Testbed Catalogue

May 2025

Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

Impressum

This document is the 2nd edition of the Testbeds Catalogue, which is a part of the C&D Toolkit prepared for the NAHV Consortium meeting held on the 28th and 29th of May 2025 at the Urban centre Trieste as part of ongoing project efforts.

NAHV is funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

The content of this release was contributed by the leaders of individual testbeds, each of which holds responsibility for the accuracy of the information provided.

The NAHV Testbeds Catalogue was curated by META Circularity Ltd, C&D Manager of the North Adriatic Hydrogen Valley innitiative, co-financed by the European Union.

Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

The purpose of this document

This Catalogue provides an overview of the industrial initiatives that make part of the North Adriatic Hydrogen Valley (NAHV), a Horizon Europe project co-financed by the European Union through the support of the Clean Hydrogen partnership and its members.

This is a public document that is a part of the Communication and Dissemination Toolbox of the NAHV. Its main purpose is to provide more insights to the interested public and in particular, to potential stakeholders of the testbed projects and other exposed initiatives of the NAHV into their nature and background, state-of-the-art and implementation time frame.

The aim of the NAHV Consortium of 37 partners is to further engage with interested stakeholders in the exposed testbed projects and other initiatives by creating opportunities for all.

This is the second edition the NAHV Testbeds Catalogue.

For more information about the NAHV please, consult the website here: www.nahv.eu and register to the NAHV Newsletter.

Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

About the NAHV

The **North Adriatic Hydrogen Valley** (NAHV) is a **Horizon Europe project**, supported by the **Clean Hydrogen Partnership**.

Initiated at the first Ecosystem North Adriatic Conference in Nova Gorica in autumn 2021, the project addresses a regional industry's call for a coordinated innovation ecosystem.

The project builds on a 2022 agreement among Slovenia, Croatia, and Italy's Friuli Venezia Giulia Autonomous Region, aligning with the European Green Deal and Hydrogen Strategy.

On 14th March 2022, institutional representatives from Slovenia, Croatia, and the Friuli Venezia Giulia Autonomous Region signed a joint letter of intent, emphasizing regional cooperation to accelerate hydrogen-based solutions and sectoral integration.

The NAHV aims to connect industrial clusters, ports, and hydrogen valleys across Europe, enhancing the local hydrogen ecosystem and inter-regional value chains.

The project is led by **Holding Slovenske elektrarne** (HSE) and is governed by a **Joint Working Group** consisting of representatives of the competent authorities of the three constituent territories.

To meet the objectives of the **European Hydrogen Strategy** and the **European Green Deal**, the NAHV project foresees, among other, the development of **17 testbeds** which will cover the complete hydrogen value chain from production to distribution, storage and end-use, with specific applications also developed to **decarbonise** the three NAHV territories by harnessing renewables such as solar energy, with **the aim of improving system resilience, security of supply, and energy independence** in line with the REPowerEU action plan.

In the next few years, the NAHV will contribute to the **REpowerEU** target of **10 million tonnes of domestic renewable hydrogen** to replace natural gas, coal and oil in hard-to-decarbonise industries and transport sectors.

Throughout the project, the NAHV follows the quadruple helix approach, which is based on the interaction in the sphere of a knowledge economy between the **academia**, the **industry**, the **government**, particularly the authorities representing the three target territories and related institutions, and the **general public**.

More information and updates on the website: www.nahv.eu

Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

The NAHV's distinctive ambition and main objectives

The project's main goal is the creation of a hydrogen-based economic, social and industrial ecosystem based on the capacity of the quadruple helix actors. This will drive economic growth, generating new job opportunities within the framework of both the green and digital transitions and, by creating the conditions for wider EU replicability, it will contribute to the creation of a European Hydrogen Economy.

To fulfil these objectives, the NAHV project involves a well-rooted partnership of **37 organisations**, covering the transnational Central European area of three territories – Slovenia, Croatia and the FVG Region, demonstrating cross-border integration of hydrogen production, distribution and consumption, and building up capacities for an **annual hydrogen production of over 5000 tons** of which **over 20% is expected to be exchanged within the area of the NAHV**.

Replicability will also be ensured for the whole NAHV model, with the uptake of **at least five additional hydrogen valleys in Europe, particularly in Central and South-Eastern Europe**.

In this sense the NAHV is **one of the most promoted hydrogen valleys in Europe**. It is **the first transnational Hydrogen Valley in the EU**, merging two countries and one region, and is set to contribute to opening Central Europe to the Balkans.

The NAHV clusters several industrial and research initiatives to carry out testbed applications across the complete hydrogen value chain (production, transport, distribution, and end use with storage). Its concept is a result of the stimulus of the North Adriatic cross-regional innovation ecosystem, as industries have already implemented important investment in the North Adriatic Region, including building the first privately funded hydrogen re-fuelling station (HRS).

The project therefore provides guidance to several initiatives already put in place by the industries and research organisations. In fact, the NAHV is **a strong industry-driven initiative**, built bottom-up and supported by universities and governments.

Renewable hydrogen is universally considered to be an important energy vector for combating climate change. It enables the decarbonisation of hard-to-abate sectors, acting as a no-emission fuel with vast potential for industrial development and job creation.

Its benefits are also acknowledged through the many dedicated national hydrogen (H2) strategies which have been published globally in recent years. Simultaneously, the emergence of a hydrogen market economically stimulates regions where hydrogen is produced, and associated technologies are deployed by creating new jobs and showcasing the regions as environmental forerunners.

Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

Policy and Regulatory Framework

Policies and Guidelines

Objective

To analyse the current policies on hydrogen, develop regulatory sandbox & policies guidelines to incentive the adoption of innovations in hydrogen value chain and to create a common legal framework regarding the production, use and distribution of hydrogen, propose an incentive and funding system to support the production and adoption of hydrogen by the private sector and set up a sustainable renewable H2 market on the NAHV.

Policies Analysis

The IMWG, together with stakeholders, will map the existing policy and regulatory framework related to hydrogen value chain in Croatia, Slovenia, Italy, and at EU level. The task involved:

- Policy data collection in energy, environment, infrastructure and hydrogen.
- Benchmarking in a comparative matrix (NAHV Legal Framework Matrix).
- Review of EU best practices and sandbox pilots.
- Drafting a Regulatory Sandbox Handbook and annexes.
- In-depth analysis of Italy's hydrogen legislation, including sandbox proposals

This provides a cross-country comparison, identifying regulatory gaps (e.g. for hydrogen bunkering in ports) and proposes legal experimentation through sandboxes to simplify procedures and support investment.

Regulation Revision and Sandbox

Regulation Revision

Regulatory sandboxes are controlled environments allowing temporary exemptions to test new technologies and models not fully aligned with current laws. These promote both innovation and learning for future regulation (regulatory discovery).

Activities Carried Out

- Defining the regulatory framework (document review, benchmarking, matrix development)
- Legal team proposal for regulatory sandboxes
- Draft of the NAHV Regulatory Sandbox covering:
    - Goal setting, indicator development, stakeholder involvement
    - Legal analysis and exemptions
    - Risk and liability considerations
    - State aid compliance and implementation design

Completed Outputs

- Analysis of the hydrogen supply chain and legal frameworks
- Proposals for Italian regulatory sandboxes
- NAHV Regulatory Sandbox Handbook with EU best practices

Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

Stakeholder Advisory Forum

What is the SAF and what are its aims?

The Stakeholder Advisory Forum (SAF) acts as a **consultation body** of the NAHV project. The SAF is built to collect and represent the voice of the stakeholders of the NAHV according to the **quadruple helix model**:

1. Universities and Public Research Organizations;
2. Businesses and business associations;
3. Policy makers, institutions;
4. Citizens, NGOs and a more cross sectorial component made by financial institutions, investors and other organizations, such as clusters and other Hydrogen Valleys.

SAF acts as a "laboratory", to merge different perspectives and foster a common interest, ensuring vertical and horizontal cooperation and participation during the project lifetime and beyond, aiming at move beyond traditional sectoral thinking in order to achieve the overall and balanced **development of a hydrogen ecosystem in the NAHV territories and beyond**, also tackling societal challenges related to the deployment of hydrogen technologies and solutions.

As of May 2025, more than 30 stakeholders covering the whole quadruple helix support the NAHV project, providing advisory opinions, supporting the dissemination of project's results, and making the voice of the end users and of citizens heard, as a source of ideas and needs to develop the NAHV's ecosystem also via surveys and interviews as well as providing data, information and feedback from the field to project partners and policy makers.

SAF membership is open for everyone...! Please, visit the website for more information.

SAF first contributions

Key takeaways from the first two meetings are:

- Connecting research institutes and universities with companies to transfer and enhance research results is essential to support the uptake of innovative solutions in the green hydrogen value chain, according to an interdisciplinary approach and also by means of sharing research infrastructures.
- Suggested facilitation factors are participation to joint projects, university programs involving business mentors, establishment of joint research labs, public calls to access research and innovation infrastructures.
- Building a solid legislative and regulatory framework is crucial to build a hydrogen market, to enhance international collaborations and to implement green hydrogen technologies.

Co-funded by the European Union

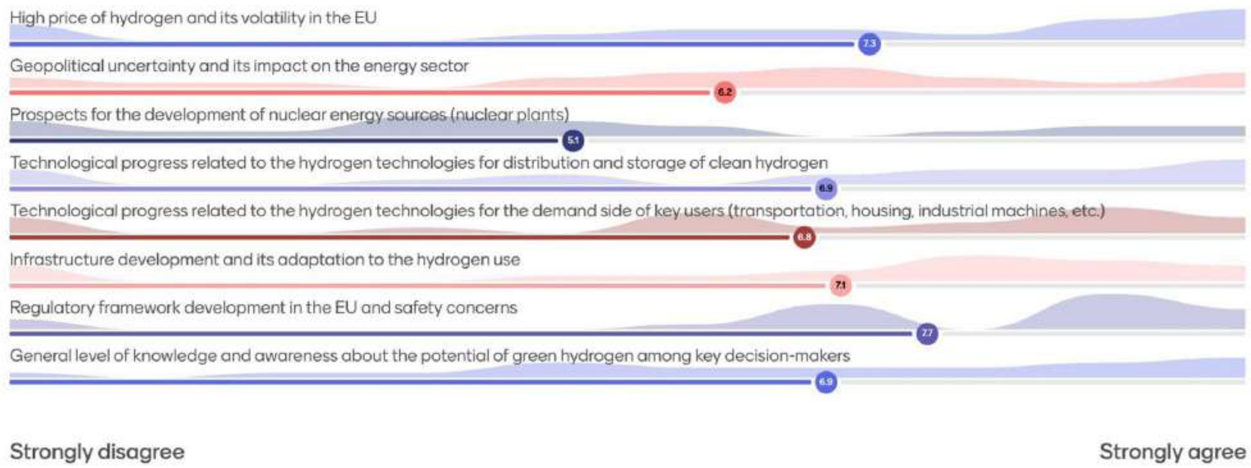
The project is suported by Clean Hydrogen Partnership and its memebers.

SAF

- NAHV shall play the role of a model observatory of the valley ecosystem on the field, supporting the matching of supply and demand and the creation of a cross-border market. Some key actions have been identified such as creating matchmaking mechanisms and national and regional facilitation tools to facilitate opex, establishing an offtaker alliance. The regulatory framework should be both effective and conducive to investment.
- Political strategies should be backed by action plans built with the support of all the actors of the ecosystem according to a quadruple helix approach.
- Further risen topics for action were the importance of developing awareness activities for citizens and of building appropriate skills for the hydrogen value chain workforce, to be further explored in upcoming meetings.

An example of stakeholders' view on the green hydrogen market main drivers (Mentimeter focus group responses)

4) Please, assess the importance of the main drivers of the evolution of the green hydrogen market from 1 (least important) to 10 (max. importance)?



Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

Equipping the Region for a Hydrogen Future: Education, Training, and Innovation in Action

The **University of Rijeka**, in collaboration with the **universities of Trieste and Ljubljana**, is spearheading a major educational initiative within the NAHV project. The goal is to equip the region's workforce with the skills needed to drive Europe's hydrogen transition, through flexible learning opportunities, vocational programmes, and a future competence centre.

Key Milestones and Ongoing Activities

Micro-Credentials

A new programme titled "Decarbonization and Hydrogen Energy" is set to begin in the 2024/2025 academic year. It offers 30 ECTS credits and combines online learning, hands-on workshops, and international student challenges. Developed with academic and industry partners, it provides targeted upskilling and reskilling for professionals in hydrogen-related sectors.

The programme covers:

- Hydrogen technologies and renewable integration
- Policy, regulation, and community-led energy solution
- Real-world safety and system design training
- A bilingual delivery model (Croatian and English) to support international mobility.

With €200,000 in secured funding, it is designed to be both accessible and scalable.

Vocational Training

Detailed market research has identified urgent needs for roles such as hydrogen refuelling station operators and safety specialists. New training programmes are being designed with practical, job-ready skills in mind. Developed in cooperation with regional governments and industry stakeholders in Croatia, Slovenia and Italy, and supported by the European Social Fund, these programmes aim to close key workforce gaps in the emerging hydrogen economy.

This educational initiative is laying the foundation for long-term growth in hydrogen expertise across the region. Through collaboration between universities, industry, and public authorities, it ensures that learning stays aligned with real-world technological and economic needs.

Looking Ahead: A Competence Centre for Hydrogen

A new macro-regional competence centre is in development. It will serve as an interdisciplinary hub for hydrogen research, training, and academic programmes—ranging from Bachelor's to PhD level. The centre will focus on topics such as:

- Hydrogen storage and electrolyser technologies
- Maritime hydrogen applications
- Advanced materials and applied R&D
- Integration of research into education

What's Next?

- Launch of the first micro-credential programme in 2024/2025
- Rollout of pilot vocational training courses
- Continued development of the competence centre as a regional innovation driver
- Deepening collaboration with industry and public stakeholders to ensure impact and relevance

These actions reflect a strong commitment to building a skilled and forward-looking hydrogen workforce.

Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

Building H2 friendly culture within the educational ecosystem of high schools and vocational schools

Key Objectives and Ongoing activities

Within Task 7.2.2, as part of the effort to increase the overall awareness about H2 within community, the University of Rijeka, in collaboration with the universities of Trieste and Ljubljana, is focusing on high schools and professional schools' students and staff, to foster the integration of H2 in educational programmes.

Building systematic collaboration

Initial contracts have been established with relevant high schools and professional schools, aiming to map relevant and interested educational institutions in the targeted area.

Periodic meetings with local technical and professional schools are planned to establish collaboration with students and professors, as well as with local/national authorities responsbile for high and vocational schools' programs.

Communication is Key

Communication programs dedicated to high and vocational school students will be developed with the following objectives:

- Promote a H2 friendly culture among students and staff
- Increase awareness of H2 as and eco-friendly energy alternative
- Foster the creation of new H2 focused educational programs
- Foster the interest of the students to pursue academic and professional paths within H2 related fields

Practicality and interactivity for success

Activities within Task 7.2.2 will aim to provide as much practical and interactive experience as possible. This is necessary to attract attention from and comittment by students of young age.

These will include organizing various activities, such as periodic presentations of NAHV and the newest developments in H2 technology and uptake, dedicated workshops (at least 8) involving at least 500 participants overall, and a „H2 week" in which talks and visiting tours to existing hydrogen facilities will be organized at a later stage in the project.

What's Next?

- Identification of optimal collaboration approaches and priority actions
- Definition of a joint action plan
- Development of communication program and shared content
- Rollout of communication actions („H2 week", workshops, field visits, etc.)
- Regular coordination meetings with schools and relevant stakeholders (e.g. local/national authorities, NGOs involved in education)

Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

Renewable Hydrogen Testbed Applications

For industry & hard-to-abate sectors

Objectives:

- implement and validate new solutions and testbed applications for renewable hydrogen valorisation in the industry sector;
- cover the complete value chain of renewable hydrogen from production to distribution, storage and end-use;
- support the decarbonisation of the industry sector, with particular focus on steel, glass industry and many other hard-to-abate companies, by replicable testbed plants distributed across all the three target involved territories.

For the energy sector

Objectives:

- implement and validate new technologies and testbed applications for the energy sector's renewable hydrogen valorisation;
- support the decarbonisation of the energy sector applications, with particular focus on hydrogen generation sets, backup-power systems, electric supply of infrastructures and gas grid injection in blending mixtures;
- cover the complete value chain of renewable hydrogen from production to distribution, storage and end-use by replicable testbeds distributed across all the three target involved territories;
- develop a FCH application.

For the transport sector

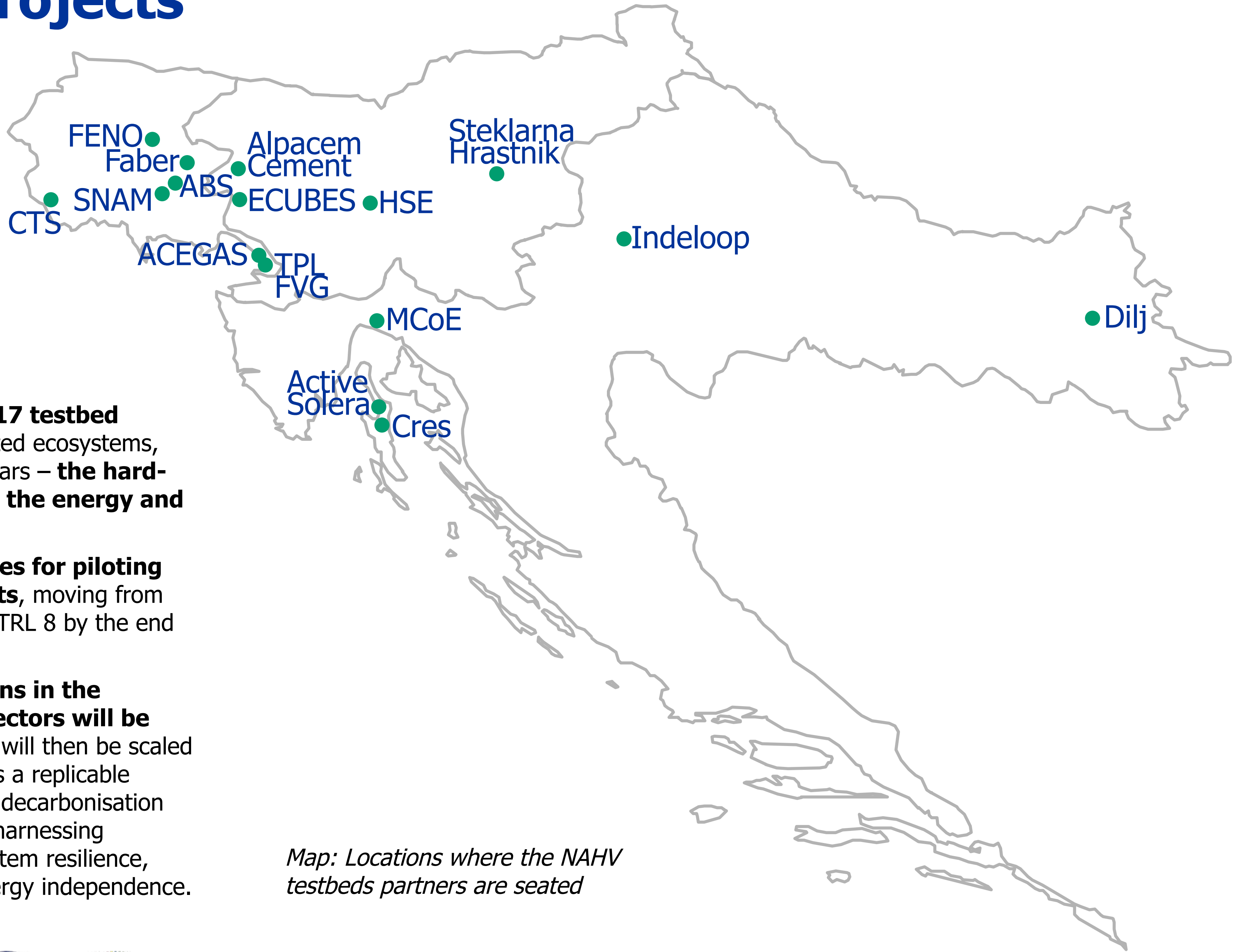
Objectives:

- support the decarbonisation of the transport sector applications, with particular focus on waterborne applications, public transport fleets, and private vehicles;
- implement and validate testbed applications for the transport sector's renewable hydrogen valorisation, also enabling synergies with other sector of application and production;
- cover the complete value chain of renewable hydrogen from production to distribution, storage and end-use by replicable testbeds;
- develop three FCH applications.

Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

Testbed Projects



The project has activated **17 testbed applications** in their related ecosystems, clustered in three main pillars – **the hard-to-abate industries and the energy and transport sectors.**

These act as **real-life cases for piloting global hydrogen markets**, moving from TRL 6 at the beginning to TRL 8 by the end of the project.

Four fuel cell applications in the energy and transport sectors will be demonstrated. Testbeds will then be scaled up to the industrial level as a replicable model, contributing to the decarbonisation of the three territories by harnessing renewables to improve system resilience, security of supply, and energy independence.

Map: Locations where the NAHV testbeds partners are seated

Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

I. Hydrogen as a partial replacement for natural gas in a kiln of a roof tile producer Dilj, Vinkovci, Croatia

Testbed Leader: DILJ

Ciglarska 33, 32100 Vinkovci, Croatia

Director/representative: Davor Vidaković / Krešimir Ižaković (kresimir.izakovic@nexe.hr)

Objectives and Project Description

World's first on-site hydrogen production installation within tunnel kilns for roof tile production.

Complete supply chain from production to consumption of green hydrogen.

Safely introduce the benefits of hydrogen to the local community.

Entire process is highly efficient, resulting in significant CO2 savings per invested €.

After successful implementation of the project, technology can be deployed in other factories in ownership of Dilj d.o.o., and any other tunnel kiln in roof tile and block brick production industry all over the world.

Key Metrics

Project must prove through industrial testing that it is possible to use hydrogen in the process of roof tile production with the same heat distribution and same quality of the final product.

After the project implementation we expect to **reduce CO2 emissions for more than 20 %** and **energy consumption for more than 10 %**.

PEM Electrolyser will be used for hydrogen production, yearly hydrogen production up to **315 t/year**.

Total budget of the project is **45.067.500** euro and contains testing in kiln and hydrogen production, electricity production, grid connection and storage. **The portion from NAHV amounts to 3.978.095,26 euro.** For the project competition additional co-financing is needed.

Produced hydrogen will be used as replacement for natural gas, it will be blended from 20 % to 100 % with the natural gas.

Impact and Benefits

The project will enable Dilj to reduce CO2 emission, reduce energy consumption and dependency on the natural gas supply.

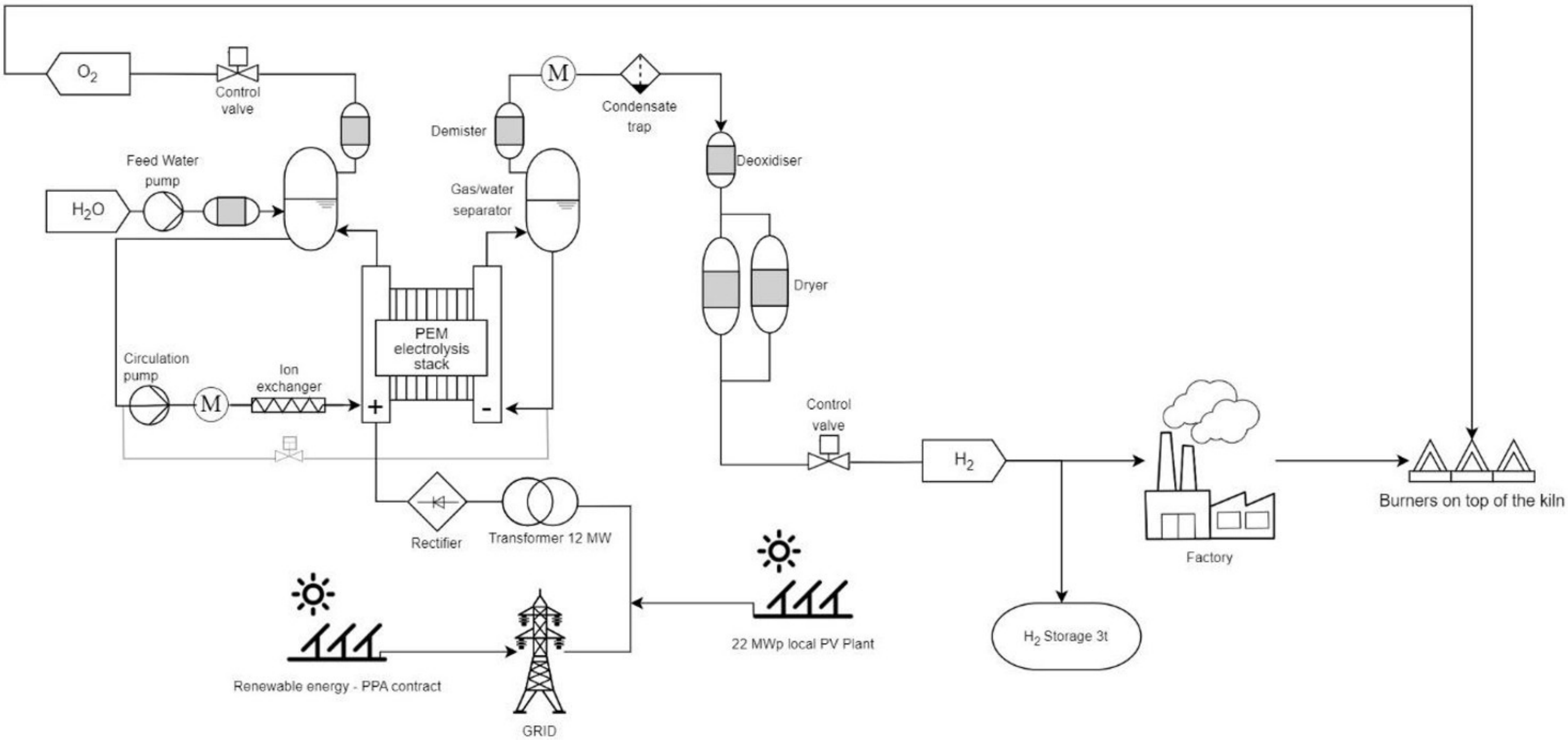
Dilj will position itself as one of the industry leaders of the green transition in roof tile production.

The project aims to demonstrate safe hydrogen usage to the local community.

Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

Production process scheme of the DILJ testbed



The project is suported by Clean Hydrogen Partnership and its memebers.

Current status, process highlights and main challenges at Dilj, Vinkovci

Current Status

Phase 1 of the project is ongoing, which includes:

pipeline drawings for hydrogen supply from trailer to the kiln preparation, technical discussion with burner suppliers, search for possible suppliers of hydrogen needed for the test to implement first phase of the project.

Grid connection and RES production at Dilj, Vinkovci

Challenges faced

Phase 1: Main obstacle in the Phase 1 of the project is securing uninterrupted quantities of hydrogen during the 5 - 10 days. For test it is necessary to ensure 780 kg of hydrogen per day. This is a challenging task for all contacted hydrogen suppliers.

Phase 2: Replacing natural gas with Hydrogen, will be financially viable only if we are able to maximize efficiency of hydrogen production, and reduce energy consumption. Possibility to use oxygen for kiln oxidization, and to reduce amount of air which we are impelling for burning process will help us to reduce overall energy consumption.

PEM Electrolyser used for hydrogen production will be used also for grid balancing to diminish price difference between electricity used for hydrogen with efficiency of 65 % and natural gas with CO2 emissions added.

Additional CAPEX and OPEX subsidy will be needed to enable switching from natural gas to hydrogen.

Progress Highlights

Through conversations with potential suppliers, we found out how difficult it is to find a reliable supplier of larger quantities of hydrogen and hydrogen equipment in general.

We are in the final stage of negotiations for testing our products in a laboratory using hydrogen combustion only. Testing of existing hydrogen burners at the test site is also being arranged, as preparation for the kiln testing phase.

Future Plans

Phase 1 – testing of hydrogen on the kiln will be done till March 2026.

After results of Phase 1, we will continue with phase 2 of the project. In parallel with phase 1, electricity production and storage projects will be prepared, as the cheap electricity is the key for shifting from natural gas to hydrogen in hard to abate industries, until hydrogen pipelines are built.

Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

II. Hydrogen utilisation in special steel production and treatment, ABS, Pozzuolo del Friuli, FVG, Italy

Testbed Leader: ABS (Acciaierie Bertoli Safau)

Via Buttrio 28, Pozzuolo del Friuli 33050, Italy

Director (or representative): Lorenzo Campagna

Project Description

Industrial validation and implementation of experimental hydrogen burners to transform steel ingot heat treatment furnaces (typically divided into four control zones fed by a total of eighteen 233kW burners) to achieve effective total decarbonisation, using carbon-free energy carriers such as renewable hydrogen either as a blend or as a total replacement for traditional fossil fuels. Continuous fine-tuning and testing of control equipment, measuring systems, burners, operational and safety practices, and maintenance up to the replacement of all existing burners in a 100% hydrogen furnace, to assess the impact on the treated steel of an atmosphere composed of water vapour as well as nitrogen and oxygen. Similarly, the impact on refractory materials in the furnace chamber will be assessed.

Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

III. The testing of highly efficiency hydraulic piston compressor CUBOGAS, Snam, FVG, Italy

Testbed Leader: Cubogas (affiliated entity), Snam (beneficiary)

Location of the testbed: Friuli-Venezia Giulia, Italy (AcegasApsAmga hydrogen production plant)

Director/ representative: Mauro Galletta (m.galletta@cubogas.com), Andrea Antenucci (andrea.antenucci@snam.it)

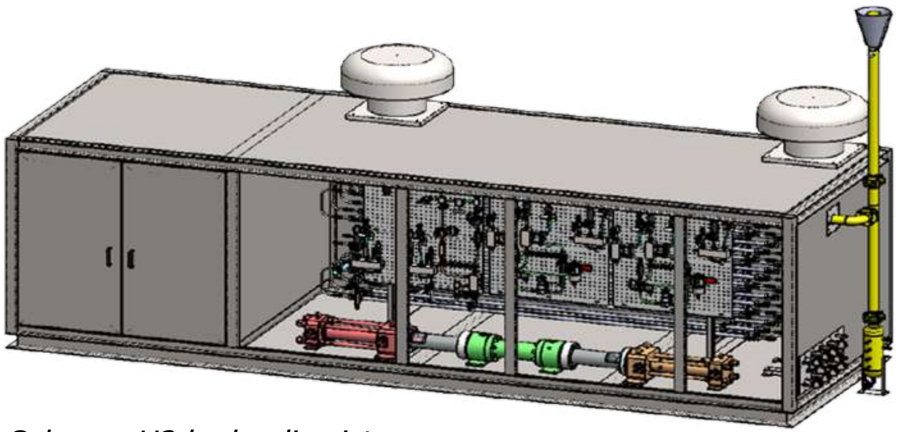
Project Description

The validation of an innovative H2 compressor at TRL 6 will be implemented. The project will improve the system CapEx from 7’700 €/kW to 5’600 €/kW and will test the highly efficient compressor at AcegasApsAmga hydrogen production plant in the site of Trieste, a new plant under realization that will produce green hydrogen from electrolysis process (5MW) with electrical energy supplied from co-developed renewable plant at site. The hydrogen plant will serve mobility and logistic applications. The compressor will work up to 500 bar with an energy efficiency target of 3 kW/kg. The test aims to achieve a main sealing elements maintenance interval higher than 3000 hours.

Impact and Benefits

The compressor selected for the testbed – which will be produced by Cubogas as Snam affiliated entity – introduces an innovative solution for hydrogen compression, utilizing a hydraulic oil-driven reciprocating compressor.

A key innovation is the inclusion of distant pieces between the oil and gas cylinders, which ensures that the hydrogen remains uncontaminated even in the event of seal failure. This design prioritizes the purity of the hydrogen, crucial for sensitive applications.



Additionally, the system’s hydraulic unit is enhanced with an electric motor and inverter controlled by a PLC, offering precise control and energy efficiency.

Cubogas H2 hydraulic piston compressor

Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

IV. Blending mix usage in rolling mill pre-heating furnace for hard-to-abate industrial application, FENO, FVG, Italy

Testbed Leader: FENO (Ferriere Nord)

Friuli-Venezia Giulia, Italy

Director (or representative): Loris Bianco

Project Description

Industrial validation and implementation, in cooperation with the equipment supplier, of new burners (and relative piping, blending, and control systems) able to use renewable H2 blending with natural gas in reheating furnace of rebars rolling mills, to keep the billets at high temperature (typically 1,100-1,200°C) before rolling, to improve steel ductility, or to promote the formation of a specific microstructure. The prototypal reheating furnace will have to ensure at least the same level of safety during operation and quality of the product after rolling, surface quality in terms of scale formation, scale adhesion, and decarburization. Moreover, also air emissions will be verified in terms of CO2 reduction, and a particular focus will be devoted to NOX.

Considering the large consumption of the burners around 19 MSm3/year of Natural Gas, systems able to work in blends of H2/ Natural Gas, up to 50% H2, will lead to a consequent reduction of the emission of CO2, and other GHG of about 10.000 ton/year.

Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

V. H2 production for cement industry decarbonisation, Alpacem Cement, Anhovo, Slovenia

Testbed Leader: Alpacem Cement

Anhovo 1, Anhovo, 5210 Deskle, Slovenia

Director (or representative): Sašo Seljak (saso.seljak@alpacem.si)

Objectives and Project Description

This testbed project aims to **build a containerized electrolyser** ranging from **0.5 to 1 MW**, equipped with necessary storage and connections to utilize the produced hydrogen in the transport sector. The current storage and filling infrastructure will be upgraded or replaced as part of this project. One **hydrogen truck** will be purchased for cement transportation. Know-how on producing renewable hydrogen at a competitive price tailored to the energy profile and needs of the cement plant will be gained.

A feasibility study will explore using hydrogen directly in production and scaling systems, including battery integration, to maximize renewable energy use and support grid balancing.

The goal is to reduce the carbon footprint by replacing fossil fuels in the kiln and converting captured CO2 into methane or methanol.

System sizing and component selection will align with the goal of producing 50 tons of green hydrogen annually, guided by economic and technical analyses. All necessary permits will be obtained before installation. The hydrogen-powered truck will be evaluated based on technical and economic criteria, and relevant legislation will be reviewed. The project will provide data to support the broader adoption of hydrogen fuel in transportation, reducing the end product’s carbon footprint.

Total Budget

The **total project budget is 5.525.000 euro**, with **NAHV providing a grant of 500,000 euro**.

Key Metrics

The testbed project aims to produce **50 tons of hydrogen annually.**

The produced hydrogen will primarily fuel hydrogen truck(s) for cement delivery. Any surplus hydrogen will be supplied to other end-users within the NAHV network or made available for public filling stations.

Impact and Benefits

Established production will represent a **source of hydrogen in west part of Slovenia**. Although it will be used for Alpacem transportation task it will be also available for other NAHV partners and for potential public users in future with its (public) filling station (municipal buses, cars, etc.).

The use of hydrogen in transport will **contribute to significant reductions in CO2 emissions** and thus to **the EU’s goal of zero emissions** in **the field of transport**.

Clean Hydrogen Partnership

Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

Current status, process highlights and main challenges at AlpacemCement, Anhovo (Slovenia)

Status

Economically technical study of WP 3.5 is done. This includes the sizing of necessary equipment, capital expenditure (CAPEX) and operational expenditure (OPEX) study for different scenarios.

Identifying and evaluating potential suppliers for necessary components and technologies is done.

Challenges

The cost of producing hydrogen remains high, posing a significant economic challenge.

Uncertain national legislation complicates the need for permits, particularly construction permits, which affects project timelines and planning.

Securing the necessary subsidies to close the financial structure for the project remains a challenge, with no additional subsidies secured thus far, and an unsuccessful bid in one public tender.

Progress highlights

Participation in a round table discussion as part of the AMETHyST project, organised by the Energy and Climate Agency for Podravje, focused on local green hydrogen ecosystems and their role in the Alpine region's transition to a post-carbon lifestyle.

Attendance at the conference "Hydrogen as a Key Factor in the Green Transition: Challenges and Opportunities" organised by the Ministry of the Environment, Climate, and Energy in June 2024.

Engaging in active discussions with the Ministry of the Environment, Climate, and Energy regarding potential national subsidies and the process of obtaining construction permits. These discussions are crucial for securing financial support and navigating the legal requirements for project implementation.

Sandi Gorišek presenting at the "Hydrogen as a Key Factor in the Green Transition: Challenges and Opportunities" conference organized by the Ministry of the Environment, Climate and Energy in June 2024

Future Plans

Securing the necessary subsidies through public tenders to ensure a closed financial structure for the project, navigating the legal and bureaucratic processes to obtain the required construction permits and completing the selection of equipment suppliers to ensure all necessary components and technologies are available are in the focus.

Clean Hydrogen Partnership

Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

VI. Efficient utilization of water electrolyser system in the glass industry, Steklarna Hrastnik, Slovenia

Testbed Leader: Steklarna Hrastnik

Cesta 1. maja14, 1430 Hrastnik, Slovenia

Director (or representative): Tilen Sever

Project Description

Hrastnik1860 will lead the implementation of a hydrogen pilot for the glass industry, integrating a large-scale PEM water electrolyser and hydrogen storage system into an existing oxyfuel glass furnace. This innovative system will utilize both hydrogen and oxygen generated through electrolysis, enhancing the energy efficiency of the furnace while driving the decarbonization of the glass melting process. The initiative aims to establish a reliable and sustainable supply of renewable energy, significantly reducing the environmental footprint of the industry.

In addition, Hrastnik1860 will leverage its expertise in renewable hydrogen utilization, developing valuable know-how on the efficient use of water electrolyser (WE) technology within the glass industry. By coupling the WE system with an existing glass furnace and renewable energy sources (RES), the project will improve the reliability and security of renewable energy supply while decarbonizing the production process.

HRASTNIK1860, glass works seated in Hrastnik, Slovenia is a protagonist in the hard-to-abate sector.

Key Metrics

Technology: PEM electrolyser coupled with existing glass furnace and PV system

Hydrogen Production: 500 Nm³/h

Plant Capacity: 2.5 MW PEM electrolyser, 120 MTPD oxyfuel furnace

Impact and Benefits

Through the use of a 2.5 MW water electrolyser and mid-pressure hydrogen storage, we are developing expertise in renewable hydrogen applications for the glass industry. This system will be integrated with an existing 120 t/day oxyfuel glass furnace, using hydrogen to boost energy efficiency and cut greenhouse gas emissions.

The WE system will be partially powered by existing renewable energy systems and incorporated into auxiliary services to the Transmission System Operator (TSO). Advanced hydrogen storage and control mechanisms will manage supply fluctuations. A state-of-the-art combustion system will enable flexible hydrogen use in the furnace, making this 8 million € testbed a key pillar of our decarbonization efforts.

Current Status

We are now preparing for the implementation of a water electrolyser, which will enable on-site hydrogen generation. In the interim, successful trials using hydrogen supplied

Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

Efficient utilization of WE system in the glass industry, Steklarna Hrastnik, Slovenia

by trailers have demonstrated the system's readiness, achieving a 60% hydrogen intake rate. This marks a key milestone on our path to reaching the target production capacity of 500 Nm³/h and highlights our commitment to sustainable innovation in the glass industry.

At Hrastnik1860, initial trials using trailer-supplied hydrogen have been successfully conducted, achieving a hydrogen intake rate of 60% in the oxyfuel glass furnace.

Future Plans

Looking ahead, our efforts are concentrated on the advancement of the hydrogen production infrastructure, with electrolyser installation scheduled to commence in 2026. Initial test production utilizing hydrogen generated from the electrolyser is planned for 2027. This phase will serve as a critical validation point for the system's operational integration, providing essential data to support the transition toward low-carbon, hydrogen-fueled processes in glass manufacturing.

Rooftop photovoltaic system supporting the integration of renewable energy with the water electrolysis system and glass furnace.

Production of premium glass bottles during trial operation of the oxyfuel furnace utilizing hydrogen as the fuel source.

Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

VII. Clean hydrogen from non-recyclable waste through SMO solar process, Active Solera, Cres, Croatia

Testbed Leader: Active Solera

Cres, Croatia

Director (or representative): Ivana Chaux-Jukic

Project Description

Development and optimization of a patented SMO (Solaire-MicroOndes) Solar Process, an energy autonomous waste processor using exclusively solar thermal energy to transform non-recyclable carbon-based waste into competitively priced Clean Hydrogen and Energy, together with Carbon Products. After construction, the thermolyser and gasifier will be tested and validated independently in the mechanical workshop, then modules will be connected in a complete SMO unit and tested. The Artificial Intelligence controlling system will be implemented to monitor the process, executing automated adjustments to ensure optimal operations. The completed SMO unit will be tested with local Croatian inputs, on the island of Cres prior to site commissioning. H2 purity will be analysed. Measured KPIs will be compared to projected yields.

In a second phase, the site will be operating, delivering clean hydrogen converted to electricity (by using hydrogen engines and experimental fuel cell stationary power genset) directly injected to the grid. Operational phase will be monitored assessing production KPIs, logistic functionalities and human resources availability.

Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

VIII. H2 production through industrial symbiosis and asset enhancement, ACEGAS, Trieste, FVG, Italy

Testbed Leader: ACEGAS

Via del Teatro, 5, Trieste, Italy

Director (or representative): Giacomini Massimo (mgiacomini@acegasapsamga.it)

Project Description

An electrolyser prototype will produce renewable hydrogen. The hydrogen production plant will be electrically powered by renewable energy purchased from RES plants and produced by a photovoltaic field. In a perspective of industrial symbiosis, the hydrogen production plant will use the purging of the cooling towers of the waste-to-energy plant. The hydrogen produced will be stored and made available to users, including the logistics sector and the local public transport service.

Key Metrics

Electrolyser power: 5 Mwe

Hydrogen production: 370 t/y

The hydrogen produced will be made available to the logistic the sector and the local public transport service.

The total budget of the project has just been updated to 19,3 million euros.

Impact and Benefits

The goal is to increase the overall efficiency of the developed system, reduce the environmental impact of the process and thus develop a scalable solution.

Current Status

The executive project of the hydrogen platform, or the plant complex dedicated to the production of renewable hydrogen, was launched, and the project is expected to be delivered in early 2025.

Last June, the request for authorization to build the plant was formalized, currently under the jurisdiction of the FVG Region. It’s expected to be completed by March 2025.

The process for purchasing the electrolyser is completed.

Production plant in Trieste

Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

H2 production through industrial symbiosis and asset enhancement, ACEGAS, Trieste, FVG, Italy

Progress Highlights

This type of plant, given the novelty they represent, requires a cooperative approach that pools the skills of the greatest number of parties involved. In our case, we involved parties such as the University of Trieste and the Bruno Kessler Foundation to identify the optimal conditions for the project and the best partners to involve in the implementation phase.

The collaboration of the institutions was also extremely important to define the authorization process and the involvement of the territory; in this context, the collaboration we found in the FVG Region was fundamental.

Production plant in Trieste

Future Plans

The tender for the construction of the hydrogen production platform, i.e. all the civil and electromechanical works necessary to host the supply of the electrolyser and to make the production plant operational. The start of the works is scheduled for the first half of 2025.

Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

IX. Assessment of the natural gas network's suitability for trasporting hydrogen blends, FVG, Italy

Testbed Leader: ACEGAS

Friuli-Venezia Giulia, Italy

Director (or representative): Maria Mazzurco

Project Description

To obtain the "Technological Qualification" (TQ) of the existing distribution network, a testbed application will be conducted in order to evaluate the use of ACEGAS own methane gas distribution network assets for the injection of increasing% of hydrogen, beyond the current regulatory limits (2 %), as well as the hydrogen storage in case of peaks production. The technical feasibility of an increase in the maximum permissible pressures will be evaluated, while continuing to ensure compliance with the highest safety and environmental protection standards, according to the innovative "Performance Based Design Method" of ASME B31.12: 2019.

The study will make it possible to assess in advance the suitability of the elements of a network section for the distribution of a mixture of natural gas and hydrogen. Preliminary indications will be given on the suitability of components and types of utilities connected to the network itself, and critical points, considerations and suggestions regarding the different percentages of mixture will be reported.

Task:

- Qualitative assessment of the identified network's H2 compatibility;
- Analysis of existing users and compatibility assessment.

Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

X. H2 by gasification of organic material for small microgrid in the industry area, Indeloop, Zagreb, Croatia

Testbed Leader: Indeloop

Zagreb, Croatia

Director (or representative): Danica Maljković

Project Description

The project involves the construction of a 2 MW photovoltaic (PV) plant coupled with a 430-kW proton exchange membrane (PEM) electrolyser. This system will facilitate the daily production of approximately 200 kg of hydrogen. The plant uses thermal conversion (gasification) to turn organic material, such as non-recyclable plastics, sludge, and textiles, into hydrogen and carbon black. It consists of three main systems: thermal conversion, cleaning and cooling, and hydrogen preparation. The plant is also capable of processing wastewater sludge. The estimated yearly production of hydrogen is 80 tonnes. Additionally, the project plans to install 200 kW fuel cells along with hydrogen storage. The electricity produced from the 2 MW PV system will be used to power the PEM electrolyser. The stored hydrogen will also be used in fuel cells for electricity production when necessary, creating a small microgrid within an industrial area in Zagreb, Croatia.

Key Metrics

Technology: Gasification, PV system, PEM electrolyser, and fuel cells.Hydrogen Production: 200 kg per day, 80 tonnes per year.Plant Capacity: 2 MW PV system, 430 kW PEM electrolyser, and 200 kW fuel cells.

Impact and Benefits

The testbed project will create a sustainable energy source for the industrial area, reducing reliance on conventional energy grids. The gasification plant tackles the problem of non-recyclable organic waste while providing clean hydrogen for energy use. The stored hydrogen can be used for fuel cell electricity generation, enabling greater energy autonomy in the local industry.

Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

H2 by gasification of organic material for small microgrid in the industry area, Indeloop, Zagreb, Croatia

Current Status

The plant's construction is underway, with the PV and PEM systems being installed. No specific challenges have been reported at this stage. Future milestones include commissioning the PEM electrolyser and completing hydrogen storage installation.

Progress Highlights

The project has demonstrated how waste2energy plants can help industries transition toward self-sufficiency while managing organic waste sustainably. Early successes show that the model could be replicated in other industrial settings across Europe, enhancing local energy resilience.

Future Plans

Upcoming steps include completing the hydrogen storage system, integrating the 200 kW fuel cells, and operationalizing the microgrid. The project aims to contribute to the region's broader hydrogen economy, with potential expansions based on the plant's performance.

Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

XI. Hydrogen ecosystem solutions and production for emerging markets, HSE, Ljubljana, Slovenia

Testbed Leader: HSE

Koprska ulica 92, 1000 Ljubljana, Slovenia

Director (or representative): Jerneja Sedlar (jerneja.sedlar@hse.si)

Project Description

HSE is currently developing a renewable hydrogen production and distribution facility. The testbed aims to convert surplus energy from intermittent, renewable sources into renewable hydrogen. The hydrogen will be utilised as a renewable energy source in the cement and glass industries, local transport, and electricity production.

The testbed includes a PEM electrolyser, a compressor station, a hydrogen refuelling station for cars and buses, and a hydrogen transport vessel refuelling station for four transport trailers.

The facility will solely rely on renewable energy sources, establishing it as the first commercial size electrolysis plant in Slovenia and the pioneering renewable hydrogen production facility in the region.

Key Metrics

Our testbed is split into two phases.

In the first phase the plan is to deploy a 3 MW PEM electrolyser, with the goal to produce 300 tons of renewable hydrogen per year. This setup includes two 150 kW compressors capable of compressing hydrogen up to 950 bar. The hydrogen will be distributed to a 350 or 700 bar dispenser for buses and cars or to one of four dispensers with variable pressure settings for transport vessels, compatible with road, rail, and water transport. There will be modular stationary storage at 500 bars (initially 500 kg) and 900 bars (initially 40 kg) for use at the refuelling station.

The first phase budget is approximately 15.000.000 euros, with NAHV covering 30%. The start of commercial operations is planned for Q2 2026.

In the second phase, the plan is to deploy an up to 30 MW electrolyser system to increase our production capacity from 300 to 3.000 tonnes per year. The plan is to expand our transport and distribution facility based on demand and may also incorporate infrastructure for injecting renewable hydrogen into the existing gas pipeline.

Current Status

The municipality confirmed the spatial planning for the first phase of the project, and the responsible ministry formally denied the need for an environmental study, shortening our timeline by about a year.

The documentation necessary for the building permit application is being prepared with the plan to apply for the permit by the end of the summer.

In the meantime, the spatial planning process has started for the second phase of the project and there is a new spatial plan in preparation, to be confirmed by the municipality.

Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

Hydrogen ecosystem solutions and production for emerging markets, HSE, Ljubljana, Slovenia

Future Plans

Our main focus now lies in getting the building permit for the first phase of the project and finishing the spatial planning process for the second phase of the project.

The focus will then be on launching a public tender for the procurement of the needed equipment for the first phase of the project and implementing the system into the vast energy production portfolio.

Efforts are being made to identify the possible hydrogen offtakers in Slovenia and in the region in general. After all, 20% of the renewable hydrogen must be distributed across the border.

Impact and Benefits

The hydrogen plant will greatly improve the utilisation factor of our ever-growing intermittent power generation portfolio, allowing renewables to keep running while producing hydrogen using that electricity instead of shutting them off when the market deteriorates. The hydrogen will be used as fuel by the neighbouring municipality, which is planning to switch to hydrogen for all their public transport buses, greatly improving their carbon footprint.

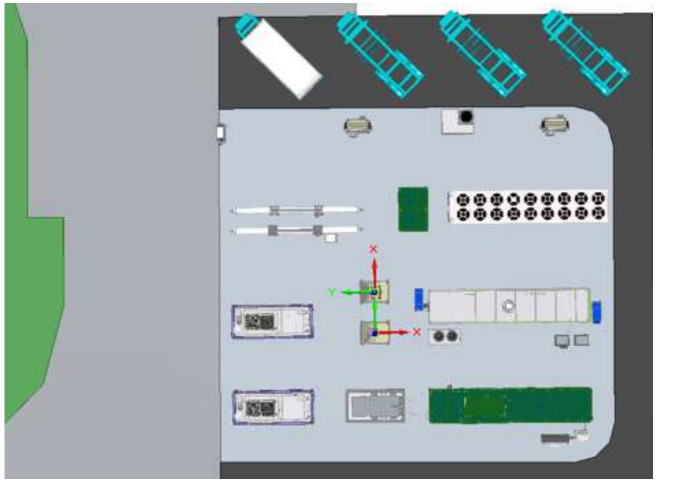
It will be used as a showcase for the hydrogen market in Slovenia, being the first car and bus hydrogen refuelling station in the country.

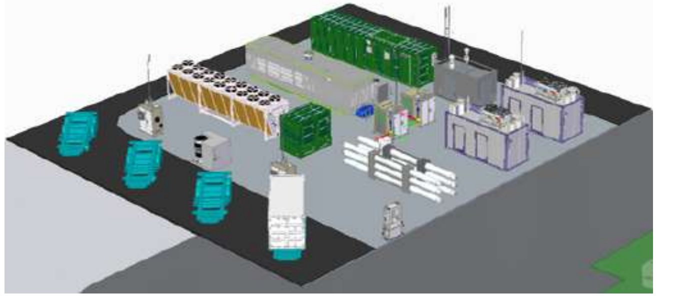
The hydrogen will be available for use as a coolant for the generators via the existing pipeline in the power plant. It will be tested as an energy source for the two hydrogen ready gas turbines that TEŠ has installed. The electrolyser will utilise a heat recovery system, so we can use the excess heat in our district heating system, providing up to 1 MW of heat to the two neighbouring municipalities.

Progress Highlights

One of the significant milestones of the project was the official letter from the Ministry of Natural Resources and Spatial Planning, denying the need for an environmental study for these types of facilities in Slovenia.

As the project progresses, more ideas and opportunities on the use of renewable hydrogen as a renewable energy source are emerging.





Potential plant layouts, subject to change as the project advances.

Co-funded by the European Union

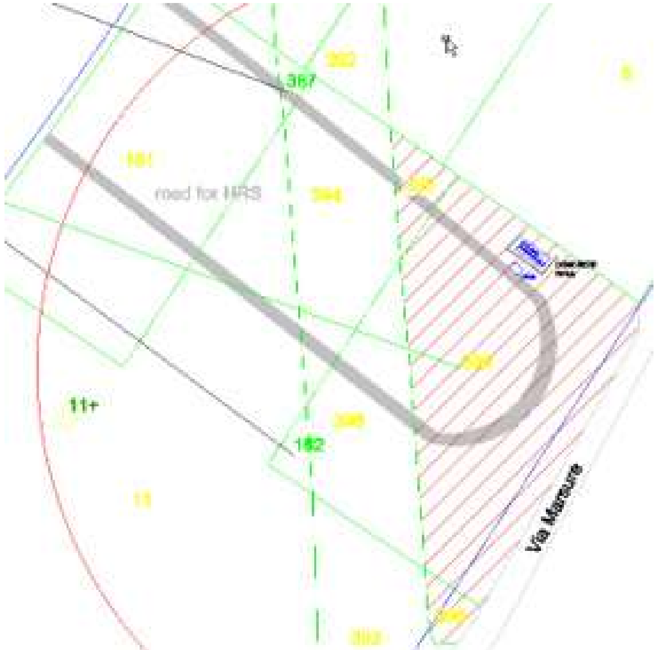
The project is suported by Clean Hydrogen Partnership and its memebers.

XII. Integrated hydroelectric and HFC power station for retail distribution of hydrogen, CTS, Brugnera, Italy

Testbed Leader: Clean Technology Systems H2

Brugnera (PN) – Viale Lino Zanussi 1 – 33070, Italy

Director (or representative): Federica Zagarella (f.zagarella@ctsh2.com)



Map of the potential location of the testbed

Project Description

The testbed focuses on validating and implementing a small, potentially distributed hydrogen refuelling station with onsite renewable H2 production. The station will produce up to 2 tons of renewable H2 annually, powered by either a small hydroelectric station or a photovoltaic plant. The H2 will be produced using an AEM electrolyser (35 bar max pressure), ensuring 99.999% purity, and stored in a 2324-liter system. The electrolyser type will depend on the power source: AEM for variable solar power (60 kW) and AWE for continuous solar power (1 MW). Rainwater collected from the cabinet roof will be used in the electrolytic process. After compression to 300 bar, H2 will be stored and used to refuel vehicles according to SAEJ2601: 2010 standards, reaching up to 350 bar in two phases. Additionally, a Fuel Cell (HFC) will provide up to 5kW of energy for small devices, lighting, or self-supplying the station. An industrial research activity will also focus on developing a high-pressure demo electrolyser that supplies H2 at 350 bar without compression.

Impact and Benefits

CTS H2 S.r.l. will develop the first demo modular and transportable HRS powered by renewable energy source, in circular economy regime, and in cogeneration state, serving Fuel Cell Electric Vehicles (FCEVs) along the north Adriatic corridor. The HRS will be located in a “plug and play” container that can be moved by truck transport; depending on the power plant size, more modular containers can be moved and installed.

Once fully operational, the system will be able to fuel buses for running 50 thousand kilometres yearly with a production of 6000 kg of hydrogen implying the possibility to use at the same time 30000 kW of thermal energy and 7000 kW of electricity.

The system will be able to sequestrate 56.600 kg of CO2 and release 30000 Nmc of oxygen, corresponding to the effect of a 1.1 hectare of forest per year.

Thanks to the fuel cell, each kWh of electrical energy produced from hydrogen will depurate 250 litres of air per hour.

Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

Benefits and key metrics for the integrated hydroelectric and HFC power station of CTS, Brugnera, Italy

Key Metrics

AEM or SPECIAL AWE electrolyser (35 bar maximum pressure) with 99,999% purity;

Inertial buffer tank;

2324 litres cylinder rack as storage tank;

Filling process (compression to 350 bar) in 2 phases;

Fuel Cell (5kW);

Production of carrier to fuel buses for potentially running 50'000 kilometres;

A small innovative AES electrolyser on company test bench for the H2 production in high pressure.

Current Status

The testbed project is in the preliminary design phase. CTS H2 S.r.l. is in discussions with potential stakeholders to identify a suitable location and renewable energy source (RES). However, progress is slow due to several challenges: finding stakeholders to invest in fuel cell electric vehicles (FCEVs), identifying a strategic site for hydrogen-integrated heavy vehicles with expansion potential, locating a site near renewable plants (the initial hydroelectric plant has logistical and authorization issues), and securing further investments and a suitable site for the hydrogen refuelling station (HRS). Additionally, the project faces budget reductions despite significant efforts to engage stakeholders.

Progress Highlights

This project builds on 18 years of experience in the hydrogen sector by CTS H2. The goal is to create an innovative, modular, and transportable hydrogen refuelling station (HRS) that efficiently produces green

Key Features

Modularity: The HRS will be made of easy-to-assemble modules in mini-containers, allowing for rapid installation and flexible configurations.

Transportability: The modules will be designed for easy movement on standard vehicles, even to remote locations.

Efficiency: The system will maximize energy efficiency, from hydrogen production to storage and distribution, using IoT technologies to optimize self-consumption and reduce O&M costs.

Green Hydrogen: 100% of the hydrogen produced will come from renewable sources like solar or wind power.

Cogeneration: The system can be equipped for cogeneration, producing both electric and thermal energy by using waste heat from electrolysis.

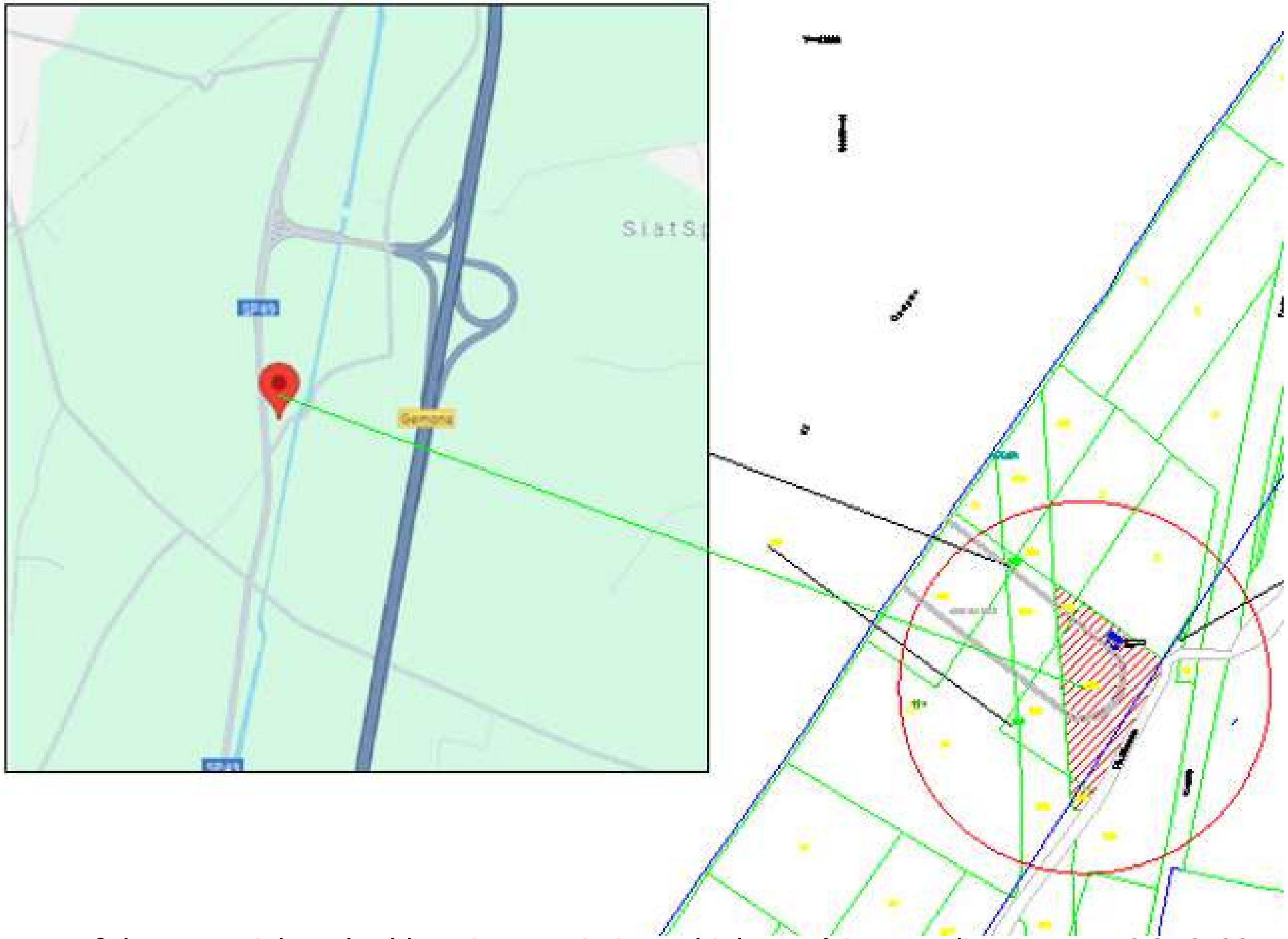
Power-to-Power: The system can operate in power-to-power mode, using hydrogen-generated electricity for auxiliary functions and grid balancing hydrogen using renewable energy sources (RES) through electrolysis.

High-Pressure Storage: Hydrogen will be stored in high-pressure tanks for greater energy density and autonomy.

Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

Benefits and key metrics for the integrated hydroelectric and HFC power station of CTS, Brugnera, Italy



Map of the potential testbed location proximity to highway (site coordination: N 46.246799, E 13.095188 - source: Google Maps).

New Electrolysis Technology: A new high-efficiency electrolysis technology will be tested to produce high-pressure hydrogen directly, eliminating the need for a compressor, reducing costs, and extending system life.

This testbed will provide an innovative, sustainable, and flexible solution for producing and distributing green hydrogen for heavy vehicles, suitable for both private and public HRSs.

Future Plans

Once clarified the budget situation and obtained the extra financing, the testbed implementation could proceed.

Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

XIII. Development of Hydrogen storage system for distribution, Faber, Cividale del Friuli (UD), Italy

Testbed Leader: FABER

Via dell'Industria, 64 33043 Cividale del Friuli (UD), Italy

Director (or representative): Alberto Agnoletti

Project Description

A new H2 storage composite vessel prototype has been industrially validated, capable of holding over 300 litres of water. The prototype is being implemented on a fully automated line to produce high-pressure gas cylinders at a mass production scale of 10,000 cylinders per year, providing an optimal compromise in terms of performance and economics. The increase in operating pressure to at least 500 bar and the advanced use of composite materials, and based on regulatory/normative documents, for an increment in the gravimetric efficiency of the cylinders to over 5% will make it possible to create vehicles capable of reaching a payload of over 1.2 tones of hydrogen.

Key metrics

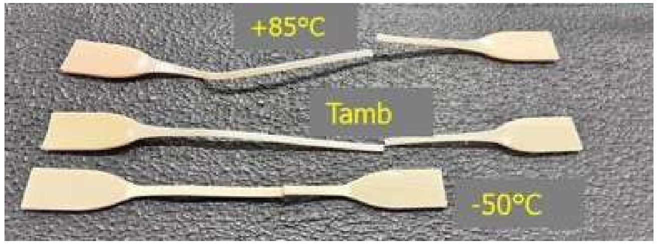
Type 4 - cylinder	
Maximum Volume	350L
Working Pressure	500 bar
Nominal Diameter	490 mm
Nominal Length	2470 mm
Nominal Weight	140 kg
Total H2 capacity	11 kg H_2
Marking and Type Approval	EN17339

Impact and Benefits

The testbed project aims to significantly impact the transport sector by providing a sustainable and efficient solution for hydrogen transportation. This will support the decarbonization projects contributing to the EU's green transition goals.

Current Status

The current status of the Faber Testbed Project indicates significant progress in several key areas. Comprehensive research and procurement efforts have successfully identified and sourced diverse materials for the liner, resin, and carbon fiber components. Initial testing phases have commenced on these materials, with a number of tests already underway. However, certain critical evaluations, such as the permeation and ageing tests on the liner materials, are still in progress.



Example of PA6 samples after tensile test at different temperature conditions

Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

Future plans for the development of Hydrogen storage system, Faber, Cividale del Friuli (UD), Italy

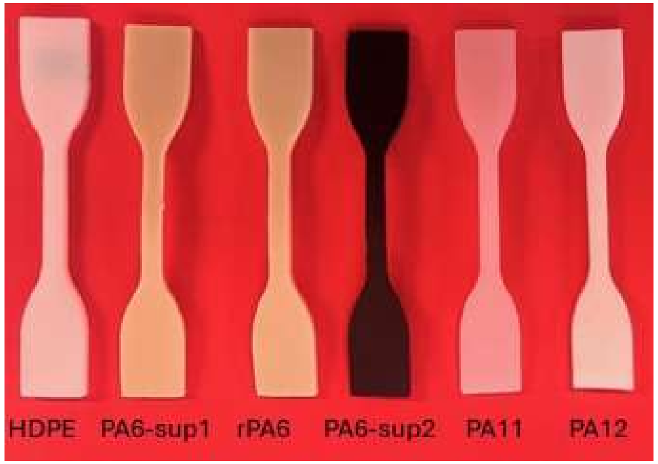
Simultaneously, the project is advancing through the design and development stages for the carbon winding. Detailed simulations are being executed to meticulously analyse and determine the optimal geometric configurations that will enhance the efficiency and performance of the carbon winding. This phase is crucial for ensuring that the final design meets the stringent requirements of the project.

The approach in material selection, combined with the testing and advanced simulation efforts, underscores the project's commitment to achieving excellence and innovation in developing high-performance components.

Future Plans

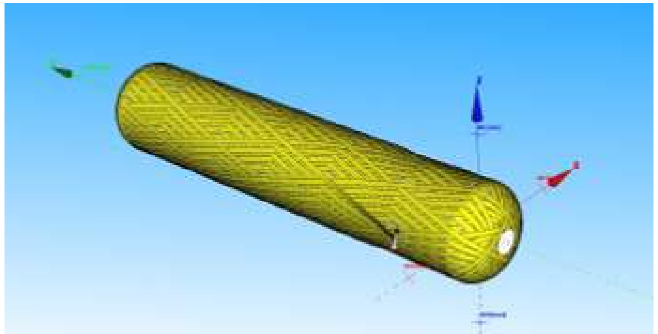
The immediate next steps involve the fabrication of the initial prototypes. Winding patterns for the composite reinforcement will be created and optimized through iterations.

Disc-shape specimens of studied materials



Dumbbell-shaped specimens of studied materials

Example of bending test phases on a pinch-off sample of a PA11 liner after blow moulding production

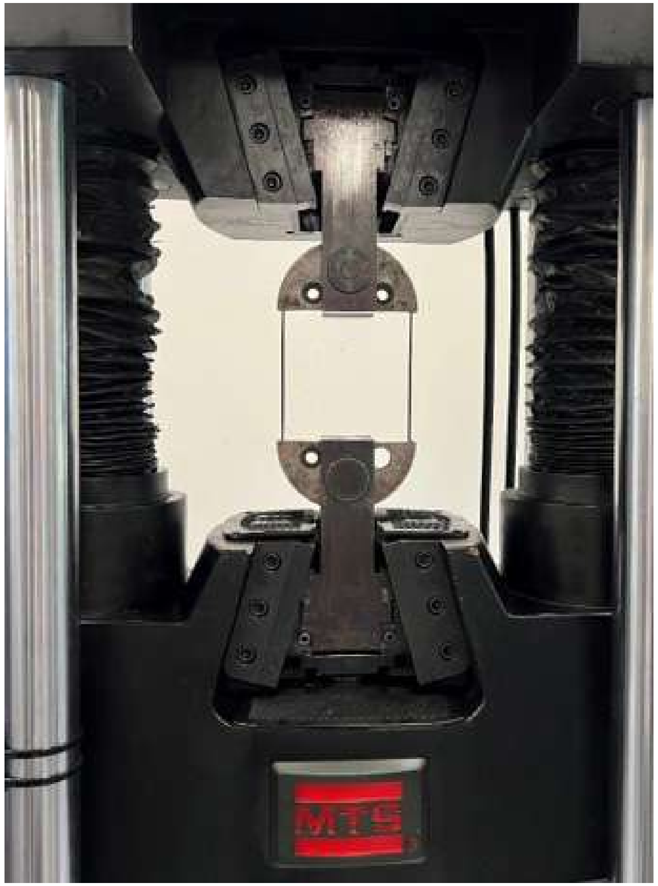


Winding pattern design for the manufacturing of the prototypes

Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

Future plans for the development of Hydrogen storage system, Faber, Cividale del Friuli (UD), Italy



Composite ring during tensile test

Tensile testing apparatus with climatic chamber

H2V
Clean Hydrogen Partnership
Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

XIV. Hydrogen propulsion 4 vessels & maritime infrastructure in the Adriatic, MCoE, Rijeka, Croatia

Testbed Leader: Maritime Center of Excellence

Rijeka, Croatia

Director (or representative): Damir Opsenica

Project Description

The innovative technology of green vessel powertrain will be demonstrated by the delivery of hydrogen-powered pilot vessel. Conceptual design and optimization will be performed in four main aspects: 1) renewable hydrogen propulsion, focussing on performance, safety, certification and supporting value chain infrastructure; 2) power management and control using advanced digital technologies coupled with build-up of the new digital data model; 3) extensive sea trials and data collection/ operational performance optimization; 4) collection of know-how, lessons learned and preparation of road map for future commercialization.

More in detail the following activities will be performed:

Hydrogen propulsion vessel conceptual design, including screening of existing Adriatic commercial fleet, data collection and evaluation of ship operating profiles, propulsion and power management systems, emission performance and existing port infrastructure supporting full supply chain, hydrogen technology value chain assessment, technology solutions assessment and value proposition.

Screening of existing ships and data collection

Screening of existing commercial ship types (fishing vessels, port work boats and tugs, coastal passenger ships and ferries and yachts) as most promising candidates for greener operation in Adriatic region.

Development of the RAG framework. The RAG model will be a central tool for data collection, analysis, and knowledge synthesis, accelerating research and decision-making processes throughout the project.

Technology screening and assessment

Screening of advanced green propulsion and powertrain systems with particular attention to environmental performance (GHG emissions) of different alternative fuels and availability considering full value chain in Adriatic region.

Simulation model development

Development of 0D/1D system simulation model of ship capable simulating energy consumption prediction, energy storage prediction. Outputs of the simulation model will be bases for definition of powertrain requirements (power output, energy density, consumption etc.).

Green powertrain solutions assessment

Analyse best practice design for retrofitting of existing or newbuilt vessel, design cost-effective modular solutions and evaluate capabilities of shipyards in Adriatic region

Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

Hydrogen propulsion 4 vessels & maritime infrastructure in the Adriatic, continued, MCoE, Rijeka, Croatia

Roadmap development

Mapping of development process and lessons learned establishment of road map and best practices for vessels for greener operations providing a road map and work processes for vessel owners, operators, shipyards and associated engineering companies. activities

Assembly of solutions catalogue

Assembly of a solutions catalogue containing a modular system design for a wide variety of vessels based on conducted research and the pilot project outcomes.

Furthermore, following activities will be performed too:

Hydrogen propulsion vessel conceptual design, including screening of existing Adriatic commercial fleet, data collection and evaluation of ship operating profiles, propulsion and power management systems, emission performance and existing port infrastructure supporting full supply chain, hydrogen technology value chain assessment, technology solutions assessment and value proposition.

Newbuilt ship design and engineering, including complete engineering for basic and detailed design, safety and operating performance analysis and assessment, preparation of certification and class documents, liaison with certifying authorities and definition of supporting port infrastructure and complete fuel supply chain.

Newbuilt ship digital technologies development, including analysis of digital twin solution for hydrogen powertrains, development of digital technologies (digital signal processing, big data and artificial intelligence-based models for powertrain process optimization and new generation of power management, all of which is relevant for greener operations of existing fleet), sensor system secure networking and integration, development of digital twin for the complete retrofitted system and equipment and control system testing on testbed prior to installation.

Pilot project – shipyard newbuilt activities, pilot vessel construction (vessel preparation and installation of hydrogen propulsion powertrain and controls), pilot vessel commissioning and sea trials with monitoring and optimization of the complete process.

Risk assessment relevant for the complete retrofit project.

Monitoring and follow-up after completion of the trial.

Current Status

The basic design of the ship has been frozen. The ship will incorporate compressed hydrogen storage tanks type IV. It is envisaged the ship capacity will be over 200 passengers. Tanks will be placed onboard at upper deck. The hydrogen tanks capacity will be 500 kg at 350 bars. It is envisaged to use 3 fuel cells, each one nominal capacity of 400 kW.

Preliminary screening of Adriatic fleet is concluded, and data evaluation is in progress.

Co-funded by the European Union

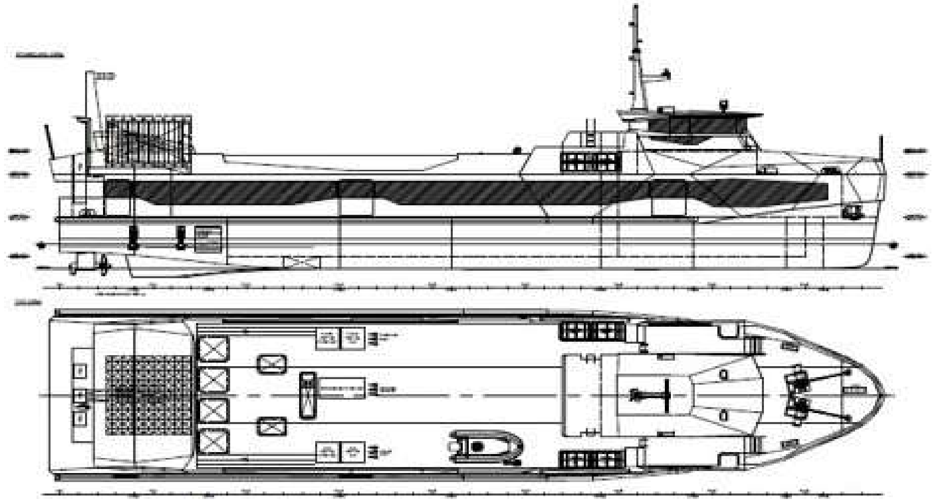
The project is suported by Clean Hydrogen Partnership and its memebers.

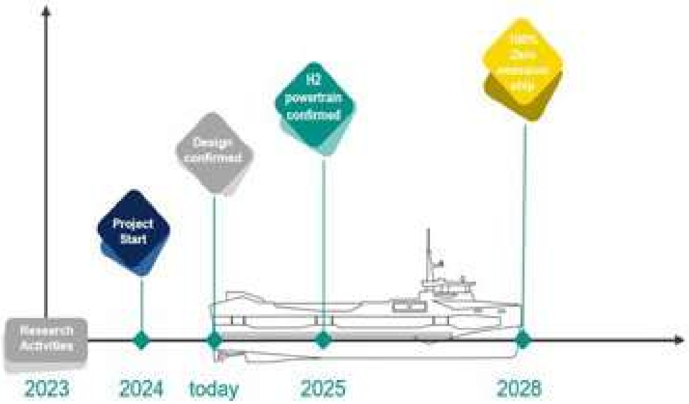
Hydrogen propulsion 4 vessels & maritime infrastructure in the Adriatic, continued, MCoE, Rijeka, Croatia

Future Plans

The nest steps involve ship detail design engineering, communication with equipment suppliers and system integrators.

Additionally, data from fleet screening are formatting, cleaning, comparing ships operation profiles, fuel consumptions and existing port infrastructure to support supply chain. Contact NAHV partners related to possible data necessary for RAG model to be implemented.





Hydrogen-fuelled vessel

Hydrogen infrastructure system

Digital technologies (efficiency & safety of operations)

Safety standard recommendations

Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

XV. Hydrogen for the public bus transport in Gorizia, Trieste Trasporti, Trieste, Italy

Testbed Leader: TPL FVG

Via dei Lavoratori, 2, 34144 Trieste TS, Italy

Partner: APT Gorizia

Director (or representative): Giuseppe Zottis (giuseppe.zottis@tplfvg.it), Luca Di Benedetto

Project Description

TPLFVG S.c.a.r.l. is a partner in the NAHV project by virtue of two initiatives undertaken by its consortium members, APT

S.p.A. and Trieste Trasporti S.p.A., both aiming to acquire hydrogen-powered buses through two different infrastructure development pathways.

APT is planning the construction of a new depot in the Monfalcone area, which will include a workshop equipped with a hydrogen production, storage, and refuelling facility. The initial fleet will consist of 8 hydrogen buses, to be introduced between 2025 and 2026. An additional 7 hydrogen buses are planned for acquisition during the 2027–2029 period.

Trieste Trasporti plans to acquire 10 hydrogen buses by 2030 and has initiated discussions with AcegasApsAmga to utilize

hydrogen produced at the Trieste waste-to-energy plant.

This ecological transition project will also significantly impact fleet management operations, including changes to logistics (e.g., refuelling processes) and maintenance activities. Safety procedures will also need to be revised accordingly.

Furthermore, the performance of the hydrogen buses will be monitored through the definition and application of specific KPIs.

The entire project aims to establish two replicable models for the production, distribution, refuelling, and management of hydrogen-powered public buses, which could be implemented in other locations as well.

The infrastructure projects for the facilities and the acquisition of hydrogen buses are part of the broader ecological transition initiative for the public transport system (PREPM-TPL), developed by TPLFVG and the Friuli Venezia Giulia Region. This plan envisions the purchase of 445 alternatively powered vehicles (electric, methane, hybrid, or hydrogen) between 2024 and 2030.

Key Metrics

An investment of 3.245.000 euros is estimated for the realization of the project.

Trieste Trasporti will also need to cover the costs for the purchase of 10 hydrogen buses, which has been estimated at 7,000,000 euros.

Impact and Benefits

The plant will allow the production of green hydrogen (maximum productivity of 400 tones/day) that will also be used to support the transition of part of the TPLFVG fleet from diesel to hydrogen power.

Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

Hydrogen for the public bus transport in Gorizia, Trieste Trasporti, Trieste, Italy

Current Status

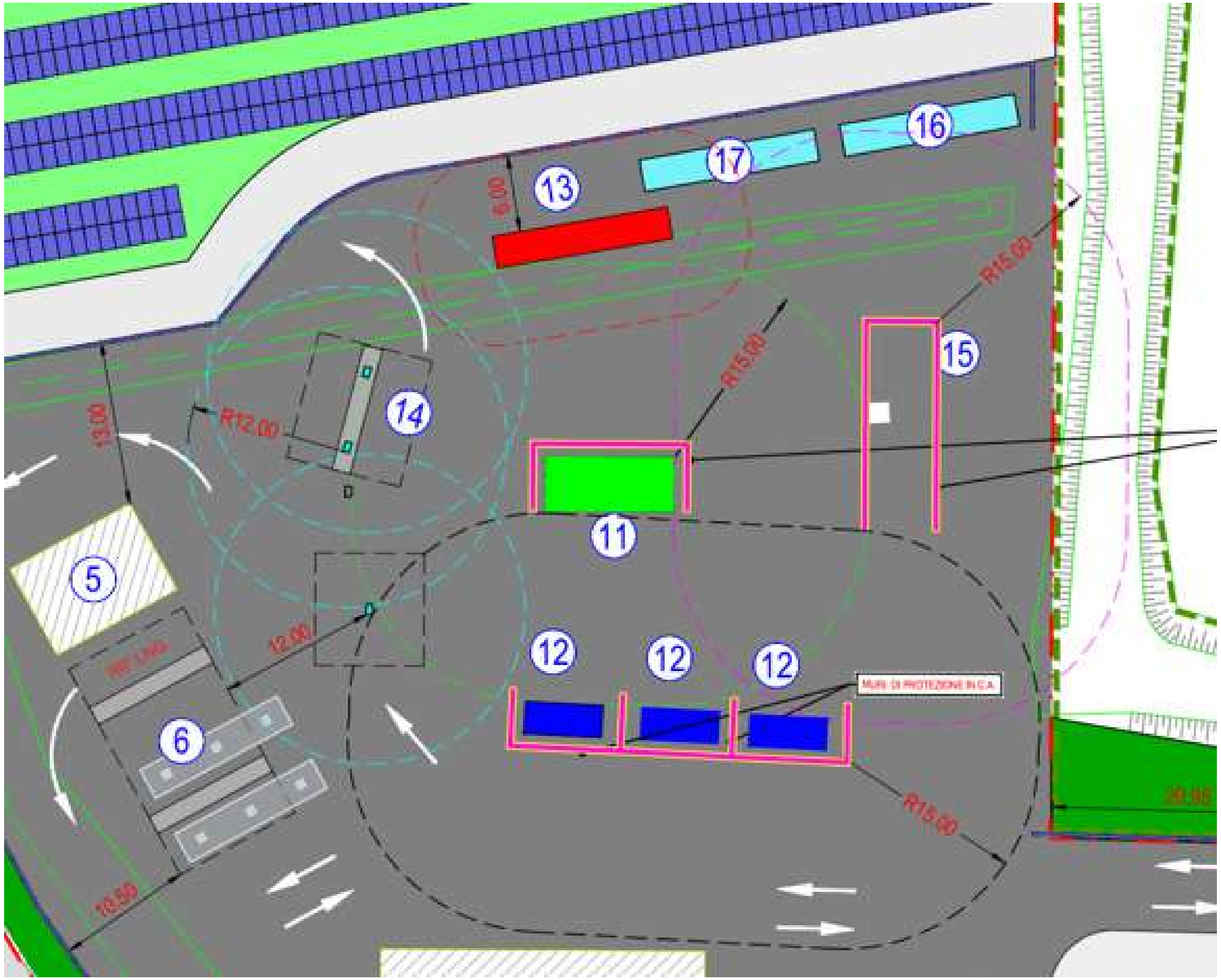
The tender for the construction of the plant has been called and awarded. The works will begin by the end of the year and finish by the 30th of June 2026.

Future Plans

The construction works will start at the end of the year.

The general layout of the refuelling station includes the following elements:

A. *MP and AP storage*
B. *Compressors*
C. *Electrolysis*
D. *Filling station*
E. *Loading from trailer*
F. *Cooling container*
G. *Container for electricity supply and auxiliary services*



Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

Hydrogen ecosystem solutions and production for emerging markets, APT, Monfalcone (Italy)

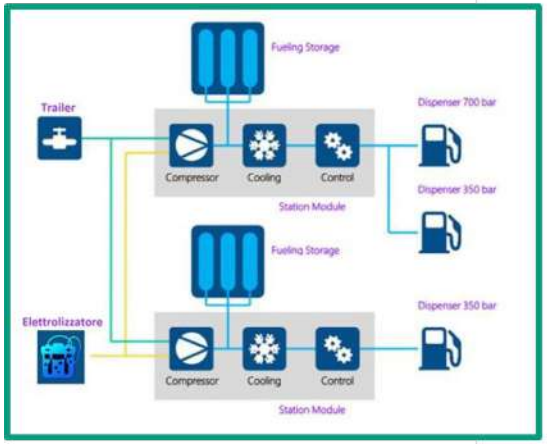
Project Description

APT is developing a new hydrogen production and distribution site as part of its new headquarters in Monfalcone Lisert, covering over 38,000 m². The hydrogen plant will focus on renewable hydrogen for public transport and vehicle fleets, with integrated solar energy generation.

It includes:

- Solar Farm Capacity: 1.67 MW
- Solar Panels: 2,834 monocrystalline silicon panels, each rated at 6000 W
- Estimated Annual Production (Year 1): 1,975,025 kWh
- Total Area: 17,000 m²

- Total Area: Over 3,200 m²
- System Components: Medium-Pressure (MP) and Atmospheric-Pressure (AP) storage, electrolyser, compressors (500 and 1,000 bar), two dispensers for buses (350 bar at -20°C), one dispenser for vehicles (700 bar at -40°C), trailer loading unit, cooling system, containerised units for gas, power supply, and accessories, control room and technical service rooms for refuelling operations.



Plant capacity:

- Maximum Power: 1 MW
- Daily Production Capacity: 400 kg of hydrogen

Integrated and mixed tender

The project is funded by the European Union under NextGenerationEU – PNRR, Mission 2, Component 2, Investment 3.3, and co-financed by the Friuli Venezia Giulia Region.

Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

Construction of a renewable hydrogen refuelling station and supply and installation of the electrolyser

CIG: A04245FC90

Announcement of procedure: 28 December 2023

Awarding of contract: 21 May 2024

Contract signed: 8 October 2024, between APT Spa and the temporary consortium (RTI) of SOL Spa and CEDEM Scarl, for a total amount of €10,246,664.09 (excluding VAT)

Partial site delivery: 20 January 2025

Validation of the executive project: 26 March 2025

APT, with a project prepared by its technical staff, was awarded second place in the national ranking for the selection "Project proposals for the construction of renewable hydrogen refuelling stations for road transport". The initiative is funded under the PNRR framework by the European Union through Decree 199 of the Ministry of Infrastructure and Sustainable Mobility.

A call for tenders was published on 19 November 2024 for the supply of vehicles planned for 2026 and 2027.

The procurement includes eight hydrogen-powered buses and one optional unit for the APT fleet (CIG B45961DD7F).

The deadline for tenders is 19 December 2024.

The total value is €6,528,705.00.

The award is expected by April 2025.

The refuelling facility is designed to serve up to ten buses and will include storage, chiller, compressor and two refuelling lines.

Feasibility studies for installation at Trieste Trasporti depots were conducted but ruled out due to regulatory constraints.

Discussions continue with the Municipality of Trieste and Acegas to find a suitable site, preferably near the electrolyser, to reduce hydrogen transport distances.

Next steps include preparing a Business Plan with Acegas, aiming to complete the facility by June 2026, and finalising a location for the refuelling station.

Trieste Trasporti is encountering difficulties in securing a suitable site, which is expected to delay the timeline by around six months.

Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

XVI. Hydrogen value chain in the maritime transportation, Island of Cres, Croatia

Testbed Leader: Municipality of Cres

Director (or representative): Ugo Toić, ugo@pplr-otokcres.info

Project Description

The Town of Cres has formally joined the NAHV Consortium in mid-September 2024, as replacement of ACI Club Marina and will undertake the planned activities and expected results envisaged in the project designed for the outgoing partner.

Up until now, the Town of Cres took the decision to join the consortium and, with the ECUBES's support has been in contact with the consortium lead partner. The Town of Cres has committed to collaborate with ECUBES in establishing a hydrogen technology hub and develop sustainable energy models and transport solutions.

Phase One

The Amendment is expected to be confirmed by May 2025. Following this confirmation, CRES and ECUBES will receive the first tranche of grant funding. Despite working with a limited budget, we have already initiated activities for Phase One. This includes gathering preliminary information necessary for a pre-feasibility study and deploying a demonstration container.

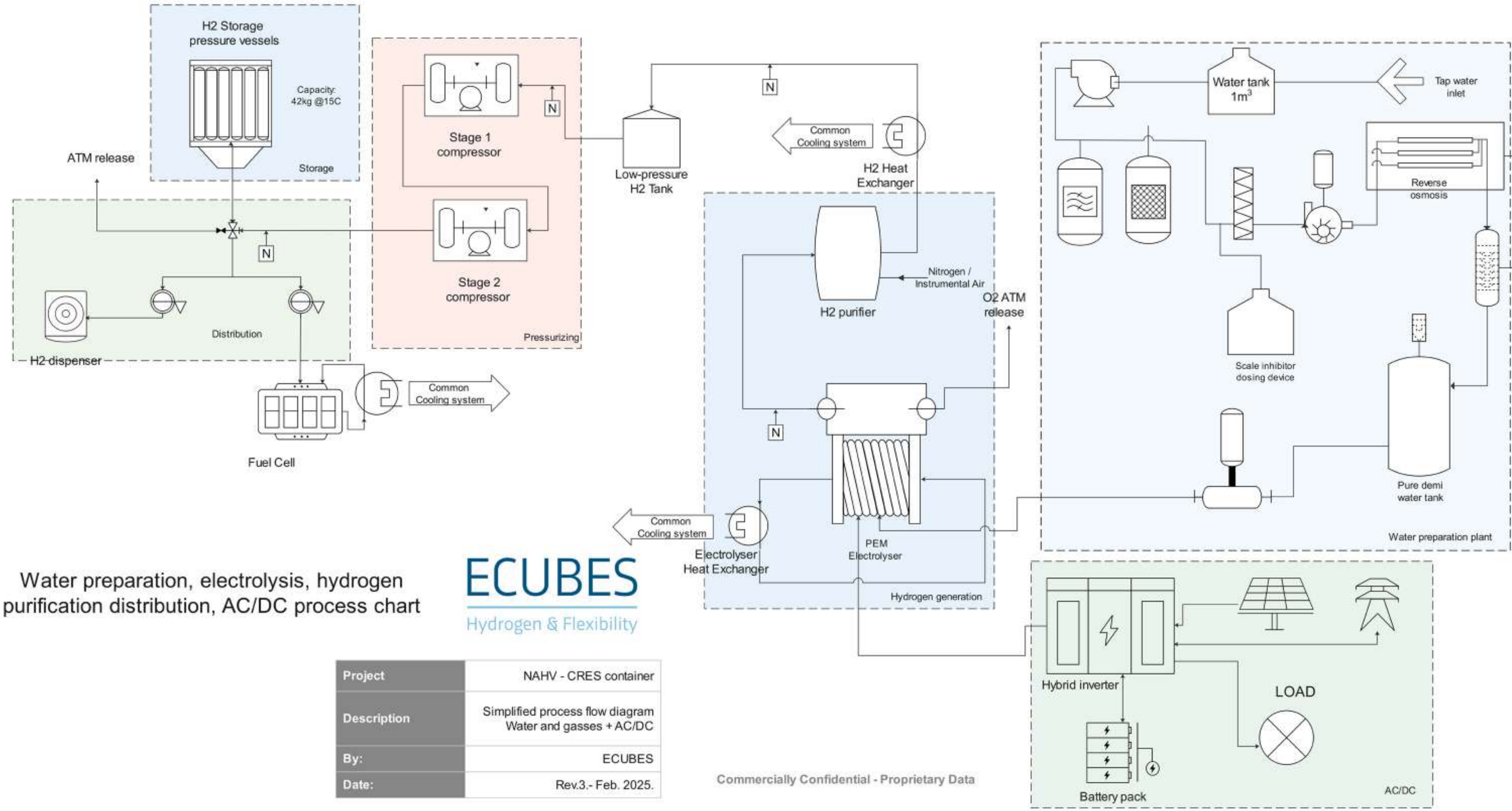
The demo container consists of hydrogen production and storage, a 350-bar hydrogen refuelling station, and a fuel cell to generate energy for community consumers. During this phase, hydrogen use is intended primarily for road transport. Subsequent phases are planned to extend hydrogen applications to the maritime sector.

We have developed an initial concept for the Phase One demonstration container and have begun engaging our wider network of stakeholders to deploy all project phases. This includes establishing a commercial HRS and developing a hydrogen-powered catamaran.

Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

Phase One concept, Island of Cres, Croatia



Water preparation, electrolysis, hydrogen purification distribution, AC/DC process chart

Project	NAHV - CRES container
Description	Simplified process flow diagram Water and gasses + AC/DC
By:	ECUBES
Date:	Rev.3.- Feb. 2025.

Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

XVII. Energy storage for distributed power generation with ECUBES fuel cell tech, Nova Gorica, Slovenia

Testbed Leader: ECUBES

Ulica Gradnikove brigade 49, 5000 Nova Gorica, Slovenia

Director (or representative): Aleksander Gerbec

Contact: Filip Margan (filip.margan@ecubes.eu)

Project Description

This project involves a highly deployable, containerized energy storage and power generation solution with 1MWh capacity, using an innovative hydrogen carrier. It will be implemented in remote areas to support hydrogen-powered vehicles or EV charging. Developed by Ecubes from TRL2 to TRL6, it has already been tested at the Salonit cement factory. Over the next two years, it will reach TRL8 and undergo extensive testing.

The solution enables renewable hydrogen production and its use in a closed-loop system, addressing intermittent renewable energy issues by integrating transport, stationary power, or seasonal storage. A fuel cell, combined with innovative hydrogen storage, provides on-demand energy.

The project also supports hydrogen as fuel for refuelling stations or general energy use, with a goal to reduce CO2 emissions. Distributed across five locations in three countries, it's expected to save 5,000 tons of CO2 annually, with a feasibility study for large-scale investment.

Key Metrics

The testbed project uses fuel cells (FC) for distributed power generation, converting hydrogen into electricity with high efficiency, durability, and silent operation. It stores energy as liquid hydrogen, a compact and efficient carrier ideal for long-term storage and transportation. In this project, it powers EV charging stations, demonstrating hydrogen's potential in clean mobility.

The system operates in a closed-loop process, minimizing waste and optimizing resource use. Designed for flexibility, the containerized energy storage system can be deployed in remote or off-grid locations. It supports clean energy by converting hydrogen into electricity, enabling distributed power generation near the point of use, which enhances efficiency and reduces transmission losses.

A key feature is carbon credit tracking, which quantifies and monetizes greenhouse gas reductions, serving as a model for regions looking to adopt hydrogen-based energy systems. The project targets 1 MWh of energy storage with liquid hydrogen for use in EV charging stations, with a total budget of €5.6517 million, covering hydrogen production, storage, and equipment.

Impact and Benefits

The project will promote the adoption of hydrogen-based technologies among businesses, SMEs, and research institutions. By demonstrating the viability of hydrogen production, fuel cells, and energy storage, participants will be able to integrate these technologies into their operations, contributing to decarbonization efforts, particularly in smart communities.

Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

Energy storage for distributed power generation with ECUBES fuel cell technology, Nova Gorica, Slovenia

Participants in energy production, storage, and distribution will benefit from the flexible, containerized system, which can be deployed in various settings, from rural areas to urban centers. The project will also provide real-time data to help participants optimize energy use and better understand hydrogen's potential, guiding future decisions and investments.

Current Status

The reactor was built, and the cold start was completed successfully. During operations, the regenerator did not work optimally, as expected for first trial runs. Currently, we are investigating the causes of underperformance, with a focus on chemical and mechanical optimisations to increase efficiency and overall performance. Once assessed, new components will be integrated while complying to all essential safety measures for certification.

During the research phase, further hydrogen carrier was identified and successfully tested in November/December 2024. We are continuing to conduct extensive research on the subject

The new hydrogen carrier is at TRL 8 and has a strong potential for deployment, particularly on the pilot projects in Salonit, Nova Gorica, and Cres. There is a great desire to investigate the possibility for hydrogen import to NAHV. We are working with stakeholders to develop solutions for long-distance hydrogen transportation, including prospective imports to the North Adriatic region.

Future Plans

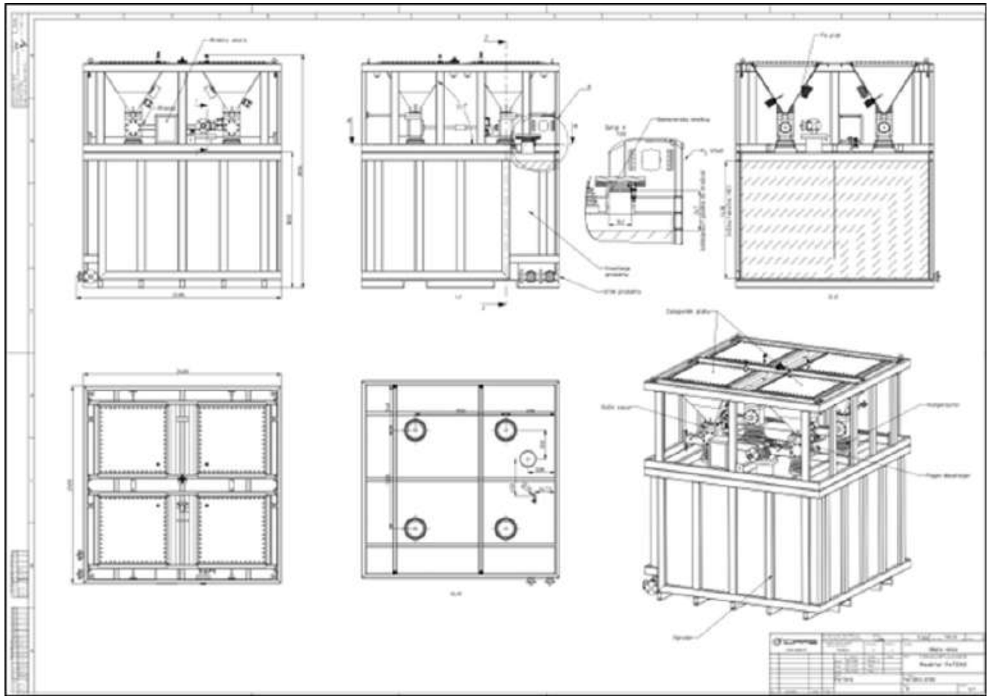
We intend to complete all of the tasks that are currently running concurrently by September and provide an update on the outcomes. This will make it apparent how we will move forward.

Regenerator TRL7

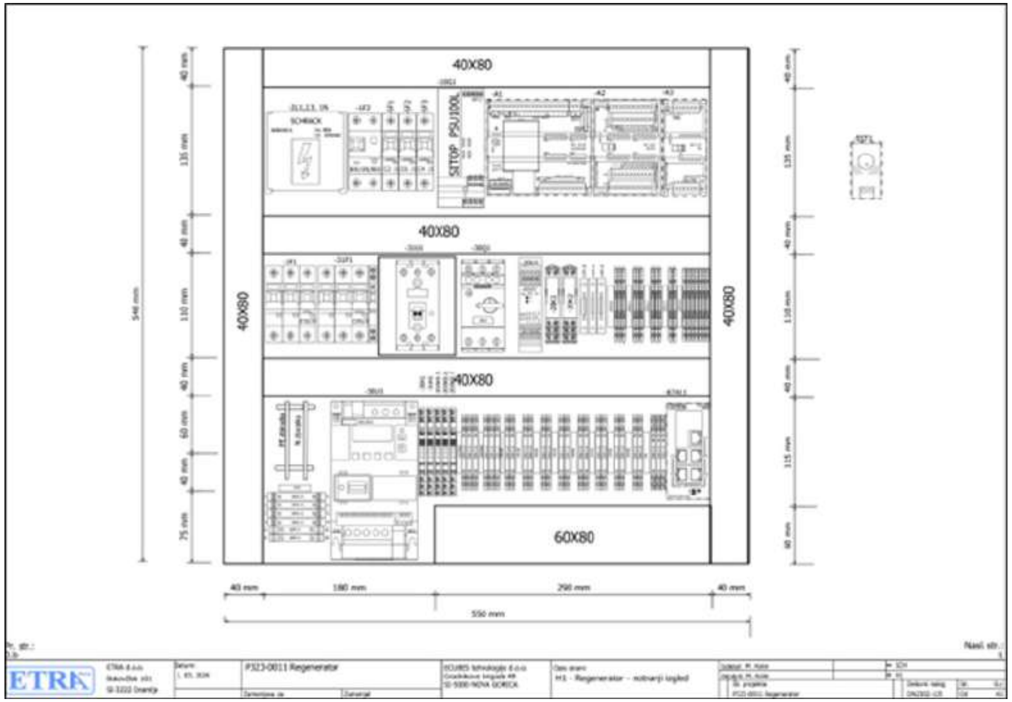
Co-funded by the European Union

The project is suported by Clean Hydrogen Partnership and its memebers.

Energy storage for distributed power generation with ECUBES fuel cell technology, Nova Gorica, Slovenia



Plans for Reactor



Excerpt from electrical plans Regenerator TRL7

Clean Hydrogen Partnership
Co-funded by the European Union
The project is suported by Clean Hydrogen Partnership and its memebers.

www.nahv.eu