NOVEMBER 2026

POSHYDON

Lessons learned from PosHYdon

From integrated design to offshore operation: practical lessons for future demonstration and scale-up projects.



THIS PROJECT IS SUPPORTED BY THE DEMONSTRATION ENERGY AND CLIMATE INNOVATION (DEI+) SCHEME THAT THE NETHERLANDS ENTERPRISE AGENCY (RVO) CARRIES ON BEHALF OF THE MINISTRY OF ECONOMIC AFFAIRS & CLIMATE POLICY

Rijksdienst voor Ondernemend Nederland

This report consolidates the main lessons recorded across the PosHYdon project. It deliberately focuses on transferable learning rather than partner-specific results. Sensitive commercial details and confidential information and results have been generalized.

Consortium note: PosHYdon's Place in the Roadmap:

Integration, Ownership and Making the Journey Happen



PosHYdon is a pioneering offshore hydrogen demonstration project installed on an existing producing oil and gas platform (Q13a-A) that generated practical experience and lessons across the offshore hydrogen value chain, helping to reduce uncertainty for future projects and policy development.

It's true value lies in the role it plays within the broader journey towards a large-scale offshore energy system. The project was established to answer a fundamental question: how offshore hydrogen can become part of a future energy system that integrates renewable generation, existing offshore infrastructure, hydrogen production, transport networks, industrial demand and regulatory frameworks.

PosHYdon represented one of the first crucial steps on a much longer roadmap. The project was designed to move the sector from theory to practice by confronting real-world questions that

could not be answered only through desk studies. How do existing regulations deal with offshore hydrogen production? How can hydrogen be integrated into existing infrastructure? How should responsibilities, liabilities and risks be allocated across multiple stakeholders? How do operators, regulators, infrastructure owners and technology suppliers work together to enable a completely new energy value chain? PosHYdon provided a practical environment in which these questions could be explored and resolved.

A key lesson emerging from the project is that offshore hydrogen is not primarily a technology challenge. Most of the individual technologies needed to produce, process and transport hydrogen already exist. The real challenge lies in integrating them into one functioning system while simultaneously aligning the many parties involved. The most difficult issues encountered throughout PosHYdon were often not located within individual technical packages, but at the interfaces between technologies, organizations, regulations, infrastructure and commercial arrangements.
Successful system integration requires ownership of the whole system. Technical excellence alone is not sufficient. Projects of this nature need a strong end-to-end owner, or system integrator, with both the mandate and the capability to oversee the complete value chain, align stakeholders, manage interfaces, resolve conflicts and take responsibility for the overall outcome. Without such ownership, there is a risk that each organization optimizes its own scope while critical gaps emerge between different parts of the system.

PosHYdon ultimately succeeded because of the exceptional commitment, collaboration, flexibility and perseverance and collective broad and in-depth expertise of all partners involved. When unforeseen challenges arose, parties repeatedly stepped beyond their contractual responsibilities to identify solutions and keep the project moving forward. This collaborative spirit enabled progress where formal project structures alone would not have been sufficient. While this approach can work in a pioneering demonstration project, it is unlikely to be sustainable as offshore hydrogen develops into a commercial market involving larger investments, more stakeholders and greater financial exposure.

For future projects, ownership of the complete system should therefore be explicitly assigned from the start. An organization must be responsible not only for delivering individual components, but for ensuring that the entire value chain functions as intended. This includes technical integration, stakeholder alignment, regulatory engagement, commercial arrangements, operational readiness and long-term system performance. The need for such ownership only increases as projects move from pilot scale to commercial deployment.

The energy transition will not achieved by delivering individual technologies and / or projects. It is achieved by creating functioning systems. PosHYdon shows that building those systems requires a clear long-term vision, a roadmap that extends beyond individual projects, and strong ownership of the complete value chain. By helping to define that roadmap and demonstrating how diverse stakeholders can work together to overcome complex integration challenges, PosHYdon has made an important contribution to the development of offshore hydrogen.

Executive summary

PosHYdon was established to demonstrate MW-scale offshore hydrogen production on an existing existing offshore platform while integrating hydrogen production with existing infrastructure and operating practices. The project demonstrated that existing offshore facilities can be adapted to support hydrogen production, providing practical evidence for the reuse of offshore assets in future hydrogen developments.

Beyond technology demonstration, the project explored how offshore assets, organizations and regulatory frameworks can support the development of an offshore hydrogen sector.

A key finding is that offshore hydrogen is not primarily a technology challenge, but a system integration challenge. The most significant barriers emerged at the interfaces between technology, infrastructure, regulation, permits, contracts and stakeholders rather than within the individual technologies themselves.

The project succeeded through strong collaboration and commitment across the consortium. However, future commercial projects will require a dedicated end-to-end owner or system integrator with the mandate and accountability to align stakeholders, manage interfaces and take responsibility for the overall outcome.

PosHYdon's most important contribution is therefore not only the technology demonstrated, but the pathway it helped create for future offshore hydrogen developments. By providing practical experience with offshore deployment, infrastructure integration, permitting, safety and stakeholder coordination, the project has reduced uncertainty for future projects and helped lay the foundations for large-scale offshore hydrogen production in the North Sea.

Main messages:

1. System integration is crucial

PosHYdon showed that offshore hydrogen production is a highly integrated system rather than a collection of individual components. The electrolyser had to interface with offshore power systems, platform operations, safety systems, gas infrastructure, permitting requirements, and onshore gas network specifications. Decisions made in one area frequently affected multiple others. The project demonstrated the importance of strong interface management, a common design basis, and clear end-to-end ownership to ensure that all technical, operational, and regulatory elements work together as a single operable system.

2. Freeze requirements earlier, but plan for learning

Late clarification of operational philosophy, signals, utilities, explosive atmosphere classification, lifting conditions and offshore requirements created redesign and field modifications. Stage gates should be combined with realistic contingency. While the knowledge on safe design and operational hydrogen systems is largely available, limited experience by stakeholders can create perceptions of risk that affect project execution. Projects should therefore actively plan for learning, confidence building, and stakeholder acceptance.

3. Maximize onshore assembly and testing

Offshore execution is constrained by weather, limited access, and complex logistics. Maximizing modular assembly and integrated testing onshore reduces offshore activities, identifies interface issues early, and improves the efficiency of offshore installation and commissioning.

4. Secure all enabling conditions from the start

The production unit is only one part of a larger system. Infrastructure readiness, gas-quality specifications, certification, permits, power availability, contractual arrangements and downstream acceptance can become critical schedule and cost drivers. Seemingly obvious preconditions should be treated as project deliverables and actively managed and included in the Stage Gate approval and review process from the start.

5. Governance must match technical complexity

Large and complex projects require a structured development approach to progressively reduce uncertainty and support informed decisions on scope, budget, schedule, and quality. This does not always align with subsidy schemes that require early commitments.

Chapter 1

PosHYdon in context

PosHYdon, the Pilot for Offshore Hydrogen Production, brought together fifteen partners to demonstrate a 1 MW-class offshore hydrogen production system on the existing oil & gas production platform Q13-A. The intended value chain combined electricity supply, seawater treatment, electrolysis, hydrogen processing, remote control, injection into existing hydrocarbon infrastructure and transport to shore. The project was supported through the Dutch DEI+ demonstration scheme.

Project ambition

- Demonstrate that H2 can be produced, processed and transported offshore.
- Demonstrate the feasibility of repurposing existing offshore infrastructure towards H2 blending.
- Evaluate the impact of offshore conditions on the integrity, reliability and performance of the H2 production system.
- Evaluate the effects of fluctuating wind power on the performance of the H2 production system.
- Provide research outputs and operational performance data to support future decisions related to large scale H2 production.
- Demonstrate suitability of a consortium model to delivery of complex energy transition projects.

A project delivered across changing conditions

The journey extended from concept development and consortium formation to engineering, onshore integration, offshore installation, commissioning and operational testing. Along the way, the project had to resolve additional challenges due to local grid congestion, offshore qualification questions, permits, downstream facility requirements, gas-quality constraints, enhanced insights on hydrogen pipeline integrity and material performance, and contractual acceptance. These dependencies explain why lessons from PosHYdon are relevant beyond hydrogen technology alone.

The report addresses governance, engineering, QHSE, modular construction, controls, regulation, existing-infrastructure reuse, operations, funding and knowledge sharing.

Chapter 2

Lessons learned – a more generic view

The lessons are organized around the decisions that future projects may need to make. Each lesson therefore answers three questions: what happened, why it matters and what should shall be learned from this. Illustrative cases experienced in PosHYdon, with more details, are described in the next chapter.

2.1. Governance and consortium

A large consortium can mobilize unique capabilities, but organizational cooperation alone is not enough. Technical interfaces, decision authority, risk ownership and financial responsibilities must be equally explicit. PosHYdon consortium included the complete relevant expertise for the project delivery.

A dedicated, solution-oriented team mattered

What happened	Partners responded quickly, maintained short communication lines and used a note-fix-test mentality during integration and commissioning.
Why it matters	Novel projects inevitably encounter scope gaps and unexpected interfaces. Contractual clarity is necessary, but delivery also depends on responsive technical collaboration.
For future projects	Set up an empowered multidisciplinary integration and commissioning team with clear decision rights, rapid issue closure and daily interface coordination during critical periods.

Managing stakeholders throughout the project

What happened	PosHYdon involved a large and diverse group of stakeholders, including consortium partners, operators, regulators, infrastructure owners and funding bodies. During the extended project duration, stakeholders, priorities and external conditions changed, requiring repeated alignment and engagement.
Why it matters	Stakeholder support is changing throughout a long-running demonstration project. Changes in organizations, regulations, responsibilities and external circumstances can directly affect project progress and decision-making.
For future projects	Treat stakeholder management as a continuous project activity. Regularly revisit assumptions, maintain active engagement and anticipate changing stakeholder interests, particularly for parties outside the core project consortium.

Align scope with each partner's natural role

What happened	PosHYdon brought together partners with complementary expertise, but the allocation of project scope did not always fully reflect each party's natural role, mandate and ability to take responsibility for delivery. Some scopes and expectations were not sufficiently clear at the start, including responsibility for interfaces and emerging work.
Why it matters	A consortium is strongest when each partner can contribute where it adds the most value. Aligning responsibilities with expertise, mandate and resources strengthens ownership and reduces unnecessary coordination.
For future projects	Structure the consortium around the capabilities needed to deliver the project. Assign each scope to the party with the appropriate expertise, mandate and resources, and make ownership explicit for activities that cross organizational boundaries.

Establish an overall integrator and owner-user-supplier governance

What happened	The consortium structure addressed cooperation, but technical coordination across equipment packages was less defined. The overall project-management role also evolved during execution.
Why it matters	Without one integrated responsibility, gaps between packages are discovered late and partners optimize their own scope rather than the full system.
For future projects	Appoint an overall project manager and a technical system integrator at the beginning of the project. Establish clear governance by defining owner, user, and supplier roles, change management, escalation routes, and acceptance criteria in the consortium agreement and execution plan.

Make decisions through stage gates

What happened	Final scope and some approvals were not available at the start of assembly. For example, reviews by technical authorities late in design generated additional requirements.
Why it matters	Late decisions shift engineering work into construction, increase pressure on site teams and raise cost and schedule risk.
For future projects	Use formal concept, design, constructability, procurement and readiness gates. Bring vendors, operators, regulators and technical authorities into the reviews before commitments. Align upfront the key deliverables at each gate.

Budget for uncertainty and emerging scope

What happened	As a first-of-a-kind project, PosHYdon encountered additional activities and costs that could not all be foreseen at the proposal stage. At the same time, the DEI+ framework provided limited flexibility to accommodate significant changes to the originally agreed scope and budgets.
Why it matters	Demonstration projects are designed to learn, and learning inevitably creates unforeseen work. Without sufficient contingency, emerging requirements can put pressure on partner budgets, resources and schedules.
For future projects	Include realistic contingency in partner budgets and schedules from the outset, particularly for integration, interfaces and emerging technical requirements. Funding arrangements should also anticipate that first-of-a-kind projects may need to adapt as new insights emerge.

2.2. Engineering and system integration

Start with an integrated design basis

What happened	Industrial package specifications had to be reconciled with asset-owner requirements for an existing offshore platform. User and technical requirements were not always fully defined at the beginning.
Why it matters	Greenfield equipment can be compliant in isolation yet incompatible with brownfield utilities, space, hazardous-area classification, operating philosophy or maintenance practices.
For future projects	Issue an integrated design basis covering offshore environment, process conditions, utility envelopes, codes, QHSE (Quality Health Safety and Environment) hierarchy, control philosophy, maintenance, lifting and end-to-end acceptance.

Define operations at the same time as functional design

What happened	As the project developed, the operational philosophy and control responsibilities became increasingly detailed, requiring the functional design to evolve accordingly.
Why it matters	Bringing operational experience into the design early helps ensure that controls, responsibilities and system functionality reflect how the installation will actually be operated.
For future projects	Define and approve the operations and maintenance philosophy before basic engineering, including the operational responsibilities, such as: remote operation, start-up, shutdown, degraded modes, data ownership, alarm management, and emergency response.

Perform vendor interface agreements early

What happened	As the different vendor packages were brought together, the project progressively aligned communication protocols, signals, utilities and physical connections across the complete system.
Why it matters	Early alignment of vendor interfaces helps packages work together as one system and reduces modifications and re-testing during integration and commissioning, which can lead to additional costs and delays.
For future projects	Establish interface agreements and an interface register during basic engineering. Define signal lists, communication protocols, utility conditions, mechanical tie-ins, battery limits and supply boundaries before fabrication, and keep them aligned as the design develops.

Engineer for the final installation condition

What happened	Additional work was required for container weights, grillage, weather protection, lightning protection and earthing.
Why it matters	A system designed mainly for an onshore test location may not satisfy offshore lifting, structural, environmental and integrity conditions.
For future projects	Verify mass, center of gravity, lifting points, sea fastening, structural loads, corrosion protection, weather exposure, earthing and maintainability before module fabrication.

2.3. Safety, standards and offshore qualification

Offshore hydrogen combines the characteristics of hydrogen equipment with an existing oil-and-gas safety regime. The project found that the challenge was not a lack of safety attention, but the need to reconcile different standards, asset-owner requirements and interpretations early enough to influence the design. Safety qualification also had to cover the complete system, from hydrogen production and injection at Q13a-A to transport through the pipeline and handling at P15.

Establish the applicable standards hierarchy

What happened	Partners used different QHSE standards, while DNV (Det Norske Veritas) and SodM (Staatstoezicht op de Mijnen) assessments required additional work and internal changes.
Why it matters	Conflicting or unclear requirements create redesign and uncertain acceptance.
For future projects	At project start, agree the governing codes, asset-owner specifications, certification route, deviations process and evidence required for final consent.

Use safety studies and a connected design process

What happened	The project used HAZID (Hazard Identification), HAZOP (Hazard and operability study) and LOPA (Layer of Protection Analysis) studies to identify hazards, examine process deviations and determine the required protection layers. The studies generated actions covering venting, hazardous-area classification, gas detection, backflow protection, operating pressure, lifting, maintenance, personnel training and emergency arrangements. The findings were subsequently tracked through a formal action close-out process.
Why it matters	Safety assessment should evolve together with the design. Findings should be translated into practical design, operational and organizational measures, with assumptions revisited as new information becomes available.
For future projects	Build on the PosHYdon approach by treating safety assurance as an integrated and continuous process. Connect safety studies, action tracking and Management of Change throughout design, construction and commissioning, ensuring that new insights are consistently translated into the design and operating philosophy.

Design hazardous area requirements for hydrogen

What happened	Existing electrical equipment on the receiving P15-C installation was generally rated for gas group IIA, while higher hydrogen concentrations could require equipment suitable for IIB+H□ or IIC. The studies also showed that hydrogen could increase the extent of hazardous areas and reduce the effectiveness of methane-based gas detection.
Why it matters	Hydrogen classification can affect lighting, junction boxes, motors, detectors, cable systems and layout. For brownfield facilities, a change in gas group or hazardous-area extent can create a large modification scope. The permitted hydrogen concentration can therefore become a safety-critical design parameter rather than only a process parameter.
For future projects	For new facilities, design for the relevant hydrogen hazardous-area classification from the start. For brownfield assets, document a risk-based deviation and mitigation strategy before procurement.

Use layout as safety control

What happened	Hydrogen detection was required in enclosed areas above possible leak points. Open, high-elevation placement of hydrogen-containing equipment can reduce accumulation risk.
Why it matters	Detection alone should not compensate for avoidable confinement or unnecessary leak sources.
For future projects	Apply inherent-safety principles: minimize flanges, prefer open ventilation, place potential leak sources away from enclosed areas, and integrate gas detection with shutdown and ventilation philosophy.

Treat onshore testing as an operational site

What happened	The onshore integration site required permits to work, security, inspections, procedures, control room arrangements, emergency coordination and practical logistics.
Why it matters	Integrated onshore testing provides a controlled environment to validate the complete hydrogen system, resolve interfaces and build operational experience before offshore deployment. Maximizing testing and issue resolution onshore reduces offshore work and rework, where access, logistics and modifications are typically more complex and costly.
For future projects	For future projects Plan the test site as a temporary operating facility, with clear site authority, QHSE management, insurance, emergency response, storage, customs and dismantling arrangements.

2.4. Modular construction, testing and offshore installation

Build and prove as much as possible onshore, but do not underestimate the engineering, permits, specialist resources and cost required to create a representative integrated test.

Make the onshore test representative

What happened	The full system was integrated and functionally tested onshore, including control and vendor interfaces.
Why it matters	A representative test identifies issues while access is easier and modifications are less costly. It also trains the offshore team.
For future projects	Develop the onshore test plan from offshore acceptance criteria. Replicate utilities, communications, load cases, trips, start-stop sequences and operations.

Measure the system, not only the components

What happened	A power meter was installed to measure total system demand at the onshore location.
Why it matters	The sum of supplier nameplate values may not fully represent integrated demand, start-up peaks or auxiliary consumption.
For future projects	Measure full system electrical demand and transient peaks before offshore deployment. Reserve capacity for controls, water treatment, cooling and other auxiliaries.

Control configuration and traceability through transport

What happened	Modules and parts were tagged to support disassembly, transport and reassembly.
Why it matters	Configuration errors can be introduced when a tested system is split and moved.
For future projects	Use a controlled packing list, photographs, cable and hose identification, preservation records, red-line drawings and a defined recommissioning test after transport.

Modularization reduced offshore exposure

What happened	The system was assembled in tagged modular sections, tested onshore, disassembled and transported for offshore installation.
Why it matters	Offshore time is expensive and operational windows are constrained. Moving work onshore reduces uncertainty and creates a controlled learning environment.
For future projects	Design transportable modules from the start. Include lifting, grillage, cable routing, reconnection, preservation and offshore retest requirements in the modularization plan.

One construction chain improved continuity

What happened	Using contractor support across onshore and offshore activities reduced handovers and enabled knowledge gained during assembly to travel with the installation team.
Why it matters	Handover loss is a major risk when a first-of-a-kind system moves between sites and organizations.
For future projects	Where commercially feasible, contract for continuity across onshore assembly, transport preparation, offshore installation and commissioning, with one point of responsibility.

2.5. Controls, interfaces and operational readiness

Define communication and signal requirements in the design phase

What happened	PosHYdon successfully integrated multiple vendor systems using various communication interfaces. The flexible architecture allowed additional signals and operational requirements to be incorporated as the system design matured.
Why it matters	Flexible interfaces supported successful system integration, while the experience showed that earlier alignment of signals, protocols and control responsibilities can further reduce engineering effort and modifications during commissioning.
For future projects	Define and agree the I/O, communication protocols, control responsibilities and key operational signals during basic engineering. Validate the interfaces through integrated testing and, where appropriate, cross-vendor simulation before deployment.

A scalable supervisory control platform supports integration

What happened	The Emerson DeltaV™ platform successfully provided the supervisory control layer for PosHYdon and proved sufficiently flexible to accommodate evolving requirements during system integration.
Why it matters	A flexible control platform helps integrate different vendor packages, supports learning during demonstration and provides room to accommodate changes as operational experience develops.
For future projects	Select a control architecture that supports both integration and future scale-up. Define clear boundaries between package controls, supervisory control, safety systems and remote operations, while ensuring that cybersecurity and data requirements are addressed from the start.

Preserve standard packages where possible

What happened	Standard supplier equipment was less flexible when late changes were requested. Nel used a black box approach to retain standard third-party certifications inside the electrolyser container.
Why it matters	Excessive customization increases certification, configuration management and long-term support risks.
For future projects	Keep certified vendor packages standard where possible. Adapt at clearly defined external interfaces and identify any required deviation before purchase.

Treat data as a project deliverable

What happened	The pilot depended on operational data for performance, techno-economic and policy learning. Some analyses were limited by unavailable measurements or uncertain tag interpretation.
Why it matters	Missing definitions or measurements reduces the value of the demonstration even when the plant operates.
For future projects	Approve a data-management plan before testing: tag list, units, time synchronization, quality flags, calculated variables, ownership, retention, test metadata and validation responsibilities.

2.6. Permitting, regulation and stakeholder alignment

Map the complete approval chain

What happened	The project required attention to offshore operation, environmental permits, pipeline use, gas quality, equipment certification and receiving facilities.
Why it matters	Different authorities and asset owners govern different segments. One unresolved approval can block the complete supply chain.
For future projects	Create a regulatory and assurance register in concept phase, including competent authority, legal basis, evidence, decision date, dependencies and owner for each approval. Include legal advisors in the team at an early stage.

Engage regulators and independent verifiers early

What happened	As the first offshore green hydrogen production project integrated into an operating Dutch gas-production platform, PosHYdon required extensive interaction with both DNV as independent verifier and SodM as competent authority. Existing offshore oil-and-gas regulations had to be interpreted for hydrogen production, hydrogen injection into natural gas, modified hazardous area classifications, venting arrangements and the use of new equipment on an existing installation.
Why it matters	Projects that combine new hydrogen technologies with existing offshore infrastructure operate at the intersection of multiple regulatory frameworks. Technical compliance alone may not be sufficient. Regulators and verifiers must be confident that the project demonstrates an equivalent or improved safety level compared to existing offshore operations.
For future projects	Engage regulators, classification bodies and independent verifiers from the concept phase onwards. Agree early on the verification scope, required studies, acceptance criteria and documentation expectations. Allow time for iterative reviews and clarification requests, particularly where hydrogen-specific guidance is limited or where existing oil-and-gas requirements need to be interpreted for new applications.

Engage authorities before procurement

What happened	The sector and authorities needed time to assess offshore hydrogen risks, while additional studies and design evidence were requested during execution.
Why it matters	Late clarification can invalidate purchased equipment or delay construction and operation.
For future projects	Use pre-application meetings and an agreed evidence plan. Share the concept, hazards, deviations and proposed risk controls early, and record decisions and open points.

Use proportionate, risk-based demonstration pathways

What happened	Existing rules were often applied case by case and prescribed limits did not always fit an emerging concept.
Why it matters	Demonstrations need flexibility to generate evidence, but safety, environmental protection and system integrity must remain explicit.
For future projects	Develop a time-limited demonstration pathway with defined operating envelope, monitoring, stop criteria, independent assurance and a route for translating evidence into future guidance.

Coordinate regulation with third-party acceptance

What happened	Formal consent did not by itself resolve all commercial and liability concerns of parties connected via the downstream infrastructure.
Why it matters	A technically and legally permissible activity may still be blocked when third parties perceive unmanaged exposure.
For future projects	Run regulatory, technical-integrity, insurance, liability and commercial workstreams in parallel. Identify every affected party, including those outside the consortium, during the initial risk assessment.

2.7. Existing infrastructure, blending and downstream acceptance

Reuse of offshore infrastructure can reduce the need for new assets, but it expands the project boundary. Hydrogen injection affects the producing platform, export pipeline, receiving platform, gas processing, measurement, contracts, connected producers and the gas-entry specification. PosHYdon therefore demonstrates that infrastructure reuse is as much an interface and governance challenge as a technical question.

Confirm the full transport route before FID (Final Investment Decision)

What happened	Pipeline integrity, receiving facility readiness, gas entry limits and third-party liabilities remained critical dependencies.
Why it matters	Assuming that unresolved issues will close during execution can leave a completed production unit without an accepted export route.
For future projects	Before FID (Final Investment Decision), obtain a route-to-operation decision for every segment. Quantify residual risks, define alternatives and include the cost and learning impact of each fallback.

Model mixing and low-flow cases

What happened	Numerical flow analysis by means of CFD (Computational Fluid Dynamics) found good hydrogen-natural-gas mixing in the assessed cases, but slower mixing and possible upstream diffusion or local accumulation at low flow. Horizontal injection was preferred.
Why it matters	Design based only on nominal flow can overlook start-stop and declining production conditions.
For future projects	Assess maximum and minimum carrier gas flows, start-stop transients, dead legs, vertical sections and injection orientation. Use results to define operating limits and detector or purge requirements.

Apply mixture-specific safety factors

What happened	Mixtures up to the assessed hydrogen fractions behaved closer to natural gas than pure hydrogen in several combustion aspects, but ignition energy was lower and the flammability range increased.
Why it matters	Neither pure hydrogen nor pure natural gas assumptions alone capture all relevant hazards.
For future projects	Base risk assessment on the actual composition and credible concentration range, adding safety factors for ignition, flame speed and flammability where appropriate.

Plan metering and certification early

What happened	Low concentration hydrogen measurement and green gas certification required specialist protocols and calibration arrangements. Limited calibration capability created schedule risk.
Why it matters	Measurement is necessary for safety, allocation, certification and claims of renewable value.
For future projects	Define the measurement concept, uncertainty, calibration traceability, data protocol and certification process during design, not shortly before operation.

2.8. Project controls, funding and commercial arrangements

Map the complete approval chain

What happened	The DEI+ framework supported the pilot however changes to the scope were difficult within the framework. This made scope evolution and a gated development approach challenging to accommodate.
Why it matters	Innovation needs learning-driven changes, while public funding needs transparency and control. Both requirements must be designed into the plan. This balance may remain a challenge.
For future projects	At the proposal stage, align assumptions, decision gates, change scenarios, and contingency mechanisms with the funding authority, and make partner risk exposure and responsibilities explicit.

Do not reach FID with unresolved enabling conditions

What happened	Power capacity, material integrity, downstream acceptance and other dependencies had an impact on the project, schedule/budget.
Why it matters	A project may complete expensive hardware and at the same time still missing the conditions needed to operate and learn from testing.
For future projects	Use an Final Investment Decision readiness checklist covering utilities, permits, route to market, integrity, liability, insurance, certification and operating organization.

Keep risk quantification connected to cost and schedule

What happened	The project faced additional engineering, lease-extension costs, scarce remaining contingency and time limited access to power and facilities.
Why it matters	Qualitative risk registers are insufficient when delays directly create rental, mobilization and project extension costs.
For future projects	Quantify risk exposure, time dependency and learning impact. Update the forecast after each major decision and escalate when contingency is no longer adequate.

Early visibility built support

What happened	PosHYdon maintained visibility through industry events, technical presentations, partner communications and continuous engagement with relevant stakeholders.
Why it matters	For a long-running first-of-a-kind project, continued engagement helps stakeholders understand the project's progress, challenges and broader relevance, even when timelines and circumstances change.
For future projects	Treat communication and stakeholder engagement as continuous project activities. Communicate progress and challenges openly, share learnings as they emerge, and keep the project's longer-term purpose visible throughout the journey.

Government support enables learning beyond the project

What happened	PosHYdon received public support through the DEI+ program, enabling the consortium to undertake a first-of-a-kind demonstration in a highly regulated offshore environment.
Why it matters	Many project activities generated value beyond the immediate project scope, including permitting experience, regulatory learning, infrastructure assessments, safety studies and stakeholder engagement. These benefits support the development of the broader offshore hydrogen sector but are difficult to capture within a single commercial business case.
For future projects	Early-stage system integration projects require committed public support and a long-term perspective. Funding mechanisms should recognize the value of demonstration, learning and risk reduction alongside direct technical results.

Chapter 3

PosHYdon Learning Through Doing – Illustrative Cases



Case 3.1. The Onshore Test Site Became a Hydrogen Plant

Before offshore installation, PosHYdon was fully assembled, integrated and operated at the InVesta test facility in Alkmaar, the Netherlands. The objective was not only to verify individual components, but to demonstrate the performance of the complete integrated system under realistic operating conditions before deployment offshore.

What happened

The onshore test phase evolved into much more than a factory acceptance test. The project team had to establish many of the elements normally associated with an operational industrial facility, including site security, fencing, access control, camera surveillance, insurance arrangements, fire brigade involvement, permit-to-work procedures, operational procedures, environmental permits (e.g. for noise and venting H2), inspections, control room activities and startup and shutdown operations.

The site was used to assemble, integrate and test the complete hydrogen production system, allowing the project team to validate interfaces, operating procedures and system behavior before offshore installation. The campaign also provided practical experience with logistics, storage, customs processes, equipment deliveries, packing lists and transport preparation.



Why it matters

The experience demonstrated that integrated system testing cannot be treated as a simple commissioning activity. Once a complete hydrogen production facility is assembled and operated, many of the requirements associated with a permanent operating installation also apply. The onshore integration phase played a critical role in identifying technical and organizational issues before offshore deployment, where modifications would have been significantly more expensive and difficult to implement. At the same time, it provided operators, contractors and project partners with practical experience that improved readiness for offshore installation and operation

Lesson learned

Integrated onshore testing should be planned and managed as a temporary operating facility. Project planning should include operational procedures, safety management, security arrangements, logistics, permitting, emergency response and stakeholder coordination from the outset. The onshore integration phase represents a critical step in demonstrating the complete system, building operational experience and reducing risk before installation offshore. By choosing the onshore test first, the offshore start-up went very smoothly.

Case 3.2. Increasing the Permitted Hydrogen Blending Limit from 0.02 mol% to 0.5 mol%

One of the most significant non-technical challenges encountered by PosHYdon was obtaining acceptance for hydrogen in the existing natural gas value chain.

At the time of the project, Dutch gas quality regulations allowed a maximum hydrogen concentration of only 0.02 mol% in the gas entering the transmission network (Staatscourant 2021, 20909 | Overheid.nl > Officiële bekendmakingen). The PosHYdon concept envisaged offshore hydrogen production on Q13a-A, transport via the existing offshore gas infrastructure to platform P15, and eventual delivery to the onshore gas system. This meant the existing regulatory limit became a critical project constraint, as the expected H2 concentration would increase up to 0.5 mol% depending on the operational strategy of the electrolyser system.

To increase the permitted concentration in the natural gas pipeline, the engagement with all the relevant stakeholders took place; Ministry of Economic Affairs and Climate Policy, gas network owners and operators, end users of the natural gas. Each of the parties involved had different responsibilities, risk perceptions, contractual interests, and concerns regarding gas quality and system integrity. As a result, achieving alignment required extensive coordination, evidence sharing, and stakeholder engagement until the permission was granted. The process lasts approx. 1 year.

What happened

To obtain approval, the consortium and the stakeholders involved had to demonstrate that increasing the hydrogen concentration would not adversely affect downstream infrastructure, gas quality, allocation and balancing systems, contractual arrangements, connected producers, or end users. This required a series of technical studies, risk assessments, and extensive consultations with the Ministry, network operators, infrastructure owners, and other stakeholders across the gas value chain. Based on the evidence provided and alignment achieved between the involved parties, approval was ultimately granted to increase the permitted hydrogen concentration from 0.02 mol% to 0.5 mol% H_2.

Why it matters

Although the increase from 0.02 mol% to 0.5 mol% seems small, it represents a 25-fold increase in the accepted hydrogen concentration. This was a major achievement because it demonstrated that:

- Gas quality rules can be adapted based on evidence,
- Technical studies can support regulatory flexibility,
- The real challenge is often stakeholder acceptance rather than pure technical.

The case showed that technically feasible solutions may require additional time where evidence, acceptance and alignment are needed across multiple parties in the gas value chain.

Lesson learned

The limiting factor for hydrogen integration was not the electrolyser or the pipeline. It was the need to align regulatory requirements, gas quality standards, infrastructure operators, commercial partners and authorities around a common level of acceptable risk. Depending on the landing point, the stakeholder network could be less or more complex.

Case 3.3. From Q13a-A to P15-C: Qualifying an Existing Pipeline for 20 mol% Hydrogen

One of the key questions in PosHYdon was whether existing offshore gas infrastructure could safely transport hydrogen. To transport hydrogen from offshore platform Q13a-A to P15-C, the project relied on the existing 20+ km oil and gas pipeline, where hydrogen concentrations could reach approximately 20 mol% H_2. This required a detailed assessment of the pipeline's suitability for hydrogen service.

What happened

A comprehensive integrity assessment was performed for the pipeline, covering hydrogen-material interaction, fracture toughness, fatigue crack growth, pipeline stresses, pressure containment, free-span behavior and vortex-induced vibration. The assessment was supported by testing of pipeline material samples at a specialized facility in the UK, a process that took more than three months. The study concluded that the pipeline could safely accommodate the assessed hydrogen blend under the defined operating conditions and trial duration.

Why it matters

PosHYdon demonstrated that reuse of existing gas infrastructure is an opportunity. Pipeline suitability cannot be determined solely by hydrogen concentration limits. Asset condition, material properties, fatigue behavior, operating history and hydrogen-specific degradation mechanisms must all be understood before transport can be considered acceptable. At the same time, the successful qualification of the showed that existing offshore infrastructure can support early hydrogen deployment, potentially avoiding the cost and complexity of entirely new transport systems.

Lesson learned

Existing pipelines should be qualified for hydrogen service through a comprehensive, asset-specific integrity assessment rather than assumed suitable based on availability or historical service. Early involvement of integrity specialists, testing facilities and regulators is essential when developing hydrogen transport solutions that depend on existing infrastructure.



Case 3.4. Seawater Filtration, Operational Reliability and the Limits of Unmanned Operation

One of the objectives of PosHYdon was to demonstrate reliable offshore hydrogen production with minimal operator intervention. The concept relied on seawater as the primary feed source, which was treated by the Hatenboer water-treatment system before being supplied to the electrolyser.

What happened

During offshore operation, rough sea conditions combined with the relatively near-shore location of the platform resulted in high concentrations of sand, suspended solids, biological material and other debris entering the seawater intake system. Filter fouling occurred significantly faster than anticipated at Q13a-A.



The automatic self-cleaning filter was unable to cope with the contamination load and entered backflush mode approximately every minute. As a result, water flow to the PosHYdon treatment system became unstable and the inlet pressure repeatedly dropped below the required operating range of the Hatenboer unit.

This had consequences beyond a routine maintenance issue. Frequent manual cleaning was required to maintain operation, automatic operation could not be sustained, and prolonged low inlet pressure created a risk of damage to the internal pump. As a result, the system could not be reliably operated in an unmanned mode and was ultimately placed in an idle state while mitigation measures and operational alternatives were evaluated.

Why it matters

The experience demonstrated how strongly offshore system performance can depend on local and changing environmental conditions. Supporting systems such as seawater intake and filtration can temporarily become the limiting factor for the entire production system, even when the hydrogen production equipment itself performs as intended.

Lesson learned

Feedwater preparation should be treated as a mission-critical function and designed for the range of environmental conditions expected at the specific offshore location, including periods of rough weather and elevated sediment or debris loading. Future projects should characterize seasonal seawater conditions, provide sufficient filtration capacity and redundancy, monitor fouling performance, and demonstrate autonomous operation under representative conditions before transitioning to an unmanned operating philosophy.



Case 3.5. Hydrogen Venting: When the Learning Objective Becomes the Permitting Challenge

A central objective of PosHYdon was to produce and transport green hydrogen through existing offshore infrastructure. When downstream transport through the P15 route became uncertain, the consortium had to explore alternative pathways to complete the pilot and preserve its learning objectives. This led to an extensive assessment of offshore hydrogen venting and alternative hydrogen disposition options.

The project started from the principle of eliminating hydrogen venting wherever possible. Following an extensive assessment, this proved not to be feasible. The project therefore compensated for the limited emissions.

What happened

Following challenges associated with transporting and processing hydrogen downstream of the Q13a-A platform, the consortium evaluated no fewer than 17 alternative options, including offshore storage, hydrogen transport by vessel, dedicated pipelines, flaring, conversion to chemicals, reconversion to electricity, relocation of the pilot and offshore venting.
The assessment concluded that, within the project schedule, budget and learning objectives, venting hydrogen directly from the Q13a-A platform was the only realistic fallback option. However, this required a permit amendment and extensive justification to demonstrate that venting represented the BAT (Best Available Technique) under the specific circumstances of a time-limited demonstration project.

The project team prepared detailed environmental, technical and regulatory assessments comparing venting with alternatives such as hydrogen flaring. These studies showed that although flaring could reduce direct hydrogen emissions, it would introduce significant additional complexity, costs, NOx emissions, safety studies and new equipment with installation and decommissioning impacts. The estimated implementation time for a flare solution exceeded one year and could not realistically be accommodated within the remaining project timeframe and boundaries.

The permitting process involved an exceptionally rigorous and thoroughly substantiated assessment of the relevant environmental, safety, and operational considerations. It addressed environmental impact, greenhouse gas equivalence, operational safety, project objectives, alternative technologies, public perception and

the value of learning generated by the pilot. The permitting process lasted more than 6 months.

Why it matters

PosHYdon demonstrated that permitting innovative projects often requires assessing the broader system context rather than a single technical decision. What initially appeared to be a question of whether hydrogen could be vented became a much wider exercise in balancing environmental impact, technical feasibility, safety, costs, planning constraints and project value.
The case also highlighted that regulators, operators and project developers may be operating in areas where practical experience is limited. As a result, significant effort may be needed to build confidence, evaluate alternatives and establish a shared understanding of risks and benefits. The challenge was therefore not only technical but also institutional.
Perhaps most importantly, the exercise demonstrated that preserving the learning objectives of a first-of-a-kind project can sometimes require solutions that differ from those that would be selected for a long-term commercial facility.

Lesson learned

The greatest challenge was not demonstrating that hydrogen venting could be done safely, but obtaining acceptance that it was an acceptable solution. Technical evidence alone was insufficient. Public perception, regulatory caution, environmental considerations and the limited operational experience with hydrogen all influenced the discussion.
PosHYdon showed that first-of-a-kind hydrogen projects must actively address stakeholder confidence and societal acceptance alongside technical and regulatory requirements. Building trust, explaining the rationale behind decisions and communicating the broader value of the learning objectives can be as important as the underlying engineering analyses.

Case 3.6. Demonstrating Dynamic Offshore Hydrogen Production

One of the key objectives of PosHYdon was to demonstrate the ability of an offshore electrolyzer system to operate under variable power conditions representative of renewable energy sources. In addition to testing steady-state operation, the project also executed a series of test profiles designed to evaluate system performance under dynamic load conditions, including startup and shutdown sequences.

What happened

During the offshore pilot campaign, the PosHYdon system successfully operated under a range of operating conditions, including steady-state operation, load changes, start-up sequences, and shutdown procedures. A series of dynamic operating profiles was developed to emulate the power fluctuations expected from a real-world renewable electricity source, particularly offshore wind. These profiles allowed the project to evaluate the response of the integrated hydrogen production system under representative future operating conditions. The integrated system, consisting of the electrolyser and supporting balance-of-plant equipment, was able to follow predefined operating profiles while maintaining stable and safe operation..
The campaign also generated valuable operational data on system behavior during startup, load changes and shutdown events, providing insights beyond what could be obtained from laboratory or factory testing.

Why it matters

Future offshore hydrogen production is expected to be increasingly linked to renewable electricity sources such as offshore wind. As a result, electrolysers must be capable of operating flexibly rather than continuously at a fixed load. PosHYdon demonstrated that dynamic operation is technically feasible in a real offshore environment. Importantly, the successful execution of the



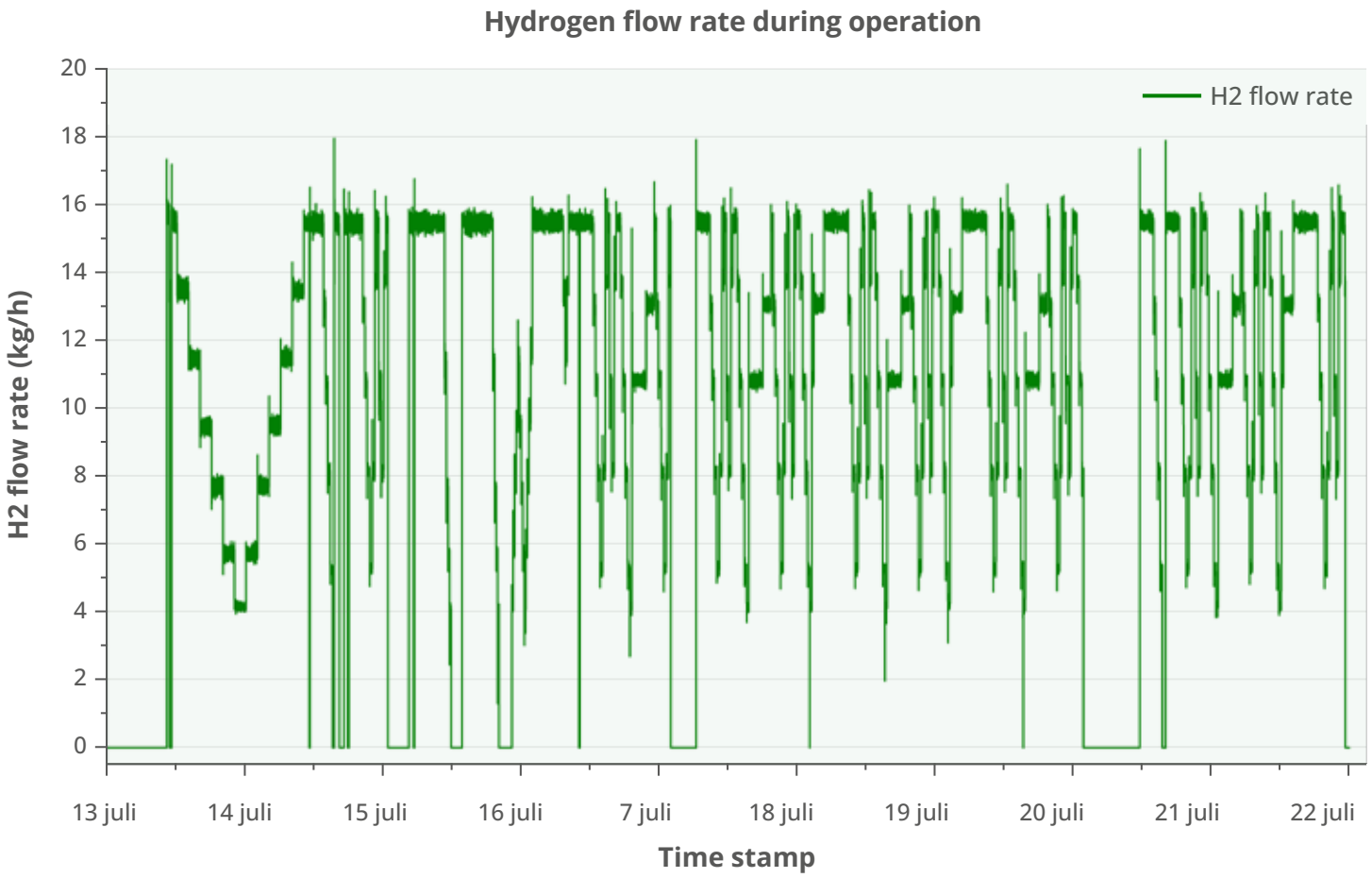
test profiles showed that system performance depends not only on the electrolyser stack itself, but also on the ability of supporting systems such as water treatment, cooling, controls and power electronics to respond to changing operating conditions. The test campaign therefore provided confidence that offshore electrolysis can support future energy systems where production must adapt to changing power availability.

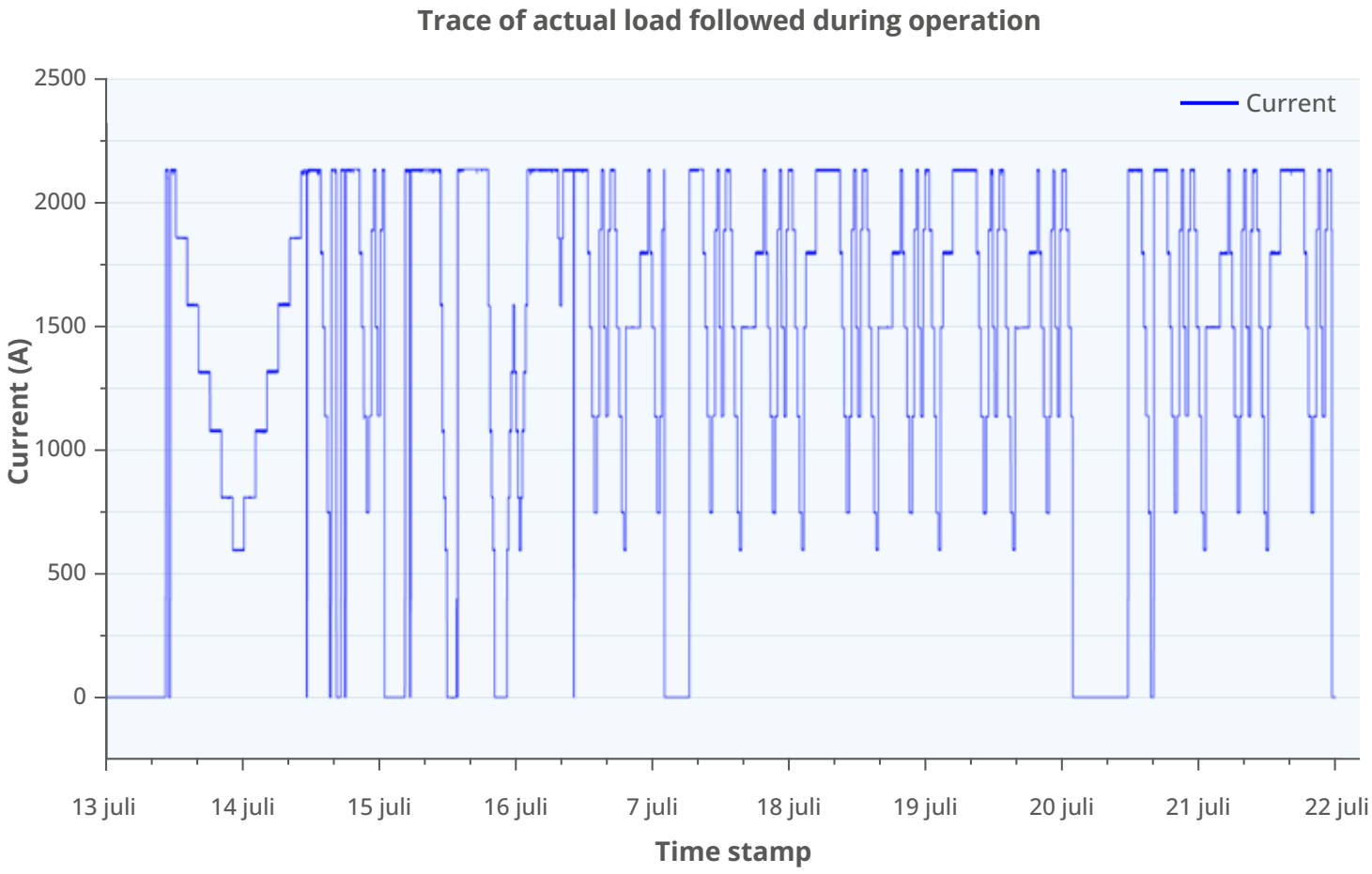
Lesson learned

Dynamic operation should be assessed at the level of the complete system. Future projects should include extensive testing of start-up, shutdown and load-following behavior under realistic operating conditions and monitor interactions between the electrolyser and balance-of-plant systems.

The project also demonstrated the importance of a well-designed (including placement) instrumentation and monitoring strategy. Obtaining meaningful insights into system performance requires the careful placement of sensors throughout the process to accurately measure key operational parameters such as temperature, pressure, flow rates, power consumption and process flow purity. Instrumentation requirements should therefore be considered from the early design stages of projects, as adequate sensor coverage is key to diagnose operational behavior, identify performance losses and validate system performance.

In addition to this, the efforts for harmonizing data collection, transfer and analysis should not be underestimated, especially in future projects when there are multiple owners of various subsystems.


Hydrogen flow rate during operation
H2 flow rate
H2 flow rate (kg/h)
20
18
16
14
12
10
8
6
4
2
0
13 juli
14 juli
15 juli
16 juli
7 juli
18 juli
19 juli
20 juli
21 juli
22 juli
Time stamp


Trace of actual load followed during operation
Current
Current (A)
2500
2000
1500
1000
500
0
13 juli
14 juli
15 juli
16 juli
7 juli
18 juli
19 juli
20 juli
21 juli
22 juli
Time stamp

Conclusion

PosHYdon brought together a unique combination of expertise from across the offshore, energy and hydrogen sectors to achieve something that had never been done before. Through close collaboration between industry, knowledge institutes, regulators, infrastructure operators and government, the project successfully transformed an ambitious concept into a functioning offshore hydrogen demonstration. Throughout the project, partners remained committed to a shared objective, working together to overcome technical, operational, regulatory and organizational challenges that could not have been solved by any single organization alone. The project's success reflects not only technical expertise, but also the determination and resilience of all partners to stay the course when circumstances became challenging.

The most lasting contribution of PosHYdon is the experience and confidence it has created for the sector as a whole. The project generated valuable knowledge on offshore hydrogen production, infrastructure reuse, safety, permitting, system integration and operational performance. Equally important, it demonstrated the value of open collaboration, mutual trust and a willingness to learn together. The lessons captured in this report provide a strong foundation for future projects and help pave the way towards large-scale offshore hydrogen deployment. PosHYdon shows that when industry, government and knowledge partners work together around a common ambition, innovation can move beyond concepts and become reality.

POSHYDON

THIS PROJECT IS SUPPORTED BY THE DEMONSTRATION ENERGY AND CLIMATE INNOVATION (DEI+) SCHEME THAT THE NETHERLANDS ENTERPRISE AGENCY (RVO) CARRIES ON BEHALF OF THE MINISTRY OF ECONOMIC AFFAIRS & CLIMATE POLICY

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