

E-ammonia

Alternative maritime fuel information sheets
Document 1 of 8



Mærsk Mc-Kinney Møller Center
for Zero Carbon Shipping

About this document

Shipowners, managers, and operators face considerable uncertainty when selecting low-emissions fuels and technologies to meet decarbonization targets and comply with regulations. Transitioning from fossil-based fuels to low-emissions alternatives is essential for shipping's decarbonization. While several fuel options can reduce greenhouse gas (GHG) emissions, each has distinct strengths and limitations in terms of emissions, scalability, technological maturity, and cost — there is no silver bullet solution.

To navigate the uncertainty around fuel selection, the Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping (MMMCZCS) has developed a set of information summaries on eight alternative maritime fuels. These summaries provide a snapshot overview of the risks and opportunities associated with e-ammonia, blue ammonia, e-methanol, bio-methanol, e-methane, bio-methane, e-diesel, and biodiesel. The shared information is based on a collation of analysis and insights from several sources, including previous MMMCZCS research projects and insights from interviews we conducted with industry experts at our partner organizations.

Readers can use these fuel snapshots to identify key aspects that deserve close attention when evaluating and comparing alternative fuels for future fleet fueling strategies.

Each information summary is organized into four main subject areas that support evaluation across the eight fuel pathways:

- [Sustainability considerations](#)
- [Fuel availability potential](#)
- [Maritime uptake](#)
- [Commercial considerations](#)

This document focuses on [e-ammonia](#). For additional insights into alternative maritime fuels towards 2050, we encourage readers to take a look at the [MMMCZCS fuel pathway maturity map](#) on our website.

Nothing in these information sheets shall be taken as advice, predictions, or recommendations, and readers should read the disclaimer before using the information sheets.

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Sustainability considerations

- Similar to other alternative fuels, e-ammonia is expected to be subject to sustainability compliance. However, the industry currently lacks mandatory and harmonized criteria — particularly regarding life-cycle assessment (LCA) methodologies for emerging options, including e-ammonia.
- Besides climate impact, notably based on electricity source (see 'Life cycle GHG emissions,' below), the main sustainability risks for this fuel include:
 - Safety and health considerations from the toxicity of ammonia. Seafarers, workers, and community safety must be considered in case of exposure to ammonia leaks.^{1,2}
 - The same toxicity accounts for the natural environment's exposure to ammonia leaks, where severe eutrophication and negative biodiversity impacts can be expected.³
 - Moreover, e-ammonia production requires significant resources, including land, water, and low-emissions electricity (see 'Fuel availability potential'). Depending on the production method and location, this resource demand can also lead to sustainability risks associated with land use changes, freshwater change, biodiversity loss, and conflicts surrounding land and water use rights, especially in water-scarce regions or during water-scarce seasons.^{1,4,5}

Life cycle GHG emissions

- Life cycle emissions include all GHG released across the full value chain – from feedstock and resource extraction to transportation of the fuel to market and final use on board the vessel.
- For e-ammonia, life cycle GHG emissions intensity is typically in the range of 15-32 g CO₂eq/MJ,^a depending on factors such as the electricity mix, hydrogen production efficiency, and Haber-Bosch process efficiency. Publicly available data is still limited, as large-scale e-ammonia production is in early development stages.^{6,7}
- The main drivers of life cycle emissions intensity are associated with electricity used for hydrogen production through electrolysis, logistics to market, and nitrous oxide (N₂O) emissions during combustion. In addition, e-ammonia combustion requires a pilot fuel, which slightly increases overall GHG emissions and should be accounted for in life cycle calculations.^{8,9}
- LCA is essential for evidence-based decision making, as it provides transparency on a fuel's full emissions profile. Results can vary depending on methodological choices and data sources. Accurate descriptions of the system boundaries and assumptions are necessary for comparisons.

^a g CO₂eq/MJ = grams of carbon dioxide-equivalent per megajoule of energy



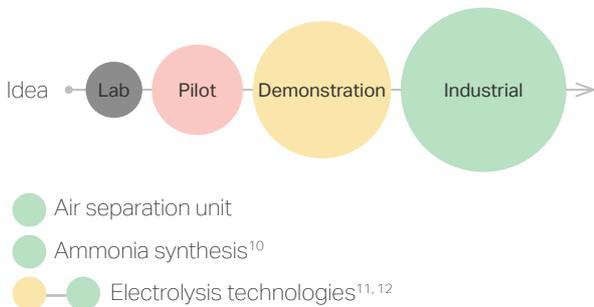
Fuel availability potential

- Feedstock availability

The main feedstocks for e-ammonia are low-emissions electricity (for electrolysis), water (split into hydrogen using electrolysis), and nitrogen (from air).

All of these are available for e-ammonia production, although hydrogen from electrolysis will mostly be found in regions rich in renewable energy sources, such as solar and wind.

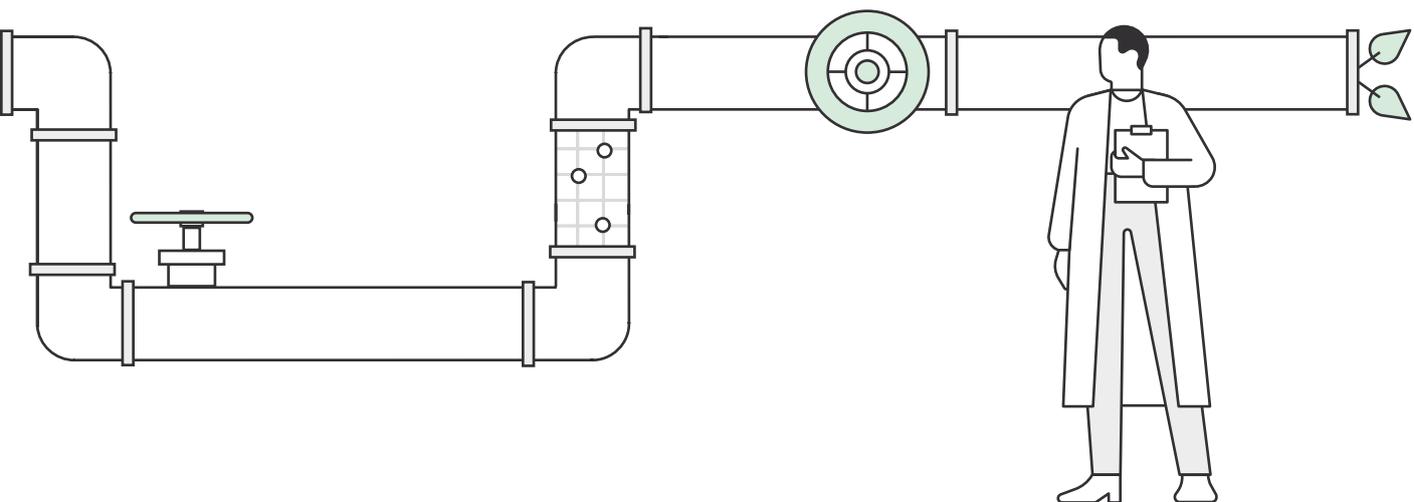
- Industrial maturity



- Infrastructure requirements

E-ammonia plant, water supply, renewable electricity, ammonia distribution, and port storage.

- To support large-scale e-ammonia production, the manufacturing rate for electrolyzers needs to be optimized and scaled up.² Doing so will reduce costs and support the production of sufficient quantities of e-hydrogen.
- The development of an e-ammonia production plant can take 5-6 years. This includes the permitting and engineering, procurement, and construction work for the catalytic plants.¹³
- Producing e-ammonia fuel at scale will also require significant expansion of renewable electricity supply, balancing, and transmission lines.
- Existing best practices for ammonia storage can be adapted to apply to storage of ammonia as a fuel.¹⁴



Maritime uptake

Safety

- Using ammonia as a fuel involves safety risks: primarily toxicity, but also combustibility and flammability risks in confined spaces where sufficient oxygen is present. Many of these risks can be mitigated through design and operational practices.^{15, 16, 17}
- The International Maritime Organization (IMO) has developed technical provisions and approved interim guidelines for the safety of ships using ammonia as fuel in December 2024.¹⁴ The non-mandatory guidelines align closely with the IGF Code^b and SOLAS^c principles and provide a shared safety and design reference point as ammonia-fueled projects emerge.
- Specific training and upskilling will be needed to prepare the crew for operation and maintenance on ammonia-fueled vessels. Current frameworks for seafarer training need to be expanded to meet ammonia's unique challenges.¹⁸ The IMO is developing interim guidelines on training specific to ammonia's unique characteristics.

Vessel technology

- Ammonia cannot be directly used as a fuel in conventional vessels and engines. Given ammonia's properties, significant modifications compared to onboard fuel storage and conversion systems for fuel oil are needed to safely use ammonia as a marine fuel. Both new vessel designs and retrofit designs, particularly for LNG^d and LPG^e vessels, are being developed.¹⁶
- Along with the installation of the world's first commercial dual-fuel two-stroke ammonia engine in 2025,¹⁹ the development of main and auxiliary ammonia engines is progressing with a major focus on solutions to reduce combustion emissions and pilot fuel requirements.^{20, 21}
- According to engine manufacturers, a commercial dual-fuel engine requires typically around 5% pilot fuel (at 100% engine load), with further reductions expected as engine technology matures. The total GHG reduction observed for smaller pilot amounts is above 95%, which is a substantial improvement compared to previous reports.^{9, 22, 23}
- SCR^f can be used to handle emissions of nitrogen oxides and ammonia slip.²⁴
- Methods of operating and tuning the engine to reduce emissions of N₂O, a potent GHG, are being evaluated.^{16, 25}
- Assuming shipyard availability, the estimated timeline for shipyard delivery of an ammonia-fueled vessel is ~ 3-4 years from entry in the order books. This timeframe can be shortened as time and experience progress.²⁵

^a IGF Code = International Code of Safety for Ships Using Gases or Other Low-flashpoint Fuels

^c SOLAS = International Convention for the Safety of Life at Sea

^d LNG = liquefied natural gas

^e LPG = liquefied petroleum gas

^f SCR = selective catalytic reduction

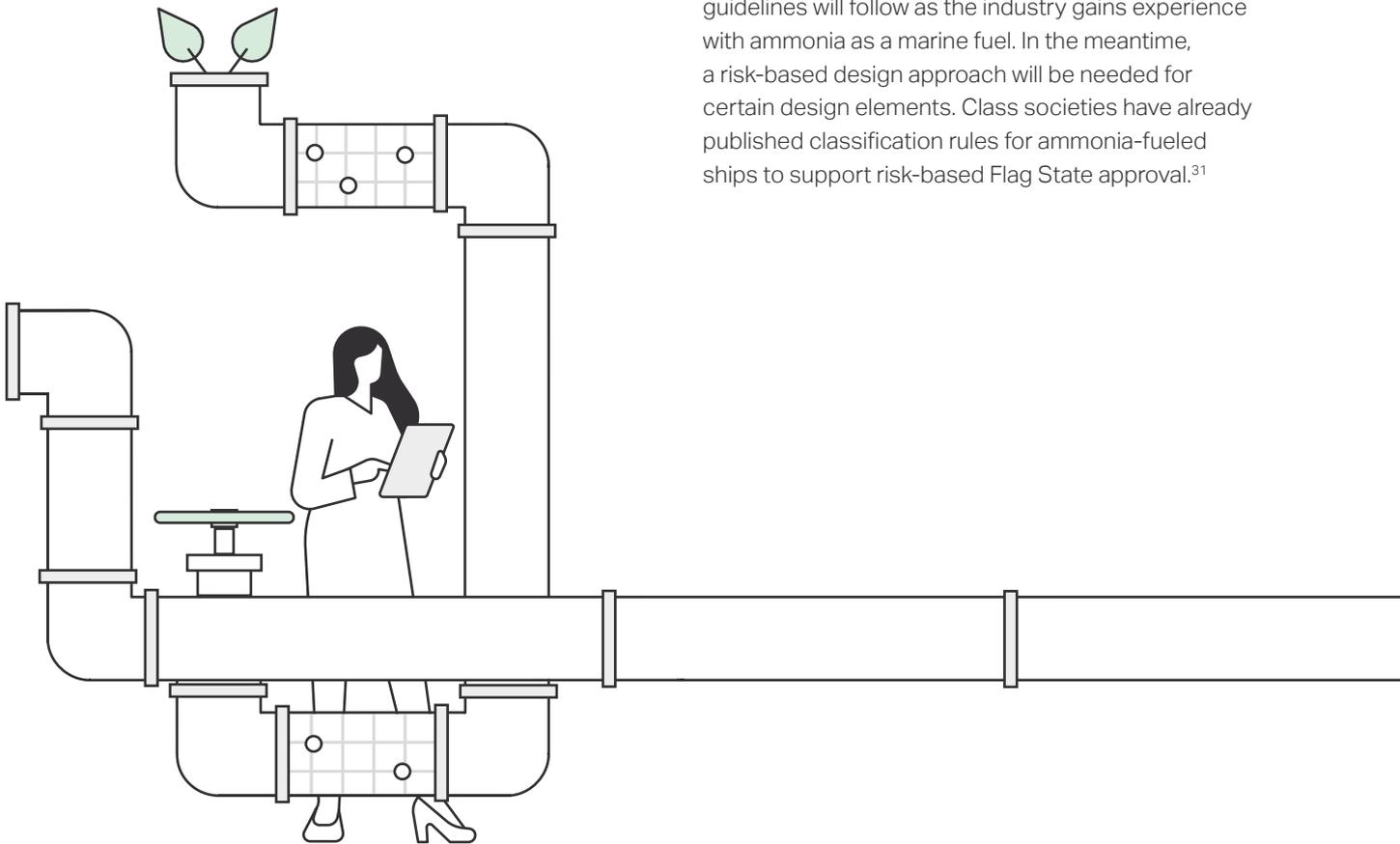


Logistics, storage, and bunkering

- There is well-established experience with onshore storage, handling, and transportation of ammonia. Additionally, a bunkering guideline has been developed and published by SGMF.^{9,26}
- Only a few ports are currently equipped for ammonia bunkering, and a few demonstration projects are ongoing.²⁷
- The current gaps to enable ammonia fuel bunkering are mainly: standardized bunkering procedures, crew training and competence, and port infrastructure readiness.

Regulatory and certification

- The IMO Net-Zero Framework is a set of technical and economic measures aimed at delivering emissions reductions according to the IMO's 2023 GHG Strategy. The timeline for the framework's adoption and implementation remains to be finalized.²⁸
- Final guidance on sustainability criteria and quantification of well-to-wake GHG emissions from fuels is still under development by the IMO.²⁹ These guidelines will be combined with the development of certification schemes to ensure that the utilized alternative fuels are produced according to a set of sustainability requirements and reduce GHG emissions.
- As part of the integration of ammonia regulations in the IGF Code, the IMO approved the first version of non-mandatory interim guidelines for the safety of ships using ammonia as fuel in 2024.³⁰ These provide guidance and some prescriptive requirements for safety standards. Further development of the guidelines will follow as the industry gains experience with ammonia as a marine fuel. In the meantime, a risk-based design approach will be needed for certain design elements. Class societies have already published classification rules for ammonia-fueled ships to support risk-based Flag State approval.³¹



⁹ SGMF = Society for Gas as a Marine Fuel

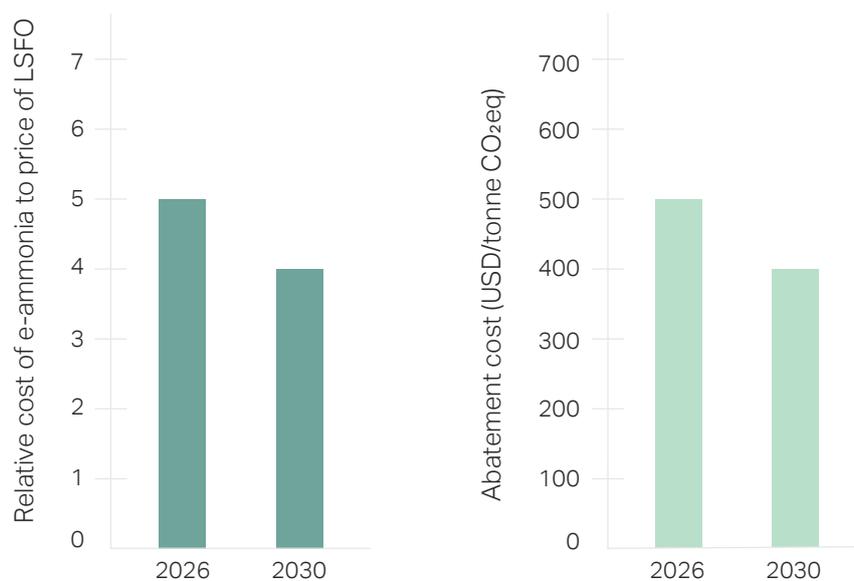


Commercial considerations

Cost and market development

- Production costs for e-ammonia are estimated to be 5.0 times the price of low-sulfur fuel oil (LSFO) per unit energy in 2026 and 4.0 times the price of LSFO per unit energy in 2030.^h The main cost drivers for this fuel are the infrastructure for renewable electricity and electrolyzer stacks.
- The estimated abatement cost is around 500 USD/tonne CO₂eq avoided emissions in 2026 and around 400 USD/tonne CO₂eq avoided emissions in 2030, excluding vessel cost.^{32,h}
- The current ammonia commodity market is based on fossil-based production that primarily serves the fertilizer industry with additional use in chemical manufacturing.³³
- Emerging demand in the fertilizer industry could support switching from conventional gray ammonia to lower-emissions options like blue or green ammonia.³⁴
- The demand for low-emissions ammonia is expected to increase in Asia, driven by the power sector in Japan, supported by local government emissions targets and subsidy schemes.³⁵

Figure 1: Modeled cost (left) and abatement cost (right) for e-ammonia in 2026 and 2030. Values are illustrative outputs from analytical modeling using an assumed levelized cost of electricity of 30-40 USD/MWh. Values do not represent market prices or forecasts.



^h These figures are model-based estimates provided for analytical context only and do not represent market prices or forecasts.



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Go to these links to learn about other alternative maritime fuels.

Document 2: [Blue ammonia](#).



Document 6: [Bio-methane](#).



Document 3: [E-methanol](#).



Document 7: [E-diesel](#).



Document 4: [Bio-methanol](#).



Document 8: [Biodiesel](#).



Document 5: [E-methane](#).



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