Costs, savings and consumer impact: the economics of sustainable shipping

PwC analysis finds that switching to low-carbon shipping fuels may lead to only marginally higher costs for consumers

Costs, savings and consumer impact: the economics of sustainable shipping

Published by PricewaterhouseCoopers GmbH Wirtschaftsprüfungsgesellschaft

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April 2026, 27 pages, 11 figures, Softcover

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At a glance

- PwC analysis shows that adopting low-carbon shipping fuels causes only an almost negligible increase in the costs that consumers pay for goods.
- Shipping companies would have to switch to these fuels in any case to comply with regulations and avoid penalties under the regulations planned by the IMO and already adopted by the EU.
- At-scale adoption of low-carbon shipping fuels requires a coordinated effort by the entire industry to provide infrastructure and fuels.
- Although low-carbon fuels are currently still more expensive than HFO, it already makes economic sense to invest in dual-fuel ships (assuming that the IMO regulations are adopted as planned).

Executive Summary

For shipping companies, emerging regulations at the global, regional and national levels are making the transition towards sustainable fuels and technology more important. The International Maritime Organization's (IMO) Global Fuel Standard, for one, would mandate annual reductions in greenhouse gas (GHG) intensity, such that ships running only on heavy fuel oil (HFO) could eventually pay $380 per tonne of CO_2 equivalent (CO_2e) emitted. This would effectively lead to fuel costs increasing by 30% in 2030 and nearly doubling in 2035. Among other things, these carbon penalties are intended to reward low-emissions shipping – creating financial incentives for companies to switch to sustainable fuels.

First movers might find that the economic obstacles to transitioning to low-carbon shipping are less formidable than expected. New estimates by PwC Germany and the University of Technology Sydney's Institute for Sustainable Futures (UTS-ISF) show that the use of low-carbon shipping fuels will barely increase the prices of some consumer goods. For a television, the extra cost could be 1.4%. For a pair of sneakers, it could be just 0.3%.

The opportunity for shipping companies to make progress is considerable. The global commercial fleet handles 80% of global trade, but 95% of vessels still burn conventional fuel. Some larger shipping companies are already pressing ahead. They're switching to lower-emissions fuel blends, launching ships that can run on either conventional or sustainable fuels, and placing bets on future fuels, such as synthetic ammonia. They're also shaping the future, engaging in the development of green shipping corridors.

These moves aren't just environmental gestures: they're strategic plays for competitiveness in a sustainable fuel ecosystem that is now taking shape. Ultimately, the aim is to slow the increase in damage caused by storms and other climate-related hazards, which are already affecting shipping. Executives who understand these dynamics can better decide how they'll strengthen their business by implementing sustainability measures.

> Decarbonisation in shipping is increasingly being driven by financial rather than purely regulatory factors. ESG criteria, green financing instruments and net-zero commitments are reshaping investment decisions across the value chain.
>
> **Socrates Leptos-Bourgi**
> Global Shipping & Ports Leader, Partner at PwC Greece

How sustainable shipping fuels will affect consumer prices

The transition to sustainable shipping fuels will change the cost profile of goods that travel by sea. Green fuels such as bio-methanol and e-methanol can cost two to three times as much as conventional marine fuels, even after fees for carbon emissions are accounted for. Vessels with dual-fuel HFO/methanol engines sell for between 15% and 20% more than conventional ships.

PwC Germany modelled the impact of these costs on consumer prices, based on 2030 forecasts for fuel costs (comparing 100% HFO with 100% green fuel, based on an average of bio-methanol and e-methanol prices) and the IMO's proposed CO_2 emissions fees. We found that the impacts varied depending on the category of products or services in question, but overall, the barriers to switching fuels are less formidable than business leaders might think – and in some instances, they would be negligible.

Prices of **high-value consumer products** would rise only marginally if shipped using sustainable fuels. The price of a television, for example, would rise 1.4%. Sneaker prices would go up 0.3%. Solar panel prices, however, would increase by 4.6%.

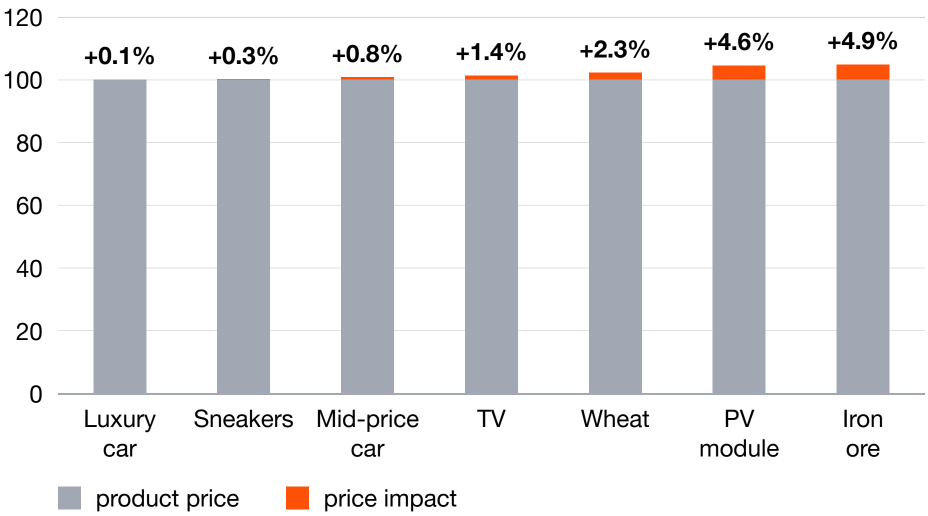
Cars shipped on a 100% green-fuelled pure car and truck carrier (PCTC) would be subject to negligible cost increases. For mid-priced vehicles, consumers could pay an extra 0.8%. In higher-priced segments such as luxury cars, sustainable shipping would add only 0.1% to the selling price.

Commodities shipped in bulk on 100% green-fuelled vessels would see slight price increases. Wheat prices would rise by 2.3%, while iron ore prices would increase by 4.9%.

Leisure cruises illustrate how a service sector might absorb green-fuel costs. PwC analysis suggests that running cruise ships on 100% green fuel would, on average, add around 19% to ticket prices: the price impact on leisure cruises was thus greater than in any other category we studied. However, these costs could be distributed among cabin classes in a way that matches different passengers' willingness to pay. The main reason for the higher projected price increase for this sector is that the additional costs would have to be spread over far fewer passengers on a cruise ship than products on a cargo ship.

Fig. 1 Calculatory cost impact on transported goods

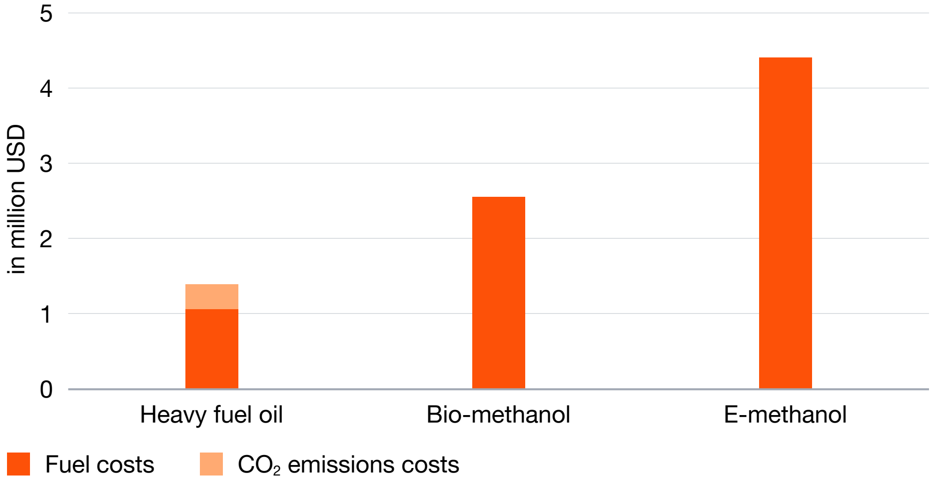
Price impact in % on 100% product price



Note: Price increases for all items reflect estimates for shipping on vessels using 100% green fuel in the year 2030.
Source: PwC analysis conducted in collaboration with the University of Technology Sydney's Institute for Sustainable Futures (UTS-ISF) (2024)

Fig. 2 Fuel cost comparison for a vehicle carrier vessel route

PwC modelling of a typical journey for a pure car and truck carrier shows the impact of using sustainable fuels on the fuel cost.



Note: The calculation is based on the Pure Car and Truck Carrier (PCTC) vessel Hoegh Target travelling the Bremerhaven–Dubai–Bremerhaven route (a distance of around 6,430 nautical miles each way, totalling 12,860 nautical miles).
Source: PwC analysis conducted in collaboration with the University of Technology Sydney's Institute for Sustainable Futures (UTS-ISF) (2024).

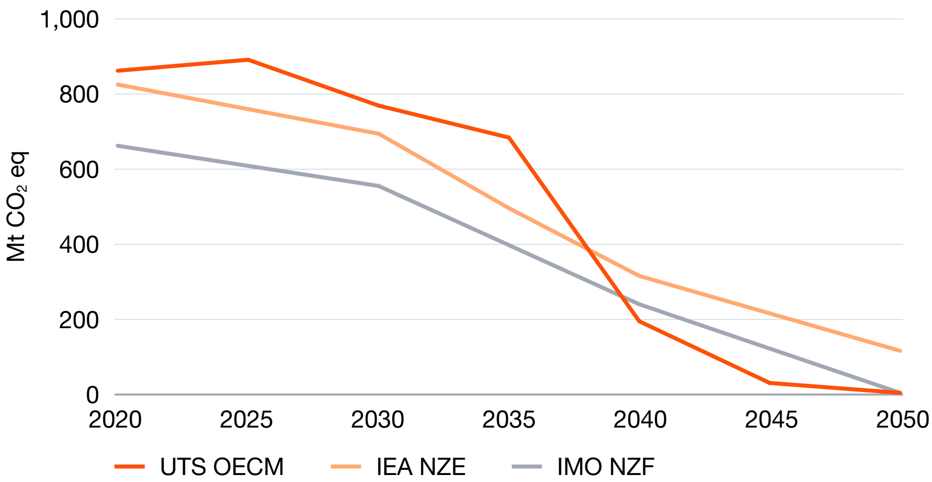
These findings suggest that companies transporting their products on the high seas could opt for green shipping without adding significantly to consumer prices. Even without emissions charges at the levels proposed by the IMO, the price increase resulting from green shipping would be in the same order of magnitude. Demand from shipping customers would, in turn, create a strong incentive for the shipping industry to adopt sustainable fuels. Nevertheless, the transition away from traditional shipping fuels such as HFO would involve practical challenges for companies to navigate.

Shipping's route to net zero

The shipping sector is a cornerstone of global trade, but it also accounts for nearly 3% of all global greenhouse gas emissions, making decarbonisation of the sector critical to meeting international climate targets. Figure 3 illustrates three major pathways for reducing emissions by 2050: the Net-Zero Framework (NZF) from the International Maritime Organization (IMO), the Net Zero Emissions scenario (NZE) from the International Energy Agency (IEA), and the One Earth Climate Model (OECM) from the University of Technology Sydney (UTS). The IMO pathway focuses on incremental improvements and regulatory compliance, and the IEA scenario delivers significant reductions, but both fall short of complete decarbonisation. The OECM scenario represents the most ambitious trajectory, achieving full net-zero emissions by 2050 through a comprehensive approach that combines alternative fuels, technological upgrades and increased operational efficiency.

Under the OECM scenario, emissions would have to decline sharply from 2035 onwards, driven by large-scale adoption of sustainable fuels such as bio-methanol, e-methanol and e-ammonia. This pathway exceeds the goals of the IEA model and is in line with a 1.5°C climate target, but it requires substantial investment, new infrastructure and global cooperation. The implications are clear: incremental measures will not suffice. To meet climate objectives, the shipping industry must accelerate its transition away from traditional fuels, expand green corridors and harmonise international policies. Although the transition involves higher costs for fuel and vessels, the impact on consumer prices remains modest, reinforcing the economic viability of sustainable shipping. Achieving net zero is technically feasible, but success depends on decisive action across the entire maritime economy.

Fig. 3 Normative pathways for reducing greenhouse gas emissions in the shipping sector



Sources: UTS 2024; IEA 2023; IMO 2020.

Fuel efficiency: the first stage in decarbonising shipping

Straightforward tweaks to ship operations can deliver substantial cost savings and emissions reductions, and many are already in widespread use. The practice of "slow steaming" – deliberately throttling down ships to cut fuel consumption – started to spread in 2008, in response to high fuel prices and overcapacity during the crisis that the shipping industry was facing at the time. This allowed the industry to boost its energy efficiency by 15% to 20% between 2008 and 2022. More recently, companies have been using artificial intelligence (AI) to squeeze out more efficiency. Techniques include streamlining docking, and flagging declining engine or hull performance so that workers can make proactive repairs.

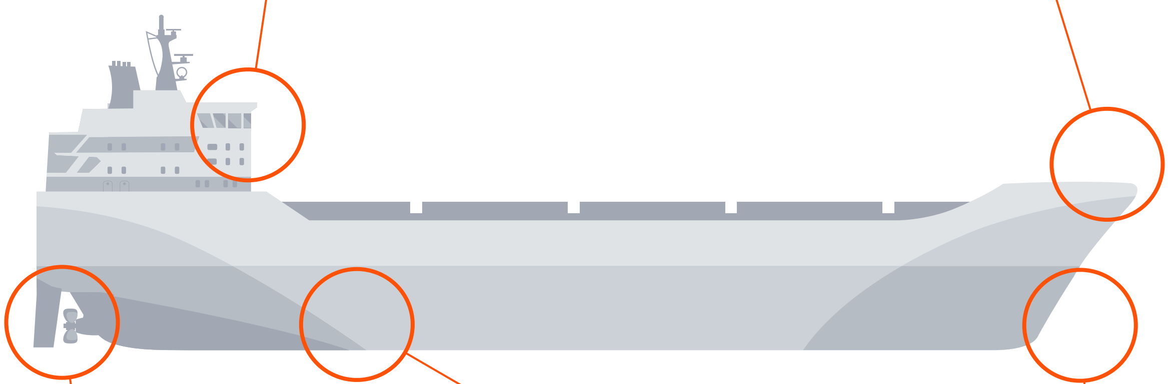
Many shipping companies are upgrading vessels with equipment and technology that make each barrel of fuel go further. More than 8,700 ships – about a third of the global fleet, by tonnage – already sport some fuel-saving features. These modifications include low-friction hull coatings, bow-reshaping retrofits, and special propeller fins and ducts that streamline the flow of water. These can be added during routine dry docking, at a modest capital cost. According to IEA **estimates**, they can deliver energy savings of 15% – enough to lower a typical container ship's operating expenses by $2 million to $5 million per year, and its total cost of ownership (TCO) by as much as 10%.

Other new technologies for even more efficiency gains are currently on trial. Air lubrication systems that create bubbles under ship hulls can reduce drag, cutting fuel consumption by 4% to 8%. Wind-assisted propulsion systems, such as rotor sails and towing kites, provide enough extra thrust to lower fuel consumption by as much as 5%. Figure 4 gives an overview over theses measures.

Fig. 4 Boosting the fuel efficiency of ships

Slow streaming
The practice of deliberately throtting down ships spread after 2008, leading to a 15–20% improvement in fleet-wide fuel efficiency.

Wind-assisted propulsion
Systems such as rotor sales and towing kites can lower fuel use as much as 5%.



Propeller fins and ducts
Propeller upgrades – such as pre-swir find, ducts, and propeller boss cap find – optimise water flow, improving fuel efficiency by 4–6%.

Hull modifications
Applying nanotech or silicone-based coatings lowers biofouling and water resistance enough to cut fuel consumption by 3–5%. Air lubrication systems reduce drag by 4–8%.

Bow reshaping retrofits
Bulbous bow attachments help older ships reduce wave resistance, delivering fuel savings of up to 15%.

Source: PwC analysis.

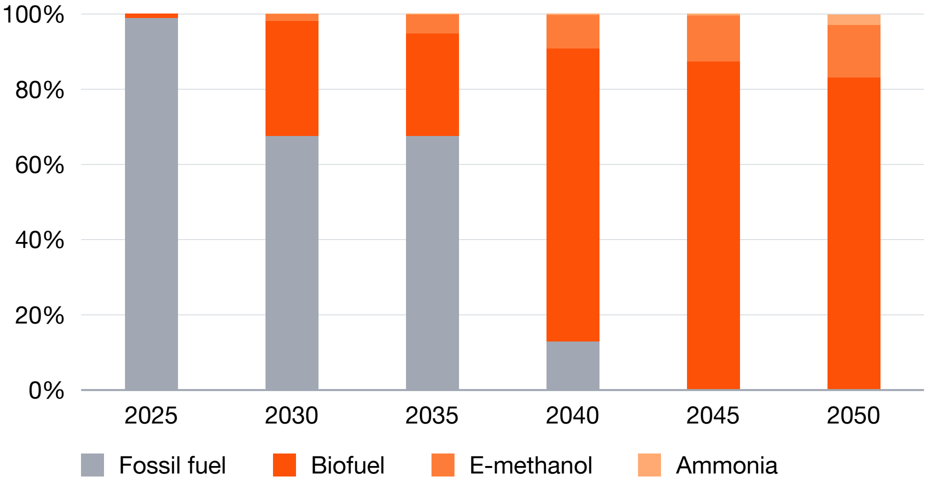
Alternative fuels: the key to full decarbonisation of shipping

There are three main types of alternative shipping fuels: transitional fuels that can reduce emissions in the short term, biofuels made from organic feedstocks, and synthetic fuels derived from compounds produced using renewable energy. The uptake of each type will depend on how quickly the underlying technologies advance and how quickly the industry installs bunkering infrastructure in key locations.

Scenarios based on global 2024 results from the OECM illustrate some of the possibilities. As shown in Figure 5, net-zero emissions in the shipping industry by 2050 would require biofuels to make up the majority of the industry's fuel mix, a sizable proportion of this being e-methanol. The relative significance of these fuels, however, varies widely across different scenarios. This variability makes it important for shipping organisations to strive for alignment on goals and standards, as we discuss later.

Fig. 5 Net-Zero Shipping Fuels: Biofuel-Led Scenario

Achieving net-zero emissions by 2050 would require a rapid shift to alternative fuels.



Note: The chart shows a fuel mix that would enable the shipping industry to reach net-zero emissions by 2050. This is based on the assumption of a medium level of available renewable carbon.
Source: The University of Technology Sydney's Institute for Sustainable Futures (UTS-ISF) (2024).

Transitional fuels could help reduce shipping emissions in the short term, while the infrastructure and technology for other alternative fuels are developed. Of these fuels, liquefied natural gas (LNG) is the most commercially advanced. LNG results in 20% to 23% less "well-to-wake" CO_2 (total emissions produced from extraction through to combustion) than conventional fuels. However, LNG's main component is methane, which is itself a potent GHG. Preventing methane from escaping into the atmosphere is therefore vital if LNG is to deliver on its potential to reduce emissions.

Biofuels are derived from organic materials such as plant biomass and municipal solid waste. They produce 60% to 90% less CO_2, on a well-to-wake basis, than conventional marine fuels. Biofuels also offer convenience: they work in existing marine engines with minimal modifications. Various biofuels are already being blended with conventional fuels or used in their pure form for pilot projects and short-distance shipping, mainly fatty acid methyl esters (FAME) and hydrotreated vegetable oil (HVO). A big challenge with biofuels, though, is availability. **Analysis by DNV** suggests that the amount of biofuel produced for shipping would have to increase tenfold by 2050 to achieve net zero. This, in turn, would require a massive increase in overall biofuel production, and 20% to 50% of the entire global supply – estimated at between 500 million and 1,300 million tonnes of oil equivalent (Mtoe) in 2050 – would have to be allocated to the shipping sector.

> Bio-methanol offers a near-term decarbonisation pathway, but its scalability is constrained by limited biomass availability. Expanding e-methanol production is therefore essential to diversify supply and unlock cost reductions through scale.

Dirk Niemeier
Clean Hydrogen, CCUS and Sustainable Fuels Solutions Leader, Director at PwC Strategy& Germany

Synthetic fuels emit almost no net carbon emissions because they are made from renewable compounds. One type, synthetic methanol, has distinct advantages as a marine fuel. It can be used in many existing engines, and it can be stored using existing methanol-bunkering infrastructure at certain ports. It can be made from biomass (resulting in bio-methanol) or from green hydrogen and captured CO_2 (resulting in e-methanol). Then there's synthetic ammonia: made from green hydrogen and atmospheric nitrogen, it contains no carbon. However, ammonia is corrosive and toxic, and burning it can produce nitrogen oxides (NOx), which are air pollutants. For these reasons, the OECM scenario shown above limit synthetic ammonia to 3% of the shipping sector's 2050 fuel mix.

What about electrification?

For short-distance shipping, electrification provides another way to decarbonise, just as it does with cars, trucks and rail. Progress on electrification is being made at the margins, on vessels such as ferries and river barges. However, electrification has little chance as a practical solution for long-distance and heavy-duty shipping because current batteries are heavy and bulky. Because of this, PwC only modelled the use of liquid fuels and gases because they account for nearly all shipping fuels today and will probably do so for the foreseeable future.

The elements of a sustainable shipping ecosystem

Full decarbonisation of shipping, achieved through the transition to alternative fuels, has much in common with the transition from internal-combustion vehicles to electric vehicles. It requires an entire ecosystem of businesses – suppliers, equipment manufacturers, infrastructure providers, policymakers, financial institutions, engineers, customers – to converge on the same goals, at the same pace. Decarbonisation also opens up countless opportunities for companies to create value in new ways. The following section examines the major shifts that will result from this reconfiguration of shipping.

Policy: accelerating decarbonisation

Regulations are already helping to accelerate decarbonisation in shipping. In particular, two frameworks established by the European Commission are likely to have a major impact. Since January 2024, the EU Emissions Trading System (ETS) has required shipping companies to purchase emissions allowances covering tank-to-wake CO_2 emissions within and between EU and European Economic Area (EEA) ports. The resulting costs create an impetus for shipping companies to decarbonise. FuelEU Maritime, introduced in January 2025, complements the EU ETS by setting GHG intensity limits for ships over 5,000 gross tonnage (GT), aiming for an 80% reduction by 2050. It should be noted that carbon costs imposed by these EU frameworks have been excluded from the modelling undertaken for this article in order to make the results globally comparable.

> Clear and effective regulations are crucial for the maritime transition to net zero, offering a predictable framework that empowers stakeholders to efficiently invest in sustainable technologies and build a stable value chain.
>
> **Takuya Kozumi**
> Executive Officer, NYK Line

At the global level, the IMO has announced plans for two key measures as part of its Net-Zero Framework: a Global GHG Levy and a Global Fuel Standard. The Global GHG Levy would require ship owners to pay for each tonne of GHG emissions. The fees collected would **support** innovation, research, infrastructure, training and technology transfer for the industry's transition to net zero, as well as initiatives to help states that are vulnerable to climate risks. The Global Fuel Standard aims to promote the use of zero-emission fuels by requiring gradual reductions in GHG intensity. These measures are **scheduled** to be discussed in 2026, for adoption a later year.

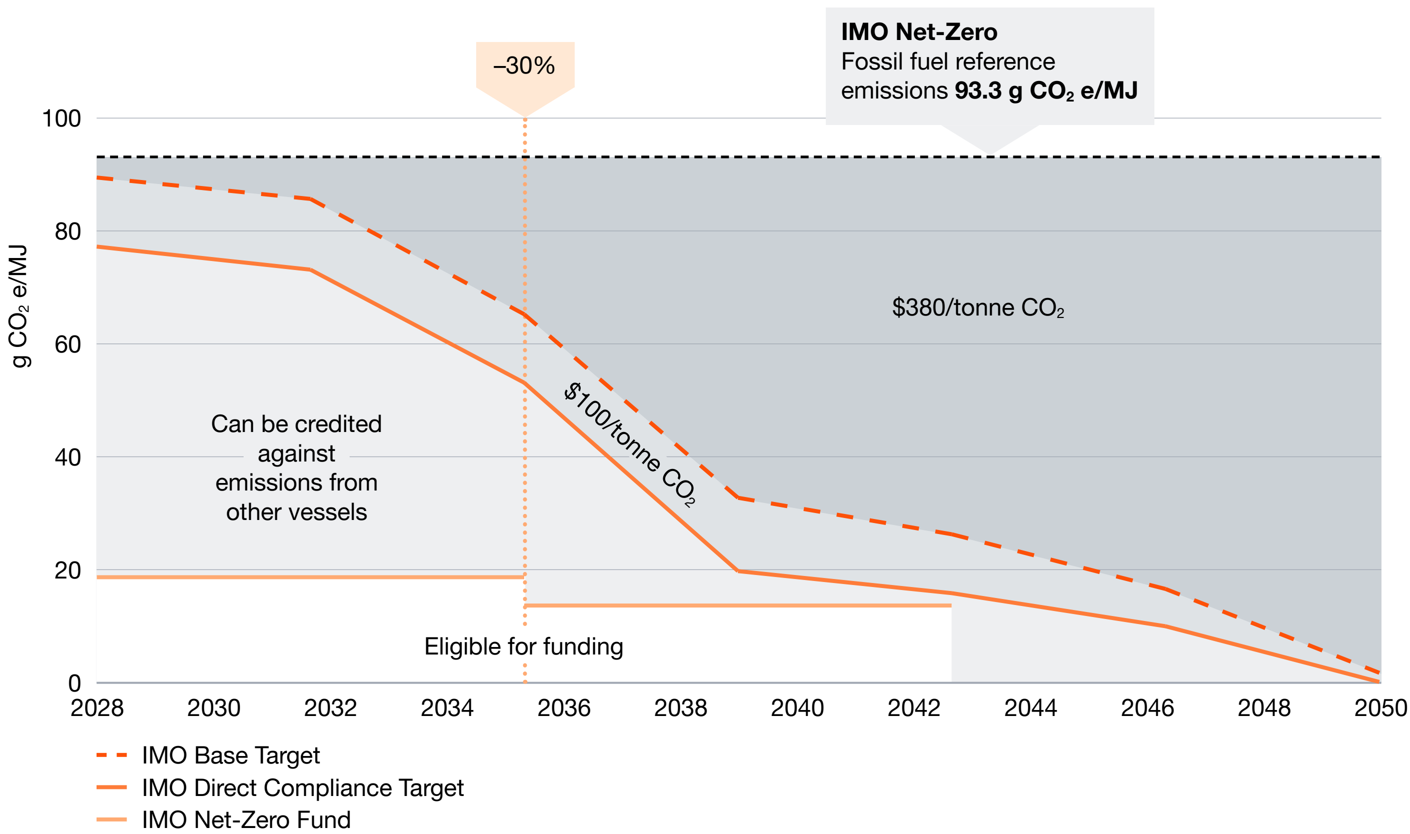
If adopted as planned, the IMO's Global Fuel Standard would introduce compliance levels designed to accelerate the shift to low-emission fuels. Under the current proposal, international ships over 5,000 GT would need to reduce GHG emissions by 65% by 2040, applying a well-to-wake framework that accounts for the full life cycle of fuel emissions. This mechanism would include two target categories with associated charges: a Base Target, which would involve a cost of around $380 per tonne of CO_2 for emissions above the threshold, and a Direct Compliance Target, which would apply a lower charge of approximately $100 per tonne for shortfalls against stricter goals. These targets are intended to create financial incentives for operators to adopt sustainable fuels and technologies.

The framework would also introduce incentive mechanisms to reward early movers. A banking scheme could allow emissions reductions beyond the Direct Compliance Target to be carried forward or transferred to other vessels, while a reward scheme is expected to provide funding for ships achieving CO_2 intensity of no more than 19.0g CO_2e/MJ between 2028 and 2034 and no more than 14.0g CO_2e/MJ from 2035 onwards. As shown in Figure 6, the IMO is aiming for a 30% reduction in GHG intensity by 2035, progressing towards near-zero emissions by the mid-21st century. While the timeline for adoption remains uncertain and subject to ongoing negotiations, these measures – if implemented – would be likely to influence ship design, operational practices and fuel choices worldwide.

> At Höegh Autoliners, we are committed to reducing our carbon footprint. To deliver on this commitment, we are using biofuels and have invested $1.5 billion in twelve dual-fuel, ammonia-ready vessels, with the final four in the series delivered ammonia-capable directly from the shipyard starting in 2027. Regulatory measures, including carbon pricing and support for clean fuels, are essential to scaling sustainable shipping. Without these, the market may not develop at the pace required to limit global warming.

Lise Duetoft
Chief Strategy, People and Digital Officer, Höegh Autoliners

Fig. 6 Emissions reduction targets under the IMO's Net-Zero Framework



Sources: IMO 2025a, IMO 2025b, DNV 2025a, DNV 2025b, DNV 2024, Gard 2025.

Cost and compliance under the IMO's proposed Global Fuel Standard

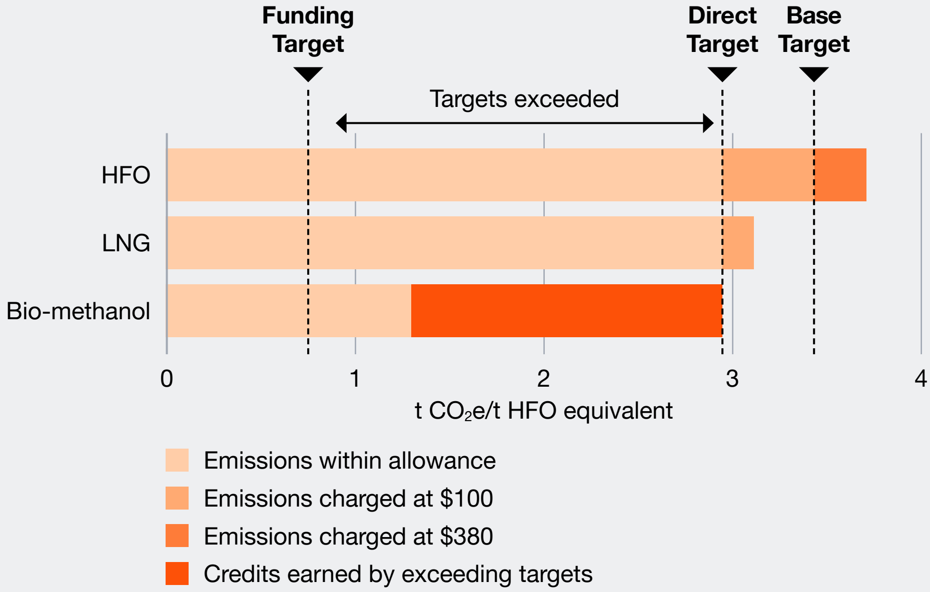
If implemented, the IMO's Global Fuel Standard could significantly influence fuel economics and compliance strategies for shipping companies. Figure 7 compares three fuel options – HFO, LNG and bio-methanol – against the proposed compliance levels for greenhouse gas intensity in 2030.

Under the current proposal, HFO would exceed both the Base Target and the Direct Compliance Target, resulting in penalties of approximately $154 per tonne of fuel. LNG performs better, meeting the Base Target but falling short of the Direct Compliance Target, which would lead to a smaller penalty of around $12.80 per tonne of substituted HFO. Bio-methanol, by contrast, fully meets both targets, making it the best option under the framework. Bio-methanol could also generate credits for surplus reductions – up to 1.6 tonnes of CO_2e per tonne of substituted HFO – which shipping companies could bank or transfer to other vessels, potentially earning rewards for achieving ultra-low emissions.

This highlights the strategic importance of fuel choice in managing compliance costs and leveraging incentives. While the timeline for adoption remains uncertain, anticipating these changes will allow shipping companies to better align their investments with upcoming regulations.

Fig. 7 Compliance costs for different fuels under the IMO's Net-Zero Framework

Reference year: 2030



Sources: PwC Analysis; IMO 2025a; IMO 2025b, DNV 2025a; DNV 2025b, DNV 2024; Gard 2025.

Infrastructure: preparing ports for sustainable shipping

The transition to alternative shipping fuels also requires ports to be retooled with suitable storage and bunkering systems. Methanol can be stored at ambient temperatures, but it calls for rigorous safety protocols. Ammonia is more complex: it must be handled with great care, using supercooled, corrosion-proof equipment.

Nevertheless, the chances of the right bunkering infrastructure being built appear to be good. Some 120 ports, including large ones such as Rotterdam and Gothenburg, now offer methanol bunkering. Ammonia bunkering technology is advancing through pilot projects, and more than 50 initiatives have sprung up to establish green shipping corridors. These multi-stakeholder efforts are intended to standardise fuel types, port infrastructure, ship technologies and routing strategies in ways that favour alternative fuels. The idea is that if shipping companies and port operators have more certainty about their future operating environment, they can invest in new technology with more confidence.

> Biofuels and LNG are already part of our bunkering infrastructure. Methanol and ammonia terminals are currently in an early phase, but have been constructed in Antwerp with operations expected from 2027 onwards.
>
> **Arne Strybos**
> Climate Transition Developer, Hydrogen and CCUS, Port of Antwerp-Bruges

Finance: funding the transition

Converting the world's shipping fleet and port infrastructure to alternative fuels will be a capital-intensive undertaking. For financial institutions, that creates an opportunity, starting with the outlay needed to retrofit or replace the 95% of commercial ships that currently run on conventional fuels. Lloyd's Register found that retrofitting one large container vessel to run on LNG costs approximately $35 million; methanol conversions cost about one third of this figure, according to DNV.

In Europe, regulations require financial institutions to support the shipping sector's transition while favouring owners and operators that can demonstrate credible decarbonisation pathways, robust data and effective management of EU ETS and FuelEU exposure. As more of these requirements take effect, shipping companies' access to capital will increasingly depend on whether they are delivering real emissions-reduction measures, transparent reporting and transition plans in line with requirements.

> "Creating an effective cost allocation system is crucial, not just within the shipping industry but across other industries, and ultimately for society as a whole.
>
> **Keita Akazawa**
> Corporate Sustainability Division General Manager, Mitsui O.S.K. Lines

Technology: enabling production of sustainable shipping fuels

To produce synthetic fuels for ships, energy companies must have large, reliable supplies of “green” CO_2 that has been pulled from the atmosphere or biogas plants. Cycling this atmospheric CO_2 into synthetic fuel means that there are no net carbon emissions when the fuel is burned. Scenarios based on global 2024 results from the OECM, developed in line with a 1.5°C warming pathway, suggest that making synthetic fuel for the maritime sector alone will require an average of 136 million tonnes of CO_2 per year in 2050.

That amount far exceeds what carbon-capture systems produce now. The IEA estimates that bioenergy with carbon capture and storage (BECCS) installations collect around 2 million tonnes of CO_2 annually, while direct air capture (DAC) systems collect just 10,000 tonnes per year. Accelerating the rollout of carbon capture will therefore be essential to decarbonising the shipping sector.

Scaling renewable fuels for maritime transport will depend on three distinct constraints: commercial, technical and regulatory. From a commercial perspective, biomass availability could become a critical issue. By 2050, the maritime sector may require as much as 12 exajoules (EJ) of a global biomass allocation of 100 EJ across all sectors. Effective allocation of biomass resources among competing industries – such as chemicals, aviation and shipping – would be essential to ensure sufficient feedstock for biofuels such as bio-methanol and HVO.

On the technical side, availability of renewable carbon could represent one of the most significant challenges. Producing synthetic fuels such as e-methanol and e-ammonia would require approximately 136 million tonnes of CO_2 annually by the mid-21st century, captured through technologies such as DAC and BECCS. These technologies are currently in their infancy, and substantial investment would be needed to scale them to meet this level of demand. Figure 8 outlines the two broad renewable fuel pathways available to the maritime sector – e-fuels and biofuels – along with their respective feedstocks and GHG savings compared with heavy fuel oil (HFO).

Regulatory considerations could have a significant influence on the adoption of ammonia as a marine fuel. Although ammonia offers a carbon-free combustion profile, it also creates a major concern in the shape of nitrous oxide (N_2O), a GHG nearly 300 times more potent than CO_2 that can be generated in the combustion process. Burning ammonia also produces nitrogen oxides (NOx), which contribute to acid rain and smog, while ammonia slip – unburned, highly toxic ammonia released into the atmosphere – can form hazardous particulate matter. In addition, ammonia’s corrosive and toxic nature poses safety risks that may require stringent precautions, such as human-free refuelling systems and specialised ship designs.

The potential commercial, technical and regulatory challenges are thus significant. However, if they can be addressed through coordinated action and innovation, renewable fuels have the potential to form the backbone of a fully decarbonised shipping sector.

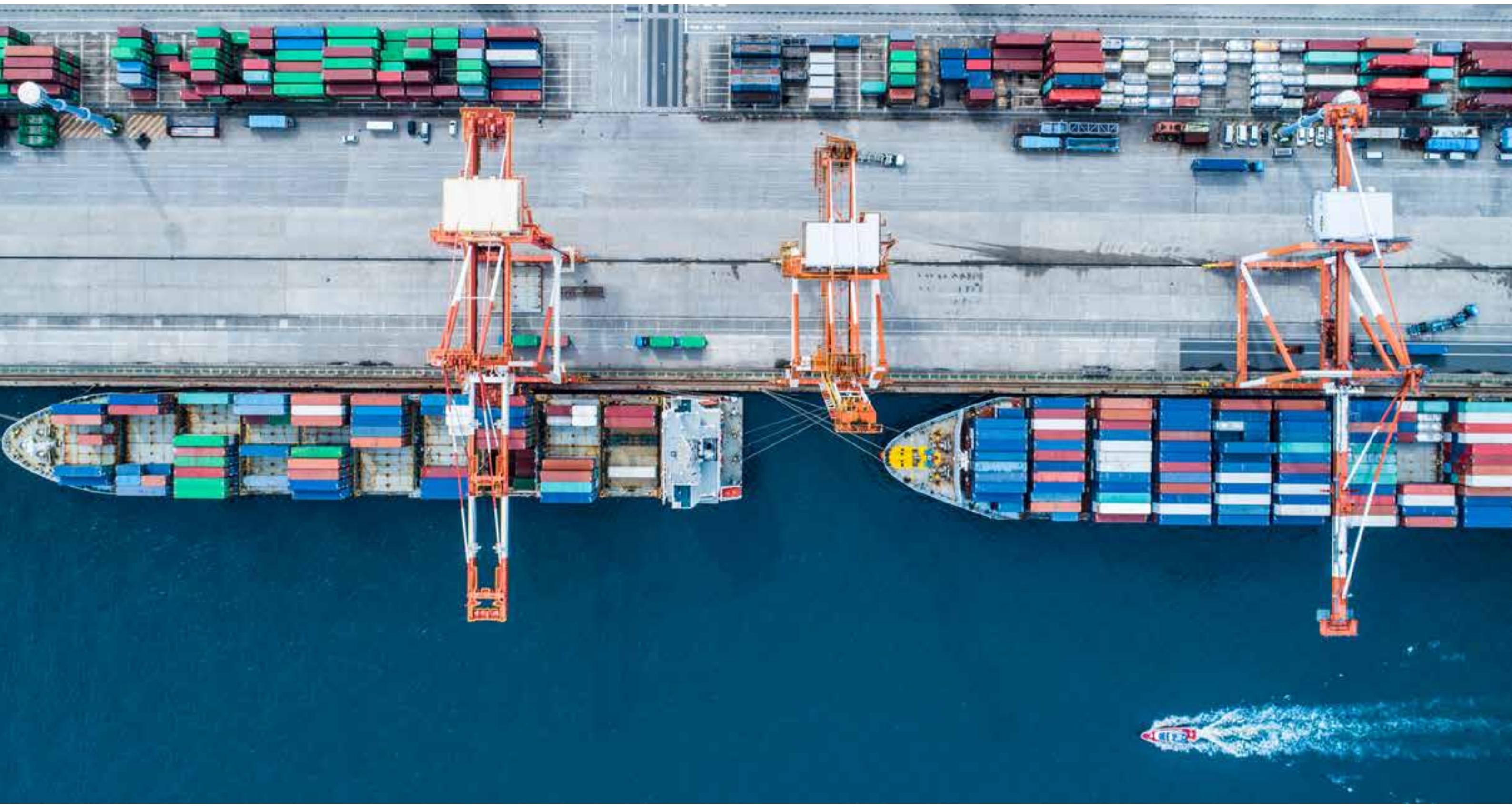
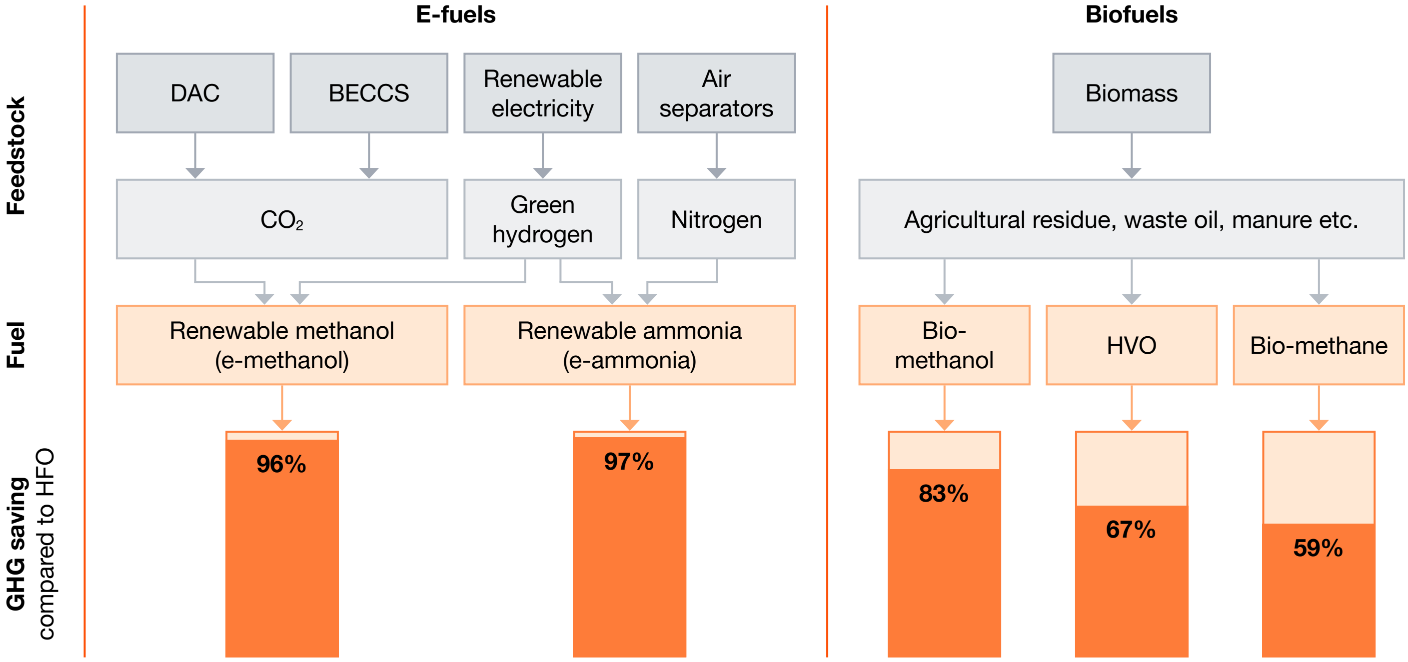


Fig. 8 Renewable fuel pathways for the maritime sector

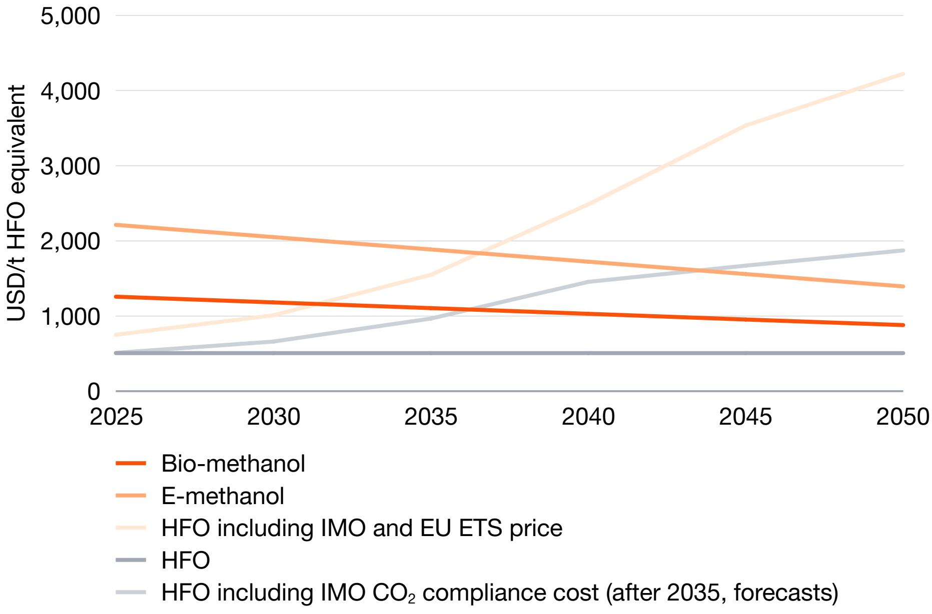


Notes: The OECM assumes availability of 100EJ of biomass to supply biofuels and chemicals to critical sectors (chemicals, aviation, maritime, high-temperature industrial heating). The OECM assumes availability of 2.4Mt to 381Mt of carbon for maritime fuels, averaging 136Mt per year by 2050 (fuels produced from renewable carbon for the chemical, maritime and aviation sectors).
Sources: UTS and PwC analysis, EU 2018, Lloyd's Register 2026.

Fuel price trajectories could change significantly by 2050 if renewable energy becomes more affordable and technologies such as carbon capture and electrolysis advance as expected. Figure 9 illustrates projected price trends for conventional and alternative fuels between 2025 and 2050, expressed in USD per gigajoule (GJ). HFO is likely to become increasingly expensive if compliance costs under the IMO and EU regulations are applied. In contrast, the prices of green fuels such as bio-methanol are projected to fall over time, first narrowing the cost gap with fossil fuels and then falling below HFO in 2035.

Regulations such as FuelEU Maritime and the IMO's proposed greenhouse gas levy may further raise the effective cost of carbon-intensive fuels, making low-emission alternatives more competitive. If these trends materialise, shipping companies that invest early in green fuel infrastructure and dual-fuel vessels would gain a strategic advantage. By 2050, the combined effect of technology-driven cost reductions, economies of scale and carbon pricing could make sustainable fuels the more economical choice for global shipping.

Fig. 9 Projected fuel price trends, 2025–2050



Note: CO_2 prices have been calculated by GHG intensity based on the IMO's Net-Zero Framework targets for 2040 and 2050.
Sources: ShipUniverse 2025, DNV 2025, Maritime LNG Report 2025, Lloyd's Register 2025.

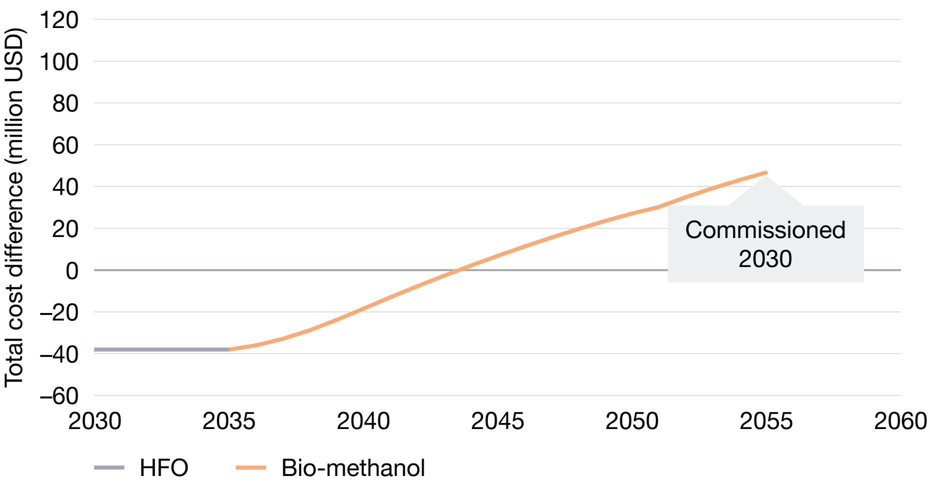
Investment by shipping companies in response to current regulations

NPV analyses are already highlighting the shifting economics of future vessel investments. As an example, we modelled investment in a dual-fuel ship and an HFO-only ship, and compared the operating costs of the two over time. Assuming that the IMO regulations are implemented in 2028 (and, thus, a CO_2 surcharge is applied to HFO), the analysis shows that the dual-fuel ship (and, therefore, having the choice between conventional fuel and low-carbon fuel) is already the more economical option, as well as being more environmentally friendly.

Figure 10 below shows that investing in a dual-fuel ship is disadvantageous from the initial cost perspective. In our case, this higher total cost compared to an HFO-only ship persists for several years (until 2044) – we assume that shipping companies will continue to bunker HFO so long as it remains cheaper. But when the IMO regulations kick in and a surcharge is applied to HFO, already in 2035 HFO and biomethanol might reach price parity. After 14 years the introduction of the surcharge, the total cost of the HFO-only ship will have overtaken that of the dual-fuel ship. This calculation assumes that the IMO regulations will be implemented as planned.

The key implication of this analysis is that investment decisions being made today need to be taken in light of potential changes. Global shipyard orderbooks are nearly full, the lead time between placing an order and vessel delivery can be up to five years, and fuel flexibility may become a competitive advantage. Far from being an idealistic green pursuit, the current surge in orders for dual-fuel ships is being driven by tangible economic incentives.

Fig. 10 Total cost difference of a dual-fuel ship compared to a conventional ship



Assumptions: Utilization of 75%, WACC 9%, 25-year life, capex of $226m (conventional)/ $260m (dual-fuel), 15% premium for dual-fuel vessel
Sources: Lloyd's Register Group Limited 2026, PwC analysis.

Next steps for shipping ecosystem players

Evolving regulations and technological advancement are turning decarbonisation opportunities into a business reality across the entire maritime transport ecosystem, putting real value into play. Achieving the industry's net-zero ambitions will require coordinated action from all ecosystem players – not any single stakeholder group alone. As the figure below illustrates, each player has a distinct and critical role to play, and there are concrete steps every one of them can take now to gain an advantage while accelerating the collective transition.

Fig. 11 All maritime transport ecosystem players now have to act consistently in order to prepare for the future

Shipping ecosystem players

Fuel producers
- Build up sustainable fuel capacities
- Realize best cost production

Shipping transport customers
- Use sustainable shipping for Scope 3 reductions
- Promote sustainably shipped products

Regulators
- Provide globally harmonized regulation
- Provide incentives for first-movers

Shipbuilders and engine OEMs
- Accelerate development of dual-fuel ship design
- Scale engine solutions for alternative fuels

Cruise travel "operators"
- Build differentiated "green cruise" offerings
- Exploit willingness to pay of certain customer groups

Shipping companies
- Invest forward-looking in dual-fuel readiness
- Understand willingness-to-pay and green-premium models of customers

Capital providers
- Expand green-financing instruments
- Implement Accountability Frameworks that support adoption of emission-reduction

Port operators
- Build and operate safe bunkering infrastructure for methanol and ammonia

> Current trends in low-carbon marine propulsion indicate a preference for new vessel construction over retrofitting, with LNG dual-fuel engines being a popular choice among ship owners.

Dr Florian Gruschwitz
Senior Business Development Manager, Everllence

Across the Ecosystem: Act Now, Act Together

The transition to sustainable shipping demands that every player in the maritime transport ecosystem steps up in parallel, each contributing where their influence and capabilities matter most.

Shipping companies sit at the heart of the transition. Replacing vessel fleets to run on alternative fuels requires forward-looking investment now – given a cargo ship's lifetime of 25+ years – to avoid future non-compliance penalties. Companies must carefully assess which alternative-fuel vessels to choose, considering fuel availability, technological maturity and bunkering infrastructure, while leveraging financial incentives to close the investment gap. On the commercial side, product-aware pricing and transparent cost communication can turn sustainable shipping into a demand-driving product feature rather than just a compliance cost.

To mention some of the other players only: fuel producers need to build sustainable fuel capacities at scale in politically stable, cost-competitive regions; shipbuilders and engine OEMs must accelerate dual-fuel ship designs and scale engine solutions for alternative fuels; port operators are essential in building safe bunkering infrastructure for methanol and ammonia and expanding renewable-fuel storage capacity; capital providers must expand green-financing instruments tied to credible emission-reduction strategies; and regulators need to deliver predictable, globally harmonised regulation alongside meaningful incentives for first-movers. On the demand side, shipping transport customers – including retailers and consumer-facing brands – can accelerate the shift by using sustainable shipping for Scope 3 reductions, while cruise travel operators can differentiate through "green cruise" offerings using sustainable fuels.

A Collective Imperative

Sustainable shipping is increasingly proving to be a manageable – and in some cases minimal – additional cost for consumers. As regulations advance and low-carbon technologies mature, greener shipping could well become an economically sound choice, as well as an environmental necessity.

But realising this potential requires all ecosystem players to act consistently and collaboratively – ensuring that technology advances, infrastructure is built, and capital flows into viable alternative-fuel solutions. Those who invest early will be best placed to create both financial and strategic value.

> Investment decisions in green marine fuels are currently being affected by a high degree of uncertainty. Volatile energy prices, unclear long-term regulations and fragmented certification standards are making reliable capital allocation difficult.

Burkhard D. Sommer
Head of the Maritime Competence Center, Partner at PwC Germany

Methodology

For this article, shipping decarbonisation pathways were constructed based on research funded by PwC Germany and conducted in collaboration with the University of Technology Sydney's Institute for Sustainable Futures (UTS-ISF) using the One Earth Climate Model. The pathways are based on the 1.5°C scenarios that UTS-ISF researchers published in 2024, which include sectoral pathways at the global level and for the G20 countries.

The costs and consumer price impacts of green shipping were modelled by PwC under the following assumptions:

Vessels and routes: Representative vessel types (e.g. container ships, pure car and truck carriers, bulk carriers, cruise ships) and typical trade routes (e.g. Shanghai-Rotterdam for container ships, Bremerhaven-Dubai for pure car and truck carriers) were based on real-world data. Key parameters include vessel speed, fuel consumption, capital expenditure for dual-fuel retrofits, and operational profiles.

Fuel conversion and price: Due to the difference in energy density between heavy fuel oil (HFO) (40 megajoules per kilogram [MJ/kg]) and methanol (19.9MJ/kg), achieving the same energy output as a given amount of HFO requires roughly twice the mass of methanol. This difference was taken into account in the modelling. Future fuel price trajectories (2028–2030) were modelled using published data and scenario assumptions, incorporating expected declines in green fuel costs due to technological advances and new regulations.

Carbon price: Prices were applied to ship emissions in line with the mechanism proposed by the International Maritime Organization's (IMO's) Net-Zero Framework. This pricing mechanism sets out a tiered system that will charge ships for emissions in excess of certain thresholds for greenhouse gas (GHG) intensity between 2028 and 2035.

Product transport simulations: The incremental cost of sustainable shipping was modelled for representative products using shipping costs as a share of the total product cost and the projected impact of higher fuel and compliance costs.

Emissions reduction estimates: Life-cycle GHG emissions reductions were estimated for each fuel and vessel scenario, using well-to-wake emissions factors and regulatory thresholds.

Capital expenditures and operating expenditures: Cost assumptions for vessel retrofits and new vessels were based on industry benchmarks (e.g. dual-fuel methanol engines were assumed to cost 15% to 20% more than conventional engines).

Route and product selection: The analysis focuses on major global trade routes and representative product categories.

To validate these assumptions, we interviewed stakeholders from shipping companies, port authorities and fuel suppliers. The modelled results were also cross-checked against recent studies and market data to ensure robustness and credibility.

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The authors would like to thank **Ruben Dario Galvan, Anselm von Urach, Ioannis Hatzilidis, Anica Moritz** and **Dimitrios Sakipis** for their contributions to this article.

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