NS H2V Ports

North Sea Hydrogen Valley Ports

Creating the hydrogen corridor between North Sea ports

Deliverable D 3.1

Market overview of hydrogen-powered short-sea and inland vessels in Europe

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Contents

Abbreviations

AWI	Alfred Wegener Institute
CTV	Crew Transfer Vessel
CO_2	Carbon dioxide
DWT	Deadweight tonnage
GT	Gross tonnage
H_2	Hydrogen
HFO	Heavy Fuel Oil
kW	Kilowatt
kWh	Kilowatt-hour
LNG	Liquefied Natural Gas
MARPOL	International Convention for the Prevention of Pollution from Ships
MGO	Marine Gas Oil
MPP	Multipurpose vessel
MSW	Municipal Solid Waste
MW	Megawatt
NH_3	Ammonia
NO_x	Nitrogen oxides
OSV	Offshore Service Vessel
PEMFC	Proton Exchange Membrane Fuel Cell
PM	Particulate Matter
RFNBOs	Renewable Fuels of Non-Biological Origin
Ro-Ro	Roll-on/Roll-off
SO_x	Sulphur oxides
SOFC	Solid Oxide Fuel Cell
TEU	Twenty-foot Equivalent Unit

Executive Summary

Ports are vital to Europe's economy, handling three-quarters of the EU's external trade while serving as energy hubs. With climate policies, stricter emissions regulations, and investments in renewables reshaping the maritime sector, ports are increasingly positioned as clean energy nodes. Meanwhile, hydrogen and its derivatives are emerging as key alternatives to fossil fuels, particularly for short-sea, coastal, and inland shipping.

Alternative fuels attracting interest today —hydrogen, ammonia, and methanol— and alternative propulsion technologies (e.g. dual-fuel combustion engines and fuel cells) all come with their own trade-offs and risks.

For coastal, inland and short-sea shipping, hydrogen seem today well-suited to vessels that operate on shorter routes and return frequently to port. A dozen of pilot and demonstration projects have been carried out across Europe, and particularly around the North Sea over the last five years, which have demonstrates the feasibility of hydrogen solutions for vessels such as tugboats, pilot boats, crew transfer vessels, barges, and short-haul cargo and container ships.

As of 2025, thirteen hydrogen- and methanol-powered vessels are already operational across Europe, ranging from ferries and barges to research and offshore supply vessels. Beyond these early demonstrators, a new generation of larger vessels is on order—including bulk carriers, container ships, tankers, and ferries—with propulsion systems up to 6.4 MW. Most are expected to enter service before 2030, anchoring the North Sea region's leadership in maritime decarbonization.

The transition remains at an early stage, but momentum is building. Current pilot projects are paving the way for early commercial adoption, and by the end of the decade, a growing fleet of hydrogen-powered vessels is project to create tangible demand for clean fuels across European ports.

1 Introduction

The port sector is crucial to the European and the North Sea Region economy. EU ports handle more than two million calls per year[1], and represent around 75% of the EU's external trade volumes. Beyond trade, many ports are also energy hubs, facilitating the import of fossil energy products, the harvesting of offshore oil and gas fields, and the servicing of offshore energy facilities.

With climate and decarbonization policies driving continued investment in renewabe electricity capacity and hydrogen production facilities, many ports are now pivoting to ***clean*** energy hubs, with a focus on offshore wind energy, hydrogen and derivatives.

At the meantime, internal conventions (MARPOL, Emission Control Areas), EU laws (EU Sulphur Directive, Ambient Air Quality Directive, Refuel EU maritime, EU Emission Trading Sscheme), and national regulations are pushing ship owners to look at low-carbon propulsion technologies, not only for international shipping but also for inland, coastal and short-sea shipping.

In this new environment, ports have a central role to play in bunkering and supplying sustainable fuels for shipping, and to industries located within the port area or its immediate surroundings. To prepare for this change, ports must assess the likely use cases for clean fuels and the related fuel storage and demand needs.

Against that background, this report will briefly describe current low-emission fuels and propulsion technologies, explore relevant vessel types and use cases for inland, coastal and short-sea shippings and present existing demonstrators and early commercial vessel deployments.

[1] https://ec.europa.eu/eurostat/web/products-eurostat-news/w/ddn-20250128-1

2 Alternative fuels and propulsion technologies

As decarbonization obligations are becoming more widespread across the maritime sector, interest for hydrogen and derivative fuels has been steadily growing. Today, attention is revolving around three potential fuels, e-hydrogen, e-ammonia and e-methanol gathered under the term “Renewable Fuels of Non-Biological Origin” (RFNBOs) under EU legislation.

This section briefly describes the main characteristics of these fuels, their availability and safety concerns associated with them.

2.1 Description of alternative fuels

2.1.1 Hydrogen

- **General characteristics**

Hydrogen (H2) is a colourless, odourless, tasteless gas that is the simplest and lightest member of the family of chemical elements. It has a low volumetric energy density and therefore storing or using it at atmospheric pressure and temperature requires a substantial amount of space. This weakness can be compensated by compressing or liquefying hydrogen, and thus making its storage, transportation, and use easier.

- **Availability**

European hydrogen consumption reached 7.9 Mt in 2023[2], 95.5% of which coming from natural gas through a process known as steam-methane reforming. Production of renewable and low-carbon hydrogen is nevertheless expected to steadily grow in the next decade with the ramp-up of electrolyzer capacity across the world, and multiple targets and incentives to increase production of renewable hydrogen in Europe and beyond (H2 Global, European Hydrogen Bank, Renewable Energy Directive, etc.).

While low-carbon hydrogen production is ramping up, its availability to the shipping sector is expected to remain limited in the coming years, except in industrial areas hosting or located next to large electrolyzers and/or import terminals.

- **Safety considerations**

While hydrogen has been used in industrial applications for more than a century and is already subject to well-established safety protocols, its use for maritime applications is more recent.

[2] Clean hydrogen monitor 2024, Hydrogen Europe

When designing new vessels or planning a retrofit, specific hazards associated with hydrogen systems should be taken into account:

- High flammability;
- Asphyxiation hazard if oxygen is replaced;
- Risk of embrittlement for certain metallic materials and equipment that are exposed to hydrogen;
- Hazards associated with the storage procedure, e.g. high storage pressure for gas, or low temperature for cryogenic liquid.

2.1.2 Ammonia

- **General characteristics**

Anhydrous ammonia (NH3) is a carbon-free compound of nitrogen and hydrogen, with a strong, irritating odour. Depending on pressure and temperature, ammonia can be found as a colourless gas, a colourless liquid and even as a white solid[3].

- **Availability**

There is extensive land-based experience with the production and use of ammonia as a fertiliser, refrigerant and chemical. With a production of 183 Mt in 2022[4], it is the second-largest chemical product manufactured globally and is generally available in regions with agricultural and industrial demand.

- **Safety**

Use of ammonia requires strict safety measures due to its high toxicity even at low concentration level. The exposure to an ammonia atmosphere causes various physical effects, such as eyes irritation and even blindness, respiratory effects ranging from tract irritation to pulmonary edema, and skin burns.

Ammonia is also a flammable gas, if concentration in the air is in the range of 15-28%, and oxygen is present together with an ignition source such as a a spark or an open flame[5].

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[3] European Chemicals Agency (ECHA), *Anhydrous Ammonia (EC 231-635-3) – Registration Dossier (7.11.1 Health hazards)*. Available at: https://echa.europa.eu/registration-dossier/-/registered-dossier/15557/7/11/1

[4] IRENA, Global trade in green hydrogen derivatives: Trends in regulation, standardisation and certification (Renewable Energy Agency, 2024) ISBN 978-92-9260-619-0. Available at: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2024/Oct/IRENA_Green_hydrogen_derivatives_trade_2024.pdf

[5] National Institute for Occupational Safety and Health (NIOSH), *Emergency Response Card – Ammonia, Anhydrous*: "Lower explosive (flammable) limit in air (LEL), 15%; upper explosive (flammable) limit in air (UEL), 28%." Available at: https://www.cdc.gov/niosh/ershdb/emergencyresponsecard_29750013.html

2.1.3 Methanol

- **General characteristics**

Methanol (CH3OH) is water-soluble and readily biodegradable, comprising four parts hydrogen, one part oxygen, and one part carbon, and is the simplest member of a group of organic chemicals called alcohols. Methanol is a key product in the chemical industry. It is mainly used for producing other chemicals such as formaldehyde, acetic acid and plastics, which are then used in thousands of everyday products, including plastics, paints, cosmetics, and fuels.

- **Availability**

Typically, methanol is produced with natural gas. However, greener production pathways exist, based on renewable feedstocks such as agricultural waste, Municipal Solid Waste (MSW), sewage, renewable electricity, and captured CO2. Around 98 million tonnes (Mt) are produced per annum, nearly all of which is produced from fossil fuels (either natural gas or coal). Less than 0.2 Mt of renewable methanol is produced annually, mostly as bio-methanol[6]. Supply of e-methanol obtained by combining carbon dioxide and green hydrogen produced with renewable electricity is still marginal, with a first plant opened in Kassø (Denmark) in early 2025, but close to 20 additional plant projects are currently under development across Europe and 2 Mt of e-methanol could be produced by 2030[7].

The main advantage of methanol is its existing distribution network and infrastructure. Methanol is already a globally available commodity with extensive distribution and storage capacity in place. Millions of tonnes of methanol are transported each month to diverse and scattered users, by ship, barge, rail and truck. There are currently 122 ports with methanol storage facilities worldwide[8].

- **Safety**

The three main safety risks of methanol fuel are its high flammability, the poor visibility of a methanol flame in daylight and its toxicity: methanol is irritating to the eyes, the skin, and the respiratory tract. It can cause permanent damage to the optic nerve and central and peripheral

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[6] Innovation Outlook : Renewable Methanol, IRENA AND METHANOL INSTITUTE (2021), International Renewable Energy Agency, Abu Dhabi

[7] Cleantech reality Check, Maritime E-fuels : Sinking before we sail?, Breakthrough Energy and Systemiq, 2024

[8] https://www.dnv.com/expert-story/maritime-impact/Methanol-as-fuel-heads-for-the-mainstream-in-shipping/

nervous system with just a single acute exposure. Safety measures must therefore be taken, such as venting systems, especially on ships carrying passengers.

2.2 Alternative propulsion technologies

To use hydrogen and derivatives, two propulsion technologies are mainly considered today: dual-fuel combustion engines capable of burning diesel and clean fuels, or fuel cells, usually running on hydrogen and using hydrogen stored on board or ammonia (through a cracker) or methanol (through a reformer).

2.2.1 Combustion engines and dual-fuel engines

Combustion engines convert chemical energy from fuel into mechanical energy to move the ship and are the primary type of propulsion system used in shipping today. While the century-old technology is well-known and mastered, the introduction of new fuels, i.e. e-methanol, e-ammonia and e-hdyrogen in combustion engines, brings new challenges and trade-offs:

- A **hydrogen** fueled combustion engine works in much the same way as a diesel fueled combustion engine. Hydrogen is combusted to produce water with no carbon-based emissions; however, the temperature of the reaction produces nitrogen oxides, which are harmful to human health. Whilst these emissions can be minimized by controlling the combustion process or aftertreatments, they can never be completely removed, and the control process adds costs to the engine. Another issue is potential hydrogen embrittlement, i.e. the phenomenon where hydrogen can penetrate the metal components of the engine and reduce their ductility, leading to brittleness and cracking. This can compromise the engine's structural integrity and overall durability.

- Using **ammonia** creates other challenges related to ignition, combustion efficiency, emissions, and safety. Ammonia's slow burning velocity can lead to challenges in achieving stable and complete combustion within the engine cylinder. While ammonia combustion doesn't directly produce carbon dioxide, it can generate significant amounts of NOx and N2O, both of which are potent greenhouse gases. Uncombusted ammonia can also escape the engine, potentially leading to safety concerns and environmental impacts[9].

[9] S. Valera-Medina et al., "Ammonia Combustion and Emissions in Practical Applications: A Review," *Carbon Neutrality*, vol. 3, no. 1, 2024. Available at: https://link.springer.com/article/10.1007/s43979-024-00088-6

- Finally, **methanol**'s lower volatility compared to gasoline or diesel can make cold starting more difficult. While methanol combustion can produce less greenhouse gas emissions, it can also lead to increased NOx emissions compared to gasoline. Unburned methanol and other pollutants can also contribute to higher emissions during cold start and low-load operation. Finally methanol's corrosive properties can affect fuel lines, pumps, and other engine components[10]

Dual-fuel engines are very similar to regular marine engines, but are capable of operating on two different types of fuel, typically:

- A conventional fuel (like marine diesel or marine gas oil), and
- A cleaner alternative fuel, such as liquefied natural gas (LNG), methanol, hydrogen or biofuels.

Depending on the engine's operating point, only have a small quantity of diesel oil will have to be burnt after going to dual fuel mode.

2.2.2 Fuel Cells

Fuel cells generate electricity through an electrochemical reaction, rather than combustion. Using hydrogen as a fuel in an onboard fuel cell system educe the air pollutant emissions further than any internal combustion engine because fuel cells have no incomplete combustion products; they also have a higher efficiency than internal combustion engines and do not require any pilot fuel.

When a hydrogen fuel cell system is used, the emissions of NOx, sulphur oxides (SOx), or PM can be fully eliminated, since the fuel cells have no incomplete combustion products, and no pilot fuel is needed. If a carbon fuel is reformed inside the fuel cell into hydrogen, a low amount of NOx emissions may be formed in the subsequent heat and energy recovery systems[11].

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[10] IEA AMF, *Fuel information – Methanol*, Available at: https://www.ieaamf.org/content/fuel_information/methanol

[11] U.S. Department of Energy, "Does the use of hydrogen produce air pollutants such as nitrogen oxides?" Available at: https://www.energy.gov/eere/fuelcells/does-use-hydrogen-produce-air-pollutants-such-nitrogen-oxides

While different technologies co-exist today at various maturity stages, two seem to be most seriouslsy considered for maritime applications: proton-exchange membranes fuel cells (PEMFC) and Solid Oxide Fuel Cell (SOFC). Both technologies come with their own limits: PEMFC have a high power density, offer fast start-up and dynamic response and operate at low temperature (~60–80°C), but require very pure hydrogen to maintain their durability[12]. On their part, SOFC systems offer high energy efficiency (up to 60%, and >80% with cogeneration), fuel flexibility, but only operate at high temperature (700–1,000°C), require several hours to reach full power and are sensitive to thermal cycling[13].

2.3 What fuel for short-sea, coastal and inland shipping?

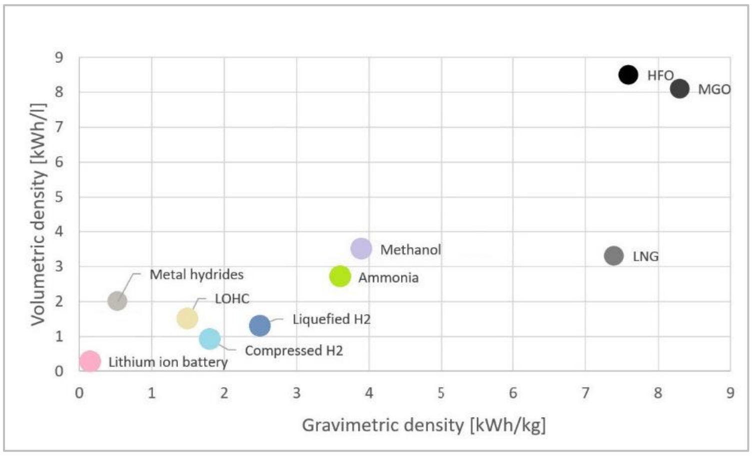
All fuels described before have their pros and cons, and trade-offs must be made to integrate them into vessels. In addition to safety, one key challenge in relation to vessel design is energy density, which directly affects the volume or weight that is required to store a certain amount of energy.

Figure 1 shows the gravimetric and volumetric energy densities of several fuels. It is clear from this figure that the energy density of conventional diesel (HFO & MGO) cannot be matched by clean alternatives : the required storage volume roughly doubles when diesel is substituted with methanol or LNG, and is multiplied by six for hydrogen.

[12] “Fuel Cell Systems for Maritime: A Review of Research Development, Commercial Products, Applications, and Perspectives” — MDPI. URL: https://www.mdpi.com/2227-9717/11/1/97

[13] “Fuel Cell Technologies and Applications for Deep-Sea Shipping” — May 2024 report. URL: https://safety4sea.com/wp-content/uploads/2024/05/MMMCZCS-Fuel-Cell-Technologies-and-Applications-for-Deep-Sea-Shipping-2024_05.pdf

Figure 1: volumetric and gravimetric energy density of various traditional and alternative fuels



Source: adapted figure from Royalihc

Consequently, either in compressed or liquid form, hydrogen storage significantly reduces cargo space and increases vessel displacement. This makes hydrogen an unlikely candidate for long-distance transport, however short-sea, coastal and inland shipping which are characterized by frequent return to ports and shorter travel distances, appear to be more promising use cases.

3 Vessel types and use cases

In the following section, the main characteristics and purpose of vessels potentially suited to hydrogen and derivatives are described.

3.1 Tugboats

Tugboats are small but powerful vessels designed to tow, push, or guide larger ships in ports —especially when those ships lack the manoeuvrability needed for docking, turning, or navigating narrow inland or coastal waters. Generally, they offer the following services:

1. Harbor Assistance
   - Help cargo vessels, container ships, and barges dock or undock safely in tight port environments.
2. Towing and Pushing Barges
   - Move non-self-propelled vessels like barges up rivers or through canals.
3. Manoeuvring Support
   - Assist short-sea ships in turning, positioning, or stabilising when entering or leaving inland ports.
4. Emergency Response
   - Can act in emergencies (e.g., fire, grounding, mechanical failure) by towing or repositioning vessels.

3.2 Pilot boats

Pilot boats are small, fast vessels used to transport maritime pilots to and from larger ships. Pilots guide ships through challenging or regulated waterways, such as harbours, rivers, or locks. These vessels provide the following services.

1. Transporting Pilots to and from Vessels
   - Deliver local harbor or river pilots to inbound vessels before they navigate tight inland waterways or enter port.
2. Support for Safe Navigation
   - Pilots board moving cargo or container ships and take over navigation in areas where local knowledge is critical (e.g., tides, currents, bridge clearance).

3.3 Crew transfer vessels & Offshore service vessels

Crew Transfer Vessels (CTVs) are specialized boats designed to safely transport personnel—mainly technicians and crew—to and from offshore installations, most commonly offshore wind farms, oil and gas platforms, or other marine-based infrastructure. They are designed for short-sea travel of up to 100km/50 miles at a high speed.

Offshore service vessels (OSVs) also known as Offshore Supply Vessels, are specialty ships designed for operating on the ocean, serving multiple purposes. They can serve as platform support, anchor handling, construction, maintenance, and more. Contrary to CTVs, they can remain at sea for several days or weeks.

3.4 Barges

Barges are flat-bottomed boats primarily designed for transporting heavy goods, materials, or equipment over water, especially on rivers, canals, and other inland waterways. They typically do not have their own propulsion and are towed or pushed by tugboats or towboats, though some modern barges may be self-propelled.

3.5 Container vessels

Container vessels used in coastal areas or on inland waterways are specially designed ships or boats that transport standardized cargo containers (e.g., 20-foot or 40-foot containers) over short distances. They typically carry 100 to 1,000+ TEU (Twenty-foot Equivalent Units) vs. 20,000+ TEU for ocean vessels.

3.6 Cargo vessels

Cargo vessels that transport general or bulk goods over short distances play a crucial role in regional logistics networks between smaller ports, industrial areas, and larger seaports for further distribution or export. Different sub-category of cargo vessels can be identified:

- General Cargo Vessels carrying packaged goods, machinery, timber, pallets, steel coils, etc.
- Bulk Carriers transporting dry bulk cargo like grain, sand, cement, coal, or minerals.
- Multipurpose Vessels (MPP) handling both general cargo and containers or project cargo.
- Ro-Ro Cargo Vessels, designed for roll-on/roll-off cargo like trucks, trailers, and vehicles.

3.7 Research vessels

Coastal research vessels are specialized ships designed for scientific studies in coastal waters, estuaries, and nearby ocean areas. Unlike large oceanographic research vessels that sail far offshore for extended missions, coastal research vessels typically operate closer to shore, on shorter trips, and with smaller crews.

3.8 Summary table of vessels and use cases

Vessel type	Typical size and capacity	Deadweight range	Propulsion power	Speed	Range
Tugboat, pilot boat[14]	24–32 m length, ~60–80 t bollard pull	300–800 GT	3–5 MW (typically diesel-electric or hybrid)	Up to 13 kn	Harbour operations (~50–100 nm)
Crew Transfer Vessel[15]	15-30 m length 12-24 passengers	Approx. 100–300 GT	1–2 MW (diesel or hybrid)	20 – 25 kn	Up to 100 km / 50 nm
Container vessel Feeder?)[16] [17] [18]	100 – 180m length	Approx. 100 TEU bis 3,000 TEU (500 – 50,000 GT)-	1 MW to 24 MW	16 – 22 kn	Up to 1000 km (~500 nm)
Cargo vessel [19] [20]		500 to 5,000 DWT (100-4,000 GT)	400 kW to 3 MW	12 – 14 kn	Up to 1000 km (~500 nm)
Ro-Ro ferry [21] [22] (Ro-Ro cargo ships?)		1,000 to 15,000 DWT (3,000 – 25,000 GT)	400 kW to 15 MW	18 – 22 kn	Up to 1000 km (~500 nm)
Research vessels	20 – 50m length	100–1,000 DWT		10 – 15 kn	Up to 1000 km (~500 nm)

[14] https://www.damen.com/vessels/tugs/asd-tugs?view=models
[15] https://www.seazip.com/our-fleet/?gad_source=1&gad_campaignid=22429050848&gclid=EAIaIQobChMIhOL-uMzkjgMVZnJBAh0aDRp9EAAYASABEgJFcfD_BwE
[16] https://www.man-es.com/docs/default-source/document-sync/propulsion-of-2-200---3-000-teu-container-vessels-eng.pdf
[17] https://ship-spotting.de/schiffe/schiffstypen/schiffstypen-containerschiffe/datenbank-containerschiffe/
[18] https://sin.clarksons.net/
[19] https://ship-spotting.de/schiffe/schiffstypen/schiffstypen-frachtschiffe/#Daten
[20] https://sin.clarksons.net/
[21] https://ship-spotting.de/schiffe/schiffstypen/schiffstypen-ro-ro-schiffe/
[22] https://sin.clarksons.net/

4 Overview of hydrogen and derivatives powered vessels

Hydrogen-powered vessels have been seriously considered for slighlty more than a decade, given the growing pressure for the transport sector to decarbonize. After an initial phase of demonstration and pilot projects, early commercial deployments have now started. More vessels are expected to be delivered before 2030, making the North Sea region a world leader in short-sea and inland shippin decarbonization.

4.1 Vessels in operation today

The North Sea Hydrogen Valley Port project has identified 13 vessels in operation today on short-sea shipping route or inland waterways, relying either on hydrogen or methanol as their main propulsion fuel.

Antonie Cargo vessel

The MS Antonie is one of the first hydrogen inland cargo vessel in operations in Europe. With a length of 135-metre and a cargo capacity of 3,700 tons, the vessel is used to transport salt for the company Nobian - from Delfziul to Rotterdam – a 600 km roundtrip. The vessel is equipped with a 1100 kWh battery back, a 320 kw fuel cell and consumes 1200 kg of hydrogen per roundtrip.

Photo credit: NPRC

Breakthrough superyacht

Photo credit: Feadship

Breakthrough is the world's first hydrogen fuel-cell powered 118.8-metre superyacht, designed to cruise emission-free over short distances and to power hotel loads with zero emissions, using onboard cryogenic storage at −253°.

The vessel is equipped with a 3.2 MW fuel cell systems, with dual-fuel bio/diesel engines also installed on-board as back-up propulsion system and range extender.

Coriolis research vessel

The Coriolis is a 30-meter long vessel used for environmental research in coastal areas by the Helmotz-Zentrum Hereon research center. Harbored in Hamburg it will be used for research around the Baltic and the North Sea.

Photo credit: Hereon/ Jewgeni Roppel

The vessel is equipped with a 100 kW fuel cell system and a battery pack. The propulsion system has been designed to be very flexible and allows the electric traction motors to draw power from diesel generators, batteries or batteries and fuel cells. On board the Coriolis, a tank system using metal hydrides (MH) to store hydrogen is used instead of a conventional pressurised or liquid hydrogen storage tank.[23]

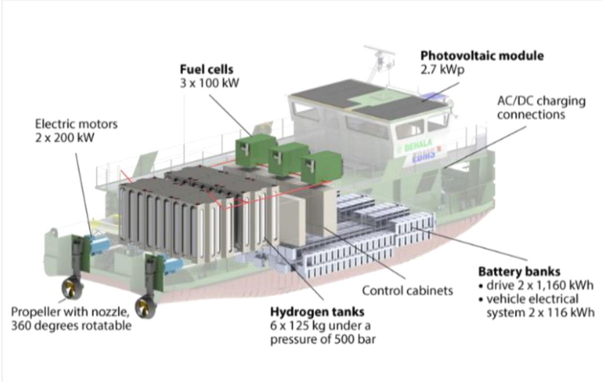
Coastal Liberty


Photo credit: eCap Marine

Coastal Liberty, a 43 m offshore supply vessel (OSV) owned and operated by the Dutch branch of the Jifmar Group, has undergone a refit and now sails emission-free on green hydrogen on the Wadden Sea. The vessel is equipped with fuel cell engines providing 400 kW of power coupled with 280 kWh batteries. To power the vessel over multiple days, 200 kg of hydrogen are stored on-board at 380 bar.

[23] https://www.hereon.de/innovation_transfer/coriolis/index.php.en

Elektra push boat



The 20-meter long push boat is a demonstration vessel built by the Technical University of Berlin to demonstrate alternative power systems on inland waterways. Elektra is equipped with a 300 kW fuel cell systems combined with a 2.5 MWh battery. In battery-electric mode, the tug can cover up to 65 km (40 miles) over an 8-hour period before recharging is required. On hydrogen, Elektra is able to travel a minimum of 100 km (62 miles) over a 16-hour day or longer. Since 2021, the push boat is navigating on the Elbe river and used to carry Siemens turbines, which need to be shipped from the production site in the center of Berlin to the Western Harbor or to Hamburg.

Energy Observer

Photo credit: Antoine Drancey / Energy Observer

This 30.5-m by 12.8-m experimental vessel was launched in 2017 to be the first self-sufficient zero-emission vessel capable of producing hydrogen and electricity on board without emitting greenhouse gases. The boat produces and stores hydrogen using seawater thanks to: Three types of solar panels spread over 130 spm surface (21 kW peak), two vertical axis wind turbines (2 x 1 kW). It is also fitted with a traction kite and two reversible electric motors (2x41 kW) of hydrogenation, one lithium battery (106 kWh), one desalinisator, one electrolyser, one compressor, one fuel cell (22 kW), and tanks capable of storing 62 kg of hydrogen.

Hydra ferry

MF Hydra is the world's first liquid hydrogen-powered ferry. Put in commercial operation by the company Norled in 2024, the 82.4-meter-long vessel can transport up to 300 passengers and 80 vehicles. It is powered by two 200 kW fuel cells, two 440 kW diesel generators, and two Shottel thrusters, allowing it to move at a speed of 9 knots. With its 80 cbm hydrogen storage tank, the vessel must only be refuelled every other week.

Photo credit: Norled

H2Barge 1

Photo credit: Future Proof Shipping

The 110- by 11.45-metre *H2 Barge 1* was originally built as a conventionally-powered containership for sailings on the Rhine River, but underwent conversion to operate on hydrogen fuel in 2023. With a capacity of 193 T, the vessel is powered by a fuel cell system with a total output of 900 kW to supply propulsive and auxiliary power and a 1,037 kWh lithium-ion battery pack for peak shaving, secondary, and bridging power. The hydrogen is placed above the fuel cell system in two 40-foot containers housing a total quantity of approximately 900 kilograms under a pressure of 300 bar. H2Barge 1 will ships cargo between Rotterdam and Antwerp via the Meuse River and is operated by the company Future-Proof Shipping.

H2barge 2

H2Barge 2 - formerly known as Fenny 1 and FPS Waal - was built as a conventionally powered inland containership and underwent in 2023 a complete retrofit with the removal of its combustion engines and their replacement by a 1.2 MW fuel cell systems combined with hydrogen storage, battery packs and electric drive train. The vessel has been in operation on the Rhine since 2024, carrying up to 200 containers between Rotterdam (the Netherlands) and Duisburg (Germany), a roundtrip of more than 400 kilometers.

Photo credit: Future Proof Shipping

Hydrotug 1

Photo credit: CMB.Tech

The Hydrotug 1, the world's first hydrogen-powered tugboat, was launched in 2024 in the port of Antwerp (Belgium). The vessel is powered with two dual-fuel engines that can run either on hydrogen or on traditional fuel. The tug has a length of 30.17 metres, a width of 12.5 metres, a weight of 678.8 tons and a bollard pulling power of 65 tons. The tug can store 415 kg of compressed hydrogen in 54 gas cylinders installed on the deck.

Methatug

In 2024, the port of Antwerp launched the world first methanol-powered tug boat. The 30-metre-long tugboat has a traction force of 50 tons and can store 12.000 litres of methanol, enough for two weeks of tug work. The vessels is powered by two dual-fuel engines that can seamlessly switch from diesel to methanol.

Photo credit: Port of Antwerp

Uthörn coastal research vessel

Photo credit: Alfred Wegener Institute

In 2023, the Alfred Wegener Institute (AWI) replaced its coastal research vessel with the "Uthörn", a methanol-powered ship. With a length of 35 m and equipped with two 300 kW motors, the Uthorn can accommodate a crew of up to 25 people, and sail for 1200 nautical miles at a maximum speed of 10 knots. As explained by the AWI, this technology was chosen over battery electric as *"the batteries would weigh ca. 60 metric tons (or have a volume of ca. 45 m³) and voyages lasting several days would require several of these huge batteries. As a result, a fully electric Uthörn would have to be more than twice as large, consume correspondingly more energy, and its manufacture alone would create a CO_2 footprint so large that it could hardly be compensated for in the course of its service life."*[24] Due to challenges with the injection element of the methanol motors caused by cavitation erosion, the Uthörn is currently not in operation.

Zulu cargo vessel

Stretching 55 meters in length and with a cargo capacity of 400 tons, the ZULU 06 was designed by LMG Marin. The vessel has a power generation system supplied by equipment provider ABB Marine & Ports and two 200 kW hydrogen fuel cells delivered by manufacturing company Ballard. The 300 kg of compressed hydrogen enable seven days of operational autonomy.

Photo credit: Gauthier Mignot / Sogestran Group

[24] https://www.awi.de/en/fleet-stations/research-vessel-and-cutter/uthoern.html

4.2 Planned hydrogen-powered vessels

Energy Observer 2

The current design of the EO2 is a 160-meter container ship, capable of carrying up to 1,100 TEU containers with a range of 14 days, corresponding to 1,600 nautical miles. Equipped with electric propulsion powered by 4.8 MW of fuel cells.

HyEkoTank project vessel

The EU-funded HyEkoTank project will develop a 2.4 MW fuel cell system on the 18,600 deadweight tonnage (dwt) product tanker. The hydrogen tanker concept will be a state-of-the-art vessel retrofitted to reduce greenhouse gas emissions during voyage and in port by 100%. The vessel to be retrofitted with the zero-emission technology will be Samskip's MPP vessel Kvitnos.

LH2 vessels

Picture credit: LH2Shipping

The company LH2 Shipping has received funding for the construction of two short-sea shipping bulk carriers to be deployed in the North Sea before 2030. Both vessels are to be equipped with 2 MW hydrogen fuel cell systems powered with liquid hydrogen.

Møre Sjø's bulk carriers

Image credit: GreenH

In 2025, Norwegian shipping company Møre Sjø ordered two hydrogen-powered bulk carriers, with delivery set for 2027. The 85-meter, 4,000 dwt newbuilds, featuring a hybrid propulsion system based on hydrogen fuel cells and battery storage will transport sand, stone, asphalt mix, and specialty cargo along the Møre coast, in Western Norway. They will be fueled by compressed hydrogen supplied by

GreenH, sourced from six planned green hydrogen production facilities located in Hammerfest, Bodø, Sandnessjøen, Kristiansund, Rogaland, and Tønsberg.

RH2IWER project‘s 6 inland vessels

The RH2IWER project will demonstrate six commercially operated vessels on the Rhine. These vessels will be of varying lengths and types: 86 m, 110 m and 135 m; and container, bulk and tanker vessels with installed power ranging from 0.6 MW to around 2 MW. Start of operation is expected in 2026.

Samskip’s short sea container vessels

The logistics company ordered at the end of 2023 two 135-meter short sea container ships which are due for delivery in 2026. Both vessels will be powered by a 3.2 MW hydrogen fuel cell each and operate between Oslo Fjord and Rotterdam, a distance of approximately 700 nautical miles.

Viking Libra & Viking Astrea ferries

In March 2025, the Viking Libra ferry was jointly announced by Viking Lines and Financtieri, operators and builder of the vessel, repectively. The Viking Libra will have a gross tonnage of approximately 54,300 tons, with 499 staterooms that can host 998 guests and is scheduled for delivery in late 2026. The vessel will be capable of navigating and operating with zero emissions, allowing it to access even the most environmentally sensitive areas, thanks to a new 6.4 MW fuel cell systems.

The Company’s subsequent ocean ship, the *Viking Astrea*, which is also currently under construction and scheduled for delivery in 2027, will also be hydrogen powered.

Map of deployed and announced short-sea and inland hydrogen-powered vessels

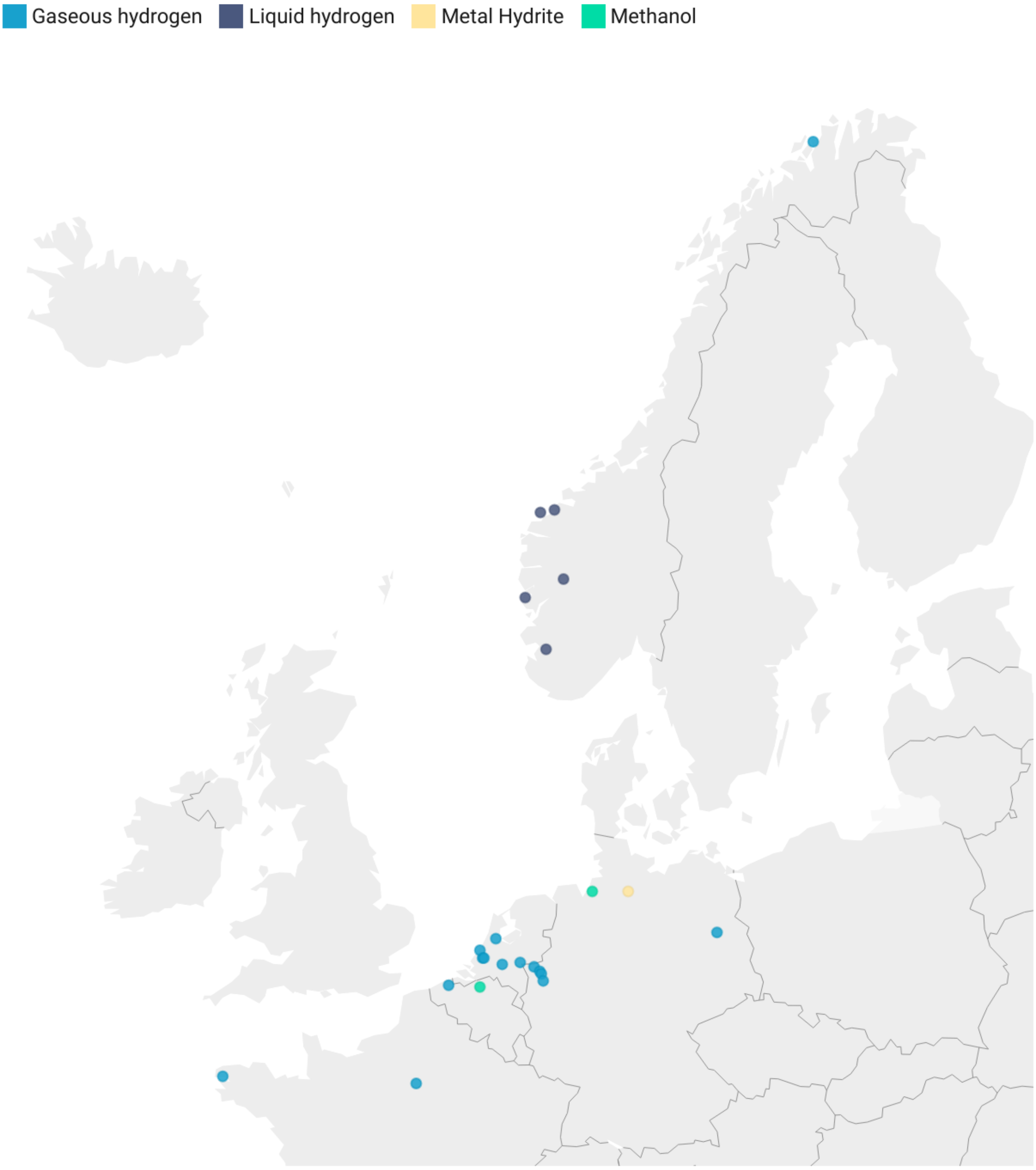


Table 1 : Overview of alternative fuel vessels, in operations and announced.

	Vessel name	***Vessel type***	***Fuel***	***Fuel stored***	***Engine type***	***Engine/fuel cell power***	***Expected delivery***
Commissioned Vessels	Antonie	Cargo	Hydrogen	Gaseous hydrogen	Fuel cell		
	Breakthrough	Yacht	Hydrogen	Liquid hydrogen	Fuel cell	3.2 MW	
	Coriolis	Research vessel	Hydrogen	Metal Hydride	Fuel cell	100 kW	
	Coastal Liberty	OSV	Hydrogen	Gaseous hydrogen	Fuel cell	2 x 200 kW	
	Elektra	Push boat	Hydrogen	Gaseous hydrogen	Fuel cell	3 x 100 kW	
	Energy Observer	Research vessel	Hydrogen	Gaseous hydrogen	Fuel cell	1 x 22 kW	
	H2 Barge 1	Cargo	Hydrogen	Gaseous hydrogen	Fuel cell	3 x 275 kW	
	H2 Barge 2	Container	Hydrogen	Gaseous hydrogen	Fuel cell	6 x 200 kW	
	Hydra	Ferry	Hydrogen	Liquid hydrogen	Fuel cell	2 x 200 kW	
	Hydrotug 1	Tugboat	Hydrogen	Gaseous hydrogen	Dual-fuel combustion engine		
	Methatug	Tugboat	Methanol	Methanol	Dual-fuel combustion engine		
	Uthörn	Research	Methanol	Methanol	Dual-fuel combustion engine	2 x 300 kW	
	Windcat 57	CTV	Hydrogen	Gaseous hydrogen	Dual-fuel combustion engine		
	Zulu	Cargo	Hydrogen	Gaseous hydrogen	Fuel cell	2 x 200 kW	
Announced vessels	Energy Observer 2	Bunkering barge	Hydrogen	Gaseous hydrogen	Fuel cell	4.8MW	2028
	HyEkoTank	Tanker	Hydrogen	Gaseous hydrogen	Fuel cell	2.4 MW	
	Hydrocat 58	CTV	Hydrogen	Gaseous hydrogen	Dual-fuel combustion engine		Q3 2025
	Hydrocat 60	CTV	Hydrogen	Gaseous hydrogen	Dual-fuel combustion engine		Q3 2025
	LH2 1	Bulk carrier	Hydrogen	Liquid hydrogen	Fuel cell	2 MW	2028
	LH2 2	Bulk carrier	Hydrogen	Liquid hydrogen	Fuel cell	2 MW	2028
	“Møre Sjø” 1	Bulk carrier	Hydrogen	Gaseous hydrogen	Fuel cell		
	“Møre Sjø” 2	Bulk carrier	Hydrogen	Gaseous hydrogen	Fuel cell		
	RH2IWER 1	Tanker	Hydrogen	Gaseous hydrogen	Fuel cell	2.0 MW	2027+
	RH2IWER 2	Dry cargo	Hydrogen	Gaseous hydrogen	Fuel cell	600 kW	2027+
	RH2IWER 3	Container	Hydrogen	Gaseous hydrogen	Fuel cell	600 kW	2027+
	RH2IWER 4	Container	Hydrogen	Gaseous hydrogen	Fuel cell	1.8 MW	2027+
	RH2IWER 5	Tanker	Hydrogen	Gaseous hydrogen	Fuel cell	1.5 MW	2027+
	RH2IWER 6	Container	Hydrogen	Gaseous hydrogen	Fuel cell	1 MW	2027+
	Samskip 1	Container	Hydrogen	Gaseous hydrogen	Fuel cell	3.2 MW	2026
	Samskip 2	Container	Hydrogen	Gaseous hydrogen	Fuel cell	3.2 MW	2027
	Viking Libra	Ferry	Hydrogen	Liquid hydrogen	Fuel cell	6.4 MW	2026
	Viking Astrea	Ferry	Hydrogen	Liquid hydrogen	Fuel cell	6.4 MW	2026

5 Conclusion

Suitable applications for hydrogen powered vessels abound today. After an initial phase of prototyping and demonstration with small vessels and propulsion systems close to or below 1 MW, a new generation of zero-emission vessels is about to be deployed across Europe.

New vessels with a power demand of up to 6.4 MW have now been ordered and are expected to hit the water by 2028, all of them around the North Sea, the Channel or on the Rhine.