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H2 international

THE E-JOURNAL ON HYDROGEN AND FUEL CELLS

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Cover image Fuel Cell Boats (Sources: Sandia National Laboratories, Broedrene Aa, Water-Go-Round)

Category: Advertorial | **Author:** Clean Energy Partnership

WHAT WILL MOVE US IN THE FUTURE

The Clean Energy Partnership is on the move with hydrogen

Knowing that a successful structural change in the transport sector can make a decisive contribution to a reduction in CO_2 emissions, the Clean Energy Partnership (CEP) works in the field of mobility powered by hydrogen and fuel cells, and has already produced an array of internationally acclaimed results: Fuel-cell vehicles suitable for everyday use are on the road in Germany, the expansion of the infrastructure has picked up speed, the market activation of H_2 mobility has begun. The industrial partnership is dedicated to the H_2 electrification of the heavy-duty sector, the production and logistics of green hydrogen, and the development of an 'RCS (Regulations, Codes, Standards) Platform' that will serve to involve even small and medium-sized companies from the H_2 sector in regulatory decisions in Germany, Europe, and worldwide. The partners consider the entire hydrogen chain, from production to tank.

Source: C. Scharff / CEP

HEAVY DUTY – LEARNINGS FROM THE PASSENGER CAR SECTOR Studies show that hydrogen can play a key role in reducing CO_2 emissions in the heavy-duty sector. In the logistics sector in particular, there is already great demand for emissions-free vehicles; some manufacturers are already developing production-ready hydrogen-powered commercial vehicles. Since H_2 electrification is a global topic in heavy-duty logistics, the CEP is in international dialogue with major players in the H_2 industry. Learnings from the passenger car sector can be transferred to the truck sector, and the existing expertise can be used to help reach an agreement on a global refueling standard.

GREEN HYDROGEN: PRODUCTION AND LOGISTICS The electrification of the transport sector is especially sustainable if renewable energies serve as the basis for emissions-free mobility. So another focus of the CEP is the development of solutions for the production and logistics of 'green hydrogen' in the terawatt-hour range. The partners have developed a definition of 'green hydrogen' as a basis for the repositioning of the industry that is needed in this context. The green hydrogen used by the companies meets all the criteria and requirements of TÜV Süd (CMS 70 standards 'Production of green hydrogen' in the version dated December 11th, 2017). In addition, it also essentially corresponds to the European CertifHy project's definition of 'green hydrogen'.

IN DIALOGUE WITH POLICYMAKERS To leverage synergies, the Clean Energy Partnership cooperates with key associations and institutions across all sectors. In order to realize a holistic H_2 economy, industry needs the unrestricted support of policymakers. The CEP, as an established source of knowledge, is in close contact with political representatives at both federal and state level. The industry partners support the work of the various political actors with consistent lines of argumentation, precise requirements, and important timings. The CEP also participates in the discussion on funding guidelines designed to facilitate research on new technologies and the strengthening of 'hydrogen regions', as well as accelerate market activation.

RETROSPECTIVE When the Clean Energy Partnership took up its work in 2002, there were neither H_2 vehicles nor H_2 filling stations in Germany. The clearly formulated goals of the companies involved were to establish everyday suitability of high-performance vehicles; fast, safe refueling; and system capability of accompanying technologies for optimum production, storage and logistics. With this in mind, the H_2 technology was researched and developed, data on vehicle and plant operation evaluated, and knowledge about H_2 mobility expanded bit by bit. The development of a global standard for refueling passenger cars is one of the partners' success stories. These successes were only been possible because the CEP offers something quite unique: a protected framework for cooperation between competitors. ||

Clean Energy Partnership CEP

CLEAN ENERGY PARTNERSHIP (CEP)

The partners in the Clean Energy Partnership (CEP) are working across multiple sectors towards the market activation of hydrogen and fuel-cell mobility as part of a sustainable energy transition. Air Liquide, Audi, BMW, Daimler, H2 Mobility, Honda, Hyundai, Linde, OMV, Shell, Total, Toyota, and the Westfalen Group are all involved in the project. In order to make optimum use of resources and synergies as the partners work together towards their goals in the spirit of a shared mission, the project is organized into working groups: Market Activation & Modes of Transport, Car Filling Stations, Green Hydrogen & Logistics, Regulations & Promotion, Strategy Circle, and Communications, with their respective subordinate focus groups.

www.cleanenergypartnership.de/en

Category: Electric Transportation | **Author:** Sven Geitmann

RADICALLY NEW MARINE PROPULSION

Zero Emission Shipping symposium in Hamburg

Fig. 1: A visual representation of the ZES symposium

Environmentalists have had the maritime sector in their sights for some time. Cruise liners in particular emit large amounts of pollutants on route to the world's natural – sometimes seemingly untouched – landscapes, or their diesel generators are running to power onboard systems while they are docked. However, now that shipping companies are switching to LNG, the market could see a change for the better. Fuel cells, too, could soon play an important part in the design of cleaner marine propulsion.

Even though the industry was clearly aware that its strong reliance on diesel generators would need to come to an end someday, it showed little willingness to entertain alternatives. Now, after several years of discussing the pros and cons of liquified natural gas use, the ultracold fuel has become part of a broader push for reducing the emissions from large watercraft. Probably the most prominent example of this shift in attitude is the AIDAnova cruise liner. This LNG-only vessel was christened at Meyer Werft in Papenburg, Germany, on Aug. 31, 2018.

When German environmental association NABU published its yearly list of the cleanest cruise liners last August, AIDAnova was the only ship to be given four green screw propellers and a (limited) recommendation. The chief executive of NOW, Klaus Bonhoff, said about the changes at the top of NABU's rankings that "ships powered by renewably sourced liquid fuels, such as LNG, are especially suitable for longer trips that require lots of energy." At that time, all other cruise liners were still using heavy fuel oil. This type of bunker fuel is cheap but extremely damaging to the environment, which explains why those vessels had been rated much worse.

With the construction of AIDAprima and AIDAperla in 2011, AIDA Cruises became one of the first cruise lines to use LNG to power its ships. They both have dual-fuel engines that can run on the liquid while docked, provided that it is available on-site.

But LNG is not "the panacea for the shipping industry's problems, since it too is a fossil fuel," NABU stated and pointed to a recent study by Transport & Environment. It added that "the benefits of replacing diesel with LNG to protect the climate are negligible at best."

ENVIRONMENTAL RULES NARROW THE PATH Similar to what is happening with land-based transportation, there have been years-long efforts to clean up the maritime sector. For example, a decision has been made to allow only fuels that contain 0.5 percent of sulfur or less worldwide starting in 2020. Additionally, the EU is planning to lower the limit from 3.5 percent today to 0.1 percent, the current threshold across Sulfur Emission Control Areas, such as the North and the Baltic Sea. Years ago, when ever-stricter targets were driving up the cost of cleaning the exhaust from ships pow-

The AIDAnova cruise ship is the grey one among the black sheep in the family.

NABU transportation expert Dietmar Oeliger, as quoted by ndr.de

ered by the tar-like sludge known as heavy fuel oil, ship operators likewise began looking for alternatives. That was when LNG started to gain traction.

In comparison to diesel, natural gas requires a relatively large amount of energy to be cooled to below -160 °C, condensed into a liquid and stored aboard a ship. But when it is converted back to gas and burned, it produces 90 percent lower nitrogen oxide and 20 percent lower carbon dioxide emissions. It also cuts particulate matter emissions by around 98 percent and all the sulfur is removed during liquefaction. And yet, like the chicken-and-egg dilemma the fuel cell industry has been faced with on land, there are comparatively few ports offering LNG fueling.

"Upgrading a vessel carrying 1,400 twenty-foot equivalent units of cargo to run on LNG could offset the annual carbon dioxide emissions of 1,500 and the nitrogen oxide emissions of 500,000 diesel-driven passenger cars."
NOW

ZES SYMPOSIUM IN HAMBURG On Sept. 4, 2018, NOW, the organization in charge of implementing the German government's transportation and fuel strategy, held a Zero Emission Shipping symposium at SMM, an international maritime industry show, in Hamburg to update attendees on recent developments in the market. As in 2016, roughly 150 people came to the event to discuss low-emission alternatives to conventional ship fuels.

The event program was divided into three parts: LNG, batteries and fuel cells. Early on, it became clear that fuel cells needed the most research and development efforts of the three technologies. However, what became just as clear was that many stakeholders in the sector saw significant opportunities for fuel cell use in short-sea and inland waterway transportation and onboard power supplied to a ship at a berth. One current challenge is that while more efficient engines cut fuel consumption, the pollutants that ships do not emit at sea will be produced as soon as generators remain running because of a crowded port.

IMO
The International Maritime Organization, a specialized U.N. agency, has a key role in regulating the industry. In all, 174 countries are members of IMO and have agreed to cut greenhouse gas emissions by at least 50 percent by 2050 compared to 2008. As the deadline to submit change requests for 2020 has passed, the objective now is to include fuel cells in Part E of the IGF code, short for the International Code of Safety for Ships Using Gases or Other Low-Flashpoint Fuels, by 2024. In this context, methanol is also being tested for its viability as a fuel in the sector.

LNG STORMS THE DIESEL CASTLE At ZES, Christian P. Hoepfner, the general manager of the Wessels shipping line, gave insights into marine LNG use. With the help of a vessel called Wes Amelie, he demonstrated that the exhaust was "no longer noticeable at any cargo weight. There is no smoke, no sooth particles and no smell." Wes Amelie was converted to run on LNG within 90 days, with 60 percent of the cost paid through the government's fuel strategy. The upgrade had reduced carbon dioxide emissions by around 31 percent, Hoepfner said. Even at a methane leak rate of around 25 percent, which had been the latest figure at the time, the ship would end up with lower GHG emissions. And the cost of the liquified fuel itself could be cut "by 25 percent or more."

Another intriguing report came from Christian Becker, who gave a presentation on the recently completed LNG PowerPac® devices by HPE Hybrid Port Energy. These containerized systems produce 1.5 megawatts of electric power, are easy to transport and can supply ships with energy while they are in port. Becker said that HPE was planning to "make hydrogen part of our offerings, since Norway and Denmark have requested it." The 40-foot containers could be put either directly on a quay or, like others, onto a ship, where they would be operational within 30 minutes.

Fig. 2: The AIDAprima cruise liner was ranked third by NABU, despite the use of heavy fuel oil.

HYDROGEN ONLY FOR FERRIES? Gerhard Untiedt from shipbuilder Meyer Werft again stressed that "LNG has become a viable method to power passenger ships," adding it was "the fuel that will dominate the next decades. We don't believe biofuels will be serious competition, not to mention that their availability is limited." As for electric propulsion systems, he said that "batteries and hydrogen are not suitable to power ships long distance. We don't consider hydrogen to be an engine fuel at all, except for ferryboats and similar vessels."

"The target for 2050 can only be reached by using radically new marine propulsion systems based on hydrogen and batteries."
Esben Poulsson, chairman of the International Chamber of Shipping

During the following discussion, the political representatives attending the symposium signaled a willingness to sit down and talk. Thorsten Herdan, who heads one of the energy policy departments at the economy ministry, called on the representatives for businesses and associations who had gathered at the event to present a list of proposals they liked to see being implemented as part of new government regulations. Achim Wehrmann, who heads the transportation ministry's maritime industry division, said he would cooperate with both the industry and the economy ministry. But he also stated that his division would go it alone if no organization was going to make suggestions. The VDR association of German shipping companies had none. Instead, it said how difficult it was for any ship operator to imagine that something besides heavy fuel oil could power its vessels. ||

Category: Electric Transportation | **Author:** Sven Geitmann

FUEL CELL WATERCRAFT

e4ships 2.0 – maritime projects to last

Fig. 1: Illustration of HySeas III, [Source: DLR]

Hydrogen and fuel cells are becoming ever more popular in the maritime industry. After many years spent on research and development, it seems as if both technologies could enter the market soon.

Launched in 2009, the e4ships flagship project had been a way to explore a variety of options for fuel cell use in the shipping market. Seven years later, the venture and all of its subprojects came to an end. Around that time, in September 2016, those involved gathered for a conference to discuss e4ships' successes and failures, finding that the millions of euros the National Innovation Program Hydrogen and Fuel Cell Technology had poured into the endeavor had done little to encourage progress (see H2-international, October 2016 and March 2017).

HyFerry, a subproject with the aim of studying fuel cell ferry operations in the North Sea, was paradoxically one that the industry abandoned quite early on. Nowadays, ferries are among the most promising application areas for the technology in the maritime sector. Just last August, Siemens and PowerCell Sweden inked a cooperation agreement to advance fuel cell-powered marine propulsion. Joachim Hoffmann, who works at Siemens Marine, confirmed to H2-international that Norwegian hybrid ferries in particular are making waves – in a good way.

DEMONSTRATION PROJECTS CONTINUE Since many still believed that there was strong potential for growth, the German government set up e4ships 2.0 in 2017. That decision also prompted the creation of several follow-on projects, namely MultiSchIBZ, SchIBZ2, Pa-X-ell 2, RiverCell 2 and ELEKTRA.

The successor to Pa-X-ell again focuses on powering systems and equipment aboard cruise liners. It intends to install methanol fuel cells throughout a passenger ship to ensure that each fire zone is independently supplied with electrical and thermal energy, even when the ship is in port (see fig. 2).

RiverCell 2, launched in April 2017, uses fuel cells made by Serenergy and alternative (low flash-point) fuels to develop and test a hybrid engine that can supply all the energy aboard a river cruiser. The project will run until September and is being supported with EUR 2.1 million.

ELEKTRA was originally part of RiverCell 1 (see H2-international, July 2016). It is the name of both a project and the zero-emission, hybrid-electric towboat that the venture aims to design and build. The vessel is to transport goods across the region and beyond, or, more specifically, between Berlin and Hamburg and farther, to Poland. Reportedly, it will be equipped with three of Ballard's low-temperature FCveloCity®-HD fuel cell modules, NMC batteries manufactured by Hoppecke and a PV system. The modules will have a capacity of 100 kilowatts each, while two batteries will provide 1,025 kilowatt-hours to power the boat and another one 300 kilowatt-hours to supply energy on board. The PV installation will offer an additional 1.8 kilowatts. The hydrogen for the fuel cells will be stored at a pressure of 500 bars inside six 125-kilogram cylinder packs. These packs could be transferred at relative ease from a truck to the boat. Expectations had been that the vessel would be placed in commercial service in Berlin's West Port in late 2018. However, construction has been postponed until the end of this year and test runs are now planned for 2021.

ELECTRIC YACHT TO RUN ON LOHC In the meantime, numerous other maritime projects have been launched in addition to e4ships. For example, a Rendsburg-based builder of superyachts, Nobiskrug, is testing the viability of LOHC for storing hydrogen on all-electric motor yachts. Last August, it announced that it was developing an LOHC system in partnership with H2-Industries. Holger Kahl, Nobiskrug's chief executive, said that his company believed "hydrogen will become the energy source of the future. And it can be stored in LOHC fluid." A low-flammable and non-explosive liquid, the fluid had good storage properties: "One advantage of LOHC is that it can be kept and transported in conditions similar to diesel."

Michael Stusch, the founder and chief executive of H2-Industries, said that the vessel would become "the first all-electric watercraft equipped with LOHC technology developed by H2-Industries. It will have a range of over 1,000 nautical miles and a speed of 10 knots." His statement sounded like an announcement the business had made in 2013, when it had partnered with motion code: blue, a ship engineering firm, to build an LOHC-based superyacht. That project, however, never made it past the planning stage.

But now, H2-Industries' aims to go beyond the yacht industry. Together with shipbuilder PortLiner, based in the Netherlands, it wants to become an influential player in the market for zero-emission transportation on inland waterways. The Dutch business is designing all-electric cargo ships drawing energy from so-called Powerboxes. Those boxes are actually containers, which would initially house batteries but might store LOHC later on, it was reported, so

they could offer sustainable, zero-emission cargo shipping on rivers and canals. Last September, at international maritime trade show SMM, both companies jointly presented a plan on how to bring their idea to market.

WIR! INITIATIVE CAMPFIRE In northeastern Germany, a project is underway to take advantage of both the region's proximity to the Baltic Sea and its abundant wind resources to create an integrated system based on the idea of "Fuel from Wind and Water – Transforming the Energy and Maritime Markets in the Northeast." In early 2018, a group of businesses and research institutes set up the CAMPFIRE initiative to adapt multiple types of marine propulsion systems for use with zero-emission fuel. Following a thorough discussion about the suitability of several energy carriers, the group's conclusion was that "utilizing surplus wind power to create climate-friendly synthetic fuels by means of thin-film electroceramic membranes is an extremely efficient process that has a long-term future."

At a workshop held on Sept. 11, 2018, in Stralsund's Ozeaneum, Christian Pegel, the minister for energy in the German state of Mecklenburg-West Pomerania, said the development of zero-emission engines for watercraft offered exciting prospects, considering that "electricity generated by wind farms in the state could be used to cut emissions in the shipping sector. As a result, two of our most cherished industries, renewable energy and shipping, could provide greater added value for the region and support the transformation of energy markets."

Accordingly, the 70 representatives that are now partners in CAMPFIRE all agree that a project to turn the area bordering the Baltic Sea into a haven for zero-emission transportation "can be implemented by 2030 if marine engines are powered by locally produced renewable fuels and the use of those fuels is coupled with innovative energy generation devices either made of electroceramics or based on technologies available on the market." The aim during and after the five-year implementation stage will be to offer new types of propulsion systems and membrane components for sale. Reportedly, another important item on the agenda will be the production of renewable ammonia (NH_3) from wind power generated in the region.

> The CAMPFIRE initiative was launched by the German education ministry as part of WIR! – Innovating Regional Change. It has grown to include 30 businesses, both small and large, research organizations and universities. All of them are based in the country's northeast, in an area extending from Rostock to Stralsund and Greifswald to Neubrandenburg.

TEST RUN ON LAKE CONSTANCE The south of Germany is designing hydrogen watercraft too. Since 2007, researchers at the HTWG university in Konstanz (see HZwei, July 2007) have been steadily making improvements to a hybrid research vessel that goes by the name of Solgenia. Last summer, during a three-day test run, the boat was powered by methanol instead of the previously used compressed hydrogen. It took five years to get a hydrogen fueling station commissioned on one >>

side of the Lake Rhine. Now, however, the leader of the research team, Richard Leiner, is concentrating on methanol, which he believes is easier to handle and less expensive.

Following the test, during which the boat traveled 84.5 miles (136 kilometers) at an average speed of 4.6 knots (8.5 kilometers per hour) and consumed 25.2 liters of the liquid fuel, Leiner told H2-international his team was "thrilled by the simple handling of methanol compared to hydrogen." He added that after "10 years of working with hydrogen, I am now convinced that the technology is not suitable for operating small boats. Methanol, on the other hand, is as easy to handle as gasoline and diesel, which is why I think boat owners will be more likely to accept it as a substitute."

Additionally, the EU set up a project named Maranda. It has brought together European companies in an effort to test a fuel cell hybrid engine on board a research vessel called Aranda. Equipped with PowerCell MS-100 fuel cells, the system was manufactured by Hyon, a joint venture between Nel, Hexagon Composites and PowerCell Sweden. Last June, certification body DNV GL greenlighted the business's use of modular fuel cell solutions for watercraft.

SCOTLAND'S BIG HIT In Scotland, the focus is again on ferryboat operations. As part of the Big Hit project, plans are to adapt a high-sea ferry running between the Orkney islands of Mainland and Shapinsay to use hydrogen instead of traditional options (see H2-international, September 2016 and July 2018). By 2021, a fuel cell made by Ballard is expected to replace diesel aboard Ferguson Marine's HySeas III. It was reported that the hydrogen required for the ferry would come from renewable sources available nearby.

The German Aerospace Center, also known as DLR, has been supporting the project by providing economic and environmental assessments and estimating the potential market. Thomas Vogt, who heads the energy systems analysis department at the organization, said that "we intend to show if and how a hydrogen ferry like the one running between two of Orkney's islands could be used in other regions of Europe." HySeas III, launched July 1 last year, is being funded by the European Union and will cost an estimated EUR 12.6 million (see fig. 1).

ON TO NORTH AMERICA In late June 2018, Canadian stack manufacturer Ballard and the ABB Group, a multinational corporation, signed a memorandum of understanding with the aim to develop a fuel cell system for powering maritime vessels. The module is to provide a capacity of 3 megawatts but be equal in size to a fossil fuel engine. Peter Terwiesch, who heads ABB's industrial automation division, said the next generation of watercraft would be electric, connected and data-driven. "We are excited to collaborate with Ballard Power Systems on driving the development of fuel cell technology that will power the vessels of the future," he noted.

Rob Campbell, Ballard's chief commercial officer, added that "the rapidly evolving marine market represents an exciting growth opportunity for zero-emission fuel cell technology." Through creating and delivering megawatt-scale containerized PEM fuel cell systems that had been put up on land, Ballard had gained the experience and knowledge needed to ensure effective collaboration on the design of clean energy solutions for key uses in the maritime market. In the meantime, ABB has teamed up with the Norwegian SINTEF research institute to model a multi-megawatt engine based on two 30-kilowatt stacks by Hydrogenics.

The Water Go Round project in the United States wants to start operating its first fuel cell vessel in September, when it expects to have Hydrogenics fuel cells supply two 300-kilowatt electric motors on Catamaran Zero (see magazine cover). Reportedly, the watercraft will be equipped with Hexagon-made 250-bar tanks that can store 264 kilograms of hydrogen and allow the watercraft to go for two days without refueling. The catamaran's keel was laid on Nov. 8, 2018.

Its design originates with Joseph Pratt, who had created several drafts of a hydrogen-powered vessel during his time at Sandia National Laboratories. He proved the viability of his ideas by publishing a paper titled SF-BREEZE, or "San Francisco Bay Renewable Energy Electric Vessel with Zero Emissions", together with Lennie Klebanoff. Today, Pratt is the chief executive and co-founder of Golden Gate Zero Emission Marine. Tom Escher, president of San Francisco's Red and White Fleet, said what Pratt had thought up was a "game changer. We can eliminate pollution from ships." He also said that it "could have a major impact on every shipyard in the country." Paul Jaenichen, the former head of the U.S. Maritime Administration, remarked that the prospect of pollution-free transportation had seemed like science fiction not too long ago. SF-BREEZE, however, had made it possible to turn that prospect into a reality.

Another Sandia-born idea was the design of a coastal research vessel called Zero-V, a 10-knot ship with a range of 2,400 nautical miles. The ship was to be refueled with liquid hydrogen at four ports of call on America's West Coast. The project resulted in five commercially viable concepts of passenger ships running on fuel cells only.

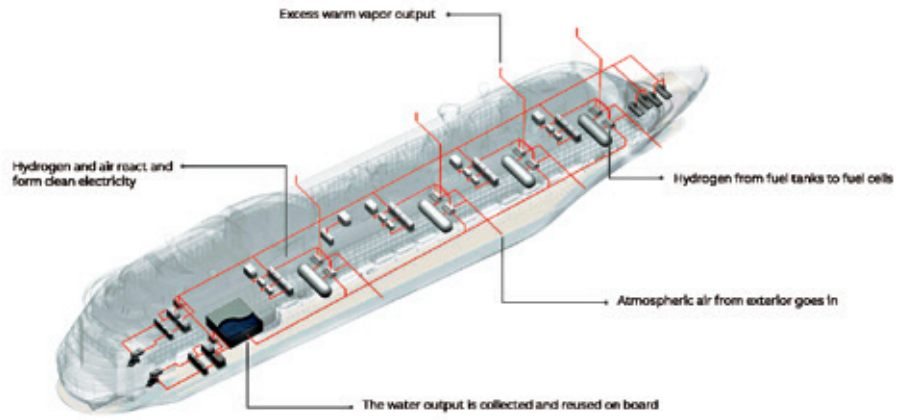
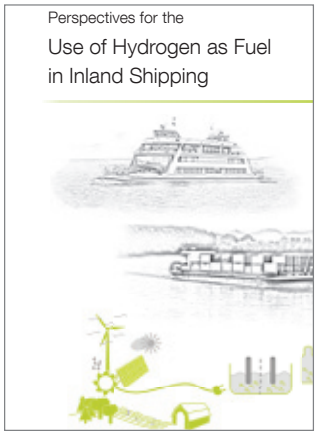


Fig. 2: Energy supply aboard a cruise liner, [Source: ABB]

GE Jenbacher was acquired by General Electric in 2003. Last June, however, the U.S. corporation sold its entire distributed power business to financial investor Advent International for USD 3.25 billion.

Additionally, two electric catamarans using solar energy and hydrogen are sailing around the world, the Energy Observer and the Race for Water. In November 2017, H2-international had already reported about the former's journey around the globe. The Race for Water catamaran is also equipped with PV panels and batteries, as well as a fuel cell system manufactured by Swiss Hydrogen.

HYDROGEN IN COMBUSTION ENGINES Another, entirely different, technological pathway was chosen for a marine research project launched last July. Called HyMethShip, it goes beyond renewable hydrogen production, adding carbon dioxide to create methanol. This carbon dioxide is later removed from the fuel in a membrane reactor, also known as a methanol reformer, and stored temporarily in a tank. Hydrogen produced via the process is then burned in a reciprocating engine. When the ship is in port, the carbon dioxide in the tank is again used to create methanol, completing the cycle.



"Perspectives for the Use of Hydrogen as Fuel in Inland Shipping" is available for download at www.hydrogeit.de/study-marigreen.pdf

The EUR 9.2 million venture is being coordinated by the Large Engines Competence Center, a Graz University of Technology department dedicated to research on engines that are used to power, for example, sea vessels and industrial facilities. "The concept describes one possible way to store large quantities of renewable energy over a longer period of time while allowing for a virtually zero-emission propulsion system," said Stephan Laiminger, chief consulting engineer at Jenbacher Gasmotoren, a partner in the HyMethShip consortium. ||

November 5, 2018, marked the publication of a new feasibility study examining the outlook for hydrogen use in inland waterways transportation. Commissioned by Mariko and FME, it was part of an EU-funded project called MariGreen and was written entirely in English. Its author, Sören Tinz, chairs the combustion engine department at RWTH Aachen University. He writes that the use of hydrogen for inland waterway vessels is often technically feasible but has not yet become economically viable for ship operators. In his eyes, the main barriers to growth are the substantial cost of producing renewable hydrogen and the high prices for converting the watercraft. To eliminate these barriers, he recommends initiating, developing and promoting demonstration projects to prove the technical feasibility of those systems in a real-world setting.