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Date: 26 October 2015
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1 Adopted approach for the development of the CertifHy Guarantee of Origin (GoO) scheme

1.1 Introduction

The approach described hereafter is the outcome of a development process and repeated consultations carried out between April and September 2015. Annex 1 contains the last consultative report which has been used as basis for the present report.

Based on the analysis performed and feedback received, the three following essential requirements were identified:

- The greenhouse gas (GHG) emissions intensity (based on a Life-Cycle Analysis (LCA) approach) of the hydrogen (H₂) produced by a facility, which participates to the Green hydrogen GoO scheme, even, must not be excessively high also for the hydrogen generated without a GoO.
- The scheme needs to support also the commercialisation of low-GHG emissions hydrogen, even when it is not of renewable origin (“dual purpose scheme”).
- The approach needs to provide a way for defining the GHG content of hydrogen produced with generation of a GoO, but sold without it, and hence belonging to the “residual mix”.

1.2 Adopted approach

The adopted approach is designed to:

1. allow the generation of GoOs both for (i) CertifHy Green hydrogen (combining renewable origin with low GHG emissions) and for (ii) hydrogen that carries a low level of GHG emissions (applying the same low GHG emissions criteria as for CertifHy Green hydrogen), hereafter referred to as “CertifHy Low-GHG hydrogen”
2. structurally ensure that the GHG emissions intensity of any non-certified hydrogen produced by a facility producing CertifHy Green hydrogen or CertifHy Low-GHG hydrogen does not exceed that of the benchmark process, i.e. steam methane reforming (SMR) of natural gas.

To that end, the following conditions for producing CertifHy Low-GHG and/or CertifHy Green H₂ are defined:

- Only facilities producing H₂ with GHG emissions lower than the benchmark value - 91.0 gCO₂eq/MJ¹ - since sign up or over the preceding 12 months are eligible.
- Under the additional conditions listed further below, these facilities will be able to produce

1. CertifHy Low-GHG H₂

¹ This value has been calculated within the CertifHy project in: Altmann, M., Weindorf, W.: Extended Life-cycle Analysis of Hydrogen Production, Deliverable No. 2.3, 3 July 2015; the benchmark value should be re-evaluated regularly to accommodate for relevant changes such as e.g. efficiency improvements in the benchmark process.
² whichever duration is the shorter
2. CertifHy Green H₂ in proportion of the share of renewable energy in the non-ancillary energy used.

- The further conditions are the following:
  
  **Condition 1**: The emissions associated to CertifHy Green H₂ and CertifHy Low-GHG H₂ must be lower than the Low Emissions Threshold, set at 36.4 gCO₂eq/MJ, i.e. benchmark value minus [60%]⁴

  **Condition 2**: H₂ produced by this facility that is neither CertifHy Green nor CertifHy Low-GHG must have emissions lower than the benchmark value.

Notes:

- CertifHy Green hydrogen is also CertifHy Low-GHG hydrogen: both must meet the same Low Emissions Threshold.

- The above requirements do not exclude reducing the quantity of CertifHy Green H₂ or CertifHy Low-GHG H₂ generated in order to offset excessive emissions of the residual mix of the facility (non-CertifHy Low-GHG and non-CertifHy Green H₂), nor allocating zero emissions to these products. Examples of such offsetting approaches are provided in Annex 2, however development of the needed detailed requirements for their implementation is outside the scope of the CertifHy project.

- Unless offsetting is applied, Condition 1 implies that CertifHy Low-GHG H₂ and CertifHy Green H₂ can only be generated using pathways with emissions lower than the Low Emissions Threshold.

1.3 Adopted definition of CertifHy Green Hydrogen

The following definition for CertifHy Green Hydrogen is derived from the adopted approach:

**CertifHy Green Hydrogen definition**

CertifHy Green hydrogen is hydrogen from renewable sources that is also CertifHy Low-GHG-emissions hydrogen

Hydrogen from renewable sources is hydrogen belonging to the share of production equal to the share of renewable energy sources (as defined in the EU RES directive) in energy consumption for hydrogen production, excluding ancillary functions.

CertifHy Low-GHG hydrogen is hydrogen with emissions lower than the defined CertifHy Low-GHG-emissions threshold, i.e. 36.4 gCO₂eq/MJ, produced in a plant where the average emissions intensity of the non-CertifHy Low-GHG hydrogen production (based on an LCA approach), since sign-up or in the past 12 months, does not exceed the emissions intensity of the benchmark process (SMR of natural gas), i.e. 91.0 gCO₂eq/MJ.

³ Ancillary energy is energy consumed by systems which are ancillary to the production process, such as the electricity consumed by cooling circuit pumps, i.e. which is not one of the essential directly applied energy inputs for generating hydrogen.

⁴ Reduction value to be confirmed at a later stage.
1.4 Calculation of the amount of CertifHy Low-GHG and CertifHy Green hydrogen generated

When the GHG emissions intensity of the hydrogen produced since sign-up or in the preceding 12 months which is neither CertifHy Green H2 nor CertifHy Low-GHG H2 is below the benchmark value, i.e. 91.0 gCO2eq/MJ, the facility is eligible to produce CertifHy Green H2 or CertifHy Low-GHG H2. Otherwise it is not.

When the facility is eligible, the shares of CertifHy Green hydrogen and CertifHy Low-GHG hydrogen produced in a given production batch, defined as production in a specific time frame [t1; t2], are determined as follows:

Notations:
- $e$ is the average emissions intensity of the considered production batch
- $\alpha$ is the share of renewable energy in the non-ancillary energy used for the considered production batch
- $e_0$ is the emissions intensity of the benchmark process
- $e_L$ is the CertifHy Low-GHG emissions intensity threshold.

If the average emissions intensity of the production batch is greater than or equal to the benchmark ($e \geq e_0$), the share of CertifHy Low-GHG hydrogen and the share of CertifHy Green hydrogen are both equal to zero.

Otherwise ($e < e_0$):

If a share of the hydrogen produced is renewable (see section 1.3), the production batch is split into two parts – the renewable share, $\alpha$, and the non-renewable share ($1-\alpha$).

The emissions intensity of the renewable share and non-renewable share, respectively $e_R$ and $e_{NR}$, are determined by allocating the GHG emissions of the renewable and non-renewable energy inputs respectively to the corresponding product.

The following criteria are then applied:

- If the emissions intensity of either the renewable share or non-renewable share exceeds benchmark ($e_R > e_0$ or $e_{NR} > e_0$), no CertifHy Green $H_2$ nor CertifHy Low-GHG $H_2$ is generated.

- Otherwise ($e_R \leq e_0$ and $e_{NR} \leq e_0$)
  - If $e_R \leq e_L$, both CertifHy Green $H_2$ and CertifHy Low-GHG $H_2$ may be generated for all the renewable share.
  - If $e_{NR} \leq e_L$, CertifHy Low-GHG $H_2$ may be generated for all the non-renewable share.

Use of part of the renewable batch for offsetting the emissions on the non-renewable batch is described in Annex 2.
1.5 Residual mix calculation

The hydrogen produced by a participating facility that is sold without a CertifHy Low-GHG hydrogen or CertifHy Green GoO constitutes the “residual mix”.

The adopted approach ensures that the GHG emissions of the residual mix do not exceed the benchmark.

This enables the sale of a GoO to another hydrogen user than to the one actually using the product at the origin this GoO, while assuring that the GHG emissions intensity allocated to this product does not exceed the benchmark.

1.6 GoO content concept

The GoO concept associated to the adopted approach includes two main sections.

The first section provides factual data and characteristics regarding the production batch of hydrogen – defined by the source facility and the timeframe of production – to which the product covered by the GoO belongs.

The second section presents the application of the defined criteria for establishing that the unit amount (1 [MWh]) covered by the GoO complies with the corresponding requirements of CertifHy Green hydrogen or CertifHy Low-GHG hydrogen. Different product definitions may be developed and applied to the GoO scheme in the second GoO section, each with their own criteria, however, the latter do not affect the factual data in the first section, which includes all the information required for verifying whether or not each of these criteria are met.

Two GoO eligibility criteria are defined: one for CertifHy Green hydrogen and one for CertifHy Low-GHG hydrogen.

These are designed to be implemented together: if the product is covered by a CertifHy Green Hydrogen GoO, it is also covered by a CertifHy Low-GHG Hydrogen GoO, with identical GHG emissions.

GoO’s are issued only for unit amounts of product complying with at least one of the provided criteria.

Note: The concept allows generating a single GoO for hydrogen that is both CertifHy Green and CertifHy Low-GHG and that may be used as either one or the other. Whether or not this should be preferred to a system where GoOs for either CertifHy Green hydrogen or CertifHy Low-GHG hydrogen are generated for a given amount of hydrogen (as decided at time of production) will be determined in the course of the development of the GoO scheme (WP4).
Table 1. GoO Content Concept

<table>
<thead>
<tr>
<th>Data on Origin Production Batch</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Date and time of hydrogen production (beginning and end)</td>
<td>g CO2$_{eq}$/MJ$_H^2$</td>
</tr>
<tr>
<td>• Facility (identity, location, date of start of operation, process and capacity)</td>
<td>g CO2$_{eq}$/MJ$_H^2$</td>
</tr>
<tr>
<td>• Energy sources (including GoO information if applicable)</td>
<td>%</td>
</tr>
<tr>
<td>• Raw material sources (including sustainability information if applicable)</td>
<td>g CO2$_{eq}$/MJ$_H^2$</td>
</tr>
<tr>
<td>• GHG emissions intensity of hydrogen produced</td>
<td>g CO2$_{eq}$/MJ$_H^2$</td>
</tr>
<tr>
<td>• Information on any support scheme (e.g. investment support, feed-in tariff, …)</td>
<td></td>
</tr>
<tr>
<td>• For hydrogen produced as a by-product:</td>
<td></td>
</tr>
<tr>
<td>o Main product</td>
<td></td>
</tr>
<tr>
<td>o Basis of GHG emissions allocation (e.g. input energy share)</td>
<td></td>
</tr>
<tr>
<td>• Average GHG emissions intensity of all H$_2$ produced by the facility during the 12 months</td>
<td>%</td>
</tr>
<tr>
<td>preceding date of production</td>
<td></td>
</tr>
<tr>
<td>• Share of renewable energy in total energy input* for producing the hydrogen</td>
<td></td>
</tr>
<tr>
<td>• Average GHG emissions intensity of the renewable share</td>
<td>g CO2$_{eq}$/MJ$_H^2$</td>
</tr>
<tr>
<td>• Average GHG emissions intensity of the non-renewable share</td>
<td>g CO2$_{eq}$/MJ$_H^2$</td>
</tr>
<tr>
<td>*excluding ancillary energy consumption</td>
<td></td>
</tr>
</tbody>
</table>

Eligibility for CertifHy Green Hydrogen Guarantee of Origin

CertifHy Green share of production [options]
Allocated GHG emissions intensity [options]
CHG emissions offsetting

Criteria:
Does the unit quantity of hydrogen covered by this document belong to the CertifHy Green share of production?

Yes/No

Is the emissions intensity of the unit quantity of hydrogen covered by this document lower or equal to the CertifHy Low-GHG threshold (36.4 gCO$_2$$_{eq}$)?

Yes/No

CertifHy Green Hydrogen Guarantee of Origin

Eligibility for CertifHy Low-GHG Hydrogen Guarantee of Origin

Allocated GHG emissions intensity
CHG emissions offsetting applied

Criterion: Is the emissions intensity of the unit quantity of hydrogen covered by this document lower or equal to the CertifHy Low-GHG threshold (36.4 gCO$_2$$_{eq}$)?

Yes/No

Low GHG Hydrogen Guarantee of Origin

Issuing Number:
(At least one of the above criteria must be satisfied for a GoO to be issued)

Annex 1: Stakeholder consultative report

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<th>Description</th>
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</thead>
<tbody>
<tr>
<td>ΔH</td>
<td>Enthalpy of Reaction</td>
</tr>
<tr>
<td>AP</td>
<td>Affiliated Partner (to the CertifHy project)</td>
</tr>
<tr>
<td>CCS</td>
<td>Carbon Capture and Storage</td>
</tr>
<tr>
<td>ETS</td>
<td>Emissions Trading Scheme</td>
</tr>
<tr>
<td>FQD</td>
<td>Fuel Quality Directive</td>
</tr>
<tr>
<td>GHG</td>
<td>Greenhouse Gas</td>
</tr>
<tr>
<td>GoO</td>
<td>Guaranty of Origin</td>
</tr>
<tr>
<td>I/O</td>
<td>Input / Output</td>
</tr>
<tr>
<td>IPCC</td>
<td>Intergovernmental Panel on Climate Change</td>
</tr>
<tr>
<td>LCA</td>
<td>Life Cycle Analysis</td>
</tr>
<tr>
<td>LHV</td>
<td>Lower Heating Value</td>
</tr>
<tr>
<td>RED</td>
<td>Renewable Energy Directive</td>
</tr>
<tr>
<td>RES</td>
<td>Renewable Energy Sources</td>
</tr>
<tr>
<td>SMR</td>
<td>Steam Methane Reforming</td>
</tr>
</tbody>
</table>
1 Introduction

The European project CertifHy develops the first EU-wide framework for the generation of Guarantees of Origin (GoO) for green hydrogen. The objectives of this ambitious initiative are to develop a widely accepted definition of green hydrogen, to design a robust GoO scheme for green hydrogen and to propose a roadmap to implement the initiative across the EU.

A key point in the project is the definition of green hydrogen. In order to have a comprehensive definition, the consortium starts with the identification and characterisation of the possible ways of production, distribution and supply of hydrogen, followed by an extended life-cycle analysis (LCA), which has been used as basis for the development of options to define green hydrogen. The definition described in this report has been developed taking into account the results of a survey amongst the Affiliated Partners of the project and a series of workshops.

As the design of a GoO scheme is directly dependent on the definition of green hydrogen, this definition has been developed together with a basic concept of a GoO which will be further detailed within the CertifHy project.

At the section 7 of this report, a number of still-opened questions are addressed, for which we would appreciate the readers’ feedback.
2 Summary of consultation process

The consultation process on the definition of green hydrogen started along with the kick-off of the project, in December 2014, and is expected to last until summer 2015.

The consultation process has been divided into the following steps:

1. Step 1: Definition and selection of criteria for preparing green hydrogen definition options
   a. This step has been done by the consortium, based on input from an online survey with the participation of Affiliated Partners;
   b. The main concepts and conclusions from the survey have been presented at a technical workshop with Affiliated Partners;
   c. Key inputs in this process were obtained from the Public Launch event where most structural questions related to the GoO were analysed, having significant impact on the way the definition of green hydrogen and the development of a GoO scheme.

2. Step 2: Formulation of a comprehensive document (this document), including the concept and structure of the future GoO, along with a definition for green hydrogen fully compatible with the proposed GoO.

3. Step 3: Consultation on the most suitable GoO options, along with the definition of green hydrogen (with this document as a basis)
   a. This has been done in an interactive process with Affiliated Partners, where the results were discussed at a technical workshop on July 8th.

4. Step 4: The selected proposal will be presented to the wide community, seeking for further input and final endorsement.

The steps are presented in Figure 1.
This chapter focuses on steps 1 to 3 of the process, which have already taken place and represents the largest part of the work to be undertaken under this consultation. The following steps are a natural continuation of this document and its consultation with the wider community.

2.1 Step 1: Definition and selection of criteria for preparing green hydrogen definition options

In the starting phase of the consultation, efforts were focused on developing strong criteria for potential definitions of green hydrogen. In particular, attention was given to:

- Ways of proving the origin of the (renewable) sources,
- Appropriateness of various GHG thresholds existing in EU regulation, methodology to benchmark low GHG emission,
- Criteria to define by-product hydrogen,
- Completeness of all H₂ production pathways,
- Approach to deal with losses associated to transport and storage, and
- Consideration of environmental impacts beyond climate change.
As a result of this work, the project looked into the two main approaches for defining green H\textsubscript{2}, renewable origin and GHG emissions based. On that basis, Affiliated Partners were consulted through an online survey.

\subsection{Outcome of the on-line survey with Affiliated Partners}

The survey was structured around two main approaches for defining green hydrogen. For each approach, a set of questions on the criteria were put forward.

The first approach was based on share of renewable energy and sustainability of feedstock. In this case the use of renewable energy and/or renewable feedstock is a condition for producing green hydrogen, and the amount of green hydrogen produced can be determined by the share of renewable energy and/or renewable feedstock in the total used or by a threshold.

Main conclusions:

- Share based approach: green H\textsubscript{2} needs to be proportional to RES input (avoid all-or-nothing thresholds). A 65\% RES share in the energy used should lead to a 65\% green hydrogen share out of all hydrogen produced.
- Attention should be paid to the emissions associated to the non-renewable part of the input (no agreement on how to apply the penalties/bonuses).
- All energy sources (from the non-RES input) to be eligible.
- By-product: Case by case analysis necessary.

The second approach was based on greenhouse gas (GHG) emissions. In this approach the GHG emissions of hydrogen production including all upstream process steps are calculated in a Life Cycle Analysis (LCA). Hydrogen produced will be considered green if the associated GHG emissions are lower than a certain pre-defined threshold.

Main conclusions:

- Share based approach: green H\textsubscript{2} needs to be proportional to low-GHG input (avoid all-or-nothing thresholds)
- GoOs for electricity and gas as a way to identify low-GHG input (preferred option)
- The reference value for GHG emissions should be those associated to SMR of natural gas in centralized plants
- Consistency with RED/FQD methodology (however a specific emission saving \% couldn’t be agreed)
- By-product: substitution and the energy allocation methods the preferred ones.
2.1.2 Key outcomes of the Affiliated Partners workshop (23 April 2015)

During the workshop the results of the survey were presented and it came clear that:

- Affiliated Partners would like the GoO to cover both renewables-based hydrogen and hydrogen with low GHG emissions.
- Green hydrogen should refer to hydrogen from renewable energy sources.
- The value of defining low-carbon hydrogen was not so evident. The GoO should provide information on the GHG emissions of the hydrogen produced. The market could then decide how “low” the GHG emissions should be and set a price to it.
- In any case, the GoO should be as factual and transparent as possible.

So more fundamental questions regarding the renewable H₂ approach where left unanswered:

- Should the GHG emissions intensity associated to renewable H₂ be 0?
- Should a process be eligible for producing renewable H₂ even if its overall emissions are greater than that of the reference process?
- Should the share of renewable H₂ produced be in line with the contribution of the process to the reduction of GHG emissions compared to the conventional process?

2.1.3 Key outcomes of the second Affiliated Partners workshop (7 July 2015)

The following is a summary of the discussions and decisions made at the workshop:

- There was a general agreement with the proposal that green hydrogen should refer to renewables-based hydrogen. Some Affiliated Partners expected however an additional definition for low-carbon hydrogen to be included.
- The share of “hydrogen from renewable sources” in total hydrogen production is equal to the share of renewable energy in total energy consumption. In processes requiring several energy inputs, renewable energy will need to be part of at least one of the main energy inputs (in this case, main energy input refers to an energy source that represents at least [x%] of the overall process demand). There was not agreement on the level of the threshold.
- One definition proposed states that Green hydrogen should be hydrogen from renewable energy source and with a GHG footprint below a certain threshold. Two saving thresholds were discussed: -50% or -70% of the reference process (SMR of natural gas). No agreement was found on the level and whether the threshold should evolve over time (similarly to the RED approach for biofuels).
A second definition, leading to green hydrogen with zero GHG emissions was presented and discussed. Under such approach, the emissions would be offset by reducing the active share of green hydrogen. The total energy used for producing all hydrogen in the facility during one year would need to emit fewer emissions than the reference process. No agreement could be found whether this definition or the previously presented definition should be supported.

For by-product hydrogen, it was agreed that energy allocation was the most suitable allocation method.
3 Proposed Dual Purpose GoO for “Premium” Hydrogen

The CertifHy Consortium has developed a market outlook for “premium” hydrogen. It concludes that if Europe is to continue its ambition policies on climate change, energy security and competitiveness of its industry, hydrogen will play a significant role in the decarbonisation of the transport sector, and to a lesser extent, it will contribute to reduce emissions on the energy-intensive industry. Under a policy driven scenario, about 17% of all hydrogen could be originated from renewable and/or low-carbon sources by 2030, representing a market of about 1.7 million tons of “premium” hydrogen per year.

“Premium” hydrogen will be required to comply with different regulations and policies. In some cases, proving the (renewable) origin of the energy to produce hydrogen will be requested (e.g. Renewable Energy Directive). In some other cases, a proof of reduced emissions would be sufficient (e.g. Fuel Quality Directive, Emissions Trading Scheme). In those cases where regulation is not the main driver, the market and final customer will decide whether hydrogen should be low carbon, or specifically from renewable energy sources (e.g. food processing industries due to sustainability/green labels, corporate social responsibility, fuel cell vehicles users).

In any of the cases, The CertifHy project recommends that the GoO for hydrogen should address the market and regulatory needs of different hydrogen users. Therefore, the GoO should be designed in such a way that information about its (renewable) origin and its associated GHG emissions are provided to the final customer.

The following table present an overview of EU regulation and market drivers that could have an impact on demand for hydrogen. Depending on the scope of the driver, hydrogen may need to be produced from a low-GHG source (indicated in blue), from renewable energy sources (indicated in green), or none of them (indicated in grey).

---

1 Premium hydrogen refers to renewables-base and/or low-carbon hydrogen. The concept “green hydrogen” is not yet used as its definition has not yet been fully elaborated.

2 Deliverable 1.3. “Generic estimation scenarios of market penetration and demand forecast for “premium” green hydrogen in short, mid and long term”, CertifHy WP1, June 2015
Table 1. Overview of Regulatory, market and economic drivers for green hydrogen in a CO2 policy driven scenario

<table>
<thead>
<tr>
<th>Drivers for hydrogen/green hydrogen in the main 3 markets analysed (policy driven scenario)</th>
<th>Industry</th>
<th>Mobility and transport</th>
<th>Power to gas (injection into the natural gas grid)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel quality directive</td>
<td>Refineries</td>
<td>Amonia (other chemicals)</td>
<td>metal processing</td>
</tr>
<tr>
<td>RED (including Renewables Transport target)</td>
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<tr>
<td>Emissions Performance standards for passenger cars</td>
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<tr>
<td>Air quality (Low Emissions Zones)</td>
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<tr>
<td>Alternative fuel infrastructure directive</td>
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<tr>
<td>Mix driver-regulation through ETS (Cap, exemptions, CO2 price)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oversupply of variable renewable energy/ Energy storage market</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consumers choice-clean transportation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CSR- Green marketing/Company image</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cost competitive vs. SMR of natural gas (reference technology)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Relevance/Impact on green H2 demand</td>
<td>No impact</td>
<td>Low/limited demand potential</td>
<td>High demand potential</td>
</tr>
</tbody>
</table>

| Type of hydrogen demand | for RES based hydrogen | for low-carbon hydrogen | for hydrogen |

---

3 Deliverable 1.3. “Generic estimation scenarios of market penetration and demand forecast for “premium” green hydrogen in short, mid and long term”, CertifHy WP1, June 2015
The potential benefits of a dual purpose GoO are the following:

- Allows the development of a fully operational and ready-for-use GoO system attending two well identified needs - rather than only one - with regards to the supply of green hydrogen (anywhere where hydrogen can be delivered, thanks to tradability of the GoO), hence increasing total market value and resilience to evolving demand and availability of hydrogen.
- Allows developing a (comprehensive) regulation-ready GoO scheme, satisfying the requirements from different existing EU legislation, including those that aim to reduce the carbon footprint of fuels (FQD, ETS) and increase the share of renewables in the energy system (RED).
- Allows to fully exploiting the environmental performance of a given process by taking advantage of both the renewable and low GHG hydrogen produced (example: electrolyser running with a combination of renewable electricity and electricity from a low-carbon mix).
- Provides a mechanism supporting both the development of renewable and low carbon hydrogen production pathways.
4 Definition of “green” hydrogen

As explained in section 3, given the identified need to cover different policy and market needs, an inclusive GoO scheme that addresses both the use of renewable sources and use of low-GHG processes is proposed.

As far as low-GHG hydrogen is concerned, providing a definition of “low-GHG” is not necessarily required. Indeed, policy instruments and regulation that incentivize the use of low-GHG processes aim to reduce GHG emissions; hence information on the GHG footprint could be sufficient to fulfil this objective. For instance, the Fuel Quality Directive and the Emission Trading Scheme do not use specific thresholds for the selection of eligible processes/technologies; all processes are valid as long as they help achieving the emission savings reduction objectives.

4.1 Hydrogen from renewable sources

According to the Renewable Energy Directive, ‘energy from renewable sources’ means energy from renewable non-fossil sources, namely wind, solar, aerothermal, geothermal, hydrothermal and ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases.

As shown in the figure below, various hydrogen production pathways from renewable feedstock also involve the use of additional energy.
Applying the definition of “energy from renewable sources” to hydrogen, the share of “hydrogen from renewable sources” in total hydrogen production can be defined as the share of renewable energy consumption in total energy consumption in the hydrogen production process.

Note: Energy consumption in the steps upstream of production (such as the energy consumption to grow crop used as feedstock) is therefore not included.

With this approach, “hydrogen from renewable sources” may be produced from an energy and/or feedstock mix where only one form of energy or feedstock is renewable.

Taking as hypothetical basis that hydrogen is produced by Plasma gasification of a mixture of industrial and municipal waste containing 30% biomass, with 80% of the electricity used being renewable, and with the assumption that electricity represents 35% of total energetic input, the renewable H₂ can be calculated as follows:

The industrial waste input represents 65% of total energy input with 30% renewable biomass content, electricity represents 35% of total energy input with 80% of electricity being renewable. The share of renewable energy in total energy input is 65% x 30% + 35% x 80% = 47.5%

As a result, 47.5% of hydrogen production is renewable.
If the waste does not have any renewable content (0% biomass), the share of hydrogen from renewable sources then is 65% x 0% + 35% x 80% = 28%

The proposed definition of “green” hydrogen is based on the above definition of “hydrogen from renewable sources”.

4.2 CertifHy definition of green hydrogen – first proposal

A first proposal for defining green hydrogen taking into account the policy framework and customer expectations is the following:

Green hydrogen is hydrogen from renewable sources (see chapter 4.1) with an associated GHG emissions intensity (based on an LCA approach) below a specified threshold. Any biomass used shall comply with the sustainability requirements according to the Renewable Energy Directive.

In other words: The percentage of green hydrogen of a production is equivalent to the percentage of renewable sources (energy including ancillary energy requirement and feedstocks) used for the production. This hydrogen percentage will be considered green if the related GHG emissions (based on an LCA approach) are below a certain threshold.

(See Question 5 in chapter 7).

Share of renewable energy input

A share of the hydrogen generated by a process using a combination of different forms of energy input will be renewable, if renewable sources are used for at least one of the energy forms. In order to avoid any market disturbance, energy inputs should be required to exceed a minimum share of total energy input in order to allow green hydrogen to be produced. This
will prevent processes that use renewable energy only in energy input which is not substantial (below a threshold) to be able to produce green hydrogen.

(See Question 1 and Question 2 in chapter 7).

**GHG emissions associated to the green hydrogen**

The application of a threshold on the life cycle GHG emissions intensity is consistent with the Renewable Energy Directive (2009/28/EC). For further explanations on GHG emission calculation on special cases (e.g. by-product hydrogen) please see Annex 0.

![GHG emissions of hydrogen production on an LCA basis](image)

Figure 4. **GHG emissions of hydrogen production on an LCA basis**

The application of three example thresholds in Figure 4 shows that a threshold will have influence on the processes and raw materials that might be eligible to produced green hydrogen.

(See Question 3 in chapter 7).

**Sustainability of raw materials**

Additionally and in order to avoid the creation of further requirements on sustainability for raw materials, it is proposed to use the same sustainability criteria as defined in the RED for any biomass raw material used in the production of green hydrogen.
Furthermore, under this definition, a *materiality threshold* of 5% in relation to the total energy sources is proposed. This materiality threshold means that up to 5% of the input energy can be conservatively estimated without the need of exact measurements. This is applied in order to reduce the efforts of measuring minor energy consumptions (e.g. ancillary systems such as pumps, ventilation, etc...). This does not imply that 5% of the energy will not be accounted for.

In cases where hydrogen is a by-product the above definition can be applied keeping in mind that sustainability of raw materials other than biomass is not covered by this definition.

(See Question 6 and Question 7 in chapter 7).
5 Guarantee of Origin (GoO) concept for “green” hydrogen

A robust Guarantee of Origin System requires clear and factual information to be provided to final customers in order to increase users trust and transparency on the system. In order to achieve this goal a concept for a GoO is proposed. This approach will be adapted and further elaborated within the course of the CertifHy project.

It is proposed to have two main sections of the GoO which will be issued for green hydrogen produced. The GoO shall be of the standard size of 1 MWh (based on the lower heating value). No more than one guarantee of origin shall be issued in respect of each unit of hydrogen produced.

Table 2 shows a draft of GoO datasheet:

Table 2. GoO Concept

<table>
<thead>
<tr>
<th>Unique Identification number (ID)</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data on Origin</td>
<td></td>
</tr>
<tr>
<td>Date and time of hydrogen production (beginning and end)</td>
<td>%</td>
</tr>
<tr>
<td>Facility (identity, location, date of start of operation, process and capacity)</td>
<td>g CO2eq /MJH2</td>
</tr>
<tr>
<td>Energy sources (including GoO information if applicable)</td>
<td></td>
</tr>
<tr>
<td>Energy efficiency of the process</td>
<td></td>
</tr>
<tr>
<td>Raw material sources (including sustainability information if applicable)</td>
<td></td>
</tr>
<tr>
<td>GHG emissions intensity of hydrogen produced</td>
<td>%</td>
</tr>
<tr>
<td>Information on any support scheme (e.g. investment support)</td>
<td></td>
</tr>
<tr>
<td>For by-products:</td>
<td></td>
</tr>
<tr>
<td>o Name of main product</td>
<td></td>
</tr>
<tr>
<td>o Sustainability information of main product (if available)</td>
<td>%</td>
</tr>
<tr>
<td>Share of renewable energy in total energy input</td>
<td></td>
</tr>
</tbody>
</table>

Eligibility for CertifHy Green Hydrogen Guarantee of Origin

| Criteria 1: Does the hydrogen covered by this GoO belong to the share of hydrogen from renewable energy sources? | Yes/No |
| Criteria 2: Is the GHG emissions intensity of the hydrogen covered by this guarantee of origin lower than [35,8] g CO2eq /MJH2? | Yes/No |

CertifHy Green Hydrogen Guarantee of Origin

| Share of hydrogen from renewable energy sources | Yes/No |
| Name of Organization requesting issuance: | % |
The information presented in the GoO shall be confirmed by an accredited independent third party.

5.1 First section of a GoO (data on origin)

The first section of the GoO shall contain general information (fact sheet) of the produced unit. Using as reference the requirements of RED Article 15 §6, the following requirements are proposed to be included to a GoO scheme.

A guarantee of origin shall specify at least:

- The energy source / sources including any electricity GoO if applicable;
- The raw material sources including any sustainability information;
- Start and end dates of production;
- The identity, location, process and capacity of the installation where the green hydrogen was produced;
- The energy efficiency of the process
- In case that hydrogen is a by-product, the name of the main product and sustainability information of the main product
- The GHG emissions for the green hydrogen produced;
- Any information related to investment supports or any other type of support scheme;
- The date on which the installation became operational.

5.2 Second section of a GoO

A second section will include the definition of green hydrogen and might be used for further labels to comply with market demands.

This section will provide the information needed to confirm the compliance with the definition of green hydrogen, as established by the CertifHy project (see chapter 4.2):

- The sources are renewable according to RED;
- The GHG emissions are lower than the threshold (see chapter 7.1);
- The raw materials comply with sustainability requirements (if applicable) (see chapter 7.3).
6 Limitations of the first proposed definition and proposed options for addressing these limitations

6.1 Limitations

The approach for defining the amount of green hydrogen produced by a given facility, as presented in chapter 4.2, presents a number of limitations, reviewed hereafter.

6.1.1 Overall emissions

As shown in the figure below, alternative pathways for producing hydrogen may, depending on the energy source used, emit much more GHG emissions that the one most commonly applied (steam methane reforming of natural gas) and proposed as the benchmark. For instance, the GHG emissions intensity of electrolysis, one of the main processes for generating green hydrogen, can greatly exceed the benchmark, by a factor of up to 4.7 if electricity generated from coal is used.

![Figure 5. GHG emissions of hydrogen production on an LCA basis](image-url)
As a result, the average GHG emissions intensity of hydrogen produced by electrolysis with a 50% share of renewable electricity is greater than that of the benchmark process—up to 2.3 times—for all residual mixes studied except 100% nuclear.

Table 3. \( \text{H}_2 \) GHG emission for a facility based on electrolysis

<table>
<thead>
<tr>
<th>Energy mix</th>
<th>Zero GHG renewable electricity* share</th>
<th>Residual mix</th>
<th>GHG emiss. of ( \text{H}_2 ) from res mix</th>
<th>GHG emiss. average ( \text{H}_2 )</th>
<th>( \text{gCO}_2\text{eq/MJ} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>90%</td>
<td>100% coal</td>
<td>423,7</td>
<td></td>
<td></td>
<td>127,1</td>
</tr>
<tr>
<td>80%</td>
<td>100% coal</td>
<td>84,7</td>
<td></td>
<td></td>
<td>211,9</td>
</tr>
<tr>
<td>70%</td>
<td>100% coal</td>
<td>169,5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60%</td>
<td>100% coal</td>
<td>169,5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50%</td>
<td>100% coal</td>
<td>211,9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>90%</td>
<td>100% NG</td>
<td>19,2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>80%</td>
<td>100% NG</td>
<td>38,3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>70%</td>
<td>100% NG</td>
<td>57,5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60%</td>
<td>100% NG</td>
<td>76,6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50%</td>
<td>100% NG</td>
<td>95,8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>90%</td>
<td>100% nucl.</td>
<td>0,8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>80%</td>
<td>100% nucl.</td>
<td>1,5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>70%</td>
<td>100% nucl.</td>
<td>2,3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60%</td>
<td>100% nucl.</td>
<td>3,0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50%</td>
<td>100% nucl.</td>
<td>3,8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>90%</td>
<td>EU mix</td>
<td>21,7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>80%</td>
<td>EU mix</td>
<td>43,4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>70%</td>
<td>EU mix</td>
<td>65,1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60%</td>
<td>EU mix</td>
<td>86,8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50%</td>
<td>EU mix</td>
<td>108,6</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* on-site or GoO red: > 89,6 SMR Ref

Considering only the emissions of the share of renewable energy used, may in practice encourage the deployment of processes with increased GHG emissions compared to benchmark despite using a high share (e.g. 50%) of renewable electricity.

As experienced with the co-firing of biomass for the production of renewable electricity, this situation may result in a strong lack of acceptance.
6.1.2 Exclusion of certain renewable feedstock pathways

Application of a GHG emissions threshold for determining which processes may generate green hydrogen results in the exclusion of pathways that would nonetheless have a beneficial impact in terms of production of energy from renewable sources (e.g. geothermal).

Furthermore, the number of eligible green hydrogen pathways is sensitive to the threshold value applied, which is a political decision. Therefore, achieving consensus on the threshold value to be applied may be difficult.

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>green H₂ emissions share (%)</th>
<th>gCO₂eq/MJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>100% bio-waste</td>
<td>100%</td>
<td>23.9</td>
</tr>
<tr>
<td>100% corn</td>
<td>0%</td>
<td>49.7</td>
</tr>
<tr>
<td>100% landfill gas</td>
<td>100%</td>
<td>16.6</td>
</tr>
</tbody>
</table>

6.1.3 Variable GHG content of renewable hydrogen

As displayed in Figure 6, the GHG content of the input is passed on to the hydrogen produced in the conventional approach (definition presented in chapter 4).
Consequently, the GHG content of green hydrogen depends on the process and feedstock. As experienced with electricity, this introduces a quality parameter that the customer will tend to consider, increasing complexity, and potentially impacting market acceptance of those quantities of green hydrogen that have the highest emissions intensity. This may have a negative impact on market liquidity, market value, and market uptake.

### 6.1.4 Absence of means for keeping track of the “residual mix”

A guarantee of origin scheme normally requires keeping track of the GHG emissions of the production not covered by the GoO for being able to keep track of and inform the users on these as well. Indeed, hydrogen provided to a buyer who does not buy the associated GoO is hydrogen from the “residual mix” (without GoO), which is not characterized.

The proposed definition allows green hydrogen generation from facilities having in average higher GHG emissions than the benchmark, while providing no means for identifying and keeping track of the impact of these higher emissions on the residual mix.

This may result in the GoO scheme not being accepted.

### 6.2 Proposed approaches for addressing some or all of the above limitations

Potential solutions were reviewed for addressing the above limitations taking into consideration the following criteria:

- Transparency: information is easy to be found and understood in GoG
- Simplicity for the customer
- Simplicity for the producer; simplicity for the traders
- Customer trust
- Market potential (including market value)
- Support to hydrogen production from renewable and low carbon sources
- Adaptable to evolving regulatory measures
- Consistency with RED, FQD, etc.
- Consistency with other GoO certificates
- Technology neutral and robust
- Effective contribution to fulfilment of environmental goals
As a result, two alternatives amending the first approach defined in chapter 4.2 – referred to as Option 1 and Option 2 – are proposed for addressing, at least to some extent, the limitations above. These options are presented hereafter.

### 6.2.1 Option 1: Transparency on overall GHG emissions of production facility

In order to provide transparency on the overall emissions of the production facility, option 1 consists on providing - in the first part of the GoO - the average GHG emissions intensity of all the hydrogen produced in the whole 12 months preceding the end of the time interval during which the hydrogen covered by the GoO was produced. In this way any end user will be able to assess not only the characteristics of the hydrogen labelled but also the characteristics of all the hydrogen produced over a one year period. This approach will reduce the willingness to implement processes and use feedstock or energy sources with high GHG emissions within the installations that expect to have part of their production labelled as green hydrogen. It is important to mention that this approach might cause some confusion on the consumer side as green hydrogen might be created in facilities with high emissions, case in which the GoO will carry contradictory information with regards to environmental impact.

The implementation of this option does not require any change to the definition of green hydrogen as presented in chapter 4.2.

Application of option 1 simply requires amending the GoO concept (See Question 5) through the addition highlighted in below:
Technical Report on the Definition of “Green” Hydrogen

Table 5. GoO Concept-Option 1

<table>
<thead>
<tr>
<th>Unique Identification number (ID)</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Data on Origin</strong></td>
<td></td>
</tr>
<tr>
<td>• Date and time of hydrogen production (beginning and end)</td>
<td></td>
</tr>
<tr>
<td>• Facility (identity, location, date of start of operation, process and capacity)</td>
<td></td>
</tr>
<tr>
<td>• Energy sources (including GoO information if applicable)</td>
<td></td>
</tr>
<tr>
<td>• Energy efficiency of the process</td>
<td>%</td>
</tr>
<tr>
<td>• Raw material sources (including sustainability information if applicable)</td>
<td></td>
</tr>
<tr>
<td>• GHG emissions intensity of hydrogen produced</td>
<td>g CO2eq /MJH2</td>
</tr>
<tr>
<td>• Information on any support scheme (e.g. investment support)</td>
<td></td>
</tr>
<tr>
<td>• For by-products:</td>
<td></td>
</tr>
<tr>
<td>o Name of main product</td>
<td></td>
</tr>
<tr>
<td>o Sustainability information of main product (if available)</td>
<td></td>
</tr>
<tr>
<td>• Share of renewable energy in total energy input</td>
<td>%</td>
</tr>
<tr>
<td>• Average GHG emissions intensity of all the hydrogen produced by the facility during the 12 months preceding end of production</td>
<td>g CO2eq /MJH2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Eligibility for CertifHy Green Hydrogen Guarantee of Origin</th>
<th>Yes/No</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Criteria 1: Does the hydrogen covered by this GoO belong to the share of hydrogen from renewable energy sources</td>
<td></td>
</tr>
<tr>
<td>• Criteria 2: Is the GHG emissions intensity of the hydrogen covered by this guarantee of origin lower than [35.8] g CO2eq /MJH2?</td>
<td></td>
</tr>
</tbody>
</table>

**CertifHy Green Hydrogen Guarantee of Origin**
Share of hydrogen from renewable energy sources
Name of Organization requesting issuance:
Validity / expiration date: x years / dd.mm.yyyy

**6.2.2 Option 2: Offsetting of above-benchmark emissions**

This approach structurally ensures that the emissions intensity of any non-green hydrogen produced by a facility producing green hydrogen does not exceed that of the benchmark process.

Figure 7 and Table 6 show the option 2 approach.
Figure 7. Offsetting approach

Table 6. Offsetting approach (application)

<table>
<thead>
<tr>
<th>SMR onsite</th>
<th>Energy mix</th>
<th>H2</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Feedstock</td>
<td>Renewable</td>
<td>GHG intens.</td>
<td>GHG emiss.</td>
<td>Green H2 share</td>
</tr>
<tr>
<td>Feedstock energy share</td>
<td>gCO2eq/MJ</td>
<td>gCO2eq/MJ</td>
<td>gCO2eq/MJ</td>
<td>gCO2eq/MJ</td>
</tr>
<tr>
<td>100% bio-waste</td>
<td>81%</td>
<td>123,2</td>
<td>23,9</td>
<td>73%</td>
</tr>
<tr>
<td>100% corn</td>
<td>80%</td>
<td>243,6</td>
<td>49,7</td>
<td>45%</td>
</tr>
<tr>
<td>100% land-fill gas</td>
<td>78%</td>
<td>74,1</td>
<td>16,6</td>
<td>78%</td>
</tr>
</tbody>
</table>
The above values are based on the assumption that the GHG emissions intensity of the renewable energy input is 0 gCO2eq/MJ.

For example, when an 80% share of renewable electricity (with zero emissions) is used in conjunction with the EU electricity mix for producing H₂ by electrolysis, the share of green hydrogen is 52%.

The share of green hydrogen is calculated as follows:

When the GHG emissions intensity of the non-green hydrogen produced in the preceding 12 months is equal to or below the benchmark (89.6 gCO₂eq/MJ for central SMR of NG), the facility is then eligible to produce green hydrogen. Otherwise it is not.

Once the facility is eligible, the share of green hydrogen produced in a specific timeframe $[t_1; t_2]$ is determined:

When the emissions intensity of production in that time-frame, $e$, is lower than benchmark, $e_0$, the share $\lambda$ of Zero GHG Hydrogen in production which may be covered by a GoO is simply:

$$\lambda = 1 - \frac{e}{e_0} \quad [1]$$
Where:
- $e$ is the emissions intensity of all the hydrogen produced during the considered production time-frame $[t_1; t_2]$.
- $e_0$ is the emissions intensity of the benchmark process

Setting the share of zero-emissions hydrogen to $\lambda$ provides that the emissions intensity of the non-zero-emissions hydrogen is $e_0$.

If a share $\alpha$ of the energy input is renewable, the share $\gamma$ of CertifHy Green Hydrogen in production is:

$$\gamma = \min (\alpha; \lambda) \quad [2]$$

The share $\gamma$ of production qualifies for being labeled as CertifHy Green Hydrogen.

If the emissions intensity of production in the $[t_1; t_2]$, $e$, is greater than or equal to the benchmark, $e_0$, the share of zero-GHG-hydrogen and the share of green hydrogen are both equal to zero.

**Example:**

The emissions intensity of the H$_2$ produced by the plant during the past 12 months is 80.9 gCO$_{2eq}$/MJ, below the benchmark value (89.6 gCO$_{2eq}$/MJ). The plant is therefore eligible for producing green hydrogen.

Now we study the specific time-frame $[t_1; t_2]$:

If the share of renewable energy in input, $\alpha$, is 70%, and the total emissions of our hydrogen produced in this period are 45 gCO$_{2eq}$/MJ, we apply formulas 1 and 2:

$$\lambda = 1 - \frac{45}{89.6} = 0.497$$

$$\gamma = \min (70, 49.7) = 49.7\%$$

The share of green hydrogen becomes: $\gamma = 49.7\%$

In summary, under Option 2:
- The green hydrogen produced always has an emissions intensity of 0 gCO2eq/MJ.
- Green hydrogen can only be generated if the average GHG emissions intensity of the facility for producing the non-green hydrogen over the reference period (12 months) is lower than that of the benchmark process (89.6 gCO2eq/MJ for central SMR of NG).
- When green hydrogen is generated, the emissions intensity of the non-renewable hydrogen never exceeds that of the conventional process. Therefore, GoO emissions occur without negative impact on the residual mix, and H2 separated from its associated GoO can conservatively be assigned the benchmark emissions.
Finally, this approach allows all processes using renewable energy with overall emissions lower than the benchmark to produce green hydrogen. The application of an arbitrary threshold on the level of GHG emissions is no longer needed.

The implementation of Option 2 requires the definition of Green Hydrogen to be modified as follows:

**CertifHy Green Hydrogen definition - Option 2**

Green hydrogen is hydrogen from renewable sources (see chapter 4.1) with an allocated associated GHG emissions intensity of zero (based on an LCA approach) produced in a plant where the average emissions intensity of the non-zero-GHG hydrogen production (based on an LCA approach) of the past 12 months does not exceed the emissions intensity of the reference process (SMR of natural gas).

(See Question 5)

### 6.2.2.1 Extension of option 2 approach- zero GHG hydrogen

The approach described above can be applied for defining a share of zero-emissions hydrogen in any process generating hydrogen with a GHG emissions intensity lower than benchmark, (whether or not renewable energy sources are used). Consequently, three types of hydrogen may potentially be produced in a given facility:

- **Type 1**: Green hydrogen according to definition option 2
- **Type 2**: Zero-emissions hydrogen not from renewable sources
- **Type 3**: Non-zero-emissions hydrogen

When the GHG emissions intensity of the hydrogen produced in the preceding 12 months is below benchmark, a CertifHy GoO can be delivered for either type 1 and type 2 hydrogen, type 1 hydrogen being covered by a *CertifHy Green Hydrogen GoO* and both type 1 and type 2 hydrogen being covered by a *Zero GHG Hydrogen GoO*.

Observing again formula [1] and formula [2] in the previous section, we could conclude that the share $\gamma$ of production qualifies for being labeled both *CertifHy Green Hydrogen* and *Zero GHG Hydrogen*.

The same or larger share $\lambda$ of production qualifies for being labeled *Zero GHG hydrogen*.

Subsequently, if $\lambda > \alpha$, the share $(\lambda-\alpha)$ qualifies for being labeled *zero GHG hydrogen* only.
This generalization is needed in order to ensure consistent quantification of GHG emissions: zero-emissions hydrogen produced from renewable sources may be sold as zero GHG hydrogen, therefore a single method for quantifying GHG emissions needs to be applied without regards to renewable origin.

6.2.2.2 Option 2 GoO concept

The GoO concept associated to Option 2 is shown below. It allows the identification of both CertifHy green hydrogen and zero GHG hydrogen. As can be seen, there is no longer a reference to a GHG emissions intensity threshold, as the application of such a threshold is no longer required.
Technical Report on the Definition of “Green” Hydrogen

Table 7. GoO Concept option 2

Data on Origin

- Date and time of hydrogen production (beginning and end)
- Facility (identity, location, date of start of operation, process and capacity)
- Energy sources (including GoO information if applicable)
- Raw material sources (including sustainability information if applicable)
- GHG emissions intensity of hydrogen produced
- Information on any support scheme (e.g. investment support)
- For by-products:
  - Name of main product
  - Sustainability information of main product (if available)
- Share of renewable energy in total energy input for producing the hydrogen
- Average GHG emissions intensity of all H₂ produced by the facility during the 12 months preceding date of production

Units

- g CO₂eq /MJ₇₂
- %
- g CO₂eq /MJ₇₂

Eligibility for CertifHy Green Hydrogen Guarantee of Origin

CertifHy Green share of production (see formula)

Criteria no 1: Does the hydrogen covered by this document belong to the CertifHy Green share of production?

CertifHy Green Hydrogen Guarantee of Origin

Note: the GHG emissions intensity of Green Hydrogen covered by a CertifHy GoO is 0 g CO₂eq /MJ₇₂

Eligibility for Zero GHG Hydrogen Guarantee of Origin

Zero GHG share of production (see formula)

Criteria no 1: Does the hydrogen covered by this document belong to the Zero GHG share of production?

Zero GHG Hydrogen Guarantee of Origin

Note: the GHG emissions intensity of Zero GHG Hydrogen covered by a GoO is 0 g CO₂eq /MJ₇₂
Exception in the case 100% of energy input is renewable:

As green hydrogen has a GHG emissions intensity of zero, the share of green hydrogen is lower than 100% when non-zero emissions energy sources are used, even if these are 100% renewable.

It is proposed to allow the possibility of producing a 100% share of green (zero-emissions) hydrogen when only renewable energy is used, under the condition that exclusively renewable sources have been used during the preceding 12 months and that all the LCA GHG emissions are compensated by purchasing of CO2 certificates.

6.2.3 Coverage of GoO to all hydrogen production

This approach requires all the hydrogen produced and delivered to be associated to a GoO providing all relevant information regarding sources and sustainability. Consequently, the notion of residual mix disappears, as all production is characterized.

It is worth mentioning that this approach does not necessarily prevent the production of high GHG emissions hydrogen if a fraction of the consumers are not concerned about GHG emissions.

Furthermore, the approach requires in practice the disclosure of data relative to hydrogen production operations for all markets, which is unlikely to be accepted. Therefore this option is not proposed for further consideration in CertifHy.

6.3 Comparative analysis of the GoO options

Table 8 shows the summary of criteria applied to each of the above mentioned options, including some information on the limitations of the options.

<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>Reference: no measures taken to address limitations</th>
<th>Option 1 definition with transparency on GHG emissions of facility</th>
<th>Option 2 definition, with off-setting of excess emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transparency</td>
<td>Does not provide information regarding overall emissions of the facility. Conflict: rejection of green electricity from co-firing of biomass and coal in power plants</td>
<td>Addresses limitation of (1): information on Facilities GHG emissions is provided</td>
<td>Same information as (1) is provided. No particular limitation</td>
</tr>
<tr>
<td>Topic</td>
<td>Description</td>
<td>Notes</td>
<td></td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Simplicity for customer</td>
<td>Renewable hydrogen has a GHG emissions intensity that depend on the pathway. This introduces a quality parameter that the customer has to deal with, increasing complexity.</td>
<td>Same as (1). Furthermore, GoO for green H₂ may indicate that facility has high emissions, providing contradictory information as to beneficial impact. Addresses limitation of (1) and (2): the GHG emissions intensity of green H₂ is always 0, eliminating a parameter to deal with, reducing complexity.</td>
<td></td>
</tr>
<tr>
<td>Simplicity for producer</td>
<td>No particular limitation</td>
<td>Need to continuously keep track of overall GHG emissions</td>
<td>Same as (1). (Uses same LCA analysis as (1) and (2))</td>
</tr>
<tr>
<td>Customer trust</td>
<td>Potential actual detrimental impact of the H₂ production activity generating GoO’s is a source of mistrust</td>
<td>Only partially addresses limitation of (1): the fact that the system does not prevent the provision GoOs from facilities with detrimental effect remains a source of mistrust. Addresses limitation of (1) and (2): GoOs can only be generated by facilities having a positive environmental impact.</td>
<td></td>
</tr>
<tr>
<td>Market potential</td>
<td>Variable level of GHG emissions complicates mass marketing and impacts value</td>
<td>Same as (1)</td>
<td></td>
</tr>
<tr>
<td>Support to H₂ production from alternative low carbon sources</td>
<td>Many low carbon sources are excluded due to reliance on a renewable sources (e.g. nuclear electricity)</td>
<td>Same as (1)</td>
<td></td>
</tr>
<tr>
<td>Consistency with long term trend (disclosure of environmentally relevant information for all production)</td>
<td>Does not provide full information on a given facility and does not ensure information for all H₂ production</td>
<td>This option does not require information to be provide for all H₂ production</td>
<td></td>
</tr>
<tr>
<td>Consistency with RED and FQD</td>
<td>No particular limitation</td>
<td>No particular limitation</td>
<td></td>
</tr>
<tr>
<td>Consistency with other GoO schemes</td>
<td>No particular limitation. It is to be noted though that existing GoO schemes are not consistent among themselves</td>
<td>Same as (1)</td>
<td></td>
</tr>
<tr>
<td>Technology neutral and robust</td>
<td>GHG threshold is arbitrary and set of processes which are in or out is sensitive to threshold</td>
<td>The rate of conversion of renewable energy to green H₂ will depend on the GHG content of renewable energy, but other site specific factors come into play as well (such as energy efficiency). Not consistent with other GoO schemes</td>
<td></td>
</tr>
<tr>
<td>Effective fulfilment of environmental goals</td>
<td>GoOs may be generated despite detrimental environmental effects of facility production. No provision for keeping track of residual mix (i.e., production not covered by a GoO)</td>
<td>Partially address limitation of (1) as information on the whole GHG emissions of the plant is available.</td>
<td>Addresses limitations of (1) and (2): - GoO’s may only be generated from facilities having a beneficial/neutral impact. - Approach ensures that residual mix will not be negatively affected by processes generating GoO’s, eliminating need to track residual mix - This option does not take into account any sustainability aspect apart from GHG emissions</td>
</tr>
</tbody>
</table>
7 Stakeholder consultation on the most suitable GoO scheme

Following the logical consultation process presented in chapter 2, the present report shows the background and definition of green hydrogen, nevertheless some details are to be clarified in order to have a robust and transparent GoO scheme.

7.1 Definition of “green” hydrogen

The definition of green hydrogen as presented in chapter 4 covers a dual purpose: addressing renewable sources and including a threshold on the GHG emissions of the produced hydrogen.

The stakeholders are requested to assess the acceptability of the definition and to point out any practical inconveniences by applying such definition on the field.

**Question 1.** Is it necessary to include a minimum share threshold regarding the energy input form, enabling the generation of hydrogen from renewable sources?

**Question 2.** In case of a positive answer to Question 1, this minimum share should be:

- Option a) 5% of the total energy demand
- Option b) 10% of the total energy demand
- Option a) 20% of the total energy demand
- Option a) other percentage, please give a value

**Question 3.** Which threshold shall be applied to definition 1:

- a) 50% below the reference value?
- b) 60% below the reference value?
- c) 70% below the reference value?
- d) Moving threshold following RED? If yes, how fast should it move and which should be the starting % below the reference value?
- d) Other percentage, please give a (moving or fixed) value/s

**Question 4.** does the definition fit with current national initiatives in your country for the labelling and certification of green hydrogen? Please, elaborate.
7.2 Options to address the limitations of the definition

Chapter 6 shows that the definition presented in chapter 4.2 have a number of limitations, in particular the likelihood that facilities generating green hydrogen will in fact have higher overall emissions than the current reference and incapacity to limit emissions associated to the residual mix used in the hydrogen production facility. Improvements to this approach or more substantial changes can be applied to partially or fully address this challenge. On the other hand, other important aspects will also be impacted, including transparency and consistency with current GoO schemes.

Stakeholders are requested to give an opinion on the most appropriate and practicable approach to address this issue.

**Question 5.** Which definition shall apply for green hydrogen?

a) Definition 1 (see chapter 4.2)
b) Definition 1 including Option 1 of Chapter 6.2.1
c) Definition 2 (See chapter 6.2.2)

In case that none of the options are acceptable the stakeholders are requested to inform how the residual mix, transparency and other relevant issues should be treated outside the scheme in order to give a clear feedback to policy makers.

7.3 Inclusion of by-product hydrogen

The definition of green hydrogen includes sustainability requirements for raw materials (feedstocks). In case of by-product hydrogen (see examples in Annex 0) there is no available definition of sustainability for raw materials other than biomass.

The stakeholders are requested to assess the relevance of sustainability of raw materials when hydrogen is a by-product of established processes (e.g. chloralkali electrolysis, steam cracking of naphtha, etc.) and to present options on how to address sustainability in such cases.

**Question 6.** Should by-product hydrogen processes be eligible for producing green hydrogen?

**Question 7.** In case of a positive answer to Question 6 and taking into account that for GHG calculations an allocation approach is required (see Annex 0), additionally taking into account that energy allocation is required by the RED. Is energy allocation based on standard
enthalpies of formation and reaction enthalpies appropriate, when the input/s and/or output/s are not energy carriers (e.g. Chloralkali electrolysis)?

7.4 Inclusion of transport into GoO

Following the actual situation on the electricity GoO scheme, the green hydrogen GoO scheme proposed to have certificates at the production site and not at the consumer site.

The participants are requested to comments on the marked effects or disruptions due to not accounting for losses on the transport of hydrogen.

**Question 8.** Should energy consumption in transport and storage be addressed by the GoO?

The response to these questions will be assessed and the conclusions will be presented in the final report.
Annex A. GHG calculation for By-product hydrogen

The greenhouse gas emission calculation based on an LCA approach is described in [CertifHy 2015]4.

In general, the by-product H₂ is used for steam and electricity generation for consumption within the chemical complex, or it is transported to remote customers; only limited amounts of by-product hydrogen are not used, and flared or vented. Various methodologies can be applied for calculating the GHG emissions of H₂ from chloralkali electrolysis:

- Substitution method (marginal approach hydrogen): Today, by-product H₂ is used for steam and electricity generation. If this H₂ is used for other purposes, e.g. as transportation fuel for fuel cell electric vehicles (FCEV), additional natural gas is required within the chemical complex for steam and electricity generation. As a result of this substitution, the GHG emissions of the supply and use of natural gas are assigned to H₂.
- Substitution method (chlorine and sodium hydroxide by-product): H₂ is considered to be the main product, Cl₂ and NaOH are considered to be by-products. However, there is no commercially viable alternative production process for both Cl₂ and NaOH. Only for NaOH there is the Solvay process which leads to Na₂CO₃, which can subsequently be converted to NaOH. Therefore, the substitution method (chlorine and sodium hydroxide by-product) cannot be applied.
- Allocation by energy: Emissions are allocated to the products based on their relative energy content. In the present case, Cl₂ and NaOH are considered to be raw chemicals rather than energy products. Nonetheless, it is possible to apply energy allocation here based on standard enthalpies of formation of the chemicals involved in the reactions, which is used for calculating the enthalpy of reaction (ΔH; see chemical reaction below).
- Allocation by mass: Emissions are allocated to the products based on their relative weights. This allocation method is sometimes used for non-energy products, and is thus not applicable here.
- Allocation by market value: Emissions are allocated to the products based on their relative market value. This allocation method is sometimes used for products where the market values of the products show significant differences, which supports the assumption that the high-value products are the main motivation for the commercial operation, and thus higher levels of emissions should be allocated to them. This method is not suitable here.

In line with the RED/FQD methodology, energy allocation is also used for the calculation of the GHG balance of by-product hydrogen: emissions are allocated to the products based on their relative energy content.

The following two commercially relevant examples shall serve to clarify the approach [CertifHy 2015].

A.1 Hydrogen from chloralkali electrolysis

Chloralkali electrolysis is used to produce chlorine (Cl₂) and sodium hydroxide (NaOH) from sodium chloride (NaCl) and water. H₂ is a by-product. The enthalpy of reaction (ΔH) is positive which indicates that energy has to be provided to the reaction:

\[
2 \text{NaCl} + 2 \text{H}_2\text{O}_{\text{liq}} \rightarrow 2 \text{NaOH} + \text{Cl}_2 + \text{H}_2 \quad \Delta H = 540.22 \text{kJ}
\]

In general, the by-product H₂ is used for steam and electricity generation for consumption within the chemical complex, or it is transported to remote customers; only limited amounts of by-product hydrogen are not used, and flared or vented.

Cl₂ and NaOH are considered to be raw chemicals rather than energy products. Nonetheless, it is possible to apply energy allocation here as well based on standard enthalpies of formation of the chemicals involved in the reactions, which is used for calculating the enthalpy of reaction (ΔH; see chemical reaction above).

The energy content of the products can be considered to be the same as the theoretical energy input for electrolysis, i.e. the 540.22 kJ (see reaction above). The energy bound in the hydrogen amounts to 285.84 kJ, which is the higher heating value per mole of hydrogen. As a result, the allocation factor is 52.9% for hydrogen (see Table 9) [CertifHy 2015].

<table>
<thead>
<tr>
<th>Unit</th>
<th>Allocation by energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before allocation</td>
<td>kWh/kgH₂</td>
</tr>
<tr>
<td></td>
<td>kWh/kWh\text{H}_2, \text{LHV}</td>
</tr>
<tr>
<td>Allocation factor</td>
<td></td>
</tr>
<tr>
<td>After allocation</td>
<td>kWh/kWh\text{H}_2, \text{LHV}</td>
</tr>
</tbody>
</table>

A.2 Hydrogen from steam cracking of naphtha

Steam cracking of naphtha is used to generate olefins, e.g. for the production of 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 by-products, thereof about 1% hydrogen by mass, or 2.63% by energy.

Table 10 shows the yield of products and its composition for a typical steam cracking plant [CertifHy 2015].

<table>
<thead>
<tr>
<th>Product</th>
<th>Share (%-energy)</th>
<th>Energy stream (TJ/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂</td>
<td>2.63%</td>
<td>358</td>
</tr>
<tr>
<td>CO</td>
<td>0.01%</td>
<td>1</td>
</tr>
<tr>
<td>CH₄</td>
<td>16.34%</td>
<td>2,226</td>
</tr>
<tr>
<td>C₂H₂</td>
<td>0.70%</td>
<td>96</td>
</tr>
<tr>
<td>C₂H₄</td>
<td>31.14%</td>
<td>4,242</td>
</tr>
<tr>
<td>C₂H₆</td>
<td>3.46%</td>
<td>471</td>
</tr>
<tr>
<td>C₃H₆</td>
<td>15.80%</td>
<td>2,152</td>
</tr>
<tr>
<td>C₃H₈</td>
<td>0.37%</td>
<td>51</td>
</tr>
<tr>
<td>C₄H₈</td>
<td>9.15%</td>
<td>1,246</td>
</tr>
<tr>
<td>Pyrolysis gasoline</td>
<td>17.69%</td>
<td>2,410</td>
</tr>
<tr>
<td>Pyrolysis fuel oil</td>
<td>2.69%</td>
<td>367</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.00%</strong></td>
<td><strong>13,622</strong></td>
</tr>
</tbody>
</table>

Table 11 shows the input and output data for the production of hydrogen from naphtha steam cracking applying energy allocation based on typical values for the energy requirements [CertifHy 2015].

<table>
<thead>
<tr>
<th>I/O</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naphtha</td>
<td>Input MJ/MJ</td>
<td>0.9310</td>
</tr>
<tr>
<td>Steam</td>
<td>Input MJ/MJ</td>
<td>0.0135</td>
</tr>
<tr>
<td>Heat</td>
<td>Input MJ/MJ</td>
<td>0.1410</td>
</tr>
<tr>
<td>Electricity</td>
<td>Input MJ/MJ</td>
<td>0.0020</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>Output MJ</td>
<td>1</td>
</tr>
</tbody>
</table>
Annex 2: Examples of offsetting approaches

Notation of most commonly used variables:
- $e$ is the average emissions intensity of the considered production batch
- $\alpha$ is the share of renewable energy in the non-ancillary energy used for the considered production batch
- $e_0$ is the emissions intensity of the benchmark process
- $e_L$ is the CertifHy Low-GHG emissions intensity threshold.

Example 1: Offsetting of excessive emissions of the non-renewable share by reducing the share of CertifHy Green H2 generated.

The emissions intensity of the considered production batch is lower than benchmark. It is split into two parts – the renewable share, $\alpha$, and non-renewable share ($1-\alpha$), with an emissions intensity of $e_r$ and $e_{nr}$ respectively, and $e_r < e_0$.

If the emissions intensity of the non-renewable share exceeds benchmark ($e_{nr} > e_0$), the renewable and non-renewable shares of the batch may be redefined as follows:

Renewable share: $\alpha - \beta$
Non-renewable share: $1-\alpha + \beta$

with:
$$\beta = (1 - \alpha) \frac{e_{nr} - e_0}{e_0 - e_r}$$

This provides a non-renewable share with emissions equal to benchmark, allowing a certain amount of CertifHy Green H2 GoOs to be generated with the considered batch.

Example 2: Allocation of zero emissions GHG emissions to Green Hydrogen as well as Low-GHG Hydrogen:

When the emissions intensity of the considered production batch, $e$, is lower than benchmark, $e_0$, the share $\lambda$ of zero-GHG hydrogen in production which may be covered by a GoO is simply:

$$\lambda = 1 - \frac{e}{e_0}$$

Setting the share of zero-emissions hydrogen to $\lambda$ provides that the emissions intensity of the non-zero-emissions hydrogen is $e_0$.

If a share $\alpha$ of the energy input is renewable, the share $\gamma$ of zero-GHG Green hydrogen in production is:

$$\gamma = \min (\alpha; \lambda)$$