Good Practices Demonstrating the Potential of Hydrogen Technologies for consortium’s partners and Europe

This report presents 3 good practices showcasing hydrogen technology. Each section includes a detailed description of the technology, size, integrated systems, applications, and sources for verification.

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RENEWSTART

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Authors: The Institute of Power Engineering - National Research Institute, Lithuanian Energy Institute, Regional economic development agency – Stara Zagora

Contact Person: Marcin Blesznowski

Institution: The Institute of Power Engineering - National Research Institute

1. HYDROGIN – 10 kW rSOC installation

Location: Elbląg, Poland

Owner: Consortium of Hydrogin project, CBRF S.A.

Commissioning: 2023

Technology Type:

reversible Solid Oxide Cell – switching between electrolysis and fuel cell modes

Size/Parameters:

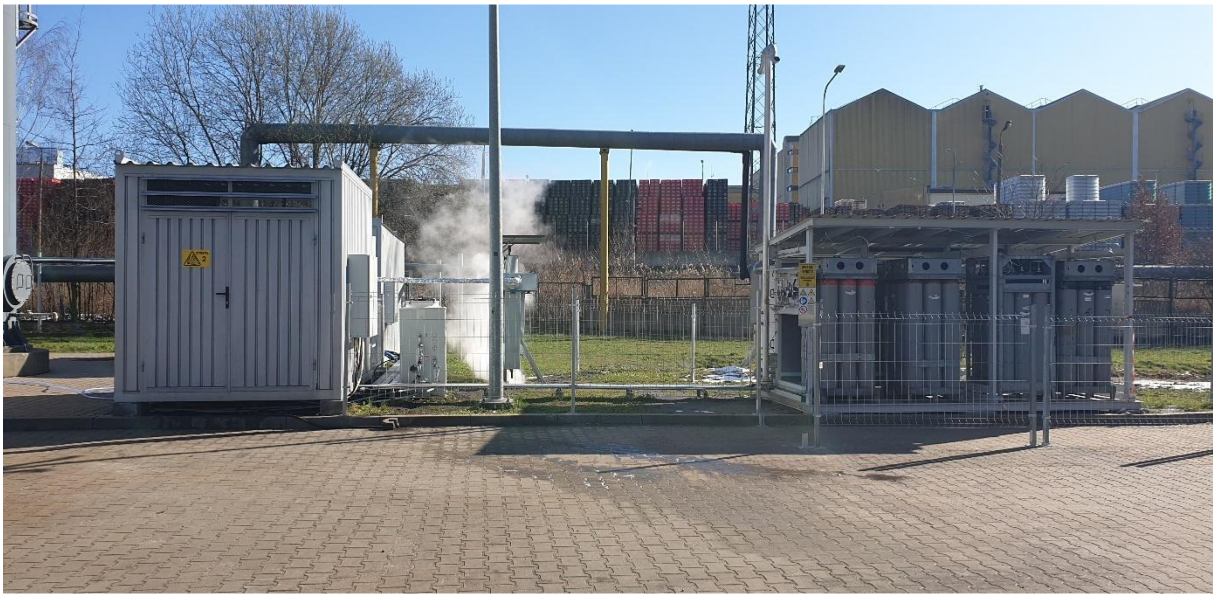
10 kW in electrolysis mode and 5 kW in fuel cell mode

Integrated Technologies:

reversible Solid Oxide Cell with biomass plant and compressed (200 bar) H2 storage

Applications:

Power sector; energy storage; increase of biomass boiler flexibility



The HYDROGIN project, commissioned in 2023 in Elbląg, Poland, represents one of the most innovative demonstrations of reversible solid oxide cell (rSOC) technology integrated with a real industrial energy system. The installation, developed by the Energa Group's R&D Centre (CBRF) in cooperation with leading Polish research institutes combines hydrogen production, energy storage, and power generation within a single modular system. Its significance lies not only in technological novelty but also in its role as a prototype for future low-carbon energy systems.

Project Results and Achievements

The HYDROGIN installation is widely recognized as the *world's first rSOC system integrated with a biomass-fired combined heat and power (CHP) plant*.

This integration is particularly important because it demonstrates how hydrogen technologies can be embedded directly into existing thermal infrastructure rather than developed as standalone units. The system is coupled with a biomass block (BB20), enabling the use of renewable heat and electricity in the hydrogen production process.

The core innovation of the project is the reversible Solid Oxide Cell (rSOC), which operates in two modes:

- **Electrolysis mode (10 kW):** converts electricity and steam into hydrogen
- **Fuel cell mode (5 kW):** converts stored hydrogen back into electricity

This dual functionality allows the installation to act as a **power-to-gas-to-power (P2G2P)** system, effectively serving as an energy storage unit.

Such systems are crucial for balancing intermittent renewable energy sources like wind and solar, enabling surplus electricity to be stored as hydrogen and later reused.

The project achieved notable performance indicators:

- Electrolysis efficiency 85% and fuel cell efficiency around 50%
- Advanced rSOC stacks with a round-trip efficiency of 43%

A particularly innovative aspect is the use of additive manufacturing (3D printing) to produce ceramic components of the electrochemical cells. This reduces production costs and enables more flexible design of the stacks.

The project was completed on time (2020–2023) and within budget, achieving all planned objectives.
It also demonstrated:

- Readiness for industrial environments
- Modular and scalable design
- Full compatibility with existing energy infrastructure

Broader Technological and Strategic Impact

HYDROGIN is more than a pilot—it is a proof-of-concept for the hydrogen economy in Poland and Europe. The HYDROGIN installation delivers several system-level benefits:

- **Improved flexibility of CHP operation** by enabling load balancing
- **Increased utilization of renewable energy**, especially biomass and surplus electricity
- **Reduction of CO_2 emissions** through green hydrogen production
- **Sector coupling** between electricity and gas systems

The project confirms that rSOC technology can play a key role in integrating renewable energy into conventional energy systems, particularly in district heating and cogeneration plants.

Future Development Pathways

The next logical step is scaling the installation from pilot (kW scale) to industrial (MW scale). The modular design of rSOC systems supports this transition.

Potential developments include:

- Integration into larger CHP plants
- Deployment in industrial clusters
- Use in hydrogen valleys and regional energy systems

Future systems could be directly coupled with:

- Wind farms
- Photovoltaic installations
- Hybrid renewable systems

This would allow dynamic hydrogen production based on real-time renewable energy availability, further stabilizing the grid.

Hydrogen produced in rSOC systems can be used to create:

- Synthetic methane (Power-to-Gas)
- Liquid fuels (e-fuels)
- Ammonia for industry

Conclusion

The HYDROGIN project in Elbląg represents a significant milestone in the development of hydrogen technologies. By successfully integrating a reversible solid oxide cell system with a biomass CHP plant, it demonstrates a practical and scalable solution for energy storage, renewable integration, and decarbonization.

Its key achievements—high efficiency, reversible operation, and industrial integration—confirm the technological maturity of rSOC systems. At the same time, its modular design and compatibility with existing infrastructure make it a strong candidate for large-scale deployment.

Looking ahead, the concept can evolve toward larger installations, deeper integration with renewable energy, and expansion into synthetic fuels and sector coupling. As such, HYDROGIN is not only a successful pilot project but also a foundation for future hydrogen-based energy systems in Poland and beyond.

2. VETNI – 30 kW SOC electrolysis installation

Location: Jasło, Poland

Owner:

Consortium of VETNI project, Orlen S.A., Institute of Power Engineering – National Research Institute and AGH University of Science and Technology

Commissioning: 2023

Technology Type: Solid Oxide Electrolysis

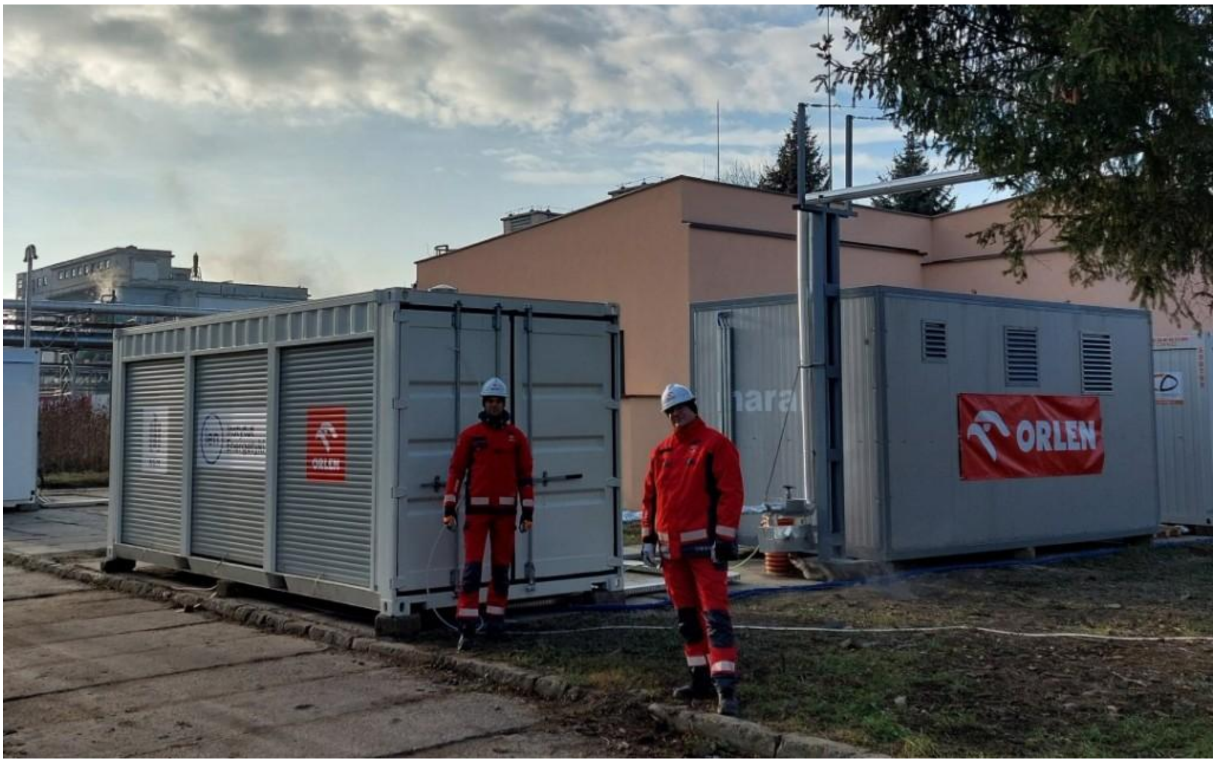
Size/Parameters:

30 kW in electrolysis mode (capacity of approx. 18 kg H2/day)

Integrated Technologies:

Solid Oxide Electrolysis with old refinery, usage of the process steam, compressed (200 bar) hydrogen storage

Applications: refinery



The VETNI project, commissioned in 2023 in Jasło, Poland, is a pioneering demonstration of solid oxide electrolysis (SOE) technology integrated with an industrial refinery. Developed by a consortium led by ORLEN S.A. in cooperation with the Institute of Power

Engineering – National Research Institute and AGH University of Science and Technology, the installation represents a major step toward high-efficiency hydrogen production in real industrial conditions. Unlike HYDROGIN (focused on reversible operation and energy storage), VETNI concentrates on efficient hydrogen generation for industrial use, particularly in the refining sector.

Project Results and Achievements

The VETNI installation is one of the first solid oxide electrolysis systems deeply integrated with an operating refinery process. It uses process steam from refinery infrastructure, significantly improving efficiency compared to standalone electrolysers.

This integration demonstrates how existing industrial assets can be repurposed for hydrogen production, reducing the need for entirely new infrastructure and lowering investment costs.

The system achieves a hydrogen production capacity of approximately **18 kg H_2 per day**, corresponding to a 30 kW-class installation.

A key technological achievement is its significantly reduced energy consumption:

- Around **42.5 kWh/kg H_2**, compared to **55–70 kWh/kg** in conventional electrolysis technologies

This confirms that SOE technology can outperform commonly used alkaline and PEM electrolysers in terms of efficiency, especially when high-temperature heat (e.g., steam) is available.

Unlike laboratory-scale prototypes, VETNI was tested in real industrial conditions, including:

- Continuous operation in refinery environment
- Load variation and system modulation tests
- Compliance with strict industrial safety standards

The installation consists of three integrated container modules, forming a complete hydrogen production and compression system.

This demonstrates the readiness of SOE systems for industrial deployment and confirms their compatibility with existing refinery opera

A major innovation within the project was the development of new electrode materials, including:

- Reduced use of expensive and toxic cobalt
- Improved durability and efficiency of electrochemical cells

The project relied almost entirely on **Polish technological solutions**, including stack design and materials engineering. This strengthens national competencies in hydrogen technologies and reduces reliance on foreign suppliers.

The hydrogen produced in VETNI is of **very high purity (5.0 grade)**, making it suitable for:

- Fuel cell electric vehicles (FCEVs)
- Hydrogen buses and transport applications

The system was designed to supply enough hydrogen to fuel several vehicles daily, linking industrial hydrogen production directly with the emerging hydrogen mobility sector.

The project was completed successfully in 2023–2024, with final reports approved and all objectives achieved.

Broader Technological and Industrial Impact

The VETNI project demonstrates that hydrogen production can be:

- **Integrated directly into industrial processes** (e.g., refineries)
- **More energy-efficient** through the use of high-temperature electrolysis
- **Based on renewable electricity**, enabling low-carbon hydrogen

It highlights a shift from centralized hydrogen production toward distributed, site-specific systems embedded within industrial infrastructure.

Additionally, the project shows how refineries—traditionally carbon-intensive—can become key hubs of the hydrogen economy, supporting both fuel production and energy transition.

Future systems can be powered directly by:

- Wind and solar farms
- Hybrid renewable installations

This would enable fully green hydrogen production and reduce dependence on grid electricity, aligning with EU climate policies.

Hydrogen plays a critical role in refining processes (e.g., hydrocracking, desulfurization). VETNI opens pathways to:

- Replace grey hydrogen (from natural gas) with green hydrogen
- Reduce CO_2 emissions in fuel production
- Support production of sustainable aviation fuels (SAF) and e-fuels

Conclusion

The VETNI project in Jasło represents a significant advancement in high-efficiency hydrogen production using solid oxide electrolysis technology. By successfully integrating the system with a refinery and validating its operation in real industrial conditions, the project proves that SOE technology is ready for practical deployment.

Its key achievements—exceptional energy efficiency, industrial integration, and the use of advanced materials—position it as a strong alternative to conventional electrolysis technologies. At the same time, its modular design and scalability make it suitable for widespread adoption across industrial sectors.

Looking forward, VETNI provides a clear pathway toward:

- Large-scale green hydrogen production
- Decarbonization of refineries and heavy industry
- Integration with renewable energy systems
- Development of hydrogen-based transport

As such, the project is not only a successful pilot but also a critical stepping stone toward a fully developed hydrogen economy in Poland and Europe.

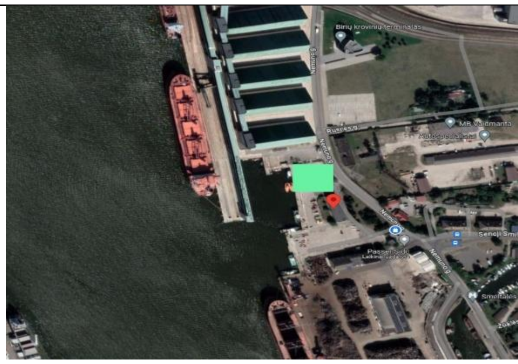
3. KLAIPĖDA PORT GREEN HYDROGEN PROJECT

Type: Industrial demonstration plant (energy & transport)

Technology: Renewable hydrogen production via PEM electrolysis

Status: Construction completed; commissioning planned 2026

The Klaipėda Port hydrogen project represents Lithuania's first operational green hydrogen production and refuelling facility and the first of its kind in the Baltic States. By producing renewable hydrogen directly at the port, the project enables the replacement of fossil fuels in port equipment, service vessels, and heavy-duty transport, significantly reducing CO_2 emissions and local air pollutants. Energy efficiency is improved through sector coupling, as electricity from renewable sources is converted into a high-value energy carrier used where direct electrification is difficult. The project demonstrates how hydrogen can support maritime decarbonization while strengthening energy security and operational efficiency in logistics hubs.



Klaipėda Port Green Hydrogen Project is an infrastructure initiative led by Klaipėda State Seaport Authority to build the first on-site green hydrogen production and refuelling hub in the Baltic States. Located in Lithuania's main seaport of Klaipėda Port, it aims to supply renewable hydrogen to ships, port machinery and road transport from 2026[1].

Key facts:

- Location: Klaipėda Port, Lithuania
- Developer/owner: Klaipėda State Seaport Authority.
- Technology: PEM electrolyzer, 2.25 MW electrical capacity.

[1] https://portofklaipeda.lt/en/port-authority/projects/green-port-hydrogen-production-and-refuelling-stations/

- Planned start of operations: 2026.
- Annual hydrogen output: ~127 tonnes of green H_2.
- Approximate project cost: ~€12 million, with ~€5.7–6 million from NextGenerationEU funds.

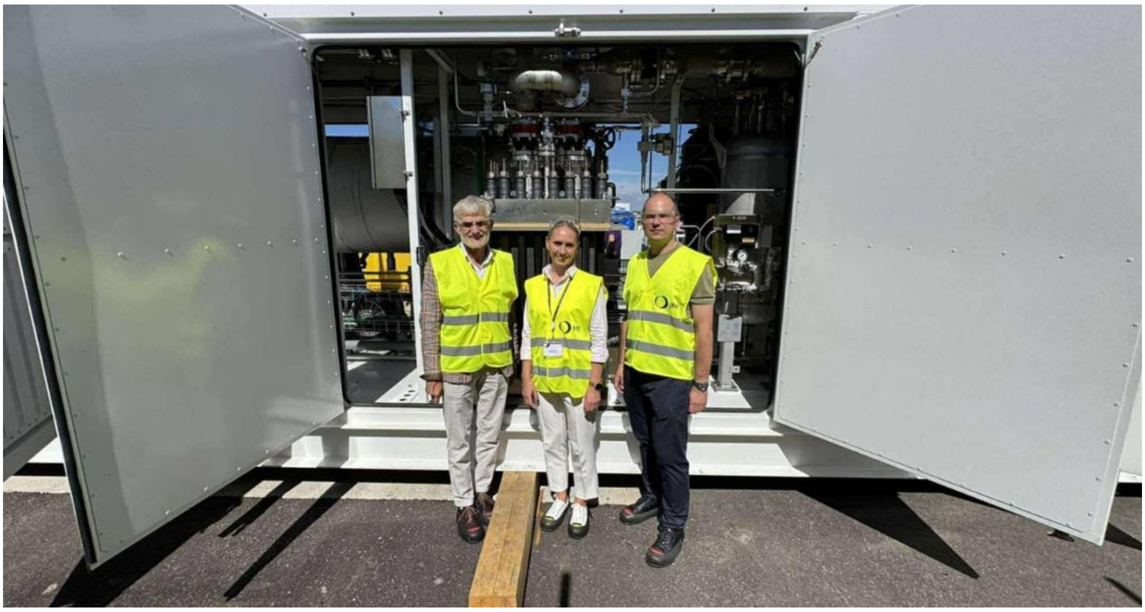
Background and purpose

The project is part of Lithuania's Recovery and Resilience Plan "Next Generation Lithuania", financed by the European Union's NextGenerationEU facility. It supports national goals to expand electrolyzer capacity and decarbonize transport and port operations. Klaipėda State Seaport Authority positions the hub as a flagship step toward climate neutrality and a model for other Baltic ports.

Project Results and Achievements

Technical concept and operations

The facility uses a polymer electrolyte membrane (PEM) electrolyzer powered by renewable electricity to produce green hydrogen. At full load, it will generate about 127 tonnes of hydrogen per year. The project includes a stationary public refuelling station capable of serving vessels, trucks, buses and light vehicles, effectively turning the port into a multimodal hydrogen bunkering and fuelling node.

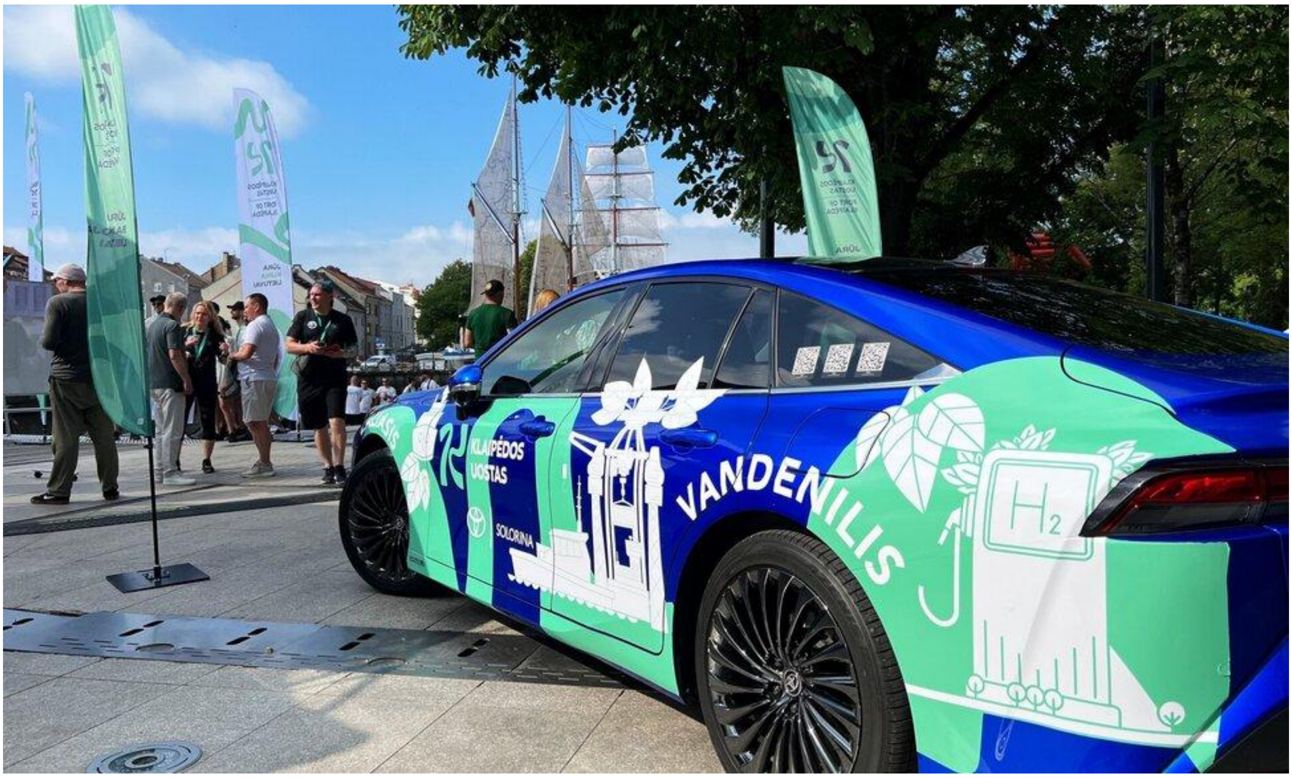


Implementation status and partners

Between 2023 and 2025, the project has secured permits, selected technology suppliers, and completed factory testing of the electrolyzer in Italy. Construction of the hydrogen station and associated infrastructure is underway, targeting commissioning and fuel production in 2026. Key industrial partners include MT Group (station EPC and equipment), IMI (electrolyzer systems), Nord Steel (storage tanks), and transport/terminal partners such as Bega and LTG Group for early hydrogen use in port and rail operations.

Recent developments and demonstration activities

Additional activities implemented at Klaipėda Port further strengthen the role of the green hydrogen project as a real demonstration plant rather than only an infrastructure investment. In 2025, Klaipėda State Seaport Authority acquired a hydrogen fuel cell vehicle, the Toyota Mirai, which is used as part of the port's hydrogen mobility demonstration and testing programme. The vehicle is intended to demonstrate the practical use of hydrogen fuel in everyday port operations and to test refuelling procedures, safety protocols, and operational costs under real conditions. The use of a hydrogen-powered passenger vehicle allows the port authority and project partners to gain operational experience with hydrogen refuelling infrastructure before the full commissioning of the hydrogen production and refuelling station. This step is important from a technological and organisational perspective, as it helps train personnel, test safety procedures, and demonstrate the feasibility of hydrogen mobility to stakeholders and the public.



Picture of Klaipėda Port direction (https://www.15min.lt/verslas/naujiena/autorinka/klaipedos-uostas-isigijo-vandenilio-degalu-elementu-energija-varoma-toyota-mirai-kur-gaus-vandenilio-1636-2630198)

In parallel, preparation works for the commissioning of the green hydrogen station have progressed significantly. At the beginning of 2026, the project entered the equipment testing and system integration phase. This stage includes testing of the electrolyser, hydrogen compression systems, storage tanks, and refuelling equipment under real operating conditions. The testing phase is particularly important because hydrogen infrastructure requires strict safety and operational verification before full-scale operation can begin. The commissioning process includes pressure testing, system control calibration, safety system verification, and integration of hydrogen production with refuelling infrastructure. These activities ensure that the hydrogen station will be able to operate reliably, efficiently, and safely once commercial operation begins.

From a technical perspective, the Klaipėda hydrogen station consists of several integrated components: a PEM electrolyser for hydrogen production, hydrogen purification and drying systems, a compressor for pressurising hydrogen, high-pressure storage tanks, and a refuelling station capable of supplying hydrogen to different types of vehicles and port equipment. The integration of these components into a single operational system represents an important demonstration of the entire hydrogen value chain, from renewable electricity to final use in transport.

Broader Technological and Industrial Impact

Role in the Baltic hydrogen ecosystem

As the first on-site green hydrogen production and bunkering facility in the Baltic region, the project is expected to catalyse a wider hydrogen economy in Lithuania and neighbouring countries. It complements regional efforts in offshore wind, electrification and alternative fuels, and aims to make Klaipėda Port a competitive, low-carbon logistics hub on the eastern Baltic Sea.

The demonstration activities at Klaipėda Port show how hydrogen can be integrated into a real transport and logistics environment. The project does not only demonstrate hydrogen production, but also hydrogen storage, transport within the port area, and final use in fuel cell vehicles and potentially port vessels and heavy-duty transport. This full-chain demonstration is particularly valuable because it allows evaluation of overall system efficiency, operational costs, maintenance requirements, and safety procedures[2].

In addition, the Klaipėda project serves as a learning platform for future hydrogen projects in Lithuania and the Baltic region. The experience gained during installation, testing, and early operation phases will help reduce technological and regulatory uncertainties for

[2] https://esinvesticijos.lt/naujienos/zaliasis-vandenilis-klaipedos-uoste-teritorija-pasieke-svarbiausi-irenginiai-atlikti-reiksmingi-bandymai

future hydrogen stations, hydrogen transport solutions, and hydrogen use in industry and transport. In this way, Klaipėda Port functions not only as a hydrogen production site but also as a pilot and competence centre for hydrogen technologies in Lithuania.

Conclusion

Overall, the recent developments, including the acquisition of a hydrogen fuel cell vehicle and the ongoing testing of hydrogen production and refuelling equipment, demonstrate that the Klaipėda Port Green Hydrogen Project is moving from the construction phase to real operation and practical demonstration. This significantly increases the project's value as a best-practice example, as it demonstrates the entire hydrogen value chain under real operating conditions and provides practical experience that can be replicated in other ports, cities, and industrial sites.