DELIVERABLE REPORT

GrInHy2.0
Green Industrial Hydrogen

Green Industrial Hydrogen via steam electrolysis

Initiative:	Fuel Cells and Hydrogen 2 Joint Undertaking (FCH2-JU)	
Grant agreement No:	826350	
Start date:	01.01.2019	Duration: 48 Months
Project Coordinator:	SZMF	

Document Classification

WP No:	4
Task No:	4.1
Deliverable No:	D4.1
Title:	Plan of action for the operational renewable electricity supply
Lead beneficiary:	SZFG
Authors:	Veronika Küsgen, Marco Hauer, Simon Kroop, Jan Freymann
Dissemination level:	Public
Due date of deliverable:	**Month 12**
Actual submission date:	**2020/03/03**
Re-submission date:	**2020/11/09**

Document Validation

Reviewer:	SF, Jan Freymann
Coordinator:	SZMF, Simon Kroop

Table of Content

Acknowledgement

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (FCH 2 JU) under Grant Agreement No 826350. This Joint Undertaking receives support from the European Union's Horizon 2020 Research and Innovation programme, Hydrogen Europe and Hydrogen Europe Research.

Table of Acronyms

GO	Guarantee of Origin
HPU	Hydrogen Processing Unit
SOEC	Solid Oxide Electrolysis Cell(s)
SZFG	Salzgitter Flachstahl GmbH

1 Introduction

Hydrogen – either as feedstock or energy carrier – holds a huge potential to significantly decrease the carbon intensity of the European industry and mobility sectors.

However, in order to comply with the European Commission's roadmap for moving towards a competitive low-carbon economy in 2050, the origin and production route of the hydrogen is essential to reach the overall greenhouse gas emission targets.

The key to that will be the hydrogen production from renewable energies and low-carbon or carbon neutral energy sources. Since these energy sources will be a limiting factor in the future, energy efficient technologies and production routes are most promising.

One of the promising technologies is the steam electrolysis based on Solid Oxide Electrolysis Cells (SOEC).

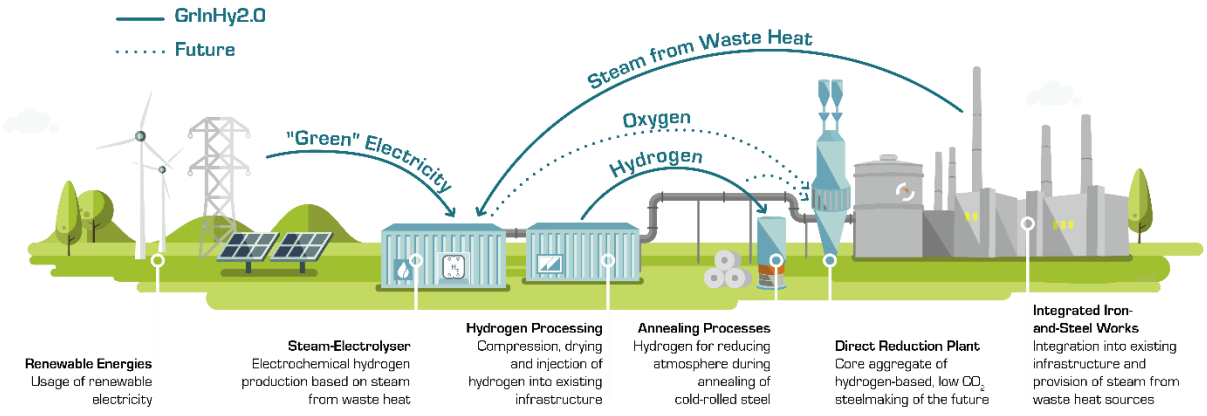

Figure 1: Project concept of GrInHy2.0

In the GrInHy2.0[1] project, the world's first steam electrolyser of megawatt class will be manufactured and operated at an integrated iron-and-steel works (see Figure 1). While using steam from waste heat of the steelmaking processes, the electrolyser shall produce at least 100 tons of 'green' hydrogen which will be fed into the existing hydrogen infrastructure. The attribute 'green' will have to comply with the current CertifHy scheme, which is an EU-wide Guarantee of Origin (GO) scheme for hydrogen developed by the CertifHy project[2].

Due to the significant thermal energy input in form of steam from carbon-neutral waste heat sources, the steam electrolysis of GrInHy2.0 shall achieve outstanding electrical efficiencies of up to 84 $\%_{LHV}$.

Parallel to this plan of action, the report of Deliverable 4.2 "Assessment of hydrogen certification standards and requirements" has been prepared. With respect to the results and recommendation of D4.2, the following sections explain and lay out the plan of action to comply with the CertifHy scheme to produce at least 100 tons of 'green' hydrogen.

[1] GrInHy2.0: Green Industrial Hydrogen via steam electrolysis
[2] for more information, see https://www.certifhy.eu/

2 GrInHy2.0 System Boundary Accounting to CertifHy

The GrInHy2.0 system consists of two containerized units: The steam electrolyser unit and the hydrogen processing unit (HPU). At nominal operation, the system produces 200 Nm^3 of hydrogen per hour at 9 bar by using 174 kWh_{th} of carbon-neutral steam from waste heat and 785 kWh_{el} of electricity (see Figure 2).

However, under the CertifHy scheme the boundary condition is defined as follows:

> *"The system boundary shall include all the production stages needed to reach a hydrogen purity of at least 99.9 %vol and a gauge pressure of at least 3 MPa."*[3]

Therefore, a theoretical electricity demand has to be calculated, equalling the "[…] consumption that would be required to reach a pressure of 3 MPa assuming an isentropic efficiency of 60 % and a single compression stage […]".[3] The power demand for such an isentropic compression from 9 bar to 30 bar equals approximately 13.5 kW_{AC}.

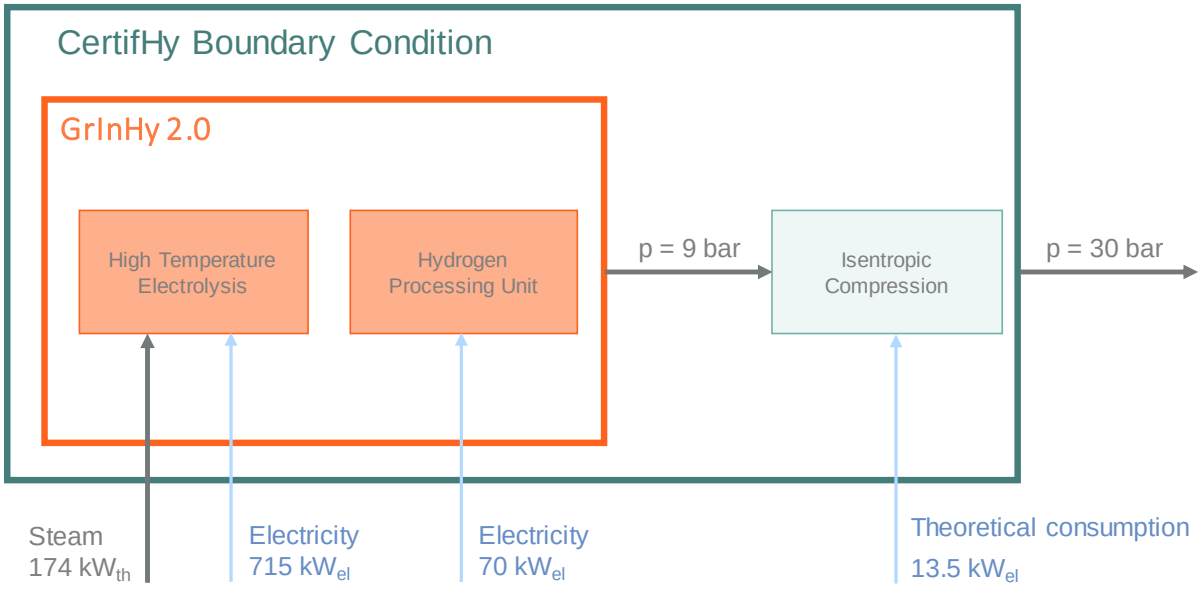

Figure 2: Power demand under the CertifHy boundary conditions

The overall power demand, assuming a theoretical system boundary of 3 MPa, equals 798.5 kW_{el} of electricity and 174 kW_{th} of heat. In total, 82.1 percent of the energy is provided via electricity while 17.9 percent is provided via heat.

Further information is provided in the report D4.2 "Assessment of hydrogen certification standards and requirements" in chapter 3.

[3] CertifHy (2019): CertifHy Scheme Subsidiary Document, CertifHy-SD Hydrogen Criteria, https://www.certifhy.eu/

3 Plan of Action

3.1 Description of Objective

This action plan describes the procedure for producing 100 tons of 'green' hydrogen during the implementation of the GrInHy2.0 project in compliance with the CertifHy scheme.

3.2 Procedure

In the following sections, the tasks of the action plan are described and scheduled. The procedure itself follows the principle of the Deming Circle.

3.2.1 Preparation and Planning Phase

The "Preparation and Planning Phase" was scheduled in the beginning of the project for the first 12 months of the project. It is divided into three main tasks:

1. *Assessment of CertifHy scheme*

   In order to produce 'green' hydrogen in line with the CertifHy scheme, it is required to identify possible CertifHy conforming hydrogen production pathways.

   This task is closed with the submission of the deliverable D4.2.

2. *Determination of the best strategy to comply with CertifHy*

   In contrary to the low temperature electrolysers that have been investigated within CertifHy, the hydrogen production via a steam electrolyser is based on both electrical and thermal energy. In D4.2 (see section 4), different options for 'green' hydrogen production have been assessed.

   After considering all advantages and disadvantages, the most time and cost-effective strategy is to solely purchase GOs for renewable electricity. Since only 82.1 percent of hydrogen is produced from electricity and would thus qualify as green, this strategy requires ramping up production from initially 100 tons to a total of 121.8 tons of hydrogen to achieve a 100 tons electricity-based 'green' hydrogen batch (Figure 3).

	initially planned	after CertifHy regulatory analysis
Total	**100 t**	**121.8 t**
Electricity share	82.1 t	100 t
Heat share unclear	17.9 t	21.8 t

Figure 3: Hydrogen production quantity under GrInHy2.0

   Therefore, the strategy follows the recommendations of the D4.2 report. This task is closed with the submission of this deliverable D4.1.

3. *Identification of possible supplier of GOs*

   Approximately 5,400 GOs for renewable electricity will be needed to produce 121.8 tons of hydrogen. Based on the monetary volume, internal purchase practices at Salzgitter Flachstahl GmbH (SZFG) require having two potential suppliers. RWE

Supply and Trading GmbH and Statkraft Markets GmbH have been identified as those potential suppliers of GOs.

3.2.2 Execution Phase

With the commissioning and final site acceptance test in month 18, the execution phase of the action plan starts.

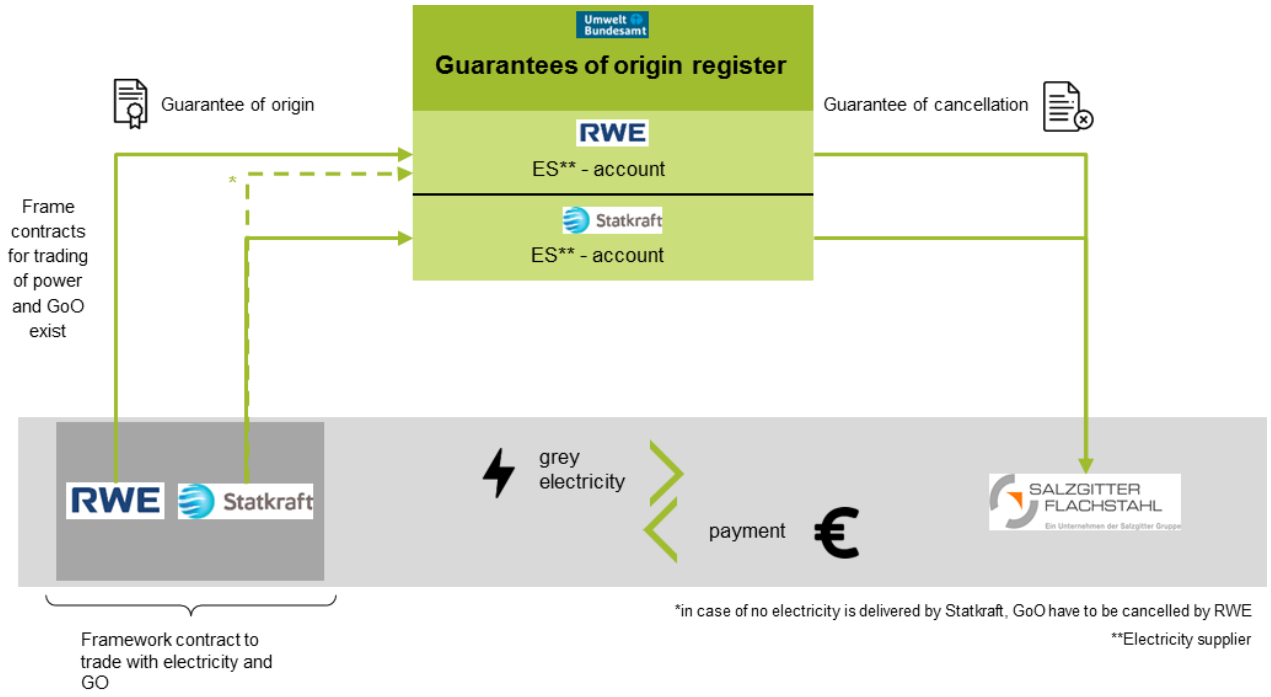

Figure 4: General principle of purchasing and cancelling of GO

The execution phase itself consists of annual sequences and follows the general principle described in Figure 4 above and the task description in Table 1 below.

Annual Sequence	Time span	Task description
#1	07/2020 – 01/2021	With the official start of operation of the GrInHy2.0 system, both the electricity and steam consumption will be measured and logged as well as the amount of hydrogen that will be fed to the hydrogen pipeline. In January of the next year, SZFG will a prepare an energy balance of the GrInHy2.0 system. Based on the electricity consumed, SZFG will purchase GOs from either one or both identified supplier and will determine the amount of 'green' hydrogen produced. In order to minimize costs related to administration and personnel, the GOs will then be cancelled by the supplier.
#2	01/2021 – 02/2022	From January 2021 until February 2022, SZFG will repeat the procedure described for the first annual sequence (#1). In addition to the determination of the amount of 'green' hydrogen produced in 2021, SZFG will also calculate the remaining hydrogen amount to reach the total of 100 tons of 'green' hydrogen.

#3	01/2022 – 01/2023	If the objective of 100 tons of 'green' hydrogen is reached in 2021, this annual sequence is redundant. Otherwise, the third sequence will follow the description of the second annual sequence.

Table 1: Task description of the annual sequences for purchasing GOs

3.2.3 Check Phase

After each annual sequence, the effectiveness of the Action Plan will be checked and adapted accordingly. By the end of the project or when reaching the objective of 100 tons of 'green' hydrogen, SZFG will publish the results and experiences either within the deliverable D3.2 "Final report on 13,000 h operational results" or the final report.

3.2.4 Act Phase

Act phase is equivalent to the exploitation of results. During and after the project, the GrInHy2.0 partners will intensify the communication with the CertifHy project based on GrInHy2.0's results and strategy.

3.3 Milestones

The action plan's degree of completion is measured in five milestones. The estimated due dates and descriptions of the milestones are listed in Table 2.

Milestones		Due Date	Description
#1	Start of operation	30/06/2020	As of today, the GrInHy2.0 system will start its operation after the positive site acceptance test in the end of June 2020.
#2	End of 1st annual sequence	31/01/2021	The first annual sequence ends with the purchase and cancelling of GOs equivalent to the electricity consumed. After this sequence, SZFG will publish the amount of 'green' hydrogen produced.
#3	End of 2nd annual sequence	31/01/2022	The second annual sequence ends with the purchase and cancelling of GOs equivalent to the electricity consumed. After this sequence, SZFG will publish the amount of 'green' hydrogen produced.
#4	*End of 3rd annual sequence*	*31/01/2023*	*Depending on the amount of 'green' hydrogen produced in 2020 and 2021, the 3rd annual sequence itself and, thus, the milestone #4 is redundant.*
#5	100 tons of 'green' hydrogen produced	31/01/2022 or 31/01/2023	Depending on the amount of 'green' hydrogen produced in 2020 and 2021, the milestone of 100 tons will be either verified in January 2022 or January 2023. With a nominal hydrogen production rate of 200 Nm³ per hour, the actual goal most probably will be reached in mid-2021.

Table 2: Milestones of the Action Plan "Operational renewable electricity supply"

4 Summary

One main objective of GrInHy2.0 is to operate a steam electrolyser in order produce at least 100 tons of ‘green’ hydrogen according to the CertifHy scheme. In contrary to other (low temperature) electrolysis technologies, the steam electrolyser is characterized by a significant thermal energy input (steam), which results in a lower electricity demand.

In GrInHy2.0, the steam is generated from carbon-neutral, inevitable waste heat sources of SZFG’s production processes of its integrated iron-and-steel works[4]. However, carbon-neutral waste heat from inevitable industrial sources is not yet specified under CertifHy.

This action plan describes SZFG’s procedure to purchase approximately 5,400 GOs for renewable electricity to produce 121.8 tons of hydrogen. This is equivalent to 100 tons of ‘green’ hydrogen that can be allocated to the electricity consumption.

To also include the carbon-neutral waste heat used in GrInHy2.0 to produce hydrogen, we strongly recommend decision-makers to categorize waste heat as renewable, carbon-neutral input energy source, if

- the source of waste heat is unavoidable, and
- no additional direct or indirect CO_2 emissions occur.

[4] see report D4.2 “Assessment of hydrogen certification standards and requirements”