EXECUTIVE SUMMARY

ASSESSMENT OF LOW-CARBON FUEL PATHWAYS FOR MARITIME TRANSPORT

Accounting for around 75% of total freight transport activity, shipping plays a central role in global trade[1]. Growth in global trade volumes over the past decade—except during the coronavirus disease (COVID-19) pandemic—has driven a steady increase in the sector's greenhouse gas (GHG) emissions, which amounted to over 1 billion metric tons $CO_{2\text{-eq}}$ in 2018[2]. The shipping sector accounts for around 3% of global annual GHG emissions[3], and without additional regulatory intervention, the sector's emissions could increase by as much as 50% by 2050[2]. The International Maritime Organization (IMO), the industry's regulator, has adopted a Paris Agreement-aligned strategy to reduce sector-wide GHG emissions by a minimum of 50% by 2050.

While technical and operational measures to increase fuel efficiency are expected to drive near-term emissions reductions, achieving deeper decarbonization of the sector to reach the IMO's ambitious 2050 goal will require a large-scale transition to low-carbon fuels and energy sources.

Key insights from the report include:

- Utilization of shore-side electric power to charge onboard batteries has reached early commercialization for certain coastal and inland maritime transport applications, such as harbor tugs, offshore support vessels, and ferries. Additionally, onshore power facilities that allow for berthed ships to use shore-side electricity in place of auxiliary engines are becoming available at an increasing number of ports, enabling emissions reductions for vessels during docking periods. However, full electrification or significant hybridization is capital-intensive and lacks sufficient scale and energy density required to feasibly decarbonize deep-sea, long voyage vessels—the most GHG-intensive fleet segment.
- Wind- and solar-assisted auxiliary power and propulsion technologies are in earlier stages of development. However, limited scale and applicability, dependence on supplemental power (often from combustion sources), and inherent variability in power supply present barriers to broader adoption within the maritime sector.
- Low-carbon fuels provide stable power and sufficient energy density to support decarbonization of deep-sea, long voyage vessels. Fuels such as hydrogen, ammonia, methanol, liquid biofuels, and synthetic or renewable liquefied natural gas (LNG) are currently under consideration and will likely play a key role in meeting the IMO's 2050 GHG reduction target.
- Biofuel blending with conventional marine fuels can reduce marine sector emissions in the near term, and this approach is readily applicable for the existing vessel fleet due to drop-in or near drop-in compatibility of many biofuels. Refined biofuels such as biodiesel are among the most technically suitable blend stocks but are costly. Unrefined bio-oils such as pyrolysis oil are potentially low-cost alternatives, but further research is needed to confirm feasibility and compatibility.

[1] IEA (2020), International Shipping. IEA, Paris. https://www.iea.org/reports/international-shipping.

[2] Fourth IMO Greenhouse Gas Study 2020: Executive Summary and Final Report. The International Maritime Organization. London: 2021. https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/Fourth%20IMO%20GHG%20Study%202020%20Executive-Summary.pdf.

[3] IRENA (2019), Navigating to a Renewable Future: Solutions for Decarbonizing Shipping, Preliminary Findings. International Renewable Energy Agency. Abu Dhabi: September 2019. https://www.irena.org/publications/2019/Sep/Navigating-the-way-to-a-renewable-future.

- The adoption of hydrogen-based low-carbon fuels such as methanol and, to a larger extent, ammonia is expected to accelerate as the existing vessel fleets retire and purpose-built, low-carbon fuel capable vessels enter operation. With methanol-capable marine engine offerings currently available commercially, that fuel has seen some early adoption, while commercial ammonia-fueled marine engines offerings are expected to be available by the mid- to late-2020s.
- LNG is currently the most mature and widely adopted alternative marine fuel, with recent and anticipated near-term uptake largely driven by compliance with criteria pollutant emissions regulations. However, it offers limited CO_2 emissions reduction potential relative to conventional marine fuels, and, in some cases, GHG emissions can be higher if methane slip is not mitigated. Synthetic or renewable LNG produced from low-carbon feedstocks (that is, electrolytic hydrogen and repurposed CO_2 or biomass) offers drop-in compatible pathways for decarbonization of LNG-fueled vessels, but application of these lower-carbon LNG substitutes as maritime fuels to date has been limited.
- Likely, decisive factors in low-carbon fuel selection include relative volumetric energy densities, storage and handling requirements, fuel price, availability/scalability, and infrastructure adaptation costs. Additional techno-economic feasibility drivers include market segment- and vessel-dependent considerations such as refueling frequency, cargo space requirements, and operational profiles. With the exception of certain drop-in biofuels, holistic redesign of vessels—and operational adaptations (for example, more frequent refueling)—may be required to accommodate these low-carbon alternatives as primary marine fuels due to their lower volumetric energy densities relative to conventional fuels[4].
- To meet Paris Agreement-aligned decarbonization targets, low- and zero-carbon fuels could account for nearly 60% of the international shipping sector's total fuel consumption in 2050[5]. Achieving this level of low-carbon fuel adoption in maritime transport will likely require substantial investment and acceleration of research, development, and demonstration efforts across the value chain.

The full report provides an overview of available emissions reductions pathways for the maritime transport sector and characterizes the landscape of key low-carbon fuel candidates, including their relative competitiveness, applicability, development statuses, and research gaps.

[4] American Bureau of Shipping (ABS) (2020), Setting the Course to Low Carbon Shipping—Pathways to Sustainable Shipping. https://absinfo.eagle.org/acton/attachment/16130/f-c1979537-0fdb-4f55-85cb-7d50deafe1cc/1/-/-/-/-/ABS%20Sustainability%20Outlook%20II_Pathways_low-res.pdf.

[5] IEA (2020), Energy Technology Perspectives 2020. IEA, Paris. https://www.iea.org/reports/energy-technology-perspectives-2020.

The Low-Carbon Resources Initiative

This executive summary was published under the Low-Carbon Resources Initiative (LCRI), a joint effort of the Electric Power Research Institute (EPRI) and Gas Technology Institute (GTI) addressing the need to accelerate development and deployment of low- and zero-carbon energy technologies. The LCRI is targeting advances in the production, distribution, and application of low-carbon energy carriers and the cross-cutting technologies that enable their integration at scale. These energy carriers, which include hydrogen, ammonia, synthetic fuels, and biofuels, are needed to enable affordable pathways to economy-wide decarbonization by mid-century. For more information, visit www.LowCarbonLCRI.com.

Technical Contact: Tatum Auvil, Research Analyst, 980.825-8263, tauvil@epri.com

3002022751 September 2021

Electric Power Research Institute
3420 Hillview Avenue, Palo Alto, California 94304-1338 • PO Box 10412, Palo Alto, California 94303-0813 USA • 800.313.3774 • 650.855.2121
askepri@epri.com • www.epri.com