E-methanol

Alternative maritime fuel information sheets
Document 3 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-methanol. 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.

Acknowledgements

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Writing led by Annalicia Poehler and Nikolaj Enevoldsen (both MMMCZCS); editorial review by Matilda Handsley-Davis and Jazelyn Rivas Rosende (both MMMCZCS); layout and design by Julia Garbowska (MMMCZCS); project steering by Estela Vazquez Esmerode and Christoffer Lythcke-Elberling (both MMMCZCS). Thanks to Maria Grammatikou (MMMCZCS) and Tobias Kleinke* (Hapag-Lloyd) for assistance with preparing the publications and to all colleagues at the MMMCZCS and partner organizations who contributed expert knowledge to the project.

Sustainability considerations

- Similar to other alternative fuels, e-methanol 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-methanol.

- Besides climate impact, notably based on electricity and carbon sources (see 'Life cycle GHG emissions', below), the main sustainability risks for this fuel include:
  - Health and safety risks from e-methanol's flammability and toxicity, which require special handling, as well as from the formation of air pollutants associated with respiratory diseases.[1, 2]
  - Risks including land use change, biodiversity losses, and increased emissions can arise if carbon dioxide (CO_2) used in e-methanol production is not sustainably sourced.[3] Examples of alternative (sustainable) CO_2 sources include direct air capture (DAC) and direct ocean capture (DOC).
  - Moreover, e-methanol 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.[3, 4, 5]

Life cycle GHG emissions

- Life cycle emissions include all GHGs 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-methanol, life cycle GHG emissions intensity is typically in the range of 0.5-21 g CO_2 eq/MJ,[a] depending on factors such as the carbon source, electricity mix, hydrogen production efficiency, and methanol synthesis process. Publicly available data is still limited, as large-scale e-methanol production is in early development stages.[2, 6, 7]

- The main drivers of life cycle emissions intensity are associated with electricity used for hydrogen production through electrolysis and the capture and processing of CO_2 to synthesize methanol, as well as logistics to market.
  - Like other carbon-containing e-fuels, e-methanol can achieve near-zero life cycle GHG emissions when produced using renewable electricity and biogenic or atmospheric CO_2. Conversely, use of high-GHG-intensity electricity or industrial CO_2 substantially increases the fuel's GHG intensity, reducing the overall climate benefit.
  - E-methanol combustion produces CO_2. These emissions are considered carbon-neutral provided that the carbon originates from biogenic or atmospheric sources, as CO_2 released during combustion roughly corresponds to carbon previously removed from the atmosphere.
  - In addition, e-methanol combustion requires a pilot fuel, which slightly increases overall GHG emissions and should be accounted for in life cycle calculations.[8]

- 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.

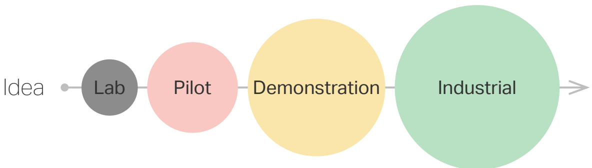
[a] g CO_2eq/MJ = grams of carbon dioxide-equivalent per megajoule of energy

Fuel availability potential

- Feedstock availability
  The main feedstocks for e-methanol are low-emissions electricity (for electrolysis), water (split using electrolysis to obtain hydrogen), and biogenic CO_2 (typically a waste stream generated by combustion of biomass).

  The availability of low-emissions electricity and renewably sourced (biogenic) CO_2 at the required scale is a key challenge. CO_2 removal techniques such as direct air capture (DAC) and direct ocean capture (DOC) can offer an alternative source of carbon feedstock – however, we do not consider these options extensively here, as the technologies are still in the demonstration phase (see 'Industrial maturity,' below).

- Industrial maturity



Carbon capture system for biogenic CO_2[9]
Carbon removal systems (DAC and DOC)[10]
Electrolysis technologies[11, 12]
Methanol synthesis[2]

- Infrastructure requirements
  Renewable electricity generation, electrolyzer capacity, biogenic CO_2 capture and transport infrastructure, and methanol synthesis and upgrading facilities.

  - To support large-scale e-methanol production, the manufacturing rate for electrolyzers needs to be optimized and scaled up.[13] Doing so will reduce costs and support the production of sufficient quantities of e-hydrogen.

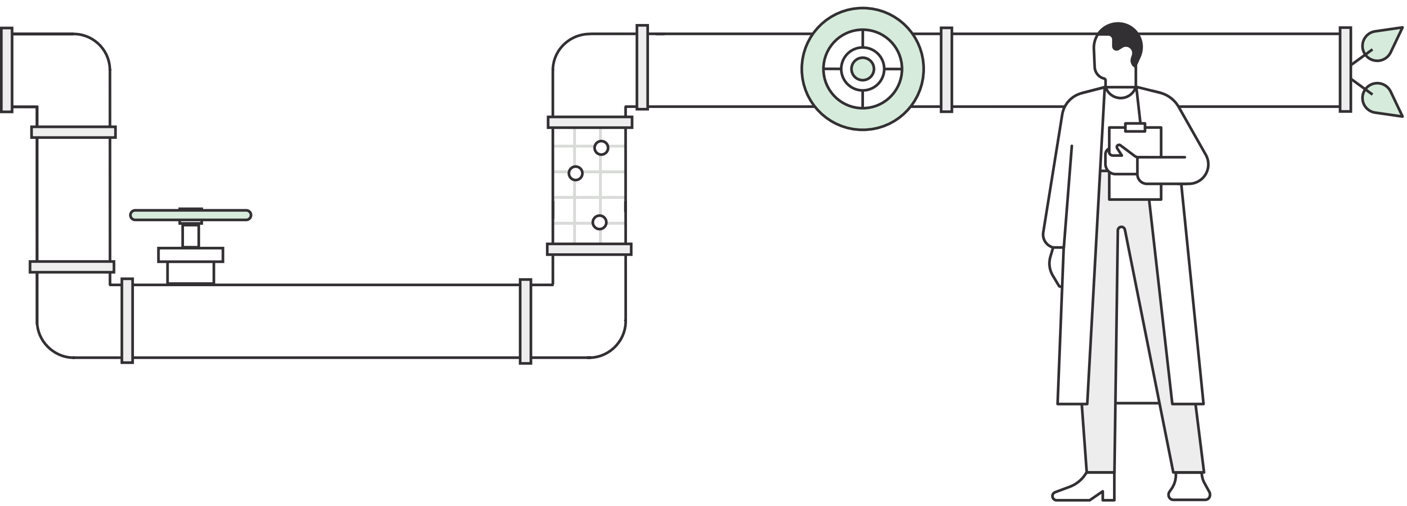
  - E-methanol plant size is expected to be scalable, but dependent on access to renewable power and CO_2 feedstock.

  - The development of an e-methanol production plant can take 5–6 years. This includes the permitting and engineering, procurement, and construction work for both the renewable energy systems and fuel synthesis infrastructure.[14]

  - Biogenic CO_2 feedstock is available from existing industries, but e-fuel production would also require capture, storage, and transport of this CO_2.[9]

  - Biogenic CO_2 transport can be through either pipeline (limited infrastructure) or truck (limited capacities).

- Producing e-methanol fuel at scale will also require significant expansion of renewable electricity supply, electrical balancing, and transmission lines.



Maritime uptake

Safety

- Safe handling of methanol as a low-flashpoint liquid on vessels has been demonstrated and is covered by established practices.[15]

- There are no significant barriers for onboard safety.

- Methanol-fueled vessels are operating commercially today. [15]

Vessel technology

- For two-stroke engines, methanol requires pilot fuel equivalent to 6% of energy at 80% load.[16]

- Assuming shipyard availability, the estimated timeline for shipyard delivery of a methanol-fueled vessel is ~ 2-3 years from entry in the order books; retrofitting can take less time.[17]

Logistics, storage, and bunkering

- There are currently limited bunkering and storage facilities for methanol.[18]

- While methanol bunkering has been demonstrated, guidelines are evolving and global standards need further development.

- Bunkering requirements differ across ports, e.g., variations in hose couplings and vapor return line requirements. A unified global standard would help ensure consistency.

- Dedicated methanol bunkering barges are few, as conventional barges cannot be used. Project-specific solutions such as using chemical tankers or cleaned biofuel barges are possible but costly and complex.[19]

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.[20]

- Final guidance on sustainability criteria and quantification of well-to-wake GHG emissions from fuels, including the treatment of fugitive emissions, is still under development by the IMO.[21] 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.

- The IMO approved the Interim guidelines for the safety of ships using methyl/ethyl alcohol as fuel (MSC.1/Circ.1621). The interim guidelines will be kept under review, taking into account operational experience gained through their application.[22]

- ISO 6583:2024 provides comprehensive details on the quality of methanol to be used as a fuel for ships worldwide, including purity, impurities, appearance, and specific chemical properties.[23]

Commercial considerations

Cost and market development

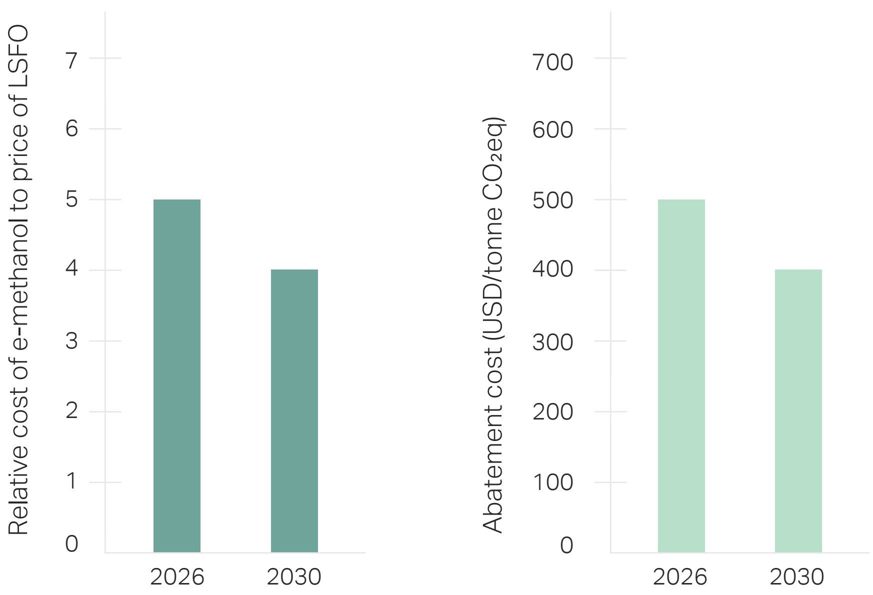
- Production costs for e-methanol are estimated to be 5.0 times the price of LSFO per unit energy in 2026 and 4.0 times the price of LSFO per unit energy in 2030.[h] The main cost drivers for this fuel include renewable energy and related infrastructure, electrolyzer stacks, and the capture, transportation, and storage of biogenic CO_2.

- The estimated abatement cost is around 500 USD/tonne CO_2eq avoided emissions in 2026 and 400 USD/tonne CO_2eq avoided emissions in 2030, excluding vessel cost.[24, b]

- In addition to maritime applications, we expect to see demand for e-methanol from the chemicals industry for the production of plastics and other hydrocarbon-based products.[2]

- Biogenic CO_2 can also be permanently stored or used to produce e-SAF.[25, 26, c] We expect these applications to compete with e-methanol production for access to biogenic CO_2.[9]

Figure 1: Modeled cost (left) and abatement cost (right) for e-methanol 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.



[b] These figures are model-based estimates provided for analytical context only and do not represent market prices or forecasts.
[c] SAF = sustainable aviation fuel

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

Document 1: E-ammonia.

Document 2: Blue ammonia.

Document 4: Bio-methanol.

Document 5: E-methane.

Document 6: Bio-methane.

Document 7: E-diesel.

Document 8: Biodiesel.

For more, visit www.zerocarbonshipping.com

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