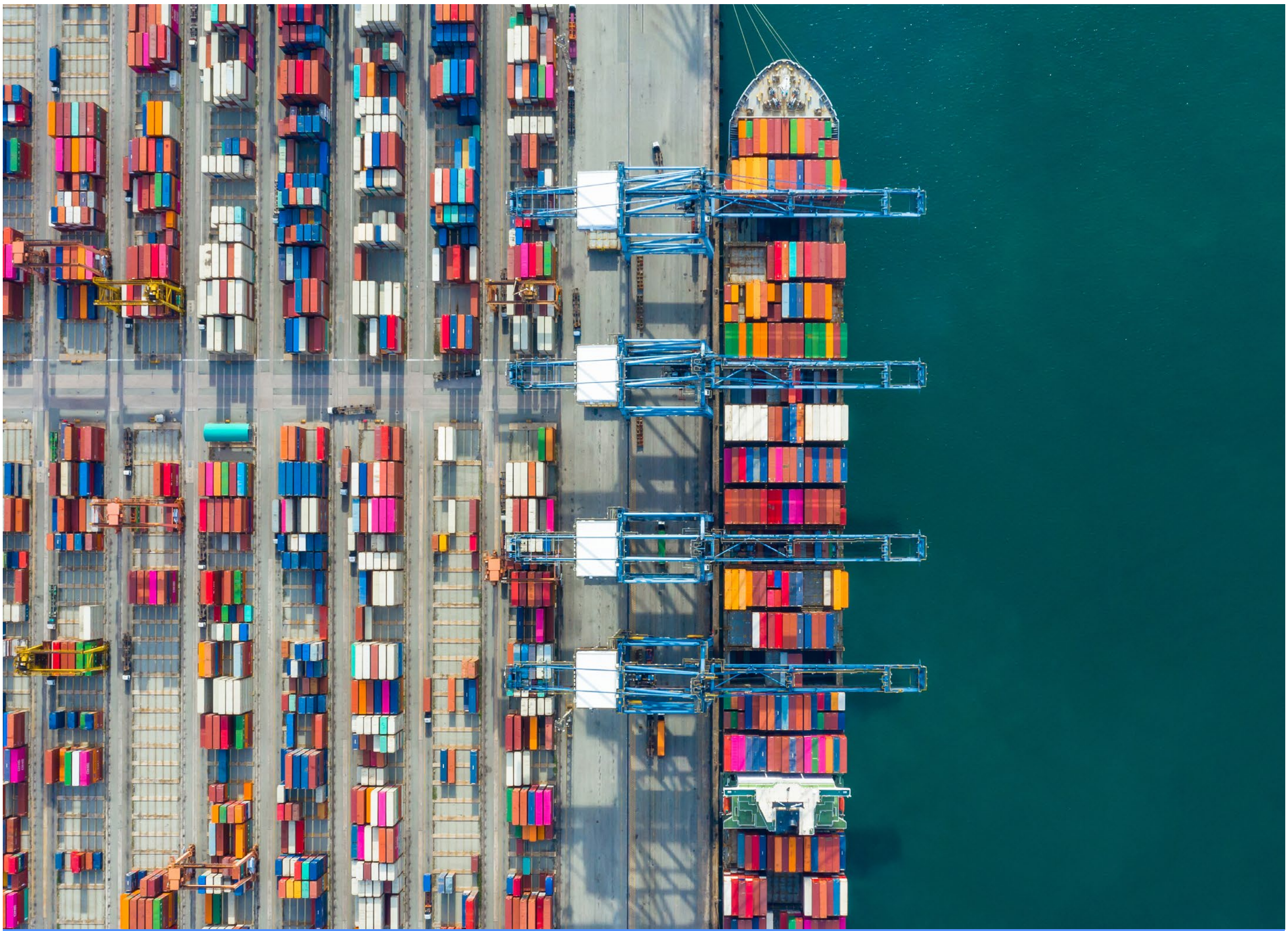
5

Shipping industry net-zero tracker

Long-term emissions reduction relies on clean hydrogen fuels like ammonia and methanol, while short-term solutions include LNG and biofuels.



- Increased vessel size, improved design efficiency and operational changes like slow steaming have contributed to emission intensity reduction. Efficiency improvements in the short term are also enablers for the long-term transition.
- Continued reliance on fossil fuels remains a major barrier, as they make up nearly all the fuel mix in the sector.

2%
Increase in absolute CO_2 emissions (2022-2023)

1%
Increase in emission intensity (2022-2023)

1%
Increase in demand (2022-2023)

SHIPPING

Key performance data 2023[150,151,152,153]

2%	Contribution to global CO_2e emissions
0.86 Gt CO_2e	International shipping CO_2 emissions (2023)
1.2%	Emissions reduction (2019-2023)
12.4	Emissions intensity (grams per tonne miles, 2023)
99%	Fossil fuels in the fuel mix (2022)
~1.4 times	Demand increase in IRENA's NZE scenario by 2050, compared to 2023
$2.6 trillion	Investment required for 2050 net zero

Performance summary

- The absolute direct CO_2e emissions for shipping were 0.87 Gt in 2019, decreasing to 0.80 Gt in 2020, then increasing to 0.84 Gt in 2022 and 0.86 Gt in 2023.[154] Thus, there has been a 2% increase in absolute CO_2e emissions from 2022 to 2023.
- The industry has reduced emission intensity by 4.6% in the 2019-2023 period.[155] This is mainly driven by speed reduction (slow steaming) especially in bulk carriers, chemical tankers and oil tankers, increase in average ship size, and improvements in ship design efficiency. However, emission intensity increased by 1% from 2022 to 2023 due to the use of inefficient routes and port congestion.

Future emissions trajectory

- As per the IEA's Stated Policies Scenario, which is considered to be the business-as-usual scenario, the absolute CO_2e emissions are expected to be 0.90 Gt in 2030 (5% increase vs. 2023), 0.85 Gt in 2040 (0.2% decrease vs. 2023), and 0.80 Gt in 2050 (7% decrease vs. 2023).[156]
- The 2023 IMO GHG-reduction strategy, which is considered to be the net-zero emissions scenario, aims for at least 20%, striving for a 30% reduction in total annual GHG emissions by 2030 (vs. 2008) and net-zero emissions by or around 2050 for the shipping industry.[157] It also aims for at least 5%, striving for 10% of fuel used by the shipping industry to be zero or near-zero-emission fuels (ZEFs) by 2030.[158]

Readiness key takeaways

Technology	3	–	– Methanol engines are in early adoption stage (TRL 9).[159] – Hydrogen- and ammonia-powered engines are in large prototype stage (TRL 5 and 6).[160] – Battery electric (TRL 9)[161] and proton-exchange membrane (PEM) fuel cell technologies (TRL 8)[162] are also in progress.
Infrastructure	2	–	– To meet IMO targets, approximately 95% of energy from clean hydrogen-based fuels (like ammonia and methanol) is required by 2050, which will require 72 MTPA of clean hydrogen capacity. Currently, 99% of energy used comes from fossil fuels. – The current supply of low-emission fuels is limited. – The infrastructure readiness score remained the same as last year due to limited progress.
Demand	3	↑	– Only 4% of the 100 near-zero-emission shipping fuel plants needed by 2030 (as per MPP) are currently financed.[163] However, 132% of the plants needed were announced, which contributed to increase in the demand readiness score.[164] – The B2B green premium is high, at 30-80%, posing a challenge for ship owners to absorb the cost of a low-emission freight. While the business-to-consumer (B2C) premium is low, at 1-2%, it is a minor component of the final retail price of products.
Capital	1	–	– Achieving net zero by 2050 for shipping requires approximately $2.6 trillion,[165] out of which around $2 trillion is required for ZEFs production facilities and around $0.6 trillion to retrofit the existing fleet with ZEF-compatible engines. – Margins are low for the sector; it is difficult to raise investments in decarbonization due to low profitability. – The capital readiness score remained stagnant due to lack of substantial progress.
Policy	2	–	– To meet IMO targets, policies should set production goals for zero-carbon fuels, and establish operational, bunkering and safety standards. – Several proposals have been made to IMO to introduce economic measures and how they can be designed. For example, the World Shipping Council proposed a "green balance mechanism" in 2024 to help close the gap between low-carbon fuels any fossil fuels.[166]

Sector priorities

Company-led solutions

Mid-term (by 2030)

- Adopt new fuels derived from clean hydrogen at scale and continue exploring biofuels for a transition period, since biofuels are expected to form approximately 8% of fuel mix by 2030 as per the IEA's NZE scenario.[167]
- Improve efficiency measures reducing the emission intensity through engine improvements, operational behaviour and design and hull options. Energy efficiency is expected to reduce emissions by 20%.[168]

Long-term (by 2050)

- Develop and deploy next-generation ships that run on zero-carbon fuels, since hydrogen-based fuels are expected to form approximately 66% of fuel mix by 2050 as per the IEA's NZE scenario.[169]
- Form partnerships with fuel providers to deliver alternative clean fuels.

Ecosystem-enabled solutions

Mid-term (by 2030)

- Expand the production and availability of low- and zero-carbon fuels like green ammonia, hydrogen and sustainable biofuels.
- Develop cold ironing infrastructure to provide shore power to ships while docked in port.
- Develop bunkering technologies and infrastructure to support next-generation ships that run on zero-carbon fuels.

Long-term (by 2050)

- Develop infrastructure to support ships using clean hydrogen-based ZEFs including ammonia and methanol. Ammonia is expected to form approximately 50% and methanol approximately 3% of fuel mix by 2050 as per the IEA's NZE scenario.[170]

Performance

The sector currently accounts for 2% of global CO_2e emissions. Fuel combustion during maritime operations has a major contribution to emissions in the shipping sector. Thus, the fuel mix used is a critical driver for emission intensity.

TABLE 6 **Shipping industry performance**

Performance metric	Change (2019-2023)
Industry output	+3.6%[171]
CO_2e emission intensity	-4.6%[172]
Total CO_2e emissions	-1.2%[173]

In the last five years (2019-2023), shipping saw an increase in global demand, while the CO_2e emission intensity (CO_2e emissions per cargo ton mile) saw a reduction of 4.6%. This decrease can be attributed to several key factors:

1. **Increase in average ship size**: The increase in average ship size across various ship types played a crucial role in reducing emission intensity.
2. **Slow steaming**: The intentional reduction in vessel speeds, known as "slow steaming" for bulk carriers, chemical tankers, container ships and oil tankers significantly contributed to lowering emission intensity.
3. **Improvements in design efficiency**: Significant advancements in the overall design efficiency of oil tankers, bulk carriers and chemical tankers led to improvement in the energy efficiency of ships, and hence further contributed to the reduction in emission intensity.

However, these improvements in efficiency, speed and size optimization alone will not be sufficient to achieve net-zero targets. In addition, ship owners are confronted with the challenge of an ageing fleet, with the global fleet averaging 22.2 years of age in 2023.[174] This presents two key issues: firstly, there is a need to introduce new vessels that run on ZEFs to replace older ships, and secondly, the existing ships need to be retrofitted with dual-fuel engines to enable operation on ZEFs.

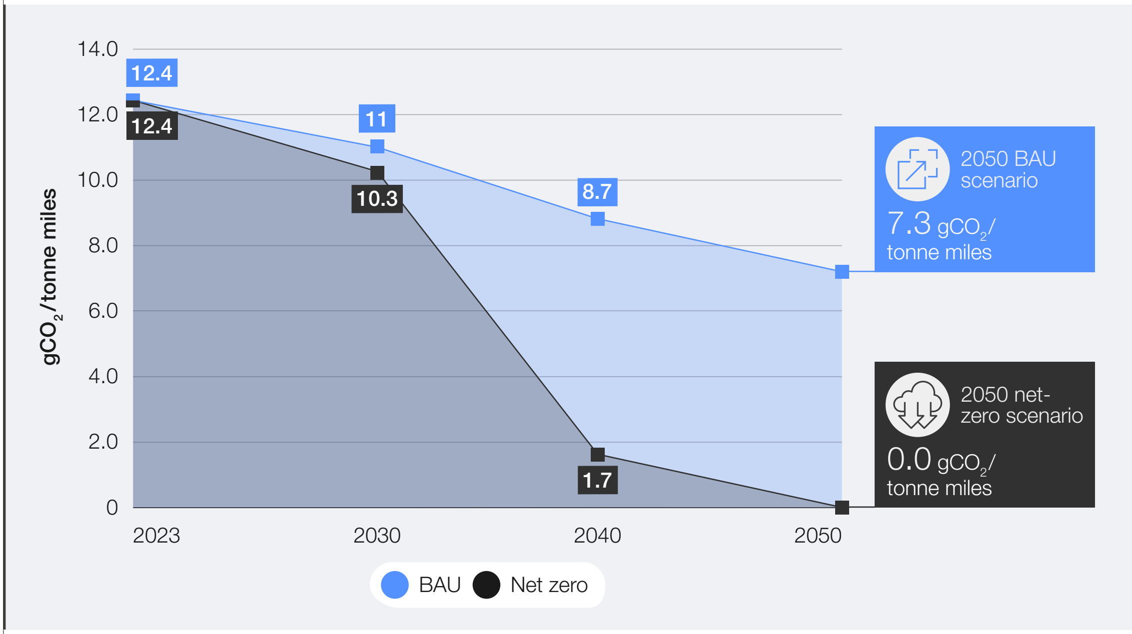
The fuel mix remains heavily dependent on fossil fuels, accounting for approximately 99% of total energy consumption. In 2022, heavy fuel oil (HFO) comprised 56% of the fuel mix, an increase from 49% in 2021, driven by a decline in the use of light fuel oil (LFO) and liquified natural gas (LNG). LNG represents approximately 6% of the fuel mix, while methanol usage remains minimal, representing less than 1% of the overall fuel mix. A substantial change in the fuel mix trajectory is required to effectively eliminate Scope 1 emissions.

Therefore, it is imperative to promote the production and use of clean hydrogen-based ZEFs. Yara Clean Ammonia, North Sea Container Line and Yara International formed a strategic partnership to develop the world's first container ship powered by clean ammonia as a fuel source in 2023.[175] Maersk launched its first methanol-powered container ship in 2024.[176] In collaboration with MAN Energy Solutions, MITSUI E&S successfully tested the world's first hydrogen-powered marine engine in 2024.[177]

Readiness

FIGURE 29

Emission intensity trajectory for shipping sector



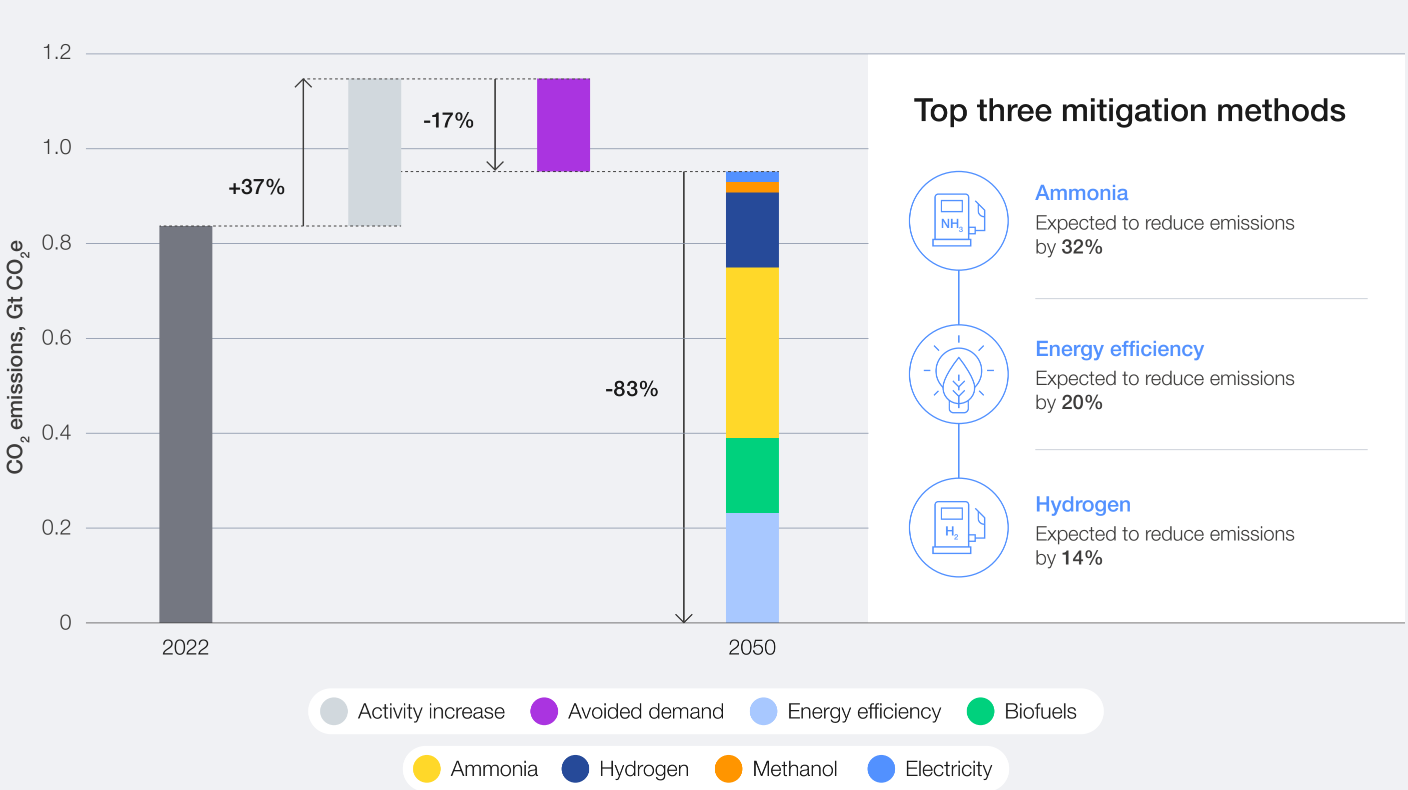
Source: Accenture analysis derived from IEA and IMO.

Overall shipping demand is expected to grow by 37% by 2050 as per the IRENA 1.5 degree scenario.[178] Dry bulk, containers, chemicals and gas tankers will account for most of the growth in shipping demand. Increasing international trade, industrialization and urbanization in emerging markets, and growth in global population (leading to rising consumption and infrastructure requirements) are expected to be the main drivers for demand growth.

Thus, the industry needs to act quickly on decarbonization to ensure reduction in emission intensity and to offset the increase in demand. The key mitigation pathways are expected to be use of hydrogen-derived alternative fuels in the fuel mix and increasing the energy efficiency.

FIGURE 30

Decarbonization levers and top mitigation methods (IRENA's NZE Scenario)



Source: Accenture analysis derived from IRENA and IMO.

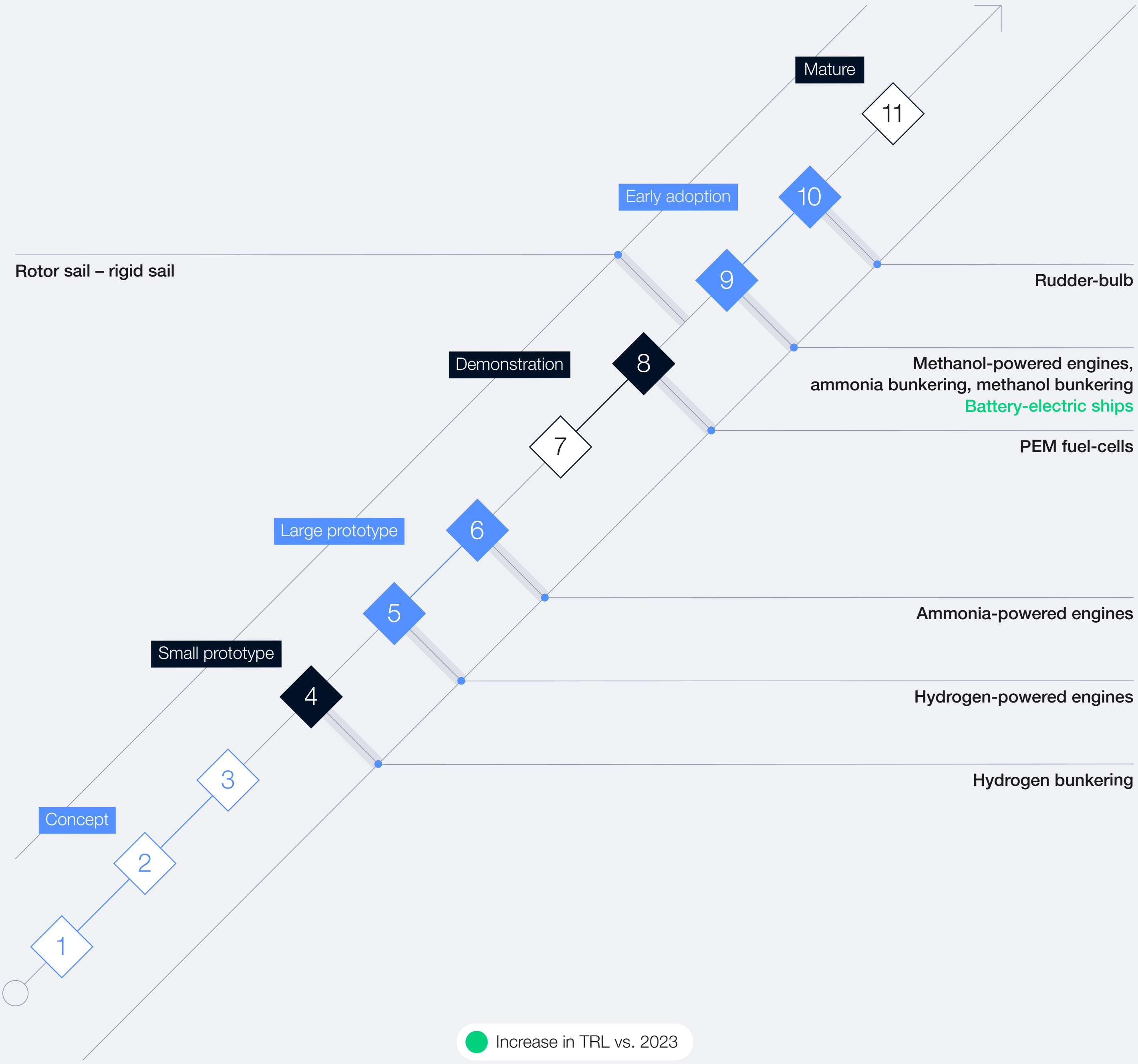
3

SHIPPING

Technology

Technologies to implement the decarbonization levers are at different readiness levels. Three key pathways are currently available: zero emission fuels and propulsion technologies, low-emission transition fuels and energy efficiency.

FIGURE 31 **Decarbonization TRLs**



Source: Accenture analysis derived from data from IEA ETP Clean Energy Technology Guide.

Technology pathway 1:
ZEFs and propulsion technologies

Hydrogen, ammonia and methanol produced using low-carbon hydrogen have up to 99% GHG emission reduction benefits compared to low-sulphur fuel oil (LSFO).[179] The switch to alternative fuels will come at a cost. The ship owners' total cost of ownership (TCO) is expected to be 40-80% higher for methanol-powered ships and 30-70% higher for ammonia-powered ships, compared to ships running on LSFO, based on future cost projections.[180] Since methanol combustion generates CO_2, it is important to mitigate these emissions, which can be done by using CCS technology. This could lead to overall negative emissions if biogenic CO_2 is used for producing methanol, and the captured CO_2 is stored permanently afterwards. At present, the production of clean hydrogen-based fuels for the shipping sector remains primarily in the demonstration phase, with full-scale commercial deployment yet to be realized. Advancements have been made with the expansion of green hydrogen production facilities in China and the US, but production is stalling in Europe. H-TEC SYSTEMS, a subsidiary of MAN Energy Solutions has established a manufacturing facility in Germany for PEM electrolysis stacks to produce green hydrogen in 2023.[181]

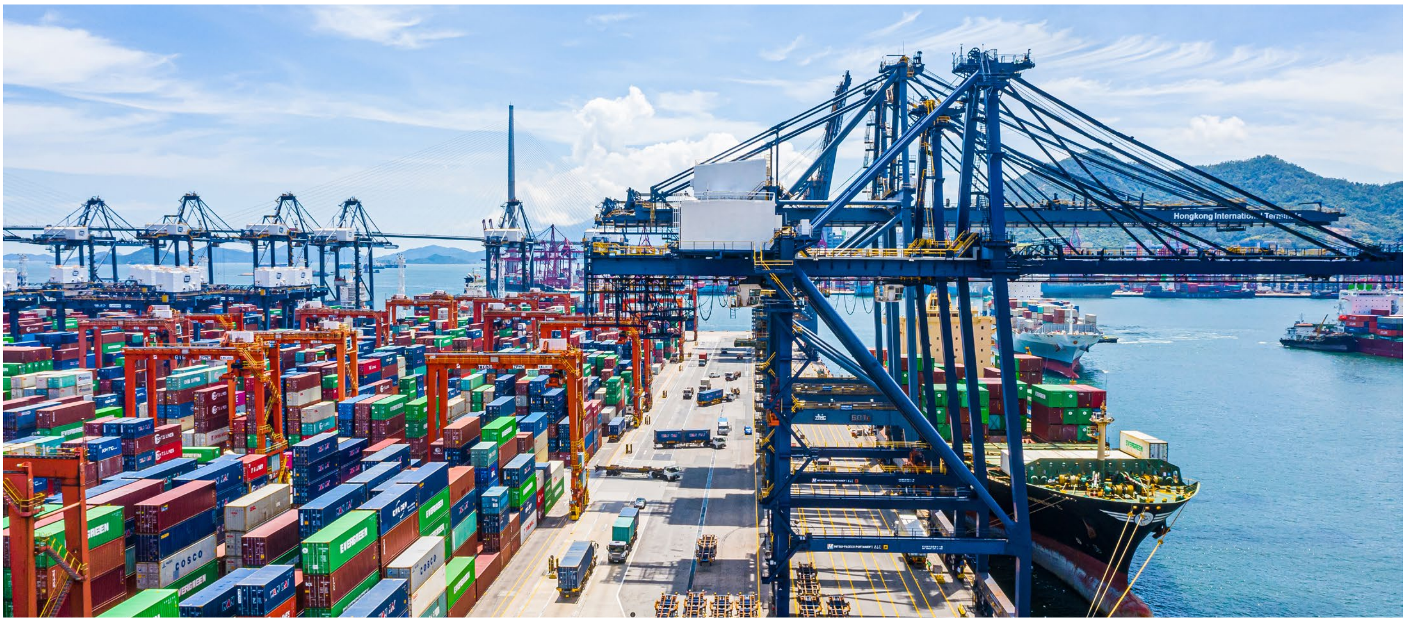
The development of a ZEF-powered shipping fleet is essential for the industry to meet its net-zero emissions targets. Methanol-powered vessels are in early adoption stage (TRL 9),[182] and while they have already been commercialized, they have not been adopted at scale. Hydrogen- and ammonia-powered engines are in large prototype stage (TRL 5 and 6).[183] Battery-electric ships, in which the power of propulsion comes from batteries, are in early adoption stage (TRL 9),[184] and PEM fuel cells are in demonstration stage (TRL 8)[185] for small and medium vessels.

Technology pathway 2:
Low-emission transition fuels

While ZEFs are expected to lead the industry towards its net-zero targets, low-emission transition fuels like LNG and biofuels will be important to support emission reduction until the production and use of ZEFs reaches desired levels. LNG-fuelled ships have up to 21% GHG (well-to-wake) emission reduction benefits as compared to oil-based marine fuels.[186] The ship owners' TCO is expected to be only 0-8% higher for LNG-fuelled ships, and 10-30% higher for ships powered by biofuels, compared to ships running on LSFO, based on future cost projections.[187] Advancements have been seen in expansion of biofuel production. Finnish biofuel producer Neste started commercial production at its renewable fuels' expansion project in Singapore in 2023.[188]

Technology pathway 3:
Energy efficiency

Improving the energy efficiency of ships is a key lever for emissions reduction for the industry, and several technologies are being developed to optimize the energy consumption of ship engines. For example, the use of sails to harness wind power has demonstrated a 5-8% reduction in shipping power consumption, and this technology is currently in demonstration to early adoption stage (TRL 8-9).[189] Another example is the use of rudder bulbs and ship propellers, which can prevent loss of energy by reducing drag. These technologies are expected to reduce ships' fuel consumption by 10% and are in early adoption stage (TRL 10).[190] The use of different types of fuel cells – such as high temperature proton exchange membrane fuel cells (HT-PEMFC), molten carbonate fuel cells (MCFC) and solid oxide fuel cells (SOFC) – is also being considered, since fuel cells are more energy efficient than internal combustion maritime engines and do not emit pollutants.



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2 Infrastructure

To meet the 2050 net-zero targets, a clean hydrogen capacity of 72 MTPA[191] will be required to produce ZEFs. This will have a 95% share of the total fuel mix in 2050 as per the Global Maritime Forum.[192] Shipyard capacities will also need to be expanded to accommodate the new dual-fuel and ZEF-compatible ships. The first ship-to-ship transfer of ammonia in an operational port environment was successfully completed in 2024, a result of the collaboration between Yara Clean Ammonia, Pilbara Ports Authority and the Global Centre for Maritime Decarbonisation (GCMD).[193]

With the addition of new ZEF-powered ships to meet the 2050 net-zero targets, it will be crucial to develop the supporting bunkering infrastructure for different ZEFs. In 2050, 95% of the fuel mix is expected to be ZEFs, which will require a bunkering capacity of approximately 913 MTPA.

FIGURE 32 **Infrastructure for decarbonization capacity**

	Current capacity used	Capacity required (2050)
Clean hydrogen production	Less than 1 MTPA	72 MTPA
CO_2 transport and storage	Less than 1 MTPA	135 MTPA
Bunkering	Less than 1 MTPA	913 MTPA

Source: Accenture calculations based on GMF.

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3 Demand

There is a lack of clear demand signals from the market, particularly around customers' willingness to pay. For instance, the exact fuel requirements to achieve the net-zero targets are still unclear to fuel producers and ship developers. Due to this, companies are hesitant to develop new ZEF-powered engines and sign long-term fuel-offtake agreements. Moreover, carriers are currently used to buying fuel on the spot and expect the cost of ZEFs to decrease in the future, which reduces the attractiveness of long-term fuel-offtake agreements.

The estimated B2B green premium for the shipping industry is high, at 30-80%. The green premium projections for low-emission fuels and ZEFs also remain high. For example, biofuels are expected to cost 2-4 times the cost of heavy fuel oil, and hydrogen-based fuels are expected to cost 4-4.5 times the cost of heavy fuel oil.[194]

However, this green premium only translates to a 1-2% increase in the final retail price to customers (in case of high-value products such as IT equipment), since shipping costs form a small percentage of the price of products. While the percentage increase of end-customer price is low, in absolute terms this is a significant increase in price of essential commodities like oil, grains and metals, and has a significant impact on developing countries.

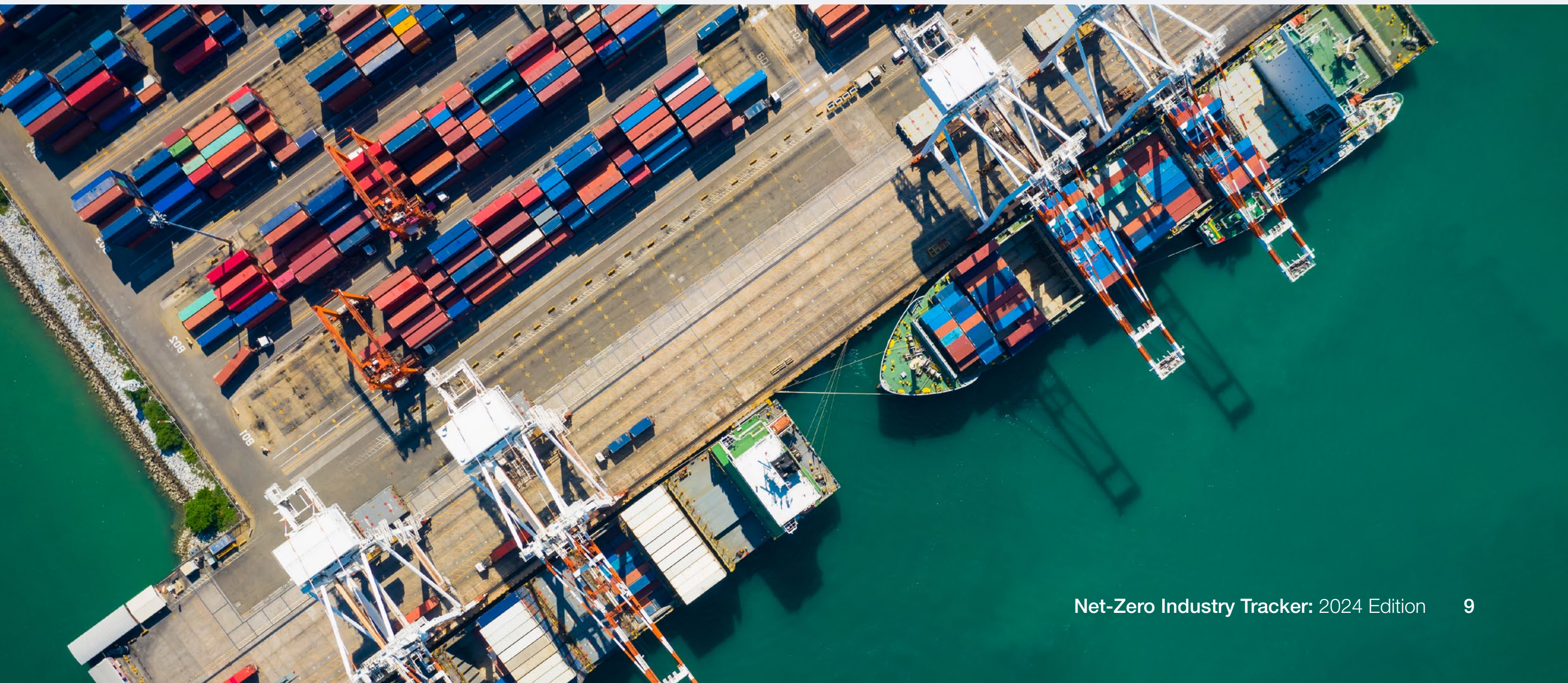
The FMC has set ambitious targets for the uptake of technologies by 2030 to enable longer-term decarbonization in 2050. Carriers have committed that at least 5% of their deep-sea shipping will be powered by ZEFs by 2030. Cargo owners have committed that at least 10% of their goods volume shipped via deep-sea shipping will be on ships powered by ZEFs by 2030, progressing towards 100% by 2040.[195]

Some players in the shipping industry are exploring the "book and claim" approach until the production and widespread availability of ZEFs improves globally. In this approach, shipping companies can purchase low-emission fuels or ZEFs (even if that fuel is not physically being used by their ships) in return for emission-reduction credits or certificates to offset their own emissions. This approach allows shipping companies to support the decarbonization of the industry (by contributing to the green premiums) and help sustain the demand for low-emission fuels and ZEFs. It also facilitates a faster, less challenging and more cost-efficient transition, as it allows a few assets to decarbonize fully, rather than asking all assets to marginally decarbonize year-on-year. Rocky Mountain Institute (RMI) and the Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping (MMMCZCS) are collaborating with the Zero Emission Maritime Buyers Alliance (ZEMBA) and Hapag-Lloyd to pilot a Maritime Book and Claim System.[196] Mitsui O.S.K. Lines has become the first Japanese company to join the Book and Claim Community (BCC) board.[197]

FIGURE 33 **Top countries/regions for shipping trade volume (2022) and ships built (2023)**

Percentage of overall sea trade volume		Percentage of total ships built	
1 China	32%	1 China	51%
2 US	7%	2 South Korea	28%
3 Singapore	4%	3 South Korea	15%
4 South Korea	3%	4 Philippines	1%
5 Malaysia	3%	5 Viet Nam	1%

Source: United Nations Trade and Development (UNCTAD).



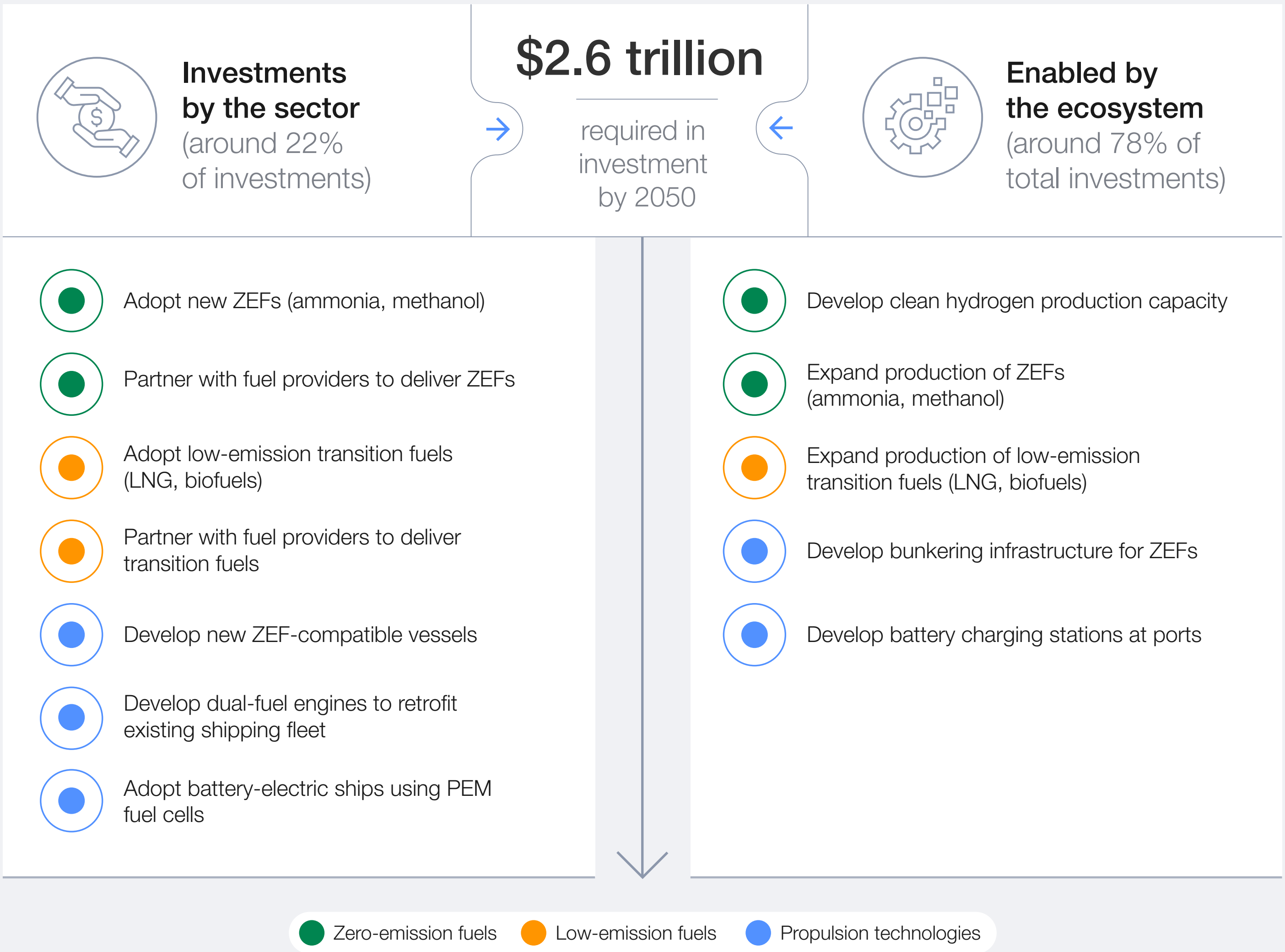
SHIPPING

1 Capital

The shipping industry will need substantial capital investment to advance the production of ZEFs and development of a ZEF-compatible shipping fleet, with an estimated requirement of $2.6 trillion.[198] This comes to an additional annual capital investment of around $91 billion, which is more than double the existing annual CapEx of $44 billion[199] in the shipping sector. The majority of this additional investment must come from the ecosystem (and not only shipping companies) to build the enabling infrastructure. Shipping decarbonization requires a scale-up of clean hydrogen, CCUS and bunkering infrastructure. The shipping sector needs to invest in retrofitting the existing fleet with dual-fuel engines to support the use of low-emission fuels and ZEFs.

It is projected that out of the total additional investment required, about $2 trillion[200] is expected to go towards ZEF production infrastructure (the majority of which will be for setting up of clean hydrogen capacity) followed by bunkering and CCUS capacity. Retrofitting the existing fleet with dual-fuel engines will require approximately $0.6 trillion of the total additional investment, based on the average cost of retrofitting being between $5 million and $15 million per ship.[201]

FIGURE 34 **Investments required by the sector and enabled by the ecosystem**



Source: Accenture analysis based on data from S&P and DNV.

The shipping industry's return on invested capital (ROIC) is at 13%[202] and its WACC is at 8.4%.[203] This narrow margin means that without additional support from external factors (such as technological advancements, policy incentives and industry collaboration), the industry may struggle to afford and implement the significant changes needed for effective decarbonization.

SHIPPING

Policy

The global shipping industry is governed by the IMO's regulations. In 2023, the IMO updated its GHG strategy to aim for net-zero emissions by or around 2050, as well as 2030 and 2040 mid-term targets and a goal for uptake of zero or near-zero emission fuels to be 5% (striving for 10%) by 2030.[204] In addition to the IMO strategy, there are several key regional policies playing a critical role in supporting the decarbonization of the shipping industry. The EU's Emissions Trading System for shipping, which sets limits on GHG emissions and requires shipping companies to purchase carbon credits for their emissions in voyages involving EU ports, has been extended in 2024 to cover all large ships (of 5,000 gross tonnage and above) entering EU ports.[205] The FuelEU Maritime regulation, which will be effective in the EU from January 2025, has set a GHG emission-reduction target of 2% in 2025 (vs. 2020), increasing to 6% in 2030 to reach 80% in 2050.[206]

As part of the ongoing meetings and negotiations of the IMO's Marine Environment Protection Committee (MEPC), several countries and organizations, including two prominent shipping trade associations, have submitted proposals. One of these is from the World Shipping Council, which represents members primarily in the container shipping segment. It has proposed a green balance mechanism to help close the gap between low-carbon fuels and fossil fuels. The mechanism would apply a fee to ships using fossil fuels and allocate credits to those using low-carbon fuels, ensuring that the average cost of fuel is equal.[207] The next significant step on the policy lever will be the Spring MEPC83 meeting in the IMO.

TABLE 7 **Shipping industry policy summary**

Policy type	Policy instruments	Key examples	Impact
Market-based	Carbon price	– EU-ETS[208] – US International Maritime Pollution Accountability Act: $150 per tonne of CO_2 emissions proposed[209] – IMO economic measure, 2023 strategy[210]	Up to $10 billion a year of additional costs for the industry due to the need to acquire carbon credits once the EU-ETS is fully implemented in 2026.[211] The proposed US carbon pricing is projected to bring in $250 billion in low-emission funding over the next 10 years.[212] Carbon pricing under IMO is still under discussion and will not be in effect before 2027.
Mandate-based	Performance standards and certification	– Energy Efficiency Design Index (EEXI)[213] – Carbon Intensity Indicator (CII)[214]	Ships must comply with these mandatory standards, which are intended to drive continuous technical and operational improvements.
	Direct regulation	– EU Alternative Fuels Infrastructure Regulation	These are mandates for major EU ports to provide shore-side electricity to vessels. They reduce emissions at ports by providing cleaner electricity as an alternative, with a specific timeline for ports to act upon (by 2030).
	Fuel standards	– FuelEU Maritime regulation[215] – US Clean Shipping Act[216] – IMO technical measure, 2023 strategy[217]	These are predictable pathways for low-emission fuels that encourage adoption and drive demand.
Incentive-based	Taxes and subsidies	– IRA clean power and green hydrogen production tax credits[218]	These credits have encouraged a 50% reduction in green hydrogen production costs, which can boost scaling of green hydrogen capacity required for low-emission fuels.[219] The feasibility of such subsidy-driven policies for developing economies is uncertain.
	Green corridors	– Green corridor pledge at COP28 between the US and UK[220]	This pledge reduces the risks of adopting low-emission fuels by deploying at a local scale and mobilizing demand. So far, 44 green corridor initiatives have been announced, involving over 171 stakeholders.[221]
	Direct funding	– Public funding for converting diesel plants to hydrogen and setting up charging stations in Croatia[222]	This provides new funds for hydrogen projects, the retrofitting of diesel plants to hydrogen and the establishment of charging stations for maritime transport.

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