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Future Fuels in the Maritime Sector—Building the Bridge to Hydrogen

By Sean T. Pribyl and Julia M. Haines*

The authors explain that as the hydrogen market develops and U.S. investment in alternate green fuels grows, stakeholders should continue to monitor future developments with regard to the emerging opportunities in the market, including grant programs, and assess whether they can help shape future U.S. and international regulations for the use and carriage of hydrogen in the marine sector.

International seaborne transportation is a primary driver of international trade and the global economy, with approximately 80 percent of global trade by volume[1] carried by ships at sea. The shipping sector has experienced steady growth for decades, although carbon dioxide ("CO_2") is the primary greenhouse gas ("GHG")[2] emitted from marine shipping. In 2012, CO_2 and GHG emissions from international shipping were estimated to be around 2.1 percent and 2.2 percent of global emissions, respectively.[3] The International Maritime Organization ("IMO") has since developed an initial GHG strategy that sets goals that international shipping should reduce total annual GHG emissions by at least 50 percent by 2050 with zero emissions targeted by the end of the century, "consistent with the Paris Agreement temperature goals."[4]

Additionally, the IMO Marine Environment Protection Committee ("MEPC") has approved draft regulations[5] to the International Convention for the Prevention of Pollution from Ships ("MARPOL") that are vessel-centric and intended to reduce GHG emissions by at least 40 percent by 2030 through

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1 https://unctad.org/system/files/official-document/rmt2018_en.pdf.

2 https://www.epa.gov/sites/default/files/2021-04/documents/us-ghg-inventory-2021-main-text.pdf.

3 https://www.imo.org/en/OurWork/Environment/Pages/Greenhouse-Gas-Studies-2014.aspx.

4 https://www.imo.org/en/MediaCentre/PressBriefings/Pages/06GHGinitialstrategy.aspx.

5 https://www.imo.org/en/MediaCentre/PressBriefings/pages/42-MEPC-short-term-measure.aspx.

factors such as technical design and vessel operation measures. These regulations are anticipated to come into force on January 1, 2023.

In the United States, the transportation sector is now viewed as the largest contributor to emissions.[6] It is estimated that the commercial maritime sector contributes more to global CO_2 emissions than every automobile in the world, due in part to the fact that the majority of vessels still utilize diesel engines such as those used on inland waterways. The effects of air pollution on human health and societal economic impact are well documented, and reducing pollution in ports is increasing in importance as portside activities are seen as a major contributor.

There is a growing focus domestically towards phasing out GHG emissions from international shipping by the end of this century, a position reaffirmed by President Joe Biden, who has reentered the United States in the Paris Agreement[7] and laid forth a $2 trillion clean energy and green jobs plan with a pledge to cut emissions from electricity to zero by 2035 and achieve net-zero emissions by 2050. However, in order to achieve a 50 percent reduction in CO_2 emissions by 2050, developing and implementing alternative fuels and energy sources will be essential to reducing GHG emissions from international shipping at a level that meets the IMO's strategic GHG reduction ambitions.

To accomplish these goals and comply with IMO limits on the sulphur content in the fuel oil used on board ships, several options have been and are being considered, including use of ultra-low sulphur fuel oil ("ULSFO"), very-low sulphur fuel oil ("VLSFO"), exhaust gas cleaning systems (also known as scrubbers) and alternate fuels such as liquefied natural gas ("LNG"). LNG has been a leading contributor to these efforts, as LNG reduces emissions, but since LNG is still a fossil fuel, regulators and stakeholders recognize that additional work is needed to transition the maritime industry to a combination of solutions that incorporate alternate and zero-emission marine fuels to help address these emissions challenges.

To that end, LNG has been viewed colloquially as a bridge fuel to other fuel types and will likely remain a necessary component of any emission reduction strategy. The unanswered question, however, is: to which fuels does that bridge lead? This article suggests that hydrogen as a fuel and cargo is a leading option.

BRIDGE TO HYDROGEN IN MARITIME—HYDROGEN 101

A growing number of proponents of hydrogen suggest it may enable a zero-GHG energy pathway as a marine fuel and commodity or cargo.

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[6] https://www.epa.gov/greenvehicles/fast-facts-transportation-greenhouse-gas-emissions.

[7] https://www.whitehouse.gov/briefing-room/statements-releases/2021/01/20/paris-climate-agreement/.

Hydrogen is non-toxic, colorless and odorless. It is less dense than air, is not a greenhouse gas and will not trap heat in the atmosphere. However, it has a significant flammability range and low ignition energy. Currently, most hydrogen is produced from coal or natural gas, although hydrogen can be produced in several ways:[8]

- Gray and brown hydrogen: Gray hydrogen is produced from natural gas through steam methane reformation, and brown hydrogen is produced from the gasification of coal. Each emits significant amounts of CO_2 but are relatively inexpensive.
- Blue hydrogen: Blue hydrogen is produced from fossil fuels such as natural gas and coal, although carbon capture and storage ("CCS") technology is used to trap, a process viewed as integral to decarbonization.
- Green hydrogen: Green hydrogen is produced by the electrolysis of water and is considered clean but expensive. It is viewed as the ideal long-term, low-carbon way to produce hydrogen.

Once produced, hydrogen can be stored as a gas at atmospheric pressure and temperature, or it can be liquefied to reduce its volume by a ratio of 800 to 1, although the temperature must be reduced to minus 253 degrees Celsius. Hydrogen can also be used in fuel cells which combine hydrogen fuel with oxygen from the air to produce energy—with the only byproduct being water. Fuel cells are similar to batteries, but unlike batteries, the fuel cell is external to the cell so it has a longer lifespan than batteries and do not die like batteries.[9] Overall, it is suggested that hydrogen fuel cells offer several benefits, including higher efficiency, less maintenance and reduced compliance costs compared to diesel options.

ECONOMICS AND ECOLOGICAL CONSIDERATIONS

There is growing industry consensus that hydrogen is needed to reach the IMO target of 50 percent CO_2 reduction by 2050. Hydrogen may offer the potential of zero carbon propulsion for marine vessels since it can used directly in internal combustion engines or through fuel cells, and as discussed, can be produced from a variety of sources using conventional or renewable energy.

Moreover, development of an emerging hydrogen economy in energy and transportation sectors could spur a long-term sustainable and clean future. However, the industry is witnessing a sea change in developing that market as

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[8] https://www.dnv.com/focus-areas/hydrogen/heading-for-hydrogen.html.

[9] https://www.dco.uscg.mil/Portals/9/DCO%20Documents/Proceedings%20Magazine/Archive/2020/Vol77_No1_Spring2020.pdf.

falling wind and solar power prices, combined with governmental and corporate sustainability goals, are accelerating a shift to cleaner energy away from natural gas. For example, LNG is under growing scrutiny for methane leaks leading some potential customers to move towards lower-carbon alternatives[10] in lieu of natural gas. Notably, major oil and gas organizations are prioritizing hydrogen in pursuit of broader sustainability and decarbonization efforts and developing strategies to build or acquire clean-energy businesses.

To illustrate, a DNV Heading For Hydrogen survey[11] found that 42 percent of senior oil and gas professionals investing in clean energy sources said their organization intends to invest more in hydrogen or develop hydrogen; 40 percent of North American respondents agreed that hydrogen will be a significant part of the energy mix within 10 years. In a separate American Bureau of Shipping ("ABS") Pathways to Sustainable Shipping survey[12] of shipowners and operators, responses indicated that hydrogen was among the most attractive fuel options for the long term, with 60 percent of respondents stating they viewed hydrogen and ammonia as the most attractive fuel choices. Notably, that survey indicated that two-thirds of owners currently have no decarbonization strategy in place. This data shows a clear trend towards hydrogen wherein the focus will be on producing low-carbon hydrogen, and more importantly, at scale.

More specifically, maritime applications can enable large-scale use of hydrogen as part of a pathway to green fuel use, which includes LNG in the short term and hydrogen as a future zero-emission solution. In fact, some shipping companies, such as Maersk, have declared goals of a carbon-neutral fleet by 2050. For ports, reducing emissions may lower health risks to its workforce and surrounding population, all while increasing competitiveness and financial sustainability, supporting the labor force with new professional opportunities and building strong partnerships with stakeholders. Overall, increased hydrogen vessel deployment could build supply chains, encourage infrastructure development and enable the creation of novel design and safety standards.

REGULATORY CHALLENGES

As a novel vessel use in maritime and port applications, there are no existing federal regulations that specifically cover the design and operation of hydrogen-

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[10] https://www.wsj.com/articles/as-the-shift-to-green-energy-speeds-up-shells-big-natural-gas-bet-is-at-risk-11616837402.

[11] https://www.dnv.com/focus-areas/hydrogen/heading-for-hydrogen.html.

[12] https://news.cision.com/american-bureau-of-shipping/r/owners-tell-abs-hydrogen-and-ammonia-are-the-most-attractive-long-term-fuel-options,c3118113.

powered vessels, including hydrogen as a vessel fuel, use of fuel cells for vessel propulsion or hydrogen bunkering. This is due in part to the presence of hydrogen as well as the use of fuel cells. In the United States, the Coast Guard Office of Design and Engineering Standards ("CG-ENG") is responsible for the evaluation of hydrogen as a vessel cargo and fuel. Hydrogen is currently designated as a cargo that is too hazardous for bulk carriage, though it may be transported in containers in accordance with the Hazardous Materials Regulations in Title 49 of the Code of Federal Regulations ("CFR").

Hydrogen is also not an approved fuel for use in marine vessels, although hydrogen is allowed under options for alternative design wherein industry stakeholders may seek approval from the Coast Guard for equivalencies to design standards. These equivalencies are bespoke and vessel-specific and are reviewed by the Coast Guard on a case-by-case basis. The alternative design route requires a risk assessment, so if stakeholders pursue equivalent standard approvals, they must develop their risk assessments on the basis of related regulations and industry standards and guidance, such as the International Code of Safety for Ships using gases or other low-flashpoint fuels ("IGF Code") and Classification Society rules, among others. Thus, it seems possible to build a commercial zero-emission vessel powered by hydrogen if stakeholders appropriately navigate the myriad of regulatory hurdles, although land-side hydrogen refueling infrastructure will likely be needed to be developed in tandem.

To that end, there are also challenges centered around hydrogen involving lack of infrastructure, lack of reliable availability, high cost and design constraints for on-board storage. Real estate in a port terminal is valuable, and hydrogen storage at a port could require a large footprint since liquid hydrogen requires about five times more volume compared to petroleum-based fuels. However, regulator and industry experience with LNG as a fuel and commodity may be a blueprint for hydrogen in shipping given the well-established LNG market and regulatory oversight.

In fact, the characteristics and risks with hydrogen and LNG are similar, and the distinctions between the two are well-known. In support, industry stakeholders could develop technical, regulatory, and economic feasibility proposals and use cases, which could in turn create demand for hydrogen. That demand could build greater acceptance, lower costs, drive further investment and establish sustainable supply chains. For hydrogen to become more widely available, public policies and corporate strategies need to align, meaning governments have to make more long-term policy commitments with commensurate investment—the cost and technical challenges of hydrogen infrastructure will be significant. Overall, the lack of a regulatory framework inhibits

technology developers, although it creates opportunities for interested stakeholders to help define and develop future regulations.

THE DEVELOPING MARKET AND FINANCING—EXAMPLES

The lack of an established hydrogen market in the shipping sector is the foremost impediment. Global investment is needed in the near future to fully realize hydrogen as a meaningful contributor to energy transition towards reduced and zero emissions in areas such as the requisite infrastructure, production, storage, transport, distribution, product development (e.g., fuel cells and electrical conversion system), manufacturing capacity and new business models.

An evolving hydrogen market is, however, already well underway in northern European countries like Norway, an early adopter of various zero-emission vessels since 2000. For example, Norwegian-based projects include the first large-scale production of hydrogen-based fuel cells to be used primarily for shipping, as well as those related to hydrogen-powered ferries, container ships, passenger boats and tankers, some of which are receiving assistance from SINTEF,[13] Scandinavia's largest independent research organization. The city of Trondheim, Norway, is investigating sub-sea hydrogen storage in ports as an alternative option that could free space at the port with the added safety benefit of reducing risk if there is a leak.

Besides Norway, companies in the Netherlands are working with the Dutch government to develop coastal shipping projects contributing to the goal of reducing and eliminated CO_2 emission through the design of a hydrogen-fueled dredger. Belgium has developed a hydrogen-powered 16-passenger shuttle moving between Kruibeke and Antwerp. Other hydrogen-related maritime projects are being developed in the United Kingdom, France, Finland, Denmark, Germany, Sweden, and elsewhere.

In the United States, use cases are currently more limited with only one hydrogen-powered vessel listed in the U.S. Coast Guard registry, the Water-Go-Round[14] passenger ferry, marketed as the first fuel cell vessel in the United States and the first commercial fuel cell ferry in the world and a project that "represents a global paradigm shift for zero-emission marine vessel power and hydrogen fuel cell technology." The question remains though: Is the United States doing enough to invest in and meet its reduced emission goals? It is likely that additional federally funded programs are needed; specifically, programs that provide financial support could include additional incentives based on

[13] https://www.sintef.no/en/.

[14] https://watergoround.com/.

emissions reductions as well as preferential treatment in evaluating environmentally favorable marine projects during application evaluations. Such investments could spur development of a strategy towards a zero-emission vessel shipbuilding capability in the United States, including regulatory and financial encouragement of adoption of zero-emission vessels into the U.S. Jones Act fleet.

In support of enabling a more economic transition to renewable and alternate fuel sources domestically, the U.S. Department of Energy's ("DOE") national laboratories are developing a research consortium[15] tasked with examining the impact of blending hydrogen in natural gas on existing gas infrastructure. The DOE Loan Programs Office ("LPO")[16] may also help incentivize commercial deployment of innovative energy technologies and advanced manufacturing necessary for the United States to achieve net-zero carbon emissions by 2050. Potential financing options also include the Maritime Administration ("MARAD") Federal Ship Financing Program (referred to as Title XI) and MARAD federal tax deferral programs. MARAD has issued a Notice of Funding Opportunity ("NOFO") encouraging states and port authorities to apply for $230 million in discretionary grant funding for port and intermodal-related projects through the Port Infrastructure Development Program ("PIDP"). The review process will consider how proposed projects address climate change and environmental justice impacts, among other situations. Applications had to be received by July 30, 2021.

The U.S. Department of Transportation ("DOT") has published a Notice of Funding Opportunity ("NOFO")[17] to apply for $1 billion in discretionary grant funding through the Rebuilding American Infrastructure with Sustainability and Equity ("RAISE") grants, formerly known as Better Utilizing Investments to Leverage Development ("BUILD") and Transportation Investment Generating Economic Recovery ("TIGER"), to modernize and create new American infrastructure—port infrastructure investments are specifically listed as eligible projects. Acting Maritime Administrator Lucinda Lessley recently

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[15] https://www.utilitydive.com/news/southern-company-gti-doe-launch-study-of-hydrogen-gas-blend-impacts-on-ga/595413/?utm_source=Sailthru&utm_medium=email&utm_campaign=Issue:%202021-02-22%20Utility%20Dive%20Newsletter%20%5Bissue:32579%5D&utm_term=Utility%20Dive.

[16] https://www.energy.gov/sites/default/files/2021-03/DOE-LPO_Program%20Handout_T17-REEE-Offshore%20Wind_2021-03-26.pdf.

[17] https://www.transportation.gov/briefing-room/us-secretary-transportation-pete-buttigieg-announces-availability-1-billion-modernize.

commented[18] that "State and local authorities are working to position ports to take advantage of a clean energy economy. . . . These infrastructure grants will continue to bolster their efforts while creating jobs in these communities and the U.S. maritime industry as a whole." Even with these current projections and opportunities, it seems that the United States could be investing more in the maritime sector if the White House intends to implement meaningful change and develop necessary markets.

FUTURE OUTLOOK

The aspirational milestones over the next few decades may seem like on the distant horizon, although the next steps for advancing the use of hydrogen and fuel cell technologies in ports and on ships require more in-depth market analyses of the opportunity and uses of hydrogen and fuel cells in maritime applications to support respective business cases. Other considerations include the development of technical and cost targets to guide research and development ("R&D"), identification of legal and regulatory barriers along with surveys of safety codes and standards, and increased focus on global collaboration. Infrastructure and hydrogen supply issues will be paramount, and hydrogen supply and demand must be developed along with the vessel applications if progress is going to be sustainable.

To manage the safety of hydrogen as an energy carrier in the near term, relevant stakeholders should ensure they are engaged in meaningful planning to understand if and how their business endeavors align with alternate fuel options and the supply chain, and then continue to undertake pilot projects and employ a risk-based approach using safety modelling and experiments. Several leading oil and gas companies are conducting R&D into the safety, efficacy and viability of hydrogen applications to prove both the technical and business viability of new hydrogen market.

In fact, the Getting to Zero Coalition[19] has already developed a blueprint[20] and mapping[21] for commercial-scale zero-emission shipping pilot projects and to which the United States can refer. The United States can now either lead or follow in developing hydrogen as a means to achieve commercially viable zero-emission vessels and supporting infrastructure. To that end, on March 31,

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[18] https://www.maritime.dot.gov/newsroom/press-releases/us-department-transportation-announces-funding-availability-port-0.

[19] https://www.globalmaritimeforum.org/getting-to-zero-coalition/resources.

[20] https://www.globalmaritimeforum.org/content/2020/11/The-First-Wave-%E2%80%93-A-blueprint-for-commercial-scale-zero-emission-shipping-pilots.pdf.

[21] https://www.globalmaritimeforum.org/content/2021/03/Mapping-of-Zero-Emission-Pilots-and-Demonstration-Projects-Second-edition.pdf.

President Biden introduced the American Jobs Plan of 2021.[22] The plan requests $2 trillion over eight years to modernize the nation's infrastructure, including $17 billion for inland waterways, coastal ports, land ports of entry and ferries, and notably, a Healthy Ports program to mitigate the cumulative impacts of air pollution on neighborhoods near ports. Stakeholders should continue to monitor relevant legislation in this space.

The benefits that hydrogen provides towards meeting GHG reduction and sustainability goals are of course balanced against regulatory hurdles and the need for government investment and incentives. By no means is hydrogen alone a panacea to meeting reduced emissions goals, although it does appear that a bridge leads to hydrogen as a necessary component of broader efforts as either a stand-alone or hybrid solution to achieve carbon neutrality. Overall, as the hydrogen market develops and U.S. investment in alternate green fuels grows, stakeholders should continue to monitor future developments with regard to the emerging opportunities in the market, including grant programs, and assess whether they can help shape future U.S. and international regulations for the use and carriage of hydrogen in the marine sector.

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[22] https://www.whitehouse.gov/briefing-room/statements-releases/2021/03/31/fact-sheet-the-american-jobs-plan/.