{el} and 585 kW_{th} of heat to produce 60 kg/h of hydrogen at 30 bar(g), corresponding to a share of 82.7% electrical and 17.3% thermal energy input.

2. Hydrogen Certification with CertifHy

2.1 The CertifHy Scheme

CertifHy is a European hydrogen certification scheme. It started in 2014 and is now in the third phase of implementation. The initiative introduces an EU-wide Guarantee of Origin (GO) scheme for hydrogen, proving the renewable or low-carbon properties of hydrogen. The current third phase focuses on the roll out of a harmonized H_2 Guarantee of Origin market, the development of an updated version of the CertifHy GO scheme and the certification of hydrogen as a renewable fuel of non-biological origin (RFNBO).

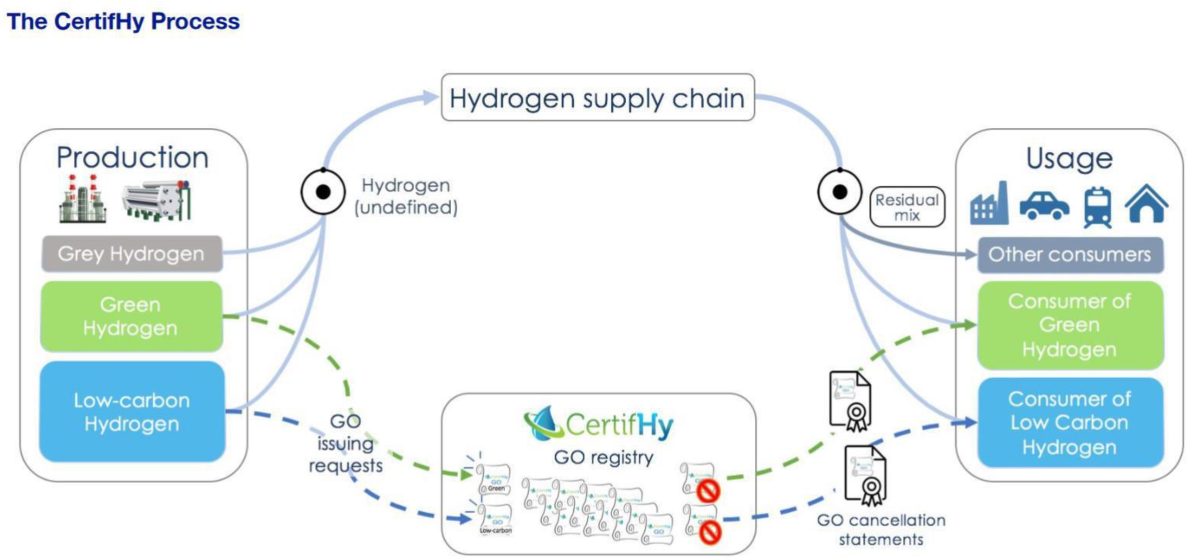

Figure 2 Simplified process description of the CertifHy GO

As shown in Figure 2, a CertifHy GO is an electronic document that guarantees and provides information to final consumers on the origin of hydrogen. It is comparable to already existing trading schemes for renewable electricity and biomethane, allowing customers and end-users to purchase the renewable properties, without being physically linked to the energy source.

2.2 Hydrogen Categories

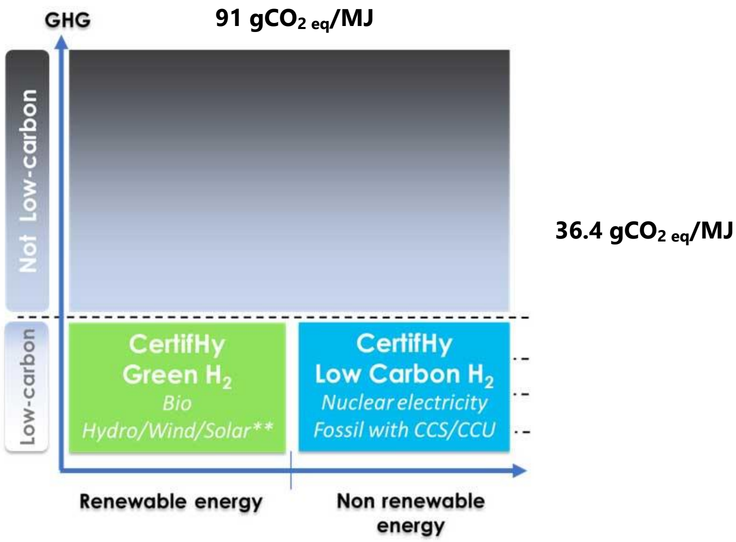

Figure 3 Categories of Hydrogen under CertifHy

For a production device to be eligible under the CertifHy scheme, the overall greenhouse gas footprint of the produced hydrogen must be lower than 91 $gCO_{2\,eq}$/MJ[1]. If this condition is fulfilled, CertifHy classifies hydrogen into three categories as shown in

Figure 3. Each category is determined by the sources of energy used to produce the hydrogen:

- **Grey Hydrogen (not eligible for CertifHy GOs):** Hydrogen derived from non-renewable energy sources with a greenhouse gas intensity above 36.4 gCO_{2eq}/MJ but below 91 gCO_{2eq}/MJ;
- **Low Carbon Hydrogen:** Hydrogen produced from non-renewable, low-carbon energy sources (e.g. nuclear or fossil SMR in combination with CCS) with a greenhouse gas intensity below 36.4 $gCO_{2\,eq}$/MJ; and
- **Green Hydrogen:** Hydrogen made from renewable energy produced from renewable sources as defined in the Renewable Energy Directive recast of 2018 (RED II) with a greenhouse gas intensity below 36.4 gCO_{2eq}/MJ.

[1] Based on a benchmark process, which is state-of-the art steam reforming of natural gas in large installations. The value refers to MJ of hydrogen, using the lower calorific value

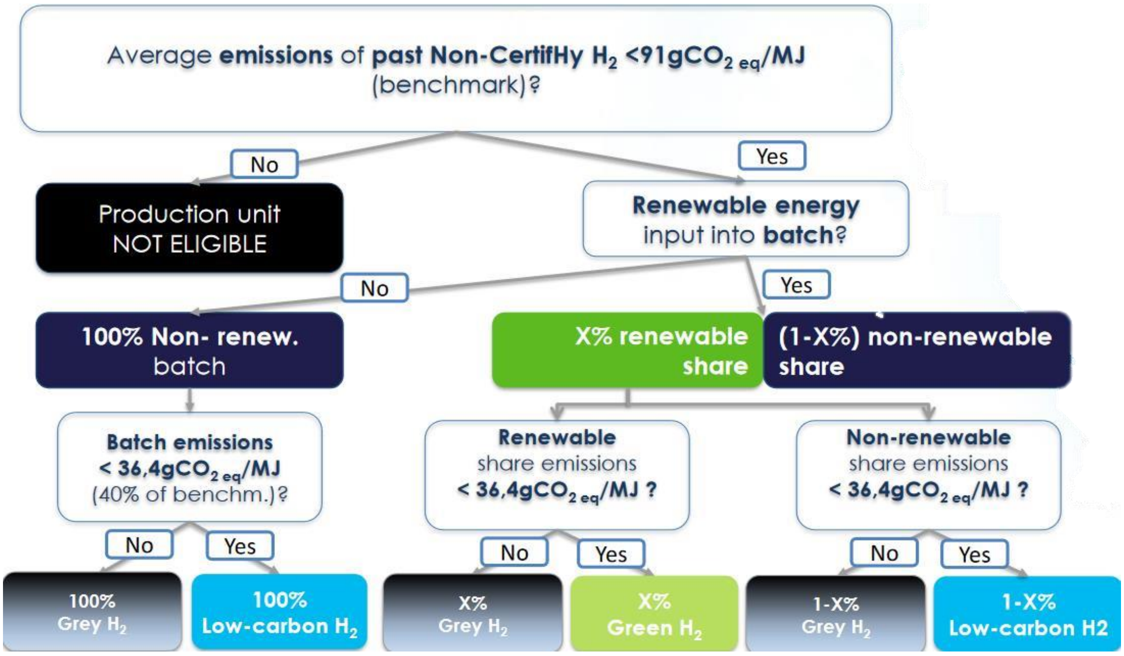

Figure 4 CertifHy Decision Tree

To determine if a certain production batch of hydrogen is eligible for green or low-carbon GO, CertifHy developed a decision-supporting framework (see Figure 4).

In a first step, the greenhouse gas intensity of the whole past hydrogen production is evaluated. If it exceeds the benchmark intensity of hydrogen produced from natural gas (i.e. 91 gCO_{2eq}/MJ), the production batch of hydrogen will not be eligible within the CertifHy scheme. If the greenhouse gas intensity is below the benchmark intensity, the quality of hydrogen is further evaluated.

In a second step, the source of the energy provided to produce the hydrogen is evaluated. If the energy originates from different sources, the hydrogen batch will be divided up into the relative shares of the different energy input sources and is then further evaluated. Each energy input source is categorized as either renewable or non-renewable source based on the definition of the Renewable Energy Directive recast of 2018 (RED II).

In a third step, the different categories of energy sources (renewable or non-renewable) are evaluated concerning their greenhouse gas intensity. If the renewable share has a greenhouse gas intensity below 36.4 $gCO_{2\ eq}$/MJ, the produced H2 qualifies as **Green H_2**, if not, then it is considered grey (and not eligible for CertifHy GOs). If the non-renewable share, has a greenhouse gas intensity below 36.4 $gCO_{2\ eq}$/MJ, the produced H2 qualifies as **Low-carbon H_2**, if not, then it is considered grey (and not eligible for CertifHy GOs).

2.3 CertifHy and MultiPLHY

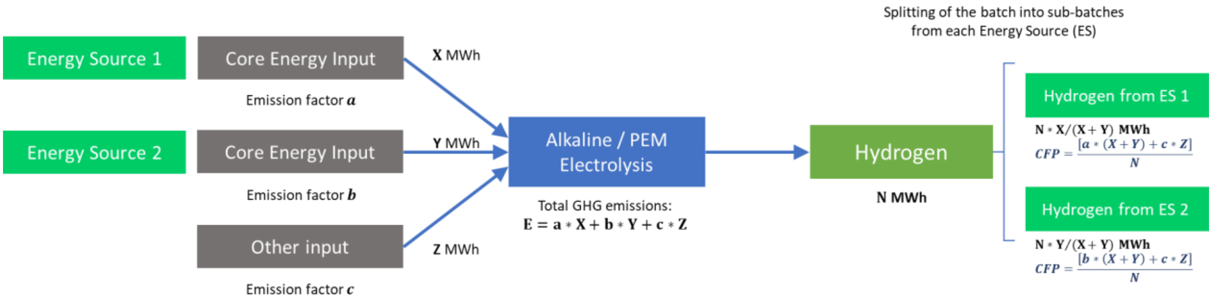

Figure 5 CFP calculation with single energy input from multiple sources[2]

At project start in 2020, the CertifHy scheme offered a clear methodology (see Figure 5) for calculating and allocating carbon emissions for both single- and multisource electrical input for electrolysis. For every input source, a sub-batch is defined for the produced hydrogen and assigns a specific footprint, considering the emission factor of the source.

In addition to electricity, however, SOEC also requires steam input for hydrogen production. At project start, the CertifHy scheme did not provide a methodology for the calculation and allocation of emissions of one or multiple steam sources. This required the MultiPLHY consortium to approach CertifHy to develop a methodology for calculating and allocating GHG emissions for the generation of steam as energy input for the solid oxide electrolyser. The process for developing this new methodology is outlined in Chapter 3.

3. Development of CertifHy Methodology for Steam Electrolysis

3.1 Approach

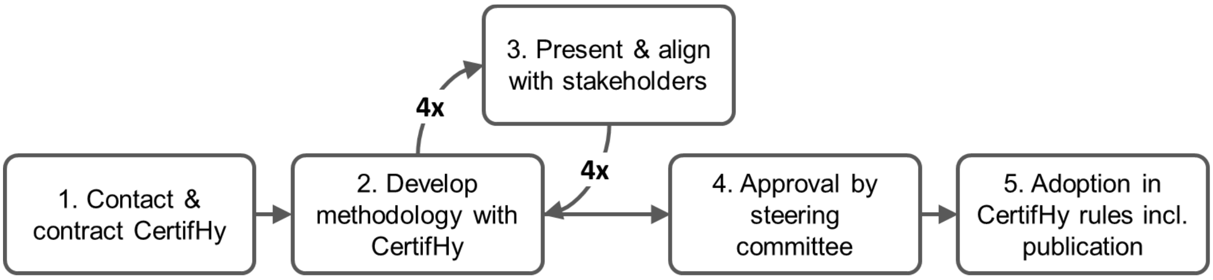

Figure 6 Process for developing a new CertifHy methodology

The new methodology was developed in close collaboration with Hinicio, who is managing the CertifHy platform, as well as aligned with CertifHy stakeholders. In a first step, Sunfire approached CertifHy to close a consulting contract with the goal to develop a methodology for calculating the CFP for steam input and amend the existing certification scheme. In a second step, Sunfire developed a methodology with Hinicio and presented and aligned the results in four iterations with the stakeholders from CertifHy Working Group 2 (WG2), a consortium of operators of H_2 production sites. The process started in 2021 and ended with a final endorsement by the working group in March 2022. The endorsed draft was then formally approved by the Steering Committee in autumn of 2022 and included into the CertifHy rules.

[2] Source: CertifHy Scheme, Subsidiary Document on Carbon Footprint Calculcation; first versions of the document only focused on water electrolysis with PEM or Alkaline electrolyzers not including SOEC

3.2 Results

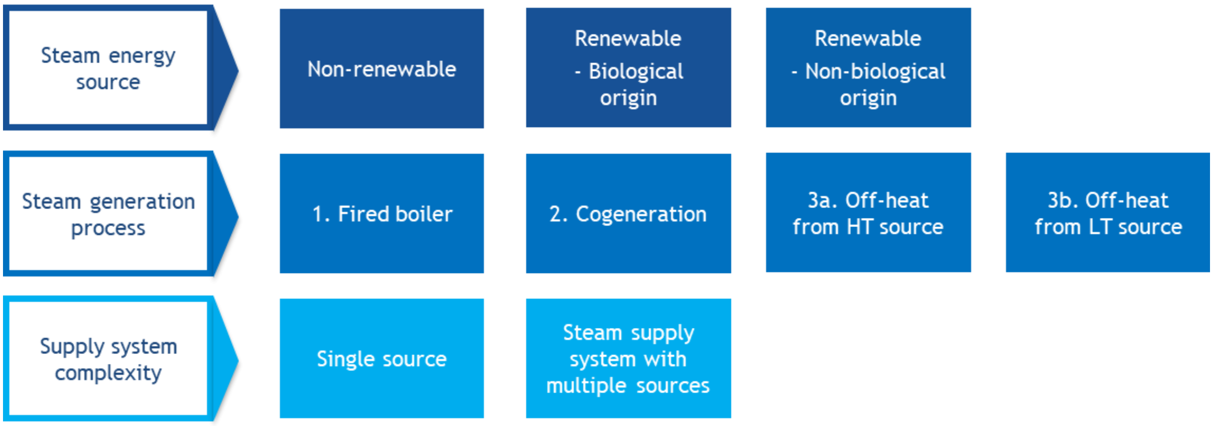

Figure 7 Key steam supply configuration aspects for calculating CFP

To determine the eligibility for hydrogen certification under CertifHy (green or low-carbon hydrogen GOs) three key aspects of the steam supply configuration need to be assessed: the energy source(s) used to produce the steam, the generation process and the supply system complexity from which an electrolyzers is sourcing the steam. The steam energy source determines whether the steam is renewable or not. The generation process determines how greenhouse gases (GHG) emissions of the energy inputs are allocated to the steam. Lastly, an approach was developed for allocating GHG emissions in a complex steam network with multiple sources and off-takers.

3.2.1 Steam Energy Source

The steam energy source determines whether steam is “renewable steam”. Following RED II definitions, steam is renewable if it is generated from renewable energy sources such as heat from solar thermal energy or biomass. For the hydrogen to be classified as ‘green’ under the CertifHy scheme, it is mandatory that the steam energy source is renewable. Hence, any non-renewable sources therefore only allow for a low-carbon hydrogen classification at best. Industrial off-heat, or ‘waste heat’, also must originate from renewable sources to qualify steam as renewable steam.

3.2.2 Steam Generation Process

The steam generation process determines the calculation of the CFP. Depending on the generation process, different allocation methods must be used (see

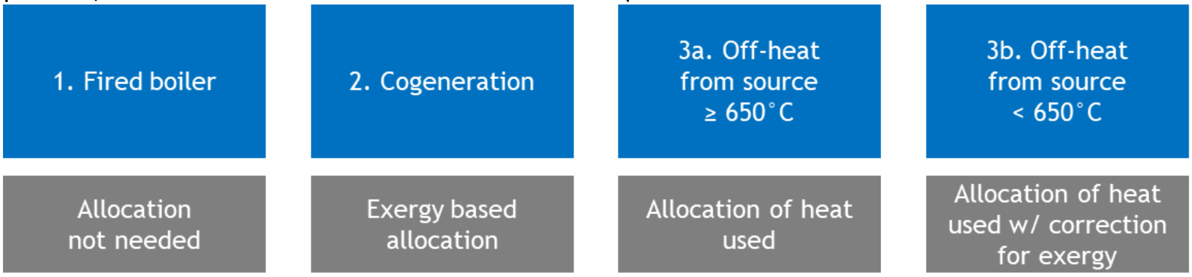

Figure 8). In general, the steam's footprint is determined by the footprint of energy used to generate the heat from which steam is generated. When the heat generating device has other purposes than producing steam, allocation of GHG emissions between different output products is required.

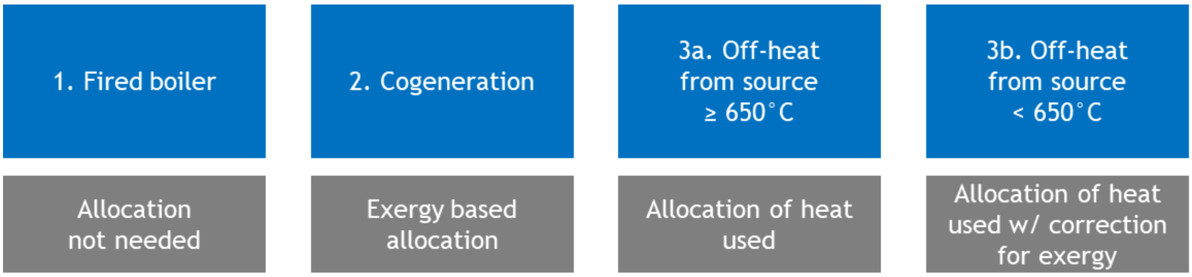

Figure 8 Steam generation process allocation methodology

1. *Fired boiler*

When using fired boilers for steam production, the methodology is straightforward. The amount of energy consumed per unit of used energy in steam to run the boiler is multiplied by the emission factor of the used fuel or electricity to calculate the steam CFP.

Emission factor of steam = *emission factor of fuel or electricity used x amount of energy consumed per unit of used energy in steam*

2. *Cogeneration*

In a cogeneration scenario when both electricity and heat are produced the emissions are allocated based on the exergy content of the products. Consequently, the Carnot factor is applied to the steam energy as specified in RED II to account for the useable energy in the steam. As the energy output of the steam source is split between electricity and heat, the emissions also need to be split accordingly, resulting in an emission split taking both the cogeneration and the Carnot factor into account. The exergy content of the electricity output is assumed to be its energy content. The exergy content of the heat is calculated by multiplying the used energy content of the steam with the Carnot efficiency C_h.

$C_h = (T_h - T_0)/T_h$ *with T_h =Temperature in K of the steam at point of delivery, T_0 =Temperature of surroundings, set at 273,15 K*

Emission factor of steam = *exergy in the heat / total exergy in electricity and heat x emission factor of the energy input to the cogeneration unit*

3. *Off-heat*

Lastly, steam can also be generated from off-heat. Off-heat can be separated into two categories with the heat grade being determined by the temperature of the heat source, not that of the heat carrying medium:

a) High grade process heat (≥ 650 °C): For steam from high grade process heat, the steam footprint is calculated using the emission factor of the heat generating input and by accounting for heat transfer losses (division by 90%). Heat losses from the heat originating process are not carried over as the used heat is a by-product.

Emission factor of steam = Em. fact. of heat generating input (g_{CO2e} / MJ_{LHV}) */ 90%*

b) Low or medium grade process heat (< 650°C): For steam from low or medium heat, a correction factor k is introduced, accounting for the lower usefulness of the heat compared to high grade heat. The correction factor k achieves this through expanding on the Carnot efficiency by dividing it by the Carnot efficiency at 650 °C (0,703): ***k*** = C_h / 0,703.

Emission factor of steam = Em. fact. of heat generating input (g_{CO2e} / MJ_{LHV}) */ 90% x* ***k***

The methodology for both high and low/medium process heat is subject to amendment following the adoption of RED II delegated act on quantification of emission savings from use of renewable fuels of nonbiological origin. Additionally, it is important to consider that off-heat is only considered renewable if the heat source is renewable as well (see Chapter 3.2.1).

3.2.3 Supply System Complexity

Lastly, with multiple heat sources within the steam supply system, allocation of emissions to the steam output can be difficult. Complex steam supply systems therefore necessitate clear allocation guidelines. A quantification approach based on "average" steam properties across the whole system was deemed inappropriate, since averaging doesn't allow to distinguish between fossil energy based and renewable energy-based steam within one system. This limits the benefits in terms of footprint quantification when introducing low carbon energy sources to the system. Also, the calculation of average steam properties requires the disclosure of steam properties for all sources. The proposed approach therefore is based on the application of "mass balance" principles to energy inputs and outputs in each loop. This allows for an assignment of a steam supply from a steam network to a designated source and aims to reduce complexity for determining renewable origin and GHG footprint.

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 following a mass-balance approach:

- 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.

4. Hydrogen Certification

At the beginning of the project, the MultiPLHY consortium aimed at requesting the issuance of hydrogen guarantees of origin through the CertifHy platform. Over the course of the project, this developed into certification through the national Dutch certification body VertiCer which has a process planned to mirror the certification methodology of CertifHy. With the goal to achieve 100 % green hydrogen production, a renewable electricity and steam supply strategy was developed that would satisfy CertifHy's (therefore also the anticipated VertiCer) Green H_2 GO requirements:

(i) Energy inputs are of renewable origin, and

(ii) The combined CFP of the electricity (82.7%) and steam (17.3%) hydrogen batches is below the 36.4 $gCO2_{eq}$/MJ threshold.

The certification strategy was developed in close alignment with CertifHy and Vertogas (which merged with CertiQ in January 2023 to VertiCer) to derive an action plan.

4.1 Energy Supply Strategy

In a first step, Sunfire calculated the required energy inputs. Due to surging electricity prices in the course of 2022, Sunfire developed different operating scenarios, each with a different amount of required electricity and steam. At this point in time, these scenarios in conjunction with electricity price volatility, will be used to inform a preferable operating scenario.

Based on the required energy input, Neste and ENGIE developed a renewable electricity supply strategy based on the purchase of GO.

The steam is planned to be sourced by Neste from a nearby energy supplier. The steam shall be certified by the "better biomass" certification system. Better biomass is considered as 100 % renewable. With a GHG intensity of 20 $gCO2_{eq}$/MJ, it would meet the 36.4 $gCO2_{eq}$/MJ threshold and thus allows for green hydrogen certification in CertifHy (and eventually VertiCer). The energy supplier provides steam to Neste's low pressure steam system, which feeds the electrolyser (and other processes). Based on the developed methodology for allocating GHG emissions in complex steam supply systems, it is required to select one (of many) steam sources and determine the renewable content and GHG emissions of that source (provided double counting is avoided). In the case of MultiPLHY, Neste selected the better biomass steam as input stream for the calculation – which fully covers the required steam demand of the electrolyser.

4.2 Hydrogen Certification Strategy

The original goal as agreed per grant agreement was to certify hydrogen via the CertifHy platform. Upon request by the Project Officer, the consortium was asked to also evaluate the issuance of hydrogen guarantees of origin through the Dutch national certification authority Vertogas following the implementation of a Dutch national system on hydrogen GOs, implementing the EU Renewable Energy Directive for guarantees of origin. Through this administrative act, Vertogas was selected as official Dutch certification body for hydrogen.

Following discussions with both CertifHy and Vertogas, the consortium will issue guarantees of origin through Vertogas. As CertifHy will seek recognition as "Independent Certification Scheme" by the Association of Issuing Bodies (AIB), it has declared it will not issue hydrogen GOs where there is a

national issuing body doing so. However, Vertogas will mirror rules and methodologies developed by CertifHy and thus apply the developed steam methodology in the scope of the MultiPLHY project.
In January 2023, Vertogas merged with VertiQ, the competent authority for electricity Guarantee of Origin, to VertiCer. Until further notice, both founding organisations, Vertogas and CertiQ, continue their activities while rules and functioning of the new organisation are under finalisation.

The preliminary understanding of the process for the issuing of Guarantee of Origin via the Dutch scheme is depicted in Figure 9 and is pending final validation by VertiCert. Neste as hydrogen producer will oversee submitting the registration form, signing the settlement agreement with the metering company and the participant agreement with VertiCer before the start of operation. During operation, Neste will select traders and send sustainability statements to VertiCer.

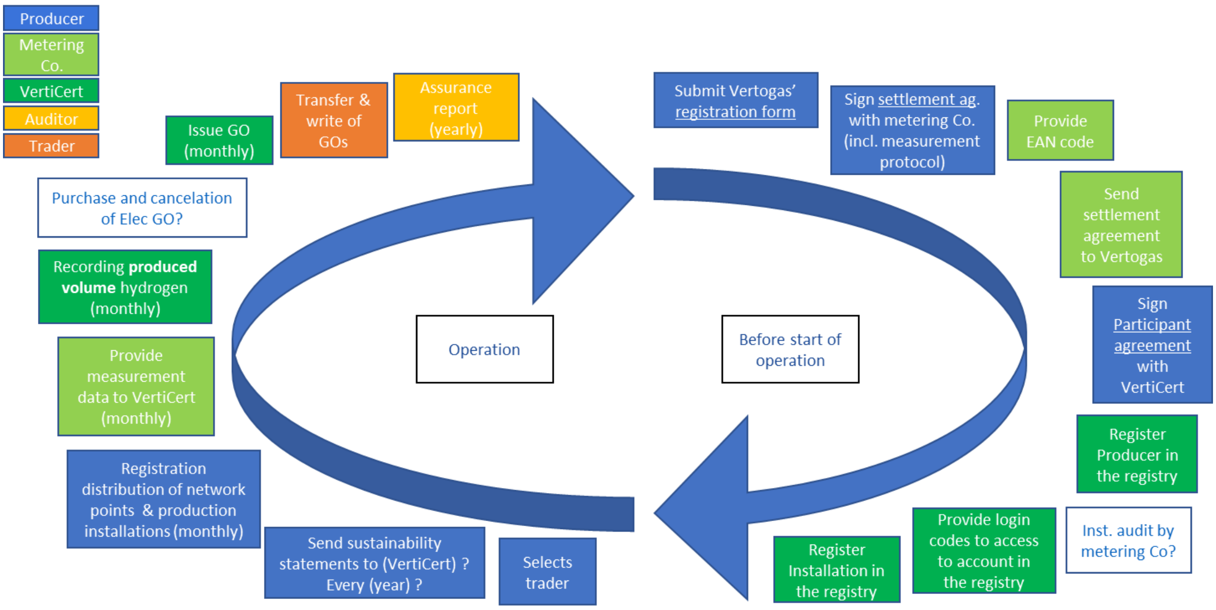

Figure 9 Certification process

The overall certification process will follow an agile approach of joint learning between the MultiPLHY consortium and VertiCer as MultiPLHY is amongst the first pilot projects requesting issuance of guarantees of origin under the Dutch scheme. For this reason, the current process is a mere indication of the required steps.

5. Conclusion

This deliverable report D6.2 assessed the certification of green hydrogen through the CertifHy platform. In this context, Sunfire and Engie have investigated the requirements to fulfil the green hydrogen criteria defined within CertifHy. The key goal was to develop a methodology to determine the renewable content and associated GHG emission of steam as one of the two energy sources used to produce hydrogen via solid oxide electrolysis (SOEC). While a methodology has been in place for electricity input, CertifHy has so far lacked a methodology for steam input.

To determine the eligibility for hydrogen certification under CertifHy (green or low-carbon hydrogen GOs) for steam, three key aspects of the steam supply configuration must always be assessed: the energy source(s) used to produce the steam, the generation process and the supply system complexity from which an electrolyzers is sourcing the steam. The steam energy source determines whether the steam is renewable or not. The generation process determines how greenhouse gases (GHG) emissions of the energy inputs are allocated to the steam. Lastly, an approach was developed for allocating GHG emissions in a complex steam network with multiple sources and off-takers.

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