Methodology for the technical replication studies

Deliverable 6.8

December 2022

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Preface

The aim of **GREEN HYSLAND** is to **deploy a Hydrogen ecosystem on the island of Mallorca**, Spain. The initiative is receiving **10 million Euros of co-funding** from the European Commission through the **Clean Hydrogen Partnership**. It is a 5-year-project that started on the 1st January 2021, and will end on 31st December 2025. The consortium is formed by **30 partners from 11 countries**, 9 from the European Union, as well as Chile and Morocco. The project will deliver the **first Hydrogen Valley in Southern Europe**, developing a fully functioning hydrogen ecosystem covering the entire value chain, from the production to the distribution and consumption of, at least, 330 tonnes per year of green hydrogen, traced through a Guarantee of Origin System. This hydrogen will be used in six different applications, as follows:

- The **hydrogen pipeline and the injection point** of part of the hydrogen produced at the Lloseta plant into the island's natural gas network operated by Redexis.
- The **100 kWe fuel cell** that will supply electricity to the maritime station of the **Balearic Port of Palma de Mallorca**.
- The **50 kWe CHP** system to be located in the **Iberostar Bahía de Palma hotel** (4*), which will cover part of the hotel's energy demand.
- The **25 kWe CHP** system to be located at the **Municipal Sports Centre in Lloseta**, which will cover part of the site's energy demand.
- The integration of **5 hydrogen buses to the EMT city bus fleet** of Palma de Mallorca.
- The integration of **hydrogen vans** in the Alfill Logistics vehicle fleet as well as potentially the use by rental car companies to incorporate hydrogen vehicles in their **rental car fleets**.

The infrastructures which will be developed within the project are:

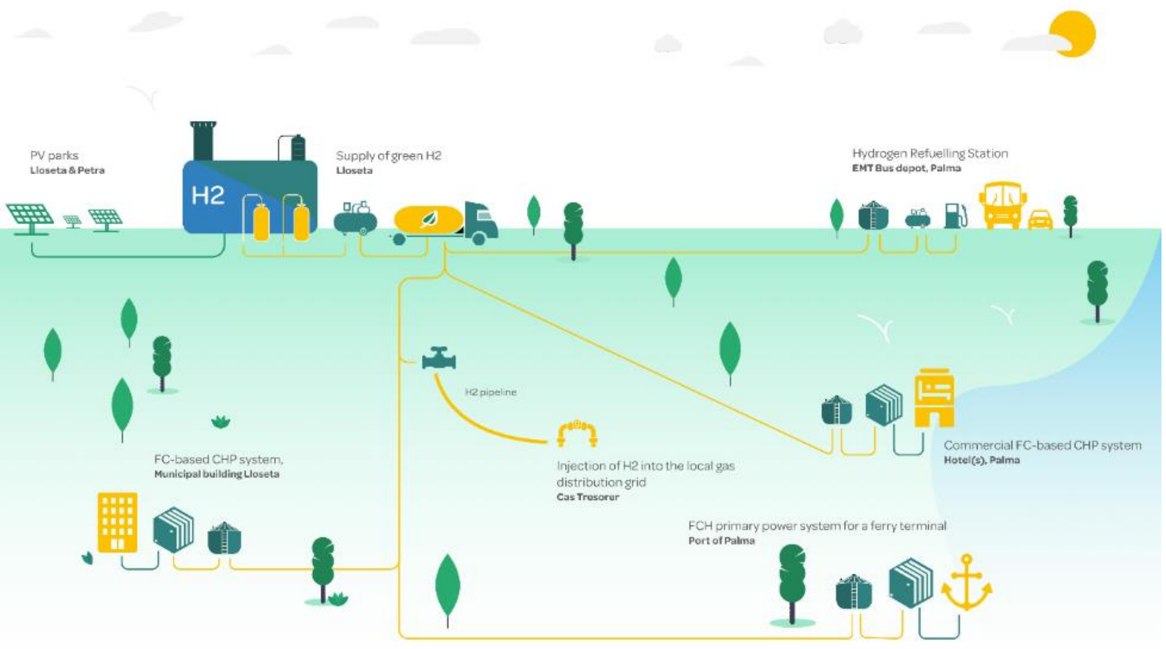
- The **green hydrogen production plant** located on CEMEX land in Lloseta.
- The deployment of a **Hydrogen Refuelling Station** (HRS) at the EMT facilities.
- The development of tube trailers which will transport the hydrogen produced in Lloseta's plant to the different applications.

This initiative aims to reduce the CO_2 emissions of Mallorca up to 20,700 tonnes per year by the end of the project.

The project will also deliver **a roadmap towards 2050** that compiles a long-term vision for the **development of a widespread hydrogen economy in Mallorca and the Balearic Islands**, in line with the **Spanish environmental and climate objectives set for 2050.** This long-term roadmap will be an evolution of the current regional roadmap for the deployment of renewable energy and the energy transition and will involve local and regional stakeholders through public consultations.

In addition, GREEN HYSLAND contemplates the **development of replication experiences** in five other EU islands: Madeira (PT), Tenerife (ES), Aran Island (IE), Rhodes (GR) and Ameland (NL) as well as Chile and Morocco. Within the project, the impact of deployment of hydrogen technologies at regional level (Mallorca and Balearic Islands) at technical, economic, energy, environmental, regulatory, and socioeconomic levels will be analysed. Additionally, detailed techno-economic studies for scaling-up renewable hydrogen production, interconnecting infrastructure, and local hydrogen end-uses, both within the island of Mallorca and beyond, will be developed to facilitate and de-risk future sector investment.

The Infrastructures for the hydrogen production and distribution, together with the end-users' pilot sites and the logistics required for the green hydrogen distribution will be developed as follows:



The deployment of the green hydrogen ecosystem in Mallorca as well its replication to other islands across the EU, Chile and Morocco is being achieved by the concerted efforts of the GREEN HYSLAND consortium:

No	Participant Name	Short Name	Country Code	Logo
1	ENAGÁS RENOVABLE S.L.	EGR	ES	enagas renovable
2	ACCIONA ENERGIA S.A.	ACCIONA ENER	ES	acciona energía
3	REDEXIS GAS S.A.	REDEXIS GAS SA	ES	Redexis
4	Empresa Municipal de Transports Urbans de Palma de Mallorca S.A.	EMT-PALMA	ES	EMT Empresa Municipal de Transports de Palma de Mallorca
5	CALVERA MAQUINARIA E INSTALACIONES S.L.	CALVERA	ES	CALVERA Hydrogen
6	AJUNTAMENT DE LLOSETA	Lloseta Council	ES	Ajuntament de Lloseta

7	AUTORIDAD PORTUARIA DE BALEARES	PORTS BALEARS	ES	
8	CONSULTORIA TECNICA NAVAL VALENCIANA S.L.	COTENAVAL	ES	
9	BALEARIA EUROLINEAS MARITIMAS S.A.	Balearia	ES	
10	INSTITUTO BALEAR DE LA ENERGIA	IBE	ES	
11	UNIVERSITAT DE LES ILLES BALEARS	UIB	ES	
12	FUNDACION PARA EL DESARROLLO DE LAS NUEVAS TECNOLOGIAS DEL HIDROGENO EN ARAGON	FHa	ES	
13	CENTRO NACIONAL DE EXPERIMENTACIONDE TECNOLOGIAS DE HIDROGENO Y PILASDE COMBUSTIBLE CONSORCIO	CNHYDROGEN	ES	
14	ASOCIACION ESPANOLA DEL HIDROGENO	AeH2	ES	
15	COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES	CEA	FR	
16	ENERCY BV	ENER	NL	
17	HYENERGY TRANSSTORE BV	HTS	NL	
18	STICHTING NEW ENERGY COALITION	NEW ENER.COALIT	NL	
19	HYCOLOGNE GMBH	HyCologne	DE	
20	FEDERATION EUROPEENNE DES AGENCES ET DES REGIONS POUR ''ENERGIE ET ''ENVIRONNEMENT	FEDARENE	BE	
21	NATIONAL UNIVERSITY OF IRELAND GALWAY	NUI GALWAY	IE	

22	THE EUROPEAN MARINE ENERGY CENTRE LIMITED	EMEC	UK	
23	GASNAM–- ASOCIACION IBERICA DE GASNATURAL Y RENOVABLE PARA LA MOVILIDAD	GASNAM	ES	
24	UNIVERSIDAD DE LA LAGUNA	ULL	ES	
25	ENERGY CO-OPERATIVES IRELAND LIMITED	En.Coop.Ireland	IE	
26	AGENCIA REGIONAL DA ENERGIA E AMBIENTE DA REGIAO AUTONOMA DA MADEIRA	AREAM	PT	
27	GEMEENTE AMELAND	Gem.Ameland	NL	
28	DIKTYO AEIFORIKON NISON TOY AIGAIOU AE	DAFNI	EL	
29	ASOCIACION CHILENA DE HIDROGENO	H2CHILE	CL	
30	Association Marocaine pour l'Hydrogène et le Développement Durable	AMHYD	MA	
31	HYENERGY CONSULTANCY LTD	HYE	NL	
32	ENAGÁS S.A.	ENAGAS	ES	

Table of contents

1. Executive Summary

This report provides the methodology that will be followed throughout the project to carry out the replication work of GREEN HYSLAND (WP 6).

The replication methodology of GREEN HYSLAND is based on two main aspects:

- the development of a new upgraded replicability tool (the HTP Tool 1.1) that will allow to analyse the green hydrogen potential of the Follower Territories and subsequently, to determine the best strategies to implement the Green Hysland concept adapted to their regions.
- how this tool and other targeted replication activities such as mapping and providing mentoring support to new islands with green hydrogen potential will be used to spread the use of green hydrogen to as many islands as possible.

Thus, this document is structured as follows:

- In Chapter 2 we introduce the subject of replicating Hydrogen Valleys for island ecosystems across the EU and the context of that work. An introduction to the origins of the HTP Tool, as well as to the HTP platform that hosts it, is also presented.
- Chapter 3 presents in more detail the achievements to be reached with the updated HTP Tool, as well as the methodology that will be followed to ensure optimum replication. For this, a 5-step process will be followed, as outlined below:
    1. As a first step, the HTP Tool will be developed further into version 1.1. in order to make it more useful for a wider range of hydrogen applications than its original version. The tool will then be used for the elaboration of the Technical Replication Studies for the 6 Follower Territories.
    2. As a second step, the initial Mapping of EU island stakeholder groups done in this document will be used to create a Long-List of islands with potential and interest in using green hydrogen in their respective territories. This will be done through a desktop study and targeted stakeholder consultations.
    3. As a third step, the identified island Long-List will be used to engage these stakeholders and recruit candidates for the GREEN HYSLAND Project Development Assistance (PDA) programme, which includes the application of the HTP Tool in 10 EU islands as well as tailor-made mentoring support.
    4. In the fourth step, the GREEN HYSLAND Technical Assistance programme will be delivered to 10 islands.
    5. In the final fifth step, the results of the replication work undertaken in GREEN HYSLAND, including the Follower Territory Replication Studies as well as the Technical Assistance programme, will be compiled and shared with island networks and at national and EU level. The timeline for this methodology is detailed in Chapter 4 and the conclusions and next steps for the rest of the project can be found in Chapter 5.

2. Introduction

2.1. The scaling up and replication of hydrogen island ecosystems across the EU and their context

The GREEN HYSLAND project relates to and implements multiple EU policy priorities:

- Inclusion of renewable hydrogen in **Directive 2018/2001 of 11 December 2018** [1]on the promotion of the use of energy from renewable sources, and the **Hydrogen Initiative**, launched in **Linz in 2018**, a declaration in which EU Member States, the European Commission, and other countries and organisations **highlight the power of sustainable hydrogen technologies for the decarbonisation** of multiple sectors of the economy, long-term security of supply and European economic competitiveness.

- **Zero Net Emissions Target for 2050**: Due to the increasingly evident climate change, Europe reached an agreement (European Green Deal, 2019, [2]) to curb EU net CO_2 emissions by 55% by 2030 and to net zero by the year 2050. It already mentions hydrogen and its technologies as a driver of change to tackle this challenge. The advent of a sustainable energy system is becoming increasingly urgent.

- **European Hydrogen Roadmap (2019)** [3]: in this document, Europe advances in its objectives to establish the Hydrogen Economy and other motivations appear, such as geostrategic ones. Europe is aware that the fight against climate change goes hand in hand with an industrial and scientific race to maintain technological leadership in the face of the firm commitment of China, India, Japan, and South Korea.

  To this end, this European Roadmap identifies several barriers to be overcome:

  - Lack of a coherent, explicit, and long-term strategy on the role of hydrogen in the energy transition.
  - Lack of instruments to guarantee early and large-scale investments. Within this lack of instruments, there is a lack of software to understand and simulate the energy transition towards the hydrogen economy and thus be able to limit the risks of these processes with so much uncertainty.

- Following the EU Hydrogen Roadmap, in 2020 the **EU Hydrogen Strategy** was published and it set out a vision for the creation of a European hydrogen ecosystem starting from research and innovation to scale up production and infrastructure, and also including an international dimension.

  The strategy focuses on the production and use of renewable hydrogen for the decarbonisation of the EU economy in a cost-effective way, in line with the European Green Deal.

- Finally, in the wake of the Ukraine war, the **REPower EU Plan** reinforces the urgent need for Europe to become as energy independent from Russia as possible, and hydrogen is a key aspect of this Plan. It sets a new increased ambition for producing 10 GW of green hydrogen in the EU and importing another 10 GW from third countries until 2030 [4].

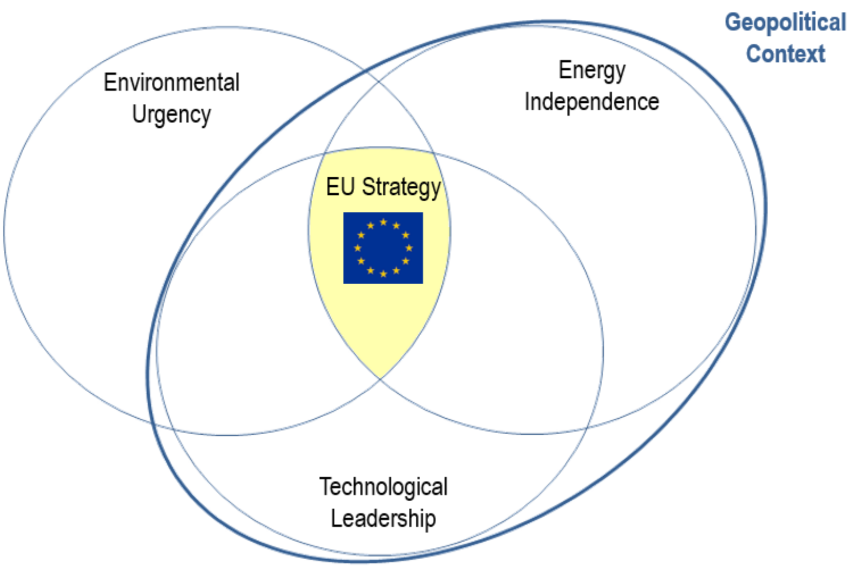


Figure 1: International context from which the European Hydrogen Strategy emerges.

- Following these policy guidelines, the **Hydrogen Europe Research** association (which represents the interests of the hydrogen industry and its stakeholders and promotes hydrogen as an enabler of a zero-emission society) developed in 2020, within the **Strategic Research and Innovation Agenda** [5], different strategic sectors for action, among which are the headings:
  - **Roadmap 20–- Hydrogen Valleys**:

    Strategy for the development of regional hydrogen ecosystems that will make the Hydrogen Economy take off. To this end, the aim is to:

    - Demonstrate the interoperability and synergy between the three pillars of the hydrogen value chain (production, storage and distribution, and end-use applications) and the other energy systems currently in place: electricity grid, gas grid, RES-E infrastructures, batteries, etc.
    - Identify the best business models.
    - Demonstrate, at system level, energy efficiency, economic profitability, and resilience.

    Ultimately, Hydrogen Valleys aim to create a new hydrogen market by upscaling, replicating and connecting different hydrogen hubs.

  - **Roadmap 18.4–- Modelling and Simulation**:

    Under this strategy, Hydrogen Europe identifies several needs to be met to accelerate technological development across the hydrogen value chain:

    - Modelling and simulation tools, essential to design products, plants, and complex systems.

  - Reliable and validated models are needed to "accelerate the understanding, prediction and improvement" of such systems.

- From the Spanish national point of view, there is also the **"Hydrogen Roadmap: a Commitment to Renewable Hydrogen"** [6], approved in **October 2020** by the Government of Spain, which seeks to position the country as a technological benchmark in the production and use of renewable hydrogen, reaching 4 GW of production capacity by 2030 and mobilising an estimated total investment of 8.900 million euros.[4]

To summarize, both for environmental and geopolitical reasons, Europe finds itself in a **context of urgent need for an energy system transition**. At the same time, it has been demonstrated that Europe has established the guidelines to achieve this objective by 2050 and has defined different strategic lines of action to solve the identified barriers. Within these strategies, the concept of Hydrogen Valleys has emerged as nuclei for developing this new energy system. These regional hydrogen ecosystems then aim to expand to form a Hydrogen Economy throughout Europe by replicating Hydrogen Valleys in other regions and by connecting existing Hydrogen Valleys with each other.

In order to enable the development of further Hydrogen Valleys, FHa will provide an enhanced software tool aligned with the needs identified by Europe above.

2.2. The Hydrogen Territories Platform & HTP Tool

HISTORY OF THE HTP AND ITS REPLICABILITY TOOL

The Hydrogen Territories Platform (HTP) is a website that was conceived as an inter-regional platform to help participants understand how their regions could successfully replicate the concept of the BIG HIT project, which was the first regional hydrogen ecosystem or Hydrogen Valley in Europe[1].

The BIG HIT Hydrogen Valley builds on foundations laid by the Orkney Surf 'n' Turf initiative and produces hydrogen on the Scottish Orkney islands of Eday partly using community-owned onshore wind energy. The aim of the BIG HIT project was to demonstrate that Scotland's Orkney Islands are a replicable hydrogen territory, using locally generated and curtailed renewable energy to produce green hydrogen, which can then be used as a clean energy carrier to store and use the valuable energy for local applications.

The Platform is chaired by the Aragon Hydrogen Foundation (FHa) and the Scottish Hydrogen and Fuel Cells Association (SFHCA), in the framework of the BIG HIT project and with the support of their project partners.

The main objective of the HTP is to ensure the replicability of the BIG HIT project concept, and particularly, the replication of business models based on the use of hydrogen and fuel cell technologies in integrated local energy systems developed in the framework of the BIG HIT project. The platform also serves as a network of knowledge transfer after the project-end in 2022.

[1] BIG HIT Project, Grant Agreement nº 700092.

For this purpose, a simulation toolkit, the so-called HTP Tool, was created to share the main lessons learned during the project, intended as a “learning by doing” tool to replicate the BIG HIT concept to other territories. Figure 2 shows the HTP website mentioned.

Figure. 2: Hydrogen Territories Platform site: http://h2territory.eu/

Originally, the first HTP Tool provided a preliminary techno-economic analysis and assessment of business models that paves the way for the replicability of the BIG HIT concept to other territories. The tool, based on Excel, was designed with one main objective: to provide HTP members, in particular public entities, and decision-makers, with an initial assessment for the introduction of hydrogen technologies in their regions.

Now, in the Green Hysland project, the objective is to take a step forward in the development of this instrument (HTP Tool 1.1) by including a dynamic simulation of the energy flows and financials of the system. Here below, figure 3 shows how this enhancement is taking shape through a simplified interface, with the aim of improving the user experience (UX), which will facilitate its use by a larger number of end-users, leading to a greater impact of the replication work undertaken in GREEN HYSLAND.

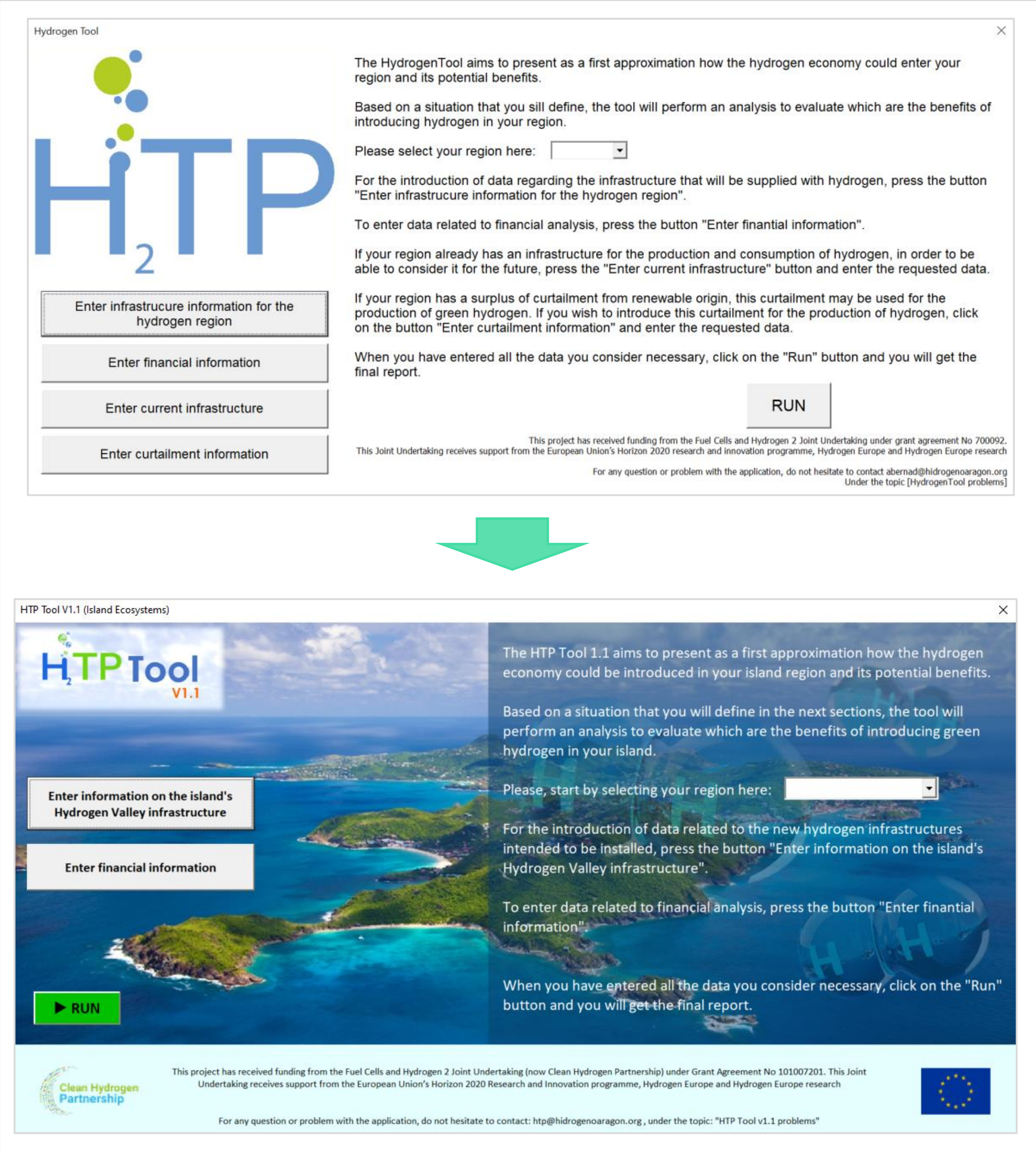


Figure. 3: Screenshot of the previous and new interface of the HTP Tool 1.1.

2.3. HTP Tool 1.1: aim & objectives

The first version of this tool created the foundation needed to better understand the mission of replicating a Hydrogen Valley.

Since the Green Hysland hub faces a new more complex Hydrogen Valley structure, the new upgraded tool will have the challenge of integrating this new reality, while remaining simple to operate. To this end a "Follower Territory Survey", edited by FHa, was launched for a better understanding of Follower Territories' (FTs) energy context and end users' knowledge on hydrogen technologies and simulation tools. The completion of the survey (included in Appendix I) by DAFNI (Rhodes), H2-Chile (Chiloé), AREAM (Madeira), GEMEENTE AMELAND (Ameland), ENERGY CO-OPERATIVES IRELAND Ltd. (Aran), AMHYD (Morocco), ULL (Tenerife), has allowed FHa to identify areas for functional improvement. Figure 4 shows, at a glance, the areas to be improved, in particular the ease of collecting regional data, the user's freedom to customise the inputs and, the need for more models to be integrated.

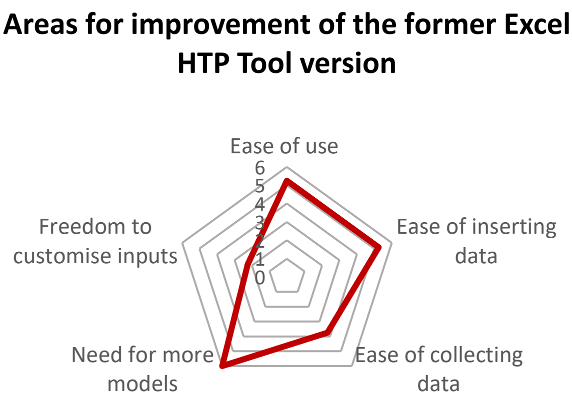


Figure. 4: Overview of the diagram that shows areas for improvement of the original Excel HTP Tool following Survey results.

Other conclusions obtained from the Follower Territory Survey are listed below:

- The case studies are highly heterogeneous, but very common features are large renewable curtailments & seasonality in the energy demand.
- In general, there are serious concerns about safety and possible impact on the tourism sector.
- There is a wide range of skills among FTs users and very different experiences with hydrogen.

In addition, several features were suggested to be added:

- Enable the ease of use for users with lower IT skills or knowledge of hydrogen technologies and the energy sector.
- Enable the user to create different scenarios according to their island context.
- Enable the user to introduce regional data.
- Enable the user to size the infrastructures.
- Enable the user to enter co-fundings, subsidies, grants, loans.
- More interpreted results: job creations, flow charts, etc.

Therefore, FHa will rely on this feedback to develop a better tool usable by the widest possible range of users.

3. Methodology for Replication

This section provides the methodology that will be applied through the different axes of action in which Task 6.2 is articulated in order to achieve the replication of Hydrogen Ecosystems to other European island territories and beyond. The methodology follows the steps below:

- **Step 1:** HTP tool upgrading to version 1.1 and the FTs' Technical Replication studies.
- **Step 2**: Mapping islands – Identification of EU islands with green hydrogen potential.
- **Step 3**: Recruitment for Technical Assistance support – Information sessions/webinars/workshops to recruit candidates for Technical Assistance programme.
- **Step 4**: Project Development Assistance (PDA) to support stakeholders in developing green hydrogen project concepts through mentoring and using the HTP Tool 1.1.
- **Step 5**: Replication Results – Final report, dissemination, and continuation beyond Green Hysland project.

3.1. Step 1: Development of HTP Tool 1.1 and of the Follower Territory Technical Replication Studies

Section 3.1.1 below presents the methodology that will be followed to model the replication potential of a Hydrogen Valley in an island region (a so-called "Hydrogen Island").

The key results of the tool upgrade are summarised in sections 3.1.2 and 3.1.3.

3.1.1. Methodology for modelling the replication process

In order to meet the replication challenge, the model will be programmed according to the following logic:

- First, the hydrogen demands to be met in the Hydrogen Valley will be calculated.
- Secondly, the aim of the algorithm is to satisfy the hydrogen demands by producing hydrogen with the electrolysers deployed in the Hydrogen Valley.
- Finally, it will be crucial to incorporate logistics, which connects demand and production, into the code.

The following figure 5 shows the above logic translated into a Sankey diagram. Here we can see the different energy flows from production to final applications. As mentioned before (section 2.3), the new tool aims to offer a better user experience and to facilitate the understanding of the calculations performed. For this reason, diagrams of this type are intended to be integrated into the too''s reports. These diagrams will allow the user to understand where there may be inefficiencies in the system and how energy is being managed.

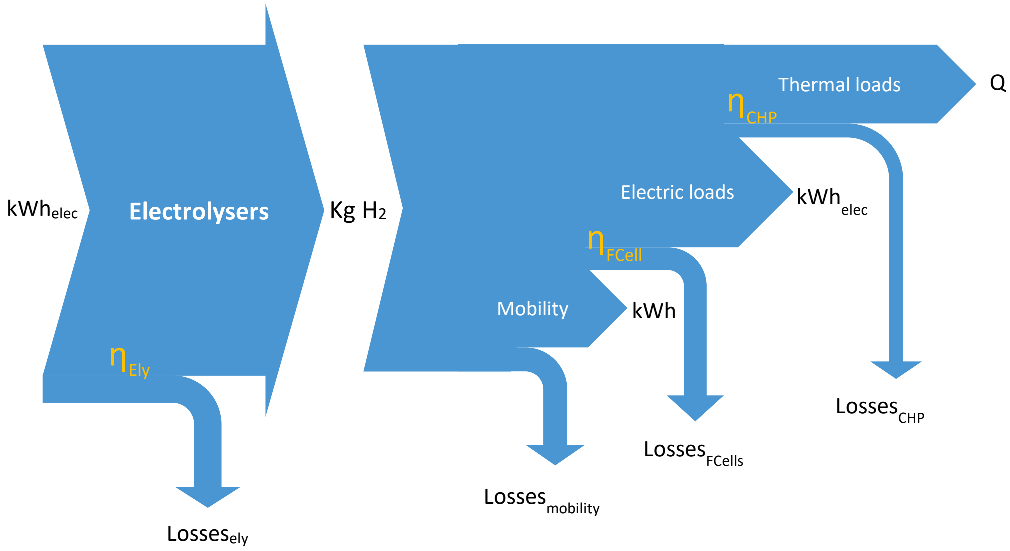


Figure. 5: Sankey diagram of the energy flows present in a generic Hydrogen Valley.

$$H_2\ Demand\ \left(\frac{kg\ H_2}{year}\right) = D_{Mobility} + D_{Elec} + D_{Therm} + D_{Blending} + \cdots \quad (1)$$

Where:

$D_{Mobility}$ = hydrogen demand from fuel cell mobility applications (heavy transport, vans, buses, vehicle fleets, etc.)

D_{Elec} = hydrogen demand from fuel cells that will power electrical loads.

D_{Therm} = hydrogen demand corresponding to that part of hydrogen consumed by a CHP fuel cell to meet heat demands.

$D_{Blending}$ = hydrogen demand corresponding to green hydrogen kilograms injected into the natural gas network.

η_{Ely} = electrolyser performance.

η_{fCell} = performance of fuel cells providing only electrical energy.

η_{CHP} = thermal performance of fuel cells providing CHP.

Losses = energy lost in any energy transformation that takes place along the hydrogen value chain.

kWh_{elec} = electrical energy input (to the electrolyser(s) plant) from renewable energies (directly or indirectly through PPAs).

Q = thermal energy load (kWh)

COMPONENTS OF THE ANNUAL HYDROGEN DEMAND

As it was already introduced in the Preface , in the Green Hysland Hydrogen Valley, the infrastructure and equipment that will be deployed are depicted in the diagram below:

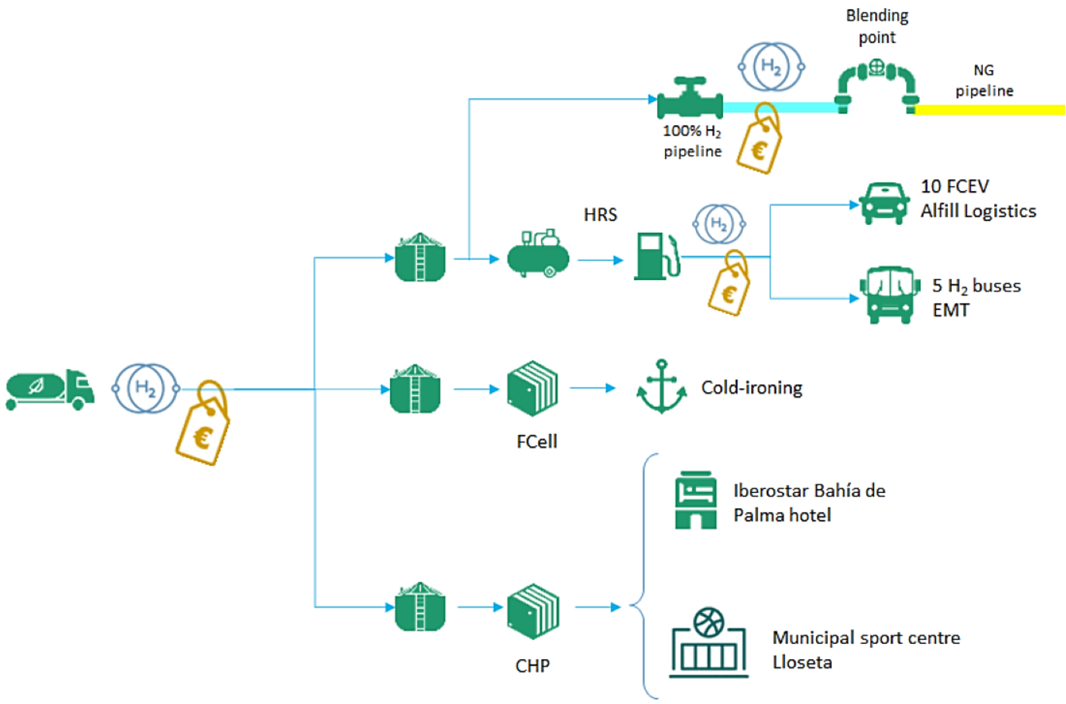


Figure. 6: Demand-side stages of the hydrogen value chain in the Green Hysland project.

Hereafter is a detailed breakdown of the models to be implemented in each link of the previous demand-side value chain diagram.

Electricity (Fuel Cells):

Hydrogen fuel cells are a technology used to generate electrical power by combining hydrogen and oxygen. They work by using a chemical reaction to produce electricity, with the only by-product being water vapor. Fuel cells are often used as a clean and efficient alternative to traditional fossil fuel-powered generators, as they emit zero greenhouse gases and pollutants. In electric power applications, hydrogen fuel cells can be used to generate electricity for buildings, vehicles, remote locations where access to a power grid is limited and, like in Green Hysland, they could be also used in ports for cold ironing, which allows ships to shut down their diesel engines while docked and instead draw power from the electrical grid to reduce air pollution. With advances in storage and distribution, hydrogen fuel cells are becoming increasingly viable as a source of sustainable energy.
In the following Sankey diagram (Fig. 7) there is a representation of the energy flows that occur in fuel cells dedicated to satisfying electrical loads.

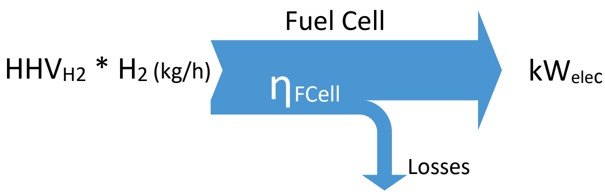


Figure. 7: Sankey diagram of a generic fuel cell application.

From this diagram, the following equation can be used to derive the hydrogen demand of these fuel cells:

$$Power\ (kW_{elec}) = \eta_{FCell}\left(\dot{m}_{H2}\left(\frac{kg}{h}\right) * HHV_{H2}\left(\frac{kWh}{kg}\right)\right) \quad (2)$$

Where:

kW_{elec} = electric power demand.

η_{fCell} = performance of fuel cells providing only electrical power.

$\dot{m}_{H2}$ = hydrogen mass flow consumed by the fuel cell.

HHV_{H2} = High Heating Value of the hydrogen molecule.

Then, the annual electric energy demand is:

$$\sum_{i=1}^{hours\ per\ year}\left(Power_i\ (kW_{elec})\right) = \eta_{FCell} * \sum_{i=1}^{hours\ per\ year}\left(\dot{m}_{H2}\left(\frac{kg}{h}\right) * HHV_{H2}\left(\frac{kWh}{kg}\right)\right) \quad (3)$$

Therefore, the hydrogen demand can now be cleared from (3):

$$\boxed{\dot{m}_{H2}\left(\frac{kg}{h}\right) = \frac{\sum_{i=1}^{8760hours}\left(Power_i\ (kW_{elec})\right)}{HHV_{H2}\ (kWh/kg) * \eta_{FCell}}} \quad (4)$$

Here below, figure 8 shows an example where the user must enter the hourly time series of the annual electric power demand for the desired application (at one-hour intervals).

$$\sum_{i=1}^{8760}\left(Power_i\ (kW_{elec})\right) \quad (5)$$

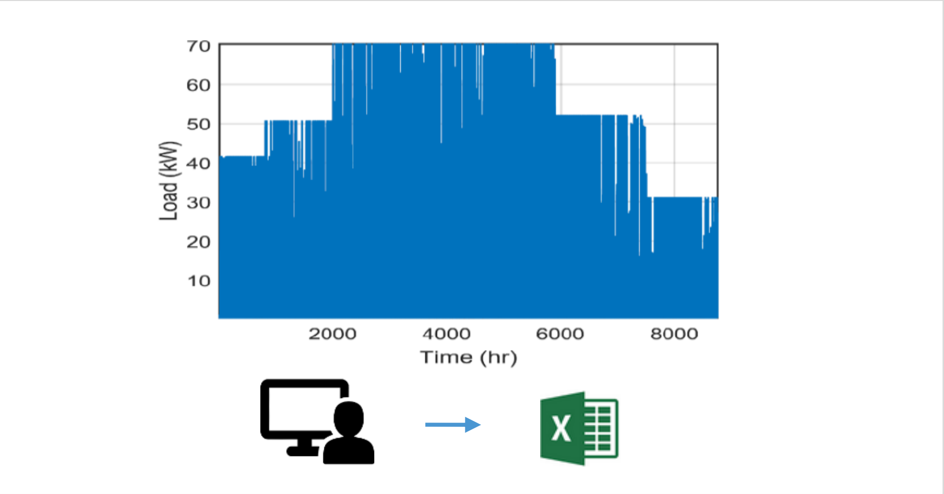


Figure. 8: Example of a seasonal annual load curve over a time interval of one hour with a peak demand of 70 kW [7]. This load curve will be easily integrated using the interface of the new version of the HTP Tool.

This feature also allows the integration of energy demand projections that could be obtained from different bibliographic sources, such as Regional Strategic Plans, Energy Transition Roadmaps, etc.

In case the dynamic fuel cell performance curve is available, it could also be integrated. An example of this curve is shown in Figure 9.

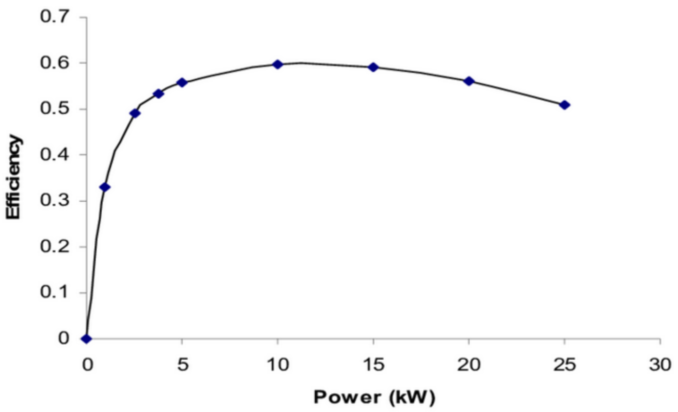


Figure. 9. Fuel Cell efficiency curve [8]

The technical and economic parameters that the user can enter to characterise fuel cells are shown in Table 1. Note that, during the course of the tool improvement, this list may be modified due to the iterative nature associated with this modelling task.

Fuel cell (e.g., cold ironing)	
CAPEX (€/kW)	
Nominal power (kW)	
OPEX (€/kW)	
Expected useful life (years)	
Efficiency (%)	

Table 1. Cold-ironing fuel cell parameters.

Combined Heat & Power (CHP) fuel cell systems:

Hydrogen fuel cells can also be used in combined heat and power (CHP) applications, where, as the name says, they generate both electricity and heat. CHP systems are designed to capture and utilize the heat generated by the fuel cell reaction, making them highly efficient and reducing the amount of energy lost as waste heat. These systems can be used for a variety of applications, including residential, commercial, and industrial settings. In addition to reducing greenhouse gas emissions, CHP systems using hydrogen fuel cells can also provide a reliable source of electricity, even during power outages, making them a valuable asset for communities and businesses looking for a sustainable energy solution. With the increasing demand for clean and efficient energy, CHP systems using hydrogen fuel cells have the potential to become an attractive option for many.

In the following Sankey diagram (Fig. 10) there is a representation of the energy flows that occur in fuel cells dedicated to CHP.

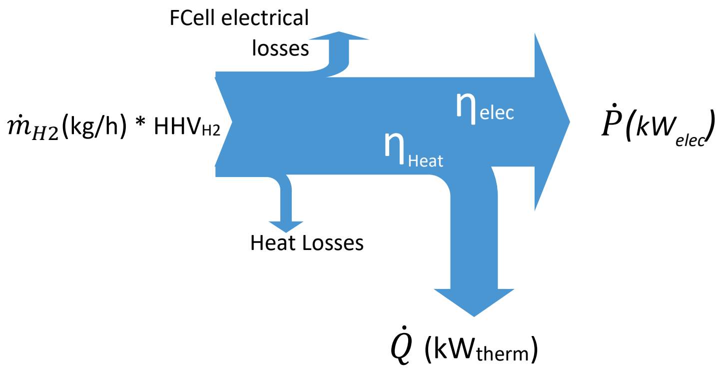


Figure. 10: Sankey diagram of a generic fuel cell for CHP application[9].

From the Sankey diagram, the following equation can be used to derive the hydrogen demand of these fuel cells:

$$\dot{Q}_{demand}(kW)_i = \eta_{Heat} * \left(\dot{m}_{H2}\left(\frac{\text{kg}}{\text{h}}\right)\right)_i * HHV_{H2}(kWh/kg) \quad (6)$$

Where:

$\dot{Q}_{demand}(kW)_i$ = thermal power demanded during hour i.

η_{Heat} = thermal performance of the CHP fuel cell.

Then, the component of hydrogen demand corresponding to the heat loads supported by the CHP appliances will be [10]:

$$\boxed{\dot{m}_{H2}\left(\frac{kg\ H_2}{\text{h}}\right)_i = \frac{\dot{Q}_i(kW_{therm})}{HHV_{H2}\ (kWh/kg) * \eta_{Heat}}} \quad (7)$$

Where $\dot{Q}_i$ is the hourly heat demand, which can be entered by the user as in the previous case:

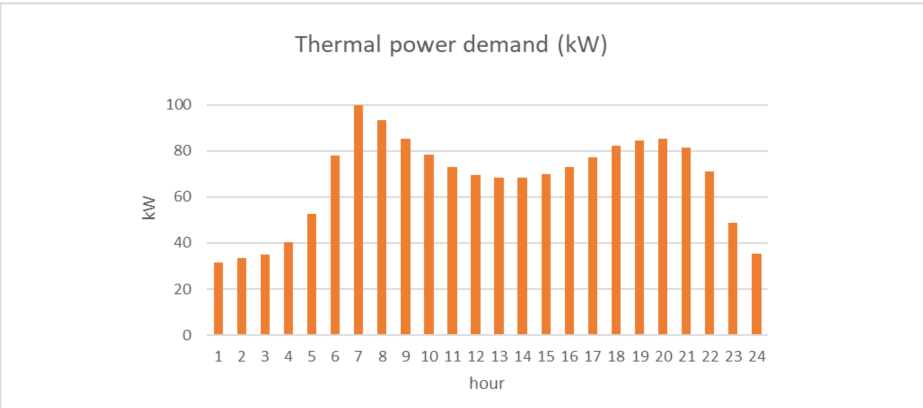


Figure. 11: Example of a daily thermal load curve over a time interval of one hour. This heating curve will be easily integrated using the interface of the new version of the HTP Tool.

The electrical energy component, produced with the CHP unit, depends on the CHP hydrogen consumption and the electrical efficiency of the unit [10]:

$$\dot{P}_{demand}(kW_{elec})_i = \eta_{Elec} * \left(\dot{m}_{H2}\left(\frac{\mathrm{kg}}{\mathrm{h}}\right)\right)_i * HHV_{H2}(kWh/kg) \qquad (8)$$

Where:

$\dot{P}_{demand}(kW_{elec})_i$ = electric power demanded during hour “i”.

η_{Elec} = electrical performance of the CHP fuel cell.

The technical and economic parameters that the user will be able to enter for characterising these fuel cells are shown in Table 2. Again, this list may be modified during the course of the tool improvement.

CHP Fuel cell (e.g., hotel, municipal sport centre)	
CAPEX (€/kW)	
OPEX (€/kW)	
Expected useful life (years)	
Net Electric Power (kW)	
Power to Heat Ratio	
Electrical Efficiency (%, HHV)	
Thermal Efficiency (%, HHV)	
Overall Efficiency (%, HHV)	

Table 2. CHP fuel cell parameters [11].

Mobility:

- H_2 Fuel cell electric buses:

  The model to estimate this hydrogen demand will be is indicated here below, in equation (9):

$$\dot{m}_{H2}\left(\frac{kg\ H_2}{\mathrm{year}}\right) = \text{Nº buses} * \left(\frac{Distance}{year} * \frac{kg_{H2}}{100km}\right) \qquad (9)$$

  The technical and economic parameters that the user will be able to enter for characterising these fuel cell electric buses are shown as follows in Table 3.

Fuel cell electric buses	
CAPEX (€/bus)	
OPEX (€/year)	
Expected useful life (years)	
H_2 fuel consumption per 100 km (kg/100km)	
Equivalent litres of diesel	
Average distance covered (km/year)	

Table 3. Fuel cell electric buses parameters.

- FCEV (vans):

  Again, the model to estimate this hydrogen demand will directly be related to the average consumption and the average covered distance:

$$\dot{m}_{H2}\left(\frac{kg\ H_2}{\text{year}}\right) = \text{Nº vehicles} * \left(\frac{Distance}{year} * \frac{kg_{H2}}{100km}\right) \quad (10)$$

  Here below, in Table 4. There are the technical and economic parameters that the user will be able to enter into the model:

Fuel cell electric van	
CAPEX (€/bus)	
OPEX (€/year)	
Expected useful life (years)	
H_2 fuel consumption per 100 km (kg/100km)	
Equivalent litres of diesel/petrol	
Average distance covered (km/year)	

Table 4. Fuel cell electric van parameters.

Blending station (2-20% vol H_2 injected):

Hydrogen blending refers to the process of mixing hydrogen gas with natural gas in pipelines, with the aim of reducing carbon emissions and moving towards a cleaner energy future. This can be done at various levels, ranging from low concentrations of just a few percent up to 100% hydrogen.

Blending hydrogen with natural gas provides a means of utilizing existing natural gas infrastructure while transitioning to a hydrogen economy. The key challenge in blending hydrogen is to ensure the safety and stability of the pipeline network and to minimize the impact on existing equipment and appliances. Hydrogen blending also presents opportunities for enhanced energy storage and distribution.

A hydrogen blending station is an essential component for incorporating hydrogen into natural gas pipelines. The following parameters must be considered to deploy an economically feasible blending station:

Blending station (2-20% H_2)	
CAPEX (€)	
OPEX (€/hr)	
Expected useful life (years)	
Energy consumption (kWh/Nm^3) or (kWh/kg)	
Max volume injected of H_2 (Nm^3/hr) or (kg/h)	

Table 5. Blending station (2-20% vol. H_2 injected) parameters.

COMPONENTS OF THE LOGISTICS CHAIN:

100% H_2 pipeline:

Hydrogen pipelines are types of infrastructure used to transport hydrogen gas from one location to another. Unlike natural gas pipelines, which are made of steel and transport primarily methane, hydrogen pipelines are made of specialized materials that can withstand the corrosive nature of hydrogen. The use of hydrogen pipelines is seen as a promising solution for the transportation and distribution of hydrogen, especially for large scale deployment of hydrogen as a fuel for industrial processes, or as a means to store excess renewable energy.
A priori, no energy balances are considered at this stage. The required data will be used to calculate the costs of this stage and the profitability of the business model. However, further literature research is needed to add an energy balance model as a function of pipe distance.

100% H2 pipeline	
CAPEX (€/km)	
OPEX (€/year)	
Expected useful life (years)	
Energy consumption (kWh/Nm^3 per km) or (kWh/kg per km)	
Max volume (Nm3/hr) or (kg/h)	
P_{min} & $P_{máx}$ (bar)	

Table 6. 100% H2 pipeline parameters.

Tube trailers:

Hydrogen transport by tube trailers refers to the transportation of hydrogen gas in cylindrical containers, known as tube trailers, that are attached to a truck. Tube trailers are commonly used to transport hydrogen gas to locations that are not connected by pipelines, such as industrial facilities or remote locations.

A priori, no energy balances are considered at this stage. The required data will be used to calculate the costs of this stage and the profitability of the business model.

Tube-trailers	
Storage capacity (kg/ trailer)	
Trailer cost (€/trailer)	
Distance (km) /day	
Diesel price (€/l)	
Average fuel consumption (l/km)	
Nº of trailers	
Expected useful life (years)	

Table 7. Tube trailer parameters.

HRS:

Hydrogen refuelling stations are facilities designed to store and dispense hydrogen fuel for hydrogen-powered vehicles. They are similar in concept to traditional petrol pumps, but instead of dispensing petrol, they dispense hydrogen gas.

These stations involve a series of processes to ensure the safe and efficient refuelling of vehicles. One of the key processes in a hydrogen refuelling station is the cooling phase, which is facilitated by a piece of equipment known as a chiller.

The need for this cooling phase arises from the properties of hydrogen and the requirements of the vehicles. Hydrogen is typically stored at high pressures in the fuel tanks of vehicles, which can be up to 700 bar. When hydrogen gas is compressed to these high pressures, it naturally heats up due to the gas laws. However, the hydrogen needs to be at a lower temperature when it is dispensed into the vehicle to ensure the safe and efficient filling of the fuel tank. This is where the cooling phase comes in. Moreover, the SAE J2601_202005 [2] and SAE J2601/2_202307 [3] standard makes this system mandatory when operating at 700 bars.

The chiller in the cooling phase works by removing heat from the hydrogen gas and transferring it to another medium, such as water or air. This process lowers the temperature of the hydrogen gas, preparing it for dispensing into the vehicle's fuel tank.

This cooling phase is crucial for several reasons:

1. Safety: High-temperature hydrogen gas can lead to increased pressure and potential safety risks.
2. Efficiency: Cooler hydrogen gas is denser, allowing more hydrogen to be packed into the fuel tank.
3. Vehicle Protection: High-temperature hydrogen gas could potentially damage the fuel tank or reduce its lifespan.

The need for a chiller is not solely determined by the storage pressure of the hydrogen gas. Other factors, such as ambient temperature, refuelling speed, and the specifications of the vehicle's fuel tank, also play a role (SAE J2601_202005 [12], SAE J2601/2_202307 [13])[4]. For instance, in areas with high ambient temperatures, the hydrogen gas can heat up significantly during compression. This can lead to a higher final temperature when the hydrogen is dispensed into the vehicle's fuel tank, potentially causing issues such as overpressure, reduced fuel capacity, and potential damage to the tank. Therefore, even for refuelling at lower pressures like 350 bar, a chiller for pre-cooling the hydrogen gas may still be necessary in areas with high ambient temperatures, especially if a fast-refuelling speed is desired. Nonetheless, while the SAE J2601 highlights the importance of temperature compensation and the role of the initial hydrogen temperature in fuelling protocols, it doesn't provide explicit details on the exact conditions requiring pre-cooling for 350 bar systems. However, given the emphasis on safety and performance, it's reasonable to assume that pre-cooling would be beneficial under conditions where there's a risk of high hydrogen temperatures during fuelling.

[2] SAE J2601_201407 is the standard for light vehicles.
[3] SAE J2601/2_202307 is the standard for heavy-duty vehicles.
[4] SAE J2601 is also being referenced in ISO 19880-1.

Now, looking at the overall structure of a hydrogen refuelling station. Here is a diagram that illustrates the different components:

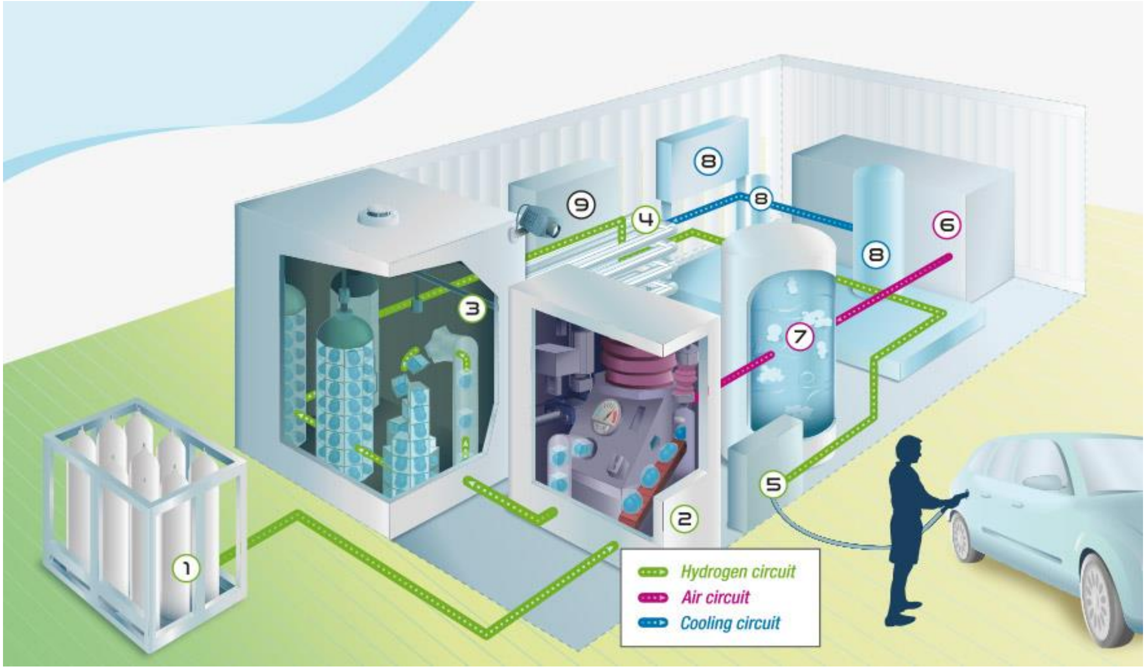


Figure. 12: A Hydrogen Refuelling Station Diagram
(https://h2me.eu/about/how-an-hrs-works/)

Where:

1. Source of hydrogen:
   Low pressure hydrogen (H2) is stored in bottles ("cylinder racks"), tanks or tube trailers.
2. Booster:
   H2 is compressed using boosters. If the HRS delivers the hydrogen at two different pressures, it means 700 bar (for light vehicles) and 350 bar (for heavy transport, like buses or trucks), the booster will increase pressures in two steps:
   - First, till 500 bars.
   - Second, from 500 bar up to 1000 bar[5].
3. Buffers:
   Once the pressure has been increased in these two stages, hydrogen is stored in two different vessels:
   - High pressure vessels (up to 1000 bar) that will be used to fill the 700 bar vehicles.
   - Low pressure vessels (500bar) that will be used to fill the 350 bar vehicles.
4. Exchanger:
   Before it is distributed, H2 is cooled using the exchanger and the refrigeration unit.

[5] The maximum storage pressure will depend on the capacity of the rack and the number of vehicles to be dispensed per day.

5. Dispenser:
   It enables distribution of H2 to the vehicle's tank, filling it in a few minutes.
6. Air compressor to drive ATEX classified control elements:
   Compressed air is commonly used to drive the control elements since pneumatic systems (air-driven) are intrinsically safe because they do not produce sparks. This makes them suitable for use in explosive or flammable atmospheres where electrical systems might pose a risk.
7. Buffer tank:
   It regulates and supplies the air needed to make the control function.
8. Refrigeration:
   Unit supplies cooling fluid to the exchanger and is made up of a buffer tank that stores and regulates the flow of the liquid, the pumps, and the electrical control cabinet.
9. General control cabinet:
   The station's electrical control cabinet.

The image above, sourced from the Hydrogen Mobility Europe website, depicts the various elements involved in the process, including the hydrogen source, compressor, chiller (for the cooling phase), and the dispenser. The chiller is typically located after the compressor and before the dispenser in the process flow. Please note that the exact configuration and components can vary depending on the specific design of the hydrogen refuelling station.

In conclusion, the cooling phase in a hydrogen refuelling station, facilitated by a chiller, plays a crucial role in ensuring the safe and efficient operation of the station and the refuelling of hydrogen-powered vehicles. This is particularly important in areas with high ambient temperatures and when high refuelling speeds are desired.

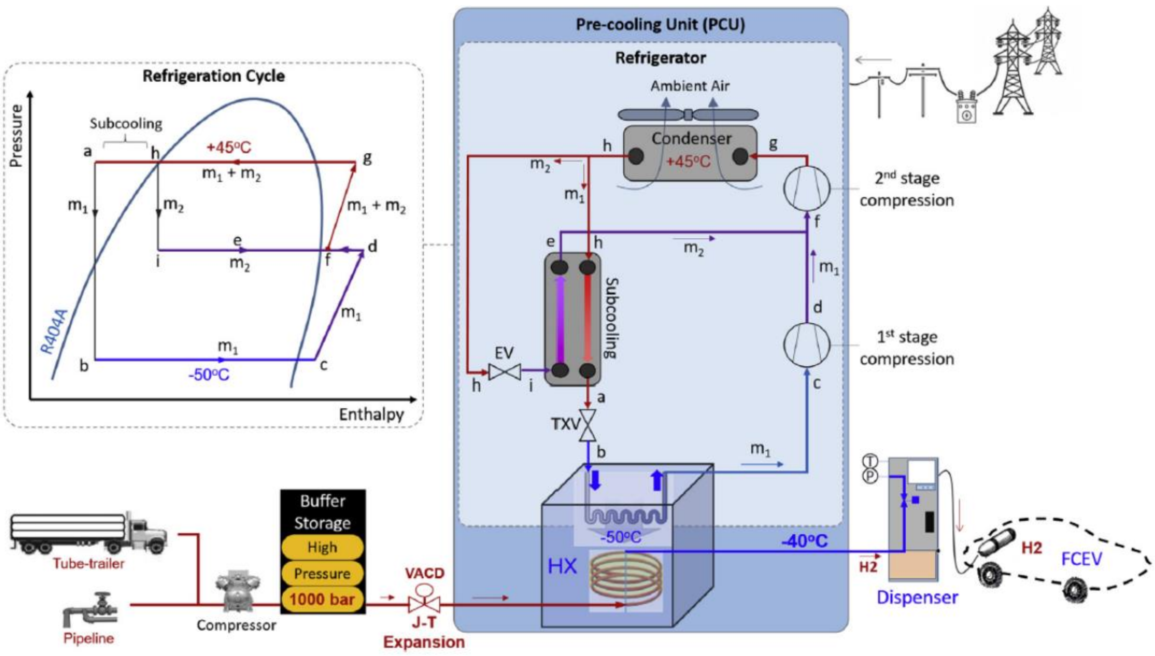


Figure. 13: Schematic diagram showing the operation of the precooling unit (PCU) at a gaseous hydrogen refuelling system (HRS)comprised of compressor, high-pressure buffer storage, PCU, and dispenser [14].

The required data will be used to calculate the costs of this stage and the profitability of the business model.

The HRS model includes the following elements:

- Stationary storage of hydrogen for light vehicles and heavy-duty vehicles refilling, such as buses:

Stationary hydrogen storage vessels	1000 bar	500 bar
Number of tanks		
CAPEX (€)		
OPEX (€/year)		
Expected useful life (years)		
Volume (kg)		

Table 8. Stationary hydrogen storage parameters (HRS)

- Compressor (or booster):

HRS hydrogen compressor (booster)	
CAPEX (€)	
OPEX (€/year)	
Expected useful life (years)	
Energy consumption (kWh/Nm^3)	
Max compression hourly (Nm^3/hr) or (kg/h)	

Table 9. HRS compressors parameters.

- The hydrogen dispensers for light vehicles and heavy-duty vehicles refilling:

HRS hydrogen dispenser	700 bar	350 bar
CAPEX (€)		
OPEX (€/year)		
Expected useful life (years)		
Electricity demand (kWh/Nm^3)		
Max dispensed volume (Nm^3/hr) or (kg/h)		

Table 10. HRS hydrogen dispenser parameters.

COMPONENTS OF THE ANNUAL HYDROGEN PRODUCTION

As introduced at the beginning of the section, once the hydrogen demand has been calculated, the aim is to satisfy it through the hydrogen production plants (electrolysers).

The hydrogen production plant (hereinafter H_2PP) business models and their infrastructures:

Given that the key objective for the successful operation of a Hydrogen Valley is **to ultimately achieve a competitive green hydrogen price**, the model should allow involved actors to calculate their profitability. For this purpose, the following entries shown in the figure 12 shall be taken into account.

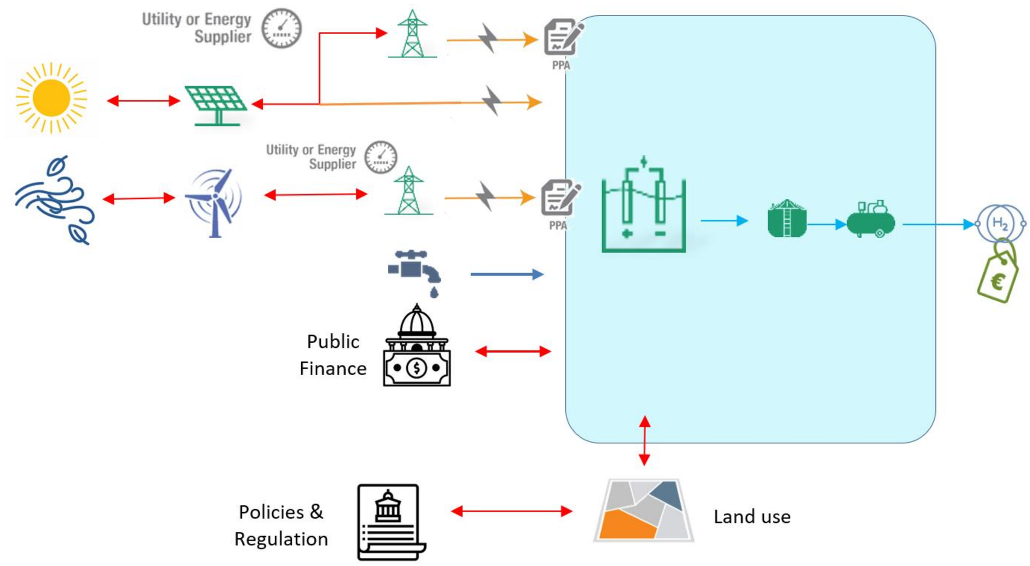


Figure. 12: Diagram defining the operating environment of the green hydrogen production plant.

The previous figure shows the hydrogen production business model that will be linked to:

- The electricity price (€/kWh)
- The origin of the electricity (must be RES):
  - Directly connected to a RES.
  - By means of a PPA (Renewable Energy Guarantees of Origin (REGO)) – Grid connected.
  - By means of curtailed renewable energy.
- The water resource (price (€/m^3), availability).
- The Policies and Regulation context that has a direct impact on permits for land use.

In addition, the model will consider the typical variables in the profitability measurements of a business model, such as CAPEX, OPEX, subsidies, other funds, etc.

The hydrogen production plant will be modelled in a simple way, by means of an energy balance together with an overall performance of the installation:

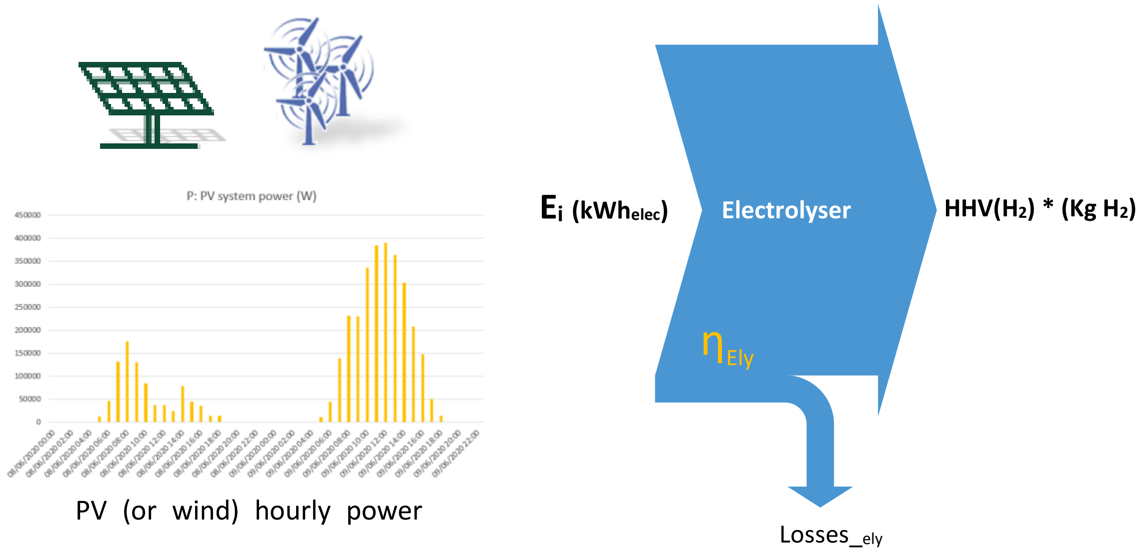


Figure. 13: Sankey diagram of the green hydrogen production plant.

$$\left(\dot{P}_{elec}(kW) * \eta_{Ely}\right)_i = \left(\dot{m}_{prod\_H2}\left(\frac{\text{kg}}{\text{h}}\right)\right)_i * HHV_{H2}\left(\frac{kWh}{kg}\right) \quad (11)$$

Hydrogen production per hour:

$$\boxed{\left(\dot{m}_{prod\_H2}\ \left(\frac{kg_{H2}}{hr}\right)\right)_i = \frac{\left(\dot{P}_{elec}(kW) * \eta_{Ely}\right)_i}{HHV_{H2}\left(\frac{kWh}{kg}\right)}} \quad (12)$$

Total hydrogen production per year:

$$\boxed{m_{prod\_H2}\ \left(\frac{kg_{H2}}{year}\right) = \frac{\left(E_{elec}\right)_{year} * \eta_{Ely}}{HHV_{H2}\left(\frac{kWh}{kg}\right)} = \frac{\sum_i^{8760}(\dot{P}_i) * \eta_{Ely}}{HHV_{H2}\left(\frac{kWh}{kg}\right)}} \quad (13)$$

Where:

E = Electric energy (kWh)

$m_{\_prod\_H2}$ = kilograms produced of hydrogen (per hr or per year)

HHV = Higher heating value (kWh/kg) = 39.41 kWh/kg or 3.28 kWh/Nm^3.

$\eta_{\_Ely}$ = hydrogen production plant performance.

3.1.2. Key result 1 – The upgraded HTP Tool 1.1

The objective of the new HTP Tool 1.1 is:

- To be operational in two timeframes:
  - **Demo version** in Q4 2023.
  - **Final version** in Q3 2024, with which the elaboration of the Follower Territories Replication Studies can be completed by the end of 2025.

The tool should enable an autonomous user experience:

- The **user** should be able to include inputs of their region (energy demand curves) and select the infrastructures (implemented in Green Hysland) that they consider appropriate in their Hydrogen Valley case study.
- The user will be able to input the parameters of interest of the Hydrogen Valley:
  - Technical parameters of infrastructures.
  - Economic parameters of business models.

3.1.3. Key result 2 – Follower Territory Replication Studies using HTP Tool 1.1

From the combination of having created the HTP Tool 1.1 and having understood how it works in the context of the Balearic archipelago, the Replication Studies for the different Follower Territory regions will be carried out after the delivery of the final version of HTP Tool 1.1 (Q3 2024). These studies will be based on the application of the HTP Tool 1.1 to its island context.

Subsequently, the final report of Deliverable 6.9 will include six replication studies for the following Follower Territories:

- Replication Study in Tenerife (Spain).
- Replication Study in Madeira (Portugal).
- Replication Study in Ameland (Netherlands).
- Replication Study in Achill island (Ireland).
- Replication Study in Chiloé (Chile).
- Replication Study in Rhodes (Greece).
- Replication Study for export of hydrogen from Morocco.

In addition to the Follower Territories within the project, more regions may be interested and could benefit from the HTP Tool 1.1 replication opportunities.

The next section discusses further opportunities and regions to replicate using the HTP Tool 1.1.

3.2. Step 2: Mapping EU islands with green hydrogen potential

The Replication Studies elaborated by the Follower Territories will serve as a basis for the preparation of a detailed Mapping Study of EU islands. The Mapping Study will be elaborated by FHa, ENER and EMEC, scouting EU islands through a desktop study and stakeholder consultations or surveys for their potential and interest in using green hydrogen in their respective territories. The Mapping Study will then be integrated within the deliverable **D6.9. Results for the Replication of hydrogen ecosystems** (M60, December 2025).

A first segmentation of the relevant stakeholder networks has been developed, and includes the following four groups:

1. Green Hysland project partners, in particular Follower Territories.
2. EU Coalition for Hydrogen Deployment in Islands (subtask 7.1.4.1).
3. Members of the Hydrogen Territories Platform (HTP).
4. Green Hysland Observers.

Sections 3.2.1-3.2.4 below further elaborate on these networks' characteristics.

The results of the Mapping Study will allow partners to identify a Long List of EU island stakeholders interested in testing the HTP Tool 1.1 and participate in other related activities (info sessions and events, mentoring programme).

3.2.1. Green Hysland Project partners

Green Hysland project partners will be informed every step of the way about the progress of the tool notably through the Steering Committee meetings taking place each month. Material will also be accessible on the project-internal MS Teams Channel and shared during meetings.

The feedback from the Green Hysland Follower Territories involved in WP6 (ULL, COOP, AREAM, AMEL, DAFNI, CHIL, AMHYD) will be especially important for the mapping of EU islands with green hydrogen potential.

The Replication Studies elaborated by the Follower Territories will make use of the HTP Tool 1.1 developed by FHa as much as possible in order to test the new version in the first 6 real-life cases.

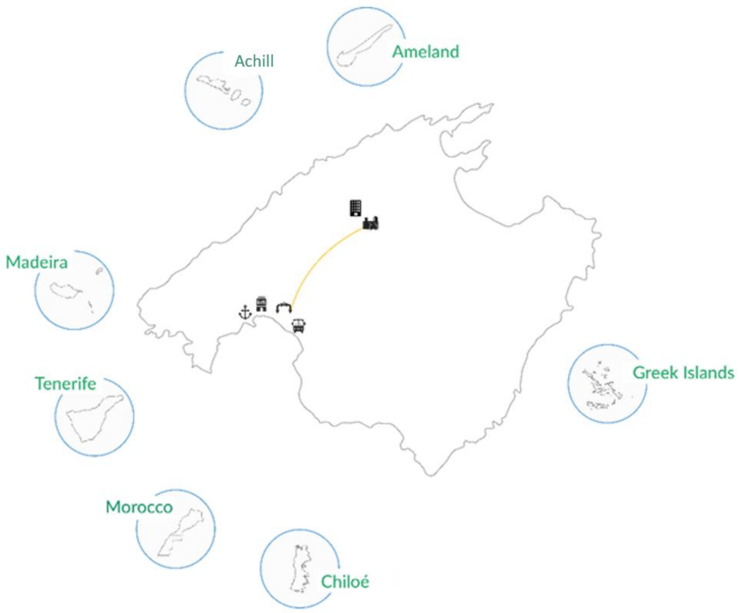


Figure. 14: Green Hysland (Mallorca) and its Follower Territories.

3.2.2. EU Coalition for H2 Deployment in Islands

As part of WP7, FEDARENE is developing a Europe-wide Coalition of initiatives and organisations working on the decarbonisation of islands' energy systems and/or the implementation of green hydrogen projects (Sub Task 7.1.4.1).

As of November 2022, the Coalition counts 16 members:

- BIG HIT (FCH JU funding);
- Clean Energy for EU Islands Secretariat;
- Clean Hydrogen Partnership;
- CPMR Islands Commission;
- FEDARENE Islands College;
- Hydrogen Territories Platform (see section below);
- Greening the Islands;
- Green Crane Initiative
- H2Ports (FCH JU funding);
- HEAVENN (FCH JU funding);
- Island Innovation;
- Jive 2 (FCH JU funding);
- Life3H (LIFE funding);
- Mission Innovation Hydrogen Valleys Platform (FCH JU funding);
- NESOI – the European islands Facility (Horizon 2020 funding);
- SEAFUEL (Interreg Atlantic funding).

FEDARENE has contacts for all these initiatives/projects essentially for cross-promotion and organisation of joint events. All members are contacted every six months to contribute to the Green Hysland newsletter, and several organisations have contacted FEDARENE to request input to feed their own platforms or to invite the GREEN HYSLAND project to their events. So far, FEDARENE has managed to organise joint online events with BIG HIT/HTP, the CPMR Islands Commission, Greening the Islands and H2Ports. More members of the partnership will be engaged in Green Hysland WP7 activities over the project duration.

With regards to Task 6.2, the organisations that are most interesting are networks of islands and initiatives focusing on islands, i.e.:

- The **FEDARENE Islands College**: composed of 12 island energy agencies and similar organizations, as well as 4 mainland energy agencies have been working on islands for some time now. They are all members of the FEDARENE network.
- The **Clean Energy for EU Islands Secretariat**'s mission is to provide support to all EU islands in pursuit of a clean energy transition following the methodology on Explore, Shape & Act. It is

the central platform for the clean energy transition of the more than 2,200 inhabited European islands.

- The **NESOI European Islands Facility**'s goal is to unlock the potential of EU islands to become the locomotives of European Energy Transition by mobilising more than 100 M€ of investment in sustainable energy projects to an audience of 2.400 inhabited EU islands and give the opportunity to test innovative energy technologies and approaches in a cost-competitive way.
- the **CPMR Islands Commission**: is one of the six geographical chapters of the Conference of Peripheral Maritime Regions, counting for 19 islands regional authorities' members from 5 sea basins: Mediterranean and Baltic Sea, the Atlantic, Indian and Pacific.
- **Greening the Islands**: an innovative organization that supports self-sufficiency and sustainability of islands worldwide, which involves more than 7000 islands through its various activities.
- **Island Innovation** has more than 100,000 Community Members and 440 Island Ambassadors. They build bridges between island stakeholders, policymakers, NGOs, private companies, and sustainability experts to create more resilient and empowered island communities. Although the scope of Island Innovation is global, currently its geographical focus is more on Pacific and Atlantic islands rather than European ones.

These six networks and initiatives alone represent a large audience of **thousands of islands**, spreading far beyond Europe.

3.2.3. Members of the Hydrogen Territories Platform

All Green Hysland Follower Territories and Observers will automatically become members of the Hydrogen Territories Platform (HTP), and all the 10 islands that will be beneficiaries of the Technical Assistance programme will be required to be members of the HTP in order to be eligible to receive Technical Assistance support. Thus, a basic membership base for the Platform will be created that the Platform can build on from after the end of the Green Hysland project.

In addition, during all relevant events and workshops organised by Green Hysland under WP7 an invitation to become members of the HTP Platform will be extended. The Platform will serve as a matchmaking centre and facilitation platform for islands and other stakeholders that can enable the deployment of green hydrogen in islands and remote territories.

3.2.4. Green Hysland Observers

Several islands and organisations interested in replicating the Green Hysland pilot project taking place in Mallorca are already involved in the project consortium. These are the Follower Territories described above in section 3.1.1. Yet, the interest in the project goes far beyond these six Followers and this was already the case from the outset of the project. Therefore, the 'Observers' status was proposed to external stakeholders who were interested in following the project, and potentially replicating some parts of it on their own islands/region.

As of February 2023, Green Hysland has 14 Observers:

1. Corsica Chamber of Commerce (FR)
2. Aran Islands Energy (IE)
3. Orkney Islands Council (UK)
4. Port of Melilla (ES)
5. Port of Tenerife (ES)
6. Port of Valencia Foundation (ES)
7. RINA Services (IT)
8. Scottish Hydrogen & Fuel Cell Association (UK)
9. Valencia Port Foundation (ES)
10. Wärtsilä (FI)
11. Skupina HSE Group
12. Universidad de Las Palmas de Gran Canaria
13. EIH2
14. OHLA Industrial

As shown by the list above, Green Hysland observers are very diverse both in geographic scope and type of organisations: besides island representatives, there are private companies, port authorities, non-profit associations, universities, and network organisations.

In addition, interest, and support from national ministries in various regions and countries (Balearic and national Spanish governments, Malta) as well as from tourism and mobility companies has been documented to the GREEN HYSLAND project.

3.3. Step 3: Recruitment for GREEN HYSLAND Technical Assistance programme

The Long List of stakeholders identified in the Mapping Study (section 3.2 will be invited to use the HTP Tool 1.1 to identify replication opportunities for their own region. For the stakeholders which are external to the GREEN HYSLAND project (i.e., Observers, members of the HTP, EU Coalition for Hydrogen Deployment in Islands), webinars and interactive workshops will be organised to raise their awareness of the existence and usefulness of the HTP Platform, HTP Tool 1.1 and the Technical Assistance programme opportunities. The stakeholders will be engaged through the following process:

1. Email invitations,
2. Information sessions on the HTP Tool 1.1 and the Technical Assistance and launch of call for Expression of Interest for the Technical Assistance programme,
3. Selection of the Technical Assistance programme participants,
4. Mentoring accompanying the use of the HTP Tool 1.1 following a selection process (s. section 4.3.3. below).

3.3.1. Email invitations

As a first step, Green Hysland partners involved in Task 6.2 will send emails to the stakeholders identified in the section above during the fourth quarter of 2023. There are several objectives for these emails:

1) to inform them that Green Hysland will hold an online info session to present the HTP Tool 1.1 and its upcoming Project Development Assistance (PDA) offer and invite them to the event.
2) to promote the info session by sharing it on their platforms (website/social media/newsletter etc.).
3) Especially for island networks or representatives/organisations with connections to island stakeholders, to ask if they can identify some specific islands within their network who would be interested in the Green Hysland project and replication activities. Here, islands that already have green hydrogen objectives or are looking to develop some projects in the near future will be sought.

Here below is a table which summarises all the different groups targeted and who within the consortium will be responsible for sending the invitation emails.

IDENTIFIED STAKEHOLDERS	RESPONSIBLE PARTNER
Green Hysland Project Partners • Follower Territories • Project deployment partners	FHa
EU Coalition for Hydrogen Deployment in Islands	FEDARENE
Members of the Hydrogen Territories Platform	FHa
Observers	FEDARENE

Regarding the members of the EU Coalition for Hydrogen Deployment in Islands, although FEDARENE will first and foremost target the islands networks and initiatives, the other members will still be contacted, as they might still be interested or know islands who would be interested in following the Green Hysland replication programme.

As far as the Green Hysland partners are concerned, those that are not Follower Territories can also prove to be valuable if they help spread the word and communicate promising leads to FHa, FEDARENE, ENER and EMEC.

3.3.2. Info Session and Launch of Call for Expression of Interest for PDA

Once invitations are sent and the promotion of the info session has been made, the event will be organised in Q2 of 2024. This session will also be the fourth EU Level Green Hysland webinar organised by FEDARENE, as foreseen within WP7.

During the session, partners will present the Green Hysland project, its status and achievements so far, and FHa will present the HTP replication tool being developed, together with the foreseen Technical Assistance programme.

Cooperation with the EU Islands Secretariat or the NESOI Islands Facility will be sought in order to attract more participants and ensure engagement for the session. On the day of the webinar, a call for Expression of Interest will officially be launched to recruit 10 islands for the GREEN HYSLAND Project Development Assistance (PDA) programme. The Technical Assistance programme will enable these islands to test the HTP Tool in 2025 and benefit from technical assistance for analysing and interpreting the tool results through the Green Hysland mentoring programme.

3.3.3. Selection of participants for the GREEN HYSLAND Technical Assistance programme

Should there be more than 10 Expressions of Interest, a list of objective criteria shall be used in order to select the 10 participants. The final selection of participants will be made in Q3 of 2024 using the following criteria:

- Membership in the HTP Platform (mandatory),
- The existence of a hydrogen project concept on the island, demonstrated through a short description of the concept.
- Number of different types of partners involved in the hydrogen project concept (e.g. Local Authority, industry, community, transport providers)
- The territory has access to an adequate amount of renewable energy resources to develop a green H2 production project.
- The existence of a clear strategy for using green hydrogen on the territory,
- Diversity in geographical scope while remaining within the EU.

3.4. Step 4: Provision of Technical Assistance support - Mentoring and Peer-to-peer exchange

Once the 10 EU islands which have an interest in using green hydrogen on their islands have been selected, the mentoring of these islands to replicate (part of) the work GREEN HYSLAND is doing in Mallorca will begin. Using their experience from implementing other Hydrogen Islands and Hydrogen Valleys such as in the BIG HIT and HEAVENN projects in the Orkney Islands and the Northern Netherlands, FHa and ENERCY will lead the Mentoring sub-task.

As a first step, an online group workshop will introduce the 10 islands to the technical capabilities of the HTP Tool in more detail than in the info session as well as the Tool's usefulness for preparing a pre-feasibility study for use of green hydrogen in different applications relevant in an island context, e.g. local and maritime transport, buildings, storage or industry.

Secondly, individual mentoring sessions each will be arranged between FHa, ENERCY and the 10 islands to provide bilateral support for using the HTP Tool and analysing its results in a local context and to provide advice and support on how to implement a Hydrogen Valley project in their island.

FHa and ENERCY will provide a summary analysis and interpretation of the HTP Tool 1.1 calculation results to mentees and, on the basis of the results as well as the outcomes of mentoring sessions, provide in a Technical Assistance Report recommendations for next steps to the 10 mentored islands for their green hydrogen journey. In parallel to the targeted mentoring, peer-to-peer exchanges with the GREEN HYSLAND Follower Territories (i.e. Madeira (PT), Tenerife (ES), Aran island (IE), Greek Islands and Ameland (NL) as well as Chiloé (Chile) and Morocco) will be organised to allow a transfer of know-how from the Follower Territories to the 10 mentored islands.

In total, the replication activities of GREEN HYSLAND will thus enable at least a further 16 islands and/or territories to explore and develop the use of green hydrogen in their territories.

3.5. Step 5: Collation of Replication Results

The results of the Replication efforts will be collected and reported within Deliverable 6.9 “Results for the Replication of Hydrogen Ecosystems” (M60, Dec. 2025). Moreover, this last deliverable will contain the results of the previously elaborated Mapping Study of EU Islands with Green Hydrogen potential.

The final results of the Replication work undertaken in GREEN HYSLAND will be presented to the public during the fifth Green Hysland webinar organised by FEDARENE in 2025. Selected participants who will have tested the tool, such as the FTs and those who will have joined the Technical Assistance programme will be invited to share their experience during the webinar.

Opportunities to present relevant HTP Tool 1.1 and the Technical Assistance replication results from GREEN HYSLAND to a wider relevant audience will also be sought to be presented at larger EU events such as EUSEW and European Hydrogen Week. This will enable the islands in question to have a platform for promoting their hydrogen projects, facilitate further investments or public funding for their initiatives and thus enable the decarbonisation of further EU islands.

One of the 10 island beneficiaries will also be chosen as location to host the final WP7 Green Hysland Workshop in Q3 2025, to further disseminate the work conducted by Green Hysland partners on replication activities.

4. Timeline/Schedule/Milestones

	2023				2024				2025			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Milestone: Demo version of HTP Tool 1.1				DEMO								
Mapping Study												
Email invitations + Promotion												
Milestone: Online info session (= WP7 2024 Webinar)												
Milestone: Launch call for islands												
Selection 10 GREEN HYSLAND Technical Assistance programme beneficiaries												
Milestone: Final version of HTP Tool 1.1							FINAL					
GREEN HYSLAND Technical Assistance Programme (Mentoring + P2P)												
Milestone: Workshop in a GREEN HYSLAND Technical Assistance location (= WP7 2025 Workshop)												
Milestone: Presentation of Replication results (= WP7 2025 Webinar)												
Follower Territories Replication Studies												

5. Conclusions

In conclusion, the proposed methodology for replicating a Hydrogen Valley in islands is a comprehensive and feasible approach. By analysing the key components of energy systems in these communities, such as energy demand and renewable energy sources, this methodology enables the design of tailored solutions that integrate hydrogen production, storage, and multiple end-usage, as per the definition of a Hydrogen Valley/Island. Additionally, the emphasis on stakeholder engagement and collaboration highlights the importance of social acceptability in the successful replication of Hydrogen Valleys. The findings of D6.9 should demonstrate that the creation of a Hydrogen Island can help islands reduce their dependence on fossil fuels, improve energy security and stability, and transition towards a sustainable energy future.

To summarise, this document has presented the methodology that will be followed for the remainder of the project, not only to carry out the technical replication studies of the Follower Territories using the HTP Tool 1.1, but also to bring the replication tools and activities developed by the Green Hysland concept to as many other island regions as possible. This methodology in turn can be replicated itself in order to multiply the benefits of replication work undertaken within the framework of the GREEN HYSLAND project.

Appendix I – Follower Territories Survey

GREEN HYSLAND

FUNDACIÓN PARA EL DESARROLLO DE LAS NUEVAS TECNOLOGÍAS DEL HIDRÓGENO EN ARAGÓN

GREEN HYSLAND

WP6 - Scaling up and Replication H2 island ecosystems

Follower Territories Survey

Objective of the replicability task:

Replicate a hydrogen-based energy solution, with an associated economic model, in islanded territories.

The challenge is not so much of a technological nature, but also non-technological aspects, so that their conjunction allows to bring new value to the territories.

Objective of the questionnaire:

To know the real situation, the expectations and the degree of preparation of the industrial/economic networks of each territory.

To whom and why:

Contacts identified by the project coordination as the main ones.

To narrow down the scope of the task and/or contrast its potential scope, always within the framework of the GREENHYSLAND project analysis.

A recapitulation of the main conclusions will be obtained after the analysis of the information received.

Index

Therefore, we need to start working on two main aspects:

- Who are you?
- What do you need?

1. Who are you?

1.1. Who is the person in charge of the replication study in your territory?

Please define:

- Your entity:
- The context of your entity in the region:
- Your position, responsibility: i.e Regional Sustainability Officer.
- Your scientific background:
- Your expertise/experience on hydrogen technologies:

1.2. What does your territory/entity expect from the Green Hysland project?

Please describe:

- Do you already have a hydrogen deployment project ongoing/planned in your region? (if YES, please describe it in 10 lines maximum). Please note that we are referring to projects beyond Green Hysland.

- What are your expectations from the Green Hysland project?

- What do you consider replication to be?

- What do you expect from a replication tool*?

*A **replication tool** is a software intended to help follower territories to translate the GreenHysland case to their own islands. To get an idea of what it looks like, please visit http://h2territory.eu/replicability-tool/ , you will find the first version developed during the BIG HIT project (hydrogen valley in Orkney islands). This tool will be used during this survey. It is a multi-parameter Excel-based tool that incorporates energy (heat, power, mobility), infrastructure, and financial parameters, and provides a techno-economic assessment relating to the deployment of a H2-based ecosystem in the specified island or territory.

1.3. What is your replication case study?

Please, provide more information:

- The case/s study/ies you may already have planned / in mind. The more detailed, the better.

  Here below, some items you could think about:

  - Infrastructure (which one and where, could you provide some map?)
  - Your potential/considered territories for replication analysis
  - Business Models
  - Social impact
  - Environmental impact
  - Scenarios
  - Time horizons
  - … feel free to add more details.

1.4. What is the context of your replication territory??

- Energy territory context?
  Please, provide a brief introduction of the energy system for the potential replication territory?
  Here below, some items you could think about:

  - Wind and solar resources?

  - Other renewable energy infrastructure (i.e. tidal)?

  - Seasonal demand?

  - Infrastructure related to H2:

    - Existence of gas grid
    - RES curtailment
    - Need for heating / cooling
    - Ferry routes

- Economic territory context?

  For instance, "our island's main income is tourism, and due to that we want to focus on offshore windmills, as onshore would be counterproductive"

- Policy context (environmental, energy market)?

- Social territory context?
  - Social acceptance of RES projects.
  - Do they have taken place any participatory activities during a project at this territory?

- Other social agents: local communities, regions/counties?

- Other complementary techno-economic resources of the territory (present and potential)

- Others?

2. What do you need?

To be efficient in the goal of replicating the hydrogen valleys in your territories, a software tool is being improved. This tool is based on the HTP Tool developed for the BIG HIT project.

The aim of this item is to have, not only feedback from your experience with this tool, but to think with you further, even "out of the box".

Therefore, once you have responded to the previous questions, you will be better prepared to use the tool with your needs in mind.

Please, download the HTP tool here. Now it's time to play. Try to use the current HTP Tool for your purposes within your case study. In order to avoid biasing your user experience, only instructions uploaded on the HTP site will be available.

2.1. How was your experience?

Please, describe:

- Is it user-friendly for you? (i.e.: What about units, vocabulary?)
  Could you evaluate next points (1-very bad, 6-very good)?

Ease of use	1	2	3	4	5	6
Ease of inserting data	1	2	3	4	5	6
Ease of collecting data	1	2	3	4	5	6
Need for more models	1	2	3	4	5	6
Freedom to customise inputs	1	2	3	4	5	6

- Is it useful for your case study?
- What would you add/delete?
    - Interpretation/analysis of results needed?
    - Subsidies/grants/loans into the calculations to make it more useful for decisionmakers and policy makers.

Now please, feel free to write down all your thoughts, for instance:

"I expect a tool that could help the region test a similar case study as Green Hysland, but it could be nice to test different demand-side policies in different time-horizons"

"I expect a very flexible tool that allows me to interact like a video game, being able to place the infrastructure over a map of my territory"

"I expect to see how profitable some business models in my social and environmental context are"

"I would like to be able to use the tool to replicate a hydrogen valley though different time-horizons, even being able to simulate the scaling up process"

...

3. Other comments?

Please, feel free to add further ideas, comments, requests.

Thank you for your time and collaboration.

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GREEN HYSLAND

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