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WIVA P&G HyWest

WIVA P&G HyWest: Regional Green Hydrogen Economy

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Kurzfassung

Das Projekt WIVA P&G HyWest wurde als Leuchtturmprojekt im Bereich Wasserstoff im Rahmen der RTI-Initiative „Energiemodellregion WIVA P&G“ durchgeführt, mit dem übergeordneten Ziel, eine regionale grüne Wasserstoffwirtschaft unter realen Betriebsbedingungen zu entwickeln, zu demonstrieren und zu etablieren. Das Projekt befasst sich mit der strategischen Herausforderung, die Sektoren Energie, Mobilität und Industrie auf eine weitgehend CO_2-neutrale Struktur umzustellen, wobei der Schwerpunkt auf der Substitution fossiler Energieträger durch grünen Wasserstoff und der Integration von Sektorkopplungslösungen lag. Durch die Kombination von Technologieentwicklung, marktorientierter Umsetzung und akzeptanzbezogenen Aktivitäten zielte HyWest darauf ab, die Modellregion WIVA P&G als international sichtbare Referenzregion für wasserstoffbasierte Energiesysteme zu positionieren.

Innerhalb der Projektlaufzeit von Dezember 2020 bis November 2025 erreichte WIVA P&G HyWest wichtige Meilensteine entlang der gesamten Wasserstoff-Wertschöpfungskette. Ein bedeutender Erfolg war die zertifizierte Produktion von grünem Wasserstoff, einschließlich der TÜV-Süd-Zertifizierung nach CMS 70 sowie der Zertifizierung gemäß der Erneuerbare-Energien-Richtlinie (RED) II für erneuerbare Kraftstoffe nicht biologischen Ursprungs (RFNBO), wodurch die Einhaltung gesetzlicher Vorschriften und die Glaubwürdigkeit auf dem Markt sichergestellt wurden. Das Projekt ermöglichte die Implementierung und den kontinuierlichen Betrieb des ersten brennstoffzellen-elektrischen Schwerlast-Lkw (Fuel Cell Electric, FCE) Österreichs in der Logistikflotte von MPREIS und demonstrierte damit die Zuverlässigkeit von grüner Wasserstofflogistik und -versorgung im täglichen kommerziellen Betrieb. Parallel dazu wurde ein auf Multi-Element-Gascontainern (MEGC) basierendes Wasserstoff-Trailer-Logistiksystem etabliert, das eine überregionale Wasserstoffversorgung von Kunden in Österreich, Deutschland und Norditalien ermöglicht. Auf Infrastrukturseite trieb das Projekt die Entwicklung von Power-to-X-Lösungen (P2X) voran, wobei das Projekt „P2X Kufstein“, eine Sektorkopplungsanlage mit Wasserstoffzentrum der Tiroler Wasserkraft AG, zunächst als regionaler Produktionsstandort geplant war und später im Rahmen einer Risikominimierungsstrategie durch die Wasserstoffproduktionsanlage „P2X Jenbach“, einer Kooperation zwischen der TIWAG-Next Energy Solutions GmbH und der INNIO Jenbacher GmbH & Co OKG, ergänzt wurde, um einen kontinuierlichen Zugang zu Wasserstoffinfrastruktur im industriellen Maßstab und entsprechende Lerneffekte sicherzustellen.

Weitere Meilensteine umfassten die Integration von Elektrolyse-Abwärme über eine industrielle Wärmepumpe, die zur Sektorkopplung zwischen Strom, Wasserstoff und Wärme beiträgt, sowie die Entwicklung von Standardbetriebsverfahren und Logistikkonzepten für Wasserstoffsysteme. Trotz externer Veränderungen, wie der Einstellung des kommerziellen Projekts „Zillertalbahn 2020+ energieautonom“, reagierte HyWest erfolgreich mit der Entwicklung alternativer Lösungen, darunter die „Novel Emergency Backup Hydrogen Refuelling Station“ und die „H_2-Kleinmengenlogistik“, wodurch Demonstrationsbetrieb, Datenerhebung und Wissensgenerierung fortgeführt werden konnten. Alle technischen Aktivitäten wurden durch umfassendes wissenschaftliches Monitoring, techno-ökonomische Bewertungen sowie makroökonomische und Akzeptanzanalysen begleitet und durch Workshops, Schulungen, Abstimmung mit Interessengruppen und Öffentlichkeitsarbeit auf nationaler und internationaler Ebene unterstützt.

Insgesamt leistete WIVA P&G HyWest einen wesentlichen Beitrag zum Aufbau der österreichischen Wasserstoffwirtschaft. Das Projekt zeigte, dass zertifizierte grüne Wasserstoffproduktion,

wasserstoffbasierte Schwerlastmobilität sowie logistikbasierte Wasserstoff-Lieferketten unter realen Marktbedingungen umsetzbar sind. Es stärkte die regionale und grenzüberschreitende Wasserstoffnachfrage, unterstützte Wege zur Dekarbonisierung der Industrie und lieferte übertragbare Ergebnisse sowie Referenzanwendungsfälle für zukünftige Wasserstoffprojekte. Durch die Integration von Technologie, Marktentwicklung und Akzeptanz schuf HyWest eine solide Grundlage für die Skalierung von Wasserstofflösungen innerhalb der Modellregion WIVA P&G und darüber hinaus und stärkte damit Österreichs Position als Leitmarkt und Innovationsstandort für grüne Wasserstofftechnologien.

Executive Summary

The WIVA P&G HyWest project was implemented as a flagship hydrogen initiative within the RTI-Initiative Energy Model Region WIVA P&G, with the overarching objective to develop, demonstrate and establish a regional green hydrogen economy under real-world operating conditions. The project addressed the strategic challenge of transforming the energy, mobility and industry sectors towards a largely CO_2 neutral structure, focusing on the substitution of fossil fuels by green hydrogen and the integration of sector coupling solutions. By combining technology development, market-oriented implementation, and acceptance-related activities, HyWest aimed to position the WIVA P&G Model Region as an internationally visible reference region for hydrogen-based energy systems.

Within the project duration from December 2020 until November 2025, WIVA P&G HyWest achieved key milestones along the entire hydrogen value chain. A major achievement was the certified production of green hydrogen, including TÜV Süd CMS 70 certification and Renewable Energy Directive (RED) II Renewable Fuels of Non-Biological Origin (RFNBO) certification, ensuring regulatory compliance and market credibility. The project enabled the implementation and continuous operation of Austria's first Fuel Cell Electric (FCE) heavy-duty truck in the MPREIS logistics fleet, demonstrating green hydrogen logistics and supply reliability under daily commercial operation. In parallel, a Multi Element Gas Container (MEGC) based hydrogen trailer logistics system was established, allowing cross-regional hydrogen supply to customers in Austria, Germany and northern Italy.

On the infrastructure side, the project drove forward the development of power-to-X (P2X) solutions, with the "P2X Kufstein" project, a sector coupling plant with a hydrogen centre operated by Tiroler Wasserkraft AG, initially planned as a regional production site and later supplemented as part of a risk minimisation strategy by the "P2X Jenbach" hydrogen production plant, a cooperation between TIWAG-Next Energy Solutions GmbH and INNIO Jenbacher GmbH & Co OKG, in order to ensure continuous access to hydrogen infrastructure on an industrial scale and corresponding learning effects.

Further milestones included the integration of electrolysis waste heat via an industrial heat pump, contributing to sector coupling between electricity, hydrogen and heat, and the development of standard operating procedures and logistics concepts for hydrogen systems. Despite external changes, such as the discontinuation of the commercial project "Zillertalbahn 2020+ energy autonomous", HyWest successfully adapted by developing alternative solutions including the "Novel Emergency Backup Hydrogen Refuelling Station" and "H2-Kleinmengenlogistik", ensuring continued demonstration, data collection and knowledge generation. Extensive scientific monitoring, techno-economic assessment, and macro-economic and acceptance analyses accompanied all technical activities, supported by workshops, trainings, stakeholder alignment and public relation activities at national and international level.

Overall, WIVA P&G HyWest made a substantial contribution to Austria's emerging hydrogen economy. The project demonstrated that certified green hydrogen production, heavy-duty hydrogen mobility, and logistics-based hydrogen supply chains can be implemented under real market conditions. It strengthened regional and cross-border hydrogen demand, supported industrial decarbonisation pathways, and delivered transferable results and reference use cases for future hydrogen projects.

By integrating technology, market development and acceptance, WIVA P&G HyWest has laid a robust foundation for scaling up hydrogen solutions within the WIVA P&G Model Region and beyond, reinforcing Austria's position as a lead market and innovation hub for green hydrogen technologies.

1 Introduction

1.1 Background and Motivation of the WIVA P&G HyWest Project

The WIVA P&G HyWest project was initiated within the RTI-Initiative Energy Model Region WIVA P&G to address the urgent need for a regional green hydrogen economy capable of contributing to a largely CO_2 neutral energy, mobility and industry system. Motivated by the challenge of substituting fossil fuels in heavy-duty transport, public transport, industrial processes and heat supply, WIVA P&G HyWest aimed to demonstrate integrated P2X solutions under real-world conditions. The project responds to volatile energy markets, sector coupling requirements, and the need for secure, certified green hydrogen supply, while positioning Tyrol as a visible reference region for hydrogen-based energy transition pathways.

1.2 Project Objectives and Expected Impacts

The core objective of WIVA P&G HyWest was the development, demonstration and market activation of a regional green hydrogen economy, covering production, storage, logistics and end use. Key goals included certified green hydrogen production (RED II RFNBO), green hydrogen logistics and supply reliability, and the build-up of concrete hydrogen demand and use cases in mobility, industry and heat. Expected impacts comprised technology development, market creation, and user acceptance, achieved through FCE heavy-duty trucks, hydrogen trailer logistics (MEGC), sector coupling via waste heat utilisation, and knowledge transfer and stakeholder engagement, thereby strengthening Austria's role as a lead market for hydrogen technologies.

1.3 Positioning within the Energy Model Region WIVA P&G Initiative

WIVA P&G HyWest is positioned as a flagship hydrogen sub-project within the Energy Model Region WIVA P&G, directly contributing to the region's transformation towards climate-neutral energy systems. The project complements other WIVA P&G activities by providing operational hydrogen infrastructure, real-world data, and internationally visible reference use cases. Through coordination, dissemination and scientific monitoring, WIVA P&G HyWest supports the systemic integration of renewable electricity, gas and mobility sectors, while enhancing regional and cross-border connectivity, notably through emerging H2 valley initiatives linking Austria, Germany and Italy.

1.4 Consortium Composition and Partner Roles

The WIVA P&G HyWest consortium brought together industrial, infrastructure, research and coordination partners, each contributing specific expertise along the hydrogen value chain. FEN Sustain Systems GmbH [1] (FENS) led project management, coordination and dissemination, supported by FEN Research [6] (FENR) in logistics, backup Hydrogen Refuelling Station (HRS) concepts and demonstrations as well as workshops, trainings and stakeholders alignment. MPREIS [9] acted as the industrial anchor, operating hydrogen production, logistics and heavy-duty FCE trucks. TIWAG [2], the subsidiary for innovative energy solutions TINEXT founded during the project lifetime and TIGAS [3] were responsible for energy infrastructure planning and P2X development, including P2X Kufstein and P2X Jenbach [11], while HyCentA [7], EI-JKU [8] and WIVA P&G [9] contributed technical studies, techno-economic analysis and scientific monitoring, ensuring an integrated and practice-oriented project approach.

1.5 Project Timeline and Work Package Structure

The WIVA P&G HyWest [12] project was implemented from December 2020 to November 2025, structured into eight work packages covering project management, infrastructure planning, technical research, business case analysis, implementation, demonstration, scientific monitoring, and dissemination. The project followed a Gantt-based milestone structure, enabling phased development from planning and feasibility studies to real-world operation and evaluation. Due to changing framework conditions, adaptive measures such as risk mitigation strategies, supplementation with P2X Jenbach, and task reallocation were applied, ensuring that despite delays and discontinuations, the project delivered robust results, validated use cases and transferable learnings for future hydrogen initiatives.

2 Methodology and Work Approach

The methodology and work approach of WIVA P&G HyWest followed a systemic, work-package-based structure aligned with the RTI-Initiative Energy Model Region framework, combining technology development, market-oriented implementation and acceptance-related activities (Figure 1). The project applied a living-lab and real-world demonstration approach, integrating planning, technical research, implementation, monitoring and dissemination in a continuous feedback loop. Activities were structured along clearly defined work packages and milestones, enabling adaptive project steering in response to changing framework conditions, while ensuring the integration of hydrogen production, logistics, mobility, industry and sector coupling under live operation conditions.

2.1 Research Methods and Applied Tools

WIVA P&G HyWest employed a combination of technical research, operations research, and techno-economic modelling to assess the feasibility and performance of green hydrogen systems. Applied methods included feasibility and technical studies, energy system simulation modelling, techno-economic assessment (TEA), and profitability calculations for P2X facilities. Tools and approaches covered power purchasing strategy algorithms based on historical time series, operations research of electrolyser systems, certification processes (TÜV Süd CMS 70, RED II RFNBO), and monitoring of Key Performance Indicators (KPIs) under real-world operation. These methods enabled a quantitative evaluation of hydrogen production, logistics, storage and end-use performance across energy, mobility and industrial applications.

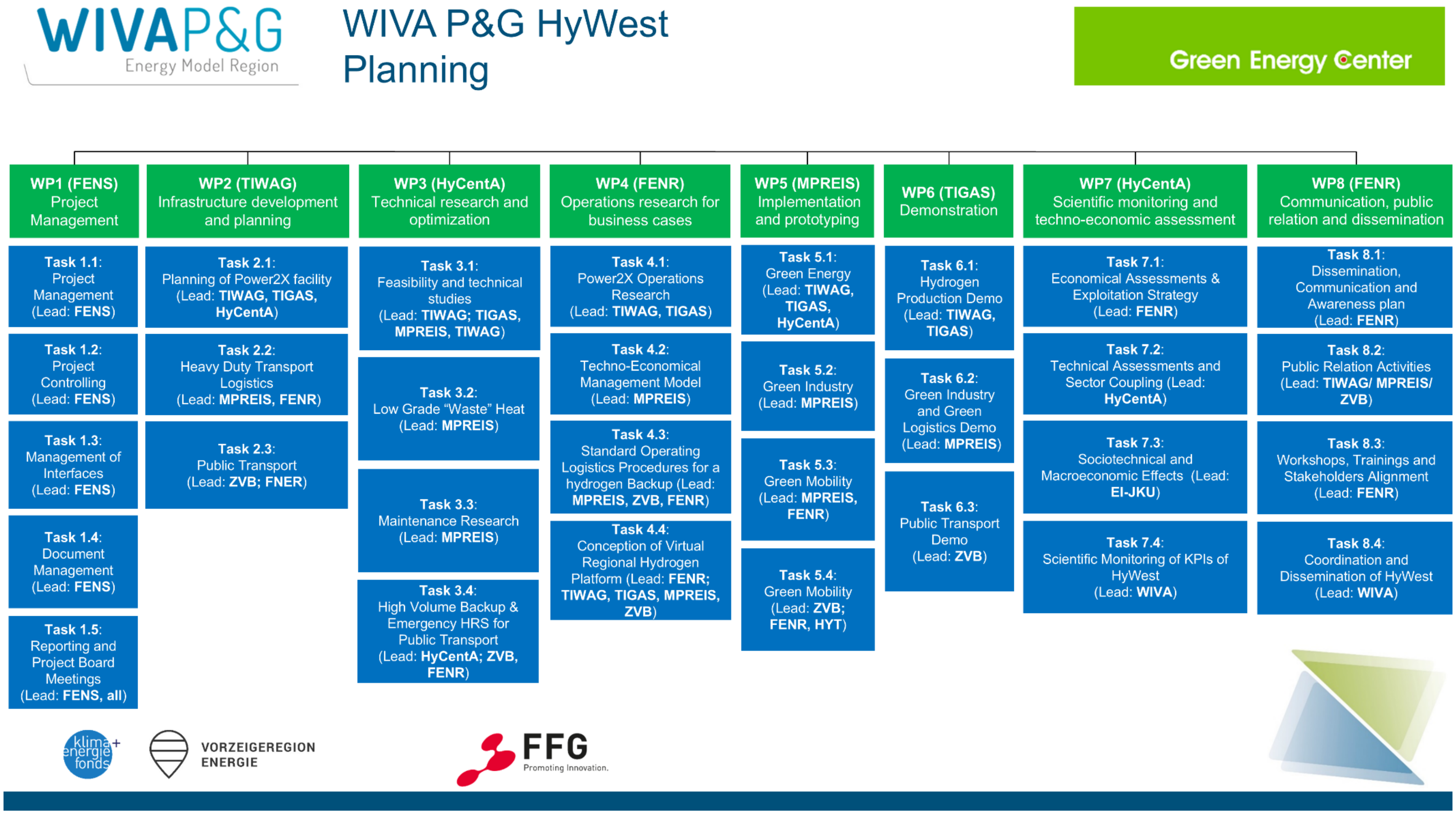

Figure 1: Overview of WIVA P&G HyWest work packages (WPs) and Tasks.

2.2 Data Collection and Validation (technical, economic, and social dimensions)

Data collection in project was conducted across technical, economic and social dimensions, using real-world operational data from hydrogen production plants, FCE vehicles, hydrogen logistics systems, and sector coupling applications. Technical data included electrolyser operation, hydrogen compression and storage, vehicle performance, and waste heat utilisation, while economic data covered hydrogen costing approaches, electricity market price signals (European Power Exchange, EPEX, day-ahead spot market), and logistics cost structures. Social and acceptance-related data were gathered through expert interviews, stakeholder workshops, and acceptance surveys, ensuring validation of results through certification, monitoring systems, and expert-based evaluation within the consortium and external stakeholder network.

2.3 Risk Management and Mitigation Strategies

Risk management in WIVA P&G HyWest was addressed through continuous monitoring, adaptive project management, and the development of explicit mitigation strategies in response to technical, economic and organisational risks. Key risks included technology risks of prototype installations, volatile electricity markets, partner availability, and changes in policy and market conditions, such as the discontinuation of the commercial project “Zillertalbahn 2020+ energy autonomous” and delays in P2X Kufstein. Mitigation measures comprised task reallocation, project duration extension, supplementation with P2X Jenbach, cost reallocations, and alternative demonstration concepts (e.g. Novel Emergency Backup HRS, H2-Kleinmengenlogistik). This adaptive approach ensured continued goal achievement and knowledge generation despite changing boundary conditions.

3 Project Implementation

3.1 Progress Overview and Key Milestones Achieved

Within the project duration from December 2020 until November 2025, WIVA P&G HyWest achieved substantial implementation progress along the hydrogen value chain. Key milestones included the certification of green hydrogen production according to TÜV Süd CMS 70 and RED II RFNBO, the commissioning and day-to-day operation of Austria’s first FCE heavy-duty truck in the MPREIS logistics fleet, and the establishment of a MEGC-based hydrogen logistics system supplying customers in Austria, Germany and northern Italy. Further milestones comprised the integration of electrolysis waste heat via an industrial heat pump, the development of standard operating procedures for hydrogen logistics, and the advancement of P2X infrastructure planning, with P2X Jenbach supplementing P2X Kufstein to ensure continued industrial-scale learning and access to real-world data.
In addition, WIVA P&G HyWest placed strong emphasis on communication, dissemination and visibility. Extensive public relation activities, including project websites, press releases, guided site visits, workshops, trainings and stakeholder events, were carried out throughout the project duration [13]. A major

milestone was the final project event held within the WIVA P&G Annual Event [14], where project results, lessons learned and transfer potential were presented to industrial stakeholders, policy makers, funding bodies and the interested public, reinforcing WIVA P&G HyWest's role as a flagship hydrogen project within the Energy Model Region WIVA P&G.

3.2 Encountered Challenges and Corrective Measures

The implementation of WIVA P&G HyWest was accompanied by manifold technical, economic and organisational challenges, requiring adaptive and proactive corrective measures. Key challenges included technology risks related to prototype installations, delays in electrolyser delivery, volatile electricity prices on the EPEX day-ahead spot market, and uncertain investment conditions for large-scale hydrogen infrastructure. A major structural challenge arose from the discontinuation of the commercial project "Zillertalbahn 2020+ energy autonomous", which affected planned public transport hydrogen applications, as well as from the economic risks of realising P2X Kufstein, despite extensive partner and investor discussions.

To address these challenges, the consortium developed and implemented a comprehensive risk mitigation strategy, including task reallocation, project duration extension, cost and funding reallocations, and the supplementation of the project with P2X Jenbach. Alternative implementation and demonstration pathways were introduced, such as the "Novel Emergency Backup HRS", rental-based FCE bus test concepts, and the "H2-Kleinmengenlogistik", ensuring that core project objectives, learning outcomes and data generation could still be achieved despite changing framework conditions.

3.3 Cooperation with FFG, KPC and KLIEN

Cooperation with the funding bodies FFG, KPC and KLIEN was characterised by continuous, transparent and solution-oriented interaction throughout the project lifecycle. The project management team worked in close cooperation with the funding bodies, particularly in response to recommendations and requirements of expert hearings, interim report evaluations, and additional questions received via FFG eCall. Significant coordination efforts were dedicated to explaining deviations from the original project plan, justifying mitigation strategies, and aligning corrective measures such as project extensions, task restructuring and cost reallocations with funding guidelines.

This intensive cooperation ensured that changes in external framework conditions were handled in a structured and compliant manner, safeguarding the project's strategic relevance and credibility. Through regular reporting, formal submissions, audits, and alignment meetings, HyWest remained a flagship project within the WIVA P&G Model Region, while contributing robust, transferable insights to national funding institutions and supporting the strategic development of Austria's hydrogen economy.

4 Technical Results

4.1 Feasibility and Technical Studies

Within WIVA P&G HyWest, extensive feasibility studies, technical investigations and real-world implementation activities were carried out by TIWAG, TIGAS, MPREIS and HyCentA, covering the full spectrum from hydrogen production and infrastructure planning to logistics, mobility and sector coupling. These activities formed the technical backbone of the project and generated validated results under live operating conditions, directly supporting the establishment of a regional green hydrogen economy.
TIWAG, supported by TIGAS and HyCentA, led the planning and feasibility assessment of P2X infrastructure, including the design of hydrogen production systems comprising electrolysis, power supply, control technology, compression, storage and HRS. All required planning documents and official approvals for P2X Kufstein were obtained and became legally binding, demonstrating the technical feasibility of large-scale hydrogen production in the region (Figure 2). Due to changing framework conditions, the project applied a risk mitigation strategy by supplementing P2X Kufstein with P2X Jenbach to ensure continued technical access to an industrial-scale P2X facility and enable further learning and experimental experience in industrial hydrogen applications (Figure 2).

Figure 2: Visualisation of P2X Kufstein (top), P2X Jenbach (bottom).

HyCentA contributed substantially to technical research and optimisation, including feasibility and technical studies, comparative analyses, and process research across multiple work packages (e.g., topics related to low-grade waste heat, maintenance research, hydrogen quality assurance, and backup and emergency HRS concepts). HyCentA also supported operations research, system modelling and evaluation of optimized system configurations, strengthening the technical foundation for techno-economic assessment and providing inputs for monitoring and KPI evaluation under real-world conditions.
MPREIS acted as the primary industrial demonstration site, providing real-world operational data and validating technical concepts under daily commercial operation. The electrolyser at the MPREIS site was operated in alignment with electricity price signals (e.g., EPEX day-ahead spot market), demonstrating flexible operation strategies. A central technical achievement was the certification of green hydrogen production (including TÜV Süd CMS 70 and RED II RFNBO), confirming both technical performance and market readiness. MPREIS also implemented the integration of electrolysis waste heat using an ammonia heat pump, enabling sector coupling with heat supply (including facility heat use and district heating-related integration), thereby strengthening the systemic feasibility of hydrogen-based energy solutions.
Several feasibility and technical studies were carried out to advance sector coupling and identify optimal use-cases for hydrogen and oxygen by-products. A key focus was on the integration of electrolysis-derived oxygen into wastewater treatment and the exploration of hydrogen-based methanisation. In the first project year, an MCI [15] master's thesis assessed the potential use of oxygen and hydrogen at a wastewater plant in Tyrol, confirming promising applications in the biological purification stage using oxygen and also simulated the use of hydrogen for biologic biogas methanisation process. In addition, in 2023 the supervision of a bachelor thesis analysing methanisation potential in Tyrol was performed.

A further topic that was investigated and evaluated was the compatibility of hydrogen injection into existing natural gas infrastructure. TIGAS and TIWAG have been involved in ÖVGW [16] activities examining material suitability and developing regulations for hydrogen refuelling, storage, and production—supported by insights from WIVA P&G HyWest and P2X Kufstein.
Furthermore, in the course of the project a second master's thesis in the field of hydrogen mobility compared the Life Cycle Assessments (LCA) of different fuels in the area of Kufstein. The results of the studies and works provided valuable assessments for the development of business cases.
In the field of hydrogen logistics and mobility, MPREIS demonstrated the technical feasibility of heavy-duty hydrogen transport through the commissioning and operation of Austria's first FCE heavy-duty truck within its logistics fleet, supported by training, monitoring and optimisation activities to improve reliability (Figure 3) [17]. In parallel, the establishment and operation of an MEGC-based hydrogen logistics system enabled bulk hydrogen transport by trailer and regional hydrogen supply to different customers and use cases, providing practical evidence for scalable logistics solutions beyond current infrastructure.

Figure 3: (left) Thomas Thaler (Managing Director JuVe), (right) Alexander Kosinski (Head of Service Hyundai).

The combined feasibility and technical activities of TIWAG, TIGAS, MPREIS and HyCentA demonstrated that certified green hydrogen production, P2X system planning and operation, hydrogen logistics and heavy-duty mobility, and sector coupling applications can be implemented under real-world conditions. Despite external constraints and project adaptations, WIVA P&G HyWest delivered robust technical results, validated system concepts and transferable know-how, providing a strong foundation for scaling hydrogen solutions within the WIVA P&G Model Region and contributing to Austria's emerging hydrogen ecosystem.

4.2 Hydrogen Production and Storage

4.2.1 MPREIS: Implementation and Operation Results

Within WIVA P&G HyWest, MPREIS played a central role in the implementation and operation of green hydrogen production and storage under real-world conditions, delivering key results across all reporting periods. At the MPREIS site in Völs, the electrolyser was successfully commissioned and operated, with hydrogen production carried out in alignment with electricity price signals from the EPEX day-ahead spot market, demonstrating flexible and market-oriented operation strategies [18]. A major operational milestone was the certification of hydrogen production according to TÜV Süd CMS70 and subsequently RED II RFNBO, confirming compliance with regulatory requirements and ensuring the marketability of certified green hydrogen (Figure 4). Hydrogen was continuously produced at full load, compressed, and stored, with operational routines established for safe handling, quality assurance and reliability.

Figure 4: TÜV Süd ISCC EU Certification (left), TÜV Süd CMS 70 certificate (right).

In parallel, MPREIS implemented and validated hydrogen storage and logistics concepts, including the use of trailer-based storage and MEGCs (Figure 5). This enabled buffer storage, peak demand coverage, and secure hydrogen supply, as well as the delivery of green hydrogen by road transport to multiple customers and use cases in Austria, Germany and northern Italy.

Figure 5: The 20 ft MEGC hydrogen container from MPREIS (source: MPREIS).

The cascaded storage tank configuration and associated operating procedures were investigated to assess operational flexibility, safety and supply reliability. Furthermore, MPREIS integrated electrolysis waste heat into its facilities using an industrial ammonia heat pump, thereby enhancing overall system efficiency and demonstrating sector coupling between electricity, hydrogen production and heat supply. The activities carried out by MPREIS demonstrated that certified green hydrogen production, storage and operational integration can be achieved under daily commercial operation, providing robust implementation results and transferable experience for the further scale-up of hydrogen systems within the WIVA P&G Model Region.

4.2.2 P2X Kufstein: Design, approvals, and progress

Within WIVA P&G HyWest, extensive design, approval and progress activities were carried out for the planned P2X Kufstein hydrogen production facility, led by TIWAG in close cooperation with TIGAS, HyCentA and project partners. The project aimed to establish a regional P2X hub contributing to green hydrogen production, sector coupling and mobility applications within the Energy Model Region WIVA P&G. Early project phases focused on concept development, feasibility assessment and technical planning, covering the full system scope including electrolysis, power supply, control technology, compression, storage, HRS and interfaces to industrial and mobility use cases.

The hydrogen production infrastructure of P2X Kufstein facility with a 1 MW electrolyser, heat recovery and HRS for the mobility sector was concepted and planned, including site layouts, technical planning and the option for gas grid feed-in. TIWAG coordinated closely with authorities to address environmental, regional planning, and technical questions, clarifying e.g. pipeline routes and safety issues. Due to the novelty of hydrogen production facility and sector coupling technologies, the clarification of some questions took longer than expected. Finally, all required authorisations could be obtained in the 3rd project year.

In parallel technical planning was completed and tender documents were prepared and submitted, but the subsequent evaluation of the obtained offers delivered unsatisfactory solutions due to the complexity of

sector coupling and interface management. As a result, the tendering process was refined. Ongoing global supply chain challenges further enhanced the difficulty to obtain satisfactory offers.
In addition to the difficulties described above, and due to the ongoing energy crisis and increasingly unfavourable economic calculations, TIWAG's management decided in the summer of 2025 to put the implementation of the plant on hold.
From a regulatory perspective, P2X Kufstein reached a high level of maturity, with all official approvals obtained and legally binding, demonstrating the technical and regulatory feasibility of large-scale hydrogen production at the Kufstein site. The project generated valuable experience in authorisation procedures, stakeholder coordination and interface management between electricity, gas, heat and mobility infrastructures, which was actively shared through ÖVGW working groups and exchanges with national stakeholders.
Although the physical realisation of P2X Kufstein was ultimately placed on hold, the activities carried out within WIVA P&G HyWest delivered substantial design knowledge, approved planning documents, tendering experience and risk mitigation insights. These results significantly contributed to the overall learning outcomes of the project, informed the supplementation with P2X Jenbach, and provided transferable lessons for future P2X projects in Austria, particularly under volatile market conditions and evolving regulatory frameworks.

4.2.3 P2X Jenbach: Implementation and operation plans

Within WIVA P&G HyWest, the implementation and operation plan of P2X Jenbach was developed as a strategic mitigation and supplementation measure to ensure the achievement of project objectives related to the establishment of a regional hydrogen economy in Tyrol, despite delays and the eventual discontinuation of P2X Kufstein. The integration of P2X Jenbach provided the consortium with continued access to an industrial-scale P2X implementation project, enabling practical experience, data collection and technical learning under real-world conditions.
In order to still achieve the project objectives for establishing a hydrogen economy in Tyrol and to provide the consortium with insights and practical experience from an implementation project, a Memorandum of Understanding (MoU) was concluded with the “sister project” P2X Jenbach.
The project is carried out by INNIO Jenbacher GmbH & Co OG and TIWAG-Next Energy Solutions GmbH (a 100 % subsidiary of TIWAG-Tiroler Wasserkraft AG) in Jenbach. In this project the construction of a P2X plant (similar to the planned approach of Kufstein) for converting electricity into hydrogen is implemented. Hydrogen is then transported via a separate grid from the P2X Facility to INNIO’s main facility in Jenbach, where it is primarily used for test runs of hydrogen engines.
From an implementation perspective, P2X Jenbach follows a stepwise construction and commissioning plan, including the installation of key system components such as electrolyser, hydrogen compression, storage tanks, pipework and control systems. Construction activities progressed during the project period, with major components installed and tested, while the delivery of the electrolyser emerged as a critical path item, resulting in a postponement of full commissioning to 2026. Nevertheless, preparatory work enabled the commissioning of the hydrogen terminal, including compressor, storage facilities and filling and transfer stations, allowing hydrogen intake from external sources and logistics-based supply during the transition phase.

Operationally, the P2X Jenbach concept focuses on industrial hydrogen use and sector coupling, with hydrogen supplied via a dedicated pipeline to INNIO's main plant in Jenbach, where it is used for test runs of hydrogen engines and hydrogen-ready gas engine technologies. The project thereby supports industrial decarbonisation, technology validation, and future hydrogen demand build-up. For the WIVA P&G HyWest consortium, access to P2X Jenbach enabled continued operations research, technical assessment of system components, and collection of real-world data, contributing to learning effects, risk mitigation and transferability.

4.2.4 Hydrogen Logistics, Distribution and HRS

MPREIS led and demonstrated hydrogen logistics, distribution and refuelling infrastructure [19] under real-world commercial operating conditions, establishing a functioning green hydrogen logistics system as a core pillar of the regional hydrogen economy. The activities focused on ensuring green hydrogen logistics and supply reliability, bridging the gap between hydrogen production, mobility and external customers, and providing transferable reference solutions for regions without pipeline infrastructure.

As described above, a central achievement was the establishment and continuous operation of a MEGC-based hydrogen logistics system, enabling the storage, transport and distribution of green hydrogen by road. Hydrogen produced at the MPREIS hydrogen site in Völs was compressed, filled into trailers and MEGCs and supplied to multiple customers and use cases in Austria, Germany and northern Italy. This approach demonstrated the technical robustness, flexibility and scalability of trailer-based hydrogen logistics, allowing cross-regional supply and market development for bulk hydrogen delivery independent of fixed infrastructure.

The HRS implemented and operated at MPREIS was integrated into the logistics concept, serving both internal and external mobility applications (Figure 6). The HRS enabled the refuelling of Austria's first FCE heavy-duty truck, which was operated day-to-day in the MPREIS logistics fleet, as well as refuelling and testing activities for additional vehicles and applications. The design, commissioning and operation of the HRS were closely linked to hydrogen quality assurance, safety concepts and standard operating procedures, ensuring safe, reliable and certified operation in compliance with regulatory requirements.

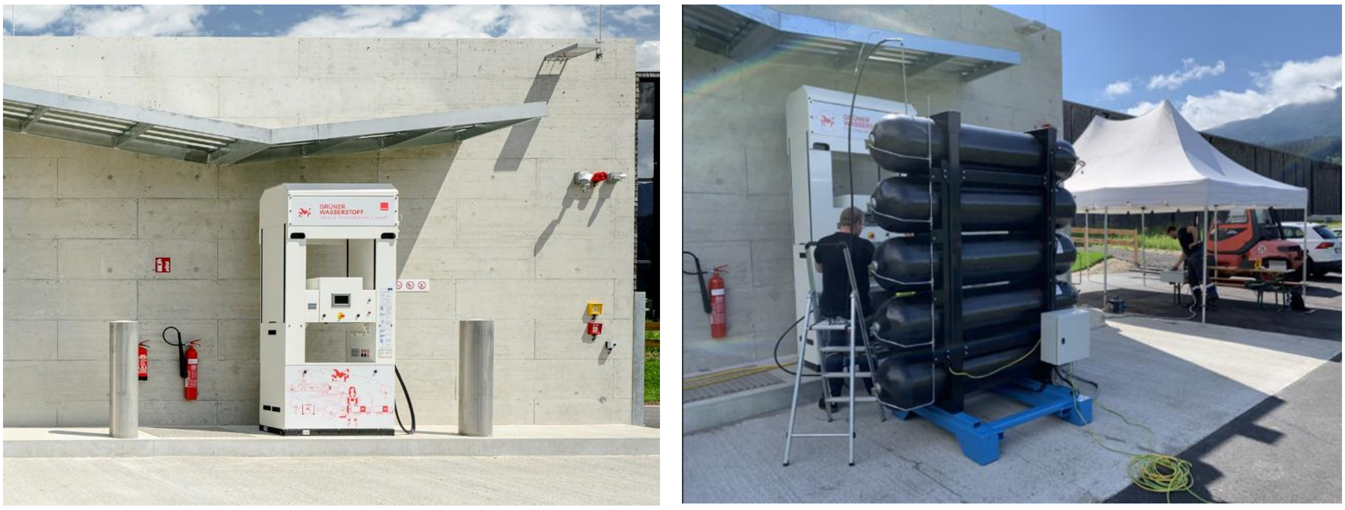

Figure 6: (left) HRS at MPREIS site in Völs with a dispenser operating at 350 bar. (right) Testing of the HRS using a hydrogen storage system dummy.

A key operational milestone was the certification of hydrogen production and logistics according to TÜV Süd CMS 70 and later RED II RFNBO, which validated not only the green hydrogen production process, but also the refuelling and trailer filling procedures. This certification enabled MPREIS to supply certified green hydrogen to external customers and positioned the logistics system as a market-ready solution. In parallel, standard operating logistics procedures, including backup and emergency concepts, were developed and refined, partly in coordination with ÖVGW working groups, contributing to standardisation and knowledge transfer at national level [20].

Operational experience gained through continuous logistics operation provided valuable insights into supply reliability, refuelling processes, trailer handling, scheduling and cost structures. The logistics system proved capable of serving peak demand, balancing production fluctuations, and supporting diverse use cases, including heavy-duty transport, industrial applications and testing environments. Through these activities, MPREIS demonstrated that road-based hydrogen logistics using MEGCs can act as an effective enabler for early hydrogen markets, particularly in regions where pipeline infrastructure is not yet available.

In addition to technical implementation, MPREIS played a key role in knowledge dissemination and visibility related to hydrogen logistics and HRS operation. Numerous guided site visits, stakeholder workshops, test drives and public relation activities were organised at the MPREIS hydrogen site, showcasing the logistics system, HRS operation and FCE truck integration to industry partners, authorities, funding bodies and educational institutions. These activities significantly contributed to public awareness, acceptance and market confidence in hydrogen logistics solutions.

4.2.5 Hydrogen Emergency Backup Systems

The conception, development and implementation of emergency backup hydrogen systems were led by FENR, responding to changing framework conditions and ensuring the continuity of hydrogen-based mobility and supply concepts within the Energy Model Region WIVA P&G. These activities were particularly important following the discontinuation of the commercial project “Zillertalbahn 2020+ energy autonomous”, which required the consortium to restructure planned public transport hydrogen applications while still achieving the project’s demonstration, learning and acceptance objectives.

A central technical result was the conception and design of the “Novel Emergency Backup HRS”, which was developed as a flexible, modular and rental-based solution for hydrogen refuelling under emergency and backup conditions. The system was designed to ensure secure hydrogen supply in situations where permanent infrastructure is unavailable or temporarily not operational, and to support test operations of FCE buses, cars and other hydrogen vehicles. The Novel Emergency Backup HRS integrates mobile hydrogen storage, standardised connectors, safety systems, and defined operating procedures, enabling safe and rapid deployment at different locations.

In parallel, FENR developed and implemented the “H2-Kleinmengenlogistik” (H2 small volume logistics) concept, addressing the need for flexible, decentralised hydrogen supply in small quantities (Figure 7).

Figure 7: Logistics system for small volume hydrogen logistics.

This logistics approach complements bulk hydrogen delivery via MEGCs, enabling emergency supply, testing, and pilot operations for mobility and research applications. The concept includes mobile storage units, vehicle-based transport, and interface-compatible refuelling solutions, providing high operational flexibility and supporting backup scenarios for public transport and light-duty vehicles. The emergency systems were designed to be compatible with existing hydrogen standards and regulations, and their development was supported by continuous exchange with ÖVGW working groups, ensuring alignment with emerging guidelines and safety requirements.

Beyond technical implementation, FENR's emergency backup activities contributed significantly to risk mitigation and system resilience within WIVA P&G HyWest. The backup HRS and H2-Kleinmengenlogistik enabled the consortium to maintain demonstration activities beyond the project, data collection and knowledge generation, even when planned infrastructure or vehicle procurements were delayed or cancelled. These systems also supported acceptance-related activities, including training, workshops and stakeholder engagement, by providing visible, tangible hydrogen applications that could be deployed flexibly across the region.

4.3 Green Energy Applications

4.3.1 P2X Operations Research

P2X operations research led by TIWAG supported the technical and economic assessment of hydrogen production systems by developing profitability calculations, optimisation approaches, and business-case models for different operational and market conditions. The work focused on production costs, anticipated market development, and sector coupling options, providing a structured basis for decision-making and for aligning project expectations with evolving framework conditions.

Throughout the project lifetime, profitability analyses and optimisation models for the P2X system were developed and continuously refined. Calculations focused on production costs and market development, revealing that electricity supply remains the dominant cost driver. Consequently, business cases for sector-coupling and by-product utilisation were created and adapted in line with the new Austrian Renewable Energy Expansion Act (EAG). However, missing national implementation guidelines, especially regarding fee exemptions and eligibility for hydrogen production, hindered reliable forecasts.

To better assess market prospects, TIWAG collaborated with stakeholders and commissioned regional hydrogen potential studies, including analyses for Tyrol and the Inntal–Rosenheim–Traunstein region. Additional exchanges with South Tyrol and visits to hydrogen projects in Vienna and Styria supported knowledge transfer.

Business-case modelling with varying investment costs (CAPEX) and operational costs (OPEX)scenarios showed that even sector-coupling and by-product strategies cannot sufficiently offset the high economic risks under current market conditions. Ongoing regulatory uncertainties (such as RED III) further complicate long-term planning. In order to enable a realization of the plant, TIWAG presented the project and business case to potential partners and investors. Despite extensive evaluations and discussions with potential partners, no agreement could be reached, so TIWAG ultimately decided to put the project on hold.

Building on these results, TIWAG's operations research also informed risk mitigation and project steering, including the supplementation of P2X Kufstein with P2X Jenbach to maintain learning effects and practical experience within the WIVA P&G HyWest timeframe.

4.3.2 Sector Coupling and Energy System Optimisation

HyCentA played a central role in sector coupling and energy system optimisation, providing scientific and technical expertise to link electricity, hydrogen, heat, gas and mobility sectors into an integrated and efficient energy system under real-world conditions. HyCentA's activities focused on feasibility analysis, system optimisation, operations research and techno-economic assessment, thereby supporting the overall objective of establishing a regional green hydrogen economy within the Energy Model Region WIVA P&G.

Power-to-X–Based Sector Coupling and System Modelling

A core contribution of HyCentA was the investigation of sector coupling concepts based on P2X systems, with particular emphasis on the integration of electrolysis into regional energy systems. This included analysing different power supply options (direct renewable electricity, public grid connection), flexible electrolyser operation, and the interaction between hydrogen production, compression, storage and end use. HyCentA supported the operations research of P2X systems, contributing to system modelling, optimisation of operating strategies, and the assessment of efficiency, flexibility and cost drivers across the full value chain.

Utilisation of Electrolysis By-products: Waste Heat and Oxygen

A key technical focus was the utilisation of electrolysis by-products, especially waste heat and oxygen, as essential elements of sector coupling and system efficiency improvement. HyCentA investigated low-grade "waste" heat utilisation, including the integration of industrial heat pumps and the evaluation of direct and indirect heat recovery concepts, enabling coupling between hydrogen production and heat supply. These analyses demonstrated how electrolysis waste heat can contribute to process heat and district heating applications, thereby improving overall system efficiency and economic performance. In parallel, HyCentA supported feasibility studies related to the use of electrolysis-derived oxygen, contributing to assessments of biological wastewater treatment and biogas methanisation processes.

Technical Feasibility, Reliability and Standardisation Activities

HyCentA also led and supported technical feasibility studies and comparative analyses across multiple work packages, including maintenance research for electrolysers, hydrogen quality assurance, and backup and emergency refuelling concepts. These activities addressed system reliability, operational safety and long-term performance, which are critical for integrated energy systems. Continuous participation in ÖVGW working groups ensured that sector coupling concepts and technical solutions were aligned with emerging standards, regulations and safety requirements, enhancing the transferability of results beyond the HyWest project.

Techno-economic Modelling and Energy System Optimisation

In the field of energy system optimisation, HyCentA contributed to techno-economic modelling and simulation, evaluating energy system configurations that combine electricity markets, hydrogen production, storage strategies and sector-coupled end uses. This included assessing cost structures, efficiency gains and optimisation potential under volatile electricity prices and changing regulatory frameworks. The modelling results supported business case development, risk assessment, and decision-making for infrastructure planning and operational strategies within WIVA P&G HyWest.

Beyond analytical work, HyCentA ensured that scientific results were closely linked to real-world implementation, incorporating operational data from hydrogen production, logistics and mobility demonstrations into model validation and refinement. This feedback loop between practice and research strengthened the credibility of the optimisation results and allowed continuous improvement of sector coupling concepts throughout the project duration.

4.4 Green Industry Applications

4.4.1 Heat Pump Integration

MPREIS implemented and operated an industrial heat pump system as a key sector coupling measure, enabling the efficient utilisation of electrolysis waste heat and contributing to the optimisation of the overall hydrogen energy system (Figure 8) [21]. The integration of the heat pump formed an important technical component linking green hydrogen production, electricity use and heat supply under real-world operating conditions.

Figure 8: Installed heat pump at MPREIS premises.

A central achievement was the integration of electrolysis waste heat from the MPREIS hydrogen production site into existing thermal infrastructure using an industrial ammonia heat pump. The system was designed to recover low-grade waste heat from the electrolyser process and upgrade it to usable temperature levels, thereby enabling its utilisation for MPREIS facilities and connection to the district heating network. The heat pump allowed an increase of the forward temperature, improving the technical feasibility of heat integration and enhancing overall system efficiency, offering a 1 500 kW heat output and saving 2.47 million kg of CO_2 annually. Its operation during the project demonstrated how electrolysis waste heat, which would otherwise be unused, can be transformed into a valuable energy resource, supporting the substitution of fossil fuels for space and process heat. The integration also served as a practical example of sector coupling, linking electricity-driven hydrogen production with heat demand in a commercial and semi-industrial context. In addition to technical implementation, MPREIS evaluated the operational interaction between hydrogen production, electricity price-driven electrolyser operation and heat demand. This provided insights into flexible operation strategies, showing how heat recovery can improve the overall economics and energy efficiency of hydrogen production systems. The heat pump integration contributed to learning effects regarding system design, control strategies and maintenance, which are directly transferable to future P2X and hydrogen projects.

4.4.2 Waste Heat Utilisation

Within WIVA P&G HyWest, the utilisation of electrolysis waste heat represented a key sector coupling and energy efficiency measure, technically implemented and scientifically evaluated in close cooperation between MPREIS and HyCentA. The waste heat concept focused on capturing low-temperature heat from the electrolysis process and upgrading it via an industrial heat pump system for productive use in process heat and district heating applications, thereby increasing the overall system efficiency of hydrogen production.

From a technical perspective, the electrolysis process generates a continuous low-temperature heat stream, which was identified as a valuable by-product rather than a loss. The system architecture consists of heat extraction from the electrolyser cooling circuit, buffer storage, and heat upgrading via an industrial ammonia heat pump, followed by delivery to high- and low-temperature heat consumers.

The stratified thermal storage tank, designed to store heat at different temperature levels simultaneously, and heat exchanger are depicted in Figure 9.

The stratified storage is filled with water which, depending on the initial/boundary conditions, can have a thermocline. Beside geometry and properties of the tank, driving mass flows are determined which define charge or discharge operation. The heat exchanger is defined by three stream temperatures and its heat transfer coefficients. Pressure drops apply to both streams.

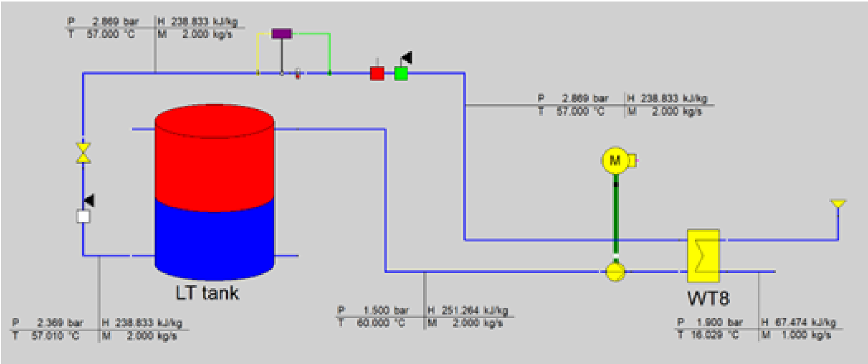

Figure 9: Stratified storage tank and heat exchanger.

A central technical element was the definition and optimisation of heat pump operating modes, with its sequential storage tanks and interfacing heat exchanger, allowing the system to switch between different heat sources, temperature levels and load conditions depending on electrolyser operation and heat demand. These operating strategies and control logics are documented in the operation mode and model figures, which were used by HyCentA for system modelling, optimisation and validation. Alternative full-system configurations were analysed during the project, supporting the evaluation of flexibility and robustness under varying boundary conditions.

In addition to the low-temperature energy of around 500 MWh generated by the heat pump, the waste heat recovery of the electrolysis plant over 10 months is presented in Figure 10, demonstrating the magnitude of recoverable heat (MWh) under real operating conditions.

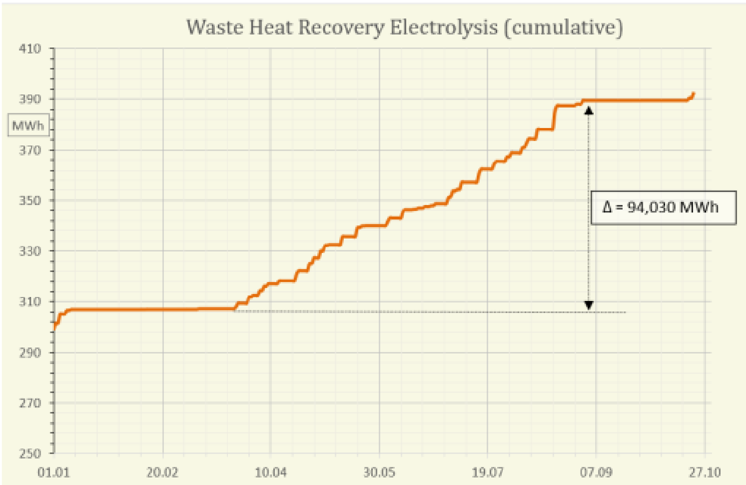

Figure 10: Waste heat recovery of electrolysis plant in MWh.

Operational results further confirm the technical feasibility and reliability of the waste heat utilisation concept. The delivered heat quantities and overall operational heat production over time demonstrated stable operation, successful integration into the heat supply infrastructure, and effective coupling between hydrogen production and heat use. These real-world results were continuously fed back into HyCentA's system models, enabling model calibration and validation against measured operational data.

4.4.3 Maintenance and Certification

Comprehensive maintenance, monitoring and certification activities were led by MPREIS to ensure the safe, reliable and compliant operation of green hydrogen production under real-world commercial conditions. A central focus was the certification of hydrogen production and logistics according to TÜV Süd CMS 70 and subsequently RED II RFNBO, which represent key regulatory and market requirements for certified green hydrogen in Austria and the European Union (Figure 4).

From an operational perspective, MPREIS established structured maintenance routines for the electrolyser, compression systems, storage units and hydrogen refuelling infrastructure, supported by continuous monitoring of operating parameters. Maintenance activities aimed at ensuring high availability, operational safety and long-term system performance, while minimising downtime and supporting stable hydrogen production. Insights from daily operation, including load cycles, pressure management and component behaviour, were systematically evaluated to support maintenance optimisation and reliability improvement.

In addition to certification audits, MPREIS maintained documentation, data logging and reporting systems to ensure ongoing compliance with certification schemes. The hydrogen production and refuelling/trailer filling process was continuously validated, providing a robust basis for audits and re-certification. The close interaction between operation, maintenance and certification ensured that technical performance and regulatory compliance were aligned throughout the project duration.

The maintenance and certification activities led by MPREIS demonstrated that industrial-scale hydrogen production can be operated safely, reliably and in full compliance with TÜV Süd CMS 70 and RED II RFNBO requirements. These results significantly strengthened the credibility, market readiness and transferability of the WIVA P&G HyWest hydrogen system and provided a reference model for future certified green hydrogen projects within the WIVA P&G Model Region and beyond.

4.5 Green Mobility Applications

4.5.1 MPREIS FCE Truck Operations

MPREIS successfully implemented and operated Austria's first FCE heavy-duty truck, representing a key demonstration of green hydrogen mobility under daily commercial operation (Figure 11). The deployment of the Hyundai XCient FC 6x2 truck formed a central pillar of the project's green mobility and logistics activities, linking certified green hydrogen production, hydrogen refuelling infrastructure, and real-world transport demand within the Energy Model Region WIVA P&G.

Figure 11: Fully assembled Hyundai truck, ready for operation.

The FCE truck has been tested under real operating conditions to gather valuable experience and further optimise the technology. Initial operational results and data from ongoing use already demonstrate the vehicle's practicality and provide valuable insights into the performance and efficiency of fuel cell vehicles in the heavy-duty transport sector.

The collected data cover various aspects such as range, energy consumption, and maintenance intervals. The truck's range is approximately 400 km per tank filling, which is sufficient for the majority of Austrian transport routes. The energy consumption of the FCEV truck meets expectations. Another important aspect is the reduction of CO_2 emissions: the FCEV truck operates emission-free, making a significant contribution to improving air quality and reducing CO_2 emissions in the transport sector. In general, 7.5 kg H2 is consumed per 100 km and the daily distance with one refuelling stop is 400 km. The substituted amount of diesel per year sums up to 5 900 Liter.

The Hyundai FCEV truck thus represents a practical solution for zero-emission transport logistics. Of particular note is the fast-refuelling time of approximately 10 minutes at the MPREIS hydrogen refuelling station, which enables the truck to be seamlessly integrated into regular operations.

Hydrogen for the FCE truck is supplied from the MPREIS hydrogen production site, with refuelling carried out at the on-site HRS using certified green hydrogen. The entire supply chain, from hydrogen production and compression to refuelling was certified according to TÜV Süd CMS 70 and RED II RFNBO, ensuring regulatory compliance and sustainability verification. Operational experience showed significantly improved reliability and fuel consumption of the vehicle over time, reflecting the learning effects and optimisation achieved during continuous operation.

To support safe and efficient use, driver training and workshops were organised in cooperation with Hyundai and project partners, focusing on vehicle operation, refuelling procedures and safety aspects.

A central part of the driver training was the comprehensive transfer of knowledge about hydrogen technology and its importance for the reconstruction of the energy system. For this purpose, partner FENR, representing the Green Energy Center Europe in Innsbruck provided a training workshop / upskilling course to the MPIRES truck drivers (Figure 12). [22]

As part of the training sessions, conducted by the Green Energy Center Europe in Innsbruck, participants received a thorough introduction to the fundamentals of hydrogen technology. This included the physical properties of hydrogen and the advantages of fuel cell technology compared to conventional propulsion systems, with particular emphasis placed on the hydrogen safety measures, proper handling of hydrogen tanks, and the importance of regular vehicle inspections and maintenance.

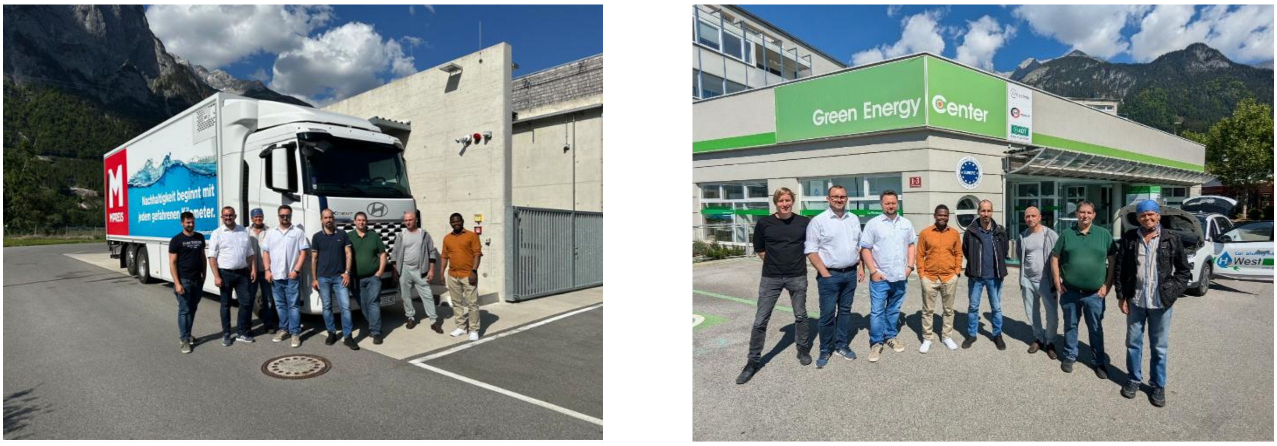

Figure 12: Training of MPREIS truck drivers on 13 May 2025.

Building on the foundations laid in May, a second training was held in December 2025 where participants received an in-depth introduction to concepts of hydrogen and fuel cell technology, vehicle architecture and high-voltage systems as well as operational procedures and best practices for daily use (Figure 13) [23]. These topics further included technical basics, operational procedures, and essential safety concepts related to hydrogen and high-voltage systems. In addition, the programme was expanded to include an introduction to a Hyundai NEXO hydrogen passenger FCEV car. This allowed participants to experience hydrogen mobility in both heavy-duty logistics and passenger transport, highlighting the versatility of fuel cell technology across different vehicle segments.

Figure 13: Training of MPREIS truck drivers on 3 December 2025.

The MPREIS FCE truck operations demonstrated that hydrogen-powered heavy-duty transport can be reliably integrated into commercial logistics, even under challenging topographic and climatic conditions. The activities delivered a high-visibility reference use case, supported the build-up of hydrogen demand, and provided transferable operational insights for future deployments of Fuel Cell Electric trucks in Austria and beyond, significantly contributing to the objectives of WIVA P&G HyWest and the emerging hydrogen economy.

4.5.2 FCE Bus Tests

The original project concept foresaw the purchase, implementation and operation of an FCE bus by Zillertaler Verkehrsbetriebe (ZVB) in the Zillertal region, combined with the testing of a novel hydrogen refuelling and backup infrastructure. The objective was to demonstrate hydrogen-based public transport under real-world Alpine conditions, including refilling processes, vehicle performance and operational reliability.

Due to the discontinuation of the commercial project “Zillertalbahn 2020+ energy autonomous” and a strategic shift by the federal government of Tyrol and Verkehrsverbund Tirol (VVT), hydrogen activities in public transport were suspended for the time being. Despite these changes, the project continued to pursue test operations and learning activities related to FCE bus use.

Within this adapted framework, test drives and demonstration activities were carried out in cooperation with HyBus Implementation [24] and H2Alpin [25] projects.

In November 2022 a first test in cooperation with the project HyBus Implementation took place in Tyrol to verify the general suitability of the Hyundai ElecCity FCE bus for further operation in the region. The bus was made available by HyBus project partner Hyundai Import and bus owner Holding Graz for test drives within the alpine terrain. These test drives took several days in the alpine surroundings of Tyrol and Vorarlberg and focused on the following topics (Figure 14):

- Mastering the most demanding driving profile Innsbruck → Kühtai → Ötz with more than 1 500 m elevation gain and consequently loss.
- Examining the braking behaviour on longer descents, as no classic braking system is built in.
- Proofing of snow chain suitability by using snow chains for the first time

The refuelling of the buses was carried out at the MPREIS HRS in Völs, with green hydrogen produced at MPREIS site with the electrolysis plant which was built as part of the Demo4Grid project.

Figure 14: Test drives with Hyundai Elec City FCE hydrogen bus from Holding Graz within the HyBus R&D project, Source: Hyundai Import GmbH; Refuelling the Hyundai ElecCity with green hydrogen at the MPREIS HRS (source: Hyundai Import GmbH).

In November 2025, the H2Alpin activities were complemented by a dedicated demonstration in Tyrol: a hydrogen-powered intercity bus from manufacturer MCV completed a test drive from Kematen via Praxmar up to Kühtai, continuing into the Ötztal valley and returning, thereby validating fuel cell propulsion under topographically challenging routes (Figure 15) [26].

The bus configuration combined a 100 kW fuel cell, a 100 kWh buffer battery, and an electric drivetrain with up to 410 kW peak output, supporting stable performance even on steep alpine sections. For the route, hydrogen was provided via green hydrogen refuelling at MPREIS in Völs in cooperation with WIVA P&G HyWest, (roof-mounted tanks 40 kg H2 available); reported consumption on the Kühtai route was around 7 kg H2 per 100 km. Beyond pure traction performance, the test also delivered operational insights: route-specific adaptation of battery charging limits and fuel cell energy supply was highlighted as important to preserve recuperation capacity on descents and avoid wasted energy, while only minor technical optimisations were identified before series production.

Figure 15: MCV FCE bus test drives in collaboration with H2Alpin project.

These activities validated the technical feasibility of FCE buses under challenging topographic and climatic conditions, including high-altitude operation and cold-weather performance, using green hydrogen refuelling at the MPREIS hydrogen site.

In parallel, the conception and testing of the “Novel Emergency Backup HRS” was developed, designed to enable flexible and temporary hydrogen refuelling for public transport applications. This included design of a unified logistics interface enabling efficient and safe small-quantity hydrogen logistics as well (Figure 16).

Figure 16: Novel Backup & Emergency Hydrogen Logistics System especially for small scale applications.

4.6 Economic and Market Aspects

4.6.1 Techno-economic Management Model and Cost Calculations

The techno-economic framework focused on hydrogen production costs, explicitly accounting for electricity procurement strategies, electrolyser operation, compression, storage and logistics, as well as certification, transport and operational expenses.

A key finding of the cost calculations was that electricity supply remains the dominant cost driver, with strong sensitivity to volatile prices on the EPEX day-ahead spot market and later shorter price intervals. Figure 17 underlines that hydrogen production costs are highly sensitive to short-term market dynamics, reinforcing the necessity of price-driven and flexible electrolyser operation as a core optimisation strategy within the techno-economic framework.

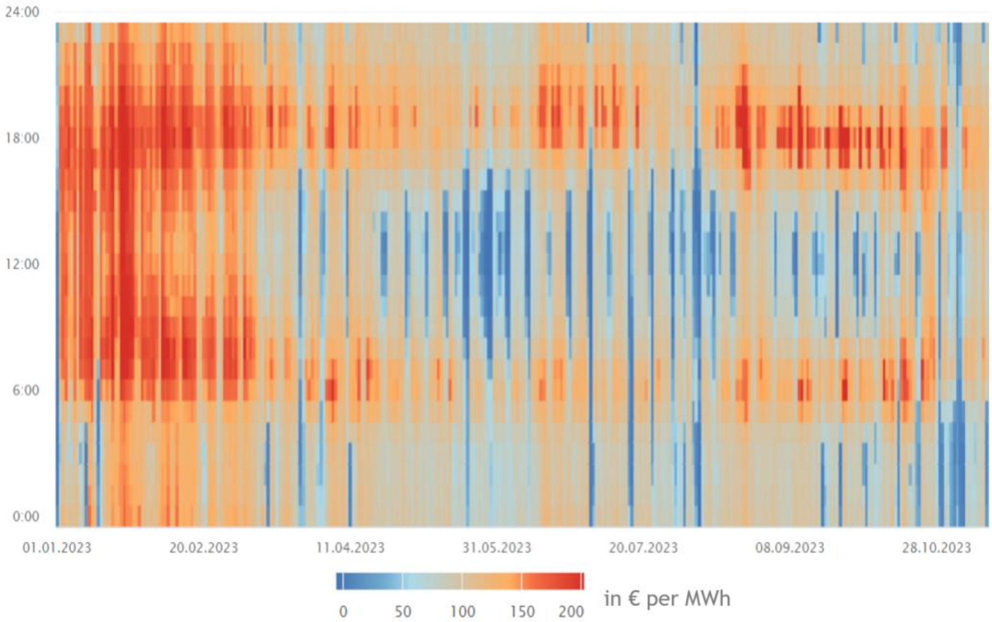

Figure 17: Austrian day ahead electricity market in 2023.

Building on this observation, Figure 18 presents electricity price forecasts derived from the MONTEL platform, which were used to extend the planning window for hydrogen production scheduling. These forecast-based inputs enabled the evaluation of forward-looking operational strategies, supporting the comparison of spot-market-based operation, forecast-assisted dispatch, and continuous operation scenarios within the techno-economic model. The integration of price forecasts improved the assessment of cost risks, revenue uncertainty and operational flexibility, while also highlighting the limitations of reliable long-term planning under volatile and uncertain market conditions.

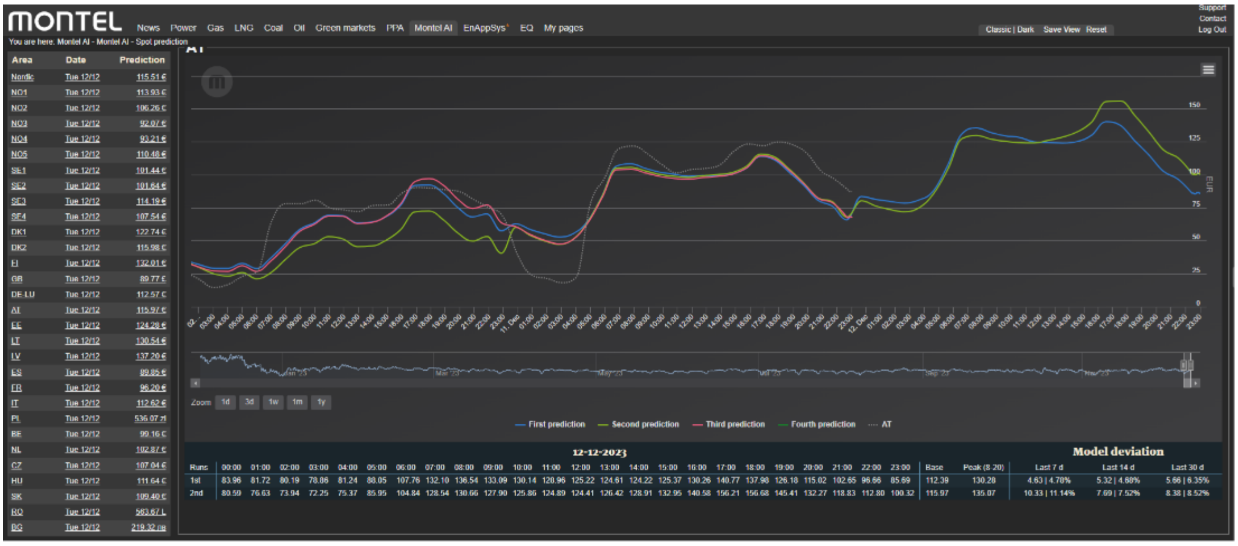

Figure 18: MONTEL platform predictions for spot market on the 12th of December 2023.

Beyond production costs, the model incorporated additional cost elements, such as MEGC trailer logistics, refuelling and backup systems, maintenance, and certification according to TÜV Süd CMS 70 and RED II RFNBO. These extensions enabled a holistic cost perspective, supporting the build-up of certified green hydrogen demand and the evaluation of different use cases in mobility, industry and sector coupling. Scenario-based analyses with varying CAPEX and OPEX assumptions were used to assess economic feasibility, market ramp-up paths and risk exposure under changing regulatory and market conditions.

4.6.2 Assessment of Business plans and Exploitation Strategy

Within WIVA P&G HyWest, the assessment of business plans and exploitation strategy was carried out as an integral part of the scientific monitoring and techno-economic evaluation, supporting strategic decision-making and the long-term objective of establishing a regional green hydrogen economy. The assessment built on real-world operational data, techno-economic modelling results, and market analyses, ensuring that business plans reflected practical implementation experience within the Energy Model Region WIVA P&G.

The business plan assessment focused on hydrogen production, logistics, mobility and sector coupling use cases, evaluating CAPEX and OPEX, and market development assumptions. Particular emphasis was placed on the economic feasibility of P2X systems, green hydrogen logistics, and hydrogen-based mobility, including heavy-duty transport and public transport applications. Analyses consistently showed that electricity costs remain the dominant cost driver, while volatile energy markets and uncertain regulatory conditions strongly influence profitability and risk exposure.

The techno-economic management model supported business case development and strategic decision-making, including the assessment of P2X Kufstein and P2X Jenbach and the evaluation of risk mitigation measures. Results showed that, despite optimisation efforts and sector-coupling benefits, economic feasibility remains highly sensitive to regulatory frameworks, including EAG implementation, fee exemptions, and EU-level requirements such as RED II / RED III.

Despite continuous optimisation and scenario-based modelling, the assessment identified significant economic risks, particularly for large-scale P2X investments, due to unfavourable market conditions, missing national implementation guidelines, and regulatory uncertainty (e.g. EAG, RED II / RED III).

Therefore, risk mitigation, phased implementation, flexible logistics concepts and knowledge exploitation, rather than immediate large-scale rollout were identified for incorporation in follow-up exploitation strategies. In general, these strategies were assessed with regard to certified green hydrogen production, including TÜV Süd CMS 70 and RED II RFNBO certification, which were identified as key enablers for market access and cross-border hydrogen supply. The strategy included the build-up of concrete hydrogen demand, notably through MPREIS logistics operations, industrial off-takers, and trailer-based hydrogen distribution to customers in Austria, Germany and northern Italy. In parallel, sector coupling and by-product utilisation, such as waste heat integration and oxygen use, were evaluated as potential value-enhancing elements within the business plans. Furthermore, WIVA P&G HyWest positioned its results to support future European cooperation and follow-up projects, with a strong focus on transferability, regulatory learning and system replication.

A central exploitation pathway was the active exchange with European projects and networks, allowing HyWest results to be shared and compared beyond the national context. In particular, networking with EU projects such as AMETHyST [27] enabled the presentation of Power-to-X concepts, sector coupling approaches and operational experience to a wider European audience. Moreover, regular networking with EU project TRIERES [28] initiated in 2023, focusing on hydrogen valley knowledge exchange.

These interactions supported mutual learning, increased visibility of WIVA P&G HyWest as a reference project, and laid the groundwork for future joint proposals and replication activities. Exploitation strategies also focused on regulatory and standardisation aspects. By contributing operational experience to working groups and expert exchanges, the project supported the alignment of hydrogen production, logistics and refuelling concepts with evolving European frameworks, including RED II / RFNBO requirements. This regulatory knowledge was identified as a valuable asset for subsequent European projects, as it mitigates uncertainty and enhances the viability and scalability of future hydrogen investments.

The project further leveraged its cross-border perspective, particularly through hydrogen logistics and supply to customers in neighbouring countries, to demonstrate European market relevance. These activities strengthened the role of Tyrol as a linking region within the European hydrogen economy and provided practical insights for corridor-based and transnational hydrogen concepts, which are central elements of many EU-funded initiatives.

As a result, the assessment of business plans and exploitation strategy provided transparent, evidence-based insights into market readiness, investment barriers and scaling potential, delivering transferable lessons for future hydrogen projects and supporting the strategic development of Austria’s hydrogen economy within the WIVA P&G Model Region.

4.6.3 Regional Integration and Follow-Up Projects

Strong emphasis was placed on regional integration and the preparation of follow-up projects, ensuring that results extend beyond the project duration and contribute sustainably to the Energy Model Region WIVA P&G. The project was embedded in a regional ecosystem of industry, energy infrastructure, mobility providers, research institutions and public stakeholders, enabling continuous exchange, coordination and alignment with parallel initiatives and strategic regional objectives.

WIVA P&G HyWest actively supported the integration of hydrogen production, logistics, mobility and sector coupling into the wider regional context, including cross-border perspectives. Activities such as hydrogen trailer logistics, industrial off-taker integration, and heavy-duty hydrogen mobility strengthened regional and international connectivity, particularly with Germany and northern Italy. The project also contributed to strategic discussions on future hydrogen corridors, including the Brenner Valley / H2 Brenner Valley, highlighting the role of Tyrol as a hub for Alpine hydrogen logistics and industrial applications.

Follow-up activities and projects were prepared based on the technical, economic and organisational learnings generated within WIVA P&G HyWest. These included the supplementation of P2X Kufstein with P2X Jenbach, ensuring continued industrial-scale P2X experience, as well as close coordination with HyBus Implementation, H2Alpin, and education-oriented initiatives such as H2CoVE [29]. These connections enabled knowledge transfer, continuation of test operations, and further capacity building in hydrogen technologies.

In addition, WIVA P&G HyWest results were systematically integrated into regional planning, stakeholder strategies and dissemination formats, including the WIVA P&G Annual Event, ÖVGW working groups, workshops, trainings and guided site visits. These activities supported the uptake and exploitation of project results, enhanced public and professional acceptance, and informed policy and funding discussions at regional and national level.

5 Social, Environmental and Acceptance Aspects

5.1 Sociotechnical and Macroeconomic Impact Assessment

A systematic assessment of the sociotechnical and macroeconomic impacts arising from the implementation of the WIVA P&G HyWest project was conducted to evaluate the interaction between green hydrogen technologies, users, markets, institutions, and regional value creation structures.

The sociotechnical assessment was conducted using the SAMBA (Socio- and Multicriteria Model for reducing Barriers Analysis) method, an in-house tool structured along STEEP dimensions (sociological, technological, environmental, economic and political). The assessment comprised defining system boundaries, conducting a structured stakeholder analysis and carrying out a qualitative barrier and driver assessment. This was supported by expert interviews with consortium partners. The results were categorised and consolidated to derive insights relevant to implementation, and were further synthesised in a SWOT-oriented evaluation of strengths, weaknesses, opportunities, and threats.

From a sociotechnical perspective, the focus was on acceptance, stakeholder perception, and user interaction with hydrogen technologies. Activities included analysing feedback from workshops, training sessions, guided site visits, expert interviews and stakeholder exchanges, and evaluating hands-on demonstration formats such as visits to hydrogen production sites, operation of FCE trucks, hydrogen refuelling and test drives of hydrogen buses. The assessment confirmed that real-world operation and visible demonstrations significantly improved understanding, trust and acceptance. However, it also highlighted remaining concerns relating to costs, regulatory uncertainty, and the long-term availability of hydrogen infrastructure.

In parallel, the macroeconomic impacts of WIVA P&G HyWest were analysed using the MOVE/MOVE2 simulation model, which is a time-series-based macroeconomic model that compares a business-as-usual scenario with a WIVA P&G HyWest investment scenario. This approach enabled investment impulses, Gross Domestic Product (GDP) effects, employment impacts and structural changes to be estimated, providing a quantitative assessment of economic effects that complements the qualitative socio-technical analysis and supports the evidence-based evaluation of project's broader impacts.

The macroeconomic impact assessment analysed the investment volumes, operating costs and value creation effects enabled by HyWest activities, as well as the substitution of fossil fuels. Using inputs from techno-economic models, KPI monitoring and business-case analyses, the assessment evaluated the contribution of WIVA P&G HyWest to regional economic activity, innovation capacity and learning effects for future hydrogen investments. It also confirmed that logistics-based hydrogen supply, heavy-duty mobility and sector coupling (e.g. waste heat utilisation) represent economically relevant early use cases.

The evaluated central macro-economic indicators, also depicted in Figure 19, are the following:

- 2020-2040 on average
    - GDP: Δ + 3.6 mio. €
    - Investment: Δ + 0.7 mio. €
    - Private consumption: Δ + 0.3 mio. €
    - Net exports: Δ + 2.6 mio. €

Based on this evaluation, the main drivers are the investment costs in domestic H2 production, storage and usage (mobility). The simulation analyses display positive effects on the Austrian economy through:

- Implementing domestic green H2 production and storage
- Usage for mobility
- Expansion of the H2 refuelling station infrastructure and trucks

via the WIVA P&G HyWest project portfolio.

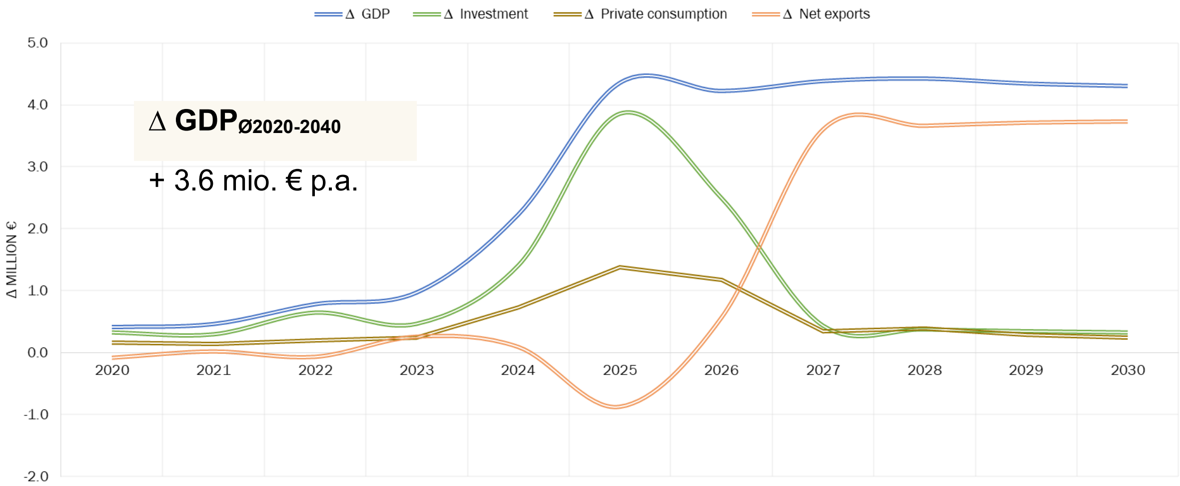

Figure 19: Average growth between 2020 and 2040, GDP: Δ + 3.6 mio. €.

Furthermore, the systemic impacts were assessed, including project's contribution to sector coupling, energy system flexibility and the long-term transition to a largely CO_2 neutral energy and mobility system.

5.2 Public Acceptance and Stakeholder Engagement

Public acceptance and stakeholder engagement were addressed as a core project dimension, recognising that the successful establishment of a regional green hydrogen economy depends not only on technical feasibility, but also on social acceptance, user involvement and transparent communication [30]. These activities were embedded across the project and explicitly reflected in the objectives related to acceptance, management of interfaces and active participation of users within the Energy Model Region WIVA P&G.

To assess and strengthen acceptance, expert interviews were conducted together with stakeholder analyses and sociotechnical evaluations, focusing on perceptions of hydrogen technologies, safety, costs and benefits in mobility, industry and energy supply (EI-JKU). These qualitative methods were complemented by workshops, trainings and stakeholder alignment activities, which enabled direct dialogue with industry partners, authorities, educational institutions, policy makers and the interested public. The involvement of stakeholders throughout the project helped to identify concerns early, align expectations and integrate feedback into project steering and implementation (FENS).

A strong emphasis was placed on hands-on demonstration and visibility, as real-world experience was identified as a key driver for acceptance. Guided site visits at the MPREIS hydrogen production and refuelling site, test drives with the FCE heavy-duty truck, and demonstrations of hydrogen logistics and backup systems allowed stakeholders to experience hydrogen technologies in live operation. These activities significantly contributed to building trust, reducing uncertainty and increasing awareness of hydrogen solutions.

Public acceptance activities were supported by extensive communication and public relation measures, including project website, press releases, conference contributions, webinars, and participation in national and international hydrogen events. WIVA P&G HyWest partners actively contributed to industry working groups, such as ÖVGW meetings, and presented results at the WIVA P&G Annual Event, ensuring broad dissemination and knowledge transfer. Education- and training-oriented formats, including train-the-trainer workshops, driver trainings and cooperation with vocational education and research projects, further strengthened capacity building and long-term acceptance.

5.3 Public Relation Activities

Extensive public relation activities were carried out by MPREIS, TIWAG and TIGAS to ensure high visibility, transparency and dissemination of project results, thereby supporting public acceptance, stakeholder confidence and knowledge transfer within the Energy Model Region WIVA P&G and beyond. These activities complemented the technical work by communicating real-world experience, lessons learned and market-relevant insights related to green hydrogen production, logistics, mobility and sector coupling.

MPREIS played a particularly prominent role in hands-on public outreach, using its hydrogen production site, refuelling infrastructure and logistics operations as living laboratories for demonstration and communication. Numerous guided site visits, technical tours and stakeholder meetings were hosted at the MPREIS facilities, enabling industry partners, authorities, educational institutions and network organisations to observe hydrogen production, HRS, trailer filling and FCE truck operations in daily

commercial use. In addition, test drives, driver trainings and expert exchanges strengthened practical understanding and contributed to building trust and awareness of hydrogen technologies.
The visibility of MPREIS' hydrogen activities was further reinforced through national recognition and awards, including the VCÖ Mobilitätspreis Austria [31], the Energy Globe Award Tirol [32], the Energy Globe Award Austria (Kategorie Luft) [33] and the Cluster Award of Standortagentur Tirol, highlighting the project's innovative character and societal relevance.
The official opening of the Sunfire electrolyser as part of the European project Demo4Grid project took place on the 2nd of March 2023 (Figure 20) [34]. This project enabled the construction of an alkaline pressurised electrolysis plant which is now used to produce green hydrogen as the basis for the MPREIS' hydrogen business case.

Figure 20: (left) Official opening of the pressurised alkaline electrolysis plant by the Tyrolean representatives of the "Demo4Grid" EU consortium. (right) HyWest research partnership; Ernst Fleischhacker (Managing Director of FEN Systems, Green Energy Center Europe), Reiner Reinbrech, representative of the Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology, Ewald Perwög (project initiator of MPREIS Hydrogen), Bernd Vogl (Managing Director of the Climate and Energy Fund), Nikolaus Fleischhacker (Managing Director of FEN Research and Head of the HyWest research centre at the Green Energy Center Europe in Innsbruck).

TIWAG and TIGAS complemented these activities through strategic communication, networking and expert contributions. Both partners actively participated in national hydrogen industry exchanges, ÖVGW working groups, and specialist meetings, where planning experience, regulatory insights and implementation challenges from WIVA P&G HyWest were shared with a professional audience. Contributions to presentations, expert discussions, plant visits and the WIVA P&G Annual Event helped position HyWest as a reference project for P2X systems, hydrogen infrastructure and regulatory learning. TIWAG ensured visibility for "P2X Kufstein – innovative sector coupling plant with hydrogen center" via a dedicated project website and coordinated PR outputs such as journal articles and press releases shared internally through the project's collaboration tools. In parallel, MPREIS maintained a dedicated "MPREIS Hydrogen" project website and a press website / press kit, which supported strong media outreach and structured handling of the high number of visit requests. These efforts were amplified by frequent visits and guided tours at the MPREIS electrolysis and hydrogen facilities (including delegations from politics and industry), plus public-facing moments such as the press conference tied to the opening of the MPREIS' HRS.

A key milestone was the final project event, embedded in the WIVA P&G Annual Event, which brought together policy makers, funding bodies, industry stakeholders and researchers to discuss project outcomes, barriers and future perspectives for hydrogen in Austria.

5.4 Workshops and Trainings

Within WIVA P&G HyWest, workshops and trainings were implemented as a central instrument for knowledge transfer, capacity building and stakeholder alignment, supporting the project's objectives related to acceptance, user involvement and skills development within the Energy Model Region WIVA P&G. These activities ensured that technical results and operational experience gained in the project were effectively translated into practical competencies and shared understanding among a broad range of stakeholders.

A wide range of workshops and training formats were organised throughout the project, targeting industry partners, logistics operators, public authorities, emergency services, educational institutions and research organisations. The content covered green hydrogen production, hydrogen logistics and refuelling, FCE vehicle operation, safety concepts, and sector coupling applications. Particular emphasis was placed on hands-on and practice-oriented formats, allowing participants to engage directly with hydrogen systems under live operating conditions.

Key activities included driver trainings for the MPREIS FCE heavy-duty truck, organised jointly with Hyundai and project partners, which combined theoretical instruction with practical refuelling and vehicle operation at the MPREIS hydrogen refuelling station (Figure 12, Figure 13). In addition, train-the-trainer workshops were conducted in cooperation with education-focused initiatives such as Erasmus+ H2CoVE, linking vocational education, industry and academia (Figure 21) [35].

Figure 21: Train the trainer workshop, H2CoVE meets WIVA P&G HyWest, March 2025.

The Hydrogen Valley experience and knowledge exchange between the TRIĒRĒS Consortium and the Austrian WIVA P&G HyWest Consortium took place in a workshop at the Green Energy Center Europe in Innsbruck, Austria, on the 10th of July 2024 (Figure 22) [36].

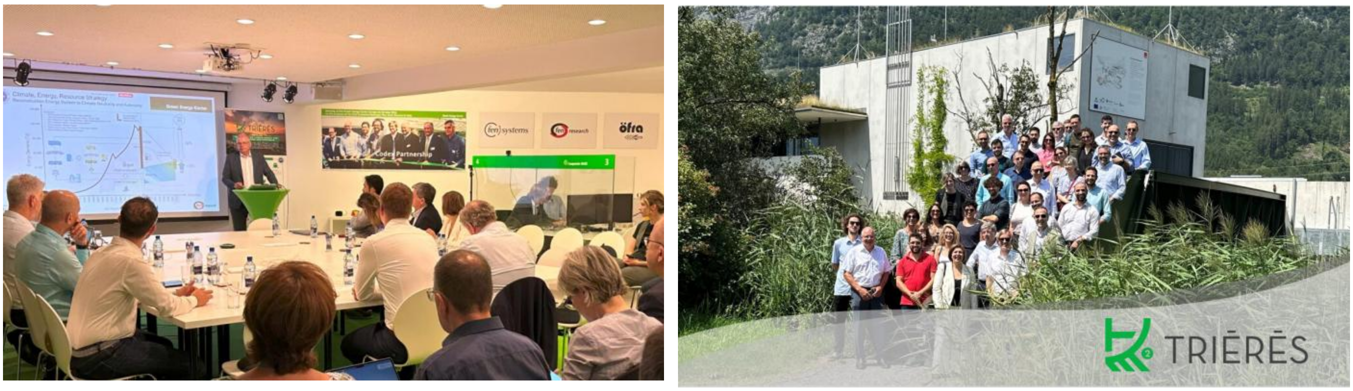

Figure 22: WIVA P&G HyWest regional hydrogen valley workshop with TRIERES consortium, July 2024.

These workshops frequently included guided visits to the MPREIS hydrogen production site, reinforcing learning through real-world demonstration.
WIVA P&G HyWest also organised and contributed to stakeholder workshops and expert exchanges, addressing topics such as hydrogen safety, refilling and rescue concepts, AFIR implementation, and standard operating procedures for hydrogen systems. These formats supported interface management, fostered cross-sector dialogue, and enabled the alignment of expectations and requirements between technology providers, operators and regulators.

5.5 Communication and Dissemination

Comprehensive communication and dissemination activities were implemented across all reporting periods to ensure high visibility, knowledge transfer, and broad stakeholder engagement at regional, national and international level. These activities were an integral part of the project and supported the objectives of the RTI-Initiative Energy Model Region WIVA P&G by communicating real-world experience, scientific results and market-relevant insights related to green hydrogen production, logistics, mobility, sector coupling and P2X systems.
A central pillar of communication was the use of real-world demonstration sites as living laboratories, particularly at MPREIS, where hydrogen production, HRS, trailer-based logistics and FCE truck operation were made accessible to a broad audience. Numerous guided site visits, technical tours and delegation visits were organised for industry representatives, authorities, funding bodies, research institutions, educational organisations and policy makers, enabling hands-on experience and direct dialogue. These activities were complemented by test drives, driver trainings and expert workshops, which significantly contributed to acceptance, trust-building and capacity development.
Across the consortium, partners actively contributed to workshops, trainings, stakeholder events and expert meetings, addressing both technical and socio-economic aspects of hydrogen deployment. TIWAG, TIGAS, HyCentA, MPREIS and FEN partners participated in national and international conferences, hydrogen-specific networking events, and specialist formats, where project progress, challenges and lessons learned were presented and discussed. Regular engagement in ÖVGW working groups enabled the transfer of technical findings and regulatory experience into standardisation and guideline development processes.

At the start of the project, P2X Kufstein was actively presented through the company website, press articles, conference lectures, and social media activities. Networking with other initiatives, including the EU project AMETHyST, enabled additional outreach and the presentation of the P2X concept to a broader audience. During the WIVA P&G Conference 2025, the project's development and the decision made for Kufstein were reported, and the P2X project in Jenbach was also introduced and showcased on site.
Scientific dissemination was ensured through peer-reviewed publications, including a journal article documenting the establishment of Austria's first regional green hydrogen economy [37], as well as through conference papers, presentations and invited lectures. Academic dissemination was further supported through the supervision of bachelor's and master's theses, addressing topics such as sector coupling, methanisation, hydrogen mobility and LCA, thereby integrating HyWest results into higher education and research.
A major dissemination milestone was the final project event, embedded in the WIVA P&G Annual Event, where project results, key findings, barriers and future perspectives were presented to a wide audience including policy makers, funding bodies, industry stakeholders and researchers (Figure 23) [38].

Figure 23: Project presentation at WIVA P&G annual event. Speakers from the project consortium from left to right; René Regenfelder (HyCentA), Daniel Jakob (TIWAG / TINEXT), Wolfgang Madl (MPREIS), Niusha Shakibi Nia (FENR), Darja Markova (EI).

In addition, continuous reporting, formal presentations and structured communication ensured transparent exchange with FFG, KPC and KLIEN, supporting project governance and strategic alignment.

5.6 Education and Capacity Building

Education and capacity building activities were implemented as a cross-cutting element to support the long-term development of hydrogen competences, workforce skills and institutional knowledge within the Energy Model Region WIVA P&G and beyond. These activities complemented technical demonstration and dissemination by ensuring that practical experience, scientific findings and operational know-how were transferred to students, professionals, operators and stakeholders involved in the emerging hydrogen economy.
A major component of capacity building was the integration of WIVA P&G HyWest activities into academic education and research training. The project supported the supervision of bachelor's and master's theses, addressing key topics such as sector coupling, use of electrolysis by-products (oxygen and waste heat),

hydrogen-based methanisation, hydrogen mobility, and LCA of different fuels. These works were closely linked to real-world project data and infrastructure, ensuring practice-oriented education and contributing to the scientific evaluation of hydrogen systems.
In parallel, WIVA P&G HyWest partners implemented practice-oriented training and knowledge transfer formats targeting operators, drivers and technical staff. This included driver trainings and workshops for FCE vehicles, covering vehicle operation, refuelling procedures and safety aspects, as well as technical trainings related to hydrogen production, storage, logistics and refuelling infrastructure. These activities strengthened operational competence, safety awareness and user acceptance among personnel directly involved in hydrogen applications.

6 Comprehensive Scientific Monitoring of KPIs

The comprehensive KPI monitoring of WIVA P&G HyWest provides a quantitative and qualitative assessment of project performance across technology, market development and acceptance dimensions. The KPI framework was aligned with the RTI-Initiative Energy Model Region WIVA P&G and evaluated using real-world operational data, consolidated over all reporting periods.

Technical KPIs

For green hydrogen production, KPIs showed continuous operation of the MPREIS electrolyser, with high technical availability and stable hydrogen output under market-driven operation. The KPI “Green Hydrogen Economy” reached 100 % goal achievement, while “Production and storage of green hydrogen” reached 80 %, reflecting the successful operation at MPREIS and the partial realisation of P2X infrastructure following the stop of P2X Kufstein. A key verified KPI was the certification of hydrogen production and logistics according to TÜV Süd CMS 70 and RED II RFNBO, confirming full compliance with sustainability, traceability and regulatory requirements.
In hydrogen logistics and supply reliability, KPIs reached 100 % goal achievement, based on the continuous MEGC-based trailer logistics, reliable refuelling operations, and cross-border hydrogen deliveries to Austria, Germany and northern Italy. The KPI monitoring confirmed stable supply performance, high refuelling reliability, and safe operation of hydrogen storage and logistics systems.
For mobility KPIs, the operation of Austria’s first FCE heavy-duty truck achieved 100 % goal achievement, with daily commercial operation, improved reliability, and reduced specific fuel consumption over time. Planned FCE bus KPIs reached 25 % to 75 %, reflecting successful test drives and demonstrations, but also the early termination of long-term bus operation tasks due to external framework changes.

Economic KPIs

Economic KPIs focused on hydrogen production costs, electricity procurement costs, and logistics-related OPEX. Monitoring results confirmed that electricity supply remained the dominant cost driver, accounting for the largest share of levelised hydrogen costs. The KPI “Economic aspects in hydrogen production” achieved 100 %, reflecting the successful development and validation of hydrogen costing approaches, including additional cost elements such as transport, trailer systems, certification and maintenance.
Scenario-based KPI analyses showed that flexible electrolyser operation, sector coupling, and by-product utilisation improved system efficiency, but could not fully offset market risks under volatile electricity prices and regulatory uncertainty (e.g. EAG, RED II / RED III). These KPI results directly informed business-case assessments and the decision to stop P2X Kufstein.

Environmental and System KPIs

Environmental KPIs confirmed a measurable contribution to CO_2 reduction, achieved through substitution of diesel in heavy-duty transport, replacement of fossil heat via waste heat utilisation, and certified green hydrogen production. The KPI "Transformation to a largely CO_2-neutral structure in the energy and mobility sector" reached high fulfilment levels, supported by sector coupling demonstrations and industrial-scale hydrogen logistics.

Sociotechnical and Acceptance KPIs

Acceptance-related KPIs reached 100 % goal achievement, including "Analysis of social and public acceptance", "Workshops & Trainings" and "Public relation activities". Quantitative indicators included numerous workshops, trainings, site visits, guided tours and stakeholder events, while qualitative KPIs showed high stakeholder interest, positive expert feedback, and increased awareness and trust in hydrogen technologies. The KPI monitoring confirmed that hands-on demonstrations and live operation were decisive for acceptance and learning effects.

Overall KPI Performance

Overall, the KPI evaluation confirmed that WIVA P&G HyWest achieved high or full goal fulfilment in most KPI categories, despite changed framework conditions and partial project adaptations. The final KPI results demonstrate that certified green hydrogen production, reliable hydrogen logistics, heavy-duty hydrogen mobility, and sector coupling applications can be implemented under real-world conditions, providing robust, quantified evidence for future hydrogen projects. The KPI framework and results constitute a transferable monitoring approach and reinforce the WIVA P&G Model Region as an internationally visible reference for hydrogen-based energy systems.

7 Conclusions, Outlook and Recommendations

The WIVA P&G HyWest project successfully demonstrated the technical feasibility, operational reliability and systemic relevance of establishing a regional green hydrogen economy under real-world conditions within the Energy Model Region WIVA P&G. Across the project duration, The project delivered certified green hydrogen production, reliable hydrogen logistics, heavy-duty hydrogen mobility, and sector coupling solutions, despite volatile energy markets and changing regulatory and economic framework conditions. A central conclusion is that hydrogen production, storage, logistics and end use can be integrated into existing energy, mobility and industrial systems, provided that flexible operation strategies, robust logistics concepts and continuous stakeholder coordination are applied.
The project achieved high KPI fulfilment in key areas such as green hydrogen logistics and supply reliability (100 %), heavy-duty hydrogen mobility (100 %), economic modelling and cost transparency (100 %), and acceptance and dissemination activities (100 %).
The certification according to TÜV Süd CMS 70 and RED II RFNBO proved to be a decisive enabler for market access, credibility and cross-border hydrogen supply. At the same time, the partial realisation of large-scale P2X infrastructure highlighted the economic sensitivity of hydrogen investments, with electricity prices and regulatory uncertainty remaining the dominant barriers to implementation.

Looking ahead, the results of WIVA P&G HyWest provide a robust foundation for scaling hydrogen solutions, particularly in regions where pipeline infrastructure is not yet available. Trailer-based hydrogen logistics, industrial off-taker integration, and heavy-duty mobility applications are expected to remain key entry points for early hydrogen markets. The P2X Jenbach project, supplemented by the learning outcomes from P2X Kufstein, offers continued opportunities for industrial-scale hydrogen production experience, sector coupling and technology validation, especially in the context of hydrogen-ready gas engines and industrial applications.

Future hydrogen deployment will depend strongly on regulatory clarity, including national implementation of EU frameworks (RED II / RED III), clear rules on electricity cost components and fee exemptions, and stable support mechanisms. Advances in electrolyser technology, cost reductions, and renewable electricity expansion are expected to improve economic feasibility over time, while growing demand from industry and mobility may further support market development.

Based on the WIVA P&G HyWest experience, several key recommendations can be derived:

- Ensure regulatory stability and clarity: Clear, reliable and timely implementation of hydrogen-related regulations (e.g. EAG, RED II / RED III) is essential to reduce investment risk and enable bankable business cases.
- Prioritise certified hydrogen systems: Early integration of certification schemes (TÜV Süd CMS 70, RED II RFNBO) should be considered mandatory for future projects to ensure market access and cross-border compatibility.
- Leverage flexible logistics solutions: MEGC-based hydrogen logistics and modular refuelling concepts should be promoted as effective enablers for early market ramp-up and regional integration.
- Focus on high-impact use cases: Heavy-duty transport, industrial off-takers and sector coupling with waste heat utilisation offer the highest near-term potential for CO_2 reduction and demand build-up.
- Combine demonstration with acceptance measures: Real-world operation, training and stakeholder engagement are crucial for public acceptance, skills development and institutional learning.
- Adopt adaptive project structures: Hydrogen projects should be designed with flexible implementation pathways and risk mitigation strategies to respond to changing market and policy conditions.

In conclusion, WIVA P&G HyWest demonstrates that regional hydrogen ecosystems can be successfully initiated through a combination of technical excellence, economic transparency, adaptive management and strong stakeholder engagement. The project provides transferable lessons and reference use cases that can guide future hydrogen initiatives in Austria and beyond, supporting the long-term transition towards a climate-neutral energy system.

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