Flagship Project
H_2Mare

Green offshore hydrogen production

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Dear reader,

Many of you will know about the potential of hydrogen. When produced renewably, it can bring together three important aims: energy security, climate neutrality, and competitive strength. This makes hydrogen the opportunity of the century and also one of our priority policy areas at the Federal Ministry of Education and Research.

We must make the best possible use of our local conditions. Germany is an industrialized country that consumes a lot of energy but, at the same time, has rather low levels of wind and sunshine. Only on the high seas do we have constant and strong winds. This is where we can generate the renewable electricity that we so urgently need. And this is where we can use that electricity to produce hydrogen in the same go.

The aim of the flagship project H_2Mare is precisely that: To enable the efficient offshore generation of hydrogen and its derivatives. However, we have weathered a few storms along the way. The Covid pandemic, the energy crisis, supply shortages and their ramifications have impacted the flagship project. The results achieved so far are therefore all the more impressive. In Denmark, H_2Mare is currently testing how to couple an electrolyser to a wind turbine. In Germany, tests are underway to operate a seawater desalination plant. Moreover, H_2Mare is developing an innovative offshore electrolyser and will start operating a container for the production of fuels at sea next year.

In this way, H_2Mare as well as the other two hydrogen flagship projects – H_2Giga and TransHyDE – lay the cornerstones of ensuring Germany's supply security. At the same time, the projects are developing the innovations to position Germany at the forefront of the international competition.

Our aims are clear: We want to make Germany a "hydrogen republic" and become leaders everywhere possible along the hydrogen value chain. This brochure provides in-depth insights into the work of H_2Mare and its various challenges. To me, this preliminary evaluation means one thing in essence: Hydrogen is the future!

I wish you an inspiring read.

Bettina Stark-Watzinger
Member of the German Bundestag
Federal Minister of Education and Research

H_2Mare

Hydrogen production directly on the high seas

At sea, the conditions are ideal for generating renewable electricity. The direct production of green hydrogen from wind power in offshore facilities without grid integration can significantly reduce costs compared to onshore production. The H_2Mare Flagship Project will therefore explore the offshore production of green hydrogen and other power-to-X products.

Offshore wind turbines produce considerably higher amounts of electricity more regularly than their onshore counterparts. The Hydrogen Flagship Project H_2Mare aims to exploit this potential by using renewable electricity offshore to produce hydrogen and its secondary products.

The partners strive to couple the water electrolyzer directly with a wind turbine - and thus provide innovative technologies to produce green hydrogen offshore. For this to succeed, both the electrolyzer and the wind turbine need to be adapted.

The H_2Mare project **H_2Wind** is researching an electrolyzer directly for the harsh conditions at sea. The H_2Mare project **OffgridWind**, on the other hand, takes care of the adaptations on side of the wind turbine. Directly coupling the wind turbine and electrolyzer is intended to reduce the costs of hydrogen production, since infrastructure costs can be significantly reduced when **a connection to the power grid is not needed**. In addition, the decoupling of electrolysis and grid relieves the local grid structures. Another advantage of offshore hydrogen production compared to onshore production is that there are much larger potential areas for the generation of wind energy.

Due to the numerous advantages of offshore production, H_2Mare also works on solutions to directly produce **secondary products** such as green methanol - in other words, offshore power-to-X. To ensure their success, the partners from the H_2Mare project **PtX-Wind** also aim to pursue pioneering approaches such as seawater electrolysis.

In addition, all technical H_2Mare projects analyse issues concerning safety and environmental impact. Life cycle assessments and technology evaluations are also being developed.

The H_2Mare project **TransferWind** is dedicated to overarching issues as well as communication and knowledge transfer. Likewise, acceptance management and regulatory framework issues are central to the work.

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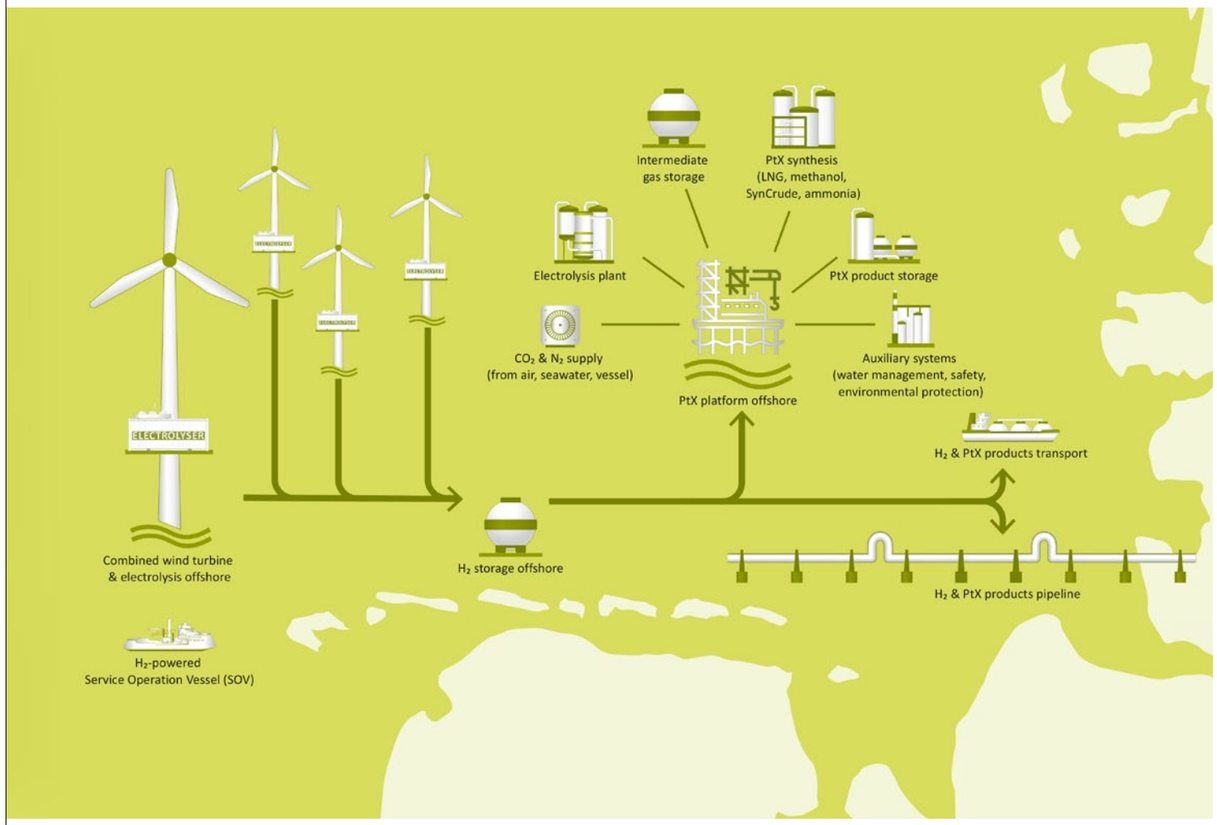


Thematic focus of H_2Mare:

- Transferability
- Potential of H_2 & PtX
- Environment & safety
- Regulation & standards
- General public & society
- Technology offshore wind & H_2

Project facts and figures

Partners: 31 *(plus 2 associated partners)*
Funding level: over EUR 100 million
Project duration: April 1, 2021 to March 31, 2025

H_2Mare is one of three Hydrogen Flagship Projects funded by the German Federal Ministry of Education and Research (BMBF) as part of efforts to implement Germany's National Hydrogen Strategy.

H_2Wind

Self-sufficient water electrolyzers at sea

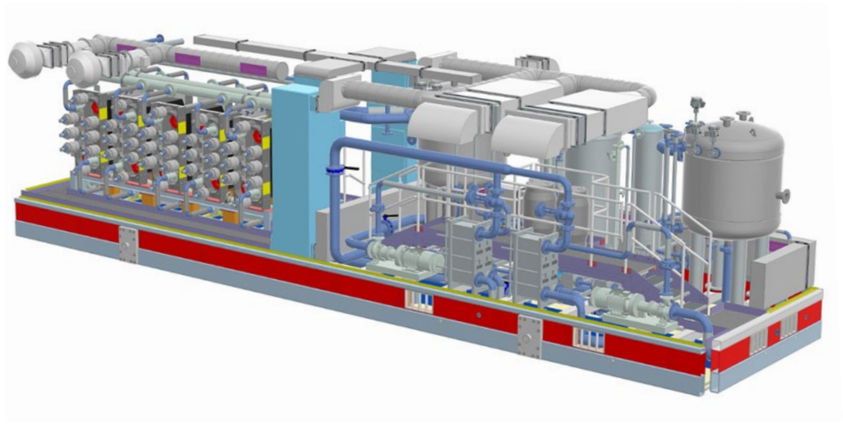


Fig. 1: 5-megawatt electrolysis container

The H_2Mare project **H_2Wind** is researching the electrolyzer, which is intended to be coupled with a wind turbine. This innovative, compact PEM electrolyzer is designed to work in an efficient and virtually self-sustaining manner despite the rough conditions at sea. To achieve this, its components must be tested under offshore conditions and adapted accordingly (Fig. 1). A database developed in H_2Wind enables individual components of the electrolyzer to be analysed in isolation and evaluated based on test data. The arrangement of the components is also being revised. This is because maintenance and assembly of the system on the high seas places significantly greater demands on the system design.

An important milestone, which can be seen in the photo, was achieved by building a prototype stack with a reduced number of cells (Fig. 2). This will be used to realistically model and research the operating behavior.

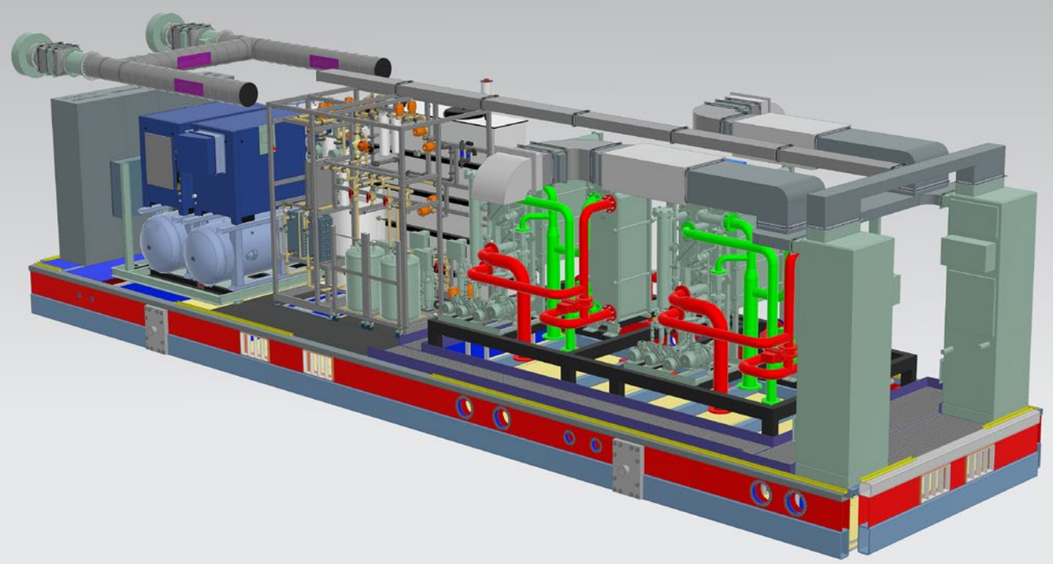
H_2Wind is also developing processes for storing the hydrogen produced, as well as for treating and supplying water for electrolysis. Researchers at the Fraunhofer Institute for Wind Energy Systems are investigating the use of locally available seawater. To this end, they are testing a thermal desalination process – based on the existing process heat of the electrolyzer (Fig. 3).

Initial tests have shown that although the different temperatures affect the start-up behavior of the desalination plant, they only have a negligible effect on the production volume of ultrapure water. H_2Wind is also investigating the time and energy required after the cold start of the plant until the required ultrapure water can be produced from the seawater fed in, and whether it is possible to dispense with the chemicals normally used in the process in the desalination plant.

By taking a holistic view of the plant, H_2Wind also identifies the conditions for operating the facility profitably.

Fig. 2: Built prototype stack with reduced number of cells

Fig. 3: Process water container for seawater desalination



OffgridWind

New wind turbine for hydrogen production

The new offshore-capable electrolyzer is to be installed on the platform of the wind turbine in future. The H_2Mare project **OffgridWind** is working on the best way to combine the turbine and the electrolyzer. The concepts developed will initially be tested on land – on an onshore wind turbine. A dedicated test infrastructure has been set up for this purpose. The tests have begun in spring 2024.

In addition to a larger platform, the offshore turbine will also require a new foundation in future. OffgridWind is researching both – supplemented by the transport of the hydrogen produced to the mainland. The partners are also simulating the operation and calculating the costs throughout the entire life cycle of the wind turbines for hydrogen production at sea.

Electrolysis platform with placement of containers for electrolysis on wind turbine. © Siemens Gamesa Renewable Energy

PtX-Wind

Offshore production of further power-to-X products

The H_2Mare project **PtX-Wind** is testing the production of other power-to-X products at sea, such as methane, methanol, Fischer-Tropsch products and ammonia. In addition to water, CO_2 and nitrogen are also required for this. These are to be extracted directly from the air (direct air capture) or the sea. PtX-Wind is also focusing on the co-electrolysis of CO_2 and water as well as seawater electrolysis. If the use of seawater electrolysis is successful, the water extracted from the sea no longer needs to be desalinated before electrolysis.

PtX-Wind will initially test the concepts developed for all synthesis products on land. For the first demonstration of a power-to-X process chain - consisting of co-electrolysis and the synthesis of fuels – researchers at the EnergyLab of the Karlsruhe Institute of Technology (KIT) have set up a power-to-Liquid container (PtL). In this container, fuels are produced from hydrogen and CO_2 using Fischer-Tropsch synthesis. The entire PtL process chain will then be demonstrated on a floating platform at sea, coupled with a co-electrolysis system from the German Aerospace Center (DLR). In addition to co-electrolysis, this will carry a direct air capture plant, PtL synthesis and wastewater treatment in containers and produce Fischer-Tropsch products that can later be used as sustainable fuels such as diesel or kerosene.

Power-to-X container for offshore use. © KIT

TransferWind

New solutions thanks to shared knowledge

The H_2Mare project **TransferWind** aims to answer overarching issues concerning all four H_2Mare projects. These include regulatory framework conditions for offshore and power-to-X systems, knowledge transfer, acceptance research and overarching technical aspects. TransferWind is also developing a concept for a filling station network that enables the direct refueling of hydrogen-powered ships. This serves to illustrate and evaluate potential applications of hydrogen produced offshore, particularly with regard to the transportation sector.

After analyzing the existing regulations for the safe and environmentally compatible construction and operation of offshore facilities, TransferWind is working on dovetailing them. By defining “guard rails” that can later be used as a guide for plant constructors and operators, options for action are to be developed and future approval processes simplified.

The professional exchange between the individual H_2Mare projects and the knowledge transfer between science, business, politics and civil society are also anchored in the project. In interviews with stakeholders and citizen dialogs, a picture of opinions on the offshore production of hydrogen was created and key factors for the acceptance of the expansion of renewable energies were identified. The interviewees attached importance to local benefits for the region, participation in the planning and implementation processes and transparent information and communication processes.

In addition to external communication, TransferWind is also involved in educational work. The “Meer & Küste” magazine, a touring exhibition by the Küstenunion and an H_2Mare online game present the potential and effects of green offshore hydrogen production to the coastal population. In this way, the project promotes acceptance of the technologies developed in H_2Mare.

H_2Mare presents itself to the public. © Fraunhofer IWES

H_2Mare

Project partners

BAM Bundesanstalt für Materialforschung und -prüfung

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DECHEMA Gesellschaft für Chemische Technik und Biotechnologie e.V.

DECHEMA FORSCHUNGSINSTITUT Stiftung bürgerlichen Rechts

DLR

DVGW Forschungsstelle ebi

EnBW

Technology for Water ENVIROCHEMIE

EUCC-D

Fraunhofer

fumatech Membranes for Separation and Energy Storage BWT GROUP

Helmholtz-Zentrum hereon

HOCHSCHULE WISMAR University of Applied Sciences Technology, Business and Design

INERATEC

KIT Karlsruher Institut für Technologie

Leibniz Universität Hannover

MAX-PLANCK-INSTITUT FÜR DYNAMIK KOMPLEXER TECHNISCHER SYSTEME MAGDEBURG

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