E-methane

Alternative maritime fuel information sheets
Document 5 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-methane. 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

This information sheet was prepared by the Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping (MMMCZCS) with assistance from our partners. Contributors marked with an asterisk (*) were seconded to the MMMCZCS from their home organization and contributed in a research capacity under the supervision and direction of MMMCZCS.

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Sustainability considerations

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

- Besides climate impact, notably based on electricity and carbon sources (see 'Life cycle GHG emissions,' below), the main sustainability risks for this fuel include:

  - Fugitive methane emissions (leakages or slips), which can occur during production, transportation, or use of e-methane. These emissions can have detrimental impacts on the environment, with methane's global warming potential being much higher than that of carbon dioxide (CO_2).[1, 2]

  - Risks including land use change, biodiversity losses, and increased emissions can arise if CO_2 used in e-methane 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-methane 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]

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-methane, life cycle GHG emissions intensity is typically in the range of <7-10 g CO_2eq/MJ,[a] depending on the carbon source, methane leakages from the supply chain, electricity mix, and production efficiency.[5, 6] Publicly available data remains limited, as e-methane production is in early development stages.

- 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 for hydrocarbon synthesis.

  - Like other carbon-containing e-fuels, e-methane 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-methane combustion produces CO_2. These emissions are considered carbon-neutral provided that the carbon originates from biogenic or atmospheric sources, as the CO_2 released during combustion roughly corresponds to carbon previously removed from the atmosphere.

  - Fractions of unburned methane slip can occur during e-methane combustion. Because methane has a high global warming potential, even small quantities of methane slip can significantly affect the fuel's overall GHG performance.[7]

- 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.

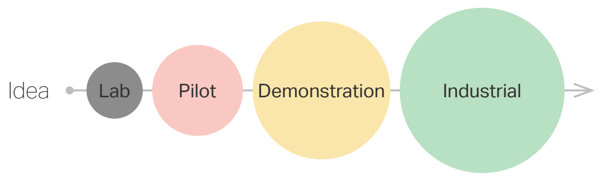
[a] g CO_2eq/MJ = grams of carbon dioxide-equivalent per megajoule of energy

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 DAC and 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[8]
- Carbon removal systems (DAC and DOC)[9]
- Electrolysis technologies[10, 11]
- Methane synthesis[12]

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

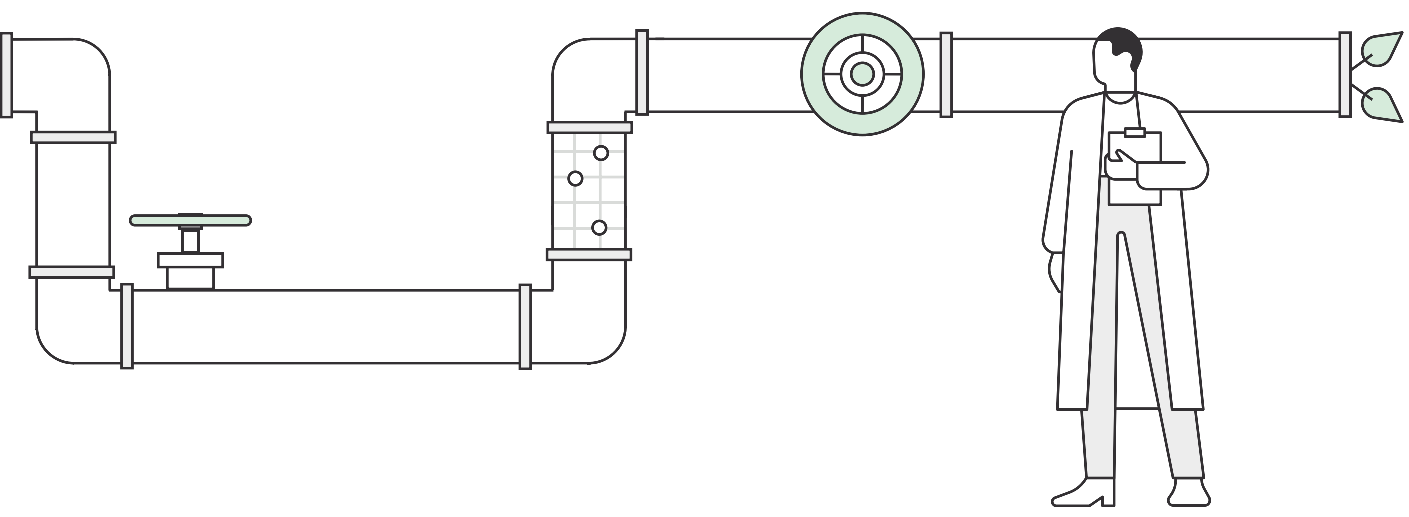
  - To support industrial-scale e-methane production, the manufacturing rate for electrolyzers needs to be optimized and scaled up.[13] Doing so will reduce costs and support the production of sufficient quantities of e-hydrogen.

  - The development of an e-methane production plant can take 5-6 years. This includes the permitting and engineering, procurement, and construction work for the catalytic plants.[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.[8] Biogenic CO_2 transport can be through either pipeline (limited infrastructure) or truck (limited capacities).

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

  - Existing natural gas networks could be leveraged to transport e-methane, but these networks are not available in all regions.



Maritime uptake

Safety

- Currently, hundreds of methane-fueled vessels are in commercial operation (using LNG).[b]

- Beyond adherence to established regulations and safe management practices, no major barriers exist for safe onboard operations or scaling of methane as a maritime fuel.[15]

Vessel technology

- For two-stroke engines, methane requires pilot fuel equivalent to 0.5-2% of energy at 80% load.[16]

- Methane slip depends on engine design and operational conditions.[17]

- Assuming shipyard availability, the estimated timeline for shipyard delivery of a methane-fueled vessel is ~ 2-3 years from entry in the order books.[18]

Logistics, storage, and bunkering

- Methane bunkering is already practiced – however, methane leaks can occur during this process, and these emissions are currently neither widely monitored nor strictly regulated.

Commercial considerations

Regulatory and certification

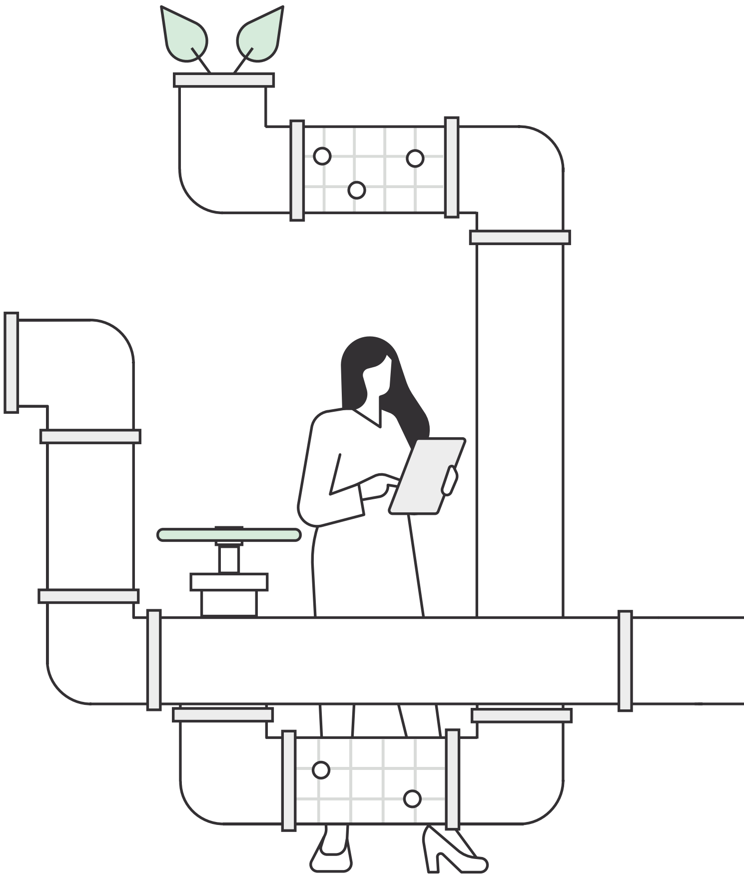
- The IMO Net-Zero Framework is a set of technical and economic measures aimed at delivering emissions reductions according to the IMO's 2023 GHG Strategy. The timeline for the framework's adoption and implementation remains to be finalized.[19]

- Final guidance on quantification of well-to-wake GHG emissions from fuels, including the treatment of fugitive emissions, and the sustainability criteria are still under development by the IMO.[20] 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 IGF Code[c] includes safety provisions for the design, construction, and operation of ships that use gaseous or other low-flashpoint fuels, including e-methane. In addition, other international standards and guidelines are used to ensure safety and quality specifications throughout the methane bunkering and supply process.[21]

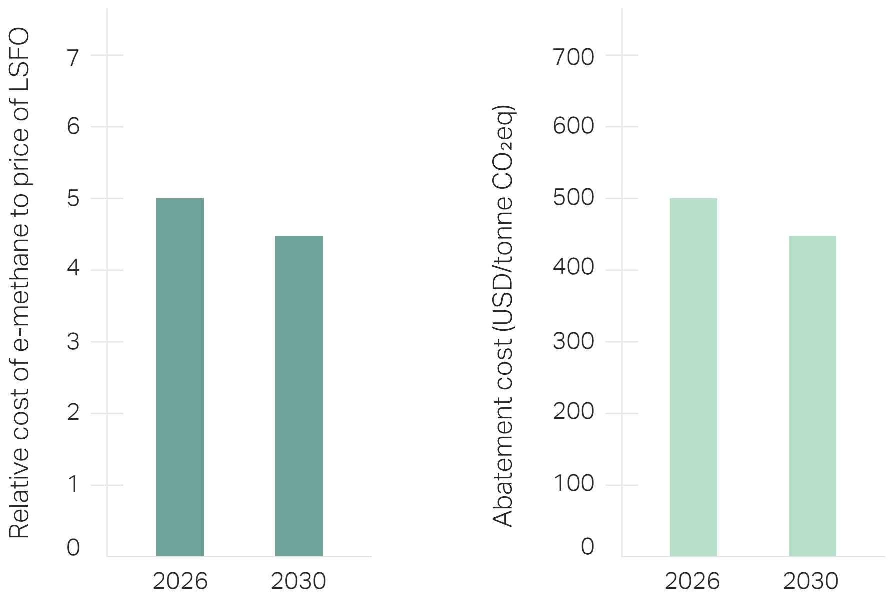
[b] LNG = liquefied natural gas
[c] IGF Code = International Code of Safety for Ships Using Gases or Other Low-flashpoint Fuels

Cost and market development



- Production costs for liquefied e-methane are estimated to be 5.0 times the price of low-sulfur fuel oil (LSFO) per unit energy in 2026 and 4.5 times the price of LSFO per unit energy in 2030.[d] The main cost drivers for this fuel include renewable energy and related infrastructure, electrolyzer stacks, and the capture, storage, and transport of biogenic CO_2.
- The estimated abatement cost is around 500 USD/tonne CO_2eq avoided emissions in 2026 and 450 USD/tonne CO_2eq avoided emissions in 2030, excluding vessel cost.[d]
- The main competing market for e-methane is consumers of gas who wish to decarbonize from existing natural gas networks.[22]
- Biogenic CO_2 can also be permanently stored or used to produce e-SAF.[e, 23,24] We expect these applications to compete with e-methane production for access to biogenic CO_2.[8]

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



[d] These figures are model-based estimates provided for analytical context only and do not represent market prices or forecasts.
[e] 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 3: E-methanol.

Document 4: Bio-methanol.

Document 6: Bio-methane.

Document 7: E-diesel.

Document 8: Biodiesel.

For more, visit www.zerocarbonshipping.com

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