WHEN TRUST MATTERS

METHANOL FUEL IN SHIPPING

Barriers and pathways to low-GHG methanol as a marine fuel

WHITE PAPER

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Executive summary

While methanol emerged as a viable marine fuel more than a decade ago, interest in low greenhouse gas (GHG) methanol has increased in recent years in response to increasingly stringent GHG regulations and commercial demands for low-GHG transport. Methanol is a liquid at atmospheric conditions, making it easier to store, transport and bunker than gaseous fuels like natural gas, ammonia, and hydrogen. Methanol is also easier to handle from a safety perspective. Today, the number of methanol-capable ships in the global fleet of merchant vessels and in the order book totals 450 vessels, second only to LNG among the alternative fuels. However, most methanol-capable vessels today still run on fuel oil or fossil methanol, with limited uptake of low-GHG methanol.

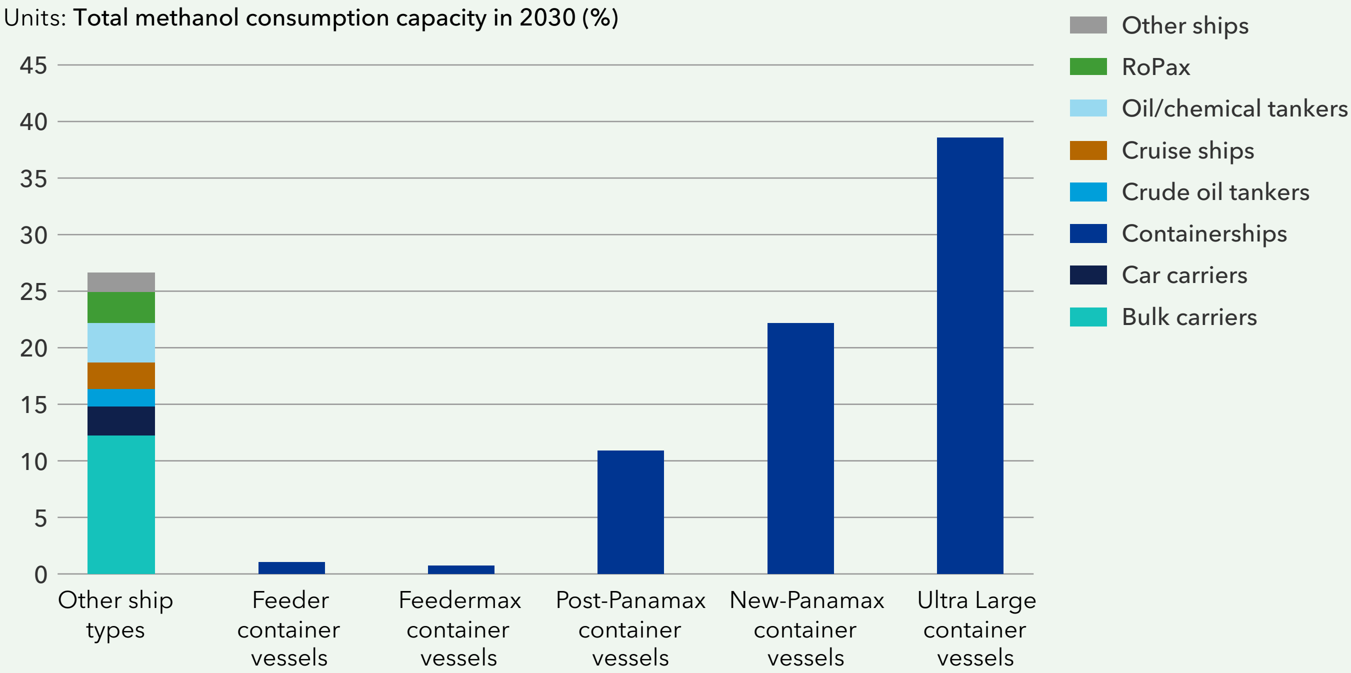
This paper examines the status of methanol as a marine fuel, addressing ships capable of using methanol as fuel, methanol fuel production, and the infrastructure that can supply them. We assess 10 main barriers to the widespread use of low-GHG methanol in shipping, with a focus on developments between 2020 and 2025. We also discuss the potential way ahead for low-GHG methanol in the coming years and decades, highlighting the challenge of balancing supply and demand in light of the potential use of methanol as a GHG compliance strategy.

As illustrated by our Alternative Fuel Barrier Dashboard for low-GHG methanol (see Figure 2), we find that there are few remaining ship-related barriers, due to significant developments after 2020. The necessary technologies for vessels to operate on low-GHG methanol are relatively mature and available, as highlighted by the growing number of methanol-capable ships in the order book. By 2030, the fleet's methanol capacity could exceed 15 million tonnes (Mt), led by ultra-large container vessels (ULCVs >14,500 TEU) and new-Panamax vessels (10,000–14,500 TEU) – accounting for 60% of total capacity, with rising interest from other segments as well (Figure 1).

Unlike LNG, ammonia and hydrogen, methanol remains liquid at ambient temperature and pressure, which means that the bunkering infrastructure closely resembles that used for conventional bunker barges. With minor modifications, methanol-capable vessels can also burn ethanol – a substance with similar properties and significant production volumes – providing flexibility in the future fuel pathway. We also find few significant barriers within what we label the shipping ecosystem, with progress in recent years within seafarer training, and stakeholder awareness and knowledge. While using methanol as fuel offers benefits, the widespread adoption of low-GHG methanol is hindered by the challenge of ensuring its availability at a competitive price.

FIGURE 1

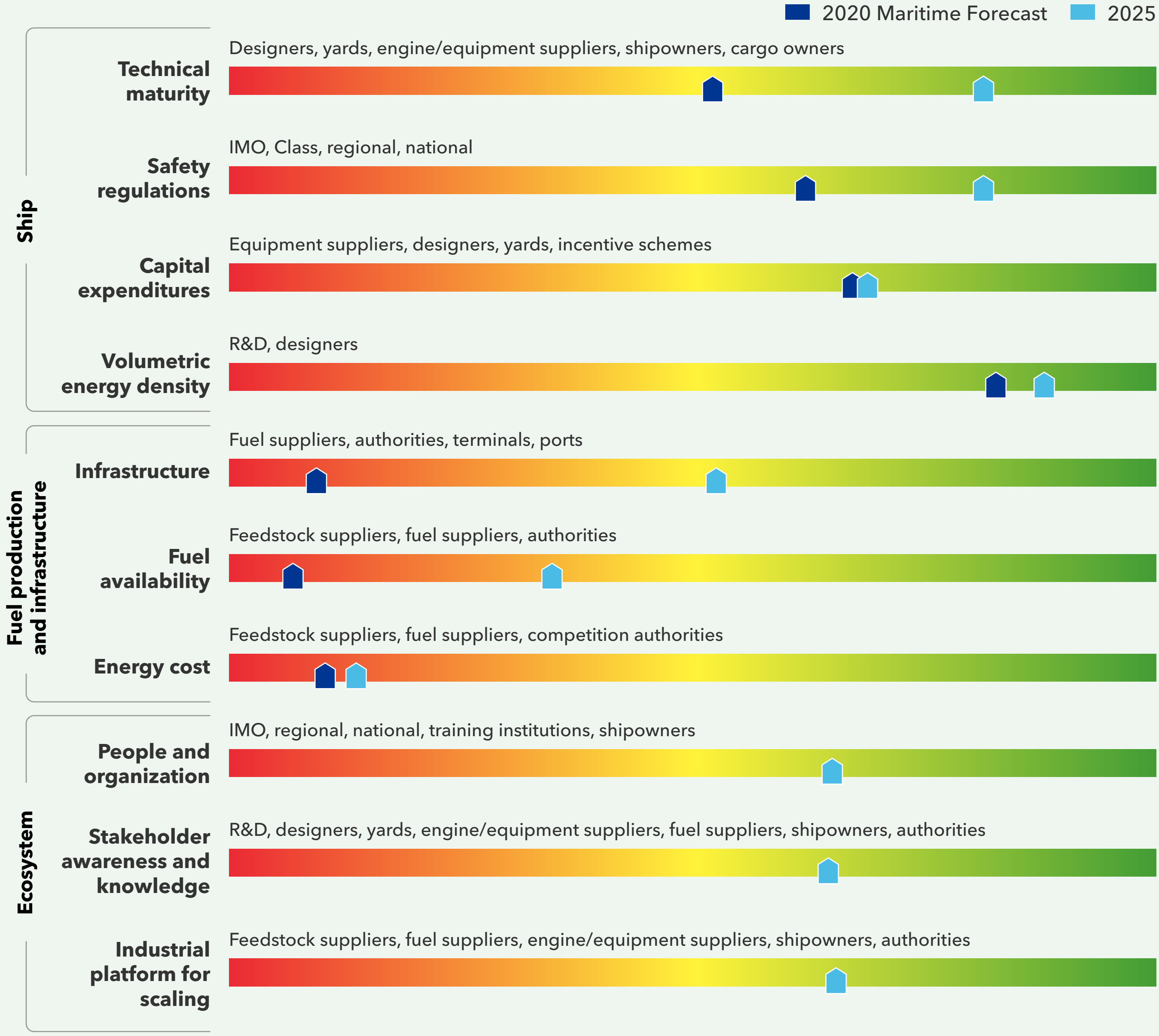
Methanol consumption capacity per ship segment as a percentage of total fleet capacity in 2030



Source: DNV

FIGURE 2

The Alternative Fuel Barrier Dashboard – an indicative status of key barriers to methanol in 2025 compared to 2020, and key players in further reducing barriers to methanol as a fuel. Red indicates barriers that remain to be solved, while green indicates parity with conventional marine fuel oils



Technical maturity refers to the current technical maturity level for engine technology and systems.

Safety regulations refer to the status of rules and guidelines related to the design and safety requirements for the ship and onboard systems.

Capital expenditures refer to costs above baseline (conventional fuel oil system) for zero-emission fuels, i.e. engine and fuel system costs.

Volumetric energy density refers to the challenges related to the amount of energy stored per unit volume, also considering the volume of the storage solution.

Infrastructure refers to the available infrastructure for bunkering.

Fuel availability refers to today's availability of the fuel, future production plans, and long-term availability.

Energy cost reflects fuel competitiveness compared with Marine Gas Oil (MGO), taking GHG-related costs into account.

People and organization refer to the lack of trained seafarers, operational procedures, and organizational structures to operate methanol-fuelled ships.

Stakeholder awareness and knowledge refer to the lack of general industry awareness and knowledge.

Industrial platform for scaling refers to the lack of existing industrial infrastructure to build on or adapt.

One aspect of low-GHG fuel availability in shipping is the mutual dependency between shipowners and fuel producers: shipowners need reliable access and stable prices to invest in methanol-capable vessels, while producers require certainty of demand to justify investments in production and infrastructure. A relatively common misconception outside shipping circles is that methanol-capable vessels will run entirely on low-GHG methanol. However, this will not be the case unless several favourable conditions are in place, including favourable methanol fuel prices and high earnings from exceeding regulatory targets.

To better understand how demand for low-GHG methanol could develop towards 2040, we model the fleet's total capacity to consume methanol as fuel (i.e. methanol capacity) and how much of this capacity is utilized. Four scenarios are explored, revealing a wide potential demand range for low-GHG methanol by 2040, from zero to 60 Mt, reflecting significant uncertainty in future uptake (see Figure 3):

- **No use:** No adoption of low-GHG methanol.
- **FuelEU Maritime:** Use enough low-GHG methanol to meet the FuelEU Maritime GHG intensity target[1]; demand grows from 0.05 Mt in 2025 to 5–12 Mt by 2040.
- **IMO NZF Base:** Use enough low-GHG methanol to meet the Base target under IMO NZF; demand reaches 1.7–2.8 Mt in 2030 and 20–50 Mt by 2040.
- **Maximum use:** Utilize the full capacity for using low-GHG methanol; demand rises from 2.9 Mt in 2025 to 24–60 Mt by 2040.

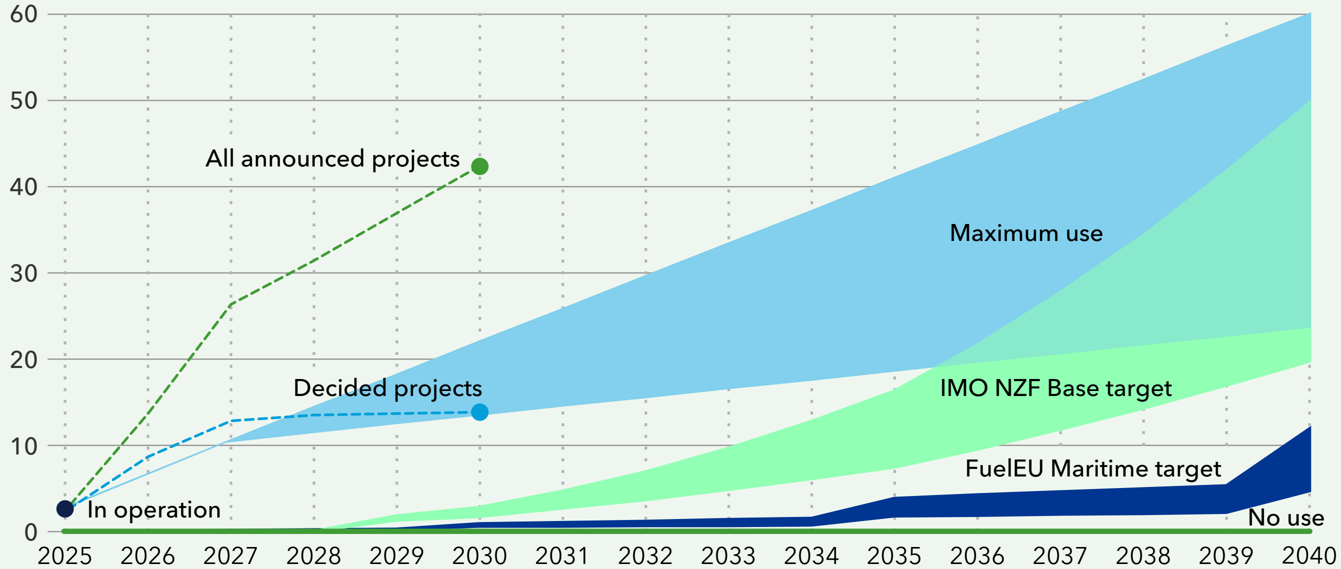
Figure 3 also includes two supply trajectories for low-GHG methanol, one based on all announced projects and one for decided projects, totaling 42 Mt and 14 Mt in 2030, respectively, up from today's 2.2 Mt. Our analysis shows that the existing production pipeline could, in most demand scenarios, meet all of shipping's needs through 2040, assuming the maritime sector is the primary offtaker. Since there are other potential offtakers of low-GHG methanol (such as chemical feedstock, gasoline blending, or biodiesel production), shipping may face competition in this regard.

The risk imbalance between shipowners and fuel producers complicates investment decisions. Shipowners investing in methanol-capable vessels face comparatively lower risks than producers who require long-term demand certainty to justify high initial costs. Ultimately, regulatory clarity is essential to send strong demand signals and unlock investment in low-GHG methanol.

FIGURE 3

Projected use of low-GHG methanol under four different scenarios: Maximum use, IMO NZF Base target, FuelEU Maritime target and No use compared to global production capacity of low-GHG methanol production projects

Units: Amount of low-GHG methanol (Mt)



Source: DNV

1 Introduction

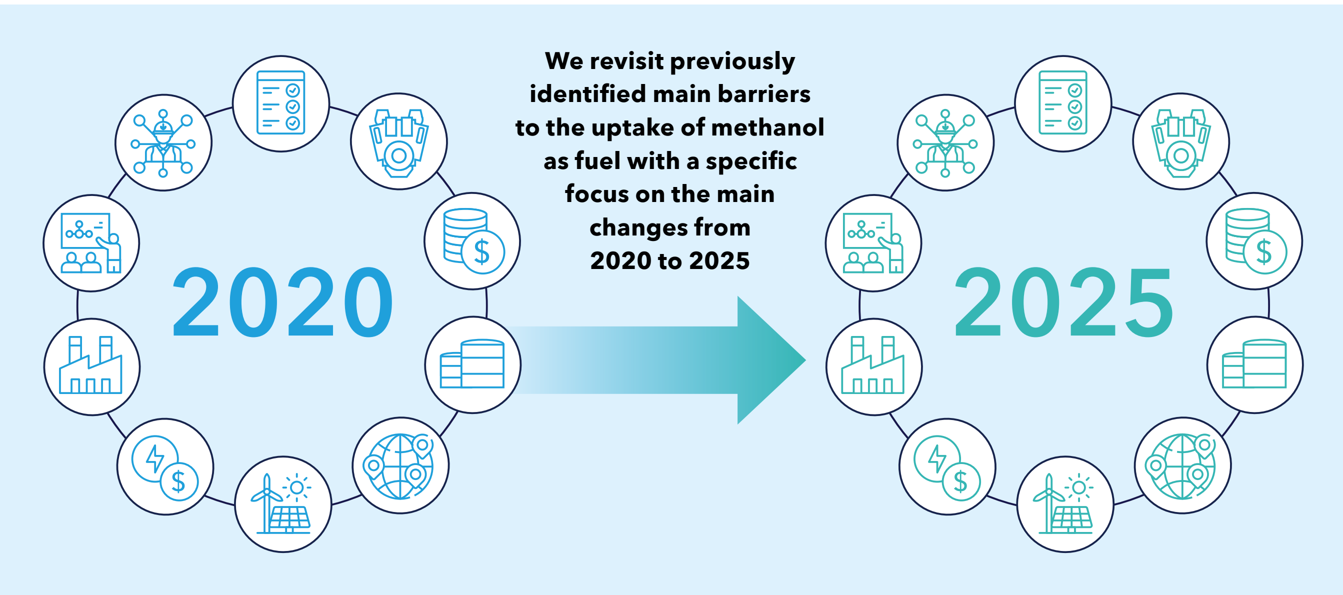
The tightening of GHG regulations for shipping intensifies shipowners' search for solutions to remain compliant and competitive. Methanol (CH_3OH) emerged more than a decade ago as a viable shipping fuel, although its original use was not to reduce greenhouse gas emissions, but was motivated by the need to curb other shipping emissions such as NO_X and SO_X, major contributors to harmful health and environmental impacts.

Compared to gaseous alternative fuels – such as LNG, ammonia, and hydrogen – methanol (a liquid) is easier to handle on board and in port, and low-GHG methanol holds a potential for widespread use in the global shipping fleet.

While methanol has been shipped as cargo for decades, it saw its first use as a marine fuel in 2015 when the RoPax vessel *Stena Germanica* was converted for methanol operation. The newbuilding orders for a series of methanol-fuelled chemical tankers were placed in 2013, and *Lindanger*, the world's first dual-fuel methanol-fuelled tanker, was delivered to DNV Class in 2016. Since then, orders for dual-fuel methanol-capable ships have grown significantly. The first wave included chemical tankers carrying methanol as cargo, which were designed to also use it as fuel. In the second wave, container vessels have dominated new orders, with the first vessel delivered in 2023. Today, the number of methanol-capable ships in the fleet and on the order book totals 450 vessels, second only to LNG among alternative fuels.

However, most methanol-capable vessels today still run on fuel oil or fossil methanol, with limited uptake of low-GHG methanol. Fuel production and bunkering infrastructure continue to lag behind fleet development, though 17 methanol bunker vessels are currently in operation or on order. Additionally, media coverage and trade events frequently highlight methanol-related news from shipowners, yards, manufacturers, fuel producers, ports, and others. The overall effect can be more confusing than clarifying, making it hard to determine the actual status of methanol as a ship fuel. Is it fulfilling its potential as a decarbonization option for deep-sea shipping? What will it take for methanol to become a scalable global marine fuel?

In this paper, we will attempt to provide clarity to these questions – addressing both ships and the methanol fuel production and infrastructure that will supply them. The paper first presents the merits of methanol as a fuel for deep-sea shipping (Chapter 2). We then assess 10 main barriers to the widespread use of low-GHG methanol, focusing specifically on developments between 2020 and 2025 (Chapter 3). We end this paper with a discussion on the potential way ahead for methanol in the coming years and decades, highlighting the challenge of balancing supply and demand in light of the potential use of methanol as a GHG compliance strategy (Chapter 4). The paper concludes by providing a practical guide on the next steps for shipowners seeking robust fuel decisions (Chapter 5).



2 Why methanol?

This chapter examines methanol's potential as a low-GHG marine fuel, covering its technical and environmental advantages, current production landscape, and future pathways such as bio- and e-methanol.

Like other alternative fuels, methanol faces adoption challenges, as outlined in our barrier analysis in Chapter 3. Nevertheless, it is considered a promising option by many, and in the following, we summarize its attributes and main advantages as low-GHG fuel.

Methanol – a liquid fuel at atmospheric conditions – is easier to store, transport, and bunker than gaseous fuels like ammonia and hydrogen. Methanol is also easier to handle from a safety perspective – despite its low flashpoint and toxic properties. Its volumetric energy density is generally comparable to that of ammonia and exceeds hydrogen. Methanol has the highest hydrogen content and lowest carbon content of any liquid fuel.

Methanol has a 10-year track record as a marine fuel, and the required technology is relatively mature and available. The order book and fleet in operation of methanol-capable vessels stands at 450 vessels. Its popularity is supported by the fact that it has the lowest CAPEX apart from a conventional fuel-oil solution. The technology is also less challenging to retrofit onto existing vessels. Furthermore, the technology offers fuel flexibility, enabling the use of both fuel oil and methanol from fossil and low-GHG-intensity sources. In addition, with minor modifications, it can also allow the vessel to burn ethanol – a substance with similar properties and significant production volumes (see text box on ethanol).

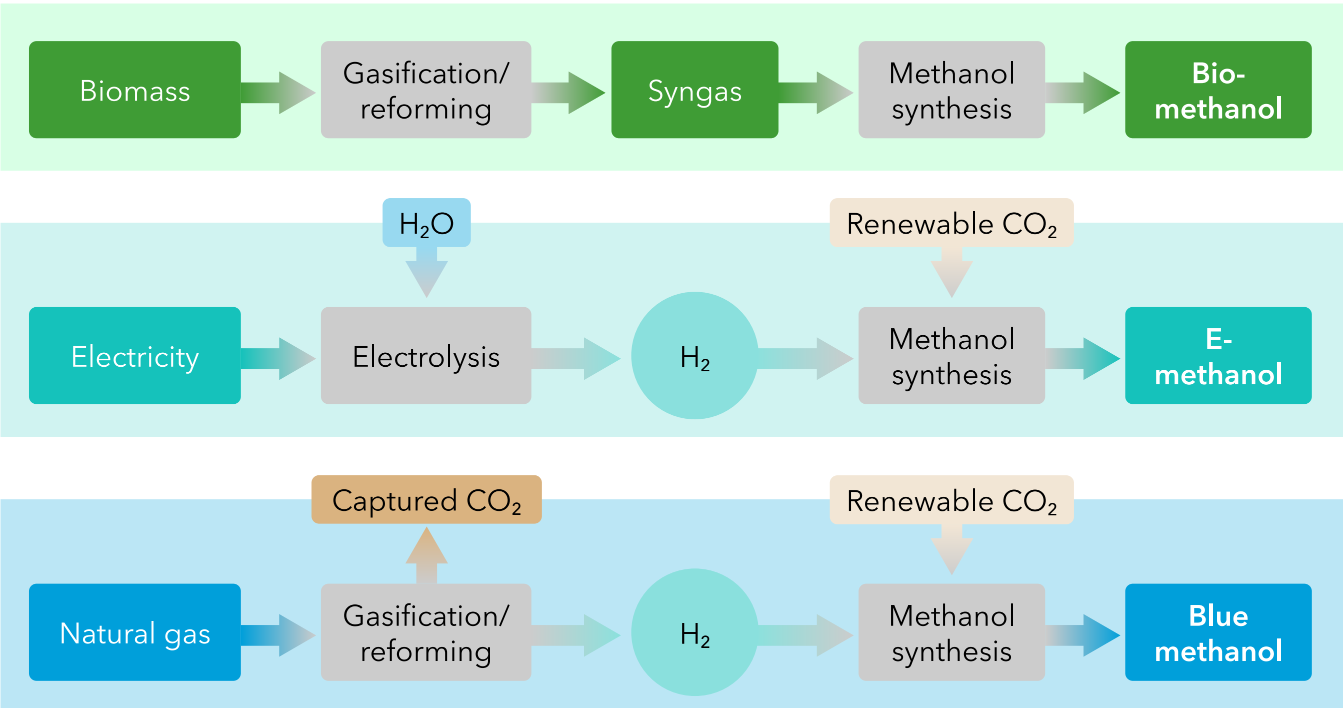
As many of the other low-GHG alternatives, methanol has environmental and health advantages beyond GHG reduction. Methanol, as a sulphur-free fuel, fully complies with the MARPOL Annex VI low-sulphur (SO_X) standards. NO_X emissions from methanol are significantly lower than those resulting from the combustion of fuel oil, but need additional reduction technology to reach IMO Tier III NO_X limits. Methanol burns cleanly, producing negligible soot and particulate matter emissions. Its high solubility and biodegradability mean that, in the event of a spill, it quickly dissolves in seawater.

Looking only at the onboard combustion and without regards to source (fossil vs. renewable, etc.), methanol produces 7% less CO_2 emissions compared to heavy fuel oil. However, when produced from fossil sources, the total well-to-wake GHG intensity can be higher than for fuel oil. The current global methanol production capacity of around 110 million tonnes (Mt) annually is almost entirely fossil-based, with approximately 65% derived from natural

Methanol has a 10-year track record as a marine fuel, and the required technology is relatively mature and available.

FIGURE 2-1

The main production pathways for low-GHG methanol; bio-methanol is produced by processing biomass from a variety of sources. E-methanol is produced by combining hydrogen and CO_2. Hydrogen is produced using renewable electricity. Blue methanol is produced from fossil feedstock with carbon capture and storage and renewable CO_2. The CO_2 used to produce the methanol will typically be captured from air (DAC) or captured from the combustion of biogenic material.



gas (grey methanol), 35% from coal (brown methanol). Less than 1% is low-GHG methanol, but the potential for scaling is large (Kylee Harris, 2021).[2,3]

Methanol with near-zero well-to-wake emissions can be produced from non-fossil sources via two main pathways: e-methanol and bio-methanol (see Figure 2-1). E-methanol, made from green hydrogen and renewable CO_2, offsets combustion emissions through its feedstock. Bio-methanol achieves similar results via the natural carbon cycle. Under certain conditions, it is even possible to produce bio-methanol with negative well-to-wake GHG intensity.[4] Alternatively, blue hydrogen for methanol production can be generated from fossil sources with close to complete carbon capture and permanent storage (CCS), to produce 'blue' methanol. However, well-to-tank emissions vary by production method and CO_2 source, which must be considered when evaluating its climate impact. To reach net zero, CO_2 should come from biomass or direct air capture (DAC), which offers scalable production without feedstock limitations.[5] Further details and suggested production pathway systematics, including combinations, can be found, for example, in IRENA (2021).

Owners of methanol-capable vessels can potentially utilize all three types of methanol to reduce GHG emissions, thereby supporting compliance with GHG regulatory targets or

Ethanol fuel in shipping

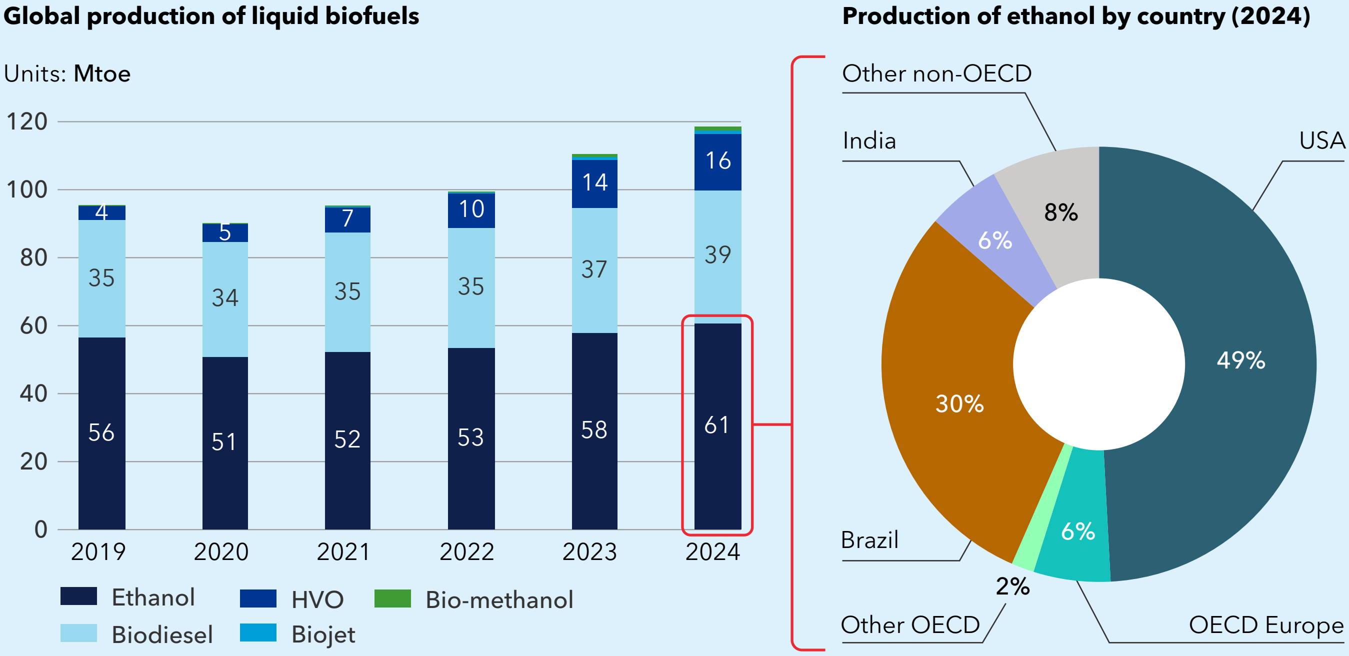
Ethanol (C_2H_5OH), which shares many properties with methanol, is increasingly recognized as an alternative marine fuel. While subject to the same safety regulations as methanol, ethanol is not classified as toxic. Its energy density is considerably greater, at 26.7 MJ/kg, compared to 19.9 MJ/kg for methanol.

As illustrated in Figure 2-2, ethanol is the most widely produced liquid biofuel, with approximately 95 million tonnes generated in 2024 (corresponding to 61 Mt oil equivalents), mainly due to its longstanding use in road transportation fuel. Its production primarily comes from sugars (27%) and starches (72%), while a small fraction (<1%) is derived from advanced feedstocks like agricultural residues (such as sugarcane bagasse and straw) (IEA, 2025c). The United States and Brazil are by far the largest ethanol producers, collectively accounting for about 80% of global output.

The issue of bio-ethanol sustainability is complex, providing benefits like lower GHG emissions, improved energy secu-

FIGURE 2-2

Global production of liquid biofuels 2019-2024 broken down by fuel type, and ethanol feedstock share and production of ethanol by country in 2024: data points are based on IEA (2025a; 2025b), except for bio-methanol, which is based on DNV AFI data on production capacities



Source: IEA and Alternative Fuels Insights (AFI) their own decarbonization ambitions. Today's main methanol production volumes are used in a wide array of products: synthetic fabrics and fibres for clothing, adhesives, paint, plywood used in construction, and as a chemical agent in pharmaceuticals and agrochemicals.[6] It follows that methanol is one of the most widely transported chemical commodities. There are over 90 methanol production facilities worldwide, and a third of the production is shipped internationally as an industrial commodity (MI, 2023). Methanol storage facilities are available in more than 115 ports.[7]

The availability of sustainable low-GHG methanol for shipping depends on parallel developments across the complete value chain, including sustainable production, bunkering facilities, and methanol-capable vessels. However, the existing production and distribution infrastructure for fossil methanol can – at least in part – be reused, making scaling easier. Reuse of existing infrastructure is an important advantage for methanol, but this requires a flexible Chain of Custody model (DNV, 2025a). Existing chemical tankers can also be converted into methanol bunker vessels.

A facility producing ethanol, the world's most widely used liquid biofuel and a potential low-GHG option for marine methanol engines.

rity, and rural development opportunities. However, it also raises concerns related to land and water use, as well as competition with food production (UN, 2022). Second-generation bio-ethanol utilizes non-food biomass like crop residues and forestry waste, reducing pressure on food supplies and land resources (Afedzi, 2025). Several countries now operate second-generation facilities, with more in development. The different production technologies differ in maturity but can substantially reduce GHG emissions compared to fossil fuels (Delft, 2023), (Afedzi, 2025). Ethanol's future viability as a low-GHG fuel depends on its assessment under IMO and EU GHG lifecycle assessment standards.

Current ongoing testbed and demonstrator projects are essential for advancing its use as a marine fuel (Delft, 2023). Engine manufacturers are preparing their engines for ethanol. In February 2024, Wärtsilä successfully tested ethanol as a primary fuel in its Wärtsilä 32 engine in Vaasa, Finland. The engine ran efficiently on ethanol with only minor modifications.[8] In September 2025, Everllence successfully operated the world's first ethanol-fuelled ME-LGIM two-stroke engine in Japan, demonstrating stable performance at all load points.[9] WinGD has announced that they will introduce the first ethanol-fuelled two-stroke marine engine in 2026, with deliveries starting in 2027. This engine builds on full-scale tests conducted in 2018 and shares its combustion concept and safety standards with WinGD's methanol engine.[10] Further, the dual-fuel methanol vessel *Laura Maersk* is being tested with an E10 fuel blend, consisting of 90% e-methanol and 10% ethanol. The trial results will help the shipowner Maersk to assess the effect of the fuel blend on key parameters such as ignition, combustion, lubricity, and emissions. The impact of the E10 fuel on NO_x emissions is considered especially important.[11,12]

As with other low-GHG fuels, we see regional differences, with ethanol gaining particular momentum as a marine fuel in Brazil, supported by large-scale production and government policies. Brazil oil major Petrobras has awarded contracts to Compagnie Maritime Monégasque (CMM) and Starnav Serviços Marítimos Ltda. for the construction and long-term charter of 10 oil-spill response vessels, with the ability to be upgraded to operate on ethanol fuel.[13,14] The Brazilian oil major plans to charter 52 new offshore support vessels by 2026 – many of which will be equipped with batteries and have potential for ethanol conversion.[15]

3 Revisiting the barrier dashboard for methanol

This chapter updates DNV's 2020 assessment of barriers to methanol adoption, using the Alternative Fuel Barrier Dashboard to compare progress between 2020 and 2025. It reviews developments across key technical and regulatory barriers while introducing new ecosystem-related challenges and the stakeholders involved in overcoming them.

In our 2020 Maritime Forecast publication, DNV assessed the key barriers to adopting methanol as a fuel, alongside other fuel options. The findings were presented through the Alternative Fuel Barrier Dashboard, created as a systematic way to compare various fuels. It provided a snapshot of the fuel statuses across seven barriers, considered the most significant challenges to the broad adoption of these fuels during the initial stage of the transition. For each barrier, the fuels were compared with the leading fossil-fuel competitor, marine fuel oil.

In the following, we present an updated evaluation of each barrier to methanol implementation, focusing on changes between 2020 and 2025. In 2025, we have also included three 'ecosystem'-related barriers in the dashboard. Understanding this ecosystem is essential, as no single party can succeed independently.

Figure 3-1 shows the updated Alternative Fuel Barrier Dashboard for methanol in 2025, compared to 2020. These barriers typically exist at the intersections between different stakeholders. Therefore, the dashboard also shows key stakeholder groups within the different barriers.

3.1 Ship-related barriers

This section assesses the developments in four ship-related barriers inhibiting methanol uptake.

3.1.1 Safety regulations

This barrier refers to the status of rules and guidelines related to the design and safety requirements for ships and onboard systems. For this barrier to be resolved, specific mandatory IMO regulations should be in place.

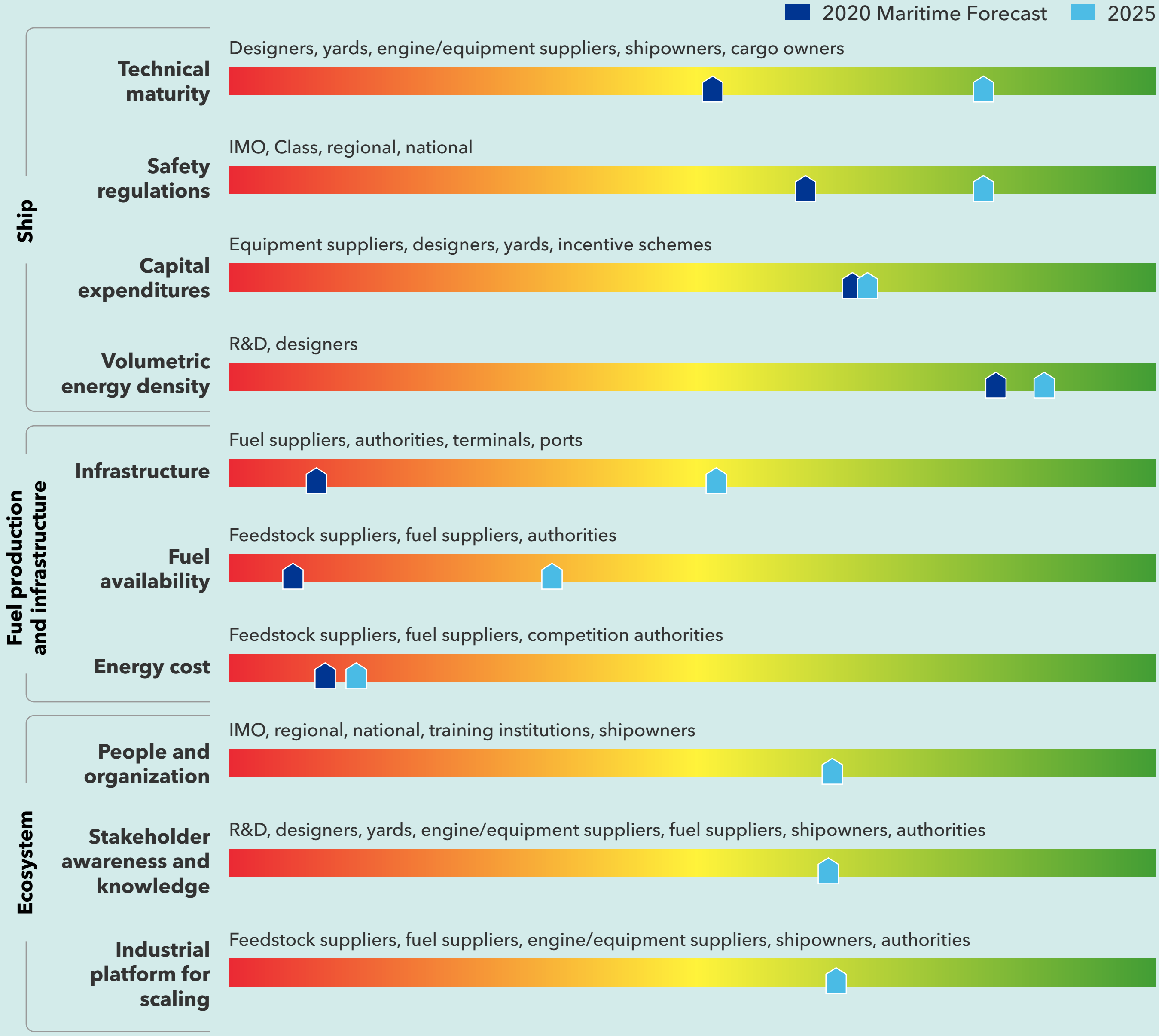
Methanol's flammability (low flashpoint) and toxicity pose new safety challenges compared to conventional fuels. This requires regulations and technical rules to support the safe design of ships and the safe use of methanol on board.

In 2020, the safety regulations barrier level in Figure 3-1 reflected that DNV class rules had been in place since 2013 and that the IMO interim guidelines were finalized that year. Since then, the rules and guidelines have been tested on several hundred newbuild projects – contributing to the significant maturation of their application and lowering of the safety regulations barrier.

Further regulatory development based on operational experience of the existing fleet is necessary to fully resolve this barrier. In the IMO, provisions for new fuels are initially developed as non-mandatory interim guidelines to gain experience with their application before the requirements are included as mandatory regulations through IGF Code amendments. The IMO has included mandatory regulations on methanol and ethanol in its work plan, aiming to incorporate these requirements into the IGF Code by 2027. Given the other items on the work plan, this can be considered an ambitious target.

FIGURE 3-1

The Alternative Fuel Barrier Dashboard – an indicative status of key barriers to methanol in 2025 compared to 2020, and key players in further reducing barriers to methanol as a fuel: red indicates barriers that remain to be solved, while green indicates parity with conventional marine fuel oils



Technical maturity refers to the current technical maturity level for engine technology and systems.

Safety regulations refer to the status of rules and guidelines related to the design and safety requirements for the ship and onboard systems.

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Volumetric energy density refers to the challenges related to the amount of energy stored per unit volume, also considering the volume of the storage solution.

Infrastructure refers to the available infrastructure for bunkering.

Fuel availability refers to today's availability of the fuel, future production plans, and long-term availability.

Energy cost reflects fuel competitiveness compared with Marine Gas Oil (MGO), taking GHG-related costs into account.

People and organization refer to the lack of trained seafarers, operational procedures, and organizational structures to operate methanol-fuelled ships.

Stakeholder awareness and knowledge refer to the lack of general industry awareness and knowledge.

Industrial platform for scaling refers to the lack of existing industrial infrastructure to build on or adapt.

3.1.2 Technical maturity

This barrier refers to the technical maturity level for engine technologies and systems. For this barrier to be resolved, the maturity level of every central component of the methanol fuel installation should correspond to Technology Readiness Level (TRL) 9. In addition, such proven technology should be available for all major ship types and sizes.

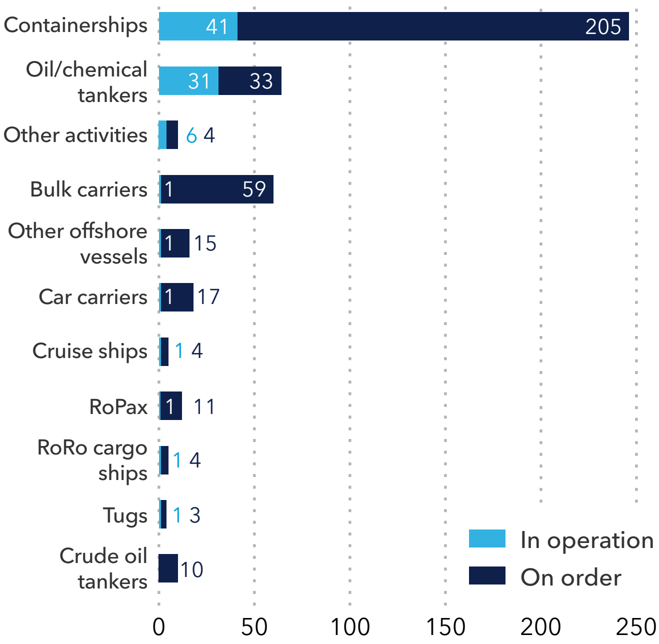
In 2020, the technical maturity barrier level in Figure 3-1 reflected that the RoPax ferry *Stena Germanica* had been converted to methanol fuel in 2015, and that several chemical tankers had used their methanol cargo as fuel for the main engines since 2016. *Lindanger*, the world's first dual-fuel methanol-fuelled tanker, was built in 2016 to DNV class. Since then, the fleet of methanol-capable ships has grown significantly. As of October 2025, there are 83 such vessels in operation and 367 in the order book – mainly containerships, but also chemical tankers and bulk carriers, as well as some car carriers. Forty of these vessels, mostly containerships, are planned or finished conversions.[16]

Internal combustion engines
The engine technology powering these vessels has matured significantly. Two-stroke dual-fuel engines using methanol dominate, with many engines on order in the container segment, while four-stroke engines are also developing rapidly. The first MAN B&W ME-LGIM engines entered service in 2016 and have accumulated over 600,000 operating hours on methanol. WinGD is developing a multi-fuel strategy for its 2-stroke engines, with a flexible working principle. When operating on methanol,

FIGURE 3-3

Growth of methanol fuel uptake by ship type as of October 2025

Units: number of ships

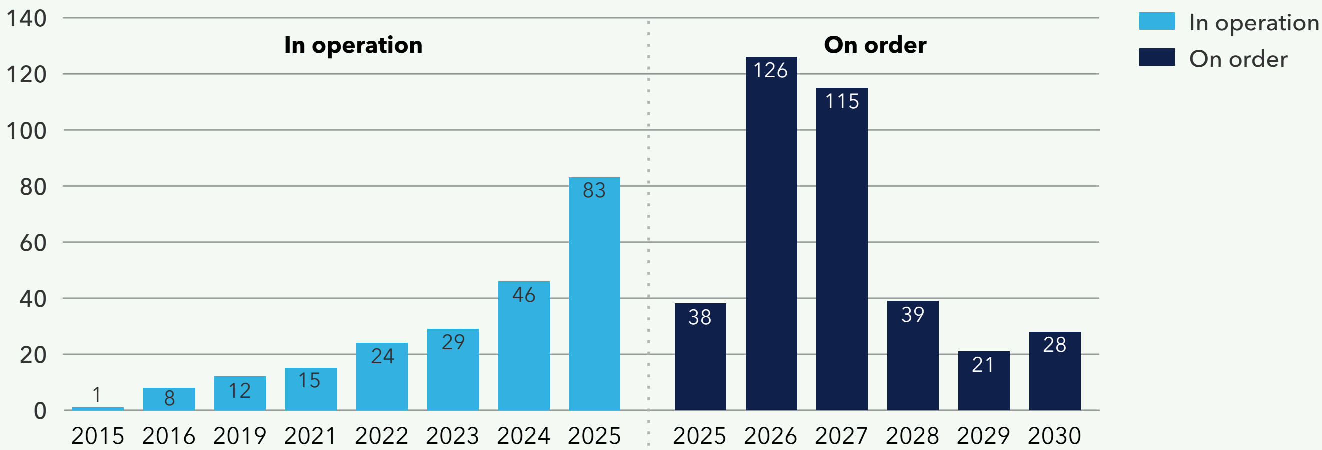


Source: afi.dnv.com

FIGURE 3-2

Growth of methanol fuel uptake by the number of ships as of October 2025

Units: number of ships



Source: afi.dnv.com

their engines are expected to follow the diesel principle, at least at higher load levels. The four-stroke engines currently available are medium-speed engines operating with the injection of liquid methanol and pilot fuel at the end of the compression stroke. This principle is already available from Wärtsilä (Wärtsilä 32 Methanol) and HiMSEN (H 32 DF LM). The engines available on the market have a 32 cm bore and cover a power range of 3,500 to 5,200 kW.

Fuel systems and other fuel technologies

In addition to engine development, progress has also been made in fuel systems and other methanol fuel technologies.

Alfa Laval's fuel supply system (FCM Methanol) was first provided to methanol carriers and has logged over 450,000 hours of operation. It can supply methanol to both main and auxiliary engines, as well as to boilers.[17] Wärtsilä (MethanolPac) also provide a complete fuel supply system for methanol-fuelled ships.[18]

The first methanol-fuelled boiler installed on board a vessel, delivered by Alfa Laval, was commissioned in early 2025.[19]

Fuel-cell technologies are also being developed for marine applications, including those that use methanol as a fuel. This technology is still in its early stages, aiming for improvements through increased efficiency and enhanced heat recovery.

New ship designs

The safe onboard integration of methanol fuel technologies affects the ship arrangement, necessitating the development of new ship design solutions. Methanol creates flammability and toxicity challenges related to bunkering, onboard storage, supply, and consumption. The fuel installation typically includes a bunkering station with integral fuel tanks, cofferdams, and tank connection space; a fuel preparation room; and double-walled pipes. An onboard methanol fuel installation is illustrated in Figure 3-4. Driven by newbuild and conversion orders, methanol-fuelled ship design concepts are developed for many ship types (see factbox on methanol retrofit).

In 2025, the barrier level in Figure 3-1 (see below) reflects that the technical maturity has significantly improved since 2020. Engine technologies and fuel systems are available from manufacturers for all major ship types and sizes, and newbuilds integrating them are on order from shipyards.

To fully resolve this barrier, the reliability of methanol engine technologies, corresponding fuel systems, and their onboard integration must be further proven in service.

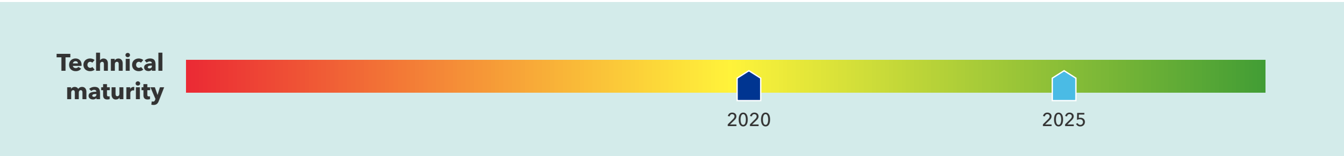
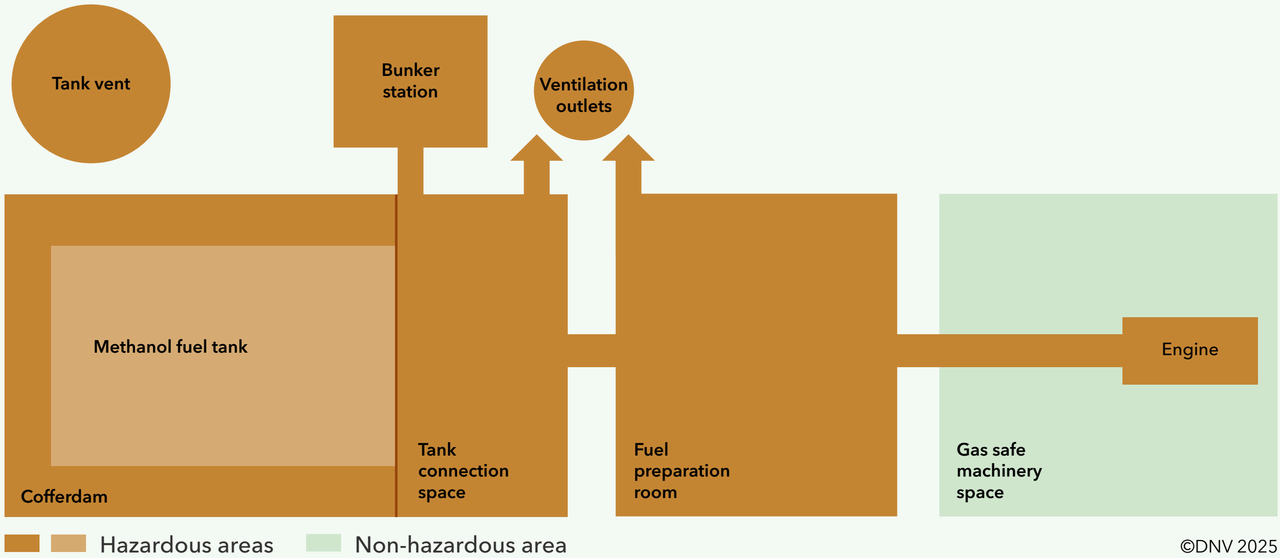


FIGURE 3-4

Illustration of onboard methanol fuel installation, all parts of which must be safely integrated



3.1.3 Volumetric energy density

This barrier refers to the challenges related to the amount of energy stored per volume unit compared with MGO, also considering the volume of the storage solution, which is in turn related to the ships' operational range and the volume needed to achieve this.

By design, the volumetric energy density is directly related to the physical properties of the fuel and storage solution. Methanol has less than half the volumetric energy density of diesel. Consequently, to match the energy content of diesel, a vessel must carry more than twice the volume of methanol or accept a significantly reduced operational range if reusing existing fuel tank capacity. Compared to gaseous fuels, methanol storage systems can be more easily integrated on board. Methanol remains liquid at ambient conditions, removing the need for pressurization, compression, or cryogenic storage. Like conventional fuel oil tanks, methanol tanks can be integrated into the vessel's hull. Due to its low flashpoint, additional safety measures such as inerting tank ullage spaces, installing protective cofferdams, and positioning tanks away from machinery or accommodation areas must be implemented.

Since 2020, the emphasis on practical designs for storing methanol on board different ship types has grown considerably, driven by newbuild orders. All these designs must address energy density by determining how much fuel can be stored on board and assessing it against operational needs, bunkering patterns, and logistics. It is generally reasonable to assume that many ships will face a reduced operating range when using methanol compared to what is achievable with standard oil-tank capacity, or they will accept a reduction in cargo-carrying capacity. One way to tackle this challenge is to evaluate the possibility of shorter bunkering intervals. Although this depends on the geographical area of operation, shorter bunkering intervals pose few or no issues for many operators, provided infrastructure is available. Additionally, methanol engines enable dual-fuel operation, allowing increased oil fuel to compensate for limited methanol storage volumes and thereby extending bunkering intervals to acceptable levels. If this strategy does not achieve the desired carbon-intensity reductions, blending in carbon-neutral oil fuel could be an option. All of this helps to address range limitations.

In sum, the severity of the volumetric energy density barrier will be a function of the ship type and trading pattern. Ships with ample deck space operating in regular trade will have more possibilities to optimize storage volumes and bunkering intervals according to their operating pattern than ships with more irregular trade and fewer possibilities for locating large fuel tanks on board.

The 2025 marker on the dashboard is shifted to the right, as the volumetric energy density is perceived as less of an obstacle to fuel use than in 2020.

World's first methanol retrofit for mega container carrier

DNV supported Cosco Shipping Heavy Industry (Shanghai), Co., Ltd (CHI Shanghai), and COSCO SHIPPING in delivering the world's first methanol retrofit of a mega container carrier, the 20,000 TEU *COSCO SHIPPING Libra*. During the project, the vessel's main engine and two auxiliary engines were converted to dual-fuel operation, and new methanol fuel tanks with a total capacity of 15,000 m^3 were installed. The conversion was completed in September 2025, 110 days after it began, including 8 days of sea trials. The retrofitting of the sister vessel, *COSCO SHIPPING Gemini*, was completed a month later, benefiting from the lessons learned during the first project, and the conversion was finished 21 days faster.[22]

By enabling a large, existing vessel to switch from conventional fuel oil to low-GHG methanol, the project demonstrates a viable pathway to significantly cut GHG emissions. The successful conversion of the *COSCO SHIPPING Libra* and *Gemini* provides a scalable model for retrofitting existing fleets, accelerating the fuel transition in the maritime sector. Everllence highlights that the potential for further large-bore retrofits is substantial, with over 300 vessels worldwide currently equipped with S90-class engines and therefore potential candidates for similar retrofits.[23]

3.1.4 Capital expenditures

The capital expenditures barrier refers to the additional investment cost (CAPEX) for a methanol-powered ship, compared to a conventional ship propelled by fuel oil. The extra costs of alternative fuel technologies necessarily constitute a larger share of the total cost for ships with lower asset values than for more advanced and expensive vessels. For this barrier to be resolved, the methanol-powered ship would have to be priced similarly to a conventional oil-fuelled ship.

Some newbuild price data is available for container vessels with dual-fuel methanol capability. It indicates that such vessels incur additional capital costs – relative to conventional vessels – ranging from approximately 9% for large vessels (22,000–24,000 TEU capacity) to about 19% for smaller vessels (around 9,000 TEU capacity)[20]. Since newbuild prices were first reported in 2023, the relative additional capital expenses for methanol-capable container vessels have declined somewhat, from about 22% in 2023 to 16% in 2025 (Q3) for vessels with a capacity of 9,000 TEU.

Proman Stena Bulk, a company operating methanol-fuelled chemical tankers, estimates that methanol-fuelled vessels may result in up to 10% higher capital expenditures than conventional ships.[21]

Overall, we assess that the level of this barrier remains roughly as high as it was in 2020, with considerable additional CAPEX still required for methanol-powered ships.

Looking ahead, we anticipate that the added costs of methanol-powered ships will decrease. The extra equipment needed to store and use methanol, and to a greater extent, gaseous fuels, will always add cost compared to conventionally fuelled ships. However, this premium is likely to lessen as technology advances, more ships are built – including more standardized series – experience is gained, and economies of scale are realized.

Assembly of methanol fuel tanks with a total capacity of 15,000 m³ forward of the engine room for the 20,000 TEU *COSCO SHIPPING Libra*.

3.2 Fuel production and infrastructure

It is evident from Section 3.1 that ship-related barriers have matured over the last few years and have reached a level where they do not pose a significant hindrance towards widespread adoption – although room for improvement remains. But the transition to alternative fuels is equally reliant on progress beyond the vessel itself. Three of the dashboard's barriers – energy cost, fuel availability, and infrastructure – highlight these external factors. In fact, these factors may be even more decisive for low-GHG methanol uptake than onboard technical issues, as the fuel must be produced, distributed, and bunkered affordably in competition with other available marine fuels. These are tightly related barriers, underpinning the challenges in making the investment decisions required to move the status towards green in the barrier dashboard.

3.2.1 Energy cost

Perhaps the most significant barrier of all is the issue of fuel competitiveness with marine fuel oils when GHG-related costs are included. For this barrier to be considered resolved, the effective fuel price should match that of marine fuel oils (with GHG-related costs), delivered to the ship.

The bio-methanol price in ARA (Amsterdam – Rotterdam – Antwerp) was around 3,500 USD/tMGOe in 2022 – falling to around 2,500 USD/tMGOe in 2025 according to Argus media (via AFI.com). For e-methanol and blue methanol, no price information is available. With the limited price history for bio-methanol, it is unclear if the drop in bio-methanol prices from 2020 to 2025 reflects a downward trend in production cost – or if it is linked to the price fluctuations of fossil methanol. Fossil methanol was priced at around 1,000 USD/tMGOe in 2022, falling to around 700 USD/tMGOe in 2025 (based on Rotterdam, SEA, and US Gulf prices) – meaning fossil prices were approximately a third of green prices. In the same period, the price of MGO has fluctuated around the price of fossil methanol.

Future cost estimates are arguably equally important to decision-makers, although they are inherently uncertain. Cost projections from DNV indicate that producing and distributing bio-/e-methanol could cost between 1,200 and 2,050 USD/tMGOe in 2050.[24] Other sources, such as IRENA and Methanol Institute (2021), indicate a cost range of about 490 USD/tMGOe to 1,900 USD/tMGOe in 2050.

This is significantly below current bio-methanol prices and reflects that advances in production technology, benefits of scale, and cost reduction for input factors could reduce fuel costs.

Regarding the barrier level, we observe that the cost of fuel itself may have decreased, at least since its peak around 2022. But we also see that the 2025 reference point – namely, the MGO price including GHG cost – is changing. The new EU regulations, the EU ETS and FuelEU Maritime, placed a price on GHG emissions from 2024 and 2025, respectively. Hence, the barrier remains high, with low-GHG methanol costing three times as much as MGO, but the marker has moved slightly to the right, and may move further in the years to come. This is reflected in the barrier level in Figure 3-1 (see below).

3.2.2 Infrastructure

The infrastructure-related barriers pertain to the availability of facilities for bunkering methanol. The barrier scale resembles that of the Port Readiness Level (PRL), a tool to assess a port's readiness for the bunkering of specific new fuels on nine levels. At level 9, a port has bunkering available as a regular port operation.[25] To consider this barrier resolved, methanol must be available (PRL 9) to deep-sea operators at the major refuelling hubs along the primary trade routes.

In 2020, demand for methanol bunkering services was very low, as most methanol-capable ships in operation were methanol tankers, which were less reliant on traditional bunkering infrastructure. Over the past five years, the potential demand side has grown substantially, as shown in Figure 3-2.

The methanol infrastructure is already fairly developed. As one of the world's most widely shipped chemical commodities and fuels, methanol storage capacity is available in over 115 ports worldwide (DNV AFI). Methanol bunkering is more similar to MGO bunkering than, for example, LNG, ammonia, or hydrogen refuelling. A recent report from the Global Maritime Forum (GMF)[26], based on interviews with industry organizations, found that ports and operators see relatively few infrastructure challenges despite the limited market for methanol bunkers at this stage.

Unlike LNG, ammonia and hydrogen, methanol remains liquid at ambient temperature and pressure, which means that the bunkering infrastructure closely resembles that used for conventional bunker barges. However, methanol ship transport pertains to MARPOL Annex II, requiring transport on chemical carriers. Consequently, bunker barges for fuel oil cannot be applied for methanol bunkering service without modifications. However, the ageing fleet of chemical tankers can serve as bunkering vessels, with minor modifications. Older tankers typically struggle to get business from oil majors after 20 years, and alternative usages are welcome. Stakeholders interviewed by GMF cited existing bunker barges / chemical tankers and storage tanks as advantages, as they can help establish 'interim bunkering solutions' at major ports.

However, large-scale bunkering requires dedicated methanol bunker barges and ship-to-ship fuel transfer. The first non-tanker ship-to-ship bunkering took place in the Port of Gothenburg in January 2023, when *Stena Germanica* was refuelled by the chemical tanker *Stolt Sandpiper*. Previously, the vessel had only received methanol by truck. Since then, numerous vessels have been supplied with methanol fuel by ship at various ports, including Antwerp, Rotterdam, Shanghai, Ulsan, and Singapore. The Canadian company Methanex has recently announced new strategic partnerships with last-mile service providers in the ARA region and in South Korea to facilitate safe barge-to-ship methanol bunkering.[27] The DNV Alternative Fuels Insight database service reports 12 methanol bunker ships of various capacity are now operational, with six more on order. Most are in Singapore, one is in Shanghai, and three are in European ports. There are now 15 ports with active methanol bunkering and another 20 ports developing methanol bunker capability, including bunkering via truck and terminal.[28,29,30]

Based on the above, we consider the infrastructure barrier level to have been significantly lowered in 2025. This is reflected in the barrier level in Figure 3-1 (see below).

To date, demand for low-GHG methanol from shipping has been modest, and most methanol used on ships has been fossil methanol on methanol carriers. Only small volumes of bio-methanol have been bunkered since 2023.

3.2.3 Fuel availability

This barrier refers to today's availability of the fuel, future production plans, and long-term availability. To consider the fuel availability barrier resolved, the production and distribution of low-GHG methanol for shipping must gradually meet the current and future demand from ships. Importantly, well-to-tank GHG emissions from this production will be a key consideration given gradually stricter fuel GHG intensity requirements.

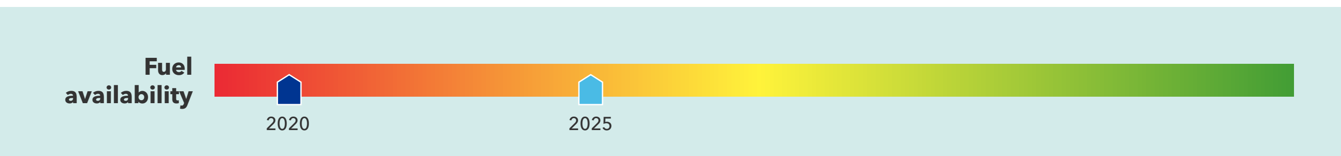
To date, demand for low-GHG methanol from shipping has been modest, and most methanol used on ships has been fossil methanol on methanol carriers. Only small volumes of bio-methanol have been bunkered since 2023. According to the Maritime and Port Authority of Singapore (MPA), methanol bunker sales in Singapore increased from 300 t in 2023 to 1,600 t in 2024. Although the specific methanol type was not disclosed, the volumes for 2023 refer to green methanol, as in July that year, the port conducted the world's first ship-to-containership green methanol bunkering operation. The Port of Rotterdam reported slightly higher bio-methanol volumes, with 800 t sold in 2023, increasing to 4,000 t in 2024 and reaching 11,800 t by Q3 2025. Other examples of methanol bunkering are reported at half a dozen locations around the world in recent years. Maersk reported the first volumes of e-methanol being bunkered in Denmark in May 2025.

Reuse of existing infrastructure is also an opportunity for methanol, but this requires a flexible Chain of Custody model (DNV, 2025a). This was demonstrated in 2023 when Equinor supplied bio-methanol on a mass-balance basis from its Norwegian plant to *Laura Maersk*, the first methanol dual-fuel feeder vessel.[31,32]

Noting that shipping is not the only potential user of low-GHG methanol, current demand from shipping is more than met by the production capacity of about 2.2 million tonnes (Mt), as reported by AFI. About 98% of this capacity is for bio-methanol, with the remainder being e-methanol. Production is dominated by the US (1.9 Mt) followed by China (0.2 Mt). With demand projected to increase, the outlook for production is important. The AFI database shows a portfolio of projects labelled as 'decided' which amounts to a capacity of about 14 Mt by 2030, with roughly 30% of capacity for e-methanol projects and 70% for bio-methanol. This added capacity is mainly from additional projects in China. Importantly, these future estimates are highly uncertain. A further discussion on the outlook for supply and demand can be found in Chapter 4.

For many, the fuel cost is prohibitively high in the short term (see Section 3.2.1) pending the full impact of global regulations and GHG pricing mechanisms. In the short term, only a limited number of ships are expected to operate on low-GHG methanol; these vessels will be dual-fuel capable, allowing them to utilize fuel oil as well. An increase in demand will occur when regulations or other substantial incentives drive the fuel transition. Based on the above, and reflected in the barrier level in Figure 3-1 (see below), we assess that there has been a significant increase in availability compared to 2020.

To accelerate e-methanol adoption for industry and shipping, DNV has recently launched the industry's first public tender portal for e-methanol procurement within the EU and the UK. The initiative connects a leading e-methanol producer with industrial offtakers across EU and UK markets, creating a new pathway to secure long-term, reliable supplies.[33]



3.3 Shipping ecosystem

The widespread use of a fuel such as methanol requires that the barriers relating to the ship (Section 3.1) and the fuel production and infrastructure (Section 3.2) are resolved – but experience shows that there are barriers beyond these systems, and they are are less physical in nature. We label them ecosystem barriers, which are discussed in this chapter.

3.3.1 People and organization

This barrier refers to the limited availability of trained seafarers and onshore personnel, as well as to operational procedures and management systems for operating methanol-fuelled ships. Compared to traditional fuels, the flammability and toxicity of methanol introduce additional complexities to bunkering and ship operations involving onboard fuel storage, fuel distribution, energy conversion, maintenance, and emergencies. While the most effective risk control measures are incorporated during the ship design and construction phases through technical solutions, it is vital to establish comprehensive training, operating procedures, and a robust safety culture to ensure the ship's safe operation. This will require changes to the safety management system, generate the need for new competencies on board and ashore, and may also affect the organization.

For this barrier to be considered resolved, methanol-specific training courses, procedures, and management systems as required by the IMO should be established and implemented to a level at which the shipping organizations operate methanol-fuelled vessels as part of their standard procedures, and competent personnel are available to crew and support the operation of these ships.

Formally, the International Safety Management (ISM) Code sets clear objectives and requirements for shipboard operations, and the entire ship safety management system required by the ISM Code will be affected by the use of methanol as fuel, encompassing normal operations, maintenance, and emergency preparedness. While this must be adapted to the use of methanol, experience from first movers indicates that this represents little challenge; shipowners interviewed by the GMF do not report this as a significant barrier.

The availability of seafarers with methanol competence will be critical for the widespread use of methanol fuel. Additionally, competence is required among all onshore stakeholders, including shipowners, ship management representatives, port operators, and fuel suppliers. The IGF Code outlines crew members' training and competence requirements, referencing the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW). At present, there are no STCW courses available for methanol. However, interim generic guidelines for the development of training provisions for seafarers on ships using alternative fuels and technologies were submitted to MSC 110 in June 2025 for approval. The development of fuel-specific guidelines will continue in 2026. DNV has developed a competence standard for methanol fuel (DNV-ST-0687).

A recent report from the Global Maritime Forum (GMF, 2025), based on interviews with key stakeholders, highlighted early bottlenecks in the availability of methanol training for first movers. One of the main challenges was the lack of training options for dry cargo crew. Unlike seafarers from the methanol carrier segment, who often have prior experience, dry cargo crew must begin with foundational certifications specific to methanol operations. However, as the number of methanol-capable vessels continues to grow, the training landscape is evolving. A broader ecosystem is emerging, with training now offered by advisory firms, technology providers, and engine manufacturers. Notably, the Maritime and Port Authority of Singapore has established a Maritime Energy Training Facility to prepare international seafarers for low-GHG emission fuels. To date, this facility has trained 620 seafarers in methanol operations.

In 2025, the barrier level in Figure 3-1 (see below) reflects that the current availability of trained crew and personnel ashore, operational procedures, and organizational structures is not considered a significant barrier to the adoption of methanol as fuel.

3.3.2 Stakeholder awareness and knowledge

This barrier refers to the lack of widespread stakeholder awareness and knowledge required for a new fuel to achieve scaling. For methanol to achieve widespread adoption, most shipowners and charterers need to feel confident in using it as a fuel, beyond just the early adopters. Similarly, crew, shipyards, manufacturers, flag states, and banks must all have trust in the fuel to fulfil their roles. Furthermore, bunker suppliers, ports, and first-line responders must be equipped to handle bunkering operations safely, ensuring that surrounding communities perceive these activities as secure. This confidence must be built, which is also a matter of perception. For this barrier to be resolved, all parties involved in the value chain must be adequately assured that methanol as a fuel will perform as expected and that the associated risks are manageable, so that their involvement with the fuel becomes of standard operations and within acceptable risk levels.

The GMF (GMF, 2025) reports that early adopters' experiences suggest that methanol is proving relatively simple in this regard. All shipowners, operators, and ports interviewed characterize the fuel in this way, describing it as "a very straightforward answer to our needs", "practical and pragmatic", and a solution "that works and can be scaled up". Initial learnings across three areas – ship design and technology, crew, and operation – support this. Engagement undertaken by early movers suggests that methanol enjoys positive perceptions among port workers, terminals, and wider port stakeholders.

Confidence is rising among stakeholders due to technical advancements, the growing number of methanol-capable vessels, increasing experience with its use onboard and in ports – including in bunkering operations – and the proactive sharing of knowledge. Thus, overall industry awareness and knowledge in 2025 are considered relatively high. This is reflected in the barrier level in Figure 3-1 (see below).

The most significant growth in demand for green methanol is expected to come from its increasing use in shipping.

3.3.3 Industrial platform for scaling

For a new and costly fuel, scaling is enormously challenging. Conventional fuels are well established, deeply integrated across the industry, and supported by significant resources. Breaking through is hard, even with regulators pushing for change, but chances improve with strong industry support. Thus, a barrier can be defined as the lack of an industrial platform. By an industrial platform, we mean existing industrial infrastructure that can be built upon or adapted, including current production facilities, transportation, storage and distribution networks, as well as customer and supplier networks. It also implies having the resources for technological, regulatory, and market development, as well as resources for communication and public relations. Finally, an industrial platform means having the financial strength to make the required investments. This barrier can be considered resolved when industry actors with these qualities are engaged and committed to introducing a given fuel to the shipping sector.

Industrial infrastructure for methanol is well established, with production facilities (albeit fossil), distribution terminals and cargo vessels, as described in Section 3.2. Furthermore, the owners of this infrastructure see the shipping industry as a potential new market for the low-carbon methanol it aims to produce, and are actively engaging to develop this market. For instance, Methanex, the world's largest methanol producer, through its subsidiary Waterfront Shipping, has pioneered the use of methanol as a marine fuel, operating a fleet of dual-fuel vessels that run on methanol and accumulating extensive operational experience. Similarly, the second largest methanol producer, Proman, operates four methanol-powered tankers.

As outlined above, expanding low-GHG methanol production is essential to meet growing sustainability targets. This expansion can be facilitated by repurposing existing infrastructure and collaborating with current methanol users seeking to reduce emissions across their supply chains. Methanol and its derivatives serve as foundational materials in a wide range of industries, including acrylic plastics, synthetic fabrics and fibres used in clothing, adhesives, paints, and plywood for construction, as well as chemical agents in pharmaceuticals and agrochemicals.[34]

Among the industrial users of methanol are companies like LEGO (plastics) and Novo Nordisk (pharmaceuticals), both of which have pledged, and in some cases already begun, to integrate low-GHG methanol into their production processes. These commitments offer producers a diversified customer base beyond the maritime sector, where companies such as A.P. Moller – Maersk have been leading the transition to green methanol as a marine fuel. This diversification helps mitigate market risk and supports its broader adoption.

Nevertheless, the most significant growth in demand for green methanol is expected to come from its increasing use in shipping.

Notably, one of the strongest drivers for production of low-GHG methanol is China, which has the largest planned production capacity (43% of total), and its leading shipowners (including COSCO Shipping Lines) are actively investigating the use of low-GHG methanol for their fleets' decarbonization. The total number of low-GHG methanol production projects in operation or announced in China exceeds 40, with production capacities ranging up to 0.6 Mtpa (0.29 Mtoe/year) for the largest projects. Several projects are located in the Inner Mongolia region of Northern China, utilizing the abundant solar and wind power resources for low-GHG methanol production (DNV, 2024c).

Development of low-GHG methanol as shipping fuel is further supported by major ports, including major bunkering hubs of Rotterdam and Singapore[35] – as well as major container shipping companies, including A.P. Møller-Maersk, CMA CGM, COSCO Shipping Lines and Hapag-Lloyd, as evident in the fleet and in the order book (see details in Section 3.1.2). Developments are further supported by trade associations, such as the Methanol Institute (MI), which represents producers, distributors, and technology providers. In sum, they represent a solid industrial platform, resulting in a low barrier level as reflected in Figure 3-1 (see below).

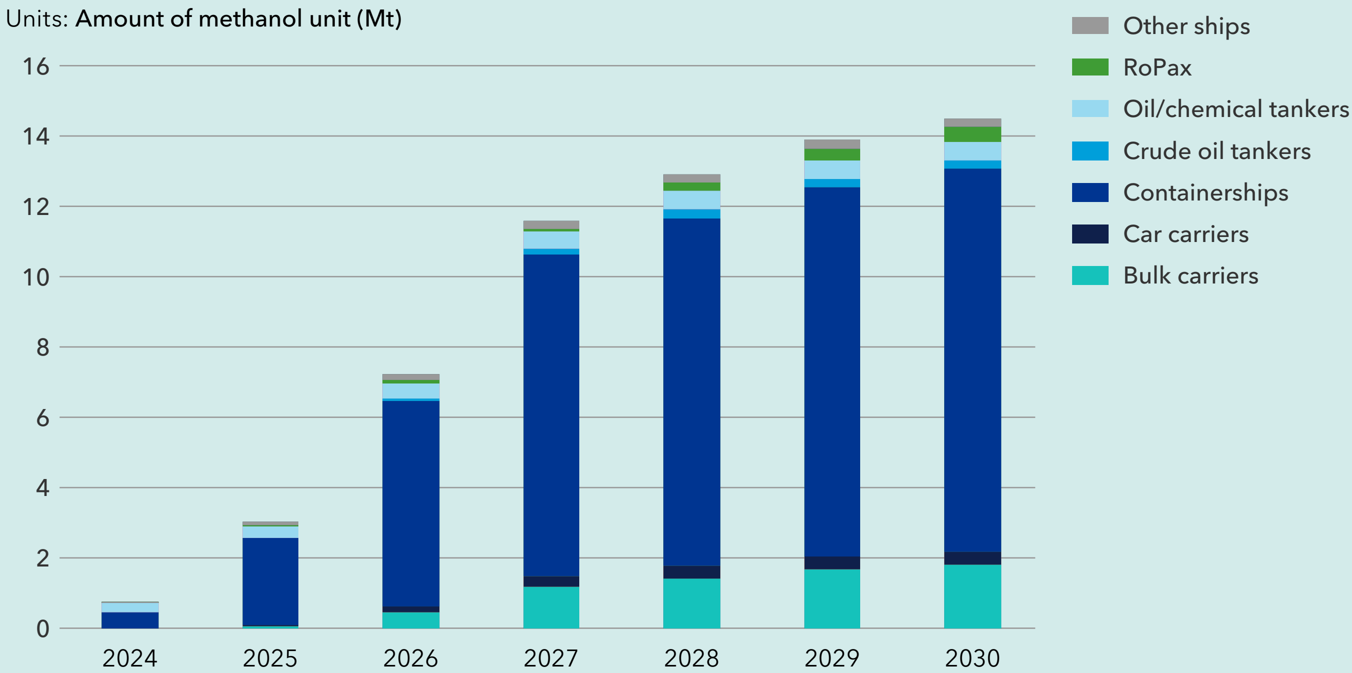
Potential methanol fuel consumption based on existing fleet and order book

Section 3.1.2 highlights that there are 83 merchant vessels in operation and 367 in the order book equipped with methanol dual-fuel engines. Containerships dominate this segment, accounting for 67% of the total, with bulk carriers and oil/chemical tankers representing 16% each. If the methanol capacity of this fleet were fully utilized, potential fuel consumption could rise to nearly 15 million tonnes by 2030 (Figure 3-5).

As discussed in Chapter 4, this capacity may not necessarily be fully utilized towards 2030. Historical data from the IMO's Data Collection System ((IMO, 2020; 2021; 2022) (2023) (2024)) supports this, showing that actual reported methanol consumption between 2019 and 2023 remains significantly below its potential (see Figure 3-6). This gap is probably caused by higher prices for fossil methanol compared to alternatives like VLSFO and MGO and low regulatory drivers. As all methanol-capable ships are dual-fuel, operators can switch based on cost and availability.

FIGURE 3-5

Total methanol consumption capacity based on ships in operation and order book, 2024–2030

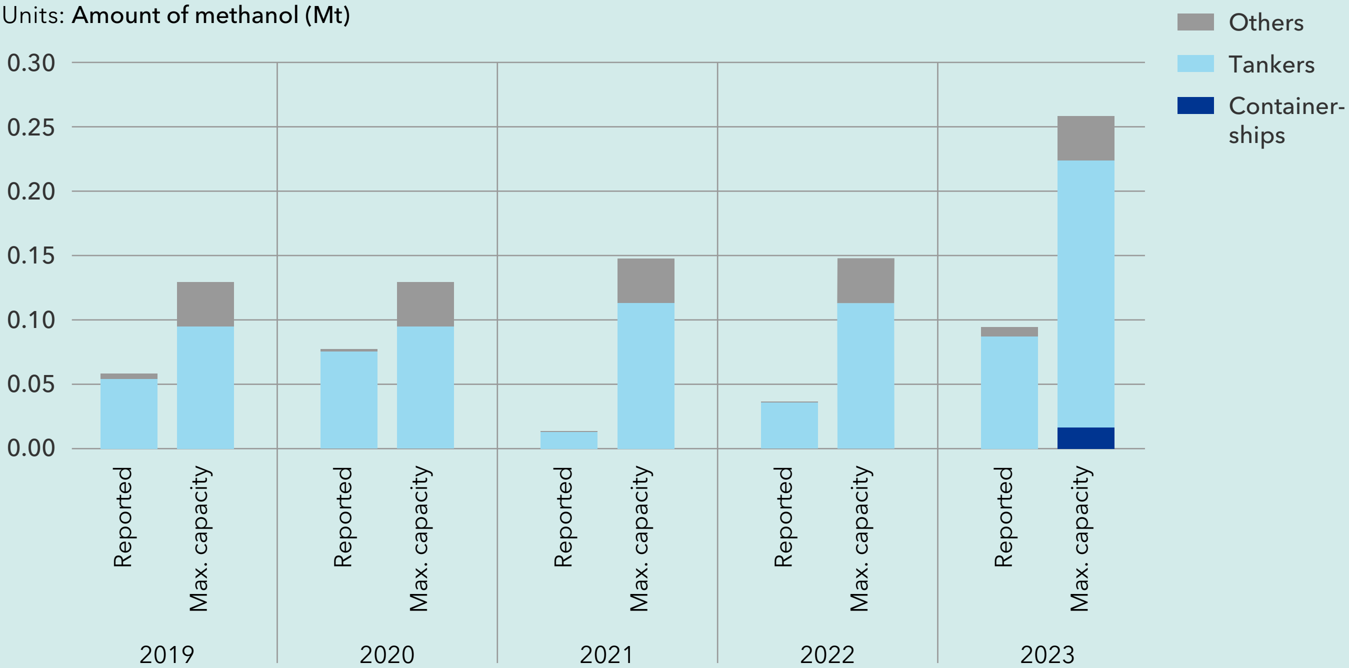


Source: DNV

FIGURE 3-6

Actual reported methanol consumption from the IMO's Data Collection System between 2019 and 2023 vs. total methanol consumption capacity

Units: Amount of methanol (Mt)



Source: DNV

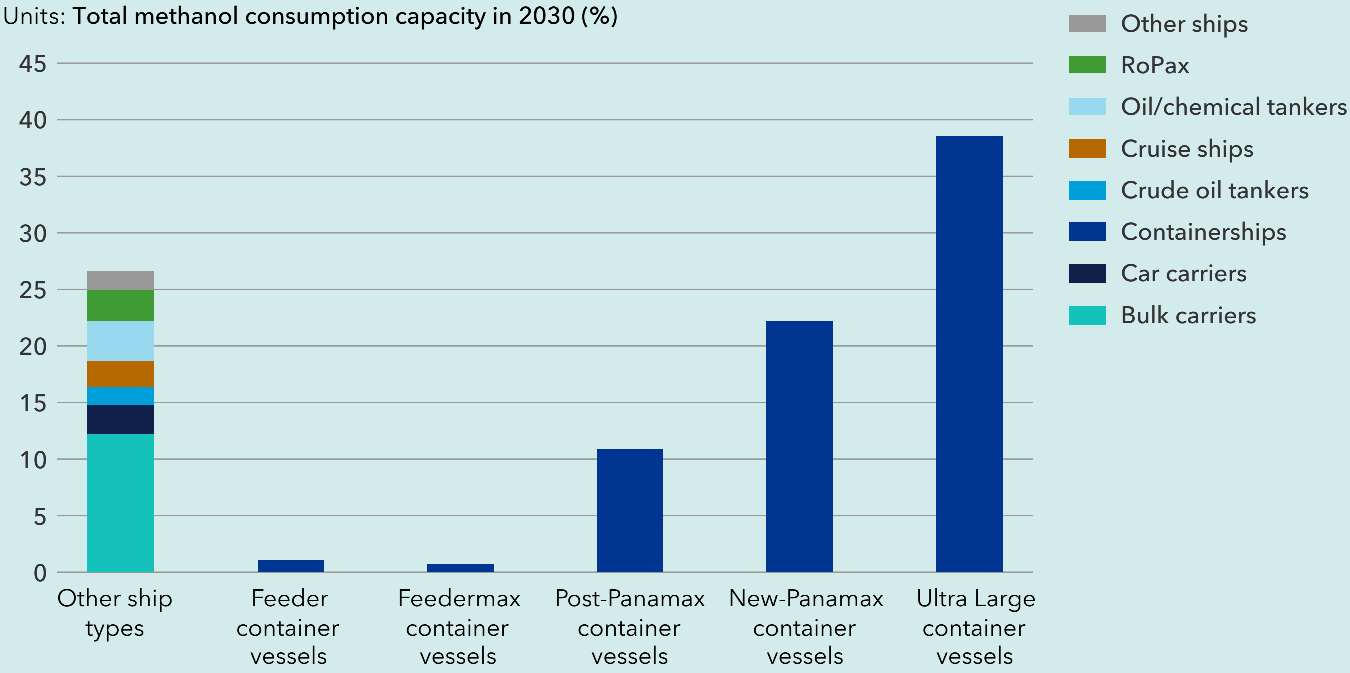
In 2030, containerships will dominate methanol capacity, potentially accounting for over 70% of the total, followed by bulk carriers with 12% (Figure 3-7). A large share of the methanol capacity increase is within the ultra large container vessel segment (ULCVs>14,500 TEU), and new-Panamax container vessels (10,000–14,500 TEU), which together represent 60% of the projected total methanol consumption capacity.

Assuming that the large container vessels in the order book will follow the same intercontinental routes as ULCVs and New-Panamax vessels in 2024, it is possible to identify key locations where methanol bunkering infrastructure will be needed (Figure 3-8). With new vessels entering service and bunkering already taking place in major ports such as Shanghai, Singapore, and Rotterdam, methanol use is expected to shift increasingly towards low-GHG variants. While most bunkering capacity is concentrated in Asia and Europe, the limited infrastructure along US coasts highlights emerging regional disparities. In this context, FuelEU Maritime may serve as an important driver for the early adoption of methanol as a marine fuel.

Most bunkering capacity is concentrated in Asia and Europe, the limited infrastructure along US coasts highlights emerging regional disparities.

FIGURE 3-7

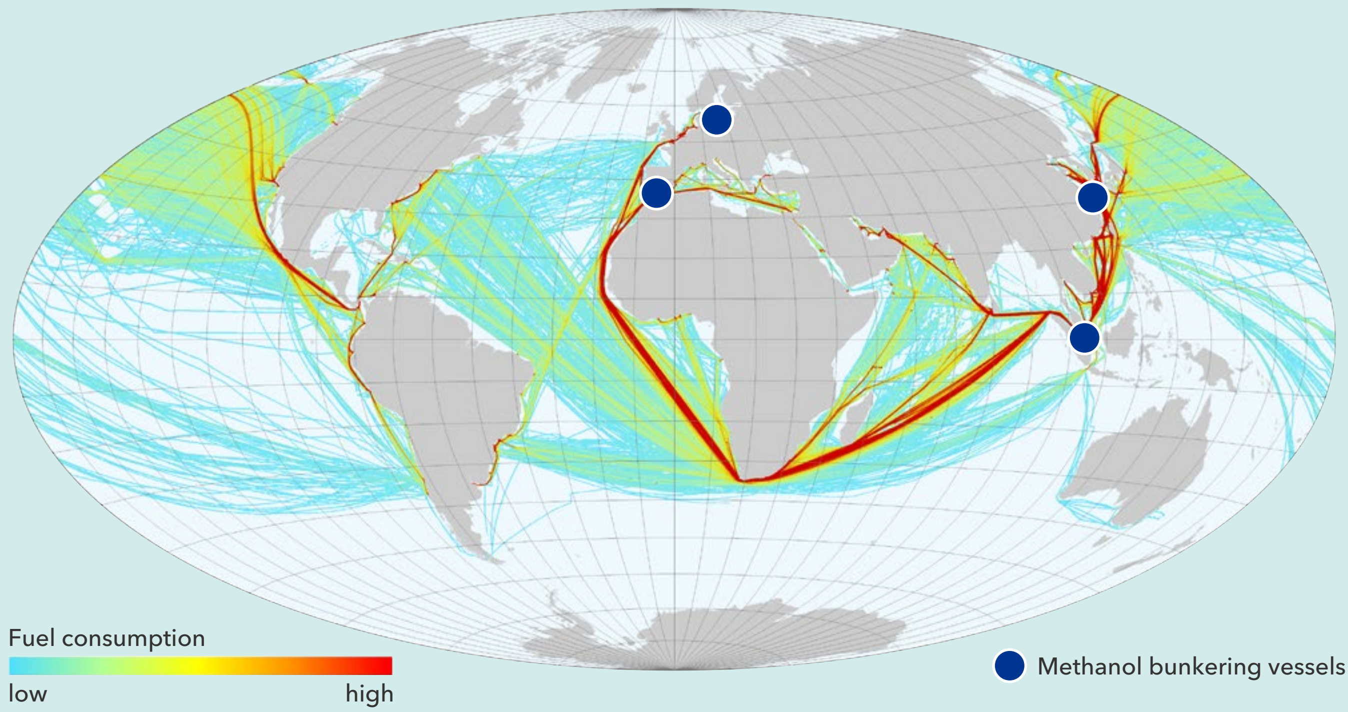
Methanol consumption capacity per ship segment as a percentage of total fleet capacity in 2030



Source: DNV

FIGURE 3-8

Spatial distribution of fuel consumption for ULCV's and New-Panamax container vessels in 2024



Sources: AFI.dnv.com, AIS data 2024

4 Demand for low-GHG methanol in shipping

This chapter examines the future demand for low-GHG methanol in shipping by presenting four distinct scenarios. Each scenario is analysed in terms of its likelihood, including the key conditions that must be met for it to materialize. The chapter also compares the projected demand under these scenarios with anticipated global supply of low-GHG methanol, discussing key factors that will influence availability for shipping.

The barrier assessment in Chapter 3 shows that fuel availability and cost remain significant challenges to the widespread use of low-GHG methanol. This conclusion is also echoed by major shipping companies that have procured methanol-capable tonnage.[36] But shipping demand outlooks for low-GHG methanol often overestimate demand by assuming vessels operate at full-methanol capacity.

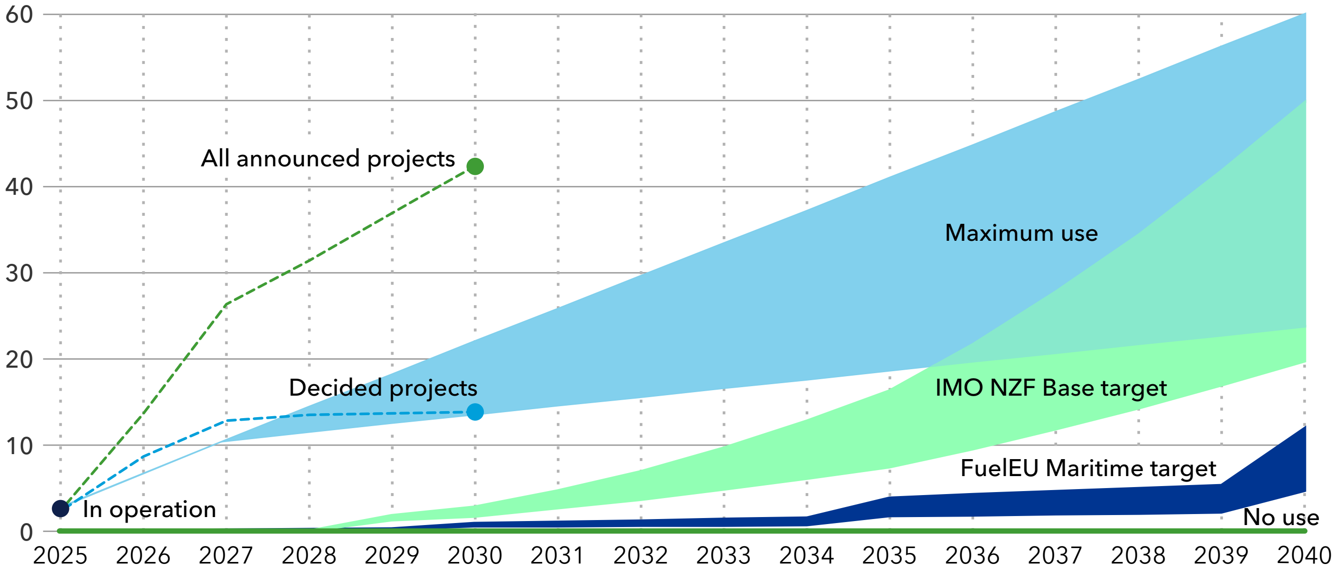
We also note that the pipeline of confirmed low-GHG methanol production projects is expected to reach around 14 Mt by 2030, which is well above current demand, highlighting a highly dynamic and uncertain market outlook.

A crucial aspect of fuel availability is the mutual dependence between shipowners and fuel producers when making investment decisions. Simply put, shipowners investing in methanol-capable vessels need predictable fuel costs and availability, while fuel producers need confidence in future demand to justify investments in production and infrastructure. In essence, developers depend on committed buyers willing to agree on fixed, long-term prices. In an emerging market with high initial capital needs, fuel producers frequently seek to sell their output in advance, leaving limited room for spot market transactions.

FIGURE 4-1

Projected use of low-GHG methanol under four different scenarios: Maximum use, IMO NZF Base target, FuelEU Maritime target and No use, compared to global production capacity of low-GHG methanol production projects – upper and lower limit for each demand-scenario reflects different growth in global fleet methanol consumption capacity after 2027

Units: Amount of low-GHG methanol (Mt)



Source: DNV

4.1 Scenarios for demand

Low-GHG methanol demand from shipping is the product of two factors: the fleet's total capacity to consume methanol as fuel (i.e. methanol capacity) and how much this capacity is utilized for low-GHG methanol, since the vessels have dual-fuel (fuel oil / methanol) capability. A relatively common misconception outside shipping circles is that methanol-capable vessels will run entirely on low-GHG methanol – as we shall see, this is not the case.

The global methanol consumption capacity of the shipping fleet can be projected with relatively high confidence through 2027, based on the current order book. After 2027, future methanol capacity depends on the number of methanol-capable vessels added to the fleet, and we consider two simple scenarios: a high-capacity case adding 3.8 Mt of new methanol consumption capacity annually, and a low-capacity case adding 1.0 Mt annually from 2028 onward.[37]

Forecasting the actual utilization of methanol capacity to operate on low-GHG methanol is more complicated. Historical numbers show that dual-fuel vessels switch from fossil methanol to conventional fuel oils when it is more cost-effective. The share of fossil methanol has fluctuated between 6% to 60% of capacity between 2019 and 2023 (see page 25: Potential methanol fuel consumption based on existing fleet and order book). As shown in Section 3.2, low-GHG methanol remains uncompetitive with fossil fuels such as MGO or fossil methanol unless the GHG-emission cost is significant – or, regulations are enforced which otherwise incentivize or mandate the use of low-GHG methanol. To better understand how this may unfold, we assess four scenarios for a shipowner's potential use of low-GHG methanol on a methanol-capable vessel:

- **No use:** Low-GHG methanol is not adopted
- **FuelEU Maritime target:** Use enough low-GHG methanol to meet the FuelEU Maritime GHG intensity target[38]
- **IMO NZF Base target:** Use enough low-GHG methanol to meet the Base target under IMO NZF
- **Maximum use:** Utilize the full capacity for using low-GHG methanol.

In Figure 4-1, we present the resulting fuel demand when these four demand scenarios are coupled with future high and low methanol consumption growth. It should be noted that the IMO NZF and FuelEU Maritime regulations are fuel agnostic, meaning that low-GHG methanol is only one of several different alternatives that can be used for compliance. More details on how we have estimated the potential fleet demand for low-GHG methanol are provided in Appendix A. Our modelling shows a broad potential demand range for low-GHG methanol by 2040, spanning from zero to 60 Mt, highlighting substantial uncertainty in future uptake. In the no-use scenario, low-GHG methanol is not utilized. In the FuelEU Maritime scenario, usage increases from 0.05 Mt in 2025 to between 5 and 12 Mt by 2040. The IMO NZF Base scenario predicts demand of 1.7 to 2.8 Mt in 2030, rising to 20 to 50 Mt by 2040. The maximum-use scenario assumes full deployment, with demand climbing from 2.9 Mt in 2025 to between 24 and 60 Mt by 2040.

Also shown in Figure 4-1 are two low-GHG methanol supply benchmarks towards 2030: one based on all announced

projects in the production pipeline, and the other considering only future projects that are decided[39], using data from DNV's Alternative Fuels Insight platform. The range in production capacity varies between 14 Mt and 42 Mt in 2030, the final year for which pipeline data is available. This represents a substantial growth from the current capacity of 2.2 Mt.

4.2 Likelihood of demand scenarios

The explored scenarios reflect four potential future situations considering key variables influencing the demand for low-GHG methanol from ships. Any conclusion drawn from Figure 4-1 on the balance of supply and demand ultimately depends on which future scenario is considered more likely. In the following, we explore this further. The probability of each demand scenario materializing depends on several key factors:

- **Fuel cost** considerations include both the price of fossil fuel alternatives and the relative expense of low-GHG methanol compared to other low-GHG fuels, while accounting for the greenhouse gas intensity associated with each option.
- **Regulatory compliance costs** include fees for not meeting GHG intensity targets and the cost of emission allowances.
- **Income streams** potentially originating from reward schemes and earnings from exceeding targets and selling surplus allowances.
- **Commercial drivers** also influence demand, particularly the ability to offer green transportation services that justify a green premium.

These factors may influence demand in different combinations and to varying degrees. In some cases, a single factor may be sufficient; in others, several may need to align. Not all must be present to justify demand. Below, we discuss the likelihood of each scenario in light of these factors.

No use
This demand-scenario reflects a situation where the business case for low-GHG methanol fails to materialize.

Clearly, some shipowners already use some low-GHG methanol, and a reversal of this situation seems unlikely. However, large-scale growth in demand will likely not be driven by commercial incentives alone – in the sense that shipowners are able to charge green premiums to cargo owners for low-emission transport services. Currently, this practice is limited to specific segments such as containerships and car carriers. Initiatives like green shipping corridors could accelerate adoption by offering targeted incentives and reducing risk for participating stakeholders.

In this scenario, we see no growth beyond the minimal use we already see today. This could materialize under two conditions: either regulatory drivers for use of low-GHG fuels are not implemented, or their incentives are too weak. In other words, the penalties for not meeting GHG intensity targets are too low (or non-existent), making it more cost-effective to continue using fossil fuels. Or, the incentives materialize but low-GHG methanol remains far too expensive to compete with other low-GHG alternatives like biodiesel. Or both these circumstances occur simultaneously. For instance, IMO NZF adoption could be delayed, weakened by insufficient incentives for low-GHG fuels, or fail to materialize altogether. CII compliance may provide some, but not enough, incentives for methanol use – compliance could rather be reached by cheaper and more available options including energy efficiency and logistical measures. While EU regulations could still provide incentives, it could be that methanol-capable vessels have no exposure to this, as they trade in other regions. However, as seen in the fact box, page 25: Potential methanol fuel consumption based on existing fleet and order book, the chances for this are slim. Still, the price of low-GHG methanol may be non-competitive, which in any case, would lead to no use.

The implications for the demand-supply balance under this scenario are quite clear; the maritime sector will not be able to support the investments needed to realize all the planned production capacity – raising the question of whether these projects can be realized at all. However, it is important to remember that low-GHG methanol has many potential offtakers beyond shipping, and that currently only a tiny share of total methanol production is used as marine fuel. Global Growth Insight reports[40] that the primary current usage of low-GHG methanol is as an input factor to biodiesel production. The second main usage is as chemical feedstock, followed by gasoline blending. Section 3.3.3 provides some examples of other industries that may also become significant offtakers of low-GHG methanol. Thus, shipping may have limited uptake, but other sectors may still drive some demand.

Under the FuelEU Maritime target scenario demand projection increases from about 0.05 Mt in 2025 to 5–12 Mt for the fleet in 2040.

FuelEU Maritime target

Under the FuelEU Maritime target scenario, demand for low-GHG methanol is driven by compliance with the FuelEU Maritime requirements. The demand projection increases from about 0.05 Mt in 2025 to 5-12 Mt for the fleet in 2040.[41]

In this scenario, the methanol-capable ships in the fleet operate on routes affected by the FuelEU Maritime regulations. Specifically, 50% of all fuel consumption for these ships is assumed to fall under EU regulations, which would be the case for vessels trading between the EU and other

regions.[42] Numerous case studies show that the penalties for non-compliance with the FuelEU Maritime regulations are severe enough to incentivize use of low-GHG fuels, see, for example, DNV (2024). Also, for this scenario to materialize, the price of low-GHG methanol must be lower than that of other drop-in alternatives, such as biodiesel. Other factors, such as those discussed in Chapter 3, could also impact uptake.

A closer look at the operational patterns of vessels expected to drive most future methanol demand suggests that FuelEU Maritime regulations will be relevant. Most order book capacity is for large containerships, and AIS data shows that many existing vessels operate on the Europe–Asia trade route (see page 25: Potential methanol fuel consumption based on existing fleet and order book). Thus, while not all methanol-capable vessels will be covered by FuelEU Maritime, a significant share likely will. We also now see plans for production and bunkering infrastructure at locations that are relevant for the Europe-Asia trade route (see Section 3.2.2). A significant share of the low-GHG methanol production pipeline is located in China. Already, the first binding offtake agreements for low-GHG methanol for marine use have been signed with Chinese fuel producers – underlining their significant role as future suppliers.

While this scenario only considers the FuelEU Maritime regulations, which specifically mandate the use of low-GHG fuels, the EU also imposes a GHG levy on ships under the EU ETS regulations. Clearly, this also influences the choice of fuel. However, the price of allowances has been relatively low since the phase-in of shipping into the EU ETS in 2024, ranging from 46 EUR (53 USD) to 79 EUR (92 USD).[43] These prices remain too low to incentivize the use of low-GHG fuels beyond the FuelEU requirements. Naturally, this may change in the years to come, as the EU's GHG targets tighten, resulting in a reduction in emission allowances and thus increased prices. Case in point: the EU just agreed to new GHG targets,[44] aiming for 90% reduction in 2040.

The implications for the demand-supply balance, and the inferences that can be drawn from Figure 4-1 based on this scenario, are that while the FuelEU Maritime regulations may provide a significant boost to low-GHG methanol demand, the demand still lags significantly behind the potential supply. Thus, based on the global supply benchmarks provided, the production pipeline for low-GHG methanol is not considered a major bottleneck for availability for shipping in this scenario – but rather, weak demand may jeopardize fuel production projects. Considering projects classified as decided, shipping would only require about 6.5% of total low-GHG methanol supply in 2030 in the most conservative scenario. Naturally, other sectors may still drive demand, as discussed above.

Numerous case studies show that the penalties for non-compliance with the FuelEU Maritime regulations are severe enough to incentivize use of low-GHG fuels.

IMO NZF Base target
The IMO NZF Base target scenario reflects low-GHG methanol demand if all methanol-capable vessels use the fuel to meet the IMO NZF Base target, assuming 2029 as the first reporting year. In this scenario, low-GHG methanol use increases from 1.7–2.8 Mt in 2030 to roughly 20–50 Mt for the fleet in 2040.

In contrast to FuelEU Maritime, IMO NZF covers all ships regardless of their area of operation. In addition, the NZF mandates higher percentages of low-GHG fuel than FuelEU Maritime. Consequently, while the FuelEU regulations are still present in this scenario, it is the IMO NZF regulations that place a cap on demand, as compliance with the FuelEU Maritime implies compliance with NZF.

The scenario assumes that the IMO NZF is adopted in 2026, although there is no guarantee for this. Further, it implies that the incentives under the NZF are strong enough to dissuade use of fossil fuel. Specifically, this requires that the price of emitting GHG emissions on a well-to-wake basis – referred to as the Tier II remedial unit cost – is high enough. In addition, the price of low-GHG methanol must be lower than that of alternative low-GHG fuels such as biodiesel, for this scenario to occur (as for the FuelEU Maritime scenario).

The implications for the demand-supply balance in this scenario seem to be that low-GHG methanol production is still not considered a major bottleneck. On the contrary, shipping would account for approximately 20% of the total based on the low production capacity estimate (considering only projects tagged as 'decided'). However, strong demand signals may still be necessary for fuel producers to have the required confidence to advance their projects fully into the operational stage.

Maximum use
In the maximum-use scenario, all methanol-capable vessels use low-GHG methanol to the greatest extent possible. As the fleet of methanol-capable vessels grows towards 2040, projected consumption under this scenario increases from about 2.9 Mt in 2025 to between 24 and 60 Mt by 2040.

Clearly, the maximum-use scenario could unfold if low-GHG methanol becomes available at prices below those of fossil fuel oil. Currently, however, this appears highly unlikely.

The more likely pathway for this scenario to materialize is through the adoption of IMO NZF, assuming that it will contain sufficiently strong incentives for methanol-capable ships to use low-GHG methanol well beyond what is needed for simple compliance with the Base target. Under the NZF, such 'overcompliance' is incentivized through the possibility of generating 'Surplus Units' or 'SUs' by using low-GHG fuels beyond the target. These SUs can then be sold to other ships to help them achieve compliance. The price of emitting GHG emissions on a well-to-wake basis (beyond the Base target threshold), the Tier II remedial unit cost, would likely act as a price ceiling for the price of SUs. Use can be further incentivized by the proposed reward mechanism, although no details on the design of this mechanism have been decided.

Thus, two out of the three conditions for this scenario closely resemble the IMO NZF scenario described above. Firstly, there must be an incentive to stop using fossil fuels. Secondly, low-GHG methanol must be more cost-effective than other low-GHG fuel alternatives. Thirdly, the financial incentives for overcompliance need to be sufficiently high to make exceeding the mandated methanol use targets attractive.

In this scenario, the demand–supply balance presents a mixed picture. In the most conservative case, assuming high growth in the methanol-capable fleet, shipping demand could outstrip supply from fuel production projects tagged as 'decided' by as much as 60%. However, supply could be ramped up further if a high share of announced projects that have not yet been 'decided' move ahead into the operational phase. For this to happen, strong demand signals from shipping are needed. Further, as discussed above, methanol is a key building block in the production of various chemicals, and other sectors may emerge as key offtakers for low-GHG methanol beyond shipping. The extent to which shipping becomes a significant offtaker of low-GHG methanol in this scenario will depend on its ability to secure supply ahead of other industries that are already major consumers of methanol.

Recall also that our supply benchmarks considered only methanol production from renewable energy sources, namely, renewable electricity and biomass. These pathways currently dominate the project pipeline for non-conventional methanol production, offering lower GHG intensity compared to conventional methods that use natural gas or coal. However, several existing and emerging projects are exploring alternative production routes that still offer significant reductions compared to fossil-based conventional methanol, including 'blue methanol' projects. If we include the supply of methanol from such projects in our supply estimates, the effective supply would increase. However, the GHG intensity is higher, meaning that more fuel is required to achieve the same GHG reduction. In addition, with minor modifications, methanol-capable vessels could use ethanol as fuel, opening up an entirely new potential fuel supply chain (see page 10: Ethanol fuel in shipping).

4.3 Summing up

What will it take for methanol to become a scalable global marine fuel? Clearly, with the current fleet and order book, methanol has a head start compared to many low-GHG fuel competitors. The large container vessels can potentially kick-start the value chain, including production and infrastructure, paving the way for other sectors to follow. Thus, there is a path for methanol to become a widespread fuel. But the key question remains how to incentivize methanol-capable vessels to actually use low-GHG methanol, instead of other (fossil or green) alternatives.

We began this chapter by highlighting that fuel availability and cost remain key challenges to the widespread adoption of low-GHG methanol. While this still holds true, our analysis shows that the existing production pipeline could, in most demand scenarios, meet all of shipping's needs through 2040, assuming the maritime sector is the primary offtaker. As discussed before, this may not necessarily be the case.

Our demand scenario analysis indicates that while FuelEU Maritime can provide an important demand signal, its impact is limited. In contrast, the IMO's Net-Zero Framework (NZF) has the potential to generate significantly stronger demand, making it a potential key enabler for scaling up low-GHG methanol use in shipping. However, the implementation of IMO NZF is not yet clear.

While FuelEU Maritime can provide an important demand signal, its impact is limited. In contrast, the IMO's Net-Zero Framework (NZF) has the potential to generate significantly stronger demand.

This suggests that the main barrier is not production capacity pipeline, but rather the need for strong and sustained demand to unlock that capacity. Clear demand signals, such as long-term offtake agreements with defined prices and volumes, will be essential to give fuel producers the confidence to invest and bring projects into operation.

Importantly, there is a risk imbalance between shipowners and the fuel producers. For a shipowner, betting on methanol means spending additional funds to enable methanol capability on board the vessel. But the vessel will not be locked to using methanol, as the dual-fuel capability will allow for use of fuel oils, and even biofuels with drop-in capability. Thus, the downside to this investment is limited. For fuel producers, the situation is quite different. For them, there is a high upfront CAPEX needed for investing in production (and distribution) capacity. Further, the return on investment depends entirely on the premise that a yet-to-be-realized market potential will actually emerge in shipping. Thus, the degree of long-term commitment needed is very different for fuel suppliers compared to shipowners. The only risk-mitigating factor is that other offtake sectors may emerge.

BloombergNEF[45] highlights that demand for low-carbon methanol is primarily driven by policy regulations, particularly within the EU. They project a demand of approximately 14 million tonnes of low-GHG methanol for shipping by 2028, roughly in line with our Maximum use scenario. While they note that demand from the maritime sector alone could exceed supply based on the current production project pipelines, our analysis suggests this outcome is far from certain. They also note that other sectors face headwinds; the chemicals sector, the largest user of grey methanol today, is subject to moderate regulations and has been slow to adopt low-carbon methanol or green hydrogen. Although major producers like Methanex and OCI Global are investing in low-carbon methanol projects, their focus remains largely on the marine fuel market. The few chemical-sector offtake agreements tracked by BloombergNEF are mostly policy-driven, as there are limited incentives for commercial buyers to opt for green alternatives. Methanol's end-use applications are also highly diverse, ranging from household products to industrial resins and construction materials. Because the input of methanol to most products is relatively low, makers with Scope 3 emission targets are likely to prioritize the decarbonization of more impactful input categories – for example, the steel materials they procure. The challenge is further complicated by the long value chain for methanol end-use sectors. Argus Media[46], similarly, states in a recent analysis that the maritime industry is the most viable landing spot for low-GHG methanol, also noting that regulatory developments will significantly shape the marine market.

For shipping to be able to offer firm long-term offtake agreements to producers, the key is regulatory certainty. Without an effective price on carbon, there is little reason to expect any low-GHG alternative to compete against the incumbent fossil fuels. This will again largely depend on the further process of developing and eventually implementing the IMO NZF.

5 Steps for shipowners toward robust fuel decisions

Shipowners face complex decisions on fuel strategies amid regulatory uncertainty. This chapter outlines a two-step approach to evaluate options and reduce risk.

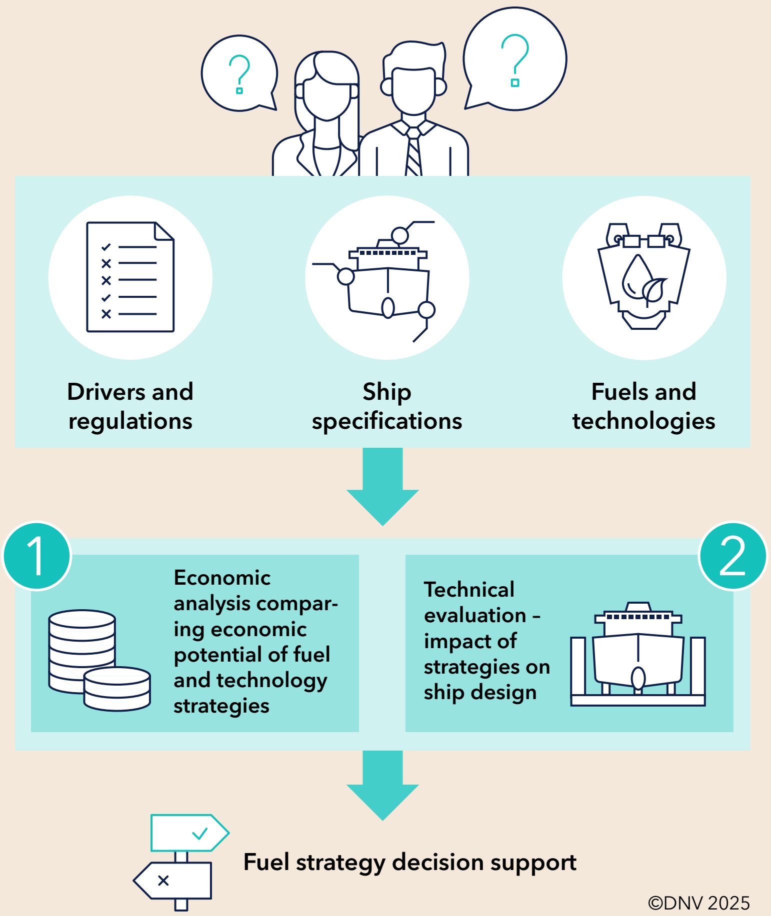
While global scaling of methanol as a fuel is of great interest to many industry actors, and high on the agenda for policymakers at the IMO, this is not a primary focus for most shipowners. Their interest lies in the commercial operation of their vessels, and a key concern is the remaining uncertainty related to the choice of low-GHG fuel to comply with regulations. This decision carries great risk, as a wrong choice will have a significant impact on long-term income and asset value. Shipowners must choose between a range of deep-sea fuel options with potentially zero or near-zero GHG intensity, including biodiesels, methane, methanol, and ammonia. Furthermore, various levels of fuel flexibility and preparatory, intermediate steps can be selected, adding to the complexity.

DNV has previously presented structured and knowledge-based approaches to managing risk and uncertainty related to fuel selection (DNV, 2021a) and launched the related Fuel Selector service.[47] Building on this work, we present a two-step framework for fuel selection (Figure 5-1) which includes an economic and a technical analysis.

An economic analysis which provides a quantitative assessment of the long-term profitability and competitiveness

FIGURE 5-1

A two-step framework for fuel selection



of different fuel and compliance strategies, including the option to pool compliance across several ships:

- The analysis should assess a ship or a fleet under a range of varying fuel and CO_2 prices, covering all GHG regulations and associated GHG trajectories, to provide a clearer picture of the robustness of each fuel strategy, considering also fuel availability (e.g. DNV's Alternative Fuels Insight (AFI) platform).[48]
- The results can indicate to what degree designs are resilient to future changes and whether they can perform well under a range of scenarios reflecting the unique set of circumstances that each shipowner must contend with.
- Sensitivities to uncertainties in investment, future newbuild or retrofit costs, and other assumptions should be investigated to make the results more robust.

The outcome of this step is the most favourable fuel strategies in a lifecycle perspective for further analysis in step 2.

Details on DNV's approach to such an analysis are provided in the 2021 edition of the Maritime Forecast (DNV, 2021a). In addition, the "Handbook for decarbonization of shipping" provides practical guidance on how to manage decarbonization risks in a structured manner, ensuring that individual ships comply with their respective target carbon intensity trajectories throughout their lifetimes (DNV, 2021b).

A technical analysis of the impact of the selected fuel strategies on the ship design, as well as an in-depth technical engineering review of the integration of the onboard fuel system for the final selected fuel strategy:

- The analysis should assess the impact on ship design related to fuel storage capacities, bunkering frequency and operation, relevant fuel storage tank designs, possible fuel storage locations on board, fuel preparation and supply, as well as onboard energy converters. The impact on the general arrangement with respect to, for example, additional space for fuel storage and location of hazardous areas should also be assessed.
- Relevant preparations for being Fuel Ready, such as trim and stability, and structural modifications, should be considered. DNV has developed Fuel Ready notations for owners who want to prepare their newbuilds for a potential later conversion to be able to use alternative fuels.
- The outcome of this step is practical guidance on technical design implications supporting the development of the alternative fuel part of the ship specification. Details on DNV's approach to such an analysis are provided in the 2021 edition of the Maritime Forecast (DNV, 2021a).

Furthermore, in the "Alternative Fuels for Containerships" paper series, DNV provides an overview of the most important technical and commercial considerations for the containership sector related to LNG, methanol, and ammonia (DNV, 2023).

The overall outcome from steps 1 and 2 is decision support for the selection of a robust alternative fuel strategy. To conduct a comprehensive analysis, expert simulation tools, detailed input data (e.g. fuel and CO_2 prices), and an understanding of the factors influencing decarbonization in shipping (e.g. the IMO Net-Zero Framework, EU-ETS, FuelEU Maritime), as well as the available technological space and design implications for the ship, are essential prerequisites. DNV offers the Fuel Selector service, which covers the above steps. It is designed to explore the financial performance of various fuel and compliance strategies for fleets and ships, assisting in the fuel decision-making process.


POWERED BY METHANOL

Appendix A – Methodology for estimating shipping's demand for low-GHG methanol

This appendix outlines the methodology used to estimate the aggregate demand for low-GHG methanol in shipping through 2040. We begin by describing the approach and key assumptions behind our projections for growth in the methanol-capable fleet, i.e. the total methanol consumption capacity.

This study then explores four scenarios for the utilization of this methanol consumption capacity, as shown in Figure 4-1. In the 'Maximum use' scenario, the required volumes of low-GHG methanol are equivalent to the total projected consumption capacity through 2040, whereas in the 'No use' scenario, zero consumption of low-GHG methanol is assumed. For the scenarios in between, we provide a detailed explanation of how vessel-level low-GHG methanol consumption was estimated to meet the IMO NZF Base target and the FuelEU Maritime target, i.e. the required capacity utilization needed to fulfil each of these regulations.

By multiplying the required capacity utilization with the total methanol-capable fleet capacity, we derive the corresponding methanol demand under each regulatory scenario.

Growth in fleet methanol consumption capacity
Based on the current fleet in operation and the current order book, the total methanol consumption capacity of the world fleet can be projected with relatively high accuracy through 2027, as new orders for delivery before 2028 are unlikely. The theoretical total consumption capacity is derived from vessel-specific AIS-based calculations using DNV's MASTER model for fuel consumption and subsequently aggregated to represent the fleet-level total estimate. This estimate assumes 100% methanol operation across the existing and projected global methanol-capable fleet, as reflected in the confirmed order book. It represents a theoretical upper bound for methanol demand, and such estimates are available through the DNV Alternative Fuels Insight (AFI) portal.

Beyond 2027, however, projections depend on the number of methanol-capable vessels added to the fleet (via either newbuilds or retrofits) and their annual fuel consumption. To make the projection for 2028 to 2040, we consider two scenarios for future methanol-capable fleet growth:

- High development scenario: Starting from 2028, approximately 3.8 Mt of methanol consumption capacity is added annually. This is similar to the total methanol consumption capacity to be added to the fleet in 2026 and 2027.
- Low development scenario: Starting from 2028, approximately 1.0 Mt of consumption capacity is added annually. This reflects a scenario where the ordering of methanol-capable tonnage slows down.

Thus, we have applied two complementary methods to estimate the total fleet-level capacity, providing annual projections through 2027 and high/low scenarios for the period 2028 to 2040.

Fleet-wide methanol demand necessary for regulatory compliance
In the IMO Net-Zero Framework (NZF) Base target scenario and the FuelEU Maritime target scenario, the key question is: What level of low-GHG methanol utilization is required over time to comply with regulatory requirements?

TABLE A-1

Applied fuel types and associated well-to-wake GHG intensity for a methanol-capable vessel

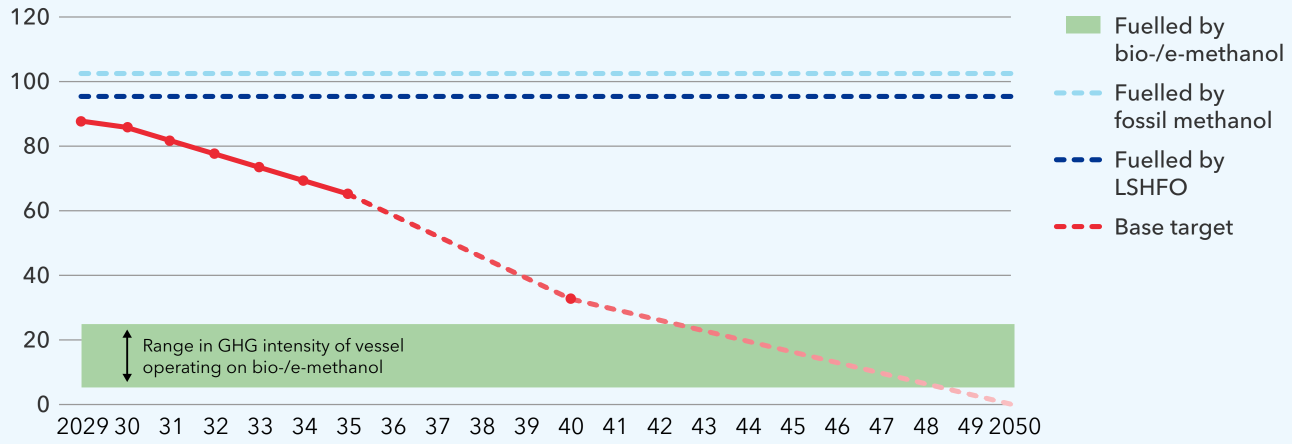
Applied fuel-types		Well-to-wake GHG intensity (gCO_2eq/MJ)	
Main fuel	Pilot fuel[(1)]	IMO NZF[49]	FuelEU Maritime
Fossil methanol (natural gas)	LSHFO	102.2	102.1
LSHFO	–	95.5[(2)]	91.7
Bio-/e-methanol[(3),(4)]	LSHFO/biodiesel	5.4[(3)]–24.9[(4)]	5.8[(3)]–24.8[(4)]

(1) Pilot fuel is assumed to make up 10% of total fuel energy use for the vessel when operating in methanol mode.
(2) The well-to-wake GHG intensity factor for low sulphur heavy fuel oil (LSHFO) under IMO NZF is based on initial default values given in 2024 IMO LCA guidelines for fuel pathway code, HFO(VLSFO)_f_SR_gm.
(3) Lower span well-to-wake GHG intensity value reflects e-methanol produced from renewable electricity with a GHG intensity of 1.8 gCO_2eq/MJ attributed to distribution and conditioning (Prussi, 2020) and FAME biodiesel produced from used cooking oil is applied as a pilot fuel.
(4) Upper span well-to-wake GHG intensity value reflects use of bio-methanol produced with a GHG saving of 84% (default value for bio-methanol from waste wood in free-standing plant) with very low sulphur fuel oil (VLSFO) used as a pilot fuel.

FIGURE A-1

Estimated GHG intensity for a vessel when fuelled with fossil methanol, LSHFO and bio-/e-methanol, compared against the IMO NZF Base target, which is currently defined in the years leading up to 2036 and for 2040: values for other years are interpolated, assuming a target of zero by 2050

Units: GHG intensity (gCO_2eq/MJ)



To estimate this, we first identify the difference between the well-to-wake GHG intensity of the various fuel options under the regulatory requirements (see Table A-1).

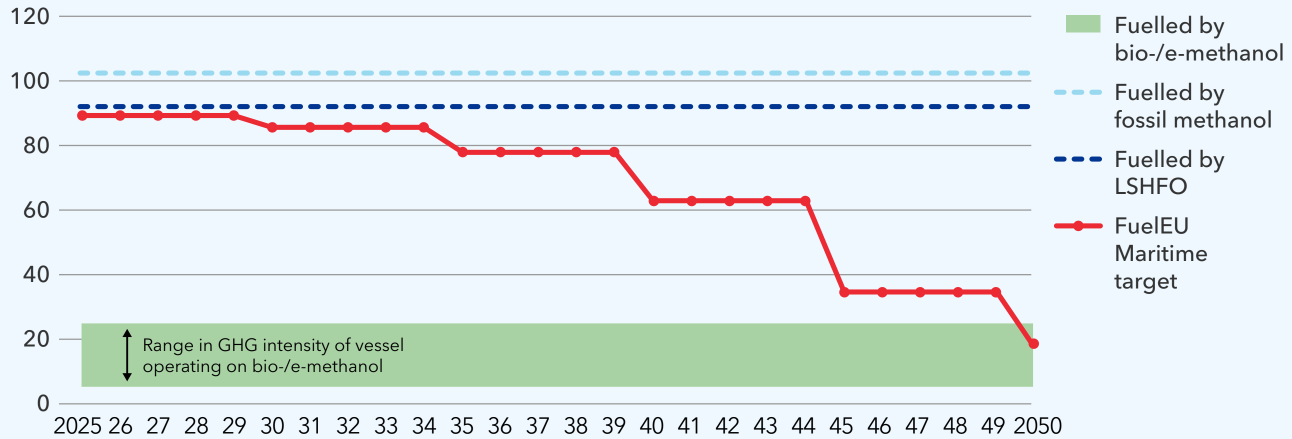
The GHG-intensity Base target defined by IMO NZF is illustrated in Figure A-1 and the FuelEU Maritime GHG intensity target in Figure A-2. Both figures also illustrate the GHG intensity levels of fossil alternatives (shown as stippled blue lines) alongside a range of likely GHG intensity values for a vessel operating on bio- or e-methanol (represented by the green shaded area), which vary depending on the specific fuel production pathway (well-to-tank).

Based on the well-to-wake GHG intensity of different fuel options and regulatory targets, we calculate the share of low-GHG methanol required for a vessel operating on a mix of LSHFO and low-GHG methanol to meet each trajectory (see Figure A-3), i.e. the methanol utilization. Results are provided as shaded areas, reflecting the span in GHG intensity of low-GHG methanol used - which will have a signifi-

FIGURE A-2

Estimated GHG intensity of a vessel when fuelled by fossil methanol, LSHFO and bio-/e-methanol, compared to the FuelEU Maritime GHG intensity target towards 2050

Units: GHG intensity (gCO_2eq/MJ)



cant impact on the share needed to meet the requirements. We see that the IMO NZF Base target becomes more stringent than the FuelEU Maritime target once implemented, requiring a significantly higher share of low-GHG methanol.[50] For instance, by 2040, compliance with IMO NZF Base target would require approximately 75% low-GHG fuel, compared to approximately 35% under FuelEU Maritime.

The vessel-specific shares of low-GHG methanol required to meet each regulatory trajectory are then applied across the projected methanol-capable fleet to estimate the aggregate demand for low-GHG methanol under each scenario, as seen in Figure 4-1.

It is important to note that the extent to which vessel owners pursue methanol retrofit projects could significantly influence the development of methanol-fuelled capacity. To date, most methanol-capable vessels have been delivered as newbuilds rather than retrofits. However, the potential for retrofitting, particularly for large-bore engines, is considerable (see page 16: World's First Methanol Retrofit for Mega Container Carrier).

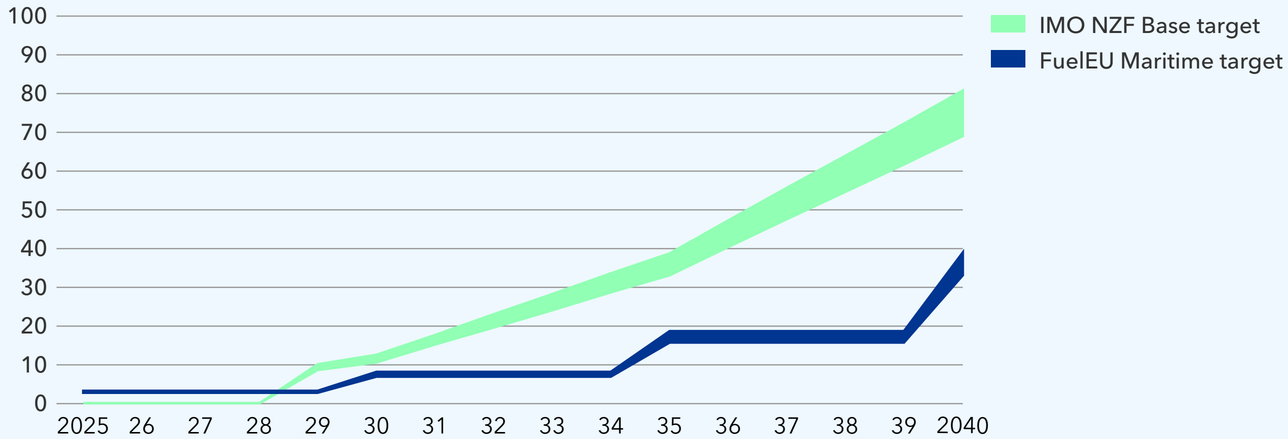
This study also acknowledges several assumptions that may affect the projected global demand for low-GHG methanol in shipping. Key uncertainties include the future price of low-GHG methanol, fossil fuel prices, commercial drivers, regulatory developments, and potential penalties for exceeding GHG intensity targets. A few sources (IEA, 2023; Zero Carbon Shipping, 2021; LR, 2023) provide projections for marine low-GHG methanol demand towards 2040, which largely align with the range of estimates presented in this study.

While methanol is a promising fuel option, other low-GHG fuels, such as methane and ammonia, are also expected to play significant roles in the future maritime energy mix. Several studies have performed comparative assessments of these fuels, evaluating and ranking them based on key factors such as GHG performance, environmental impact, technological maturity, and economic viability (Wang, Xiao, & Ji, 2025; Chen, Li, & Chen, 2025; Moshiul, Mohammad, & Hira, 2023; Law, Foscoli, Mastorakos, & Evans, 2021). The extent to which owners ordering newbuild tonnage perceive methanol as a promising fuel can significantly influence the future growth of the fleet's methanol-burning capacity.

FIGURE A-3

Energy share of low-GHG fuel methanol required to meet IMO NZF Base target or FuelEU Maritime GHG intensity target for a vessel with 100% operation within the EU/EEA

Units: Energy share (%)



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Endnotes

1 For the *FuelEU Maritime target* scenario, we assume that 50% of the fleet's methanol-burning capacity falls within the scope of FuelEU Maritime

2 The Methanol Industry, www.methanol.org

3 https://www.vgbe.energy/wp-content/uploads/2022/09/Methanol-production-and-markets-ICSC-322-Exec-Sum.pdf

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9 Everllence successfully runs world-first ethanol-fueled ME-LGIM two-stroke engine – Marine Log

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19 alfa-laval-first-methanol-boiler-installation-case-story-en.pdf

20 Clarksons Research (2025), based on quarterly average newbuild prices reported in in 2023, 2024, and 2025

21 Methanol Institute (2023), Marine Methanol, Future-Proof Shipping fuel, Marine_Methanol_Report_Methanol_Institute_May_2023.pdf

22 The second one! Shanghai COSCO Shipping Heavy Industry Delivers Another Methanol-Dual-Fuel Converted Ship-Wuhu Ping An Rubber Co., Ltd.

23 S90 Methanol Engine Retrofit Confirmed: https://www.everllence.com/company/press-releases/details/2025/10/27/s90-methanol-engine-retrofit-confirmed

24 Based on DNV's Fuel Cost Mapper (October, 2025)

25 The World Ports Climate Action Program (WPCAP) has developed a tool to assess the port readiness for the bunkering of new fuels (e.g. ammonia). It offers a transparent way to identify the port's current ability and outline the steps the port would need to take to be able to bunker the new fuel in the future. It consists of nine readiness levels, divided into three phases: research, development, and deployment.

Refer to: https://sustainableworldports.org/wp-content/uploads/Port-Readiness-Level-for-Marine-Fuelsassessment-tool-July-2024.pdf

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32 Equinor and Maersk partner up to ensure continued green methanol supply for the world's first methanol-enabled container vessel | Maersk

33 DNV launches first-of-its-kind tender portal to accelerate e-methanol adoption for industry and shipping: https://www.dnv.com/news/2025/dnv-launches-first-of-its-kind-tender-portal-to-accelerate-e-methanol-adoption-for-industry-and-shipping/

34 The Many Uses of Methanol From Clothing to Fuel: Products and Technology Highlights | Innovation | Mitsubishi Gas Chemical Company, Inc.

35 DNV Maritime Forecast to 2050, 2025 edition; Singapore executed the world's first ship-to-containership methanol bunkering operation in July 2023, followed by ordering of methanol-capable bunker vessels. In Rotterdam, ship-to-ship bunkering of methanol has already taken place several times, and a dedicated methanol bunker barge is planned to be deployed in the port.

36 For example, see CMA CGM Joins Ranks of Methanol Pioneers Putting First Vessel in Service and Methanol Institute (2023)

37 High development scenario: This is similar to the total methanol consumption capacity due to be added to the fleet in 2026 and 2027.

Low development scenario: This reflects a scenario where ordering of methanol-capable tonnage slows down.

38 For the *FuelEU Maritime target* scenario, we assume that 50% of the fleet's methanol-burning capacity falls within the scope of FuelEU Maritime.

39 'Decided' implies that either the project is under construction and/or a final investment decision (FID) has been taken.

40 https://www.globalgrowthinsights.com/market-reports/green-methanol-market-115560

41 These estimates do not take into account the RFNBO (Renewable Fuels of Non-Biological Origin) factor under FuelEU Maritime, which could effectively lower the amount of e-methanol a vessel needs to use in order to comply with the regulation's GHG intensity targets.

42 Estimated demand under FuelEU Maritime is highly sensitive to the proportion of vessels operating on trades that include voyages to or from EU/EEA ports. For this analysis, we assume that 50% of the fuel energy use from methanol-capable ships falls under FuelEU Maritime. This high value could be plausible, as a high share of total methanol consumption capacity derives from large container vessels, which could be put into operation on the trade between Europe and Asia.

43 EU Carbon Permits - Price - Chart - Historical Data - News

44 https://www.euronews.com/my-europe/2025/11/05/eu-ministers-break-deadlock-on-co2-emissions-cut-by-2040-amid-political-pressure

45 https://assets.bbhub.io/media/sites/25/2024/06/BNEF-Methanol-Report_to-publish.pdf

46 Blue Methanol Market in North America | Argus Media

47 DNV's Fuel Selector Service: https://www.dnv.com/services/fuel-selector

48 Alternative Fuels Insight (AFI) for the shipping industry: https://www.dnv.com/services/alternative-fuelsinsights-afi--128171

49 Several aspects of the IMO NZF remain under development – for example which well-to-tank (WtT) emissions factors to apply for fossil methanol. In the table, values are partially calculated based on FuelEU Maritime default factors.

50 Although meeting the IMO NZF Base target requires more low-GHG fuel than meeting the FuelEU Maritime GHG intensity target, the financial penalty for failing to comply with the latter is higher – at least considering the initial price for Tier 2 remedial units under the NZF.

Selected DNV projects

DNV has extensive experience in supporting clients in the safe introduction of alternative fuels, including methanol. We offer classification and advisory services, and lead several large industry leading cooperation initiatives, sharing insights through white papers, the Maritime Forecast Report, guidelines, best practices, and the Alternative Fuels Insight (AFI) portal. We help our customers in the fuel transition by applying our maritime standards and by providing these standards and services in combination with our deep energy sector competence.

Stena Pro Patria

Green Shipping Programme (GSP)

A public-private partnership initiated in 2015 with 120+ partners from industry and government, managed by DNV. By May 2025, the GSP had initiated 60 green pilot projects, several of which had considered the feasibility of using alternative fuels for various ship types and trades.

→ Link to project

Thome Group and SinOceanic – a greener Workhorse

GSP pilot study facilitated by DNV, investigating the feasibility of retrofitting a 2,500 TEU deep-sea containership to run on methanol. With participation from more than 20 GSP partners and contributors from the maritime supply industry including Kongsberg, Methanol Institute and WinGD.

Glocal Green Infrastructure for green methanol in Norway

GSP study facilitated by DNV, aimed at describing an effective and sustainable business model and supply chain for methanol, as well as identifying necessary steps for realization. With participation from Heidelberg Materials, Port of Grenland, and Inkster Marine.

Nordic roadmap for future fuels

A Nordic collaboration project with 70 partners, managed by DNV and funded by the Nordic Council of Ministers. The project presented the Fuel Transition Roadmap for Nordic Shipping, with a focus on methanol, ammonia, and hydrogen in 2024. Phase II of the project has recently been initiated.

→ Link to project

Maritime Technologies Forum (MTF)

A collaborative effort between Flag States and classification societies, which includes DNV, working to bridge the gap between technological progress and regulatory process across the maritime sector. The MTF has published several reports, e.g. "Guidelines for conducting

Lindanger

COSCO SHIPPING Libra

CM Hong Kong

safe inspection of methanol dual-fuel ships" and "Guidelines to develop and implement a safety management system for alternative fuels on board ships".

→ Link to project

World's first dual-fuel methanol tanker

Lindanger, built in 2016 to DNV class. Part of a fleet in which 18 of the 24 global methanol tankers are DNV-classed.

→ Link to project

Proman Stena Bulk

Proman, the world's second-largest producer of methanol, and the shipping company Stena Bulk formed their joint venture, Proman Stena Bulk, to benefit from synergies between their companies in building a fleet of modern, sustainable MR chemical tankers. Its six state-of-the-art dual-fuel MR tankers are all built to DNV class.

→ Link to project

World's first methanol dual-fuel PCTC

Built for China Merchants Energy Shipping, the *CM Hong Kong* is the world's first methanol dual-fuel Pure Car and Truck Carrier (PCTC) and classed by DNV.

→ Link to project

World's first methanol retrofit for MEGA container carrier

DNV supported Cosco Shipping Heavy Industry (Shanghai), Co., Ltd (CHI Shanghai) and COSCO SHIPPING in the delivery of the world's first methanol retrofit of a mega container carrier, the 20,000 TEU *COSCO SHIPPING Libra*.

→ Link to project

Celebrity Xcel

Royal Caribbean's fifth ship in their Celebrity Cruises' Edge series, *Celebrity Xcel*, is methanol-capable, equipped with a new engine model, along with storage and delivery systems that gives it the flexibility to use three types of fuels, including methanol.

→ Link to project

First e-methanol public tender

DNV is launching the industry's first public tender portal for e-methanol procurement within the European Union and the United Kingdom. The initiative connects a leading e-methanol producer with industrial offtakers across EU and UK markets, creating a new pathway to secure long-term, reliable supplies of this key low-carbon fuel.

→ Link to project

Celebrity Xcel

Maritime publications

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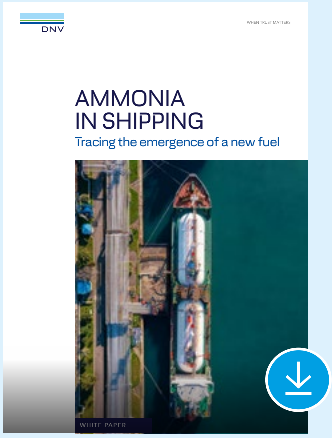
→ dnv.com/maritime/insights/publications

Maritime Forecast to 2050, report edition 2025



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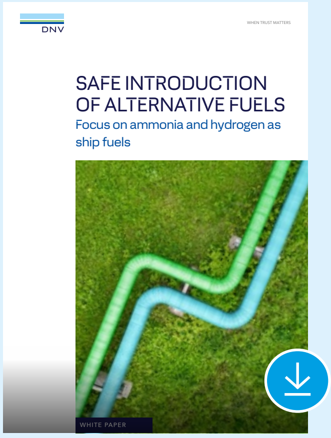

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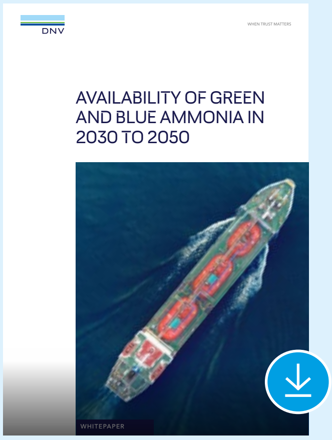

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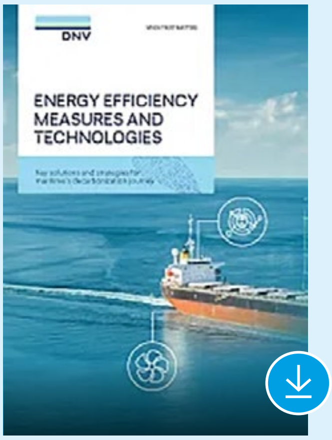

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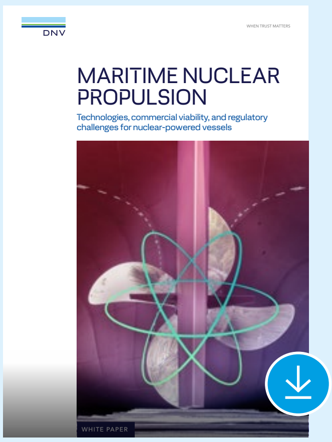

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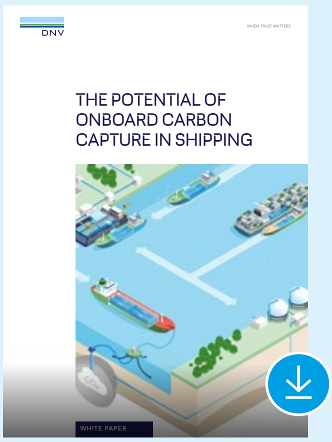

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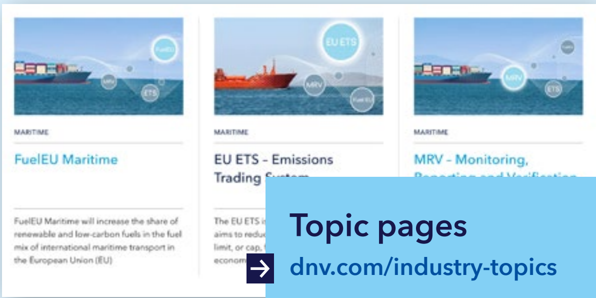

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