

# Bio-methanol

Alternative maritime fuel information sheets  
Document 4 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-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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# Sustainability considerations

- Similar to other alternative fuels, bio-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 bio-methanol.
- Besides climate impact (see 'Life cycle GHG emissions,' below), the main sustainability risks for this fuel include:
  - Health and safety risks from bio-methanol's flammability and toxicity, which require special handling, as well as from the formation of air pollutants associated with respiratory diseases.<sup>1,2</sup>
  - Production of bio-methanol as a first-generation biofuel from crops creates risks relating to land use change and biodiversity. To lower these risks, sustainability frameworks encourage using waste-based or residue-based feedstocks.<sup>2</sup>
  - Production of bio-methanol as a first-generation biofuel also creates food security risks, as resources (e.g., land, water, and crops) may be dedicated to fuel production instead of food production.<sup>3</sup>

## Life cycle GHG emissions

- Life cycle emissions account for 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-methanol can be produced via two main pathways: biogas reforming or gasification of woody biomass.<sup>4</sup>
- For bio-methanol, life cycle GHG emissions intensity can vary widely, typically ranging from 3–30 g CO<sub>2</sub>eq/MJ,<sup>a</sup> depending on the biomass feedstock, conversion technology, and supply chain logistics.
  - The main drivers of life cycle emissions include feedstock cultivation and collection, electricity used for processing, and the conversion efficiency of the technology being used. For example, the gasification route typically results in lower upstream GHG emissions due to more efficient conversion processes. However, gasification is less commonly used for large-scale bio-methanol production, primarily due to its lower technological readiness and higher complexity. In contrast, the biogas reforming pathway is more widely used and has a higher technological readiness level. This pathway can have higher upstream emissions, mainly due to fugitive methane emissions during biogas production and upgrading.<sup>5, 6, 7, 8, 9, 10</sup>
- Bio-methanol combustion produces carbon dioxide (CO<sub>2</sub>). Since this carbon originates from biogenic sources, these emissions are considered carbon-neutral, as CO<sub>2</sub> released during combustion is roughly offset by the CO<sub>2</sub> absorbed during biomass growth. In addition, bio-methanol combustion requires a pilot fuel, which increases overall GHG emissions and should be accounted for in life cycle calculations.<sup>11, 12</sup>
- 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.

<sup>a</sup> g CO<sub>2</sub>eq/MJ = grams of carbon dioxide-equivalent per megajoule of energy



# Fuel availability potential

**- Feedstock availability**

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

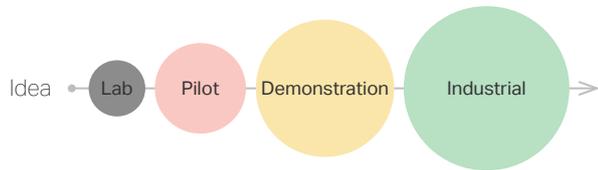
- **Biogas reforming pathway:** Feedstocks for this pathway comprises sustainable waste streams of biogenic origin that are suitable for biogas production with or without an additional supply of hydrogen. These include manure, agricultural waste, and food waste.
- **Gasification pathway:** Feedstocks for this pathway includes forestry biomass for gasification, which is available in high volumes but also subject to interest from other offtakers. Pathways using this feedstock are not yet commercialized for bio-methanol.

**- Infrastructure requirements<sup>1,9</sup>**

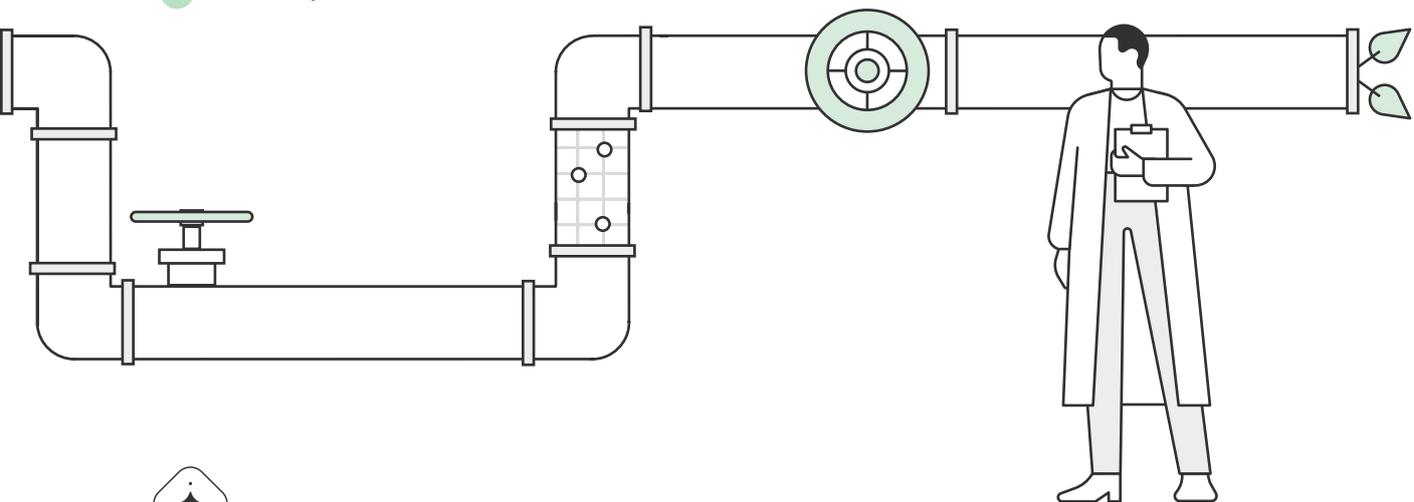
Biogas or biomass feedstock collection, gas reforming or gasification units, methanol synthesis and upgrading facilities; in some cases, access to natural gas infrastructure for bio-methane transport.

- Bio-methanol plant size is expected to be scalable, but depends on regional availability of suitable waste streams and supporting infrastructure.
- The development of a bio-methanol production plant can take 5–6 years.<sup>16</sup> This includes the permitting and engineering, procurement, and construction work for both the catalytic plants and supporting infrastructure.

**- Industrial maturity**



- Bio-methane/biogas plants using anaerobic digestion (biogas reforming pathway)<sup>13</sup>
- Methane reforming (biogas reforming pathway)<sup>13</sup>
- Gasification of biomass for methanol synthesis (gasification pathway)<sup>13</sup>
- Electrolysis technologies<sup>13, 14, 15</sup>
- Methanol synthesis<sup>9</sup>



# Maritime uptake

## Safety

- Safe handling of methanol as a low-flashpoint liquid on vessels has been demonstrated and is covered by established practices.<sup>17</sup>
- There are no significant barriers for onboard safety.
- Methanol-fueled vessels are operating commercially today.<sup>17</sup>

## Vessel technology

- For two-stroke engines, methanol requires pilot fuel equivalent to 6% of energy at 80% load.<sup>18</sup>
- 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.<sup>19</sup>

## Logistics, storage, and bunkering

- There are currently limited bunkering and storage facilities for methanol.<sup>20</sup>
- 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.<sup>21</sup>

## 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.<sup>22</sup>
- 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.<sup>23</sup> 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.
- For bio-methanol, 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.
- The IMO has approved 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.<sup>24</sup>
- 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.<sup>25</sup>

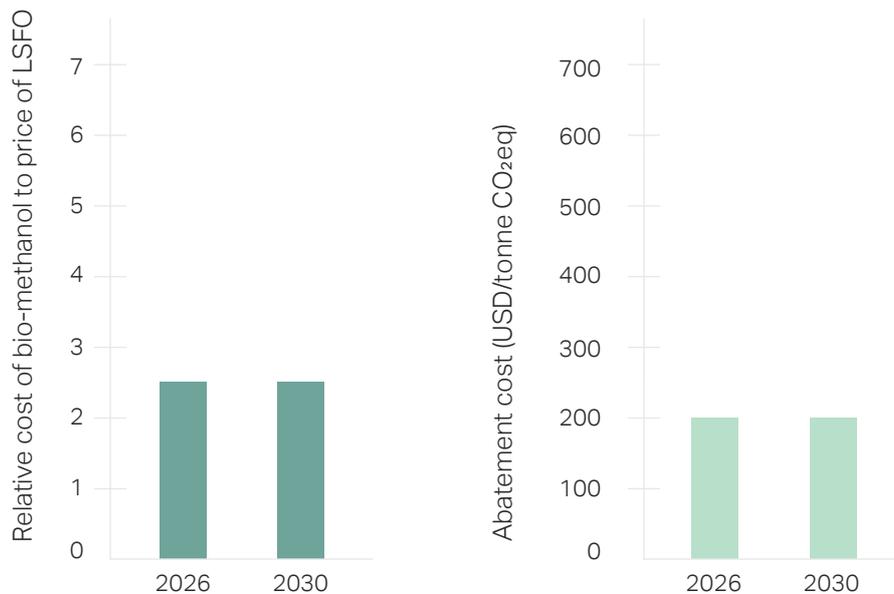


# Commercial considerations

## Cost and market development

- Production costs for bio-methanol are estimated to be 2.5 times the price of LSFO per unit energy in both 2026 and 2030.<sup>26, b</sup> The main cost drivers for this fuel include cost of biomass, cost of electricity for e-hydrogen, and capital expenditure for electrolyzer/ methanol synthesis and distillation.
- The estimated abatement cost is around 200 USD/ tonne CO<sub>2</sub>eq avoided emissions in both 2026 and 2030, excluding vessel cost.<sup>26, b</sup>
- In addition to maritime applications, we expect to see demand for bio-methanol from the chemicals industry for the production of plastics and other hydrocarbon-based products.<sup>9</sup>
- The feedstocks for bio-methanol production will also face competition: biomass may be displaced from other uses or from manufacturing other biofuels, while biogas can also be used for chemical processes and for heat and power generation.<sup>27</sup>
- For the bio-methanol production pathways that use biogenic CO<sub>2</sub>, both permanent storage of this CO<sub>2</sub> and use in e-SAF<sup>c</sup> production would also compete with bio-methanol fuel production.<sup>28, 29, 30</sup>

Figure 1: Modeled cost (left) and abatement cost (right) for bio-methanol in 2026 and 2030. Values are illustrative outputs from analytical modeling and do not represent market prices or forecasts.



<sup>b</sup> These figures are model-based estimates provided for analytical context only and do not represent market prices or forecasts.

<sup>c</sup> SAF = sustainable aviation fuel



## References

- <sup>1</sup> [North Standard. Methanol as marine fuel \(2024\).](#)
- <sup>2</sup> [Jeswani, H. K., Chilvers, A. & Azapagic, A. Environmental sustainability of biofuels: a review. \*Proceedings of the Royal Society A\* 476:2243 \(2020\).](#)
- <sup>3</sup> [Gasparatos, A., Stromberg, P. & Takeuchi, K. Sustainability impacts of first-generation biofuels. \*Animal Frontiers\*, 3. \(2013\).](#)
- <sup>4</sup> [Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping. Fuel Pathway Maturity Map: Bio-methanol – Fuel production \(2024\).](#)
- <sup>5</sup> [Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping. Biogas as a Source of Biofuels for Shipping: Methane Emissions \(2024\).](#)
- <sup>6</sup> [Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping. Biogas as a Source of Biofuels for Shipping: Well-to-Wake Greenhouse Gas Emissions \(2024\).](#)
- <sup>7</sup> [Yadav, P. et al. Environmental impact and environmental cost assessment of methanol production from wood biomass. \*Environmental Pollution\* 265 Part A: 114990 \(2020\).](#)
- <sup>8</sup> [Bazaluk, O. et al. Assessment of green methanol production potential and related economic and environmental benefits: the case of China. \*Energies\* 13\(12\): 3113 \(2020\).](#)
- <sup>9</sup> [IRENA and Methanol Institute. Innovation Outlook: Renewable Methanol. International Renewable Energy Agency \(2021\).](#)
- <sup>10</sup> [DNV. Methanol as marine fuel: Environmental benefits, technology readiness, and economic feasibility \(2016\).](#)
- <sup>11</sup> [International Energy Agency. The Role of Low-Carbon Fuels in the Clean Energy Transitions of the Power Sector. \(2021\).](#)
- <sup>12</sup> [Everllence. Methanol-ready four-stroke engines \(n.d.\).](#)
- <sup>13</sup> [Mærsk McKinney Møller Center for Zero Carbon Shipping. Using bio-diesel onboard vessels \(2023\).](#)
- <sup>14</sup> [International Energy Agency. Electrolysers - Energy System - IEA. \(2025\).](#)
- <sup>15</sup> [National Renewable Energy Laboratory. H2A: Hydrogen Analysis Production Models | Hydrogen and Fuel Cells \(2020\).](#)
- <sup>16</sup> [Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping. Biogas as a Source of Biofuels for Shipping: Insights into the Value Chain \(2024\): reference to catalytic plants on page 28 and 29.](#)
- <sup>17</sup> [DNV. Methanol fuel in shipping. \(2025\).](#)
- <sup>18</sup> [Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping. Consolidation of data from partners as collected in the Onboard Vessel Solutions \(OVS\) team at the MMMCZCS \(2025\).](#)
- <sup>19</sup> [Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping. Internal interview with industrial partner \(2023\).](#)
- <sup>20</sup> [Methanol Institute. E-Methanol & Biomethanol Plants and Ports \(2025\).](#)
- <sup>21</sup> [Beumer, C. & Society for Gas as a Marine Fuel \(SGMF\). SGMF Press Release on New Bunkering Guidelines Methanol and Ammonia \(2024\).](#)
- <sup>22</sup> [International Maritime Organization. IMO net-zero shipping talks to resume in 2026 \(2025\).](#)
- <sup>23</sup> [International Maritime Organization. 2023 IMO Strategy on Reduction of GHG Emissions from Ships \(2023\).](#)
- <sup>24</sup> [International Maritime Organization. Interim Guidelines for Safety of Ships using Methyl/Ethyl Alcohol as Fuel MSC.1/Circ.1621. \(2020\).](#)
- <sup>25</sup> [International Organization for Standardization. ISO 6583:2024 \(2024\).](#)
- <sup>26</sup> [Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping. Fuel Cost Calculator.](#)
- <sup>27</sup> [Boston Consulting Group. Biogas Can Help Global Shipping Go Green \(2024\).](#)
- <sup>28</sup> [Mikkelsen, S. e-SAF offers much promise within Sustainable Aviation Fuels | TOPSOE blog \(2024\).](#)
- <sup>29</sup> [Skov, I. R. & Abid, H. Renewable Aviation E-SAF Catalogue and System Impacts \(2024\).](#)
- <sup>30</sup> [Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping. Global Availability of Biogenic CO<sub>2</sub> and Implications for Maritime Decarbonization \(2024\).](#)



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

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



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



Document 2: [Blue ammonia](#).



Document 7: [E-diesel](#)



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



Document 8: [Biodiesel](#).



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



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