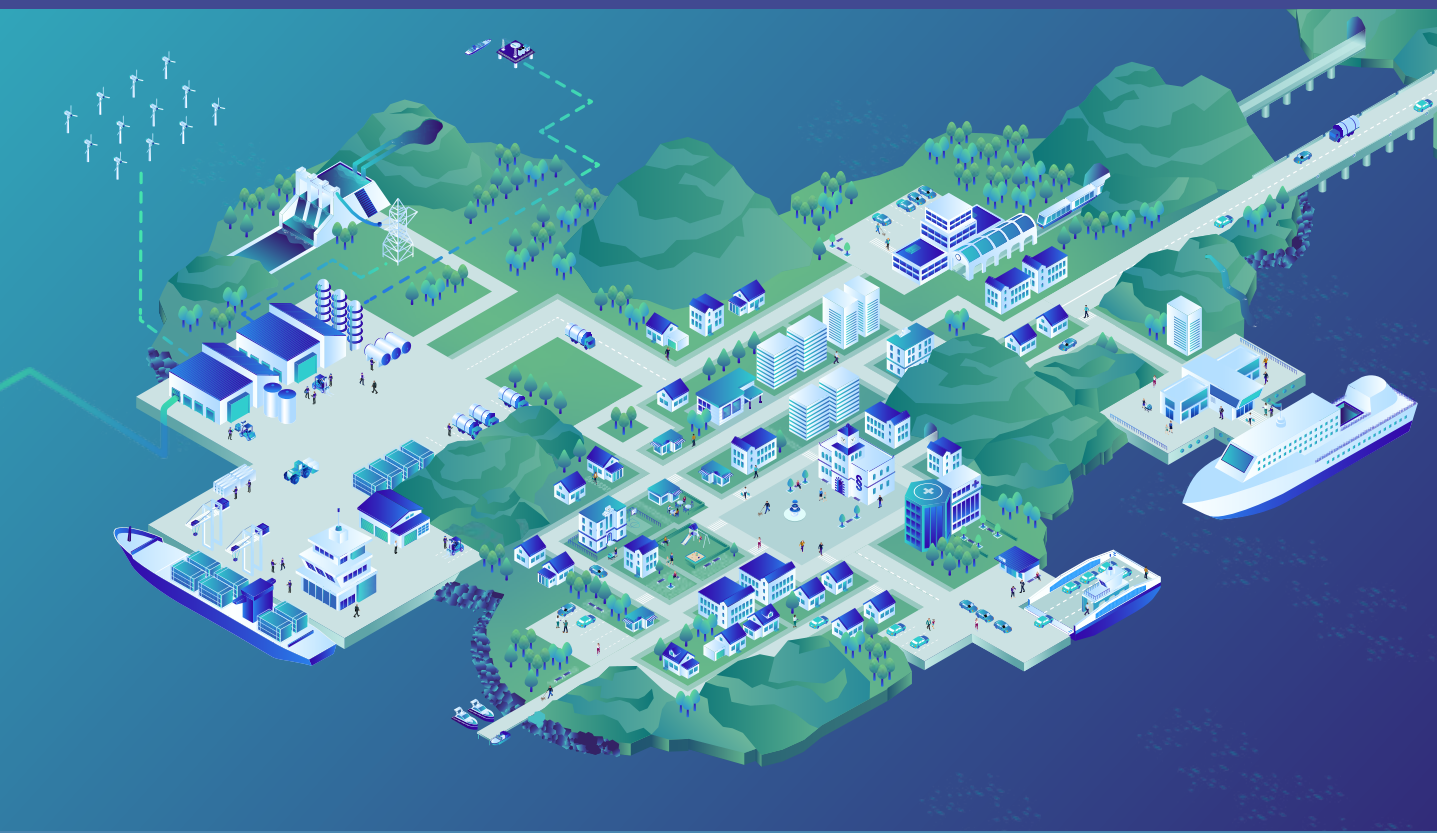
Annual Report 2024

HyValue

Norwegian Centre for Hydrogen Value Chain Research



HyValue

Norwegian Centre
for Environment-friendly
Energy Research

Table of Contents

FRONT PAGE ILLUSTRATION **HALTENBANKEN**

DESIGN **HALTENBANKEN,** MODIFIED BY **NORCE**

Dear Readers

Hydrogen, produced with minimal electricity and no CO_2 emissions, is crucial for a sustainable future. It will be a key energy carrier, fuel, and industrial input, replacing fossil fuels. FME HyValue aims to support this transition and ensure it is safe.

HyValue brings together universities, institutes, industrial companies involved in hydrogen production, transport, or use, and public sector representatives. The research covers new production methods, storage and transportation solutions, hydrogen use cases, safety and risk evaluations, social impact, and hydrogen value chains, safety and risks evaluations, and social impact and finally, hydrogen value chains.

Now in its third year, HyValue has recruited eleven doctoral students, four postdoctoral fellows. More than eighty researchers are working in the project, and nearly thirty master's and ten bachelor's students have also contributed. In 2024, several seminars, workshops, and webinars were held, which will continue in 2025. These events are key for learning, networking, and collaboration among HyValue partners.

HyValue is now at full operational speed and I believe there will be many exceptional results emerging over the next few years. I trust that the centre will contribute significantly to the growth and implementation of hydrogen value chains as part of the green transition.

Aasgeir Valderhaug
Director R&D in Elkem
Chair of the Board

Summary of 2024

FME HyValue has in 2024 picked up the pace. Important research results are emerging and good progress is being made towards achieving the centre goal of achieving sustainable hydrogen value chains.

Of particular importance for energy- and cost savings is the development of novel and more energy efficient hydrogen production methods, including photocatalysis and methane pyrolysis. Research on the latter has been strongly complemented by industry efforts. Electrolytic production of hydrogen from fluctuating power sources has been evaluated, and solutions for hydrogen production and transport using power from offshore wind have been studied. This development is complemented by studies on regulating the sea and coastal geography, with sector coupling as a key study area. Ocean wave-prediction based energy-optimisation of fuel cell / battery powered vessels at sea is being developed, taking also into account component degradation and lifetime. Ongoing studies on use of system theory and strength of knowledge models for evaluating safety are important for safe implementation, and studies of collaboration and competition law are linked to the development of sustainable business models. Understanding the interaction between society and technology implementation and the maturity of this relation, “socio-technical embeddedness”, is being studied through multiple case studies and stakeholder interviews. Finally, how European politics and policies shape hydrogen value chain development has been analysed, discussing also actor strategies.

HyValue has a continuously growing number of related projects, complementing the research areas of FME HyValue. There is also continuous development of research infrastructure, exemplified here by the UiB robotic high-througput experimentation facility and also implementation of research tools, exemplified by the AI-based chemical comparative tool of benefit for development of new catalysts.

External outreach has been achieved through participation in national and international events and conferences, with the European Hydrogen Week in Brussels and the FME conference in Trondheim as key highlights. Public dissemination has been achieved through multiple articles and popular science presentations.

All of these efforts are reported on here, and an extensive list of publications is provided for those who wish to read further, covering these efforts in detail and more.

The HyValue Centre Management

The HyValue Centre Management Team (CMT) runs the day-to-day management of the centre. The CMT consists of the Centre Director, the Deputy Director, the Centre Coordinator, as well as administrative support from the host institution NORCE.

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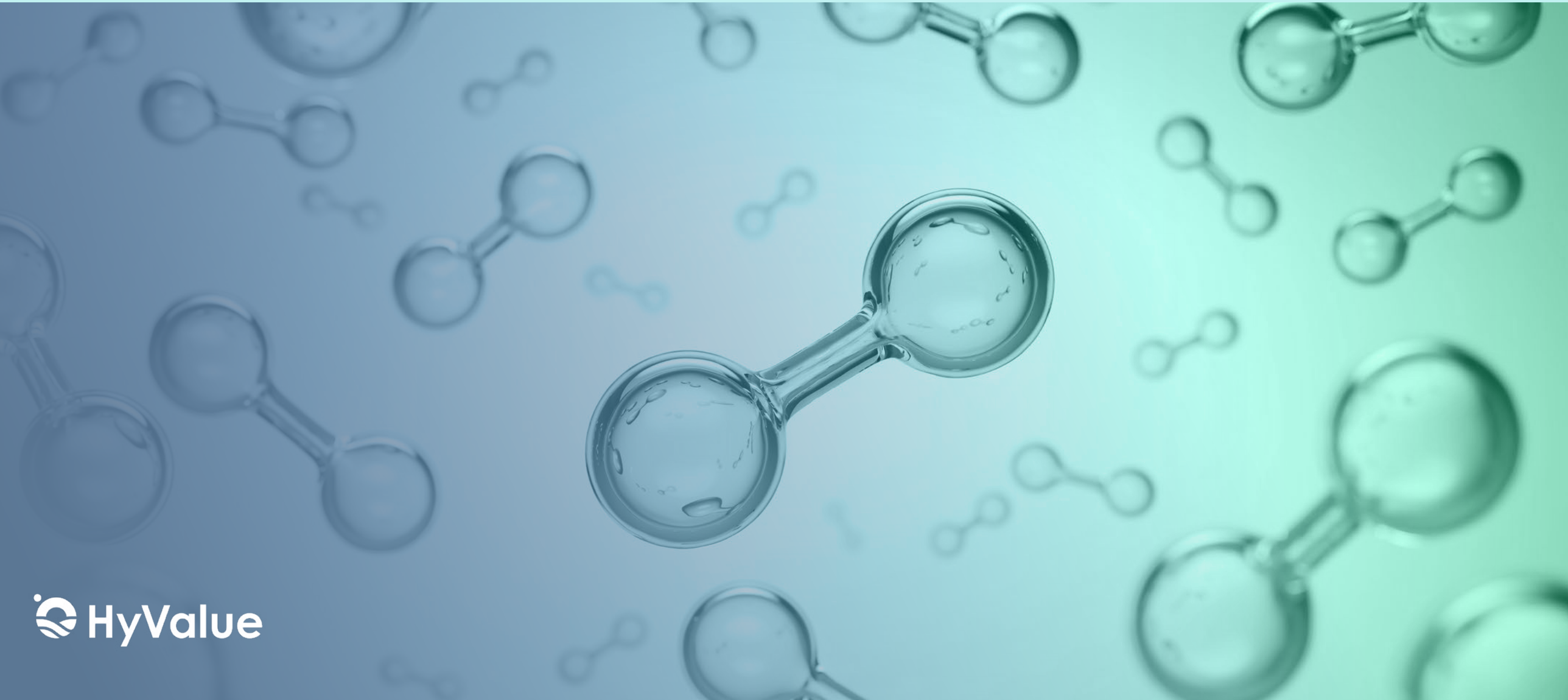
Menu

Overview



Overview

HyValue works to make sustainable hydrogen value chains possible through technology, knowledge and competence development.

The HyValue research centre brings together a broad cross-disciplinary consortium of national and international research partners with cutting-edge expertise in hydrogen related technical, economic, legal and societal fields of research. Our vision is “Achieving sustainable hydrogen value chains for a zero-emission economy”.

Our research spans from exploring new, energy-efficient methods for producing hydrogen and ammonia, to maturing the hydrogen sector as a technical system in society. HyValue provides new knowledge to assess and improve risk assessments for hydrogen transport systems and value chains. Equally important is our research on economic and regulatory barriers. The scientific work at the centre is organised in six work packages (WP1–WP6), where interdisciplinary collaboration is crucial to finding the right solutions.

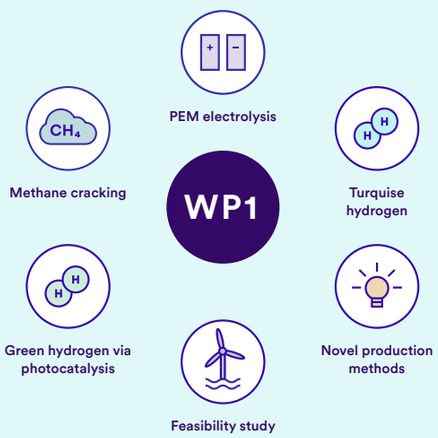
HyValue shall

1. Significantly reduce energy loss, CO_2 emissions and cost of hydrogen and ammonia production.
2. Develop cost-efficient solutions for transport, storage and distribution of hydrogen and ammonia for export and at regional scale.
3. Solve technical challenges for transition to zero-emission economy, including maritime transport and operations and industrial production.
4. Develop novel frameworks for assessing and improving the strength of knowledge in risk assessments for hydrogen and ammonia systems.
5. Explore synergies and dilemmas between economically viable, socially inclusive, and environmentally sustainable socio-technical systems for hydrogen.
6. Identify economic and regulatory barriers and propose incentive structures to accelerate implementation of a hydrogen-based energy sector.
7. Maximise impact through communication, dissemination to stakeholders and education.

WP1: Novel Production Methods

Grand challenge: Current methods of producing hydrogen and ammonia are energy-intensive and contribute significantly to carbon emissions, either directly through CO_2 or indirectly through energy loss. Inefficient production processes also increase costs.

In WP1 we develop new catalysts and materials beyond the state of art for the hydrogen production processes. In doing so, HyValue benefits from the team's competitive advantage in the development and use of predictive computational methods, including the sole de novo method experimentally validated in design of inorganic molecules, to reduce the time and cost of materials and catalyst discovery. Promising predictions are followed up by high-throughput synthesis and testing, accelerating the discovery. The new catalysts and materials will feed into the process-development tasks, facilitating breakthroughs in novel H_2 and NH_3 production methods.



Involved research partners:

UiB, HVL, NORCE, UiS

WP leaders:

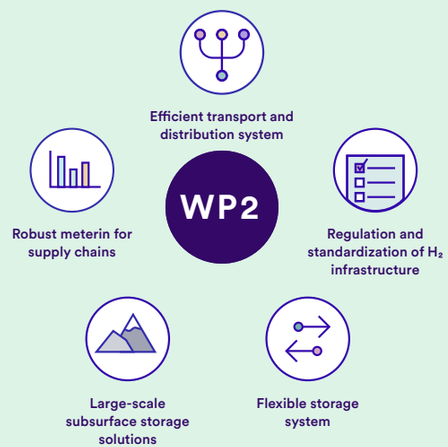
Prof. Vidar Jensen, UiB

Prof. Dhayalan Velauthapillai, HVL

WP2: Storage and Distribution

Grand challenge: Supplying pressurized and liquid hydrogen and ammonia to the end-user presents unique technical challenges, while ensuring safety and preventing accidents requires appropriate regulations.

In WP2 we work on solutions for transport and storage, including development of robust and cost-efficient measurement of hydrogen along the supply chain. Laboratory experiments serve as a basis for process simulation and development of numerical models, and equipment development and testing is performed in close cooperation with vendors and end-users. Further, development of governance structures and assessment of necessary regulatory framework for reutilization of existing gas infrastructure for hydrogen & ammonia is performed through a multidisciplinary approach combining technical disciplines with societal and legal sciences.



Involved research partners:

NORCE, UiB, UiS, TNO

WP leaders:

Senior Researcher Nematollah Zamani, NORCE

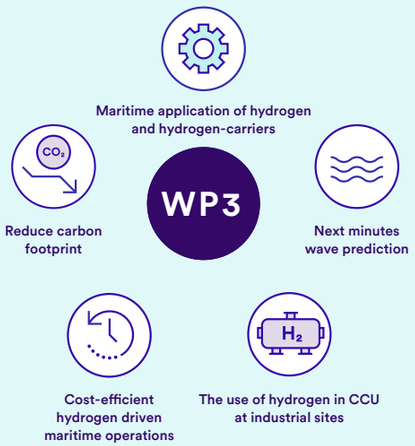
Chief Scientist Kjetil Folgerø, NORCE

WP3: End User Applications

Grand challenge: The current market for hydrogen and ammonia primarily serves industrial users. Expanding to new sectors such as transport and heating is challenging and costly, requiring high-demand segments to catalyze the establishment of scale and value chains.

In WP3, we address energy efficiency, cost and carbon footprint, with a particular focus on improving efficiency of fuel cell systems and engine technology. We develop ocean wave prediction to optimize ship control with respect to fuel consumption and fuel cell wear, and further investigate how to reduce the carbon footprint through cyclic solutions, such as replacing the coal used in silicon production with the carbon bi-product from hydrogen production. Data is collected from real-life scenarios, including input from centre user partners, and studies are conducted as laboratory or computer experiments.

End User Applications



Involved research partners:

NORCE, HVL, MIT, NHH, SNF

WP leaders:

Senior Researcher Geir Nævdal, NORCE

Assoc. Prof. Jonathan Økland Torstensen, HVL

WP4: Safety Science and Risk

Grand challenge: Expanding the use of hydrogen and ammonia requires comprehensive systems knowledge and effective tools to measure performance in terms of safety, emergency response, and regulations. However, existing risk models are inconsistent and with high uncertainty, making for poor strength of knowledge.

In WP4 we develop methods for simulating, evaluating and understanding the impact of safety risks in hydrogen and ammonia value chains, including explosion, fire and spreading of toxic gases. Event frequencies and associated uncertainties are evaluated with respect to key parameters, as exemplified in the research results section. Large-scale experiments are further planned for exploring accident scenarios, which will enable development of more accurate safety models for improved risk assessment.

Safety Science and Risk

Involved research partners:

UiS, UiB, NORCE, NHH, FZJ

WP leaders

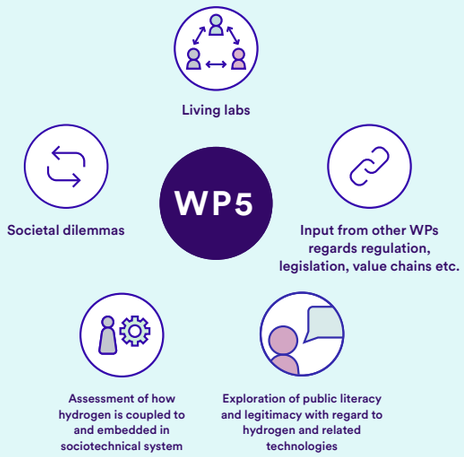
Prof. Jon Tømmerås Selvik, UiS

Prof. Trygve Skjold, UiB

WP5: Societal Impact and Embeddedness

Grand challenge: The hydrogen energy sector is an immature socio-technical system, where minor flaws and failures can jeopardize stakeholder trust and system integrity. Strategies to build confidence and resilience are crucial.

In WP5, a sociotechnical and political-economic approach is combined with institutional theory to understand and develop mitigating strategies to overcome key societal barriers and build trust. The Societal Embeddedness Level (SEL) methodology is particularly valuable for assessing societal conditions to be in assessed before deploying a technological innovation. Triangulation of societal science methods is essential in WP5, and important for co-creation of new and transdisciplinary insights on energy transitions towards sustainability.



Involved research partners:

HVL, NORCE, TNO

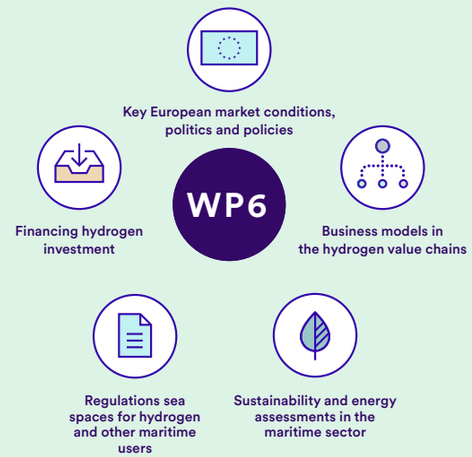
WP leaders

Prof. Lars Martel Antonie Coenen, HVL

Senior Researcher Kari Kjestveit, NORCE

WP6: Integrating Hydrogen in Value Chains

In WP6 input data from all HyValue work packages is integrated to provide new legal, financial, political sciences and economic knowledge directed to facilitate new hydrogen value chains. We resort to modern law and institutional economics: that green innovation and business could be driven by a carbon price only, that complementary investments in value chains shape business models, regulation and finance, and that knowledge and development is geo – and agglomeration dependent. The legal dogmatic method will be used to identify and interpret legal sources at different levels and legal issues will be discussed through law in context perspectives. Finally, we apply a double functional comparative method, in connection to other countries as well as comparing solutions found in the governance of other energy sources.



Involved research partners:

NHH, UiB, TØI, FNI, SNF, TNO, PIK

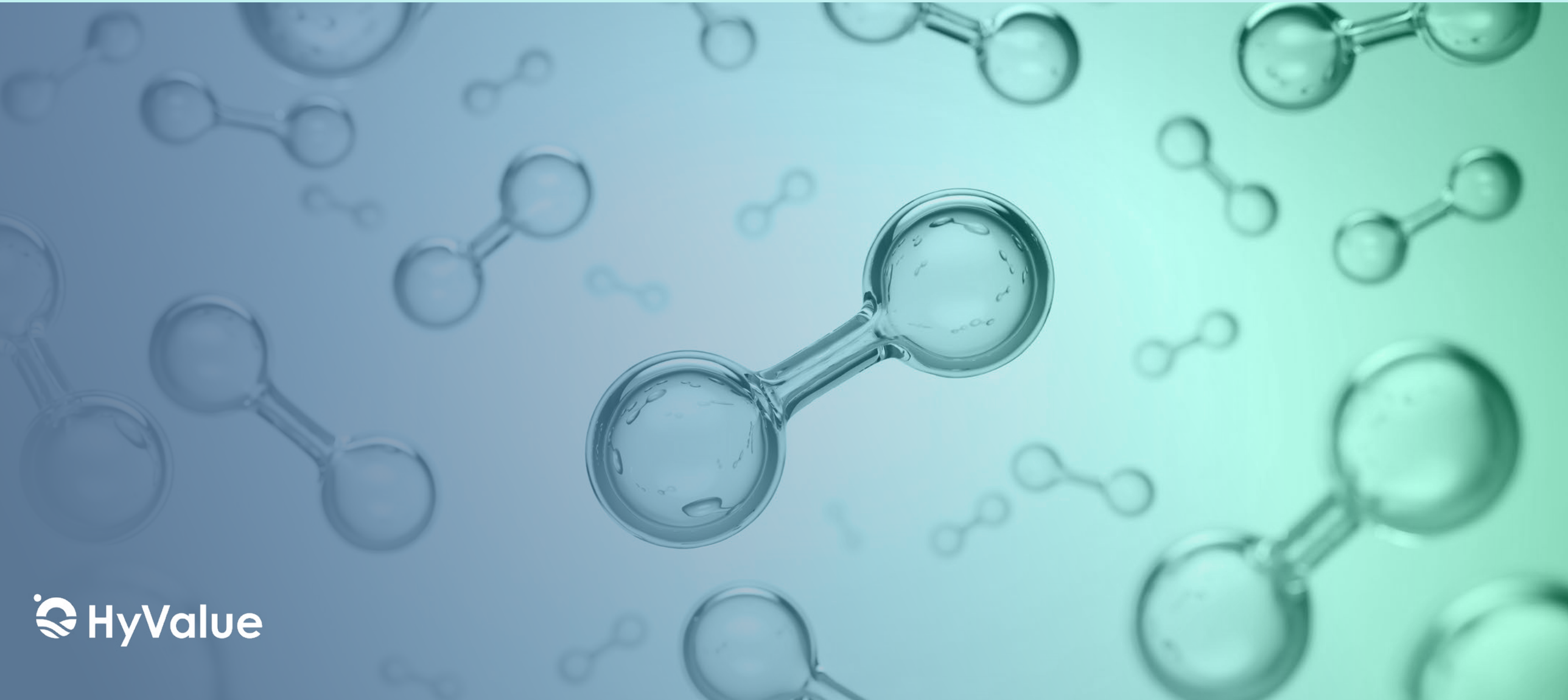
WP leaders

Prof. Gunnar S. Eskeland, NHH

Prof. Ignacio Herrera Anchustegui, UiB

Menu

Research Highlights 2024



HyValue

Hydrogen production from sunlight

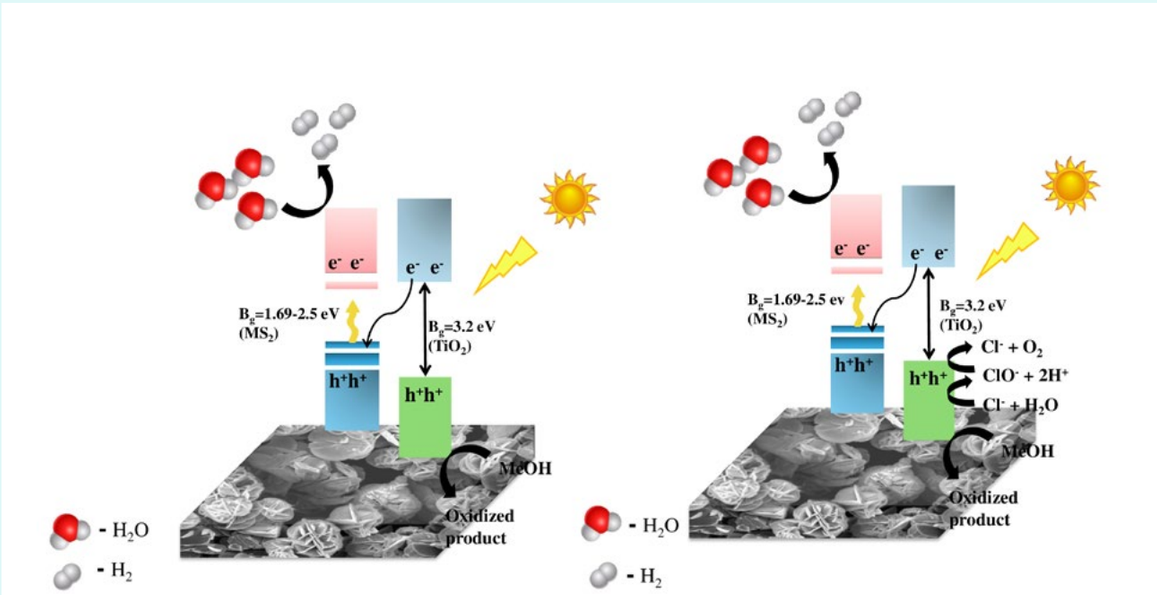
Photocatalytic (PC) and photoelectrochemical hydrogen production (PEC) use the direct energy of the photons in sunlight in combination with catalytic materials to split water into hydrogen and oxygen. The potential savings from PC and PEC applications are huge. As the sunlight is used directly, the operational power cost for production is zero, compared with traditional electrolytic hydrogen production in Norway at a cost of 1.92 per kg hydrogen at 2023 industry power rates, representing 46% of total hydrogen production cost[1]. Further, the development of noble-metal-free materials as catalysts, costing down to 0.1% of the traditional materials, greatly impacts the capital expenditure. Although still requiring significant development and scaling, such solutions have great potential in solving the challenge of hydrogen competitiveness towards 2040 and beyond.

Combinations of metal dichalcogenide-embedded titanium dioxide (NiS_2/TiO_2, CoS_2/TiO_2, SnS_2/TiO_2) nanocomposite materials have been in focus in development. Sets of these materials have been successfully synthesized, optimized and used both for PC and PEC applications. Our lab scale studies show promising results on the stability and the amount of Hydrogen produced per gram of material. These materials perform well also as electro catalysts for hydrogen production.

Two HyValue studies published clearly demonstrate that low-cost, noble-metal-free nanocomposite photocatalysts could be promising candidates for realizing efficient solar-to-hydrogen conversion from fresh water, saltwater and seawater splitting.

For state of the art, the efficiency of these processes is low due to

- use of only a limited range of the whole solar spectrum
- recombination of the electrons and holes which drive the splitting process
- stability of the catalytic materials
- challenges in separation of the produced hydrogen and oxygen



Schematic diagram for the catalytic mechanism of MS_2/TiO_2 nanocomposite in Deionized water (a) and simulated seawater/seawater (b)

[1] European Hydrogen Observatory https://observatory.clean-hydrogen.europa.eu/

Shanmugaratnam, S.; Ravirajan, P.; Yohi, S.; Velauthapillai, D. Well-Separated Photoinduced Charge Carriers on Hydrogen Production Using NiS_2/TiO_2 Nanocomposites. ACS Omega, 9, 1627-1633 (2023).

Shanmugaratnam, S.; Swathi, S.; Yuvakkumar, R.; Oltedal, V.M.; Ravirajan, P.; Shivatharsiny, Y.; Velauthapillai, D. MS_2/TiO_2 (M = Co, Sn and Ni) electrodes for electrocatalytic and photocatalytic water splitting. Fuel, 385, 134101 (2024).

Shanmugaratnam, S.; Ravirajan, P.; Velauthapillai, D.; Shivatharsiny, Y. Photocatalytic hydrogen production through water splitting on $NiCo2S_4/TiO_2$ nanocomposite over extended solar irradiation. 28th Annual Technological Advances in Science, Medicine and Engineering Conference (TASME), University of Toronto (2024).

Shanmugaratnam, S.; Shivatharsiny, Y.; Ravirajan, P.; Velauthapillai, D. Green hydrogen production through seawater splitting on MS_2 (M=Ni/Co/Sn)/TiO_2 nanocomposites. H_2 science international Conference (2024)

Electrolytic hydrogen production

Hydrogen production from fluctuating power

A student project has examined hydrogen production from a fluctuating power output of a potential small-scale hydropower plant, in an area with limited grid connection. Various electrolyzer capacities, 1 MW, 3 MW, and 5 MW, were examined through simulation to identify the most suitable option for the hydropower plant.

The 3 MW electrolyzer was found to be the best compromise, considering both optimal utilization of the power and costs, giving a total production of hydrogen in the range of 117-194 tons pr year. Levelized Cost of Hydrogen was found to be 70.90 NOK/kg in a year with median power production. This case study shows how hydrogen can utilize renewable energy that might otherwise be trapped due to infrastructure limitations

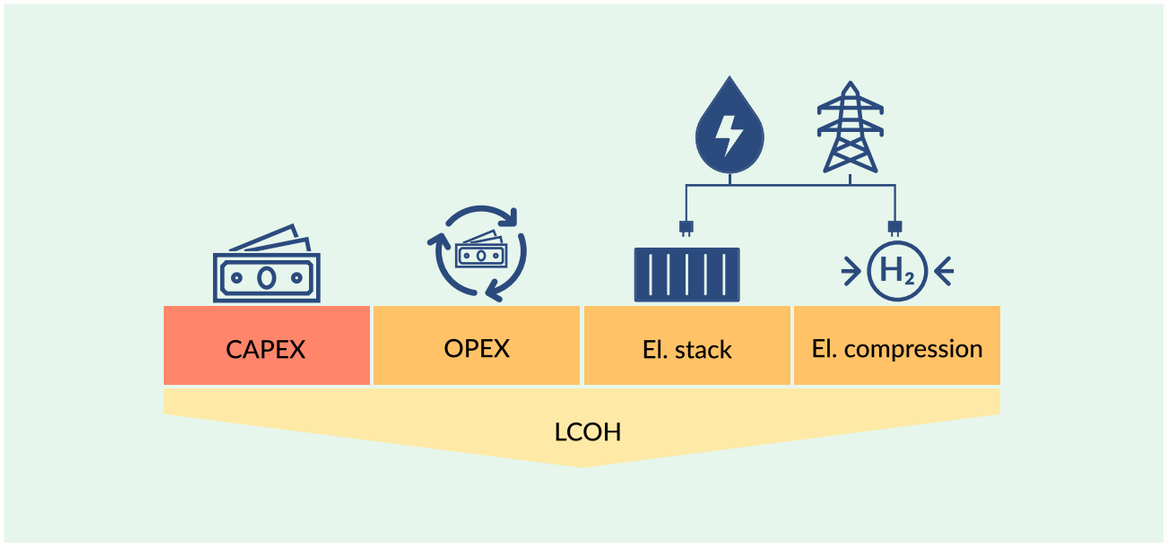


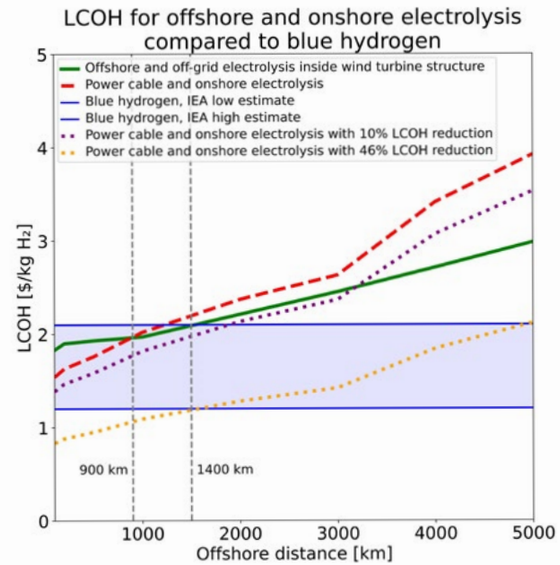
Figure from Kamilla Hagen, MSc thesis, UiB/HVL 2024.

Kamilla Valla Hagen. Hydrogen production from fluctuating small-scale hydropower. Master thesis, UiB/HVL (2024).

Green hydrogen from off-shore wind

Another topic of study has been the cost of transporting hydrogen, both in general and in the specific case of transporting hydrogen from offshore wind farms compared to transporting electricity. A general cost estimation model for transporting hydrogen was developed, including different transport methods, rates and distanc-es. A techno-economic analysis of hydrogen production and transport from offshore wind farms was performed, and this was compared with the default scenario of electricity transport from offshore wind farms.

The results indicate that offshore hydrogen production and transport will be more expensive than transporting electricity and producing hydrogen in an onshore grid-connected system, as long as the offshore distance is below ap-proximately 900 km. However, there are large uncertainties within this topic and further work must be done before any definite conclusions can be made.



LCOH comparison from "Electricity transport vs. hydrogen production from future offshore wind farms", Egeland-Eriksen and Oosterkamp, 2024.

Egeland-Eriksen, T.; Oosterkamp, A. Electricity transport vs. hydrogen production from future offshore wind farms. Proceedings of the Thirty-fourth (2024) International Ocean and Polar Engineering Conference - ISOPE 2024, 4353-4359 (2024).

Turquoise hydrogen

Pyrolytic hydrogen production (using heat) from methane can be achieved by thermal, catalytic and plasma methods. This process differs from methane reforming, in that pyrolysis splits the methane molecule into hydrogen and solid carbon, hence also known as cracking, while the reforming process involves chemical reaction with water (or steam), thereby also producing CO_2. Depending on the price of electricity used in the pyrolysis and the cost of methane or natural gas, current estimates for turquoise hydrogen production are down to below 1€/kg (if cyclic economy is exploited)[1], while electrolytic hydrogen production in Norway for 2023 is estimated at 4.2€/kg hydrogen[2]. Hence, turquoise hydrogen has great potential. However, challenges remain with respect to gas separation due to residual methane in production, process scaling, catalytic materials for improved efficiency, and process optimization. All of these areas are studied in HyValue.

Methane pyrolysis offers several advantages:

- Clean hydrogen production: Traditional methods like steam methane reforming emit over 10kg CO_2 per kg of hydrogen.
- Energy efficiency: Methane pyrolysis is more energy-efficient than electrolysis. Electrolysis uses more than 50 kWh/kg of hydrogen, while pyrolysis uses less than half of this energy (e.g. https://doi.org/10.1016/j.ijhydene.2022.10.144).
- Carbon byproduct: Pyrolysis produces three kg solid carbon per kg of hydrogen. This carbon can be used in industries such as Norway's metallurgical sector, which uses one million tons of coal and coke annually.

[1] https://www.hydrogeninsight.com/production/turquoise-hydrogen-can-be-produced-for-1-kg-in-us-and-middle-east-using-existing-technology-says-study/2-1-1760552

[2] European Hydrogen Observatory https://observatory.clean-hydrogen.europa.eu/

Thermal pyrolysis

The thermal pyrolysis process involves heating methane or natural gas to high temperatures, usually above 760°C, without oxygen. This breaks methane into hydrogen gas and solid carbon through chemical decomposition.

Thermal pyrolysis of methane has been tested in UiS laboratories, where production of hydrogen and solid carbon was observed, but only a small percentage of the methane was converted at the test temperatures below 800oC, which is the limit for these facilities.

From the results is may be concluded that we need higher temperatures than 800oC and/or development of catalysts for reducing the temperature of reaction.

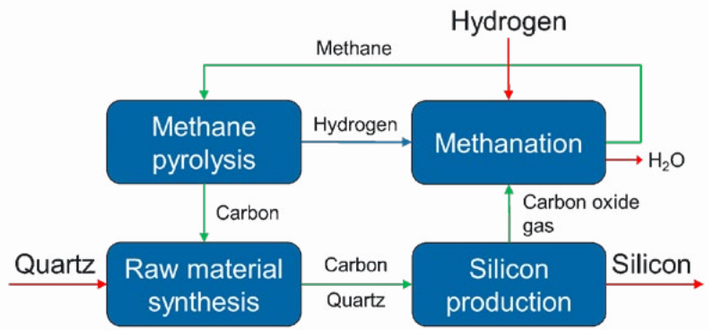
HyValue user-partner Elkem is currently considering making a new reactor which can be used to investigate thermal cracking at higher temperatures, but the focus at UiS now on development and testing of catalytic materials (which lower the cracking temperature) for improving the efficiency of thermal cracking of methane.

User-partner development

Methane Pyrolysis: A path to clean and energy-efficient hydrogen and sustainable silicon.

Elkem is exploring how carbon from methane pyrolysis can replace fossil coal in silicon alloy production, potentially reducing CO_2 emissions by 30%.

Elkem is also developing Elkem Sicalo®, a new silicon production concept that eliminates direct CO_2 emissions and external carbon reduction materials. The process captures carbon from off-gas, recycles it using hydrogen, and reuses it as solid carbon to produce silicon. Methane pyrolysis is a key part of this concept.

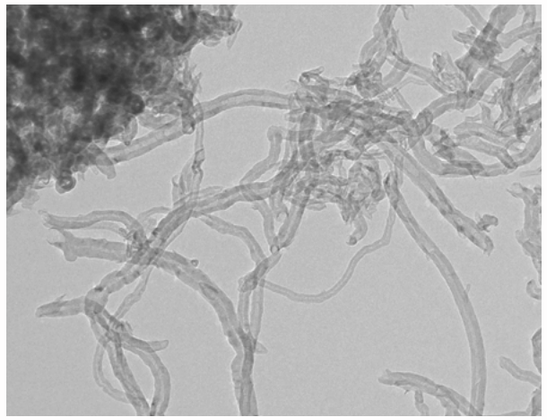


Silicon production without CO_2 emissions. The figure illustrates the Elkem Sicalo® concept, showing silicon production without CO_2 emissions, where hydrogen indirectly replaces fossil carbon. The carbon looping principle applies to all carbothermic metal production processes.

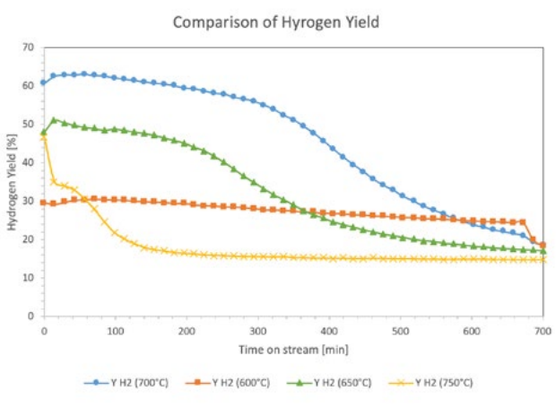
Catalytic pyrolysis

Catalytic cracking with Ni-based catalysts has been tested at UiS laboratories at temperatures of 600-700oC, showing reasonable activity for H_2 production, with carbon nanotubes as a bi-product. A series of hydrotalcite derived catalysts have been developed based on bimetallic Ni/Fe for methane cracking. These have been used in experimental studies, optimizing process conditions for maximum hydrogen yield and carbon quality.

A maximum hydrogen yield of over 60% was achieved in the study (with 100% representing conversion of all methane), but such yield is not sustainable, due to expenditure / deactivation of the catalyst over time. Catalyst deactivation rate also increases for temperatures above 700oC, impacting yield. This again illustrates the challenge with respect to durability of catalysts, as is also the case for photocatalysis. Work on optimizing the catalytic methane cracking process will continue throughout the centre duration.



Carbon nanotubes produced in methane cracking process



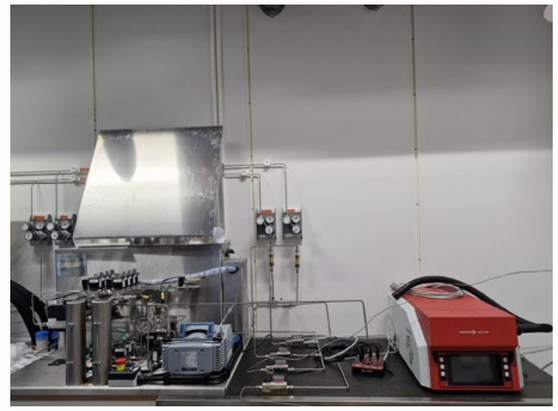
Hydrogen yield for catalytic methane cracking studies.

Gas separation

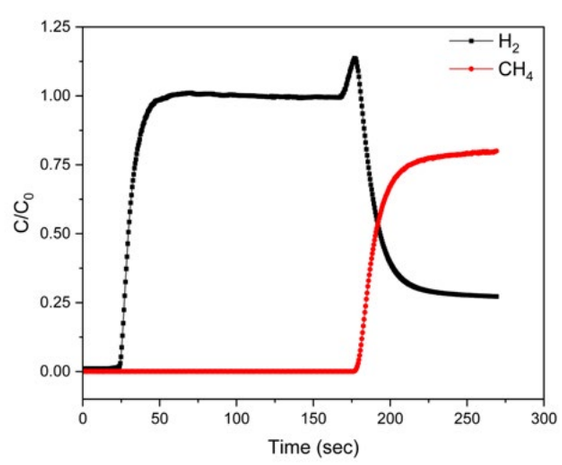
Existing methane cracking methods (aka turquoise hydrogen production) have limited hydrogen yield, resulting in residual methane. Hence the hydrogen and methane need to be separated for production of high-quality hydrogen. This is also the case for “blue” hydrogen production through the traditional steam methane reforming (SMR) process, requiring separation of the resulting $H_2/CO_2/CH_4$ mix with subsequent use or storage of the produced CO_2.

At UiS, a pressure swing adsorption (PSA) system has been installed for use in gas separation studies for improving efficiency of the current gas separation methods for turquoise and blue hydrogen. For measurement of separation efficiency, exit concentration (breakthrough) measurements for relevant gas mixtures can be obtained with this setup.

A commercially available high surface area carbon adsorbent for gas mixtures is currently being tested in the PSA setup. Initial results are promising, while a better understanding of efficiency will be gained from modelling of the results.



Pressure swing adsorption system for gas separation



Breakthrough measurements using adsorption system. C_0 is initial concentration, C is exit concentration.

Plasma pyrolysis

In the project ColdSpark, HyValue user-partner SEID is developing plasma pyrolysis of methane. In this process, pyrolysis is performed at low temperatures through application of electrical energy, turning the methane into plasma, consisting of electrons, ions and neutral atoms. These particles subsequently recombine to form hydrogen molecules and solid carbon.

There is a close synergy between this effort and the research on gas separation being performed at UiS in HyValue. This is because all the methane is not turned into plasma, so there will be residual methane. Therefore, the produced hydrogen needs to be extracted from the resulting hydrogen / methane mix.

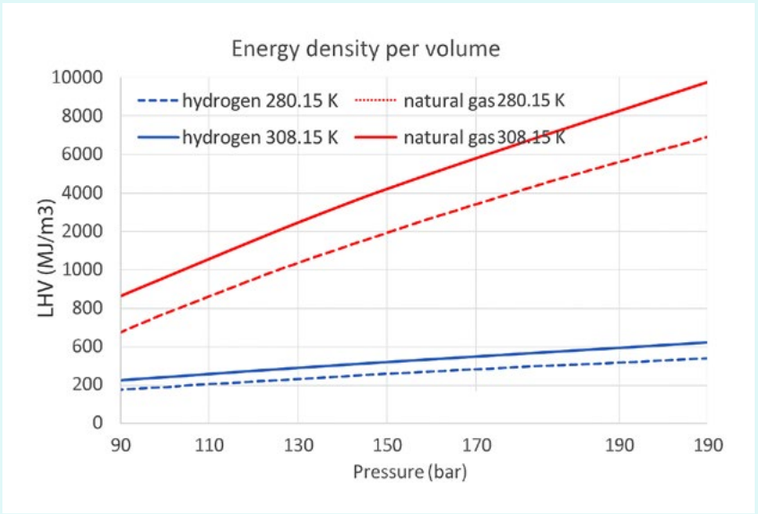
The ColdSpark methane plasma pyrolysis technology is in an early stage of maturity (TRL 5 to 6) with a current focus on process optimization and scaling. Current development involves improving energy- and cost-efficiency of the hydrogen production and increasing solid carbon production capacity, and thereby the circular economy element. Efforts are ongoing in collaboration with several HyValue partners to generate funding for further development and industrial scaling of the ColdSpark technology.

SEID methane plasma pyrolysis laboratories

Pipeline transport

Flow assurance of offshore hydrogen pipelines has been studied by modelling the dynamic behavior of such pipelines and comparing the results with natural gas pipelines. The results show notable differences in the dynamic flow properties of the two gases, for example in fluid density and viscosity.

The flow velocity of hydrogen in pipelines would have to be 3-5 times higher compared to natural gas to transport comparable energy quantities.



Energy density comparison from “Flow assurance of offshore hydrogen pipelines – a review”, Oosterkamp and Egeland-Eriksen, 2024.

Oosterkamp, A.; Egeland-Eriksen, T. Flow assurance of offshore hydrogen pipelines - a review. Proceedings of the Thirty-fourth (2024) International Ocean and Polar Engineering Conference - ISOPE 2024, 4360-4367 (2024).

Energy efficiency and cost optimisation

In ongoing work, the future wave pattern around a ship, and resulting wave force on the ship, is predicted using radar measurements of the sea combined with analytical mathematical wave models. These predictions may be used to minimize the power (ship load) required to maintain ship position or path through pro-active use of the ship's propulsion system, thereby saving fuel and cost. These predictions of required power can be used also in management of a hybrid fuel cell–battery drive, taking into account the response time of fuel cells. In knowing what future power requirements of the system may be, the combined fuel cell–battery system may be further optimized with respect to system lifetime through distribution of fuel cell / battery load, as both fuel cells and batteries degrade as a function of how they are used. Hence, the work on wave and ship-load prediction has high relevance for hybrid fuel cell - battery vessels.

The RIMARC software which this effort is building on, has been developed by NORCE and MIT Ocean Research. This system predicts wave patterns, wave forces and vessel motions for the next 4-8 minutes using measurements from standard X-band navigation radars.

In HyValue, a WaveLab with a Furuno radar has been established on the top of the NORCE office building in Haugesund. Power variation in waves and vessel motions will be measured on a test vessel, for which Response Amplitude Operators RAO (a function calculating forces on the ship as from the sea) are calculated using MIT Ocean Research QBEM software, performed also in HyValue, thereby enabling onboard next minutes predictions of wave forces and ship motion.

The combined HyValue, HyEff and RIMARC development clearly illustrates the great opportunities in development across HyValue and parallell projects, strengthening overall effort. Testing of application of wave and ship load prediction is being performed in HyValue. A commercialization project is being carried out for implementation and integration of RIMARC in existing and new ship monitoring and control applications, including decision support systems. Finally, fuel cell-battery system control is being developed in the parallell HyEff project in collaboration with UC Berkeley to enable control optimization of fuel consumption and FC-battery system lifetime, linking to RIMARC through prediction of forces on the ship.

Wave prediction development team. Leonid Vasilyev, Svein Olav Halstensen, Victoria Zinchenko, NORCE and Yuming Liu, MIT.

Regulation and law

Safety regulation

A phd-study by Brynhil Stavland on “Safety Regulation in the context of large-scale implementation of hydrogen as an energy carrier” has been finalized and is now being reviewed by the evaluation committee. One of the conclusions from that work reads: “The results suggest that theoretical perspectives beyond the realm of what is conventionally considered regulatory theory can add valuable analytical insights into regulatory matters. In other words, systems theoretical perspectives can be useful to gain an overview of the actors, responsibilities, and gaps in the regulatory framework, while knowledge quality assessment frameworks can be utilised by regulators who are tasked with navigating various sources and forms of knowledge in the development of regulatory requirements.” The phd-work presents and discusses frameworks for assessing quality of knowledge in relation to hydrogen regulation, and selection for suitable regulation strategy involving hydrogen systems.

PhD candidate Dikshya Bhandari and postdoc Ingrid Glette-Iversen, respectively, are continuing studies on use of system theory and strength of knowledge, which will support implementation of hydrogen technology in the industry.

Regulating the sea and coastal geography

Offshore hydrogen production may involve combining different energy technologies. Sector coupling has important legal ramifications and presents new challenges for regulators and project developers. Further, should energy law principles be promoted as a means for creating the best possible future energy law legislation, including hydrogen? These are important legal topics that have been addressed in HyValue articles.

Sector coupling defines the type of project and determines the applicable energy-sector legislation (e.g., oil and gas vs. offshore renewables). In Offshore Oil and Gas Infrastructure Electrification and Offshore Wind (2024),[1] Herrera Anchustegui (UiB) and Tscherning (University of Calgary) discuss how projects might be planned and authorized in an integrated energy solution. Using the example of offshore wind farms to electrify oil and gas fields, the paper highlights the importance of project planning and a solid understanding of the regulatory landscape to determine the nature of an integrated project.

In Energy Law Principles or Rather a Functional Approach? (2024),[2] Nordtveit (UiB) and Reins (University of Rotterdam) discuss whether international energy law principles should be promoted as a means for creating the best possible future energy law legislation, including hydrogen. The value of abstract principles is that they may help promote a just and foreseeable development of law in line with societal developments. Such principles do not exist in binding law, yet literature has suggested some, sparking a debate concerning whether common international principles would benefit energy law, particularly in Europe. This Hy-Value related article focuses on methodological objections stemming from the Scandinavian legal realism instead of entertaining the notion of implementing principles in binding legislation. Such pragmatic Scandinavian legal realist approach is based on assumptions that value basic considerations and the interests of the parties more than abstract constructs, favouring practical legal solutions and a case-by-case approach to energy law developments.

Bhandari, D.; Selvik, J.T. Unavailability Calculation for the North Sea Energy Island Using Fault Tree and Monte Carlo Simulation. In: Kolowrocki, K.; Dabrowska, E. (eds.), Advances in Reliability, Safety and Security – ESREL 2024 Contributions. Part 1 - Accident and Incident Modelling & Uncertainty Analysis, 47 - 56 (2024).

[1] Herrera Anchustegui, I.; Tscherning, R. Offshore oil and gas infrastructure electrification and offshore wind: a legal exploration. The Journal of World Energy Law & Business, 17(1), 35–53 (2024).

[2] Reins, L.; Nordtveit, T. Energy Law Principles or Rather a Functional Approach? European Environmental Law Review, 33, 300-308 (2024).

Collaboration and competition law

Collaboration on hydrogen projects and energy developments is common practice. However, European Union and Norwegian law set limits on how closely companies can collaborate. In Collaborating in Offshore Renewable Energy Projects and Competition Law: Consortium Bids in Deep Waters,[3] Tukun (representing our PWC project partner) and Herrera Anchustegui (UiB) assess how partners, by jointly developing a renewable energy project, such as green hydrogen production, and applying for a license, can legally form a consortium within the limits imposed by EU Competition Law.

This book chapter highlights the growing importance of sustainability, climate, and energy transition objectives in the application of antitrust rules and may serve as a guide for hydrogen partners to form their collaboration vehicles.

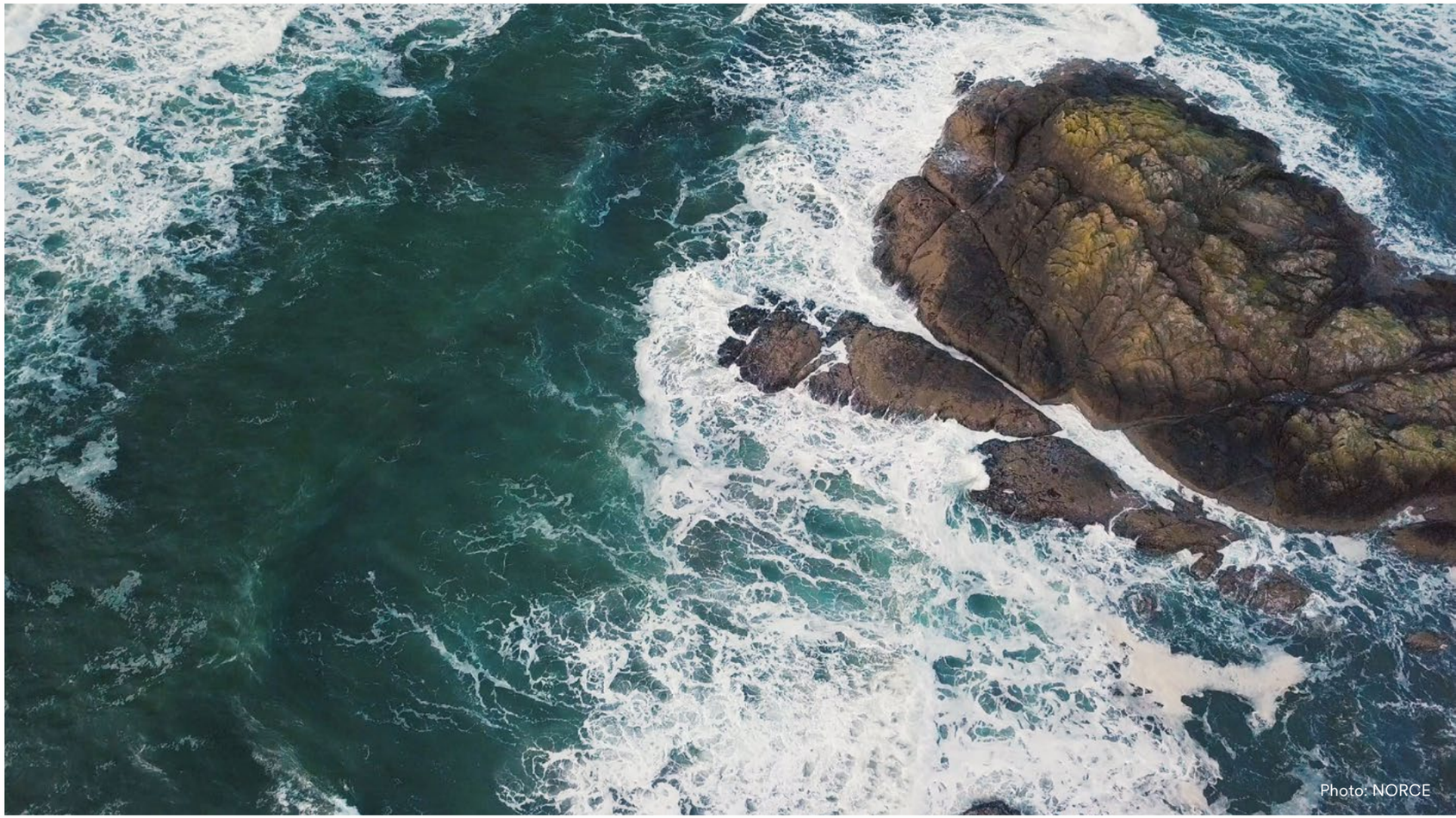


Photo: NORCE

[3] Tukun, E.; Herrera Anchustegui, I. Collaborating in Offshore Renewable Energy Projects and Competition Law: Consortium Bids in Deep Waters. SSRN Electronic Journal, 2024, 4731093 (2024).

Socio-technical embeddedness

How do actors involved in the realization of blue and green projects in Norway narrate the value crea tion of these initiatives? How is «value creation» perceived and described amongst stakeholders involved in realization of blue and green hydrogen in Norway? What values are associated with different types of hydrogen? How are local industrial history, culture, and geographical conditions reflected in each narrative? All of these are research questions being investigated in societal studies in HyValue.

There are several ongoing qualitative and quantitative studies on public, industrial and political legitimacy of hydrogen technology development and implementation. Case studies have been performed in three different places where hydrogen/ammonia projects are planned/started, consisting of extensive interviewing of stakeholders on different levels. The project/places are 1) Øygarden/Vestland (blue hydrogen and CCS, started), 2) Sauda/Rogaland (green ammonia, planning phase), and 3 Kristiansand/Agder (green hydrogen, decided). Data collection has focused on qualitative interviews with stakeholders such as project owners, municipality and regional decision makers. The research focuses on narratives on value creation due to role in the project. In addition, national stakeholders, H_2-hubs, shipowners, and energy providers have been interviewed to explore the dilemmas faced from different levels/sides of the regulations, strategies, and processes.

It is important to understand the processes, the incentives, the in-between-communication, and the status of hydrogen/ammonia in the green transition; not only locally, but also regionally and nationally. Through ongoing studies and surveys, a lot of data has been collected and is now being analysed or processed, while data collection is still ongoing. This information will be further explored in 2025.

Case study locations for planned or already started hydrogen/ammonia projects

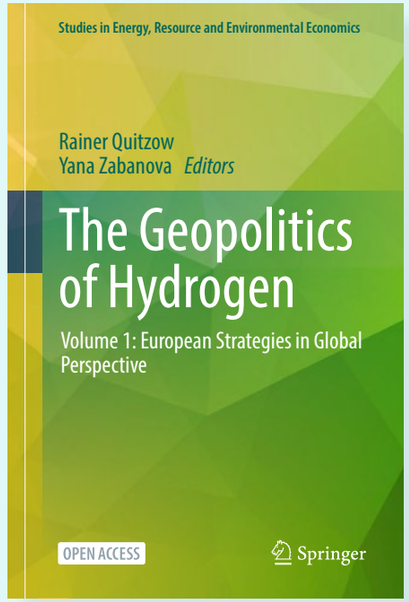
Policy

European politics and policies shaping hydrogen value chain development and actor strategies

Co-ordinated by the Research Institute for Sustainability (RIFS) in Potsdam, Germany, 19 researchers from 14 universities and research institutions in Europe jointly authored the book 'Geopolitics of Hydrogen - Volume 1: European Strategies in Global Perspective' open source-published by Springer Verlag in 2024, edited by Rainer Quitzow and Yana Zabanova.

HyValue researchers from the Fridtjof Nansen Institute contributed a chapter on the Norwegian hydrogen policy, outlining the historical roots of the 2020-published hydrogen strategy, national policy priorities and instruments, industrial initiatives, and international co-operative initiatives of policymakers and industry. Drawing on the findings of the case studies presented in this edited volume, the final chapter of the book summarizes and discusses the geopolitical challenges of hydrogen development in the European Union, reviewing how the interplay of national and EU-level politics and policies shape the EU's domestic and international hydrogen policy. It presents key insights from the evolution of hydrogen policy in the EU, as well as at the national level in Germany, France, Poland, Hungary, Spain, Italy, the Netherlands, Sweden, and Norway (as a member of the European Economic Area). After reviewing important commonalities and differences across these cases, the chapter examines their interplay with policies at the EU level as well as potential synergies and sources of tension between the selected countries.

The work discusses how domestic politics and energy policy legacies shape differing policy approaches and priorities, including chosen technology pathways for hydrogen production, priority hydrogen uses and positions towards the development of cross-border infrastructure and trade, concluding with a reflection on how Europe's strengths and vulnerabilities shape its role in the global geopolitics of hydrogen and inform its international engagement on the transition to net zero more broadly.



The Geopolitics of Hydrogen. https://link.springer.com/chapter/10.1007/978-3-031-59515-8_12

Quitzow, R. and Zabanova, Y. (eds.) 'Geopolitics of Hydrogen - Volume 1: European Strategies in Global Perspective', Berlin: Springer, 2024, 249 pp.

Skjærseth, J.B.; Eikeland, P.O.; Inderberg, T.H.J. and Larsen, M.L. (2024) 'Norway's Hydrogen Strategy: Unveiling Green Opportunities and Blue Export Ambitions', in Quitzow, R. and Zabanova, Y. (eds.) 'Geopolitics of Hydrogen - Volume 1: European Strategies in Global Perspective ', Berlin: Springer, 2024, pp. 213-232.

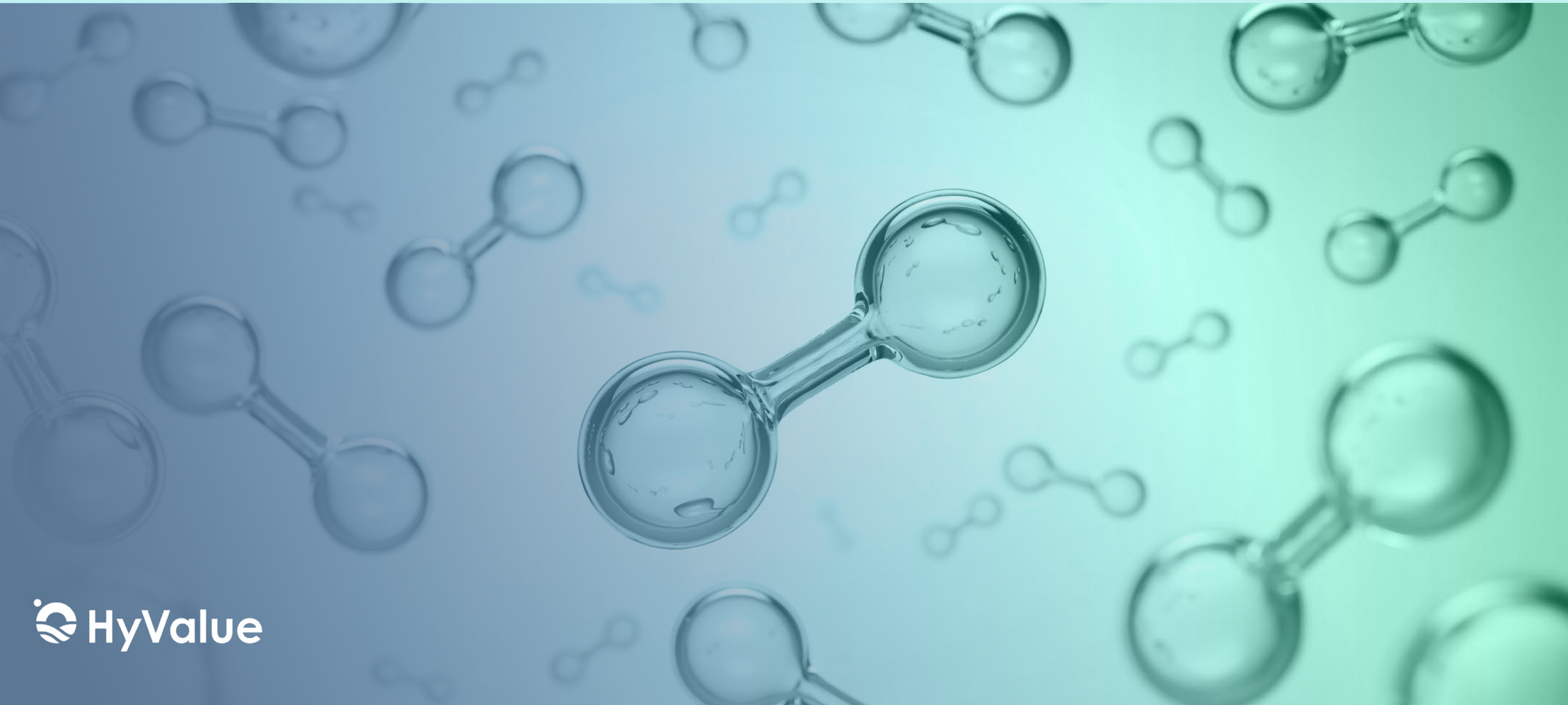
Related Projects

FME HyValue has close ties with other projects that perform complementary research and development. Although there is no formal connection to these projects, there is close collaboration in the form of workshops and seminars. Further, higher TRL projects, such as OptHyMob, strengthen the impact of HyValue research.

PROJECT	FUNDING	TOPIC
HySchool: Norwegian research school on hydrogen and hydrogen-based fuels	RCN	The primary objective of the HySchool research school is to contribute to the global energy transition by enhancing the quality of Norwegian doctoral education on the use of hydrogen and hydrogen-based fuels as energy carriers. Led by UiB.
AmPep: Ammonia Production via Electrocatalytic Processes	RCN, Equinor and TotalEnergies	Development of electrocatalytic ammonia production from water and di-nitrogen. Led by UiB.
HyMe: Reliable metering for the hydrogen supply chain	RCN, Gassco, Equinor, Shell, TotalEnergies	Development of knowledge, competence, and establishment of methodology to enable reliable, traceable, and accurate measurements of hydrogen-based energy carriers. Led by NORCE.
HyLife: Microbial risks associated with hydrogen underground storage in Europa	RCN, OMV, Total Energies, SLB, BP, Lanxess, Corrosion Alliance	Establish microbiological models for underground hydrogen storage with a focus on microbial effects from various locations in Europe. Led by NORCE.
MOCHyS: Microbiological Opportunities and Challenges of Hydrogen Underground Storage	RCN, Equinor, Total Energies	Study of microbiological opportunities and challenges related to underground hydrogen storage. Led by NORCE.
Circularity in Decommissioning	Offshore Norge & University of Bergen, Faculty of Law	Analysis of Norwegian regulations for the decommissioning of offshore infrastructure with the aim of identifying potential improvements. Led by UiB.
HyEff: Energy efficient operation of hydrogen powered vessels	RCN, Corvus Energy, Sin Oceanic, SEAM, Topeka, NORCE	Research and develop technologies to facilitate the widespread, sustainable, and energy-efficient operation of hydrogen-powered vessels, thereby reducing greenhouse gas emissions from maritime transport. Led by NORCE.
OptHyMob: Optimized Hydrogen Powered Maritime Mobility	RCN, Corvus, SEAM, SinOceanic, Topeka, NORCE	Research and development of software to optimize the design and operation of hybrid systems consisting of batteries and hydrogen fuel cells on board vessels. Led by Corvus Energy with NORCE as partner.
FME MarTrans: Transition in maritime transport	RCN with multiple partners	Accelerate the decarbonization of the maritime sector through cutting-edge research, innovation, and collaboration across the entire maritime energy value chain. Led by SINTEF with NHH and SNF as lead on RA4: Sustainable pathways.
Facilitated course development for work towards green transition	Vestland fylkeskommune	Educational project in (maritime) hydrogen technology, led by the Sustainable Energy Catapult with HVL and UiB as partners. The project is completed (2024 - 2025).
Get Hydrogen: Geo-politics of the Energy Transformation: Implications for an International Hydrogen Economy	German Federal Foreign Office	Analysis of possibilities and challenges related to growth of hydrogen in a geopolitical perspective. Led Research Institute for Sustainability, Potsdam, DE, with FNI as partner.
Metrology for smart metering in gas networks	Horizon Europe / Partnership on Metrology	Develop advanced metrology solutions for accurate, reliable, and efficient smart metering in gas networks, supporting the transition to a green and digital Europe. Led by VSL, NL, with NORCE as partner.
Legal-By-Design: Digital Disruption in the Circular Economy: An Exploratory Research project	EEA Grants	Cross disciplinary collaboration between Norway and Portugal with particular focus on legal aspects related to Digital Product Passport and hydrogen energy. Led by the University of Minho, Portugal with UiB as partner.
HERCHET: Higher Education and Research Collaboration on Hydrogen and Enabling Technologies	HK-Dir	The partners collaborate on both higher education and research in hydrogen. Task 1.2 is related to the ongoing research in this project, and PhD candidates involved in the project are also participating in HyValue. Led by HVL, with international collaborators.
INPANCEHA: Indo-Norwegian Partnership on Advanced Nanomaterials for Clean Energy and Health Applications	HK-Dir	Collaboration on novel nanomaterials for clean energy technologies, including hydrogen. Led by HVL in collaboration with Alagappa University
H2CoVE - ERASMUS Hydrogen Centres of Vocational Excellence	ERASMUS+	Equip the European workforce with high-quality vocational skills necessary for industries in the emerging hydrogen economy value chains. This involves pooling knowledge and expertise from Western Norway, Northern Netherlands, Tyrol in Austria, Estonia, and the Precarpathian region in Ukraine to build local ecosystems for skills development, thereby supporting the infrastructure needs for hydrogen production, storage, and end-use applications. Led by Vestland fylkeskommune with participation from HVL, user partners and international partners.

Menu

Research Infrastructure



HyValue

Research infrastructure

Use of robotics and automation in process screening and optimization

The UiB Energy Lab that opened in 2023 contains a robotic high-throughput experimentation facility (HTE@UiB) unique to Norwegian research: It enables automated screening and optimization of chemical processes under controlled atmosphere and is ideal for transition-metal catalyzed reactions. The HyValue ammonia synthesis project (Task 1.3) was among the very first activities to benefit from the new capability offered by the Unchained Labs Junior system (see picture). Already filled with an atmosphere of the key reactant, dinitrogen, Junior has been used in the automated screening of more than 20 different reaction mixtures in parallel. The quantification of the ammonia yield in these reactions is also performed automatically, albeit by a separate instrument (a Kjeldahl analyzer). Finally, the capability and capacity for this kind of robot-driven screening and reaction optimization in WP1 will improve drastically already from next year onward, with the installation of the national NorHTE infrastructure (Norwegian open infrastructure for high-throughput experimentation and scale-up).

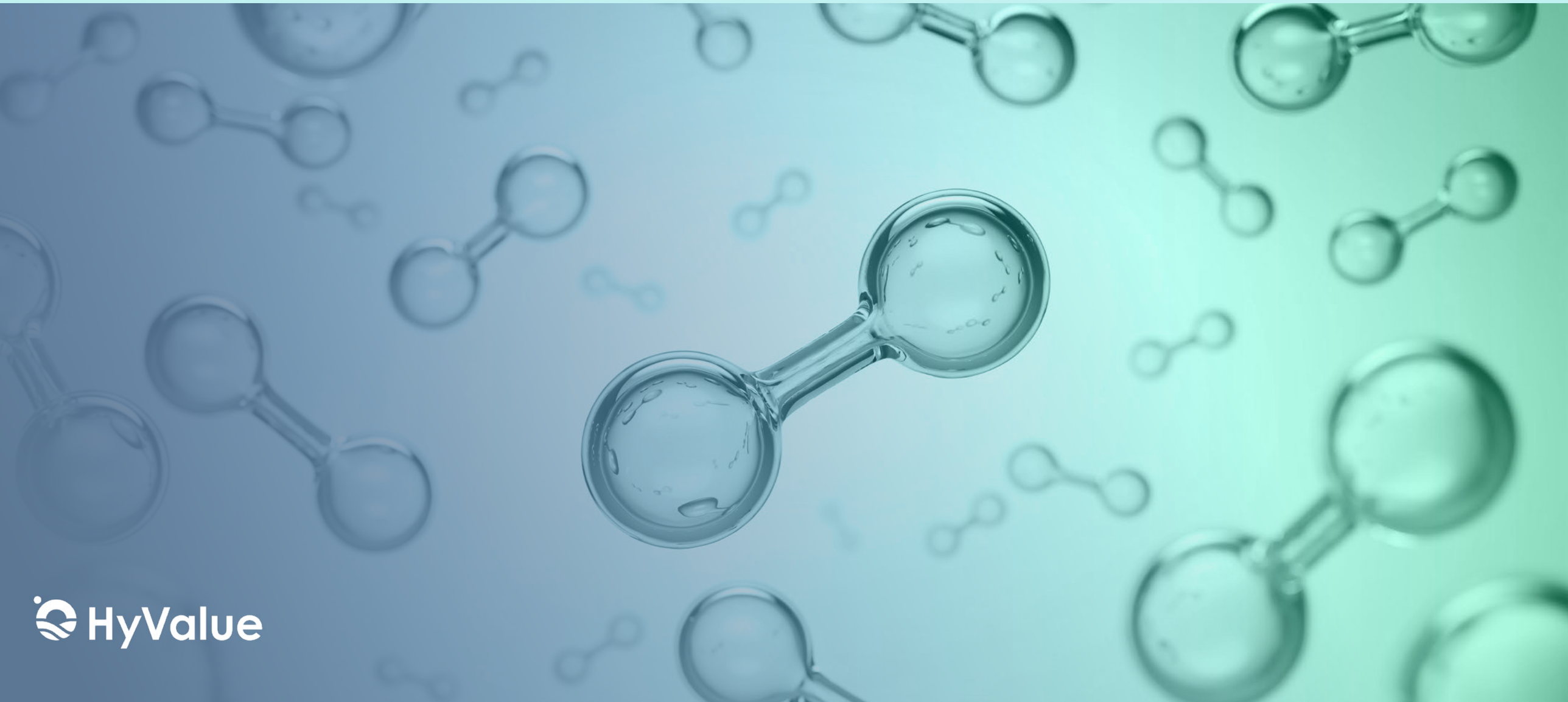
The principle that structurally similar molecules tend to have similar properties is one of the most important in chemistry. This principle helps chemists predict the behavior of unknown compounds based on known ones and underlies the large-scale and highly efficient similarity-based virtual (ligand) screenings of chemical compound databases conducted by the pharmaceutical industry to uncover potential drug candidates. In contrast, corresponding tools suitable for comparison of molecules, such as transition-metal catalysts, beyond those of organic drug-like molecules have yet to be reported.

HyValue researchers have now developed the first such tool, termed HyperShape Recognition (HSR), consistently handling and comparing any kind of molecules or chemical entities. HSR enables, for the first time, similarity-based virtual screening and computational design of transition metal catalysts. The new tool will be used, in WP1, for the search for nitrogenase enzyme-mimicking catalysts for nitrogen fixation to form ammonia. The software has been made openly available.

The HTE@UiB robotic facility used in the screening of different ligands for samarium. Photo: Jin Sigve Mæland (UiB).

Menu

In the Spotlight



Recuited fellows

HyValue PhD students

Ingrid Emilie Flesum Ringstad
WP4 & WP6, NHH, 2021-2025
Topic: Economics

Jonas Himmelstrup
WP1, UiB, 2020-2024
Topic: Mechanistic insight and catalyst and process design.

Marcello Costamagna
WP1, UiB, 2022-2025
Topic: De novo catalyst design

Dikshya Bhandari
WP4, UiS, 2024-2027
Topic: Safety Science and Risk

JKristoffer Skjelanger
WP1, HVL, 2024-2027
Topic: Green hydrogen from PEM electrolysis

Buddhika Karunaratne
WP1, HVL, 2024-2028
Topic: Green hydrogen via photocatalysis

Leif E. Hertwig
WP1, UiB, 2023-2027
Topic: Mechanistic insight and catalyst and process design

Shuyi Pan
WP4 & WP6, NHH, 2023-2027
Topic: Economics

Tomasz A. Skrzydlo
WP1, UiS, 2024-2027
Topic: Turquoise hydrogen from methane cracking

Ashika Dilshani W. Gamage
WP1, UiS, 2024-2027
Topic: Advanced Materials for Hydrogen Purification

Ruplekha Bordoloi
WP1, UiB, 2025-2028
Topic: Metal-organic frame-work for Hydrogen purification

HyValue Postdoctoral fellows

Torhild Nordtveit
WP2 & WP6, UiB, 2023-2027
Topic: Legal issues related to drafting and closing of contracts & Regulation of hydrogen transport at sea

Roweno Heijmans
WP6, NHH, finished in 2024
Topic: Economics

Niaz Bashiri Behmri
WP3, WP4, WP5 & WP6, NHH, 2024-2028
Topics: Financing Hydrogen Investment; Key European market conditions

Faraimo Jay Vai
WP5, HVL, 2024-2026
Topic: Societal impact and embeddedness of Hydrogen in Norway

Ingrid Glette-Iversen
WP4, UiS, 2024-2028
Topic: Hydrogen risk and safety

Associated PhDs and postdocs

Liina Sangolt
PhD student at HVL, 2022-2026
Topic: Offshore production of hydrogen
Funding: Ulla-Førre Foundation

Sivagowri Shanmugaratnam
PhD student at HVL & UiB, 2023-2025
Topic: Hydrogen production
Funding: NORPART

Ingrid Marie Stuen
PhD student at UiB, 2023-2026
Topic: Metering
Funding: RCN (HyMe)

Brynhild Stavland
PhD student at UiS
Topic: Safety Regulation of Hydrogen as an Energy Carrier
Funding: HySociety

Torbjørn Egeland-Eriksen
PhD defended in 2024, UiO & NORCE
Topic: Green hydrogen as energy storage and energy carrier in combination with offshore wind power

Huy Nguyen
PhD student, UiB, 2025-2028
Topic: Separation of catalyst and chemical reductant
Funding: RCN (AmPEP)

Sanjay Gopaldas Chaudri
Postdoc, UiS
Topic: Hydrogen separation and purification

Helene Hisken
Postdoc, UiB
Topic: Safety science and risk

Events

HyValue Days

HyValue Days 2024 gathered partners and researchers at the University of Stavanger in May. Securing hydrogen production with both lower emissions and costs than today, was one important topic.

Carbon intensity is a key parameter when discussing the future of hydrogen – together with cost and security of demand, said Sylvi Høiland, task leader for the hydrogen value chain in Equinor, one of HyValues partners.

Carbon intensity measures how many grams of CO_2 are released to produce a kilowatt hour (kWh) of electricity.

Lowering the carbon intensity of hydrogen production is crucial, regardless of production method. Blue hydrogen, with CCS, can sometimes have a lower footprint than green hydrogen, even though blue hydrogen entails fossil fuels and green hydrogen renewables. Let's not focus on colour, but carbon intensity throughout the life cycle, said Fionn Iversen, centre director at HyValue.

The Institute of Transport Economics (TØI) work on life cycle assessment (LCA) of hydrogen.

We need to use a common method to estimate the carbon intensity of hydrogen, and companies need to document the carbon intensity of their production, said Linda Ager-Wick Ellingsen from TØI, another HyValue partner.

Photo: Aasgeir Valderhaug, Director R&D in Elkem and Chair of the HyValue Executive Board and Sylvi Høiland, Manager Energy Systems from Equinor.

Photo: To us musicians' hydrogen is a mysterious subject, said Martinius Mentzen, when the Martinius Mentzen trio opened HyValue days by playing a mysterious piece to describe "the sound of hydrogen".

Photo: Participants at the HyValue Days 2024 in Stavanger.

HyValue events and workshops

Meet the HyValue R&D partners

TØI Institute of Transport Economics, NHH Norwegian School of Economics and Potsdam Institut fur Klimatechnik (PIK) presented themselves as part of the "Meet the HyValue R&D partners" webinar series. In the PIK webinar, Dr. Philipp C. Verpoort presented the paper "Impact of global heterogeneity of renewable-energy supply on heavy industrial production and green value chains", while Dr. Falko Ueckerdt presented the paper "On the cost competitiveness of blue and green hydrogen (with natural gas and with one another)".

Financing hydrogen implementation

The role of finance in facilitating Hydrogen's role in Europe's energy transition Fridtjof Nansen Institute, Norwegian School of Economics and the University of Bergen organized a joint webinar on the role of private and public finance of hydrogen with introductions from the European Commission, Enova and Smartenergy Italy.

Financial support programmes and means of action Via Cluster hosted on 21st of June a webinar on "Støtteordninger og virkemiddelapparatet" where representatives from Innovation Norway and the transport portfolio of the Research Council presented on the programmes of the Research Council, Innovation Norway, and EU.

Photo: Johanna Schiele gave a presentation about funding opportunities in the EU.

Photo: Sigmund Størset from ENOVA on Norwegian funding opportunities.

Outreach and conferences

Throughout the year, HyValue management and researchers has presented our research and insight at various national and international conferences, and in the media

HyValue at European Hydrogen Week 2024

In October, a large team from several HyValue partners had the privilege of participating in the European Hydrogen Week, reconnecting with our partners and establishing new potential collaborations.

Photo: At the reception of the residency of Ambassador of Norway to the EU, Anders H. Eide, Velaug Myrseth Oltedal (HVL), Gerd Schumacher (FZ Jülich), Fionn Iversen (NORCE).

Photo: HyValue stand at European Hydrogen Week in Brussels, 18.-22. Nov. 2024

The Hydrogen Symposium

At the Hydrogen Symposium in Tyssedal in May, a presentation titled “A Comparative Study of Different Hydrogen Delivery and Storage Systems for Industry: Case INEOS Tyssedal” was delivered. This presentation was based on the MSc thesis of Ann Louise Egelandsdal and conducted in collaboration with HyValue partner TechnipFMC. Using a Pugh matrix for analysis, the study compared various scenarios for the storage and supply of hydrogen for large-scale industrial use. The findings indicated that having an excess of PEM electrolysis capacity is the optimal solution for ensuring a stable and reliable supply of large amounts of hydrogen.

Photo: Yulia Arinicheva Skåtun and Velaug Myrseth Oltedal on the stage at the Hydrogen Symposium 2024.

Naere conference

The centre organized the Naere conference in Bergen, hosted by the Nordic Association of Environmental and Resource Economics (NAERE), with about 80 attendees. Presentations were made by Eskeland, HyValue researcher Niaz Bashiri Behmiri, and Pan Shuyi, with Maren Hedne also participating.

International Climate Summit 2024

HyValue researchers participated in the International Climate Summit 2024 in New Delhi, India. A delegation from HVL attended the summit and hosted a research delegation from India, organizing a seminar on academic and research collaboration between India and Norway.

Photo: Dhayalan Velauthapillai, Jonathan Torstensen, Velaug Olteda and Yulia Skåtun from HVL.

HyTack summer school

Tomasz Adam Skrzydlo, a PhD student focusing on hydrogen production, presented his research findings at the HyTack seminar. Tomasz showcased the potential of methane cracking for sustainable hydrogen production, a promising method for generating hydrogen without CO_2 emissions.

EAGE Conferences

In 2024, WP2 had significant contributions to several prestigious conferences. At the 85th EAGE Annual Conference & Exhibition in Oslo, Behruz Shaker Shiran et al. presented the effect of cyclic flow and flow rate on H_2 recovery efficiency. Additionally, Shaker Shiran et al. discussed the "Impact of Salt Precipitation on Porosity-Permeability Correlations: Implications for CO_2 Storage" at the 5th EAGE Global Energy Transition Conference & Exhibition (GET 2024).

Norwegian Hydrogen Forum Hydrogen Conference 2024

HyValue Centre Deputy Velaug Myrseth Oltedal participated at the annual NHF Hydrogen Conference on a panel discussing how to ensure a competent workforce for the energy transition. The conference took place 6th of June at Radisson Blu in Oslo.

Photo: Panel on competency for the energy transition, 2024 Hydrogen Conference

2024 FME conference

The 2024 FME conference, the first of its kind, was held on March 13th at Scandic Lerkendal in Trondheim, in connection with the NTNU Energy Transition Week. The FME conference was organised in collaboration between all FMEs. HyValue co-organised the session on “The roles of hydrogen and CCS in the short and long term” together with HYDROGENi and NCCS, where Fionn Iversen and Per Ove Eikeland also contributed with presentations under the topic “Developing a robust hydrogen market at scale”, together with Ingo Machenbach of Statkraft.

Photo: Closing panel session, 2024 FME Conference

H_2Science

Our sister FME centre HYDROGENi held their first scientific conference, H_2Science, on June 18-19 in Trondheim. The conference will be held bi-annually. HyValue was invited to contribute to the conference both in organisation and scientific contribution. Many common industry partners and representatives toHyValue and HYDORGENi attended, and HyValue Centre Director participated in the opening keynote and panel session. We will be following up with HYDROGENi on how to collaborate in such events moving ahead. https://h2science.no

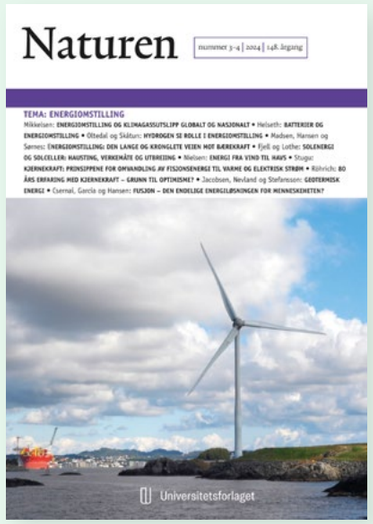
Photo: Moderators: Nils Røkke and Gunhild Allard Reigstad, SINTEF, Panel: Luigi Crema, Hydrogen Research Europe, Astrid Lilliestråle, ENOVA, Elisabeth Birkeland, Equinor, Fionn Iversen, NORCE.

In the media


Debatt

På vei mot full stopp for norsk hydrogensatsing?

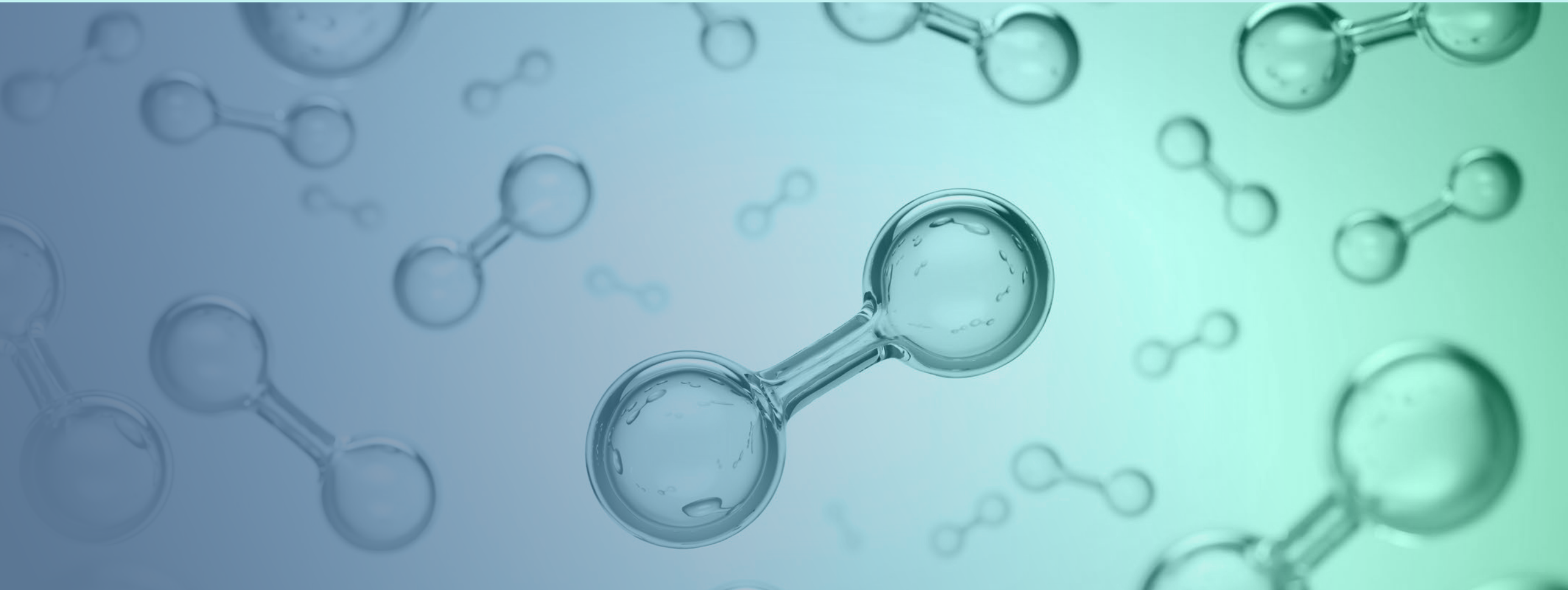
Centre Director Fionn Iversen wrote in Altinget about the need for regulations and financial facilitation to support hydrogen. “[..]there is an urgent need to develop a well-defined system for implementing new solutions so that industry knows what to adhere to. Changes are necessary for the industry to see a clear and distinct pathway for renewable projects”



A paper was published in Naturen, which is the oldest journal for popular science publications in Norway. The title of the paper is “The role of hydrogen in the energy transition”, and features both the properties of hydrogen, in which sectors hydrogen may play a part in the energy transition, as well as advantages and challenges of using hydrogen- compared to other energy carriers. The paper provides an easily accessible source of information about hydrogen and its applications, and may be used in teaching and in dissemination to the general public. The paper is only available in Norwegian.

Menu

International Collaboration



HyValue

International Collaboration

Over the past year, HyValue has strengthened its international collaboration through several significant projects and initiatives. This includes collaboration between HyValue national and international partners, international research visits, as well as work towards the EU's framework program for research and innovation and EEA funds. An overview of relevant projects, including international projects, can be found on page 38.

HyValue's international partners include several prestigious research institutions where key activities in 2024 include:

- **Massachusetts Institute of Technology (MIT), USA:** In June, Professor Yuming Liu from MIT visited NORCE and delivered an open lecture on modeling ships and waves for energy optimization in maritime transport.
- **Potsdam Institute for Climate Impact Research (PIK), Germany:** Researchers from PIK conducted a webinar on the impact of renewable energy variability on industrial production and green value chains, as well as the relative competitiveness of blue and green hydrogen and natural gas.
- **TNO, Netherlands:** In November, a Memorandum of Understanding (MoU) was signed between NORCE and TNO to enhance research collaboration with a strong focus on blue hydrogen.

Research visit to the World Bank

WP6 leader Gunnar S. Eskeland conducted research visits to the World Bank Research Department in Washington DC (April - June, 2024) and Stanford University, California early 2025. His work focuses on "Moral Cartels: Fossil Owners in Climate Treaties," exploring the role of blue hydrogen, carbon capture and storage, methane, and flaring in climate mitigation. These visits have been valuable in fostering knowledge exchange, building international networks, and advancing our understanding of critical issues.

Job Shadowing Erasmus+ Programme

In June 2024, Yulia Skåtun and Jonathan Økland Torstensen (HVL) visited Zernike Campus as part of the Job Shadowing Erasmus+ Programme. They attended the New Energy Forum, which showcased innovations in energy and mobility transitions. Highlights included hydrogen technology demonstrations and the first European Championship H_2 Grand Prix RWE. The visit provided valuable insights and fostered potential collaborations on SOFC-based energy systems research.

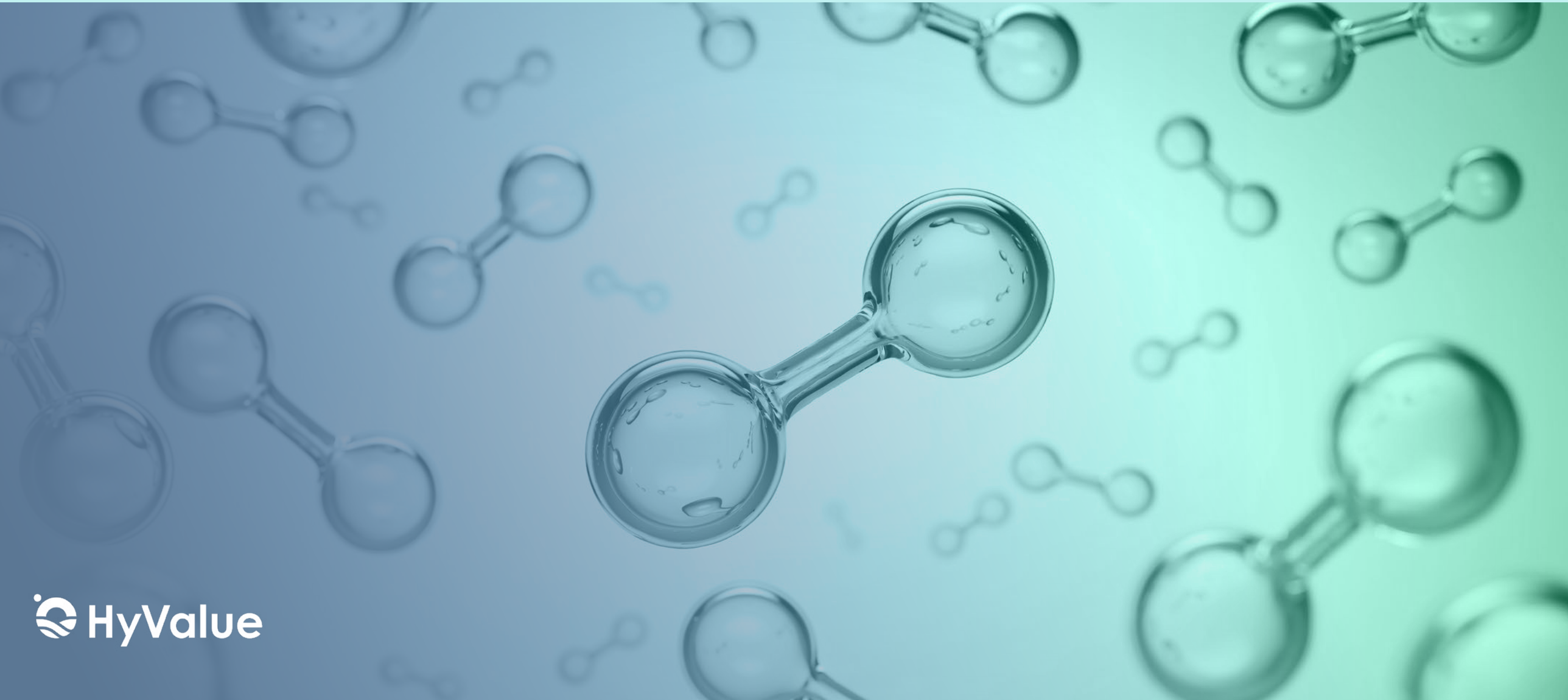
Dutch Delegation Hydrogen Visit

A delegation from the Ministry of Economic Affairs & Climate Policy and the Ministry of Foreign Affairs of the Netherlands visited HyValue in March 2024 to discuss blue and green hydrogen, gas infrastructure, and transport via pipelines from Norway to the continent. The programme included presentations on novel production methods, the North Sea Energy programme, metrology for hydrogen distribution, and underground storage. The aim of the visit was to explore development, implementation, and specific projects in these areas.

Photo: Participants at the Erasmus+ Programme for job shadowing in the Netherlands: Jonathan Økland Torstensen (HVL), Håkon Kaya (Fagskulen Vestland/Vestland fylkeskommune) and Barbara Hartering (Vestland fylkeskommune). Photo: Yulia Arinicheva Skåtun, HVL.

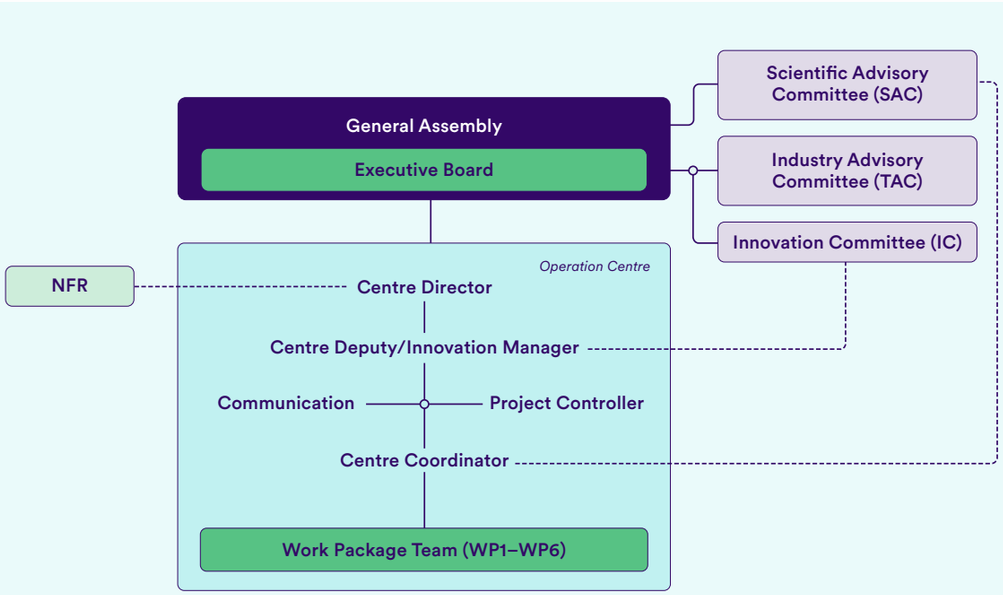
Menu

HyValue Facts



Governance Structure

The HyValue **General Assembly** is the ultimate decision-making body and consists of representatives from each partner. The **Executive Board** has a majority of members and the chairperson from the user partners, which gives the users a high degree of influence, making sure HyValue's goals and activities are well aligned with the needs of the users. The HyValue **Centre Management Team** (CMT) runs the day-to-day management of the centre. The CMT consists of the Centre Director, the Deputy Director, the Centre Coordinator, as well as administrative support from the host institution NORCE. **WP leaders** are responsible for planning and overseeing WP activities, coordinating tasks, and ensuring the delivery of results. The **Scientific Advisory Committee** consists of independent researchers who evaluate research performance and recommend key activities and priorities. The **Innovation Committee** will map key exploitable results, assess innovation potential and make recommendations for further research.



HyValue Executive Board

2024

BOARD MEMBER	AFFILIATION
Aasgeir Valderhaug (Chair)	Elkem
Aina M. Berg	NORCE Norwegian Research Institute (NORCE)
Kristine Spildo	University of Bergen (UiB)
Øyvind Midtbø Berge	Western University of Applied Sciences (HVL)
Leif Kristoffer Sandal	Norwegian School of Economics (NHH)
Helge Bøvik Larsen	University of Stavanger (UiS)
Svein Are Folgerø	Å Energi
Sylvi Høiland	Equinor
Richard Markeson	Gassco
Victoria Griffiths	Statkraft
Erlend Seppola	Apply
Frants Gundersen	Institute of Transport Economics (TØI)
Egil Hystad	Wärtsilä

Observers

OBSERVER	AFFILIATION
Åse Slagtern	The Research Council of Norway (NFR)
Per Ove Eikeland	The Fridtjof Nansen Institute (FNI)

Scientific Advisory Committee (SAC)

SAC MEMBER	AFFILIATION	COMPETENCE AREA
Kees van Wingerden (Chair)	Vysus group	Safety Science & Risk
Anna Stefanopoulou	University of Michigan	Mechanical Engineering
Kim Talus	University of Finland	Energy Law
Maartje Boon	University of Stuttgart	Subsurface storage
Ranjit Koodali	Western Kentucky University	Production Technologies

Innovation Committee

COMMITTEE MEMBER	AFFILIATION
Velaug Myrseth Oltedal (Chair)	Western Norway University of Applied Sciences (HVL)
Øyvind Frette	University of Bergen (UiB)
Arvid Nøttveit	NORCE Norwegian Research Institute (NORCE)
Sachin Maruti Chavan	University of Stavanger (UiS)
Astrid Gunnarshaug	Hydrogen Solutions AS (HYDS)
Kristin Svardal	Ocean HyWay Cluster
Jens Grendstad	Technip FMC

The Scientific Advisory Committee gave the Executive Board a report with their recommendations on HyValue activities to maximise impact.

HyValue Research Partners

The HyValue consortium is led by NORCE Norwegian Research Centre, supported by the Western Norway University of Applied Sciences (HVL) in Centre management. HyValue comprises in total 12 leading R&D institutions in hydrogen related research, including eight Norwegian partners and four international partners.

The research partners have world-leading competence in hydrogen related technical-economic-legal-societal fields of science with extensive analytical, modelling, simulation, and experimental capabilities. The research institutions are all strategically committed to the scope of HyValue and they provide multidisciplinary expertise and skills needed to carry out the ambitious research programme of HyValue including materials science, catalysis and chemical processes (UiB, UiS, HVL), porous media, biogeochemistry, underground storage (NORCE, UiS, TNO), fluid dynamics, pipeline transport, measurement science, metering research (NORCE, UiB, TNO), optimization (NORCE, MIT), safety risk assessment (UiB, UiS, FZJ), societal research (NORCE, TNO), economics and finance, LCA, value chain analysis, political science, law, energy systems (FNI, NHH/SNF, TØI, UiB, TNO, PIK).

HyValue User Partners 2024

HyValue collaborates with leading national and international industry as well as key public partners. HyValue undertakes long-term research at low technology readiness levels (TRL) to support and enable the hydrogen energy transition.

The user partners cover the whole hydrogen value chain, on the technical part from engineering to consultants / service providers, to technology, equipment and sensors providers, together with test facilities for maturing technology. Power companies as electricity providers and system operators, and energy companies as investors and infrastructure owners drive the shift, with producers and distributors making the hydrogen available. Process industry enables circular economy. Industrial parks, harbours, municipalities, and county councils are key stakeholders with respect to use-cases. Ship agency together with maritime authorities provide the link to shipping, while clusters provide connectivity with a broader field of stakeholders. Law firms support regulations and contracts development, central for achieving the energy shift. Finally, our public science centre partner VilVite provides a strong link to public dissemination.

The research team

Centre Management

Fionn Iversen, Centre Director, NORCE

Arvid Nøttveit, Centre Director (from March 2025), NORCE

Velaug Myrseth Oltedal, Deputy Director, Innovation Manager, HVL

Ellen Ingeborg Hætta, Centre Coordinator (from Oct. 2024), NORCE

Jonas Solbakken, Centre Coordinator (until June 2024), NORCE

Nazanin Jahani, Scientific Coordinator, NORCE

Ida Sollesnes, Communication adviser, NORCE

Andreas Wefring, Controller, NORCE

WP1 Novel Production Methods

WP leaders:

Vidar Jensen, Prof., UiB - Catalyst design and realization

Dhayalan Velauthapillai, Prof., HVL - Materials discovery, synthesis and characterization

Key researchers

Erwan Le Roux, Assoc. Prof., UiB - Catalyst design and realization

Håkon Eidsvåg, Researcher, NORCE/HVL - Novel Production Methods

Javier de Elio Medina, Assoc Prof., HVL - Offshore wind-based production of green hydrogen and ammonia

Jonathan Økland Torstensen, Assoc. Prof., HVL - PEM electrolysis innovation

Kristine Spildo, Prof., UiB - Electrochemistry, electrocatalysis

Pascal Dietzel, Prof., UiB - Materials discovery and characterization

Sachin Chavan, Assoc. Prof., UiS - Materials development and characterization for hydrogen purification and catalysis

Velaug Myrseth Oltedal, Assoc. Prof., HVL - Offshore production of hydrogen

Zhixin Yu, Prof., UiS - Catalysis, Nanomaterials synthesis

PhD students

Ashika Dilshani Wackwella Gamage, UiS - Advanced Materials for Hydrogen Purification

Buddhika Karunaratne, HVL - Green hydrogen via photocatalysis

Jonas Himmelstrup, UiB - Mechanistic insight and catalyst and process design

Kristoffer Skjelanger, HVL - Green hydrogen from innovative PEM electrolysis

Leif E. Hertwig, UiB - Mechanistic insight and catalyst and process design

Marcello Costamagna, UiB - De novo catalyst design

Ruplekha Bordoloi, UiB - Functional materials for hydrogen purification and utilization

Tomasz Adam Skrzydlo, UiS - Turquoise hydrogen from methane cracking

Kristine Marie Halvorsen, UiB (associated) - Development of new MOFs for the electrochemical reduction of CO_2

Liina Sangolt, HVL (associated) - Offshore production of hydrogen

Sivagowri Shanmugaratnam, HVL/UiB (associated) - Hydrogen production

Master students

Amalie Norland , HVL/UiB - Investigating voltage ripple effects in PEM electrolysis: test protocol development and experimental characterisation

Ann Louise Egelandsdal, HVL/UiB - A Comparative Study of Different Hydrogen Delivery and Storage Systems for Industrial Applications

Kamilla Valla Hagen, HVL/UiB - Hydrogen production from fluctuating small-scale hydropower

Karine Strandos, HVL - Hydrogenproduksjon frå innestengt vasskraft

Lavanya Nagulanantham, HVL/UiB - Electrode Materials for Hydrogen Evolution Reaction

Malene Nordal Ulvestad , HVL - Investigating electrolytes for AEM / AEC electrolyzers

Maria Alice Svendsen, HVL - The role of hydrogen in getting large-scale offshore wind power to markets

Mark Ruben Chalupa, HVL/Leibniz U.

Tina Eliassen Valøen, UiB - Catalysts for ammonia synthesis

Bachelor students

Dorthea Ting Arnø Sandvik, HVL - The role of hydrogen in transporting offshore wind power to markets - A techno-economic analysis

Henrik Abildgaard, HVL - Offshore fyllestasjon for hydrogen og hydrogenbærere - En konseptanalyse

Lana Azad Tufeek, HVL - The role of hydrogen in transporting offshore wind power to markets - A techno-economic analysis

Mathias Horne, HVL - Offshore fyllestasjon for hydrogen og hydrogenbærere - En konseptanalyse

Philip Massimo Clausen, HVL - Offshore fyllestasjon for hydrogen og hydrogenbærere - En konseptanalyse

Tor Christopher Gordon Kleppe, HVL - Energy Flow and System Integration for Offshore Green Hydrogen

WP2 Storage and Distribution

WP leaders:

Nematollah Zamani, Senior Researcher, NORCE

Kjetil Folgerø, Chief Scientist, NORCE

Key researchers

Adam Funnell, Researcher, NORCE - Robust metering for supply chains

Antonie Oosterkamp, Senior Researcher, NORCE - Efficient transport and distribution systems

Behruz Shaker SShiran, Senior Researcher, NORCE - Large scale and flexible storage systems

Camilla Sætre, Assoc. Prof., UiB - Metering

Hamid Yousefi, Researcher, TNO - Large scale and flexible storage systems

Håvard Ugulen, Researcher, NORCE - Robust metering for supply chains

Ignacio Herrera Anchustegui, Prof., UiB - Governance framewoks

Kjetil Daae Lohne, Senior Researcher, NORCE - Metering

Lea Stark, Researcher, NORCE - Metering

Morten Gunnar Aarra, Chief Scientist, NORCE - Experimental study of underground H_2 storage/Flow physics

Nicole Dopffel, Senior Researcher, NORCE - Experimental study of underground H_2 storage/Microbiology

Peter James Thomas, Chief Scientist, NORCE - Metering

Petter Norli, Senior Researcher, NORCE - Robust metering for supply chains

Remco Groenenberg, Senior Scientist, TNO - Large scale and flexible storage systems

Rudiger Tscherning, Prof., UCalgary/UiB - Governance framewoks

Rune Njøs, Assoc. Prof., HVL - Storage and distribution

Torbjørn Egeland-Eriksen, Researcher, NORCE - Transport models

PhD students

Ingrid Marie Stuen, UiB (affiliated) - Metering

Torbjørn Egeland-Eriksen, UIO/NORCE (affiliated, completed) - Green hydrogen as energy storage and energy carrier in combination with offshore wind power

Master students

Amalie Nordvik , UiB - Salt precipitation during gas storage in saline aquifiers

Anna Matea Skår, UiB - A Cylindrical Cavity Resonator System for Characterisation of Hydrogen Gas

Bishoy Sadaak, Upper Austria Univ. - Salt precipitation during gas storage in saline aquifiers

Elias Mykelbust Vaardal, UiB - Developing a Modular Uncertainty Calculation Tool for Hydrogen Refueling Stations

Kjartan Yri, UiB - Metering

Suhayka Mohamed, UiB - Salt precipitation during gas storage in saline aquifiers

Bachelor students

Heidi La Haganes, HVL - Analyse av batterityper for bruk i forbindelse med brenselceller

Maria Alice Svendsen, HVL - Analyse av batterityper for bruk i forbindelse med brenselceller

WP3 End User Applications

WP leaders:

Geir Nævdal, Senior Researcher, NORCE - End user applications

Jonathan Økland Torstensen, Assoc. Prof., HVL - End user applications

Key researchers

Bjørnar Ystad, Senior Researcher, NORCE - Maritime application of hydrogen and hydrogen-carriers

Leonid Vasilyev, Senior Researcher, NORCE - Use of hydrogen in maritime applications

Pawel Jan Kosinski, Prof., UiB - Use of hydrogen in CCU at industrial sites

Svein Olav Halstensen, Senior Researcher, NORCE - Use of hydrogen in maritime applications

Ulrik Thisted, Senior Researcher, NORCE - Achieving sustainable value chains in the industry

Vetle Risinggård Kjær, Senior Researcher, NORCE - Use of hydrogen in CCU at industrial sites

Victoria Zinchenko, Senior Researcher, NORCE - Use of hydrogen in maritime applications

Yulia Skåtun, Assoc. Prof., HVL -End user applications

Yuming Liu, Senior Researcher, MIT - Use of hydrogen in maritime applications

Postdocs

Niaz Bashiri Behmiri, NHH (also in WP4, 5, 6) - Financing Hydrogen Investment; Key European market conditions: power, CO_2, gas, hydrogen and energy intensive tradable products

Master students

Albert Gjørvad , HVL/UiB - Designbasis for metanpyrolysereaktor som forsknings-reaktor ved HVL

Henrik Abilgaard , HVL - Development of an AEM fuel cell test station

Håvard Heldal , HVL/UiB - Liquid Organic Hydrogen Carriers

Tobias A. Slettemyr Jetmundsen, HVL - Modeling of a Solid Oxide Fuel Cell (SOFC) System for Marine Applications Using Aspen HYSYS

Tobias Spydberger, HVL/UiB - CFD mod-ellering av metanpyrolyse

WP4 Safety Science and Risk

WP leaders

Jon Tømmerås Selvik, Prof., UiS – Risk communication and comprehension

Trygve Skjold, Prof., UiB - Phenomena, modelling, and mitigation

Key researchers

Armando José Garcia Pires, Senior Re-searcher, SNF - Risk communication and comprehension

Bjørn Johan Arntzen, Assoc. Prof., UiB - Phenomena, modelling, and mitigation

Eirik B. Abrahamsen, Prof., UiS - Risk and safety

Ernst A. Reinecke, Dr., Head of Dept., FZ Jülich - Phenomena, modelling, and mitigation

Leif Kristoffer Sandal, Prof., NHH - Risk communication and comprehension, Strength of knowledge

Margrethe Aanesen, Senior Researcher, SNF - Risk communication and compre-hension

Ove Njå, Prof., UiS – Prevention and safe design, Strength of knowledge

Stephan Kelm, Dr. Ing., FZ Jülich - Risk and safety

PhD students

Dikshya Bhandari, UiS - Identifying and Mitigating Risks in Hydrogen Energy for Safer Integration

Brynhild Stavland, UiS (affiliated) - Safety Regulation of Hydrogen as an Energy Carrier

Postdocs

Ingrid Glette-Iversen, UiS - Hydrogen risk and safety

Niaz Bashiri Behmri, NHH - Financing Hy-drogen Investment; Key European market conditions: power, CO_2, gas, hydrogen and energy intensive tradable products.

Helene Hisken, UiB (associated) - Safety science and risk

WP5 Societal Impact and Embeddedness

WP leaders

Lars Martel Antonie Coenen, Prof., HVL - Assessment of how hydrogen is coupled to and embedded in various sociotechni-cal systems

Kari Kjestveit, Senior Researcher, NORCE - Exploration of public literacy and legitimacy & societal dilemmas in the deployment of hydrogen and related technologies

Svein Gunnar Sjøtun, Assoc. Prof., HVL (replacing Coenen until mid-2025) - As-sessment of how hydrogen is coupled to and embedded in various sociotechnical systems

Key researchers

Gilda Seddighi, Senior Researcher, NORCE - Societal impact and embed-dedness

Henrik Litleré Bentsen, Senior Researcher, NORCE - Societal impact and embed-dedness

Jon Kåre Skiple, Senior Researcher, NORCE - Societal impact and embed-dedness

Rune Njøs, Assoc. Prof., HVL - Societal impact and embeddedness

Sindre Aske Høyland, Research Prof., NORCE - Societal impact and embed-dedness

Svein Gunnar Sjøtun, Assoc. Prof., HVL - Societal impact and embeddedness

Tone Njølstad Slotsvik, Senior Researcher, NORCE - Societal impact and embed-dedness

Postdocs

Faraimo Jay Vai, HVL, Societal impact and embeddedness of Hydrogen in Norway

Niaz Bashiri Behmri, NHH - Financing Hy-drogen Investment; Key European market conditions: power, CO_2, gas, hydrogen and energy intensive tradable products.

Sanjay Gopaldas Chaudri, UiS (associated) – Hydrogen separation and purification

WP6 Integrating Hydrogen in Value Chains

WP leaders

Gunnar S. Eskeland, Prof., NHH - Eco-nomic analysis

Ignacio Herrera Anchustegui, Prof., UiB - Governance framewoks

Key researchers

Aravind Satish, Junior Scientist, TNO - Regulating sea and coastal geography of hydrogen & North Sea Hydrogen-based Energy Hubs

Armando J. Garcia Pires, Senior Re-searcher, SNF - Economics

Berte-Elen Konow, Prof., UiB - Gover-nance framewoks

Eivind Hjorth Matthiasen, PhD candidate, FNI - European politics and policies shap-ing hydrogen value chain development and actor's strategies

Frants Gundersern, Director of research, TØI - LCA

Frode Skjeret, Researcher, SNF - Eco-nomics

Hamid Yousefi, Medior Scientist, TNO - Regulating sea and coastal geography of hydrogen & North Sea Hydrogen-based Energy Hub

Ingrid Sundvor, Senior Researcher, TØI - LCA

Jon Birger Skjærseth, Senior Researcher, FNI - European politics

Joris Koornneef, Strategy Cons., TNO - Regulating sea and coastal geography of hydrogen & North Sea Hydrogen-based Energy Hubs

Kenneth Løvold Rødseth, Chief Research-er TØI - Integrating hydrogen in value chains

Linda Ager-Wick Ellingsen, TØI - LCA

Malin Arve, Prof., NHH - Economics

Mari Lie Larsen, Researcher, FNI - Euro-pean clusters/politics

Mette Bjørndal, Prof., NHH - Integrating hydrogen in value chains

Per Ove Eikeland, Senior Researcher, FNI - European politics and finance

Rebecca Jayne Thorne, Senior Research-er, TØI - LCA

Remco Groenenberg, Senior Scientist, TNO - Regulating sea and coastal geog-raphy of hydrogen & North Sea Hydro-gen-based Energy Hub

Rudiger Tscherning, Prof., Calgary/UiB - Governance framewoks

Sigrid Eskeland Schütz, Prof., UiB - Gover-nance framewoks

Tor Håkon Jackson Inderberg, Senior Researcher, FNI - European politics

PhD students

Ingrid Emilie Flesum Ringstad, NHH - Economics

Shuyi Pan, NHH – Economics

Postdocs

Niaz Bashiri Behmri, NHH - Financing Hydrogen Investment; Key European market conditions: power, CO_2, gas, hydrogen and energy intensive tradable products.

Torhild Nordtveit, UiB – Law

Master students

Amandine Massant, NHH - Green ammonia shipping: Adapting established value-chains to fuel the future of clean maritime transport

Andres Guillermo , NHH - Hydrogen contracts

Caspar Clemens James von Moltke, UiS - Hydrogen in the Urban Setting - Understanding the role of hydrogen in the energy transition of Berlin through the lens of the Multi-Level-Perspective

Helene Just Rustad og Johannes Elgaaen, NHH - Finance: Sustainable Aviation Fuels

Julie Birkeland, UiB - Statsstøtte for hydrogenprosjekter etter EØS-avtalen § 61 nr. 3, med særlig fokus på Gruppeunntaksforordninngen (GBER) og/eller reglene om klima, miljø- og energistøtte

Kari Wiig, UiB - Legal Challenges in Establishing Contracts for Difference for Hydrogen under the EEA State Aid framework

Marte Hoel, UiB - Er handlingsrommet for tildeling av statlig støtte utivdet ved CEEAG-retningslinjene- med særlig fokus på hydrogenprosjekter

Runar Johnston, NHH - Green ammonia shipping: Adapting established value-chains to fuel the future of clean maritime transport

Accounts

COSTS PER PROJECT PARTNER (IN NOK 1000)	2024
Research partners:	
NORCE Norwegian Research Centre	15 210
Universitetet i Bergen	5 682
Universitetet i Stavanger	4 536
Norges Handelshøyskole	3 730
Høgskulen på Vestlandet	3 606
Fridtjof Nansens Institutt	1 222
Transportøkonomisk institutt	1 719
Samfunns- og næringslivsforskning AS	1 373
Potsdam-Institut für Klimafolgenforschung	744
Massachusetts Institute of Technology	644
Netherlands Organization for Applied Scientific Research (TNO)	120
Forschungszentrum Jülich GmbH	87
User partners	5 716
TOTAL COSTS	**44 388**

FUNDING SOURCES (IN NOK 1000)	2024
Own contribution (host)	3 912
Own contribution (national research partners)	10 561
Private funding	12 519
Public funding	1 046
International funding	957
The Research Council of Norway	15 394
TOTAL FUNDING	**44 388**

* Figures in kNOK

Publications 2022-2024

2024

Scientific publications and conference proceedings 2024

Bhandari, D.; Selvik, J.T. Unavailability Calculation for the North Sea Energy Island Using Fault Tree and Monte Carlo Simulation. In: Kolowrocki, K.; Dabrowska, E. (eds.), Advances in Reliability, Safety and Security – ESREL 2024 Contributions. Part 1 - Accident and Incident Modelling & Uncertainty Analysis, 47 - 56 (2024).

Cincotta, C.M.L.; Thomassen, Ø. Electric vehicle ownership and political preferences in Norway. Transportation Research Part D: Transport and Environment, 139, 104518 (2024).

Egeland-Eriksen, T.; Oosterkamp, A. Electricity transport vs. hydrogen production from future offshore wind farms. Proceedings of the Thirty-fourth (2024) International Ocean and Polar Engineering Conference - ISOPE 2024, 4353-4359 (2024).

Flessum Ringstad, I.E.; Tselika, K. Connectedness between green bonds, clean energy markets and carbon quota prices: Time and frequency dynamics. Journal of Commodity Markets, 36, 100442 (2024).

Herrera Anchustegui, I.; Tscherning, R. Offshore oil and gas infrastructure electrification and offshore wind: a legal exploration. The Journal of World Energy Law & Business, 17(1), 35–53 (2024).

Njøs, R.; Sjøtun, S.G.; Jakobsen, S.E.; Fløysand, A. (Re)Incorporating "the Tangible" in Industrial Path Development Analyses: The Role of Sociomaterial Contingencies in Explaining Potential Emergence of Hydrogen Production in Western Norway. Economic Geography, 100(5–6), 437–458 (2024).

Oosterkamp, A.; Egeland-Eriksen, T. Flow assurance of offshore hydrogen pipelines - a review. Proceedings of the Thirty-fourth (2024) International Ocean and Polar Engineering Conference - ISOPE 2024, 4360-4367 (2024).

Reins, L.; Nordtveit, T. Energy Law Principles or Rather a Functional Approach? European Environmental Law Review, 33, 300-308 (2024).

Shanmugaratnam, S.; Swathi, S.; Yuvakkumar, R.; Oltedal, V.M.; Ravirajan, P.; Shivatharsiny, Y.; Velauthapillai, D. MS_2/TiO_2 (M = Co, Sn and Ni) electrodes for electrocatalytic and photocatalytic water splitting. Fuel, 385, 134101 (2024).

Shiran, S.B.; Sadaak, B.; Solbakken, J.; Toigo, C.; Zamani, N. Impact of salt precipitation on porosity-permeability correlations: implications for CO_2 storage. Fifth EAGE Global Energy Transition Conference & Exhibition (GET 2024), 1-5 (2024).

Swathi, S.; Yuvakkumar, R.; Kungumadevi, L.; Ravi, G.; Velauthapillai, D. Novel synthesis of CuHCF/B-rGO composites for oxygen evolution reaction activity. Scientific Reports, 14, 25760 (2024).

Tselika, K.; Tselika, M.; Demetriades, E. Quantifying the short-term asymmetric effects of renewable energy on the electricity merit-order curve. Energy Economics, 132, 107471 (2024).

Tukun, E.; Herrera Anchustegui, I. Collaborating in Offshore Renewable Energy Projects and Competition Law: Consortium Bids in Deep Waters. SSRN Electronic Journal, 2024, 4731093 (2024).

Ueckerdt, F.; Verpoort, P.; Anantharaman, R.; Bauer, C.; Beck, F.; Longden, T.; Roussanaly, S.N. On the cost competitiveness of blue and green hydrogen. Joule, 8, 104-128 (2024).

Verpoort, P.C.; Gast, L.; Hofmann, A.; Ueckerdt, F. Impact of global heterogeneity of renewable energy supply on heavy industrial production and green value chains. Nature Energy, 9, 491–503 (2024).

2024 reports and theses

Birkeland, Julie. Statsstøtte for hydrogenprosjekter etter EØS-avtalen § 61 nr. 3, med særlig fokus på Gruppeunntaksforordninngen (GBER) og/eller reglene om klima, miljø- og energistøtte. Master thesis, The University of Bergen (2024).

Egelandsdal, Ann Louise. A Comparative Study of Different Hydrogen Delivery and Storage Systems for Industrial Applications. Master thesis, The University of Bergen (2024).

Ferguson, S.M.; Heijmans, R.J.R.K. Climate Policy and Trade in Polluting Technologies. Norges Handelshøyskole. Institutt for foretaksøkonomi, 30 (2024).

Hagen, Kamilla Valla. Hydrogen production from fluctuating small-scale hydropower. Master thesis, The University of Bergen (2024).

Heijmans, R.J.R.K.; Engström, M. Time Horizons and Emissions Trading. Norges Handelshøyskole. Institutt for foretaksøkonomi, 42 (2024).

Hoel, Marte. Er handlingsrommet for tildeling av statlig støtte utivdet ved CEEAG-retningslinjene- med særlig fokus på hydrogenprosjekter. Master thesis, The University of Bergen (2024).

Nagulanantham, Lavanya. Electrode Materials for Hydrogen Evolution Reaction. Master thesis, The University of Bergen (2024).

Norland, Amalie. Investigating voltage ripple effects in PEM electrolysis: test protocol development and experimental characterisation. Master thesis, The University of Bergen (2024).

Rustad, Helene Just; Elgaaen, Johannes. Finance: Sustainable Aviation Fuels. Master thesis, Norwegian School of Economics (2024).

Skar, Anna Mathea. A Cylindrical Cavity Resonator System for Characterisation of Hydrogen Gas. Master thesis, The University of Bergen (2024).

Skogland Nornes, J.; Melvær-Ringstad, A.F. Utvikling av et PEM-brenselcellesystem for bruk til non-invasiv karakterisering. Bachelor thesis, Western Norway University of Applied Sciences (2024).

Vaardal, Elias Myklebust. Developing a Modular Uncertainty Calculation Tool for Hydrogen Refueling Stations. Master thesis, The University of Bergen (2024).

Yri, Kjartan. Metering . Master thesis, The University of Bergen (2024).

2024 books or chapters in books

Skjærseth, J.B.; Eikeland, P.O.; Inderberg, T.H.J.; Lie Larsen, M. Norway's Hydrogen Strategy: Unveiling Green Opportunities and Blue Export Ambitions. *In: The Geopolitics of Hydrogen*, Springer, 213-232 (2024).

Tukun, E.; Herrera Anchustegui, I. Collaborating in offshore renewable energy projects and competition law: consortium bids in deep waters. *In: Research Handbook on EU Competition Law and the Energy Transition*, Edward Elgar Publishing, 118-143 (2024).

2024 conference contributions and academic lectures

Eikeland, P.O. Europeisk håndtering av energikriser – drivere og barrierer for koordinert politisk respons. Bachelor i beredskap og krisehåndtering (2024).

Eikeland, P.O. Towards a European market for hydrogen - status, strategy implementation and challenges. HyValue Days (2024).

Eikeland, P.O. Towards a European market for hydrogen status, policy drivers and challenges. FME Conference (2024).

Eikeland, P.O. Welcoming address. HyValue webinar (2024).

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