

Bio-methane

Alternative maritime fuel information sheets
Document 6 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 [bio-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.

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Sustainability considerations

- Similar to other alternative fuels, bio-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 bio-methane.
- Besides climate impact (see 'Life cycle GHG emissions,' below), the main sustainability risks from this fuel include:
 - Fugitive methane emissions (leakages and slips), which can occur during production, transportation, or use of bio-methane. These emissions can have detrimental impacts on the environment, with methane's global warming potential being much higher than that of carbon dioxide (CO₂).¹
 - Mismanaged waste feedstocks could lead to leaks of ammonia or volatile organic compounds. These leaks can contribute to aerosols^{2,3} or lead to eutrophication if waste from fertilizer-heavy agricultural production leaks into waterways.^{4,5}
 - Working with biogases can lead to health and safety risks in production plants, due to these gases' flammability and other dangerous properties.^{6,7} Moreover, odor nuisances can affect workers and neighboring communities.⁸

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.
- Bio-methane can be produced via two main pathways: biogas reforming or gasification of woody biomass.⁹
 - For bio-methane, life cycle GHG emissions intensity is typically in the range of <0 to 40 g CO₂eq/MJ^a depending on the feedstock type, biogas upgrading technology, and energy source used for processing.
 - The main drivers of life cycle emissions are associated with methane leakage along the value chain and with energy use during anaerobic digestion, upgrading, and liquefaction.
 - Bio-methane produced from organic waste streams (such as manure or sewage sludge) can achieve very low or even negative GHG intensities, as the process captures methane that would otherwise be emitted into the atmosphere.^{10,11,12}
 - Bio-methane combustion produces CO₂. Since this carbon originates from biogenic sources, these emissions are considered carbon-neutral, as CO₂ released during combustion is roughly offset by the CO₂ absorbed during biomass growth.
 - Fractions of unburned methane slip can occur during bio-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.¹³
- 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 used. 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



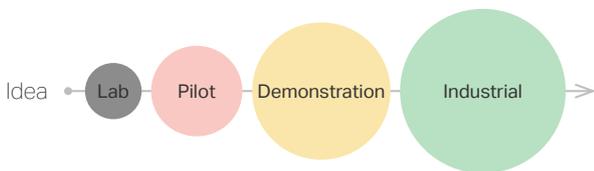
Fuel availability potential

- Feedstock availability

There are two main pathways for producing bio-methane (excluding pathways that use first-generation biomass feedstock). Each pathway relies on a different primary feedstock type.

- **Biogas reforming pathway:** Feedstocks for this pathway comprise sustainable waste streams of biogenic origin that are suitable for biogas production. These include manure, agricultural waste, and food waste.
- **Gasification pathway:** Feedstocks for this pathway include forestry biomass for gasification, which is available in high volumes but also subject to interest from other offtakers. Pathways using these feedstocks are not yet commercialized for bio-methane.

- Industrial maturity

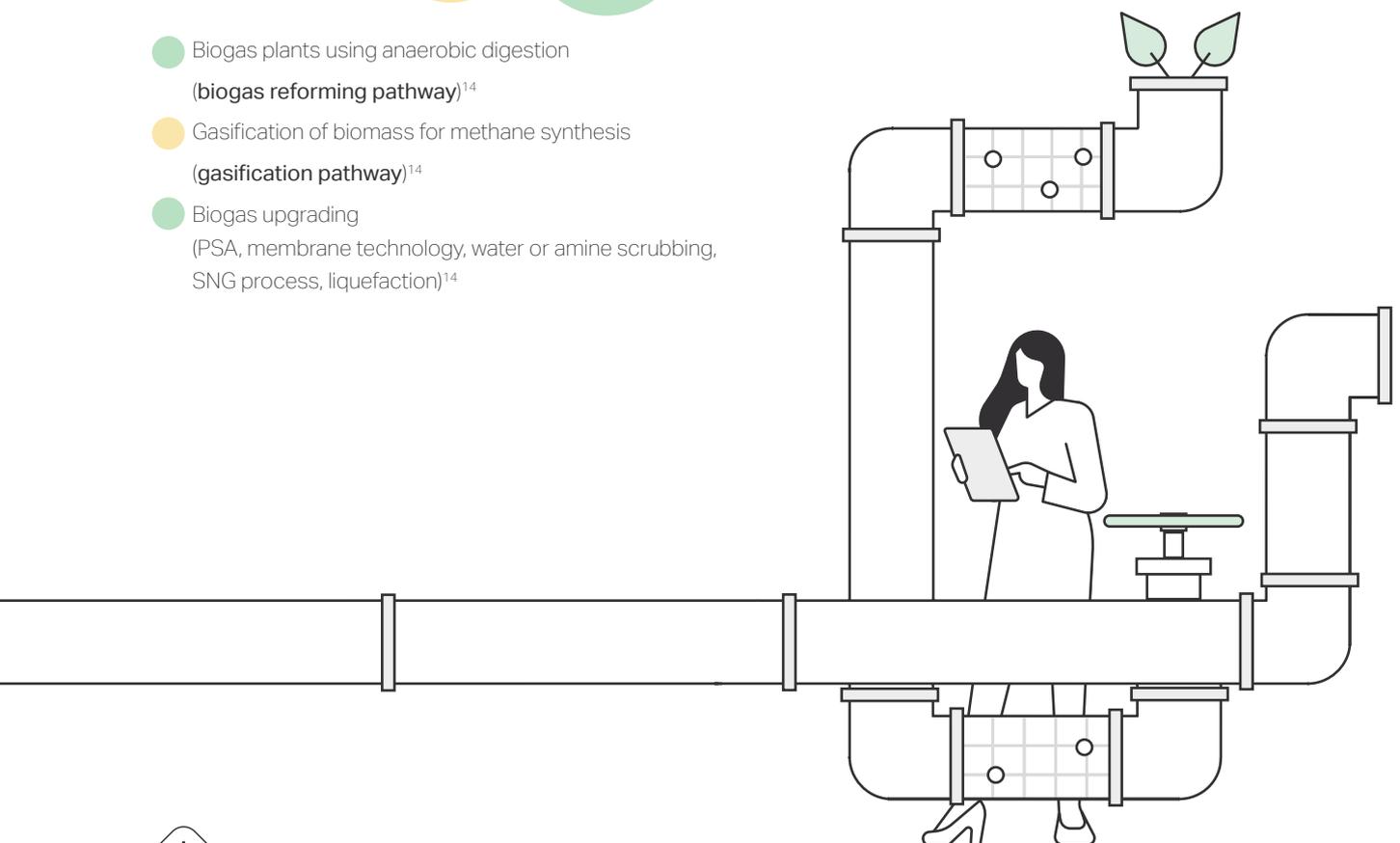


- Biogas plants using anaerobic digestion (biogas reforming pathway)¹⁴
- Gasification of biomass for methane synthesis (gasification pathway)¹⁴
- Biogas upgrading (PSA, membrane technology, water or amine scrubbing, SNG process, liquefaction)¹⁴

- Infrastructure requirements

Biogas or biomass feedstock collection, anaerobic digestion and upgrading facilities; access to natural gas infrastructure for bio-methane transport is not required per se but may enable important cost reduction.

- As suitable waste streams are not always collected, establishing appropriate collection infrastructure could enable global capacity for bio-methane production.
- Biogas production facilities in some regions are scattered or scarce.
- Existing natural gas networks could be leveraged to transport bio-methane, but these networks are not available in all regions.
- Bio-methane manufacturing costs are impacted by economy of scale for the chemical units and diseconomy of scale for the biomass transport. Hence, the economic optimum for a bio-methane producer is a balance between the two.¹⁵



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, there are no major barriers to safe onboard operations or scaling of methane as a maritime fuel.¹⁶

Vessel technology

- For two-stroke engines, methane requires pilot fuel equivalent to 0.5 -2.0% of energy at 80% load.¹⁷
- Methane slip depends on engine design and operational conditions.¹⁰
- 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.
- Clear guidance on how avoided emissions from waste-based feedstocks are treated under regulatory frameworks is especially relevant for GHG emissions quantification and market opportunities for bio-methane.
- The IGF Code^c includes safety provisions for the design, construction, and operation of ships that use gaseous or other low-flashpoint fuels, including bio-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

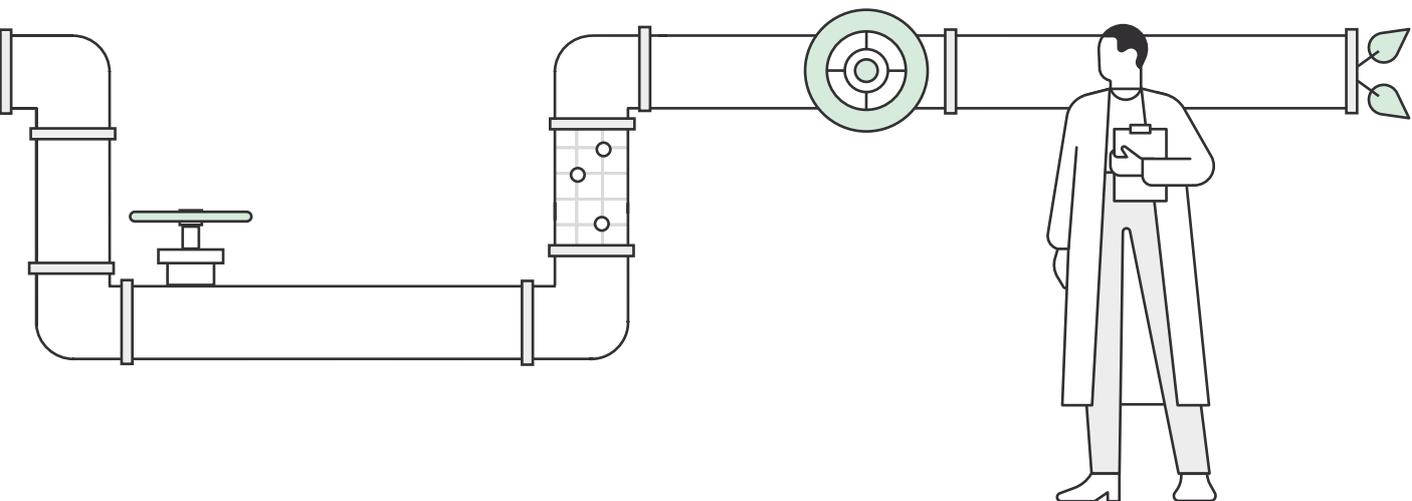
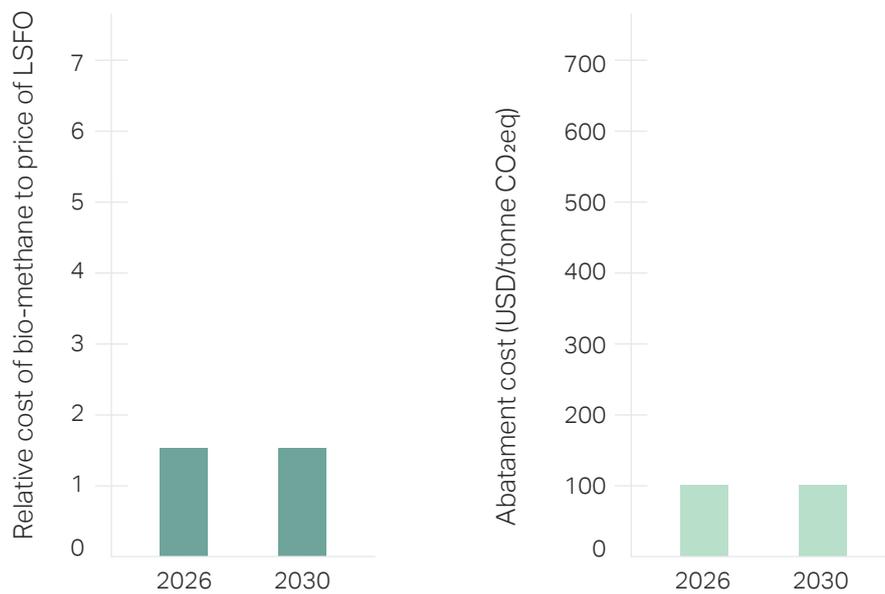


Cost and market development

- Production costs for liquefied bio-methane are estimated to be 1.5 times the price of low-sulfur fuel oil (LSFO) per unit energy in both 2026 and 2030.^d The main cost drivers for this fuel include cost of biomass and cost of biomass/digestate transport.

- The estimated abatement cost is around 100 USD/tonne CO₂eq avoided emissions in both 2026 and 2030, excluding vessel cost.^d
- The main expected competitors for bio-methane are consumers of gas who wish to decarbonize from existing natural gas networks.²²

Figure 1: Modeled cost (left) and abatement cost (right) for bio-methane in 2026 and 2030. Values are illustrative outputs from analytical modeling and 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.



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- ¹² [Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping. Biogas as a source of biofuels for shipping: Well-to-wake greenhouse gas emissions \(2024\).](#)
- ¹³ [International Energy Agency. *The Role of Low-Carbon Fuels in the Clean Energy Transitions of the Power Sector* \(2021\).](#)
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- ²¹ [International Maritime Organization. *International Code of Safety for Ship Using Gases or Other Low-flashpoint Fuels \(IGF Code\)*.](#)
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Go to these links to learn about other alternative maritime fuels.

Document 1: [E-ammonia](#).



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



Document 2: [Blue ammonia](#).



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



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



Document 8: [Biodiesel](#).



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



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