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*TransH2***Presentation of investment plan
to green hydrogen production promoters**

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Executive Summary

This report outlines the follow-up activities undertaken to present TransH2-related investment opportunities to promoters and stakeholders of green hydrogen production across the maritime hydrogen value chain. The exchanges confirmed that maritime hydrogen deployment requires stronger alignment between green hydrogen supply, port infrastructure, vessel applications, certification, permitting, skills and financing. While the Programme Area already includes relevant actors and initiatives, most projects remain at feasibility, pilot or early implementation stage.

Key opportunities identified include potential synergies between green hydrogen production, port and maritime applications, refuelling and storage solutions, testing environments, and regional cooperation initiatives

The report also highlights the role of cooperation frameworks such as NAHV initiative and other EU relevant projects in supporting capitalization, investment readiness and future project development.

Overall, the deliverable provides a basis for moving from stakeholder engagement towards more structured follow-up activities, including feasibility work, cooperation agreements, funding applications and future pilot or investment initiatives.

1 Purpose and scope of the report

This report documents the targeted dissemination of possible investments related to the *TransH2* scope to key actors in the green hydrogen production sector and in the broader maritime hydrogen value chain. It outlines how the proposed maritime applications identified by *TransH2* may align with hydrogen supply capabilities, infrastructure development, technical feasibility and market opportunities, highlighting possible synergies between production and end-use.

The report builds on D.3.3.3 – Investment Catalogue and Action Plan and, where relevant, on the stakeholder inputs collected through D.3.3.2 – Investment Data Report. The D.3.3.2 consultation confirms that the Programme Area already hosts an emerging maritime hydrogen ecosystem, involving energy companies, port authorities, technology providers, maritime operators, R&D actors, associations and clusters, while most initiatives remain still at feasibility, pilot or early implementation stage.

Within this context, D.3.3.6 focuses on the dialogue promoted by the Project Partners with hydrogen production promoters and related stakeholders. The objective is to strengthen the connection between the supply and demand sides of the hydrogen value chain and to support the practical implementation of integrated, cross-sectoral solutions for maritime hydrogen applications.

2 Strategic and methodological framework

Green hydrogen solutions for maritime transport require an integrated value-chain approach. Port refuelling infrastructure, vessels, production plants, storage systems, logistics, certification, safety procedures, permitting and financing mechanisms cannot be considered as separate elements. Their feasibility depends on the capacity to align future maritime and port-side demand with the availability of renewable, traceable and economically viable hydrogen supply.

For this reason, the targeted dissemination activities carried out within the project were not limited to green hydrogen producers alone. They also involved actors that can contribute to the technical, regulatory, industrial, operational and financial conditions required for the deployment of hydrogen in maritime applications. These include port authorities, classification societies, shipbuilders, research and innovation organisations, energy utilities, technology providers, start-ups, refuelling infrastructure developers, storage and release technology providers, public institutions and training stakeholders.

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The objective of this broader engagement was to understand how the investment plan could be connected with the needs and capabilities of the hydrogen value chain. Producers and energy utilities need credible demand signals, predictable offtake opportunities, bankable counterparts and clear regulatory conditions. Ports, vessel operators and technology providers need reliable hydrogen availability, realistic delivered-cost assumptions, safe bunkering procedures, certification pathways, permitting clarity and suitable operational models.

The report adopts both a strategic and an operational perspective. Strategically, it frames maritime hydrogen deployment within a wider North Adriatic and Italy-Croatia hydrogen corridor, where territories may play complementary roles in production, infrastructure, demand generation, technology development, certification, research, training and project financing. Operationally, it documents the exchanges with relevant stakeholders and identifies their possible contribution to future implementation.

A key methodological element is the assessment of the connection between hydrogen supply and maritime demand. The report therefore considers not only production capacity, but also, e.g., delivery models, logistics to ports, storage and compression requirements, refuelling or bunkering options, Guarantees of Origin, RFNBO compliance, safety and certification requirements, and possible cooperation or offtake structures.

The corridor approach is important because individual pilots may not create demand for hydrogen production and distribution. Aggregating demand across port refuelling stations, passenger vessels, auxiliary systems, port equipment, logistics vehicles and other compatible users can make future consumption more visible and attractive for producers, infrastructure developers and funding bodies.

The engagement process also serves to identify the main barriers that may affect future implementation. These include high capital expenditure, uncertain utilisation rates, limited initial demand, delivered hydrogen cost, availability of local or regional production, logistics constraints, permitting complexity, lack of harmonised standards, safety requirements, certification procedures and the need for specialised skills. These barriers are not only technical or economic; they also concern administrative capacity, public-sector preparedness and the ability of stakeholders to work together across sectors that are not traditionally integrated.

Particular attention is also given to cooperation instruments and investment-readiness mechanisms. At the current maturity stage, binding long-term supply agreements may be premature. However, non-binding tools such as Letters of Intent, Memoranda of Understanding, Cooperation Agreements, pre-offtake discussions, joint feasibility studies



and shared funding concept notes can document stakeholder interest, support future funding applications, clarify roles, and prepare the ground for more structured project development.

Stakeholder engagement should also address funding and financing opportunities when project concepts are sufficiently mature. . Future proposals should include not only technical descriptions of vessels or infrastructure, but also potential hydrogen sources, indicative delivery conditions, certification pathways, possible users, expected demand, permitting requirements and stakeholder commitments.

Capacity building is another enabling condition. Hydrogen deployment in ports and maritime transport requires engineers, technicians, operators, safety personnel and public officers able to manage new technologies and authorisation procedures. Training should therefore support both the industrial side of the hydrogen value chain and the public-sector functions involved in permitting, safety assessment and infrastructure approval.

Overall, the report provides a structured basis for future implementation. It records the stakeholders sensitised, the topics discussed, the synergies identified and follow-up needs, while helping define the conditions required to move from awareness-raising towards feasibility work, pilot actions, cooperation agreements, funding applications and, where appropriate, future co-investment discussions.

3 Targeted dissemination and stakeholder engagement

As part of the follow-up activities, the partners disseminated *TransH2* objectives and related investment *TransH2 ideas* through targeted exchanges with stakeholders active in port governance, classification, research and innovation, shipbuilding, hydrogen production, propulsion systems, refuelling infrastructure, energy technologies and safety systems.

The engagement was therefore not limited to hydrogen producers, but also included actors able to contribute to the technical, regulatory, industrial, financial, training and project-development conditions required for future deployment.

The exchanges addressed, depending on the stakeholder profile, issues such as:

- potential demand for green hydrogen in maritime and port applications;
- compatibility between future maritime demand and local production initiatives;
- port infrastructure, permitting and safety requirements;
- classification and certification of hydrogen systems on board;
- hydrogen propulsion and vessel retrofitting;
- refuelling infrastructure, mobile refuelling solutions and bunkering models;
- hydrogen storage and release technologies, including LOHC-based solutions;

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- technical-economic feasibility of H₂ maritime applications;
- skills, training and capacity-building needs;
- possible funding opportunities;
- possible future collaboration, project development or co-investment opportunities.

4 Stakeholders reached and possible discussion focus

Table 1 provides a detailed description of the stakeholders contacted by the Project Partners, along with the topics considered, based on their core activities, public information, direct exchanges and alignment with *TransH2* objectives.

Stakeholder	Relevance for <i>TransH2</i>	Topics addressed in the exchange
Port Network Authority of the Eastern Adriatic Sea / Port of Trieste and Monfalcone	Port governance, concession/land management, port planning, safety and infrastructure integration.	M.A.R.E. TC FVG explored the possible use of the Monfalcone port area as a testing location for H ₂ distribution in the maritime sector, including bunkering trials and the berthing of a laboratory vessel for H ₂ technologies. The discussion addressed port zoning, permitting, safety distances and possible links with <i>Hydrogen Hub Trieste</i> .
RINA	Classification, certification and technical assessment for maritime systems.	RINA's availability was requested and agreed for topics within its remit, such as certification of hydrogen propulsion systems, onboard and port-side safety assessment, refuelling procedures, port-vessel interface, feasibility of H ₂ systems on board, applied research related to the <i>TransH2</i> scope. Regulatory gaps, regulatory approach and the definition of IMO rules were also discussed.
Lloyd's Register	Classification society and maritime regulatory expertise. Lloyd's Register has issued rules for hydrogen as marine fuel, addressing the use of hydrogen in ships.	Hydrogen fuel rules, onboard storage and propulsion safety, class requirements, risk assessment and regulatory alignment for hydrogen-fuelled vessels. Digitalisation in support of the hydrogen value chain in the maritime sector was also discussed.



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Stakeholder	Relevance for <i>TransH2</i>	Topics addressed in the exchange
Area Science Park	Public research and innovation actor involved in hydrogen ecosystem development and NAHV initiative. Area Science Park is coordinator of the H2SmartLab project and involved in NAHV and in NASCHA projects.	Thanks also to the H ₂ laboratory under construction, financed by regional funds through the <i>H2SmartLab</i> project, potential R&D synergies were identified, including hydrogen valley alignment, innovation support, skills development, technology transfer and links between research infrastructures and hydrogen applications, also in the maritime field.
Fincantieri	Shipbuilding and maritime innovation.	Hydrogen system integration on board, vessel newbuild/retrofit potential, technical testing, possible use of a laboratory vessel for H ₂ technologies and processes, and discussion of the ZEUS boat as a possible test platform from September 2026.
CENERGY	Energy systems and hydrogen-related innovation actor.	Coordination of a possible local project proposal involving actors in the Trieste coastal area, support to technical structuring, energy systems integration and cooperation with several stakeholders listed in this report, with the proposal centred on Fincantieri's ZEUS vessel.
Hydrocell	Start-up interested in hydrogen propulsion systems for vessels, now focused on the implementation of H ₂ -ready systems and batteries.	Contacted in the early stages of the project, regarding possible installation of hydrogen ready solutions on board small-vessel, retrofit potential, pilot opportunities and certification barriers.
NatPower H (out of the Programme Area)	Developer of hydrogen refuelling infrastructure for boating and yachting.	Contacted in the early stages of the project, regarding refuelling station models, marina and boating demand, transferability to port/maritime HRS, infrastructure business models and safety/user-accessibility requirements.



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Stakeholder	Relevance for <i>TransH2</i>	Topics addressed in the exchange
CTS H2	Hydrogen technology company developing modular, transportable and scalable hydrogen solutions, including on site production, compression, storage, distribution and refuelling systems. CTS H2 is involved in initiatives connected to the North Adriatic Hydrogen Valley and has developed a modular HRS concept suitable for early deployment, pilot testing and progressive demand aggregation in port, logistics and maritime related applications.	The exchange focused on the possible use of CTS H2 modular and relocatable hydrogen refuelling solutions as enabling infrastructure for the first phase of maritime and port side hydrogen deployment. The system may support small scale refuelling, auxiliary power applications, port stay energy needs, port logistics vehicles, small vessels, hydrogen cartridges or transportable storage modules, as well as operational testing and training activities. Its value lies not only in the initial hydrogen capacity, but also in its ability to validate safety procedures, permitting pathways, refuelling interfaces, monitoring systems and user demand before permanent infrastructure is justified. Possible follow up activities may include pilot deployment in the Monfalcone and Trieste port area, integration with ZEUS related testing activities, and cascade funding or collaborative projects linked to NAHV.
SERICIM	Contract research and manufacturing organisation (CRMO) with dedicated laboratories and pilot plants and strong expertise in hydrogenation and dehydrogenation processes, is currently developing a patented DHR prototype within the NACHIP project	LOHC-based hydrogen filling and on demand release system; technical integration with shunting locomotive in the Trieste port area and with maritime applications; technical discussion about Fincantieri's ZEUS as DHR prototype testing vessels. Possible further public funding applications with local potential users
AcegasApsAmga	Green hydrogen production promoter in Trieste (<i>Hydrogen Hub Trieste</i>).	Identification of potential buyers/offtakers for the hydrogen produced; possible infrastructure strengthening; supply to port/logistics/maritime users; potential cooperation with future demand.



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Stakeholder	Relevance for <i>TransH2</i>	Topics addressed in the exchange
E-CUBES	Clean energy technology firm developing new technologies and solutions enabling sector coupling and energy storage	Responded to the survey on hydrogen-related investments and projects in maritime transport and port infrastructure. The proposal concerns a hydrogen-powered catamaran, hydrogen production, storage, refuelling infrastructure in the Kvarner region (Croatia).
Port Authority of Durrës (Albania)	Albania Port Authority. Port governance, infrastructure planning, maritime operations, and potential integration in regional H ₂ bunkering networks.	Identified as a favourable target group for the <i>TransH2</i> Transnational Training and Education (TTE) event on the role of hydrogen and digital technologies in maritime decarbonisation. Joined the informal <i>TransH2</i> H ₂ collaboration network as a member, with an interest in collaborating with relevant stakeholders on future investment plans and the transfer of pilot results, new solutions, and good practices to territories outside the programme area.
Durrës Port (Albania)	Albania Port Operator. Port operations, cargo handling, vessel traffic management, and operational readiness for zero-emission maritime technologies.	Identified as a favourable target group for the <i>TransH2</i> Transnational Training and Education (TTE) event on the role of hydrogen and digital technologies in maritime decarbonisation. Joined the informal <i>TransH2</i> H ₂ collaboration network as a member, with an interest in collaborating with relevant stakeholders on future investment plans and the transfer of pilot results, new solutions, and good practices to territories outside the programme area.

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Stakeholder	Relevance for <i>TransH2</i>	Topics addressed in the exchange
Port Authority of Vlorë (Albania)	Albania Port Authority. Port governance and planning in the southern Adriatic corridor, relevant to future H ₂ infrastructure expansion and cross-border maritime energy transitions.	Identified as a favourable target group for the <i>TransH2</i> Transnational Training and Education (TTE) event on the role of hydrogen and digital technologies in maritime decarbonisation. Joined the informal <i>TransH2</i> H ₂ collaboration network as a member, with an interest in collaborating with relevant stakeholders on future investment plans and the transfer of pilot results, new solutions, and good practices to territories outside the programme area.
Port of Bar (Montenegro)	Montenegro Port Authority / Operator. Major Adriatic port with strategic relevance for regional maritime decarbonisation and potential future H ₂ infrastructure integration.	Identified as a favourable target group for the <i>TransH2</i> Transnational Training and Education (TTE) event on the role of hydrogen and digital technologies in maritime decarbonisation. Joined the informal <i>TransH2</i> H ₂ collaboration network as a member, with an interest in collaborating with relevant stakeholders on future investment plans and the transfer of pilot results, new solutions, and good practices to territories outside the programme area.
Port of Adria (Bar, Montenegro)	Montenegro Port Operator. Port terminal operations and logistics; relevant as an end-user stakeholder in the transition to zero-emission maritime transport and H ₂ bunkering.	Identified as a favourable target group for the <i>TransH2</i> Transnational Training and Education (TTE) event on the role of hydrogen and digital technologies in maritime decarbonisation. Joined the informal <i>TransH2</i> H ₂ collaboration network as a member, with an interest in collaborating with relevant stakeholders on future investment plans and the transfer of pilot results, new solutions, and good practices to territories outside the programme area.



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Stakeholder	Relevance for <i>TransH2</i>	Topics addressed in the exchange
Administration for Maritime Safety and Port Management (Montenegro)	Montenegro Maritime Safety & Regulatory Authority. Maritime safety regulation, port management oversight, and permitting — key stakeholder for the regulatory and safety dimensions of H ₂ deployment in ports.	Identified as a favourable target group for the <i>TransH2</i> Transnational Training and Education (TTE) event on the role of hydrogen and digital technologies in maritime decarbonisation. Joined the informal <i>TransH2</i> H ₂ collaboration network as a member, with an interest in collaborating with relevant stakeholders on future investment plans and the transfer of pilot results, new solutions, and good practices to territories outside the programme area.
Port of Koper (Slovenia)	Slovenia Port Authority / Operator. Leading North Adriatic port with strong interest in decarbonisation, digital port management, and regional H ₂ infrastructure; highly relevant as a future node in H ₂ bunkering networks.	Identified as a favourable target group for the <i>TransH2</i> Transnational Training and Education (TTE) event on the role of hydrogen and digital technologies in maritime decarbonisation. Joined the informal <i>TransH2</i> H ₂ collaboration network as a member, with an interest in collaborating with relevant stakeholders on future investment plans and the transfer of pilot results, new solutions, and good practices to territories outside the programme area.
Cluster “Inteligentna Energija”	A business network of SMEs focused on green technologies in areas of hydro-energy (small hydro power plants), solar-energy (PV and thermal systems), biomass and energy efficiency.	Responded to survey on hydrogen-related investment and project in maritime transport and port infrastructure. Potential to establish creative partnerships between entrepreneurs, scientists and businesses.
DTA Safety & Process Engineering d.o.o.	Technology provider. Company with expertise and extensive experience on fire and gas and Fire Fighting System Integration mainly in Oil and Gas Industry but also engaged with various other market segments.	Responded to survey on hydrogen-related investment and project in maritime transport and port infrastructure.
Siemens Energy	Technology provider. Supports companies and countries with what they need to reduce greenhouse gas emissions and make energy reliable, affordable, and more sustainable.	Responded to survey on hydrogen-related investment and project in maritime transport and port infrastructure.



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Stakeholder	Relevance for <i>TransH2</i>	Topics addressed in the exchange
Leonitus	Hydrogen production investor	Responded to survey on hydrogen-related investment and project in maritime transport and port infrastructure. Innovative Production of Green Hydrogen from Wave Energy in the Port of Žigljen (Novalja) project planned.
Croatian Hydrogen Association	Association established to advance and facilitate the deployment of hydrogen technologies as key drivers of a clean, environmentally responsible industrial sector and a sustainable, competitive economy in Croatia	Responded to survey on hydrogen-related investment and project in maritime transport and port infrastructure. Project in research and innovation, demonstration/pilots, Port hydrogen infrastructure (storage, bunkering, safety systems, terminals), Vessel newbuild
Brodospas d.d.	Shipping company. Offers transport/supply of the oil rigs with necessary materials, providing marine safety both to personnel and equipment.	Responded to survey on hydrogen-related investment and project in maritime transport and port infrastructure.
Šibensko-kninska županija	Šibenik-Knin County is a regional self-government authority in Croatia responsible for coordinating regional development, public services, spatial planning, and economic growth across the Šibenik-Knin area.	Responded to survey on hydrogen-related investment and project in maritime transport and port infrastructure.

Table 1 – Targeted stakeholders and contribution to the TransH2 investment follow-up

5 Main feedback and thematic outcomes

The exchanges confirmed that hydrogen solutions for maritime transport require coordination across the full value chain: production, storage, distribution, port infrastructure, vessel technology, safety, certification, permitting, market demand and training.

The stakeholder dialogue did not yet result in formal commitments or co-investment decisions, it clarified the technical, regulatory and industrial conditions that must be aligned before pilot applications can move from concept to implementation.



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5.1 Alignment between green hydrogen production and maritime demand

The exchange with AcegasApsAmga about the *Hydrogen Hub Trieste* is particularly relevant for the supply side. The company is interested in identifying potential buyers for the hydrogen produced by the Hub. At this stage, the priority appears to be identifying credible offtakers and strengthening the infrastructure conditions needed to connect production with future uses. The possible use of liquid H₂ by cruise ships was also considered.

From the *TransH2* perspective, this creates a potential link between local green hydrogen production and future demand from port, logistics and maritime applications. Further technical exchange would be needed to clarify available volumes, delivery model, price assumptions, certification, Guarantees of Origin and possible offtake structures. Follow-up may also explore H₂ import synergies with ECUBES, where relevant contacts and technical information are available.

5.2 Assessment needs for emerging H₂ maritime initiatives

Emerging initiatives on hydrogen-based maritime applications require technical coordination and early-stage assessment before moving towards feasibility, demonstration or investment preparation. This could include simulations, performance forecasts, energy-efficiency calculations, system integration assumptions, operational scenarios and preliminary techno-economic assessments.

In this context, CENERGY can support such initiatives both as a technical coordinator and as a specialised advisor, building on its expertise in fuel cells, energy conversion, storage solutions, system modelling and prototyping, as well as on its participation in the Horizon Europe *SHYpS* project, focused on liquid hydrogen storage solutions for maritime applications.

CENERGY has also coordinated the emerging *H₂ Maritime Energy Smart Hub Infrastructures* Working Group with the support of M.A.R.E. TC FVG, as further described in the section on regional synergies (Ch. 6.1).

5.3 Mobile refuelling and low-volume applications

The exchange with CTS H2 highlighted the potential role of modular and relocatable hydrogen refuelling infrastructure as an enabling solution for early stage maritime and port side deployment. CTS H2 presented a mobile hydrogen refuelling concept expected to be ready by the end of 2026 and expressed interest in identifying first users and pilot applications.



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The main strength of the solution is its relocability and modularity. This makes it particularly suitable where permanent infrastructure is not yet justified by stable demand, but where operational testing, user engagement, safety validation and progressive demand aggregation are needed. While an initial production or distribution capacity of approximately 2–3 kg H₂/hour would not be sufficient for the full propulsion requirements of large maritime vessels, it may be appropriate for auxiliary systems, port stay energy demand, small vessels, port logistics vehicles, hydrogen cartridge-based applications, fuel cell testing and other low volume or non-propulsive uses.

In this perspective, the CTS H2 solution should not be considered only as a small-scale refuelling unit, but as a flexible pilot infrastructure able to support the transition from feasibility studies to practical demonstrations. It can contribute to the validation of refuelling procedures, safety distances, ATEX and pressure equipment requirements, remote monitoring, operator training, port side permitting and the interface between hydrogen supply and end use. These elements may generate useful operational data for future larger scale infrastructure and for the progressive development of a maritime hydrogen corridor. The discussion also touched upon possible funding opportunities, including cascade funding linked to NAHV related projects, both for single company initiatives and collaborative project configurations. Further follow up could assess the possible integration of CTS H2 technology in the Monfalcone port area, including connections with the ZEUS laboratory vessel opportunity and with future Land Port Sea hydrogen testing activities.

5.4 LOHC-based storage and release solutions

The exchange with SERICHIM focused on the potential use of Liquid Organic Hydrogen Carriers (LOHC) as an alternative solution for hydrogen storage and release in maritime applications. The discussion concerned, in particular, systems based on the Dynamic Dehydrogenation Releaser (DHR), designed to release hydrogen—chemically bound in a stable liquid carrier—in real time, according to the instantaneous demand of the user system, through a controlled dehydrogenation process.

In this context, the solution developed by SERICHIM is based on LOHC concentration of approximately 6.5%, enabling hydrogen to be safely stored and transported using existing logistics infrastructure. This approach may offer advantages in terms of storage, transport and handling compared with compressed or liquefied hydrogen, since hydrogen is converted into gaseous form only at the final stage of use. The discussion highlighted the need of further key technical aspects for maritime deployment, including thermal requirements,



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catalyst performance, system efficiency, tank volumes, and onboard integration constraints and overall economic feasibility.

SERICHIM, which engages with stakeholders to define technical specifications and system sizing, expressed its interest in contributing to a possible demonstrator involving local actors from the Trieste coastal area, with potential links to green hydrogen production, LOHC supply, port-side dehydrogenation and maritime end-use. Ongoing interlocutions with other Hydrogen Valleys are also supporting alignment on technical requirements and facilitating potential replication pathways. Upon further development and scaling, the DHR technology is expected to be made available for licensing, including to engine manufacturers using hydrogen as an energy carrier.

5.5 ZEUS laboratory vessel and testing opportunity

Fincantieri indicated the possible availability of the ZEUS vessel as a laboratory platform for testing hydrogen-related technologies and operational procedures in a maritime environment. As a hydrogen vessel classified by RINA as a Research Ship, ZEUS could support tests, trials and demonstrations related to hydrogen systems, port operations, refuelling procedures and onboard integration, thereby contributing to the ongoing development of international regulations on hydrogen. Its use would require an operator or a shipowner able to arm the vessel and cover crew, management and maintenance costs, either through shipowner investments, future project budgets or demonstrator initiatives.

5.6 Technical and certification feasibility

Contacts with RINA (also through the formalization of a bilateral *TransH2* Cooperation Agreement), and Lloyd's Register (also with their participation in a technical session in one Transnational Training and Education event) are relevant for the feasibility of hydrogen use on board vessels. The exchanges may support the identification of key conditions such as:

- class approval and safety requirements;
- hydrogen storage and fuel-cell integration on board;
- retrofit vs newbuild options;
- small-vessel pilot applications;
- port-vessel interface and bunkering procedures;
- operational limits for passenger vessels or pilot routes;
- certification pathways for hydrogen propulsion systems.



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5.7 Training and capacity-building needs

In addition, training needs have been raised from stakeholders. These needs concern both technical and administrative profiles.

Stakeholders expressed interest in academic and professional training aimed at:

- engineers and technicians specialised in hydrogen technologies;
- maritime and port professionals dealing with H₂ systems;
- public-sector officers involved in permitting and authorisation procedures;
- safety and emergency management personnel;
- project developers working on hydrogen infrastructure and maritime applications.

This need is important because hydrogen deployment in ports and maritime transport requires not only investment, but also a skilled workforce and competent public administration. Training should address both technical hydrogen competences and permitting / regulatory capacity, especially for public officials who will manage authorisation procedures for innovative hydrogen infrastructure.

From a cluster perspective, this point should be strengthened rather than treated as ancillary. Training is an enabling condition for bankability: without competent designers, class interfaces, port safety managers and public officials able to handle authorisation procedures, even technically sound projects risk remaining blocked in the pre-permitting phase

6 Synergies identified

The stakeholder engagement activities carried out within *TransH2* allowed Project Partners to identify synergies at different levels. At regional level, the exchanges helped connect concrete actors, technologies, facilities and possible testing environments in the North Adriatic ecosystem. At transnational and European level, they highlighted the relevance of broader cooperation frameworks, which may support capitalization, investment readiness, dissemination and future project development.

6.1 Synergies at regional level

The targeted dissemination activities allowed the Project Partners to envisage several potential synergies between the *TransH2* investment plan scope and the potential business of the contacted stakeholders.



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It should be noted that a dynamic working group involving several key players interested in topics aligned with the *TransH2* scope *TransH2* was initiated in November 2025 during the *Next Maritime Technology Road* event, which was organised by M.A.R.E. TC FVG. The *H2 Maritime Energy Smart Hub Infrastructures* Working Group, led by CENERGY with the support of M.A.R.E. TC FVG, initially involved several stakeholders, including Regional actors (the University of Trieste, Fincantieri, Goriziane E&C, Porto di Trieste Servizi) as well as stakeholders out of FVG Region (see Annex 2).

The initiative proposed a Hub that ideally combines land-based hydrogen production, distribution and storage, port bunkering infrastructure, and a maritime testing platform based on Fincantieri's ZEUS vessel. The Hub would operate as a living laboratory, generating operational data, safety procedures, certification evidence and technical skills needed to support the Alternative Design Approval process for hydrogen-powered maritime solutions. Its main work areas include technology derisking, regulatory and certification support, training and knowledge transfer, and environmental performance validation. The project also includes the use of a Digital Twin to simulate high-risk scenarios, support training, and provide quantitative evidence for classification societies.

Fincantieri indicated that ZEUS could potentially be made available from September 2026.

The Port Network Authority of the Eastern Adriatic Sea was not involved in the first stage of the working group. It was subsequently contacted by M.A.R.E. TC FVG after the group had expanded and after the discussion had started to focus on the possible need for a port-side testing environment, and also *TransH2* project has been presented. Preliminary exchanges among the Port Authority, Fincantieri and M.A.R.E. TC FVG identified an area of the port of Monfalcone as potential option, taking into account existing concessions and draught conditions, for hosting ZEUS and carrying out preliminary H₂ bunkering or refuelling trials.

The working group was also subsequently opened to SERICHIM, which expressed interest in the possible use of ZEUS and in port-based testing activities, particularly in relation to hydrogen storage and release solutions based on LOHC technologies. This additional involvement further strengthened the potential integration between vessel testing, port-side operations and innovative hydrogen logistics solutions. Moreover, the working group was also opened to CTS H2, as possible context where H2 mobile refuelling stations could be considered. CTS H2 may contribute to the development of a first operational hydrogen interface between land-based production or storage and maritime or port side users. Its modular and transportable systems could support early testing, small scale refuelling, auxiliary power applications, port logistics and training activities, while generating practical



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data on safety, permitting, refuelling procedures and operational requirements. This could help bridge the gap between pilot scale applications and future permanent hydrogen bunkering infrastructure.

The working group focuses on the development of an integrated Land–Port–Sea laboratory to support the deployment of hydrogen in the maritime sector. The proposed Hub aims to overcome the current hydrogen maritime paradox: shipowners hesitate to invest in hydrogen-powered vessels because refuelling infrastructure is not available, while investors do not develop infrastructure because there is not yet sufficient demand from operational vessels.

Overall, the initiative could position Friuli Venezia Giulia as a potential European centre of excellence for maritime hydrogen, connecting port infrastructure, shipbuilding, research, energy actors and public institutions. M.A.R.E. TC FVG's role could be to support coordination, territorial animation, future project proposals, training needs and the positioning of the regional maritime hydrogen ecosystem.

6.2 Synergies within Networks and Cooperation Agreements

In line with Activity 3.3, the follow-up work combined the presentation of the TransH2 investment plan to green hydrogen production promoters with a continuous stakeholder engagement process aimed at facilitating cooperation agreements between relevant promoters, Project Partners, Associated Partners and other organisations potentially involved in future cross-border investments in the Programme Area. This work was developed throughout the project and intensified during the last six months of the work package through targeted emails, bilateral exchanges, meetings, invitations to project events and follow-up discussions.

The presentation of the investment plan to green hydrogen production promoters, including initiatives such as the North Adriatic Hydrogen Valley, helped identify possible synergies between future maritime demand and green hydrogen production capacity in the Programme Area. At the same time, the cooperation agreements proposed within this framework were intended to maintain and capitalise on the dialogue initiated by TransH2, with a focus on future initiatives supporting the use of hydrogen as a maritime fuel, the transnational interoperability of hydrogen-fuelled vessels and the related port infrastructure.

Cooperation proposals were discussed or explored with several organisations, including Area Science Park, the Port Network Authority of the Eastern Adriatic Sea, the University of



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Zadar, CTS H2, Maritime CleanTech and representatives connected to the North Adriatic Hydrogen Valley initiative. Maritime CleanTech had already been involved in TransH2 through the study visit in Norway and the organisation of Workshop 1.4, while representatives of the NAHV initiative had been involved through previous exchanges, including those supported by the Friuli Venezia Giulia Region during the Norwegian study visit. Representatives of the NAHV initiative and port stakeholders were also involved in the final event in Zadar, further strengthening the connection between TransH2 results, hydrogen production ecosystems and future investment-oriented cooperation.

The fact that cooperation agreements were proposed to a wider group of stakeholders, beyond those that ultimately signed them, confirms that the dialogue had reached a sufficient level of maturity to move from general dissemination to structured cooperation proposals. It has been investigated the possibility of signing a Cooperation Agreement with the NAHV initiative. However, due to several causes, e.g. it does not have autonomous legal personality, any possible agreement connected to this framework would need to be signed with one or more partner organisations or representatives acting as operational focal points of the initiative, within the limits of their mandate and without automatically binding the whole NAHV partnership.

In this sense, Area Science Park, national public research organization and science and technology park, involved both in NAHV and in NASCHA projects, has been invited to sign such Agreement. The same is valid for CTS H2, SME involved in NAHV and H2READY.

This process resulted in three signed cooperation agreements, respectively with RINA, *MARINN* and the *MarLEN* project. These agreements represent concrete capitalization outputs of TransH2 and provide a basis for further cooperation on hydrogen-based maritime mobility, technical and regulatory alignment, innovation ecosystems, transnational interoperability, port infrastructure, future project development and investment-oriented follow-up.

6.2.1 At transnational level: cooperation between organisations

At transnational level, the cooperation agreement with the *MARINN* Centre of Excellence represents one of the concrete outcomes of the stakeholder engagement process.

In this context, the agreement with the *MARINN* Centre of Excellence represents a key capitalization result, with the potential to stimulate new initiatives in hydrogen-based innovative technologies in maritime sector and to further strengthen activities by building on local, specialized competences.



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The agreement also strengthens the cluster-to-cluster dimension of TransH2 capitalization, creating a bridge between the Italian and Croatian innovation ecosystems and supporting future cooperation among companies, research actors and technical stakeholders active in hydrogen-based maritime solutions.

6.2.2 At European level: the *MarLEN* Initiative

Moving beyond local and regional working groups, a major milestone for international capitalization was achieved through the formalization of a Cooperation Agreement between *TransH2* and *MarLEN* (Maritime Low Emission Network), signed on May 5th, 2026.

MarLEN is a 54-month European Coordination and Support Action funded under Horizon Europe, dedicated to aligning regional strengths and national research programmes to support the Zero Emission Waterborne Transport (ZEWT) Partnership.

This collaboration bridges the Adriatic-focused practical engineering of *TransH2* (hydrogen vessel concepts, infrastructure assessments, and implementation strategies) with *MarLEN*'s extensive European network of ministries, funding organizations, and public authorities across 9 countries. This structured framework yields several key synergistic dimensions:

- Capitalization and Dissemination: *MarLEN* provides a platform (including mutual learning workshops, brokerage events, and the *MarLEN* Currents newsletter) to scale the visibility of *TransH2* feasibility studies and conceptual designs to a pan-European audience.
- Knowledge Transfer: *TransH2* contributes ground-level data on the hydrogen maritime paradox and technical findings, which will directly feed into broader European discussions on clean maritime mobility and future policy-making.
- Long-Term Sustainability: Connecting with the *MarLEN* ecosystem creates a pipeline for future joint European research proposals, facilitating the replication and scaling up of *TransH2* results across other European maritime basins.

6.2.3 External support for investment preparation: the *SeaThrive* project

Future initiatives emerging from *TransH2* may benefit from the support of *SeaThrive* [1], a Horizon Europe CSA project funded by CINEA and launched in April 2026 to support selected early-stage maritime alternative fuel projects in improving their investment readiness.

SeaThrive can support hydrogen-related maritime initiatives through financial and technical analysis, demand and operational modelling, infrastructure and logistics assessment, selected advisory activities, training, matchmaking and guidance on access to EU and national funding opportunities. Some activities are open to a broader stakeholder audience,



while more direct one-to-one support is generally reserved for a limited number of selected initiatives. For *TransH2*, this may be particularly relevant for refining feasibility and pre-FEED work on hydrogen production, port refuelling infrastructure, maritime demand scenarios and associated supply chains.

SeaThrive would not directly finance hydrogen infrastructure, nor provide financial guarantees or act as an implementation partner. Its potential contribution lies in improving the technical-economic robustness, project structuring, funding readiness and bankability of future maritime hydrogen investment concepts through tools, analysis, training and networking support. For further details see Annex 1.

Taken together, the cooperation agreements, network links and investment-readiness support mechanisms described above show how *TransH2* results can be capitalised beyond the project duration. They provide different but complementary pathways: bilateral technical cooperation, cluster-to-cluster collaboration, European dissemination and policy alignment, and support to future project structuring

6.3 Possible exploitation of the project results

Table 2 schematically describes the potential investment opportunities linked to the *TransH2* framework, based on their integration with the interviews outlined in Chapter 3.

The universities involved in the *TransH2* project, together with the supporting clusters and development agencies, could contribute to all the aforementioned objectives, providing a valuable follow-up and further exploitation of the project results.

To ensure the long-term continuity, replication, and scaling-up of the identified synergies, the *TransH2* Project Partners will assume distinct, complementary roles in future follow-up initiatives and upcoming project frameworks (such as the *H2 Maritime Energy Smart Hub*, the *MarLEN* network, and the upcoming *SeaThrive* investment-readiness support mechanism). The consortium represents a consolidated transnational quadruple-helix network, bringing together academia and research, business and cluster organisations, regional development actors, technical and operational expertise, as well as associated public and industrial stakeholders. Building on the roles already developed within *TransH2*, the partners could provide a strong added value to future cooperation initiatives addressing hydrogen-based maritime mobility, port decarbonisation, clean transport systems and cross-border innovation ecosystems. Moreover, it is worth mentioning that all partners are willing to consolidate the link between maritime end-users and the upstream hydrogen value chain -

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for example with periodical meetings for updated information exchanges -, strengthening integration with the NAHV initiative.

- LP - PFRI (Faculty of Maritime Studies, University of Rijeka) and PP8 (University of Trieste, Department of Engineering and Architecture) as an academic and research partner can support the project's follow-up by contributing its scientific and technical expertise to future research initiatives. They can collaborate to address the sector's training and capacity-building needs, as well as to support the technical and regulatory assessments required for maritime hydrogen deployment. Their added value lies in scientific coordination, technical analysis, applied research, training and capacity building. In future partnerships, they could support the assessment of maritime hydrogen deployment scenarios, route and mobility analysis, environmental and operational impact evaluation, regulatory and safety-related studies, and the development of transnational training schemes for students, professionals, operators and public authorities. They could also contribute to feasibility studies, modelling activities and knowledge transfer between research, industry and policy actors.
- PP6 – START Romagna and PP7 – Navalprogetti could provide complementary operational and technical expertise. START Romagna, as a public transport operator, could bring the perspective of fleet management, service planning, multimodal integration, operational constraints, maintenance needs and clean fleet transition. Navalprogetti, as a naval engineering and design company, could contribute to vessel architecture, conceptual and preliminary design, retrofit options, onboard integration of alternative propulsion systems, safety requirements and infrastructure interfaces. Together, they could support future projects in translating research results into realistic zero-emission vessel and transport-service concepts, also considering life-cycle impacts, logistics, digitalisation, shore-side interfaces and scalability of solutions.
- PP3 – ZADRA NOVA and PP4 – Urbanex could act as regional and territorial development partners. Their role could be particularly relevant for coordinating local and regional pilot activities, aligning project outputs with territorial strategies, preparing future investment pipelines, supporting stakeholder engagement and ensuring the transfer of results to local authorities, port communities, transport stakeholders and citizens. In future partnerships, they could contribute to regional development planning, public consultation, awareness-raising, capacity building, policy uptake and the preparation of investment-oriented roadmaps for hydrogen and low-emission mobility solutions.



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- PP2 – Croatian Chamber of Economy and PP5 – M.A.R.E. TC FVG could act as business, cluster and innovation ecosystem bridges. Their added value would be to connect research and public-sector needs with companies, SMEs, technology providers, shipyards, ports, energy actors and investors. In future partnerships, they could coordinate business engagement, industry matchmaking, cross-border SME cooperation, technology scouting, innovation workshops and market-oriented dissemination. They could also support the development of value chains, commercial partnerships, funding opportunities and strategic networks in the Adriatic and wider European maritime hydrogen ecosystem.
- The Associated Partners could further strengthen future partnerships by providing strategic validation, policy connection, industrial perspective and access to relevant implementation environments. Public authorities and port-related associated partners could support alignment with regulatory frameworks, port planning, territorial strategies and investment priorities, while industrial associated partners could contribute technical insight, market perspective and potential demonstration or replication pathways. Their involvement would help ensure that project results are not limited to research outputs, but are connected to policy uptake, industrial feasibility and future deployment opportunities.

Overall, this partnership could provide a balanced and mature basis for future projects by combining scientific expertise, technical design capacity, operational knowledge, regional planning, business engagement and institutional anchoring. This integrated approach would be particularly valuable for initiatives aiming to move from feasibility and pilot concepts towards investment readiness, replication and wider deployment of hydrogen and other zero-emission solutions for maritime and multimodal transport. Cooperation agreements signed will be taken into consideration. For example, RINA may provide a regulatory view on the involved topics, also because the safety guidelines (for example the ones proposed by IMO) are not always adopted by Nations, and standards not always exist. Together with the supporting clusters and international networks like *MarLEN*, *H2 Maritime Energy Smart Hub* and *SeaThrive*, these collaborative contributions will ensure that the practical knowledge generated within *TransH2* is effectively integrated into the wider European zero-emission waterborne transport ecosystem.

Table 2 provides a first categorisation of the potential follow-up opportunities emerging from the stakeholder exchanges carried out within TransH2. It links the main synergy dimensions identified during the dialogue with possible fields of action and potentially relevant stakeholders. The table does not represent a list of confirmed investments, but



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an initial mapping of investment-oriented pathways that may support future feasibility work, project development, cooperation initiatives and capitalization of TransH2 results. These opportunities could be further developed by combining the inputs from the stakeholders identified with the complementary competences of the TransH2 partnership.

Synergy dimension	Description	Potential stakeholders relevant to TransH2 follow-up
Production-demand connection	Potential link between local green hydrogen production and future port/maritime demand.	AcegasApsAmga / <i>Hydrogen Hub Trieste</i> ; Port Authority; Area Science Park
Refuelling and pilot flexibility	Relocatable H ₂ refuelling solutions may support early-stage testing before permanent HRS deployment.	CTS H2; Port Authority; Delfino Verde (as shipowner for small vessels propulsion or auxiliary)
LOHC-based logistics and storage	LOHC technologies may offer an alternative approach to H ₂ storage, transport and release for specific applications.	SERICHIM; AcegasApsAmga; logistics enterprises operating in the Trieste and Monfalcone Port Area
Laboratory vessel and operational testing	A test vessel could allow validation of technologies, processes and possibly bunkering procedures.	Fincantieri; CENERGY; Port Authority; Goriziane E&C, Porto di Trieste Servizi
Port infrastructure and permitting	Need to align hydrogen refuelling solutions with port planning, zoning, safety and concessions.	Port Authority of Trieste; RINA
Vessel technology and certification	Hydrogen propulsion requires ship design, class approval, onboard safety and operational validation.	RINA; Lloyd's Register; Fincantieri; Hydrocell
Research, innovation and ecosystem building	Hydrogen maritime applications require R&D support, technology transfer and cross-border coordination.	Area Science Park; CENERGY; Serichim and other NAHV-related actors
Training and institutional capacity	Stakeholders need specialised training for technical staff and public officers dealing with permitting.	VET providers; RINA; universities/research bodies; public authorities
Future collaboration / co-investment	Some stakeholders may contribute to future project development, feasibility work, pilots or cooperation agreements.	Production, port, classification, shipbuilding and technology stakeholders, including the actors involved in the emerging local working group

Table 2 – Possible projects



7 Transnational ecosystem and investment dialogue

Beyond bilateral exchanges, the *TransH2* partners operate within a broader transnational hydrogen ecosystem. Initiatives such as the North Adriatic Hydrogen Valley are relevant not only for technological development, but also for networking among public bodies, companies, investors, research organisations and innovation intermediaries.

The NAHV project and its related projects bring together dozens of partners and aims to demonstrate hydrogen production, distribution and use across different sectors through multiple pilot applications. This type of framework is relevant for *TransH2* because it offers opportunities to position maritime hydrogen demand within a wider hydrogen economy.

In this context, initiatives such as the Stakeholder Advisory Forum of the NAHV project and events such as the Hydrogen Ecosystem North Adriatic Conference provide opportunities for private investors, companies, public authorities and innovation actors to exchange information on hydrogen investment plans, credit support, financing instruments, business angels and market development. The *5th Hydrogen Ecosystem North Adriatic Conference* was held in November 2025 in Nova Gorica and Gorizia and brought together policymakers, industry leaders, researchers and investors shaping the hydrogen transition in the Region. Therefore, these platforms may support the dissemination of *TransH2* results and the identification of potential partners or financing routes for future maritime hydrogen initiatives.

8 Conclusions

The targeted dissemination of the *TransH2* investment plan confirmed that maritime hydrogen deployment depends on the ability to connect green hydrogen production with concrete end-use opportunities in ports and maritime transport. This conclusion is consistent with the findings of D.3.3.2, which showed that hydrogen-related maritime projects in the Programme Area are progressing, but remain mostly at an early stage, with several initiatives still focused on feasibility, pilot activities, research and ecosystem building. The exchanges carried out by M.A.R.E. TC FVG show that the Friuli Venezia Giulia / Trieste ecosystem already includes actors that can contribute to different parts of the hydrogen maritime value chain: production, port infrastructure, safety, certification, shipbuilding, propulsion systems, R&D, refuelling infrastructure, storage and release technologies, training and funding preparation. The stakeholder dialogue also confirmed the main implementation needs already emerging from the survey, e.g. supply-demand matching,

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technical feasibility, safety and certification, port infrastructure, permitting, funding readiness, interoperability and skills development.

In Friuli Venezia Giulia, the most concrete supply-side opportunity identified by the partnership is the potential connection with AcegasApsAmga (and the *Hydrogen Hub Trieste*), which might be interested in identifying users for the hydrogen produced and in strengthening the infrastructure conditions required to connect production with future demand. At the same time, the highlighted possible early testing pathways, including refuelling, LOHC-based storage/release solutions and the potential use of a laboratory vessel in the Monfalcone port area. The CTS H2 case shows that early maritime hydrogen deployment may require flexible and modular infrastructure before large scale bunkering investments become bankable. Relocatable H₂ systems can support first users, validate procedures, build local skills and provide evidence for future permitting and certification processes, thereby reducing the risk of subsequent permanent infrastructure investments. These opportunities are particularly relevant because D.3.3.2 identified high CAPEX, long payback periods, limited access to finance, lack of demand, regulatory uncertainty, permitting complexity and lack of harmonised standards among the main barriers to implementation. In this context, small-scale testing, preliminary feasibility work and structured stakeholder cooperation may help reduce uncertainty before larger-scale investments are considered.

Overall, this deliverable strengthens the connection between the supply and demand sides of the hydrogen value chain and supports the practical implementation of integrated, cross-sectoral solutions. The next step is to move from awareness-raising and preliminary exchanges to more structured follow-up, including technical meetings, training initiatives, feasibility work, cooperation agreements and, where appropriate, future project development or co-investment discussions. Although the exchanges did not necessarily lead to formal commitments or co-investment decisions at this stage, they helped identify concrete areas where future collaboration may be relevant, e.g. hydrogen propulsion and bunkering feasibility studies, assessment of supply options from *Hydrogen Hub Trieste*, port-side analysis of HRS siting and permitting, testing of mobile H₂ refuelling solutions for auxiliary or port-stay uses, assessment of LOHC-based storage and release systems, use of ZEUS as a laboratory vessel, training programmes, future pilot projects, joint funding applications and integration with NAHV, *MarLEN*, *SeaThrive* and other hydrogen ecosystem initiatives. The future maritime hydrogen corridor will therefore require the combined contribution of producers, infrastructure managers, shipbuilders, classification bodies, technology providers, innovation actors, port authorities and public institutions.





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Annex 1

SeaThrive project

As a means of facilitating the implementation of such investments, it is important to mention the Horizon Europe (CSA) *SeaThrive* project, funded by CINEA and launched on 1st April 2026. The project is scheduled to run for 30 months.

The *SeaThrive* project can provide significant support to investment plans related to renewable and low-carbon hydrogen production and associated maritime value chains, particularly in the early feasibility and pre-FEED phases of project development.

For initiatives that may born from *TransH2*, focused on investments about hydrogen solutions for maritime applications, *SeaThrive* offers several complementary support mechanisms aimed at improving project bankability, technical-economic understanding, and access to funding opportunities.

Financial and Technical Decision-Support Tools

SeaThrive develops an integrated financial analytics framework specifically targeting alternative maritime fuels, including compressed hydrogen and liquid hydrogen produced from renewable electricity. The analytical tools are designed to support bottom-up assessments of:

- CAPEX and OPEX structures;
- electricity procurement and energy cost optimization;
- logistics and bunkering infrastructure costs;
- storage and transport systems;
- compliance costs associated with EU ETS, FuelEU Maritime, and IMO regulations;
- total cost of ownership (TCO) for maritime fuel pathways.

Particular attention is given to electricity pricing dynamics, peak shaving strategies, and grid interaction mechanisms, which are critical for improving the economic viability of electrolysis-based hydrogen production projects.

Maritime Demand and Operational Modelling

The project also supports the analysis of maritime demand scenarios through ship operation modelling based on AIS data and operational profiles. This enables the assessment of:

- suitable vessel segments for hydrogen adoption;
- expected fuel demand by route and ship category;
- onboard energy system performance;



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- fuel consumption and emissions profiles;

comparisons between hydrogen and competing fuel pathways. Such analyses are particularly relevant for identifying commercially viable deployment niches for compressed hydrogen solutions in ports and short-sea shipping corridors.

Support for Infrastructure and Logistics Planning

SeaThrive includes dedicated activities focused on the logistics dimension of alternative fuels, including:

- bunkering systems;
- port infrastructure;
- storage technologies;
- hydrogen handling and distribution chains.

Furthermore, should initiatives be developed to include also the production of H2 for maritime application, the *SeaThrive* consortium will offer its assistance. This support can help investment promoters better understand infrastructure requirements and associated cost structures across the maritime hydrogen value chain.

Proposal Development and Access to Funding

Beyond analytical support, *SeaThrive* provides direct project development assistance aimed at strengthening investment readiness and facilitating access to European funding instruments. The project foresees one-to-one support for selected initiatives, including assistance related to:

- Innovation Fund applications;
- Horizon Europe proposals;
- Connecting Europe Facility (CEF);
- EIB and BlueInvest instruments;
- national and regional funding opportunities, as for example the cascade funding opportunities provided by the NAHV related projects and ERDF.

The project consortium combines the expertise of major maritime clusters, technical institutions, and industrial stakeholders active in alternative fuel deployment across Europe.

Relevance for *TransH2*

For the *TransH2* initiative, *SeaThrive* could contribute to the preparation and refinement of investment plans by supporting:

- preliminary techno-economic assessments;



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- hydrogen production cost modelling;
- infrastructure sizing and logistics analysis;
- market and demand validation;
- compliance cost benchmarking;
- funding strategy development;
- preparation of investment-grade project documentation.

Overall, *SeaThrive* does not directly finance hydrogen infrastructure projects, but it provides an advanced ecosystem of analytical tools, training activities, stakeholder networks, and project support services capable of substantially improving the maturity, credibility, and bankability of maritime hydrogen investment initiatives.



Annex 2***H2 Maritime Energy Smart Hub Infrastructure***

Next Maritime Technology Road 2025, Community Decarbonization, working group 6
Final report excerpt



Working Group 6 - H2 Maritime Energy Smart Hub Infrastructures

Group Leader: Michele Capobianco (CENERGY).

Involved stakeholders: *Alfredo Renzetti (Aeromechs), Furio Boschieri (Fincantieri), Andrea Parmeggiani (Fondazione REI), Nicola Sommaggio (Goriziane E&C), Rodolfo Taccani (University of Trieste), Marco Storchi (Porto di Trieste Servizi).*

The structural paradox – Hydrogen is emerging as a promising solution for maritime Decarbonization, yet its adoption is proceeding with frustrating slowness due to a vicious circle: shipowners do not order hydrogen-powered vessels because refuelling infrastructure is lacking; investors do not build infrastructure because, without operational vessels, they would have neither customers nor economic returns.

The critical regulatory gap – Hydrogen as a maritime fuel is not covered by consolidated prescriptive IMO codes. The only available certification pathway is the Alternative Design Approval (ADA), a complex process based on quantitative risk assessment that requires real operational data which are currently unavailable.

The vision of group 6 – To transform Friuli Venezia Giulia into the European centre of excellence for maritime hydrogen, overcoming this paradox through an integrated laboratory capable of generating the data, procedures and skills necessary to unlock the entire value chain.

The integrated innovative approach – Overcoming the logic of isolated pilot projects by integrating three physical domains into a single functioning ecosystem: (i) the land component with a Smart Energy Hub for multimodal production, distribution and storage (compressed CGH₂ and cryogenic liquid LH₂); (ii) the port component with an intelligent bunkering terminal and a progressive evolution from Truck-to-Ship to Terminal-to-Ship and ultimately to integration with national pipelines; (iii) the marine component with Fincantieri's Zeus naval platform as a modular, plug-and-play mobile laboratory for testing under real operating conditions.

Living laboratory – The Hub is conceived as a living laboratory to systematically generate operational data, safety tests and certified procedures required by classification societies to complete the ADA process, transforming the regulatory obstacle into a territorial competitive advantage.

Bidirectional strategic vision – A dual function ensuring economic resilience and national strategic relevance: a bunkering hub for hydrogen-powered fleets (Land→Sea flow) and a gateway for the import of green hydrogen from North Africa and the Middle East destined for the industrial districts of Northern Italy (Sea→Land flow).

NEED – Need or Challenge to be Addressed

The Maritime Hydrogen Paradox

Climate urgency – Maritime transport accounts for 3% of global CO₂ emissions and 11% of sulphur oxides. The International Maritime Organization has set ambitious targets: a 40% reduction in carbon intensity by 2030 and full Decarbonization by 2050.

Systemic stalemate on the supply side – Investors do not build bunkering terminals in the absence of guaranteed demand, facing risks of underutilisation, technological uncertainty regarding the choice between CGH₂ and LH₂, and unsustainable business cases without assured volumes.

Systemic stalemate on the demand side – Shipowners do not order hydrogen-powered vessels without certainty of refuelling availability, raising critical questions about where to refuel, with what reliability, at what cost and under which operational standards.

The paralysing regulatory gap – Hydrogen as a marine fuel is not covered by consolidated prescriptive IMO codes. The only available certification pathway is the Alternative Design Approval (ADA), a data-intensive process requiring real operational data in a marine environment, system performance under marine conditions, validated emergency procedures and certified maintenance protocols. These data do not currently exist because no one has operated hydrogen bunkering and propulsion systems at commercial scale in the maritime context.

The limited competitive window – Those who first develop certified infrastructure and competencies will secure a lasting strategic advantage. The systemic deadlock impacts the entire value chain: shipowners unable to plan investments, shipyards stalled in design, ports unable to plan infrastructure, technology suppliers unable to validate components, classification societies lacking the necessary data, and the FVG industrial system at risk of losing competitive positioning.

The systemic solution – An H₂ Maritime Energy Smart Hub that overcomes the logic of isolated pilot projects through an integrated approach. The Hub is conceived as a “living laboratory” to artificially couple supply and demand, creating a controlled operational environment that systematically generates the data, operational tests and certified procedures required to unlock the ADA process.

Land Component – Smart Energy Hub with strategic multimodal storage (CGH₂ for short-range applications and LH₂ for long-range), advanced safety systems with IoT sensor networks, and integration with existing energy grids.

Port Component – Bunkering Terminal with a planned three-phase evolution: Truck-to-Ship as an initial flexible modality, Terminal-to-Ship as the main fixed pilot infrastructure, and Pipeline-to-Ship as a long-term vision integrated with the national network.

Marine Component – Zeus platform as a Fincantieri mobile laboratory with modular plug-and-play design, fully instrumented test compartments, capability to test technologies from different suppliers, and pervasive IoT sensorisation to accelerate the R&D cycle and generate certifiable operational data in a real marine environment.

Digital Nervous System – An integrated Digital Twin of the entire Land–Port–Sea ecosystem for safety simulations and what-if scenarios, prediction and optimization through machine learning, immersive VR/AR training, and automatic generation of documentation for certification bodies.

The four operational pillars include technology derisking and validation to reduce risk, regulatory pathways with direct support to ADA processes, training and knowledge transfer to

develop specialized skills, and performance validation with quantitative empirical evidence on environmental impact.

Three-phase roadmap – Phase 1 of foundation and design with consortium establishment, feasibility studies and detailed design; Phase 2 of construction and commissioning with infrastructure development and Digital Twin implementation; Phase 3 of operation and expansion with launch of commercial services and European sectoral leadership.

BENEFIT: advantages and value generated

Regulatory and Industrial Derisking – Unlocking the Entire Value Chain

Value chain unlocking through generation of empirical evidence for ADA processes – The Hub will provide certifiable quantitative safety data, certified and standardised operational procedures, validation of materials and components under real conditions, and standardised ship-to-shore interfaces, reducing certification time and costs. Each completed ADA certification can unlock investments both for individual vessels and for entire vessel classes.

Multiple economic sustainability ensured through Testing-as-a-Service revenues from technological validation for multiple clients, valorisation of intellectual property through licensing and spin-offs, certified training with specialized courses for maritime professionals, and energy gateway services for H₂ import and distribution.

Territorial development and ecosystem impact include attraction of specialized companies and direct investments, creation of qualified jobs (engineers, technicians, operators), incubation of technology start-ups and spin-offs, contracts for local SMEs with multiplier effects, and diversification of the economic base towards green high-tech sectors.

Environmental benefits include reductions in CO₂ and SO_x emissions in the maritime sector, improved port and urban air quality, concrete contribution to IMO 2030/2050 targets, and LCA validation of implemented solutions.

Strategic positioning as a primary node of the North Adriatic Hydrogen Valley and SouthH₂ gateway for strategic imports, aligned with the National Hydrogen Strategy, REPowerEU and the Clean Hydrogen Partnership, ensuring access to multiple European and national funding streams.

Structured monitoring system based on technical KPIs (certifications completed, tests validated, technologies qualified), economic KPIs (TaaS revenues, investments attracted, jobs created), training KPIs (certified professionals, courses delivered), environmental KPIs (emissions reduction, air quality) and ecosystem KPIs (start-ups incubated, partnerships activated, patents generated).

Long-term strategic value includes territorial branding of FVG as the “Silicon Valley of maritime hydrogen”, attraction of talent from across Europe, economic resilience through diversification towards green high-tech sectors, technological sovereignty with reduced dependence on extra-EU suppliers, and soft power through influence in international regulatory

fora and scientific-diplomatic networks. The Hub is not merely a project but a transformative investment redefining the territory's competitive positioning in the energy transition.

COMPETITION: competitive context and distinctive advantage

The Uniqueness of the Integrated Approach

The competitive landscape shows growing interest with several pilot projects under development; however, analysis reveals a fragmented and mono-dimensional approach focused on individual segments of the value chain, lacking the systemic vision that instead characterises the Integrated Land–Port–Sea Laboratory proposal.

Ecosystem integration – The FVG Hub is the only project worldwide that simultaneously brings together, within a few kilometres, all critical assets: a major commercial port, a globally leading shipyard, an advanced scientific hub with the Universities of Trieste and Udine, Area Science Park and, more broadly, the SIS (Scientific and Innovation System FVG), classification societies, and energy infrastructures including green hydrogen production directly within the port area and the future H₂ pipeline.

Reusable existing assets differentiate the Hub from greenfield projects: the Zeus laboratory vessel already built and operational, available port infrastructure, reusable energy connections, simplified permitting in already industrialised areas, and a consolidated network with the M.A.R.E. TC FVG Cluster of over 100 companies and active R&D partnerships.

Multi-client living laboratory as an open, multi-tenant platform with a Testing-as-a-Service model for multiple clients, as opposed to a proprietary demonstrator, ensuring faster validation for industry and economic sustainability through diversified revenues.

Dual strategic mission as a bidirectional energy gateway: Land→Sea flow for bunkering hub of maritime fleets and Sea→Land flow for green H₂ import terminal supplying Northern Italy's industrial districts, ensuring economic resilience, a robust business case and national strategic relevance.

Integrated Digital Twin as a non-replicable technological differentiator: simulation of the entire Land–Port–Sea system, continuous calibration with real operational data, integrated VR/AR training platform, predictive capabilities for optimization and safety, and acceleration of the ADA process through high-risk scenario simulations and automated certification documentation generation.

Transnational scale as a core component of the Italy–Slovenia–Croatia North Adriatic Hydrogen Valley, ensuring access to EU funding, a consolidated partner network with the ports of Koper/Capodistria, Rijeka and Venice, an expanded market across the Adriatic-Balkan basin, and progressive expansion through satellite nodes.

Certification focus as a primary mission distinguishes the Hub through systematic data generation to unlock ADA processes via co-design of experimental programmes with

classification bodies, structuring of testing according to IMO-required QRA methodologies, and direct partnerships with classification societies, creating a leverage effect whereby each ADA certification unlocks multiple investments.

Risk management through integrated strategies: regulatory delays mitigated through proactive regulator engagement; technological evolution managed through flexible design; economic sustainability ensured by revenue diversification and PPP models; competition addressed through first-mover advantage and specialisation; complex governance handled through clear structures and shared KPIs; social acceptance fostered through proactive communication; green H₂ availability ensured through an initial low-carbon phase and a transition roadmap. The greatest risk is not proceeding—loss of the competitive window and marginalisation of the regional system in the energy transition.

NEXT STEP: next steps and opportunities

From Vision to Operations

PHASE 1: Consolidation and Preparation (ongoing) for definition of the project pathway, finalisation of the proposal, feasibility assessment and groundwork for consortium establishment.

PHASE 2: Foundation and Detailed Design to achieve “Investment Readiness” with a complete blueprint. Key activities: consortium establishment with optimal legal form, statutes and governance; detailed techno-economic feasibility studies for the Land components (CGH₂/LH₂ plant sizing), Port components (Truck-to-Ship/Terminal-to-Ship configurations) and Marine components (Zeus retrofit); preliminary Digital Twin design with computational architecture and simulation models; financial analysis with a 10-year business plan and funding mapping; stakeholder engagement through workshops and roadshows. **Deliverables:** operational consortium, complete FEED design, validated business plan. **Critical milestone:** positive Investment Decision with financial commitment ≥60% of Phase 2 CAPEX.

PHASE 3: Construction and Commissioning for “Full Operability”, including construction of land infrastructure (tanks, compressors, sensors), development of the port terminal (quays, certified loading arms), retrofit of the Zeus platform (modular compartments, sensorisation), full Digital Twin development (CFD models, ML algorithms, VR/AR environment), commissioning with integrated Land–Port–Sea supply chain testing, first bunkering operation, and preparation of operational services with certified courses and ISO quality management systems.

PHASE 4: Operation and Expansion towards a self-sustaining Hub and European reference point, with launch of Testing-as-a-Service (5–8 initial clients, 35–50 courses/year), permanent environmental monitoring system with LCA analysis, capacity expansion based on validated demand, activation of the H₂ import gateway for Northern Italian industry, and sectoral leadership through participation in IMO/ISO/CEN Working Groups, hosting of international

workshops, incubation of 3–5 start-ups per year, and partnerships with European hydrogen valleys.

Role of the M.A.R.E. TC FVG Cluster

As a strategic catalyst across multiple dimensions: coordination and territorial animation by facilitating partner dialogue and managing group 6; aggregation of local enterprises by mapping FVG SME competencies and creating ATI/RTI structures; project support through drafting proposals for Horizon/FESR calls and identifying European partners; communication and positioning by promoting the Hub at international events and organising roadshows; training through needs assessment and co-design of training programmes; institutional advocacy by representing interests with the Region and Ministries and participating in EU consultations on hydrogen policies.