HYDROGEN FOR MARINE SHIPPING

Prospects

GOOD

This fact sheet is part of an Energy Innovation paper assessing clean hydrogen's value for cutting climate pollution from 12 end uses. The full report includes context, analysis, policy recommendations, and citations—see QR code or link at bottom.

Hydrogen can be used to make two alternative fuels enabling long-distance marine trips.

NOTE: *We rate long-haul marine shipping as "good" but short-haul marine shipping as "poor." This overview does not cover marine port operations.*

CONTEXT: Marine shipping vessels primarily burn bunker fuels like heavy fuel oil or marine gas oil. However, in July 2023, the International Maritime Organization's 175 member states voted unanimously to work toward net-zero marine shipping by "close to" 2050. Thus, the industry has momentum to decarbonize, but it will need policy support to ensure the costs of this transition will be borne across all parties rather than harming first movers.

Hydrogen could support a clean maritime sector in several ways. For example, hydrogen can be used directly via fuel cells or combustion to power ships, which is feasible for shorter-distance trips. However, hydrogen storage on board is a big challenge, and marine shipping requires high energy densities for long-haul, transoceanic voyages with large cargo capacities.

Hydrogen-derived e-fuels therefore hold greater promise for much of long-distance marine shipping. In particular, electrolytic hydrogen can be used to make clean ammonia (NH_3) using nitrogen from the air as well as clean methanol (CH3OH) using a net-zero source of carbon. Maritime companies are already ordering vessels that can be powered by these e-fuels.

INFRASTRUCTURE NEEDS: The direct use of hydrogen generally requires new vessels, in part to accommodate extra space required for hydrogen storage. Hydrogen must be liquefied to increase its volumetric density for storage; this requires energy-intensive cryogenic tanks to keep it at -253°C. Liquefied hydrogen also suffers from evaporative "boil-off" losses, which can quickly compound over longer voyages and erode climate benefits. Hydrogen ships would require new bunkering (i.e., refueling) equipment and processes, which no port has today.

Among the e-fuels, methanol is furthest along. Methanol's key advantages are it being liquid at room temperature (thus not needing cryogenic tanks or pressurization) and its ability to largely use existing infrastructure; in particular, it can be used with "minor modifications" to existing vessels, with some ships running on methanol today. Its key downside is its reliance on a carbon source; this can initially be sourced from fossil fuel combustion (albeit with half the climate benefit) but must eventually come from a net-zero source (e.g., biomass or the air).

Ammonia is less proven as an e-fuel, but its production is a mature process. Ammonia's key advantage is not needing a carbon source for its production, which implies a lower long-term fuel cost once enabling infrastructure is built out. Its key downside is it generally requires new ships with specialized combustion equipment and cryogenic storage to cool it to -33°C—but relative to hydrogen, its liquefication uses much less energy and results in far less boil-off.

SOCIAL IMPACTS: Conventional bunker fuels are highly polluting, releasing harmful sulfur oxides (particularly from heavy fuel oil but largely mitigated from marine gas oil), nitrogen oxides (NOx), and particulate matter that endanger port communities. Hydrogen and e-fuels can reduce or eliminate sulfur oxides and particulate matter, though NOx is more complicated and can remain high from hydrogen or ammonia combustion. Methanol and (especially) ammonia are also toxic. Methanol spills may be less harmful for the environment and marine ecosystems relative to oil; the evidence is less clear for ammonia, which may be more damaging but over a smaller area and for a shorter period of time. Supplemental power technologies—such as wind-powered sails, on-board solar, and batteries—and optimizing logistics (e.g., "just-in-time arrival") can mitigate these impacts by reducing fuel use.

COMPETING TECHS: The top competitors to hydrogen and e-fuels for marine shipping are biofuels and electrification. **Biofuels** cover a wide range of products, from ones that can be directly used in today's vessels to ones that can be converted to bio-methanol (offering a hydrogen-free option for methanol-powered ships). Some biofuel-derived products even require hydrogen for refining into renewable diesel. Biofuels' big downside is sustainable feedstock availability, as multiple sectors will be competing for the same limited supply.

Battery-powered **electric ships** are most prominently competing with hydrogen for smaller, shorter-haul vessels (e.g., ferries, tugs). They face challenges for longer-haul routes due to batteries' current higher weight and space requirements per unit of energy that they provide. However, batteries' relatively high round-trip efficiencies suggest that battery-optimized vessel designs could make direct electrification cost-effective for on the order of 40 percent of global containership traffic. Batteries also continue to rapidly fall in cost and improve in efficiency; paired with advances in supplemental power technologies and maritime logistics, electric ships may have the potential to serve even more of the long-haul shipping market.

TAKEAWAY: Hydrogen-derived methanol and ammonia may play a big role in cleaning up long-haul marine shipping, though the relative share of these e-fuels—as well as their ultimate competitiveness with biofuels and electric ships—is less certain. Battery ships' fundamental efficiency advantage is likely to win out over hydrogen vessels for short-haul marine shipping. In all cases, decarbonized shipping is likely to mitigate local pollution risks (supported by supplemental power technologies), though electric ships are needed to eliminate these risks.

FURTHER READING:

- Jessica Kersey, Natalie D. Popovich, and Amol A. Phadke, "Rapid battery cost declines accelerate the prospects of all-electric interregional container shipping," *Nature Energy*, July 18, 2022, https://www.nature.com/articles/s41560-022-01065-y
- Energy & Environmental Research Associates, "Ocean-Going Vessel Decarbonization," May 2024, https://gspp.berkeley.edu/research-and-impact/centers/cepp/projects/ocean-going-vessel-decarbonization
- Dan Rutherford et al., "Feasibility Study of Future Energy Options for Great Lakes Shipping," International Council on Clean Transportation, March 2024, https://theicct.org/wp-content/uploads/2024/02/ID-98-%E2%80%93-MARAD-report_final.pdf
- **Featured story:** Elise Hansen, "Green shipping picks up speed," Knowable Magazine, November 20, 2023, https://knowablemagazine.org/content/article/technology/2023/how-to-turn-the-shipping-industry-green
- **Full report:** https://energyinnovation.org/publication/hydrogen-policys-narrow-path-delusions-and-solutions