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THE GLOBAL CRUISE MARKET MAGAZINE

Spring 2019

New way ahead for Private Islands

Jury still out on decarbonisation solution

Even Carnival – the LNG pioneer – is still looking at alternative, potentially cleaner and more viable fuels; but, although one cruise line president has no doubt that hydrogen power is the right way forward, the answer to achieving zero emissions remains up in the air. *Susan Parker* reports.

LNG may appear to be today's industry answer to cruise ship emissions. But behind the scenes even cleaner fuel alternatives are also being carefully considered to meet the International Maritime Organization's accord – which requires a 50% reduction in maritime carbon (CO_2) emissions by 2050.

Lloyd's Register and partner University Marine Advisory Services have published a Transition Pathways study which argues that the later the industry leaves decarbonisation, the more rapid and potentially disruptive it will be for shipping. It also states: "To achieve at least a 50% reduction in CO_2 by 2050 and to be on course for a CO2 pathway consistent with the Paris Agreement, zero-emission vessels need to be entering the fleet around 2030.

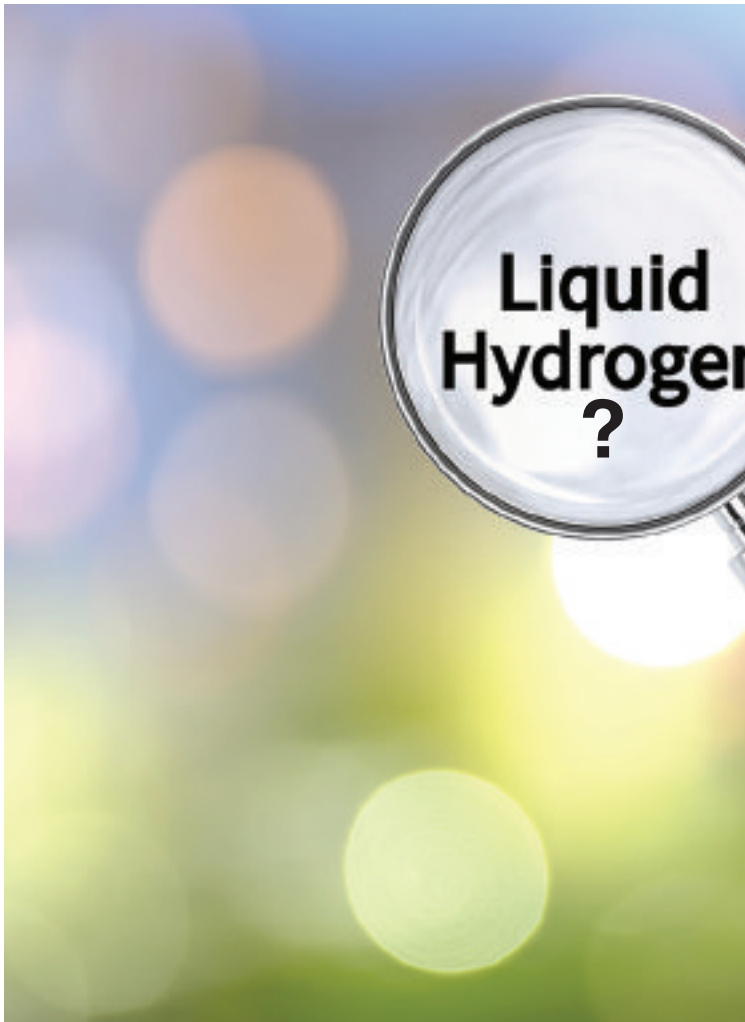
"What's more, a significant portion of newbuilds will have to be zero emission to compensate for the non-zero emissions of the existing fleet… Our experience in innovative zero-emission technologies, such as wind, hydrogen fuel cells and batteries, shows that the possibilities are there."

Viking Cruises President Torstein Hagen is in no doubt about the way forward. "Viking believes that zero emissions can only be achieved through hydrogen [H2]," he said at the Cruise Norway conference in Stavanger last October.

"If you look at the different fuel cell technologies, PEM (hydrogen) is the only one that's really able to scale up."
Klaus Vänskä

The company is allocating space on some of its newbuilds for fuel cells, although this is no quick fix. "It will take another ten years before we can get hydrogen solutions," he said, "but when you have hydrogen you save space, and the future for clean shipping is hydrogen. No doubt about it in my mind."

Carnival Corp & plc led the LNG charge with the delivery of AIDA Cruises' AIDAnova in December 2018, and multiple orders of LNG-powered ships for several



of its other brands. However Royal Caribbean Cruises, MSC Cruises, TUI Cruises and Disney Cruise Line also now have LNG vessels on their order books.

RCC has also said it will be trialling fuel cells on its LNG-powered Icon newbuilds, although it has not disclosed the type of fuel to be used.

Carnival Corporate Marine Technology Vice President Chris Millman and his colleagues are following the development of alternative fuels very carefully. Though not "deeply engaged in blue sky R&D", Carnival is a partner in a number of projects looking at fuel cells linked to hydrogen, methanol and ammonia.

"For the long term," says Millman, "hydrogen is something that we are interested in because it is one of the few ways to foresee, certainly on a ship level, zero-CO_2 emissions." However, fuel onboard is only part of the picture.

"In terms of production, hydrogen requires energy to manufacture it. Where that energy comes from is part of the general chain of the carbon footprint of the fuel. The ideal is to use renewable energy, such as wind power, to produce hydrogen – because then we would have a zero-carbon footprint."

But, in terms of supply, he says the numbers don't even begin to make sense right now. "At the moment, for liquid hydrogen [LH2] in Europe, the total capacity would fuel one of our ships for three days." With Carnival's operational model to carry two weeks' supply onboard, there is clearly a long way to go.

"At the moment, for liquid hydrogen in Europe, the total capacity would fuel one of our ships for three days."

Chris Millman

"It would require some radical shifts in the industry," Millman continues. "We have been talking to suppliers, but it is still very early days. People are still more engaged in head-scratching about whether it is going to move, and how quickly; but it is important that we engage with them, and they with us."

According to a Der Norske Veritas (DNV) GL white paper, more than 50 million metric tons of H2 are produced globally each year. This is about equal to the energy content of 150 million metric tons of ship fuel. To put this in perspective, global bunker consumption was about 266 million metric tons in 2015, while that for the cruise ship fleet was 12 million metric tons, according to the International Council on Clean Transportation.

Looking 20 years into the future, BP predicts that the world will still be heavily reliant on fossil fuels (see bar chart). By 2040 coal, oil and gas will each represent roughly a quarter of global energy consumption, while non-fossil fuel sources – renewables, hydro and nuclear – will together make up the final quarter.

The International Renewable Energy Agency forecasts that by 2020 all renewables will be cost-competitive with fossil fuels, with the best solar and wind projects significantly cheaper. China, the US and India are leading the charge, and will account for two-thirds of global renewables growth in the coming three years.

Whether or not the supply and infrastructure are in place, Millman is clear: "We have to start thinking about it now, because the life cycle of our ships is long – 30 years. So those built over the next few years will still be sailing in 2040/50".

These newbuilds could be in for a sea change in their design, according to University Maritime Advisory Services Principal Consultant Dr Carlo Raucci. "We could see a completely different design strategy in order to maximise the new technology to create zero emission ships," he notes.

ABB Marine & Ports Business Development Manager Klaus Vänskä says: "I am an advocate of hydrogen fuel cells. At ABB we are working with a number of cruise lines in studying this alternative. If you look at the different fuel cell technologies, PEM [proton exchange membrane fuel cell, i.e. hydrogen] is the only one that's really able to scale up.

"In addition it gives real flexibility in power, maintenance-free systems and a very even efficiency curve [compared to the traditional diesel engine]. But, of

course, the main reason for exploring hydrogen fuel cells is that we believe it's a strong candidate for decarbonising shipping."

Vänskä explains that synthetic fuels from hydrogen could also be used with main/combustion engines. Both MAN B&W and Wärtsilä are developing engines running on synthetic fuels, such as synthetic ammonia, methane and methanol, he says.

Put simply, hydrogen is an energy carrier. It can be produced from various energy sources, such as by electrolysis of renewables, or by reforming natural gas. "When used in combination with marine fuel cells, the emissions associated with other marine fuels could be minimised or eliminated entirely," states DNV GL. "If H2 is generated using renewable energy [green hydrogen], nuclear power or natural gas with carbon capture and storage [blue hydrogen], zero-emission ships are possible."

In the Orkneys, a group including the European Marine Energy Centre and the island council has developed a hydrogen project, Surf 'n' Turf, using tidal and wind power to produce fuel for the local ferry fleet. In its first phase a harbour-based fuel cell will provide overnight power to the inter-island ferries, replacing diesel generation.

Two further projects, HyDIME and HySeas III, are taking hydrogen to sea. The former involves retrofitting a ferry with a hydrogen diesel-injection system, which will be used to power the onboard auxiliary systems. The latter is an oceangoing car and passenger ferry to be fuelled by hydrogen fuel cells for operation in and around Orkney. It is being built at Ferguson Marine on the River Clyde, with delivery scheduled for 2020. About €9.3 million of the €12.6 million development cost has been awarded by the EU's Horizon 2020 fund.

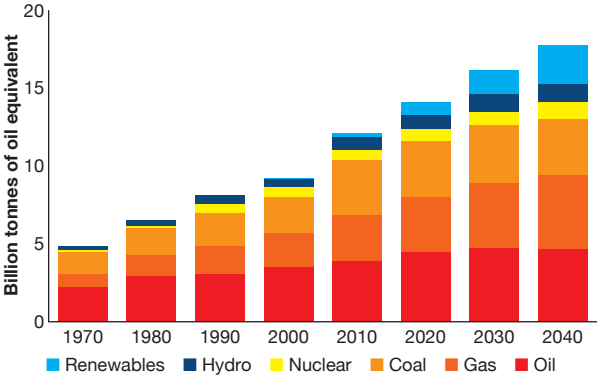
In Norway, Norled is building a ferry with capacity for 299 passengers and 80 cars powered by a combination of hydrogen and electricity, to begin operating in 2021. A shipyard has yet to be chosen. The company says it has chosen liquid hydrogen as a fuel based on an overall assessment of storage, bunkering and safety.

The hydrogen supplier has yet to be decided but Norled hopes that there will be local, Norwegian suppliers of LH2 in the future. It says this will be more cost-efficient and environmentally friendly than the present solution of supplying LH2 by truck from Europe. The vessel will be bunkered from a quayside truck to the storage tanks onboard. One filling gives about three weeks' consumption.

"In 2015 we put the first zero-emission ferry in the world, MF Ampere, into operation," says Norled Deputy CEO Lars Jacob Engelsen. "This has led to 72 siblings being built for the Norwegian market, and the start of a process whereby the new battery-technology spreads organically to other markets.

"MF Ampere has become the icon for this swift transformation to a post-carbon fossil economy. Now Norled aims for two new icons. By 2021 we will put what will probably be the first hydrogen-ferry in the world into operation. By that time we will have completed the journey to zero-emission ferry technology, covering longer distances. As this technology starts to spread, CO_2 emissions will be further reduced – leading to a total cut of 75% in CO_2 emissions from Norway's ferry sector by 2030.

Primary energy consumption by fuel
Based on current trends, with no significant policy changes. The continued scale of fossil-fuel consumption demonstrates the size of the challenge we are facing.



Source: 2018 BP Energy Outlook

"In parallel Norled aims to develop and apply the first hydrogen Express Cat in the world. This project, the ZeFF project, is being undertaken in collaboration with a bundle of world-leading suppliers, and will open up a wide range of strategic opportunities, both in the Norwegian Express boat industry and also globally."

Lars Langfeldt, DNV Global-Maritime's Senior Project Engineer, is also the classification society's Project Manager in the German e4ships cooperation. He says: "Under the lead of Meyer Werft and ThyssenKrupp Marine Systems, this venture between German shipyards, fuel cell manufacturers, academia and other maritime stakeholders has tested various fuel cell technologies.

"As part of the Pa-X-ell project, one system was successfully tested onboard a RoPax vessel [Viking Line's MS Mariella]. The aim now (under project Pa-X-ell2) is to develop a fuel cell system to be integrated into a cruise vessel, but with the present focus being on the use of methanol rather than hydrogen."

The hySOLUTIONS Project Manager, Jennifer

"The aim now is to develop a fuel cell system to be integrated into a cruise vessel, but with the present focus being on the use of methanol rather than hydrogen."
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Kreissel, is also the project coordinator for the e4ships cluster. She explains the Pa-X-ell2 project in a little more detail: "Meyer Werft is working on a decentralised energy network, and a hybrid energy system – based on HT PEM fuel cells with methanol as fuel – for oceangoing passenger ships. The fuel cell system is based on standardised modules for the production of electricity, heating and cooling. The methanol will be converted onboard into hydrogen for fuel cell use."

One part of the jigsaw is the delivery of LH2, and here DNV GL, in cooperation with Moss Maritime, Equinor and Wilhelmsen, has developed a design for a bunker vessel with a cargo capacity of 9,000m3. "The bunker vessel is a very good first step," says Langfeldt. "It will have liquid hydrogen onboard [requiring less volume] which means we have to cool it down to –253°C."

Comparing the volume required for storing liquid hydrogen with LNG, Langfeldt says it is about two times more. However, the higher energy efficiency adds up to a viable operational and environmental proposition.

He continues: "The reason the shipping industry is looking into fuel cells is that, with the higher efficiency of future systems, there is potential to produce energy on board at a price level competitive with those of conventional engines and having zero CO2, NOx, SOx and particulate matter emissions from the ship."

But this aspiring technology comes with its own set of hurdles. "The main challenge from our perspective is that there are currently no sufficient international regulations, and it will take some while to have any finalised," states Langfeldt. "The current edition of the IGF Code does not cover requirements for hydrogen as a fuel. Rules for the use of hydrogen in fuel cells are under development, and will be included in a future amendment to the Code.

"For the time being, hydrogen storage and use must follow the alternative design approach in accordance with SOLAS Regulation II-1/55 to demonstrate an equivalent level of safety. Bunkering of hydrogen-fuelled ships is subject to national regulations, and therefore needs to be evaluated on a case-by-case basis."

What is clear from the research for this article is that there is no definite way forward for the industry in this area. As Lloyd's Register Global Sustainability Manager Marine and Offshore Katherine Palmer says: "At the moment there is too much uncertainty to choose one technology/fuel over another, so a period of testing/trialling is necessary. The development of policy, standards and rules will be a significant milestone in creating a level playing field, while also addressing any safety concerns going forward to enable the uptake of zero-carbon fuels.

"Up to 2050 we may experience more than one dramatic fuel switch such as, for example, a shift from easy-to-store fuels such as biofuels to electro-fuels."

Millman is of similar mind: "Carnival has not got to a point where it is ruling anything out. It is an interesting and exciting area. It has not gone very far very quickly in the past 20 years, but in the next 20 years it will move very fast I should imagine."

"Up to 2050 we may experience more than one dramatic fuel switch such as, for example, a shift from easy-to-store fuels such as biofuels to electro-fuels."
Katherine Palmer

After all, it was not so long ago that the use of LNG was facing very similar issues to the ones confronting those trialling hydrogen; yet those have largely been overcome, albeit only on a limited number of routes to date.

Hydrogen history and current projects

Hydrogen is the oldest molecule in the universe. It appeared after the Big Bang, more than 13 billion years ago. It is colourless, odourless and non-toxic.

It was discovered in 1766 by British physicist Henry Cavendish. French chemist Antoine Lavoisier gave this light gas the name hydrogen, which is Greek for 'that which generates water'.

In 1838 German chemist Christian Friedrich Schönbein discovered the fuel cell effect, which enables the production of electricity out of hydrogen and oxygen.

The first fuel cell model was built in 1841 by English scientist Sir William Grove.

In 1898 James Dewar liquefied hydrogen by cooling it to –252.87°C.

In 1943 liquid hydrogen was tested as rocket fuel and, among others, it powers Ariane 5.

The first fuel cell prototype came into being in 1953. It was the model for the fuel cell used for the Apollo series of space missions.

In the UK about 100 diesel trains are to be converted by Alstom and Eversholt to run on hydrogen fuel cell technology. The 'Breeze' trains are due to be operational in 2022. One 15-minute hydrogen fill-up powers the train for 600 miles.

South Korea's Hyundai Motor Group is investing $7 billion (€6.17 billion) in developing hydrogen-powered systems for ships, cars and drones.

The Leeds City Gate project proposes converting the UK city's gas supply from natural gas to hydrogen. It assumes that the hydrogen will come from steam methane reforming, and that it will be stored in salt caverns.

The Port of Rotterdam Authority has teamed up with 15 companies to explore the large-scale production and application of blue hydrogen in the city's industrial area.

Air Liquide has acquired an 18.6% stake in the capital of the Canadian company Hydrogenics Corp, a leader in electrolysis hydrogen production equipment and fuel cells.