Voyaging toward a greener future: Insights from the GCMD-BCG Global Maritime Decarbonization Survey

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By Professor Lynn Loo, Dr. Sanjay C Kuttan, Michael Tan, Sanjaya Mohottala, Seng Chiy Goh

The Global Centre for Maritime Decarbonisation (GCMD) partners with industry and governmental stakeholders to help international shipping eliminate its GHG emissions by shaping standards for future fuels, financing first-of-a-kind projects, piloting low-carbon solutions in an end-to-end manner and under real-world operations conditions, and fostering collaboration across different sectors.

To help address some of the key challenges that are bottlenecking maritime decarbonization, GCMD is focusing on initiatives in four areas: (a) ammonia as a marine fuel, (b) assurance framework for drop-in green fuels, (c) unlocking the carbon value chain, and (d) energy savings technologies to improve fuel efficiency of ships.

A non-profit organisation, GCMD was co-founded by the Maritime and Port Authority of Singapore (MPA) and six industry partners, namely BHP, BW Group, Eastern Pacific Shipping, Foundation Det Norske Veritas, Ocean Network Express, and Seatrium on August 1, 2021. GCMD has additionally onboarded more than 100 center- and project-level partners, all of whom share the common goals of accelerating the deployment of scalable low-carbon technologies by validating technical and commercial feasibility, and lowering adoption barriers by leveraging the data and insights from GCMD-curated pilots and projects.

Boston Consulting Group partners with leaders in business and society to tackle their most important challenges and capture their greatest opportunities. BCG was the pioneer in business strategy when it was founded in 1963. Today, we work closely with clients to embrace a transformational approach aimed at benefiting all stakeholders—empowering organizations to grow, build sustainable competitive advantage, and drive positive societal impact.

Our diverse, global teams bring deep industry and functional expertise and a range of perspectives that question the status quo and spark change. BCG delivers solutions through leading-edge management consulting, technology and design, and corporate and digital ventures. We work in a uniquely collaborative model across the firm and throughout all levels of the client organization, fueled by the goal of helping our clients thrive and enabling them to make the world a better place.

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Executive Summary

The shipping industry is the backbone of the global economy, facilitating 90% of international trade and transporting over 11 billion metric tons of goods annually. Yet, this comes at an environmental cost: shipping is responsible for 2% to 3% of global greenhouse gas (GHG) emissions, which contribute to the supply-chain (Scope 3) emissions of every business with seaborne logistics.

By decarbonizing, the industry thereby both reduces its direct emissions and paves the way for a future with sustainable product choices for consumers. Policymakers are therefore encouraging maritime decarbonization. In 2023, the International Maritime Organization set a target to achieve net zero emissions for shipping by or around 2050.

The path to net zero for shipowners and operators requires six elements: a robust strategy and roadmap setting forth ambitions and plans; four specific decarbonization levers to reduce emissions: operational efficiency, technological efficiency, fuel transition, and shipboard carbon capture; and enablers such as dedicated sustainability teams, strategic investments in green initiatives, internal carbon prices, and digitalization.

> The Global Centre for Maritime Decarbonisation (GCMD) and Boston Consulting Group (BCG) conducted an industry-wide survey to take stock of shipowners' and operators' progress in establishing these elements.

The survey found that decarbonization ambitions are high. Many respondents (73%) view net zero as a strategic priority, and 77% have already set concrete decarbonization targets. The industry has also mobilized resources to decarbonize: respondents are investing 2% of their revenues into green initiatives, and 87% have personnel working toward green objectives.

However, adoption of these levers remains mixed. While the industry has made some progress in adopting mature and cost-effective efficiency levers, adoption of complex or nascent levers remains low. Drop-in fuels are constrained by costs and supply-side gaps, and optimism for future fuels has yet to translate into firm commitment.

The industry is now at a pivotal point, with many shipowners and operators ramping up their efforts to decarbonize. Nearly 60% of respondents are now developing decarbonization roadmaps and three-quarters plan to increase their investments in green initiatives.

There is an opportunity for stakeholders to leverage this momentum and design interventions to accelerate maritime decarbonization.

Interventions need to be tailored to the different stages where shipowners and operators are in their decarbonization journey. These stages are best illustrated using archetypes, defined based on current adoption of decarbonization levers. We see three archetypes, differentiated in their outlook, investment appetite, and challenges faced.

> Frontrunners have the greatest decarbonization ambitions and are willing to invest heavily to meet these ambitions. They are pushing boundaries, adopting even the nascent and experimental decarbonization levers.

They lead the industry in the adoption of nascent efficiency levers such as wind propulsion, and more than half are planning to initiate pilots of shipboard carbon capture solutions by 2025. Technical pilots that test, demonstrate, and improve the performance of emerging solutions can help them on this path. These pilots should take a "whole-of-value-chain" approach to uncover and address any gaps that could limit the adoption of a lever.

Frontrunners are also planning to adopt methanol and ammonia as early as 2026 and 2029, respectively. They are bottlenecked by the lack of future fuel supply and bunkering infrastructure, with 38% citing these supply-side gaps as the top challenge to adoption. To help Frontrunners meet their expedited adoption timelines, it is critical to start building future fuel infrastructure now.

Yet the infrastructure build needs to accommodate for the lower energy density of future fuels. Methanol and ammonia have a 2.4–2.8x lower volumetric energy density than fuel oil. Since 58% of shipowners and operators plan to bunker more frequently in response, it is important to equip existing ports to serve more ships, and to mobilize investment at new ports along longer routes.

Followers believe in decarbonizing their fleets, but with tighter investment thresholds and a near-term outlook, they are focused on solutions with immediate and certain value.

They have kept pace with Frontrunners in adopting mature and cost-effective efficiency levers, such as main engine improvements and slow steaming, but are behind in the adoption of levers that are nascent, such as wind propulsion and air lubrication.

The performance of such nascent levers varies widely by vessel type and route, making it difficult to assess savings and create a business case for investment. This uncertainty over performance is the top challenge to adoption for 22% of Followers, who seek greater confidence in the performance and returns of a solution before adopting it.

Data-sharing initiatives can increase Followers' confidence in nascent solutions, and help them formulate a business case for adoption. Industry bodies and classification societies can encourage stakeholders to pool data, which can then be aggregated and shared back with the industry as benchmarks.

Innovative financing mechanisms can also de-risk adoption of nascent solutions for Followers by shifting the large upfront capital expenditures (CAPEX), for solutions such as Flettner rotors, to operational expenditures (OPEX). Mechanisms such as pay-as-you-save were attractive to over half of the Frontrunners and Followers surveyed.

Conservatives are still at early stages in their decarbonization journey. They trail Frontrunners and Followers in adopting mature and cost-effective efficiency levers.

This is likely due to a lack of awareness and familiarity, cited by almost half (43%) of Conservatives as the top challenge to adopting efficiency levers.

Conservatives are best supported by measures that increase their familiarity with the decarbonization levers and help contextualize these levers to their specific fleets and operational requirements. At the same time, initiatives that build the capabilities needed to assess and deploy levers are also needed to ensure increased familiarity translates into adoption.

Maritime decarbonization is a complex but ultimately critical endeavor. Decarbonizing the shipping sector is difficult due to the industry's fragmentation, conservative operating practices, and many small shipowners and operators. Yet it is of utmost importance, as it holds the key to building greener supply chains across sectors, and to creating a future where sustainable product choices are readily available to consumers.

Five key actions stand out, as they not only directly address the varying needs of each archetype, but also require close collaboration and partnership amongst stakeholders across the maritime ecosystem.

1. Conduct technical pilots and facilitate data sharing for more nascent levers.

2. Create innovative financing mechanisms to de-risk the adoption of less mature levers.

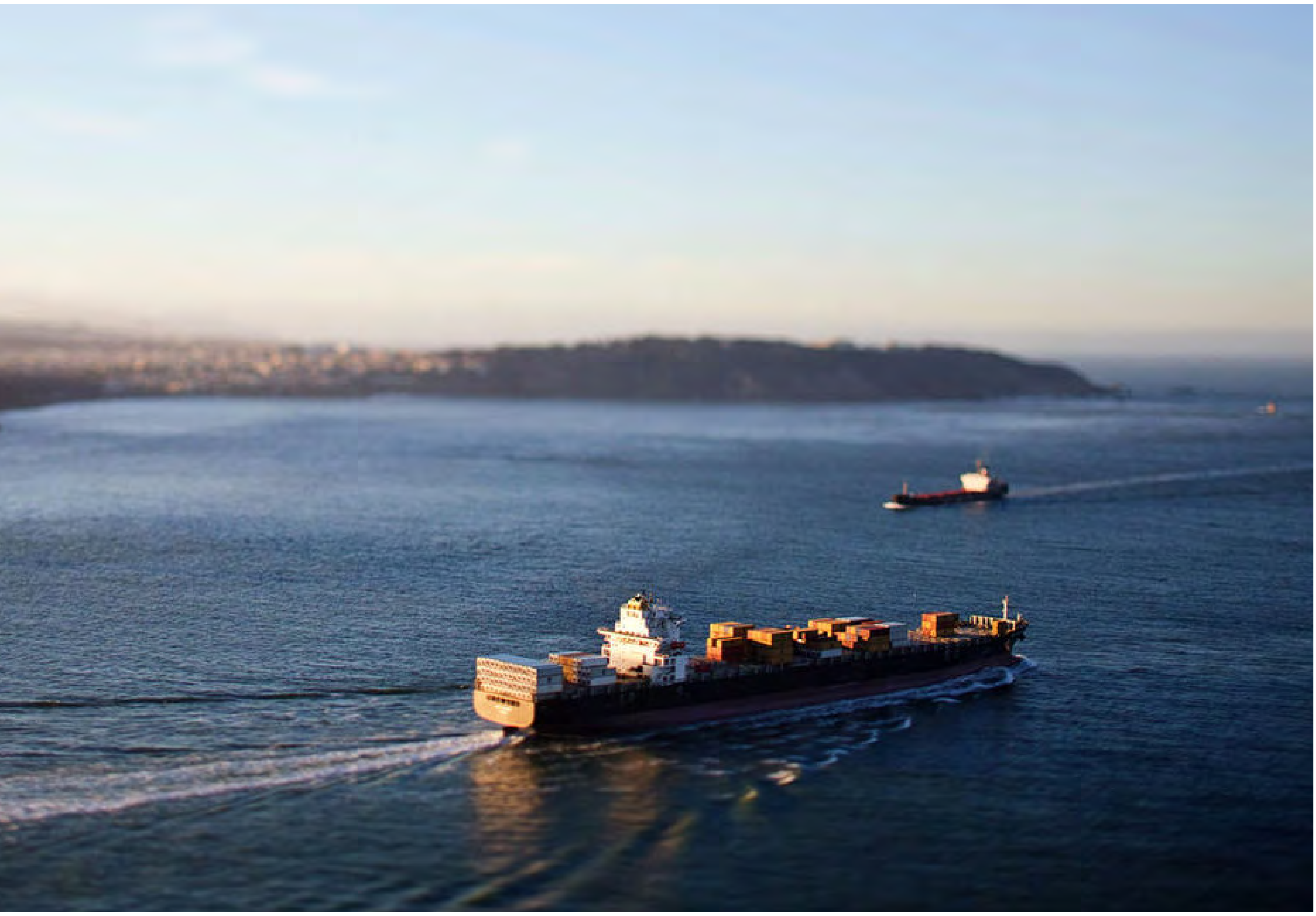
3. Support Conservatives to raise awareness, contextualize levers, and build capabilities.

4. Start to build out future fuels infrastructure and ensure supply at ports.

5. Develop mechanisms to share and equalize costs of adoption across the ecosystem.

The successful implementation of the five key actions outlined in this report demands a whole-of-ecosystem approach. Stakeholders from solution developers and ship operators to financial institutions, classification societies, and regulatory bodies have their parts to play.

By working together, we can transform the maritime sector into a beacon of environmental stewardship, and set a course for a future in which sustainability and commercial success go hand in hand.



Maritime decarbonization – a global imperative

The commercial shipping industry is the backbone of the global economy, facilitating 90% of international trade and transporting 11 billion metric tons of goods annually. Almost every international business relies on ships for either exporting goods or importing raw materials, or both.

Yet the industry's pivotal role in global economic development comes at an environmental cost: it is responsible for 2% to 3% of global greenhouse gas (GHG) emissions. Direct emissions from the shipping industry are an integral part of supply-chain emissions for every business with seaborne logistics, i.e., the business's Scope 3 emissions. By decarbonizing, the shipping industry not only reduces its direct emissions; it also paves the way for a future where sustainable product choices are readily accessible to consumers.

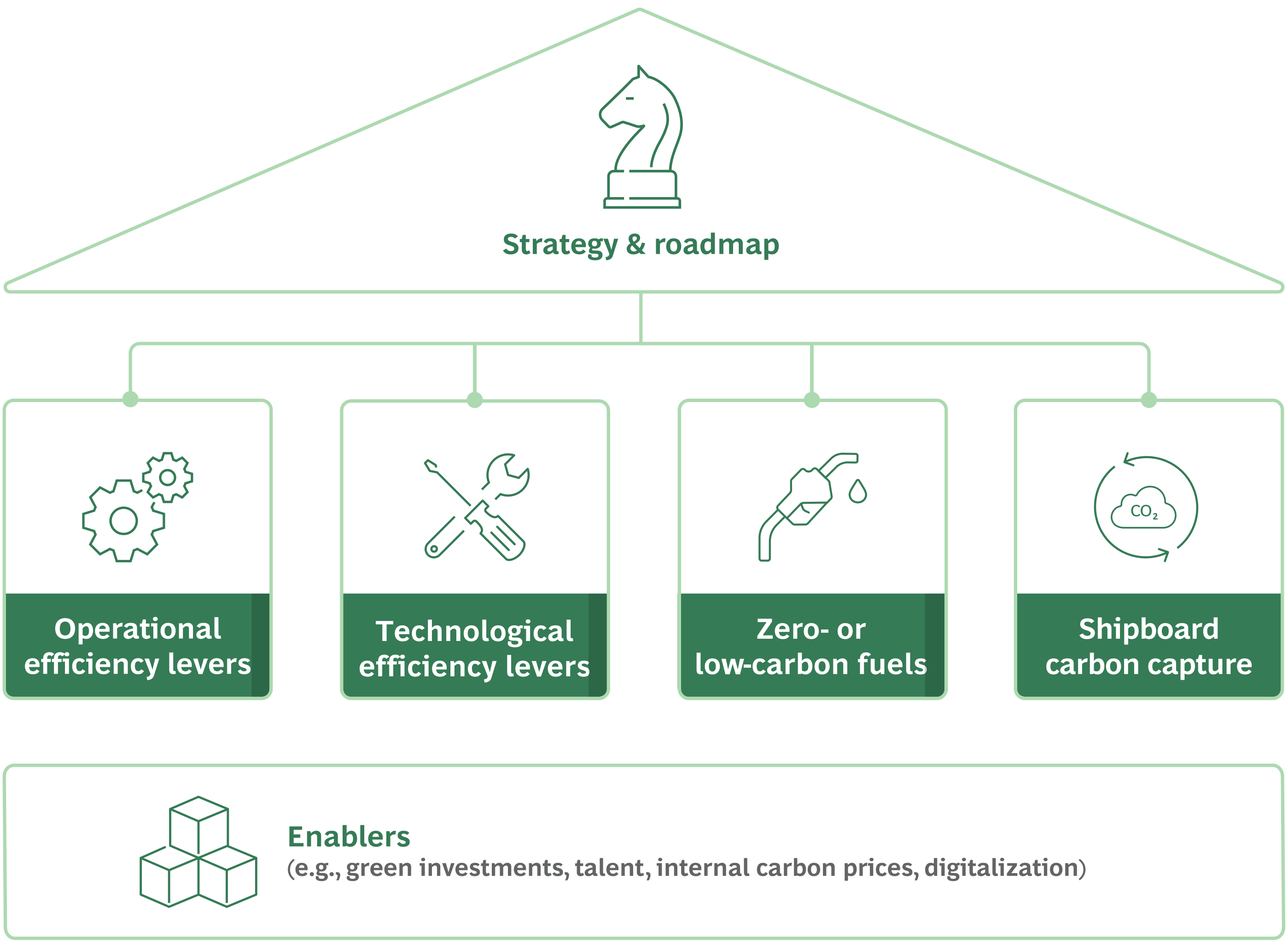
The substantial scale and widespread impact of the industry's emissions are driving consensus among policymakers and regulators. In July 2023, the International Maritime Organization (IMO) revised its decarbonization targets for the shipping sector, aiming to achieve net-zero emissions by or around 2050, with zero or near-zero GHG technologies and fuels having at least a 5% uptake by 2030. The IMO also announced interim indicative decarbonization targets of at least a 20% reduction in the sector's GHG emissions by 2030, aiming for 30%; and at least a 70% reduction, aiming for 80%, by 2040; all against 2008 levels.

The IMO has also introduced crucial initiatives such as the Energy Efficient Existing Ship Index (EEXI) and the Carbon Intensity Indicator (CII). It is now planning to develop a goal-based marine fuel standard to regulate the phased reduction of marine fuel's GHG intensity, as well as a maritime GHG emissions pricing mechanism. The call for change extends beyond the IMO, with the European Union (EU) taking decisive action to include shipping in its Emissions Trading System (ETS) by 2024, and to support the uptake of Renewable Fuels of Non-Biological Origin (RFNBOs) through its FuelEU maritime initiative.

The complex nature of shipping makes it a "hard-to-abate" industry. The industry's fragmentation, extended asset-replacement cycles, conservative operating practices, large network of small- and medium-sized enterprises (SMEs), and dispersed asset ownership create substantial obstacles to a rapid green transition. Overcoming these hurdles demands a concerted, ecosystem-wide effort.

To reduce carbon emissions in the shipping industry, shipowners and operators need to put in place six critical elements (Exhibit 1). The first is a robust strategy and roadmap setting forth decarbonization ambitions and an action plan. The subsequent four elements are specific levers that directly reduce GHG emissions: operational efficiency, technological efficiency, fuel transition, and shipboard carbon capture (SBCC). The sixth and last element encompasses enablers for decarbonization, such as dedicated sustainability teams, strategic investments in green initiatives, internal carbon pricing mechanisms, and digitalization.

Exhibit 1 - Six critical elements needed to decarbonize shipping

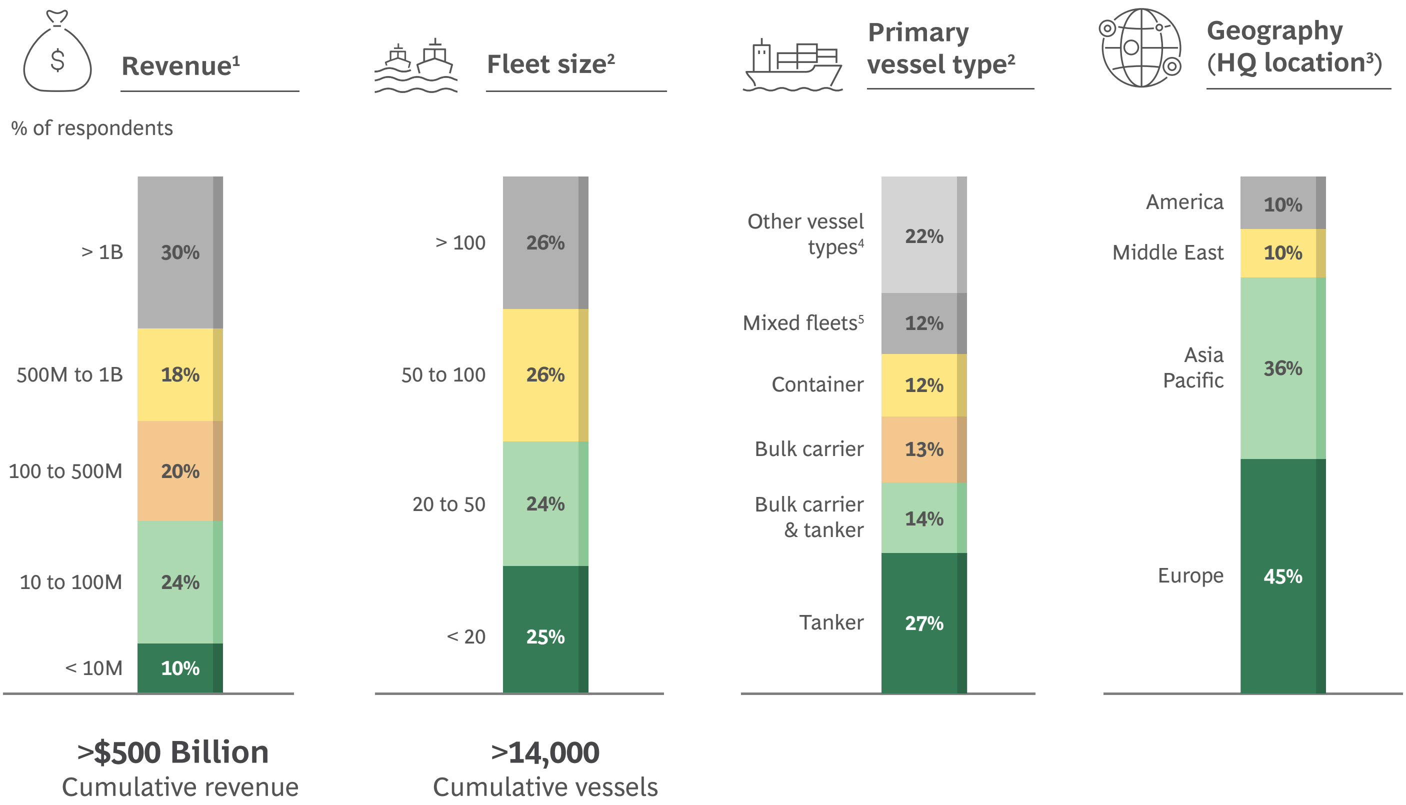


The Global Centre for Maritime Decarbonisation (GCMD) and Boston Consulting Group (BCG) conducted an industry-wide survey to take stock of shipowners' and operators' progress in establishing the six elements.

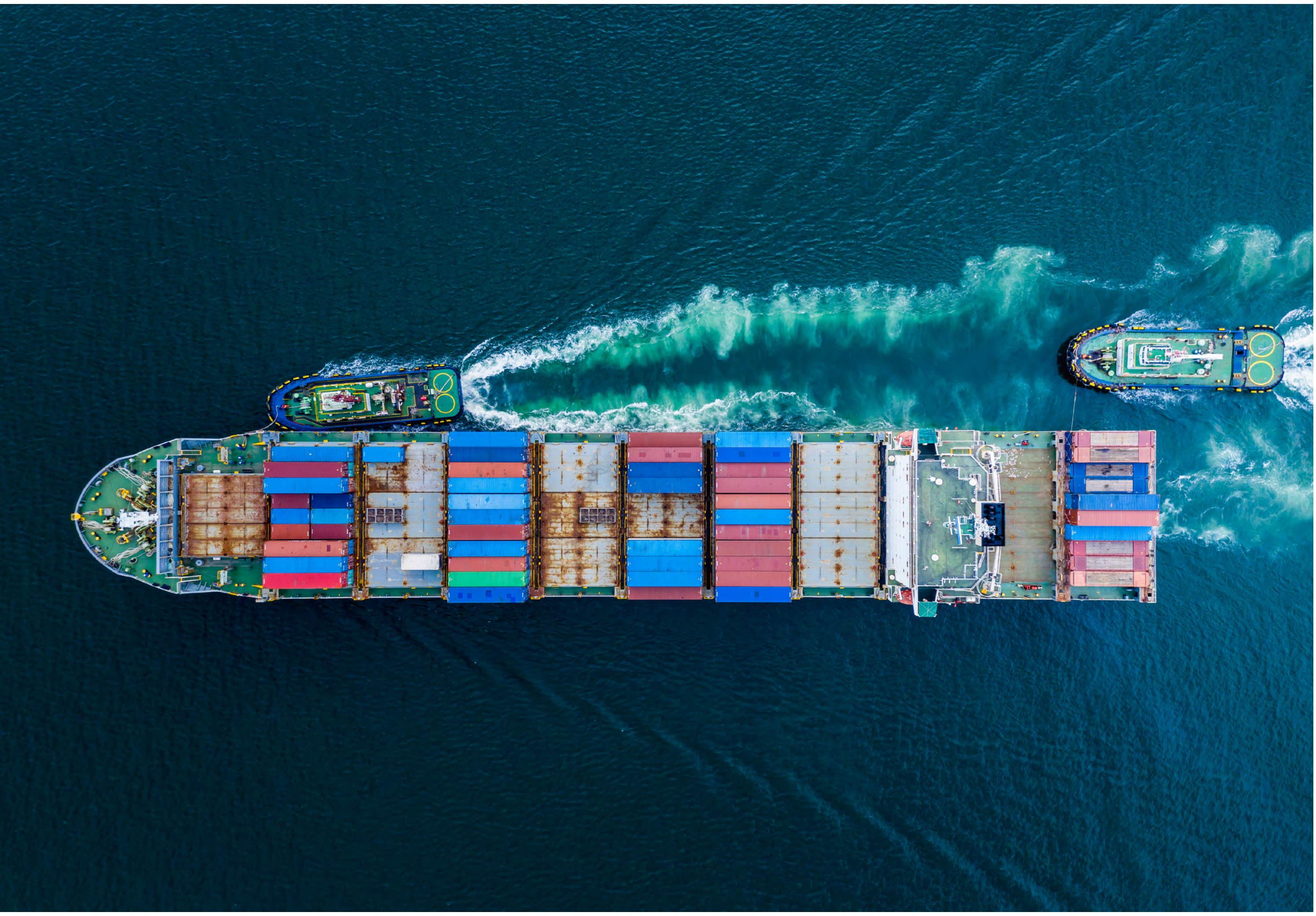
The survey collected information on their decarbonization strategies and adoption of key levers, challenges, and potential enablers, providing a comprehensive understanding of the current state of maritime decarbonization. With the survey results as a baseline, stakeholders can track the shipping sector's decarbonization journey, recognize its biggest challenges and opportunities, and develop interventions to drive further progress.

To incorporate views from across the industry, GCMD and BCG reached out to a variety of shipowners and operators across vessel types, fleet sizes, and geographies. Efforts were made to include small companies that own or operate fewer than 20 vessels. The survey received strong support from the industry, with 128 participants across segments, and 25% of responses coming from small companies, as defined above. The respondents collectively own or operate 14,000 merchant vessels, and account for US$500 billion in revenue (Exhibit 2).

Exhibit 2 - Strong industry participation with good representation across segments



[1] N=123, [2] N=125, [3] N=128
[4] Other vessel types include fleets with a majority of vessels that are not containers, bulk carriers and tankers, e.g., ferries, cruises, Ro-Ro
[5] Mixed fleets comprise a mix of containers, bulk carriers and tankers



The state of maritime decarbonization today

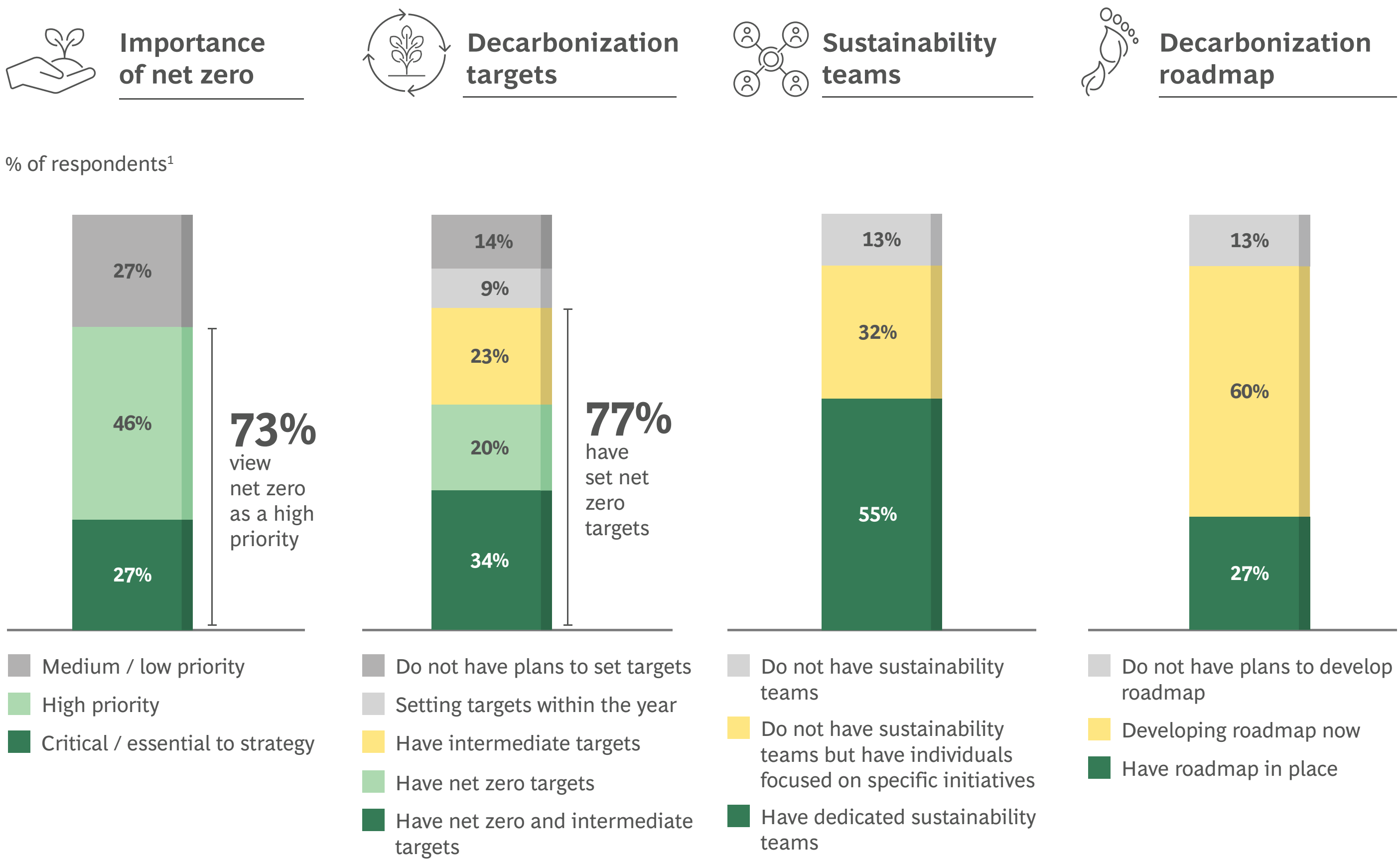
Maritime decarbonization stands at a critical juncture, as many shipowners and operators recognize the need to reduce GHG emissions. 73% of respondents view getting to net-zero operations as a strategic priority, and 77% have already set concrete decarbonization targets, including 54% who have set net-zero targets (Exhibit 3).

Shipowners and operators are now taking action to meet their sustainability ambitions. 87% of respondents have personnel working toward green objectives, with 55% having dedicated sustainability teams. A quarter (27%) of respondents have also developed clear decarbonization roadmaps, and respondents are, on average, investing 2% of their revenues in green initiatives.

Despite the growing awareness of the need to reduce GHG emissions, the industry's adoption of decarbonization levers remains mixed. We observe varying adoption levels across operational and technological efficiency levers, due to differences in ease of implementation and technological maturity.

Many shipowners and operators have already adopted operational efficiency levers that can be implemented with few disruptions to operations, such as weather routing and slow steaming. Those efficiency levers that require coordination across shipowners, charterers, and ports, such as cold ironing and just-in-time operations, see low adoption levels. Among technological efficiency levers, mature options, such as advanced hull coatings and main engine improvements, have high adoption levels; while nascent technologies, such as super-light ships, wind propulsion, and air lubrication, see low adoption.

Exhibit 3 - Green ambitions are high, with shipowners and operators dedicating manpower to green initiatives and developing roadmaps



[1] N=128

Efficiency levers can help reduce emissions in the near term but will not be enough to achieve net zero. Ultimately the industry must move away from high-carbon-intensity fuels, or to capture the carbon dioxide and other GHG emissions released from their combustion. Presently, however, significant hurdles hinder the adoption of alternative fuels and shipboard carbon capture (SBCC).

Some shipowners and operators, especially those at the forefront of the green transition, are showing optimism regarding future fuels such as methanol and ammonia. Yet widespread adoption requires overcoming challenges, such as insufficient supply and the need for new bunkering infrastructure. As the transition to future fuels will be gradual, drop-in fuels—especially biofuels—are crucial interim solutions. Even then, cost constraints and limited availability impede adoption.

As for SBCC, it is a nascent lever that is five to ten years away from scalable commercial deployment, requiring end-to-end solutions to ensure the captured CO_2 is properly locked away via downstream utilization and/or sequestration.

The shipping industry is approaching a pivotal moment as stakeholders ramp up their decarbonization efforts. Currently, 27% of respondents have a decarbonization roadmap, with 17% having set internal carbon prices. We expect these numbers to grow significantly, with 60% of respondents now developing roadmaps, and 62% setting internal carbon prices. Three-quarters of respondents also plan to increase investments in green initiatives over the next five years, with a quarter planning an increase of more than 30%.

Three archetypes of shipowners and operators along the decarbonization journey

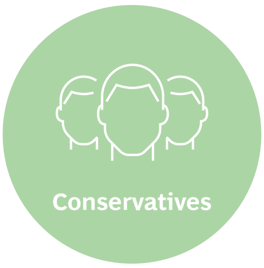
The shipping industry is heterogeneous, with a wide range of shipowners and operators with different green ambitions, investment appetites, fleet sizes, vessel types, geographies, and more. At the same time, categorization helps to guide policymakers, shipowners and operators on how to think about the industry, so they can develop interventions to accelerate maritime decarbonization.

While the most natural categorization would be to group companies based on their fleet size or primary vessel type, this categorization may not be the most effective, as companies with similar fleets may be at different stages of decarbonization, with different goals, investment appetites, and challenges. As such, we sought to group survey respondents based on their actual adoption of the various operational and technological levers, which would provide the most direct indication of where they are in their decarbonization journey.

Three decarbonization archetypes emerged—Frontrunners, Followers, and Conservatives—similar to the innovation diffusion archetypes observed in other sectors:

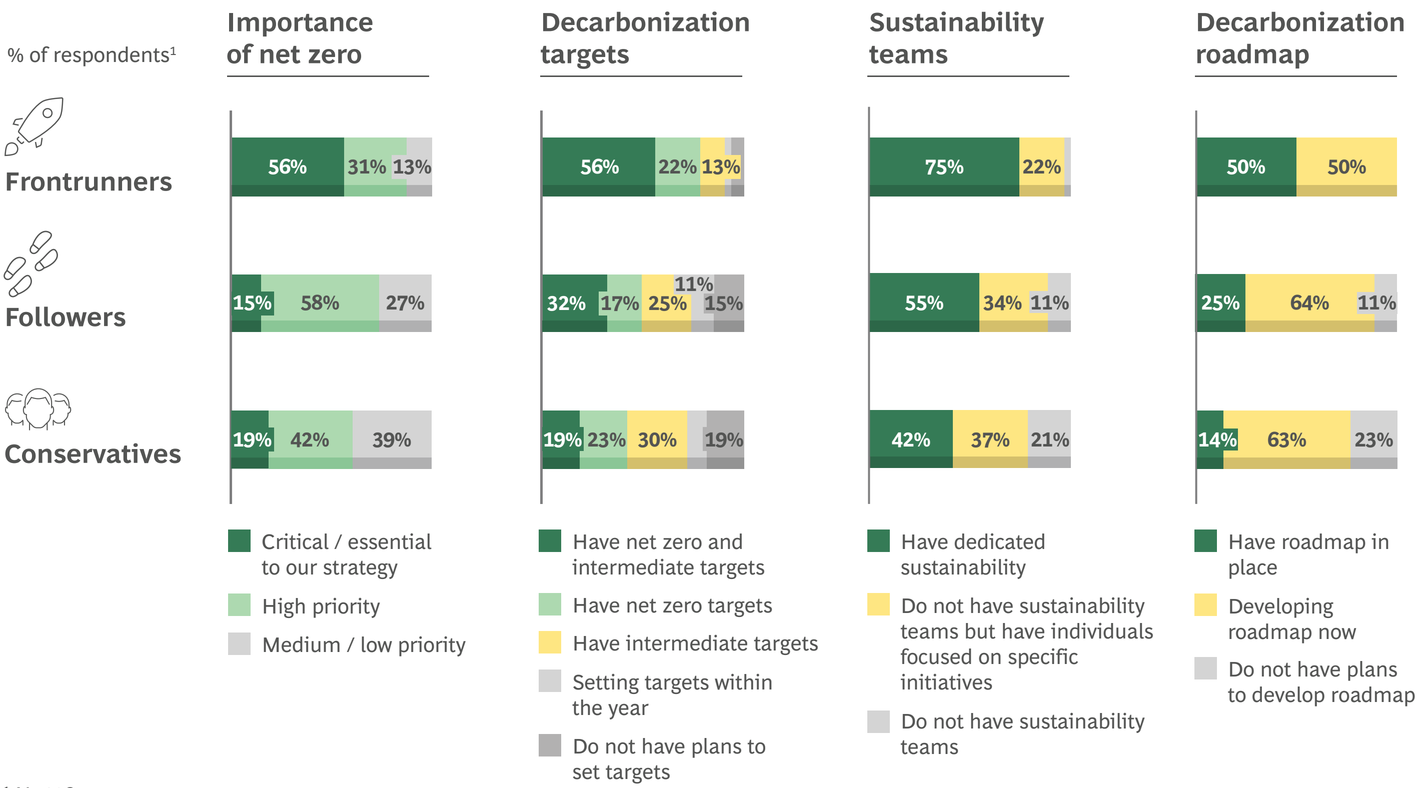
Frontrunners have the greatest decarbonization ambitions and have dedicated substantial resources to reducing emissions. They view getting to net-zero operations as a priority, and have robust targets in place to guide emissions reduction (Exhibit 4). They are well-positioned to achieve their targets, with half putting in place clear roadmaps and 75% having dedicated sustainability teams. On average, they are investing 4% of their total revenue in green initiatives (Exhibit 5), with 74% planning to increase this investment over the next five years. They are willing to invest more to retrofit their vessels with efficiency levers and to pay more for green fuels. 41% are also pricing carbon emissions into their business decisions and hence can formulate favorable business cases for sustainable solutions. Their progress to date is limited by extrinsic challenges, such as technological nascency and supply-side gaps, including the lack of green fuel availability and bunkering infrastructure.

Followers are conscious of the importance of decarbonizing their fleets, but are opportunistically adopting solutions that unlock immediate value. 73% view net zero as a priority; 49% have a net-zero target, and 25% have decarbonization roadmaps. Their pace of decarbonization is influenced greatly by economic considerations. On average, they allocate 2% of their revenues to green initiatives. They have shorter investment horizons, aiming to recoup their investment 20% faster than Frontrunners, and are willing to spend up to US$3 million per vessel for efficiency retrofits, less than half of the US$7 million of Frontrunners. Accordingly, they are less likely to experiment with nascent solutions, and are more likely to reduce emissions with mature and cost-effective levers.



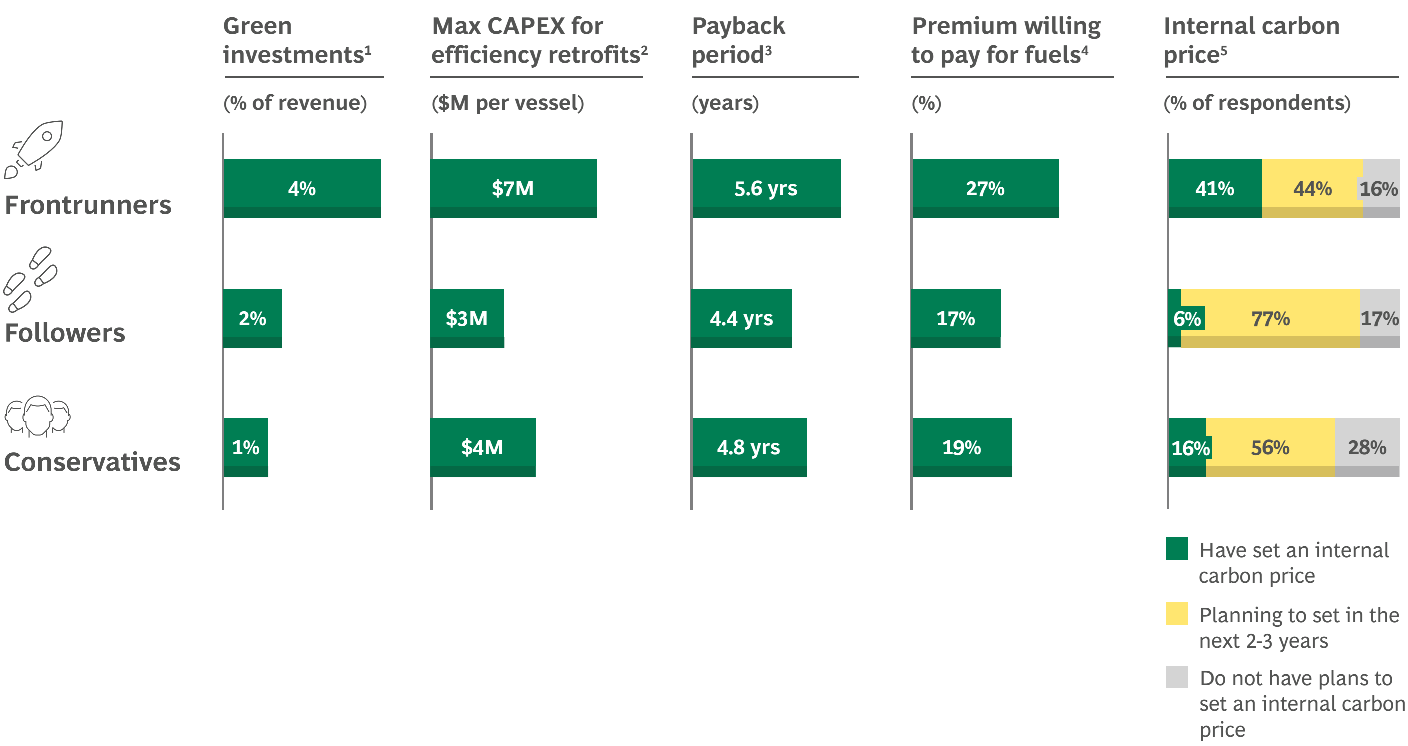
Conservatives recognize the need to reduce emissions, but have made less progress in adopting decarbonization solutions than Followers. 61% view net zero as a priority, with 42% having a net zero target and 14% with decarbonization roadmaps. They trail other archetypes in allocating resources to their green transition; 42% have dedicated sustainability teams, and on average they invest 1% of their revenues into green initiatives. With their decarbonization ambition not yet codified through targets, roadmaps, and resource allocation, they are early in their journey. They face intrinsic challenges, such as low familiarity with available solutions, uncertainty over solutions' effectiveness, and limited capabilities to assess, evaluate, and implement solutions. These challenges prevent some Conservatives from implementing established decarbonization solutions that have been adopted by other archetypes.

Exhibit 4 - Frontrunners have set up dedicated sustainability teams and developed decarbonization roadmaps to realize their green agenda



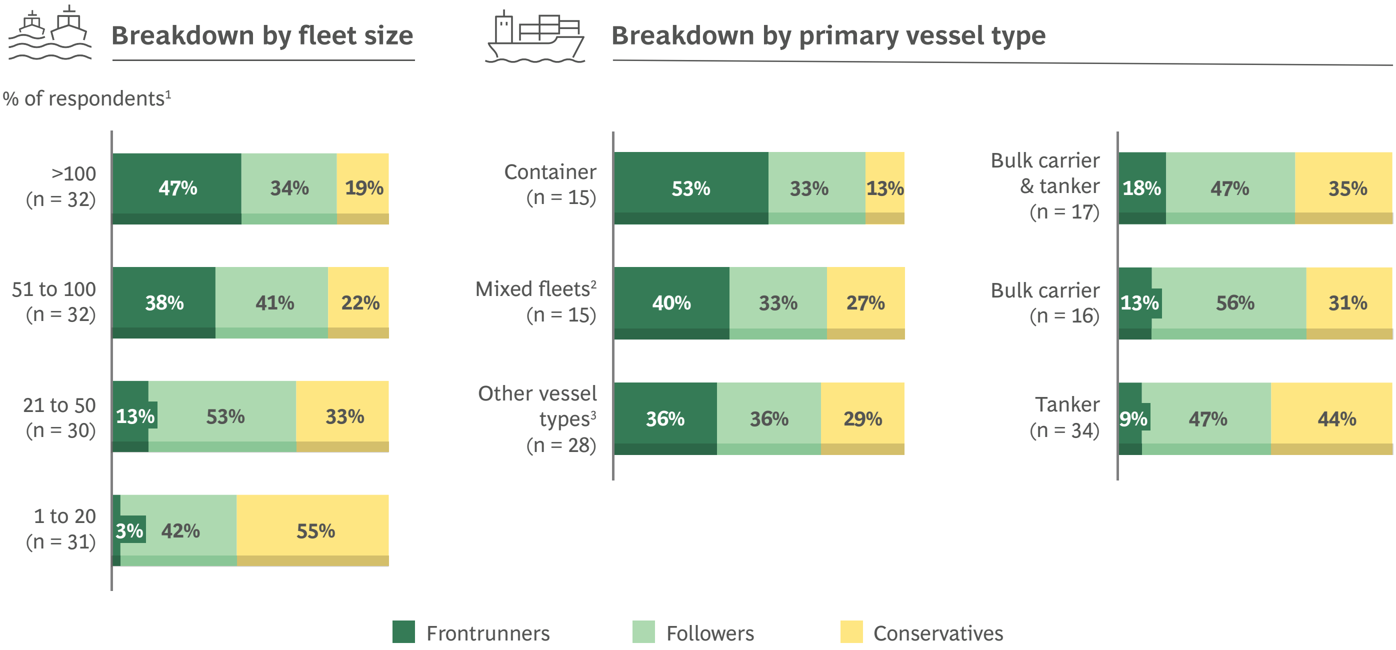
[1] N=128
Note: Values less than 10% are not shown in this exhibit

Exhibit 5 - Frontrunners are willing to invest more to decarbonize their fleets



[1] N=84, [2] N=68, [3] N=84, [4] N=116, [5] N=128

Exhibit 6 - Archetypes are present across different industry segments



[1] N=125
[2] Mixed fleets comprise a mix of containers, bulk carriers and tankers
[3] Other vessel types include fleets with a majority of vessels that are not containers, bulk carriers and tankers, e.g., ferries, cruises, Ro-Ro

An archetype lens provides insight into challenges and guides effective interventions.

When we compare the three archetypes with traditional industry segments such as fleet size and vessel type, we find a larger proportion of Frontrunners among shipowners and operators with larger fleets (Exhibit 6), as they tend to have the capital and ability to pursue their green ambitions and are often subjected to much industry scrutiny. Many Frontrunners are also found among shipowners and operators that own and/or operate containerships, perhaps due to their proximity to end customers with higher green expectations of their suppliers than customers of other segments.

While those generalizations hold, we find heterogeneity within each segment. There are Conservatives among companies with large (>100 vessels) container fleets, and Frontrunners among companies with small (<20 vessels) bulk carrier and/or tanker fleets. As such, the archetype lens provides us with a clearer way to understand the state of decarbonization across the industry, and to design more targeted and effective interventions to accelerate emissions reduction.

Driving adoption of operational and technological efficiency levers

We asked shipowners and operators about their current and planned adoption of 19 operational and technological efficiency levers, to build a robust baseline of the industry's decarbonization journey today (Exhibit 7). Operational efficiency levers refer to digital tools, procedural changes, and process improvements that optimize a ship's operations and maintenance, resulting in improved energy efficiency. Technological efficiency levers refer to engine improvements, propeller enhancements, drag reduction, and power assistance technologies that reduce fuel consumption.

In general, operational efficiency levers are more widely adopted than technological levers, likely because these have lower capital expenditure requirements and are easier and faster to implement, often with no vessel downtime.

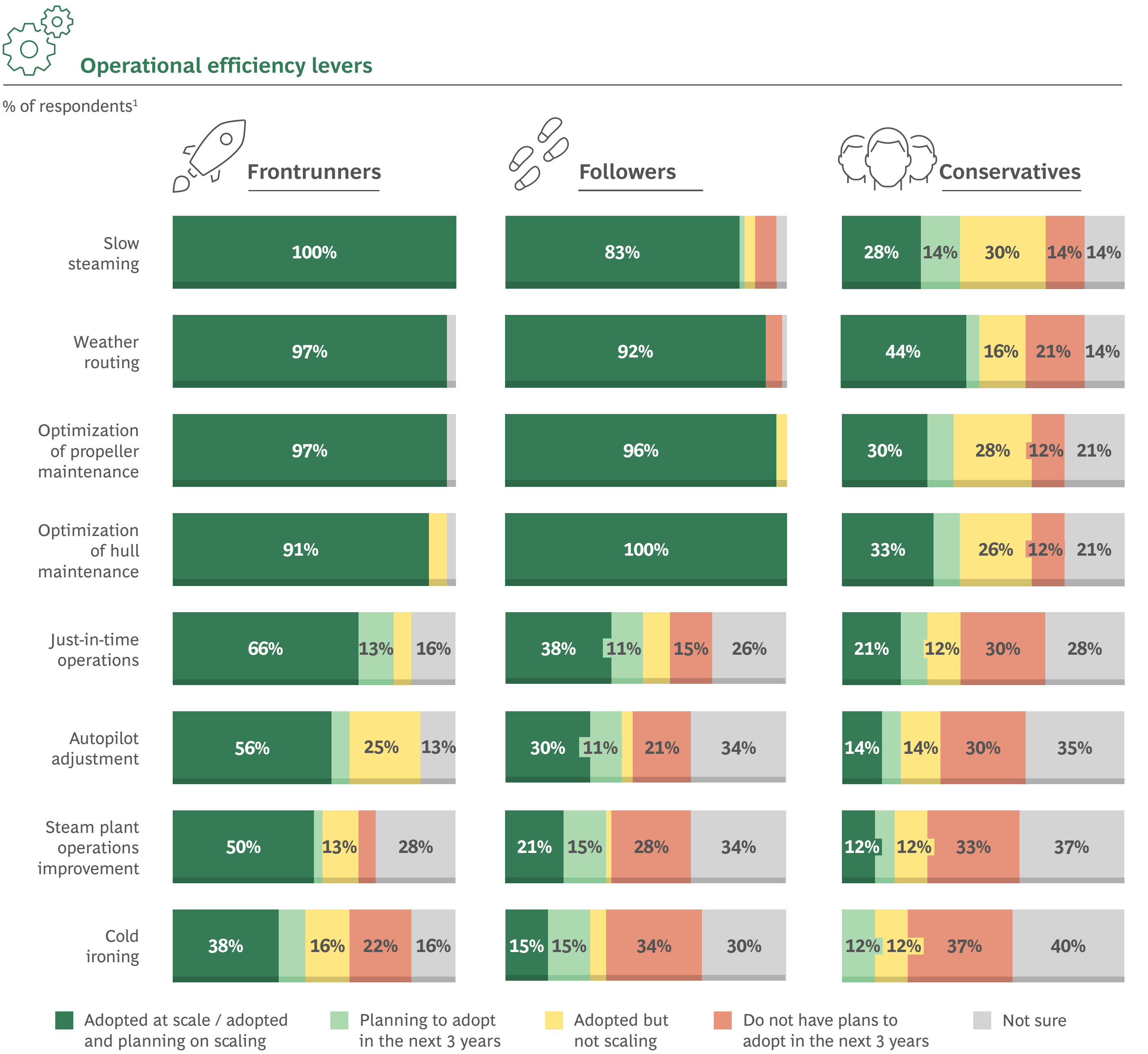
Across the operational levers, those that are easily implementable with low capital requirements—such as weather routing, hull maintenance, propeller maintenance, and slow steaming—have wide adoption, far more than the complex levers that require advanced capabilities or multi-party coordination (Exhibit 7).

Many respondents have yet to adopt just-in-time operations due to the need for complex multi-party coordination, not just with port authorities, but also with other operators. Steam plant operations improvements and autopilot adjustments have low adoption because they require specialized crew. As for cold ironing, strict emissions limits at ports could make it attractive, but adoption remains constrained by insufficient infrastructure and low returns on investment—requiring both capital-intensive retrofits and expensive shoreside electricity.

The adoption of technological levers also varies across the industry, depending on their stage of maturity, ease of retrofit, and extent of capital expenditure (CAPEX) requirements (Exhibit 7). Levers that are cheaper (e.g., under US$3 million) and easier to retrofit (e.g., can be done during dry dock), such as advanced hull coatings, main engine improvements, reduced auxiliary power demand, and propeller improvements, have moderate to high adoption levels across the industry. By contrast, hydrodynamic design, optimizing water flow around hull openings, and waste heat recovery, which can significantly reduce a vessel's carbon intensity, still see low adoption due to the difficulty or expense in retrofitting.

Nascent levers, such as wind propulsion and air lubrication, presently have low adoption levels in the industry due to uncertainty over their ROI, with only 10% to 20% of Frontrunners planning to adopt them at scale. Their performance depends on a range of operational factors, such as weather, wind speed and direction, and draft, which vary by route and ship type. Other nascent levers, such as super-light ships and solar panels, are at an early stage of commercialization and require further improvements in performance.

Exhibit 7 - Frontrunners lead the industry in the adoption of efficiency levers, Conservatives yet to adopt established levers



[1] N=128
Note: Values less than 10% are not shown in this exhibit

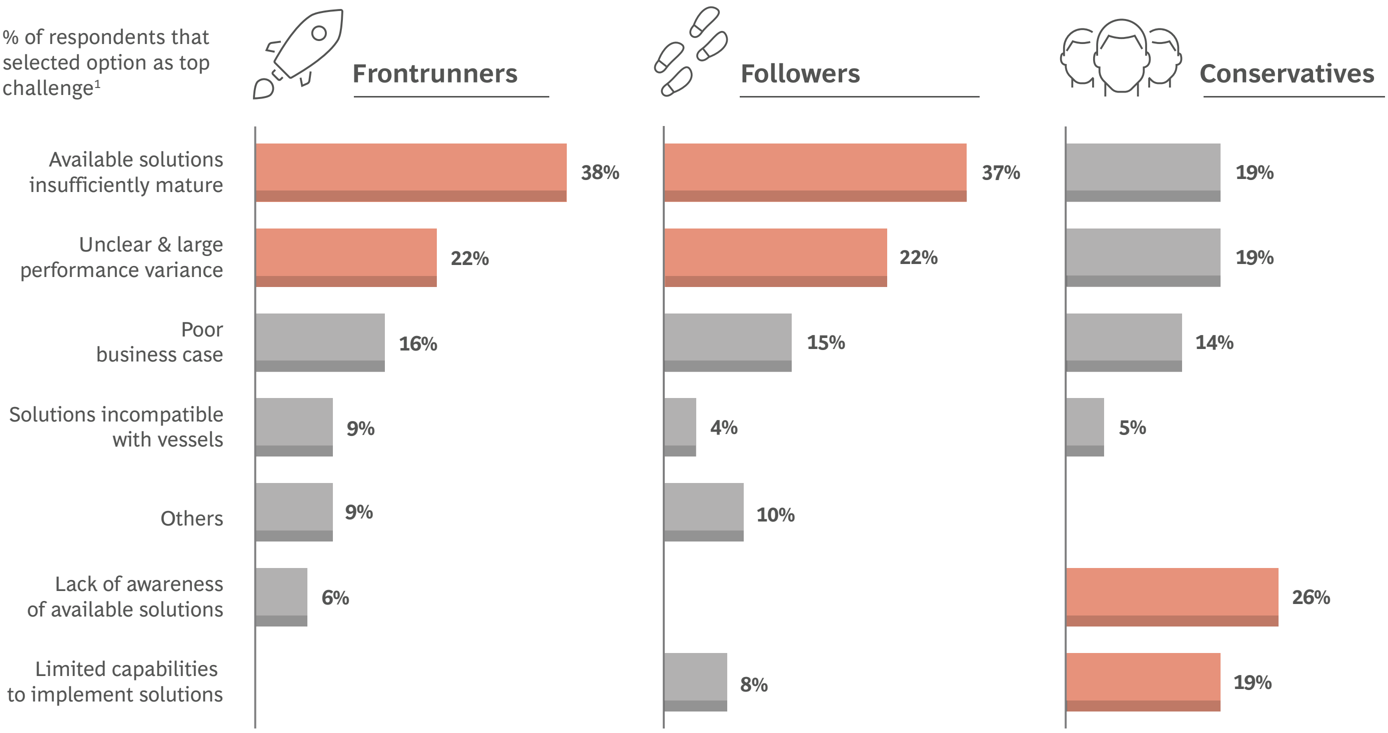
Technological efficiency levers

% of respondents[1]

[1] N=128
Note: Values less than 10% are not shown in this exhibit

Exhibit 8 - Frontrunners and Followers face technology-related challenges; Conservatives struggle with lack of awareness and capabilities

Top challenges for adopting efficiency levers



[1] N=127

As Frontrunners push boundaries in adopting efficiency levers, technological development, technical pilots, and data sharing are key.

Frontrunners have outpaced other archetypes in adopting both operational and technological efficiency levers. Frontrunners have dedicated sustainability teams and are investing heavily in green initiatives. As noted, they also have a higher willingness to spend and are willing to accept longer payback periods compared to Followers and Conservatives. These characteristics have enabled them to adopt even some less-mature levers.

Frontrunners lead the industry in adopting complex operational efficiency levers, such as just-in-time operations, autopilot adjustments, and cold ironing. They are also experimenting with nascent solutions, such as wind propulsion and air lubrication.

More than half of Frontrunners prefer to transition their fleets by purchasing newbuilds, rather than retrofitting existing vessels or purchasing used vessels. They are also optimizing the hydrodynamic design of their new vessels to meet stringent Energy Efficiency Design Index (EEDI) requirements.As Frontrunners try nascent efficiency levers, they face extrinsic technology-related challenges. 38% of them highlight a lack of solution maturity as their top challenge, while 22% highlight unclear and large performance variance (Exhibit 8).

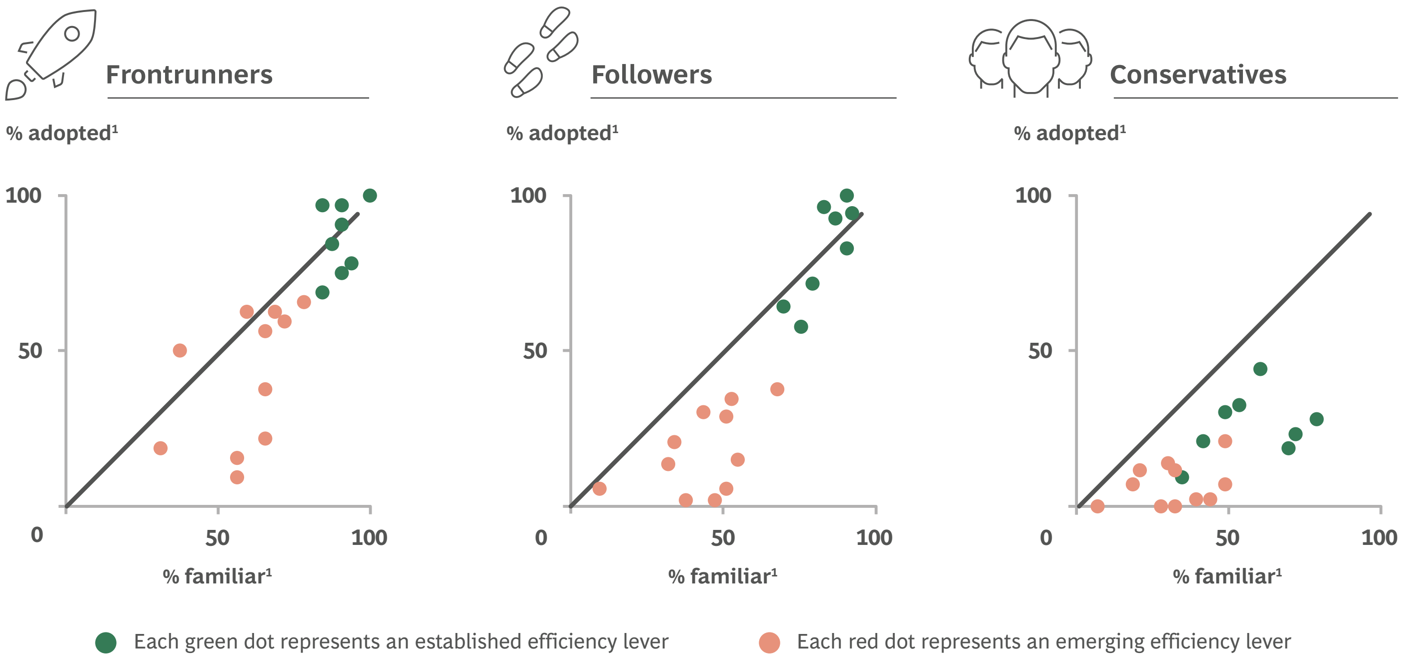
To address these challenges and support Frontrunners, investment needs to be directed toward technological development and orchestrating technical pilots. These pilots should take a "whole-of-value-chain" approach to uncover and address gaps that limit adoption, while enabling data sharing to reduce the variance and uncertainty around field performance and commercial returns.

Data sharing, innovative financing, and stringent regulation can reduce risk and increase pace of adoption among Followers.

Due to Followers' preference for solutions that unlock immediate and certain value, their investment in green initiatives is half that of Frontrunners'. They are willing to spend US$3 million on efficiency retrofits (57% lower than Frontrunners) and expect these investments to pay back within 4.4 years (20% faster). While they have kept pace with Frontrunners in adopting mature and cost-effective efficiency levers, they lag behind in adopting expensive, difficult-to-implement, and nascent levers. Followers' adoption of operational efficiency levers, such as just-in-time operations and cold ironing, is approximately half of Frontrunners', and less than a third technological levers such as wind propulsion and air lubrication.

Given this near-term outlook and risk appetite, it is critical to increase Followers' confidence in the performance of new solutions, while also de-risking adoption.

Exhibit 9 - Need to build familiarity and capabilities to accelerate adoption among Conservatives



[1] N=128

Innovative financing mechanisms, such as pay-as-you-save schemes that allow shipowners and operators to pay based on realized savings, can mitigate the risks associated with nascent technologies. Followers show clear interest in such financing mechanisms, with over half finding them an attractive proposition. Data-sharing initiatives can reduce the uncertainty in performance and returns for nascent solutions, and help increase confidence in a business case for adoption.

At the same time, regulations are critical to set the pace and induce them to become fast Followers. Energy efficiency regulations have been in force through the EEDI program introduced in 2013, and are regularly tightened. Beyond the design of new vessels, EEXI regulations have mandated a minimum compliance for all existing ships, while CII regulations go a step further to address operational energy efficiency, with a goal to track and reduce fuel consumption year over year.

With more stringent regulations, including market-based mechanisms, emerging in various regions and setting the pace of progress, Followers will need to adopt more technological and operational efficiency measures to remain compliant.

Conservatives have not adopted the most established efficiency levers, due to low awareness and capabilities.

Conservatives have yet to adopt many of the mature and established efficiency levers. Their adoption levels for operational levers, such as maintenance optimization and slow steaming, are less than half of those of Frontrunners and Followers. For established technological levers, such as advanced hull coating and main engine improvements, their adoption levels are a third of the other archetypes.

Conservatives' low adoption levels for efficiency levers are likely the result of intrinsic challenges. Almost half (43%) of Conservatives cite a lack of awareness and capabilities as their top challenge to adopting efficiency levers, compared to 6% of Frontrunners and 8% of Followers. These challenges are felt strongly by Conservatives as they are early in their decarbonization journey, lacking roadmaps, dedicated sustainability teams, and green investments. They have a lower understanding of which efficiency levers are relevant for their operating context—54% of Conservatives reported being familiar with efficiency levers, compared to 76% of Followers and 96% of Frontrunners.

Building familiarity and capabilities among Conservatives can speed up their adoption of efficiency levers. When compared with Frontrunners and Followers, Conservatives have lower familiarity for mature, cost-effective, and easy-to-adopt levers (Exhibit 9). Given that familiarity is a precursor to adoption, raising Conservatives' knowledge and understanding of efficiency levers, and helping to contextualize the various solutions to their individual fleets will be critical to enabling broad adoption. Measures that increase the industry's knowledge of efficiency levers may also help to uplift Followers, who have less familiarity with the nascent or difficult-to-implement levers than Frontrunners do. At the same time, it is critical to couple the push to raise awareness with broad-based efforts to help Conservatives build the capabilities needed to evaluate and deploy these levers across their fleet.

Navigating the fuel transition

While efficiency levers play a vital role in reducing emissions, they will not suffice to achieve net zero. The long-term solution is a transition from fuels with high carbon content to zero- or low-carbon fuels.

Low-carbon variants of methanol and ammonia are both promising future fuels. Methanol is currently more mature for adoption compared with ammonia, and some vessels have already been equipped with methanol dual-fuel engines. Stena Germanica was the first vessel retrofitted with a methanol engine in 2015 and there are now 25 methanol dual-fuel vessels in operation, with another 160 in the orderbook.[1] Methanol can be handled in liquid form at ambient temperature, so its use requires fewer adjustments to existing processes, infrastructure, and guidelines than ammonia does.

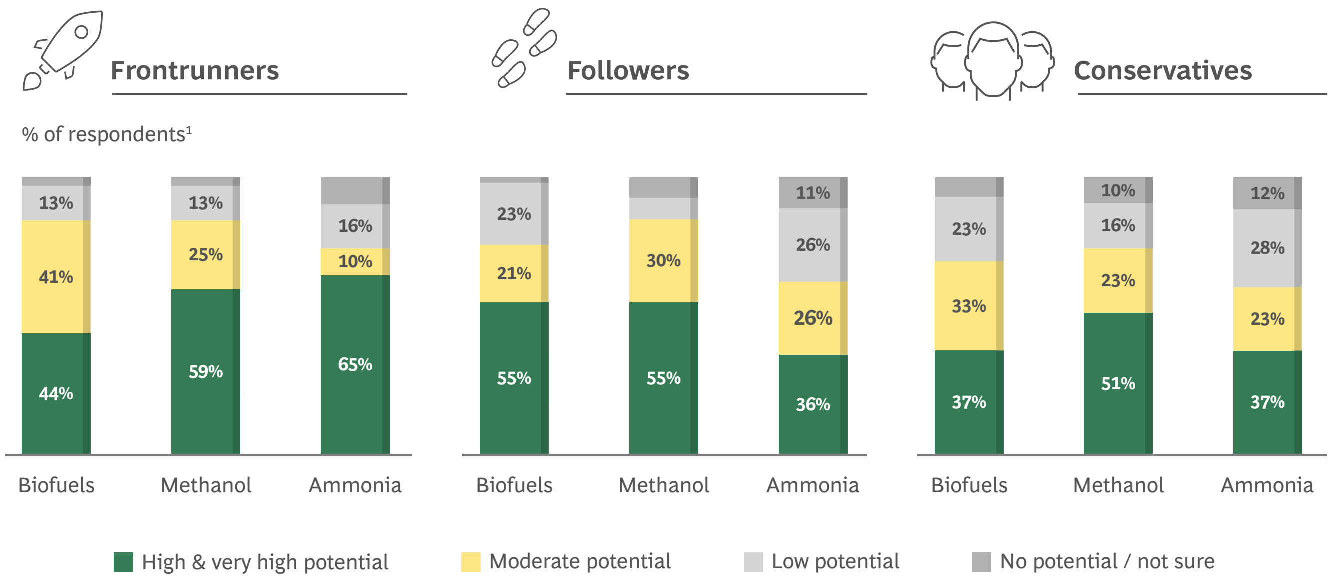
Ammonia must be liquified at minus 33 degrees Celsius for storage and transportation, and ammonia-ready engines won't become commercially available until at least 2025. Moreover, to manage the toxicity of ammonia, ports will need to develop new bunkering guidelines, covering new safety standards and procedures.

For zero-carbon emissions, ammonia is likely to be cheaper than methanol. While both green fuels require green hydrogen as feedstock, methanol production also requires biogenic or captured carbon dioxide, which either has limited availability or can be expensive to obtain, especially if obtained through direct air capture.

1. Clarksons World Fleet Register

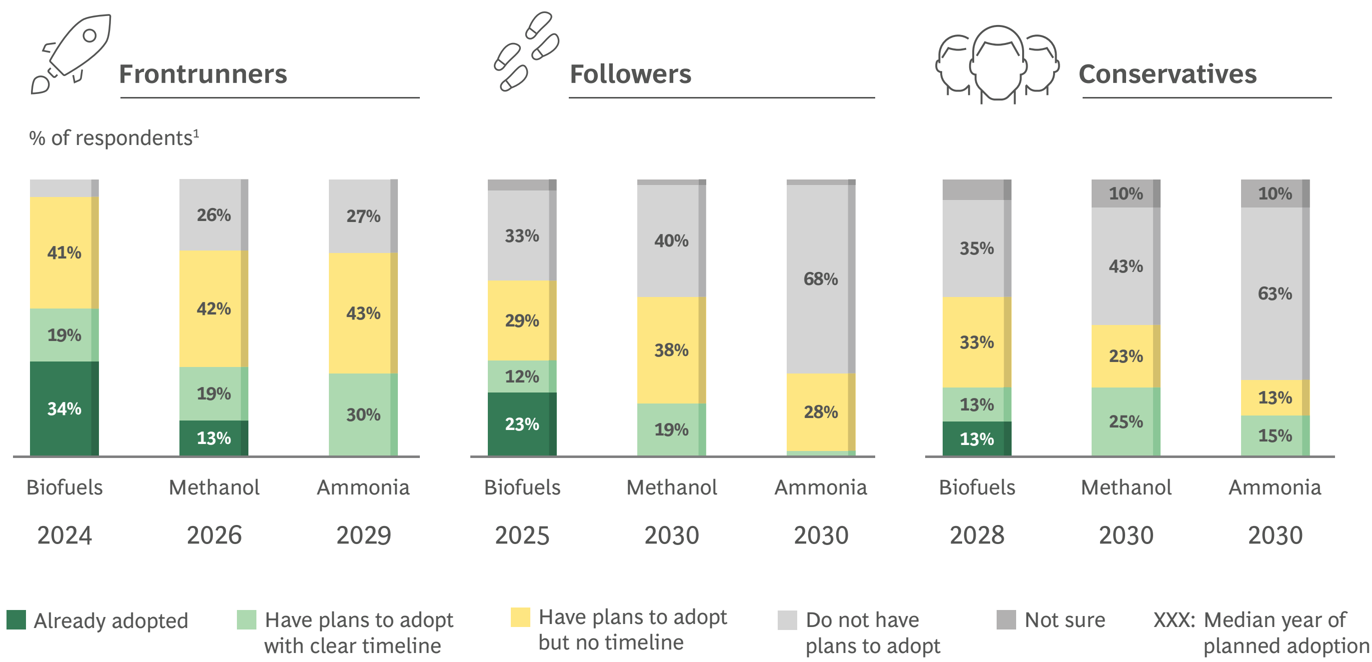
Exhibit 10 - Clear differences in fuel outlook between archetypes with Frontrunners planning to adopt future fuels as early as 2026

Long-term potential of each fuel



[1] N=128
Note: Values less than 10% are not shown in this exhibit

Current and planned adoption of each fuel



[1] N=124
Note: Values less than 10% are not shown in this exhibit

While other fuels, such as synthetic LNG and green hydrogen, can help to decarbonize the shipping sector, they face various challenges that limit broad adoption. While retrofits for LNG propulsion are the most mature among alternative fuels, LNG is a transition rather than an "end-state" fuel. As such, most shipowners and operators prefer to retrofit their vessels directly with future fuel capabilities, so they incur the costs (including opportunity costs) only once. Hydrogen, meanwhile, must be stored cryogenically at minus 253 degrees Celsius for transport, which presents significant operational challenges and costs. It also has a lower volumetric energy density than methanol and ammonia, which would entail a significant loss in cargo space.

Accordingly, the survey focused on methanol, ammonia, and biofuels, as they are expected to form a larger part of shipping's fuel mix in the medium to long term.

The three archetypes differ substantially in their outlook on fuels. Frontrunners see the highest long-term potential in ammonia, likely due to their familiarity with the fuel and confidence in managing its operational challenges. 65% of Frontrunners perceive ammonia as promising compared to 36% of Followers and Conservatives. Frontrunners also see ammonia as having higher potential than methanol—a clear difference from Followers and Conservatives (Exhibit 10).

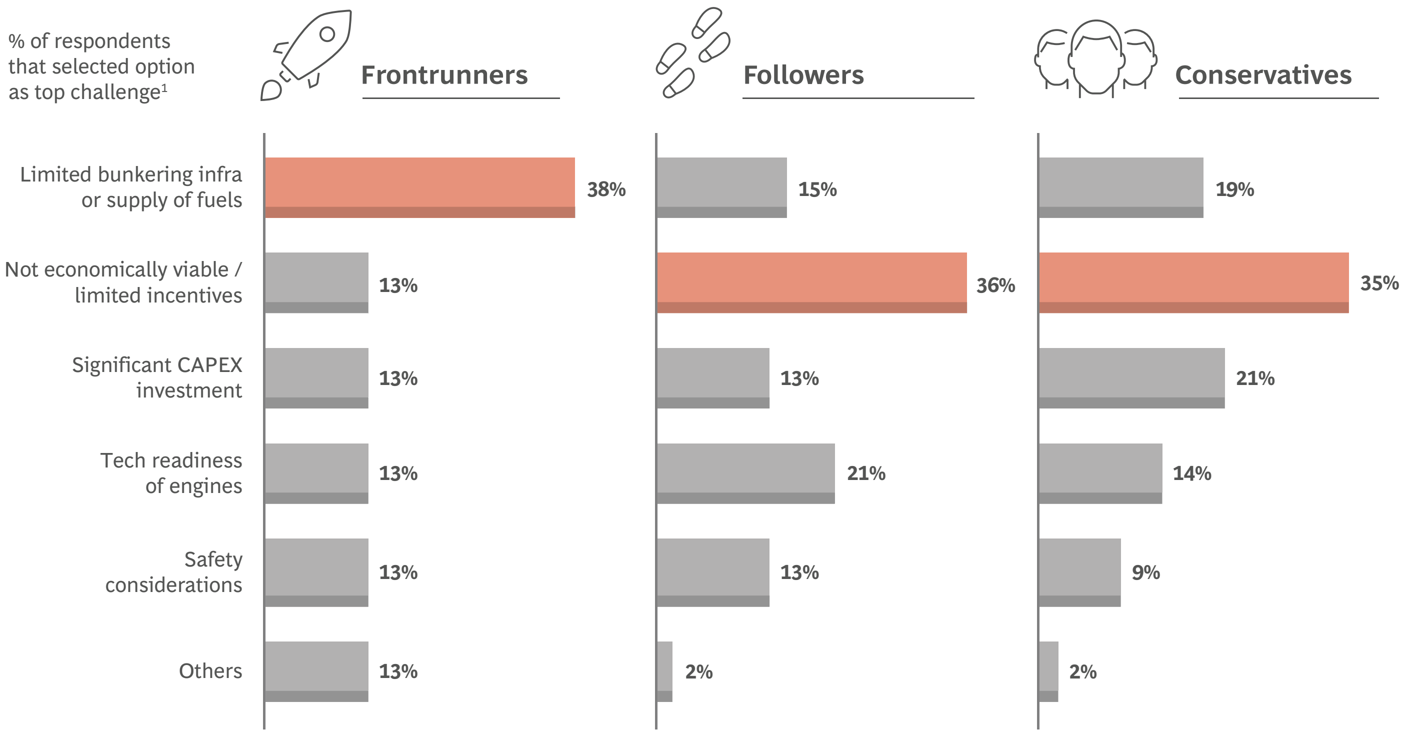
This observation is consistent with our survey data that 88% of Frontrunners are familiar with alternative fuels, compared to 55% of Conservatives. Meanwhile, Followers are the most optimistic about the long-term potential of biofuels compared to the other archetypes, reflecting their preference for solutions that have been largely de-risked today.

Frontrunners also lead the charge in adopting these fuels, likely driven by their willingness to pilot more nascent solutions and to spend more on reducing emissions. More than 90% of Frontrunners have adopted or plan to adopt biofuels, while more than 70% claim the same for methanol and ammonia, and 13% have already adopted methanol (Exhibit 10). Meanwhile, Followers and Conservatives are taking a more reserved, wait-and-see approach, particularly with ammonia. A quarter of Followers have started adopting biofuels. Yet compared to Frontrunners, fewer Followers and Conservatives have plans to adopt ammonia (~30%) versus biofuels and methanol (50%–60%).

Finally, Frontrunners' optimism on future fuels versus other archetypes is also reflected in their adoption timelines. Many plan to adopt methanol in 2026 and ammonia in 2029, while other archetypes are generally less certain.

Exhibit 11 - Supply availability and economic viability are the biggest challenges for future fuel adoption

Top challenge for adopting future fuels (by 2030)



¹ N=128

As Frontrunners are willing to pay higher green premiums and pilot nascent solutions, the biggest bottleneck to adopting future fuels is the limited availability of bunkering infrastructure and fuel supply—38% of Frontrunners report this as their top challenge (Exhibit 11). In contrast, Followers and Conservatives are more concerned about the economic viability and incentives for adopting future fuels.

Given that the supply chain and port infrastructure needed to bunker future fuels are still nascent, and will take years to build, it is critical that ports and fuel suppliers start now to limit barriers to adoption. For ammonia, this means not only investing in storage and bunkering infrastructure, but also developing safety guidelines and fuel standards to enable crews to operate this infrastructure and properly deploy ammonia. It also means developing competency frameworks so operators can be properly trained to handle this toxic molecule as a fuel.

The adoption of future fuels will likely lead to a change in bunkering patterns to accommodate for less energy-dense fuels.

Bunkering activities today are highly concentrated, with ten major ports accounting for half of global bunkering volumes. However, ammonia and methanol have lower volumetric energy density—2.4–2.8x lower than heavy fuel oil (HFO), so ships will see their operating range fall 60% to 70% for the same volume of fuel. Shipowners and operators will either need to trade off cargo space to store larger volumes of fuel onboard, or alter their operations to bunker more frequently, to account for this lower energy density.

More than half (58%) of the survey respondents across fleet size and vessel type intend to bunker more frequently, instead of increasing the size of their fuel tanks to carry more fuel. If tank sizes and operating speeds do not change, this choice will result in the need for more extensive bunkering infrastructure and new bunkering locations.

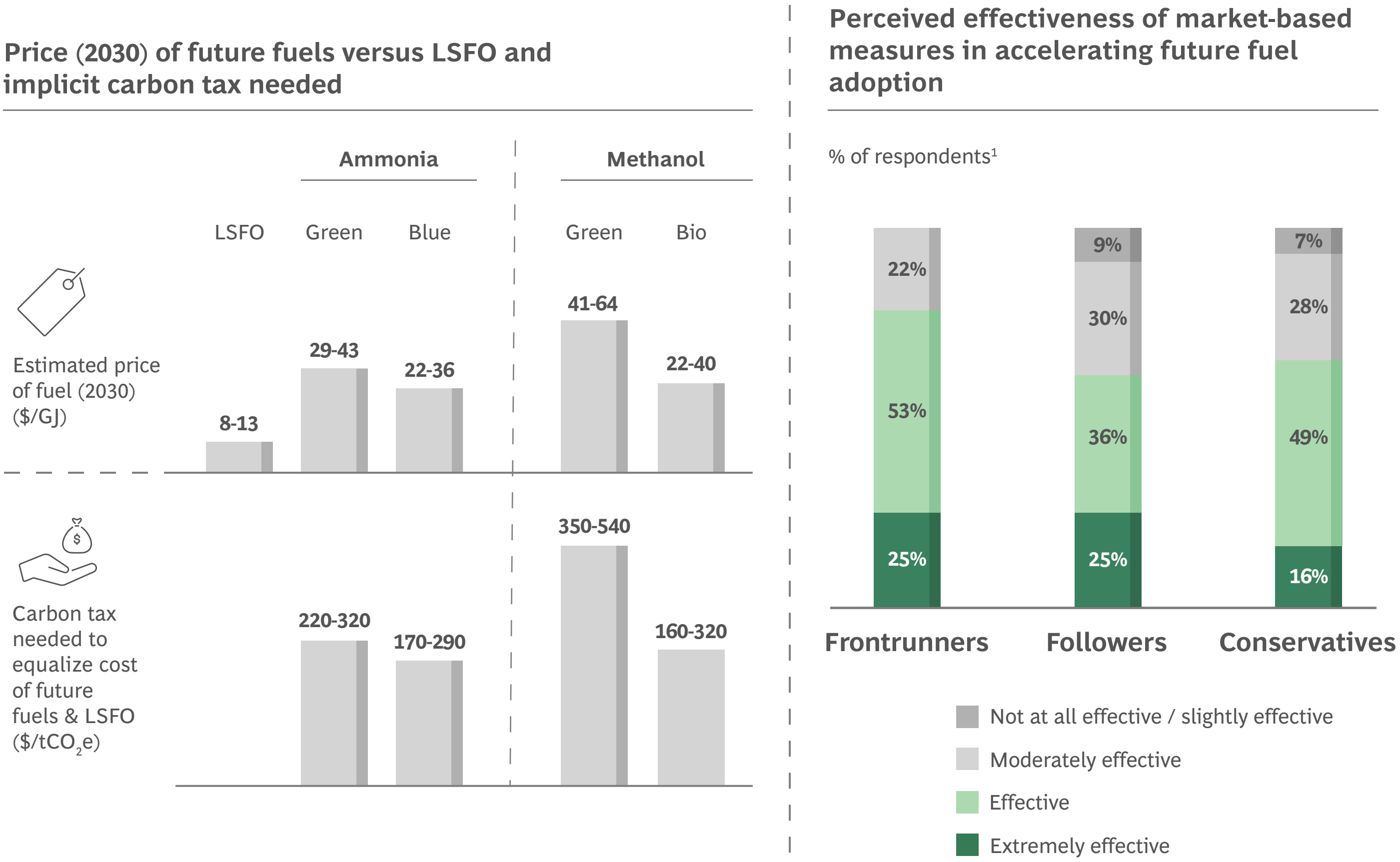
Round trips can still be done on some routes, such as the Australia to China iron ore route, while using future fuels.[2] On longer routes, such as for trans-Pacific containers, ships will need to transition from bunkering at one end of the route to bunkering at both ends.[3] In the case of the longest routes, such as the Brazil to China iron ore route, there may even be a need to bunker enroute, potentially requiring new bunkering locations to be established.[2]

Methanol and ammonia, both hydrogen derivatives, are also potential export vectors for hydrogen, given their higher energy density and relative ease of handling compared to hydrogen itself. Ammonia also offers the possibility of reconversion back to hydrogen, although the low efficiency (<30%), coupled with additional costs and GHG emissions, will discourage reconversion.

Nevertheless, the growing trade of hydrogen and its derivatives should enable the shipping industry to dovetail bunkering infrastructure requirements for ammonia (and potentially methanol) with that needed for the broad trade of hydrogen and its derivatives. This optionality would de-risk the development of fueling infrastructure at ports and attract a wider set of investors.

2. Assuming that the route is run by a Capesize bulk carrier with unchanged tank size and operating speed.
3. Assuming that the route is run by a New Panamax containership with unchanged tank size and operating speed.

Exhibit 12 - Near-term economics likely to be challenging for future fuels, cost-sharing and cost-equalization mechanisms critical



[1] N=128

Note: Ammonia and Methanol prices may vary significantly; range is determined by electrolyzer CAPEX, electrolyzer efficiency, natural gas price, source of carbon capture (bio vs point source vs DAC), carbon capture cost, LCOE, geography and macroeconomic landscape

Source: Maersk Mc-Kinney Moller Center, Yara Clean Ammonia, Methanol Institute, JP Morgan, IMO, BCG analysis

Cost-sharing and cost-equalization mechanisms critical to drive adoption.

Lowering the premiums on green fuels is also essential to accelerate adoption. The lack of commercial incentives and the low economic viability of these future fuels are top of mind for Followers and Conservatives. 35% of respondents in these archetypes select these as the leading challenges for adoption.

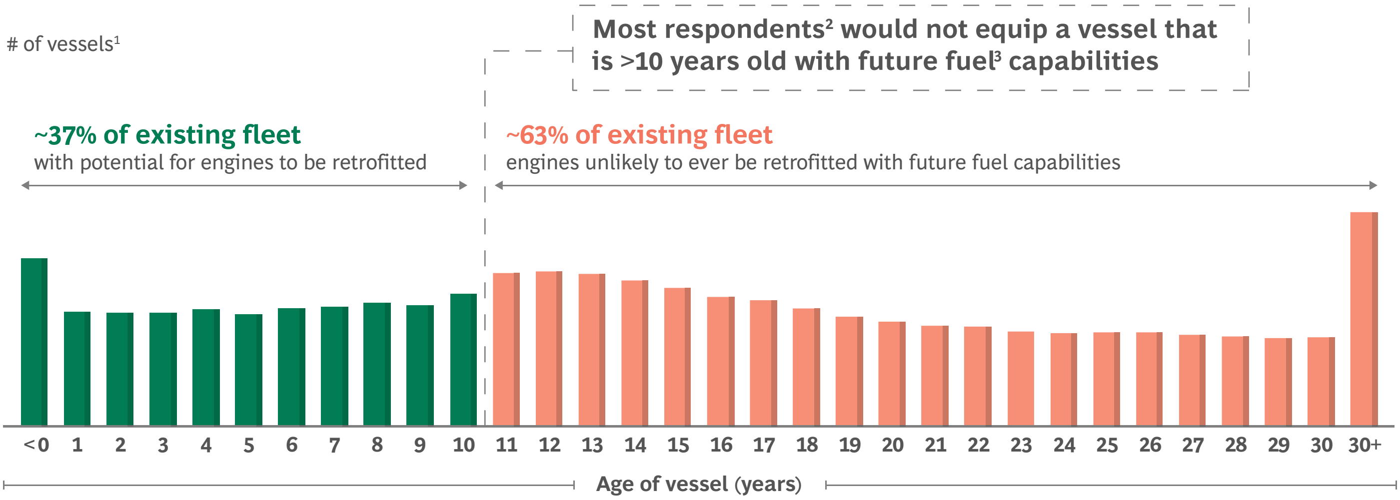
The premiums for green ammonia and green methanol are substantial. Industry estimates suggest that green ammonia will cost up to four times more than low-sulfur fuel oil (LSFO) in 2030, while green methanol will cost as much as six times more than LSFO in 2030 (Exhibit 12). At $2,500/ton of bio-methanol, Maersk paid four times more than LFSO in tonnage-equivalent, or about nine times more than the energy-equivalent, earlier this summer for its container feeder liner in its maiden voyage from Ulsan to Copenhagen.[4]

Market-based measures can help overcome these green premiums, with more than two-thirds of survey respondents citing their need for such mechanisms to accelerate future fuel adoption. Not surprisingly, the carbon price needed to equalize the prices of traditional and future fuels is expected to be very high in the near term. For example, a carbon price in the range of $200–$500/tCO_2e on LSFO would be needed for future fuels to be price competitive. For reference, the average price of a carbon permit traded in the EU, as part of the Emissions Trading System, has averaged around $90–$100/tCO_2e over the past year.

As a result, mechanisms for shipowners and operators to share costs with other stakeholders will also be needed to drive broader adoption of future fuels. Sharing costs will make the green premiums less daunting. 23% of participants highlighted the ability to pass some of the costs on to consumers as the main driver to accelerate their adoption of alternative fuels.

4. TradeWinds, June 12, 2023

Exhibit 13 - At least 63% of existing fleet will likely never be retrofitted with future fuel capabilities



[1] Analysis only includes bulkers, tankers and containers
[2] N=128. This is based on median age given by respondents from GCMD-BCG survey – "What is the maximum age of vessel that you would still consider to retrofit with future fuel capabilities?"
[3] Future fuels refer to non-traditional marine fuels such as LNG, ammonia, methanol, and hydrogen
Source: Clarksons Shipping Review and Outlook as of 2022

Interim solutions, such as drop-in fuels and shipboard carbon capture, are needed to reduce emissions while the fuel transition ramps up.

Transitioning today's fleet of vessels to run on future fuels will take time. Almost all respondents (97%) see vessel age as a key factor in retrofitting a vessel with future fuel capabilities. Most respondents are unlikely to retrofit vessels older than ten years. Accordingly, at least 63% of the existing fleet will likely never use future fuels (Exhibit 13). The actual proportion will likely be higher due to constraints, such as engine technology, shipyard capacity, the willingness to invest and absorb opportunity costs, and the supply availability of these fuels. As such, interim solutions, like drop-in fuels and shipboard carbon capture, will be critical for reducing emissions in the near to middle term.

Drop-in fuels refer to low-carbon alternative fuels that ships can use without modifying their engines. Most Frontrunners (78%) plan to adopt drop-in fuels in three to five years. Close to half of Followers and a third of Conservatives are considering drop-in fuels in the same timeframe. Most (85%) respondents planning to adopt drop-in fuels are considering biofuels, but supply availability and economic viability remain key challenges that need to be overcome.

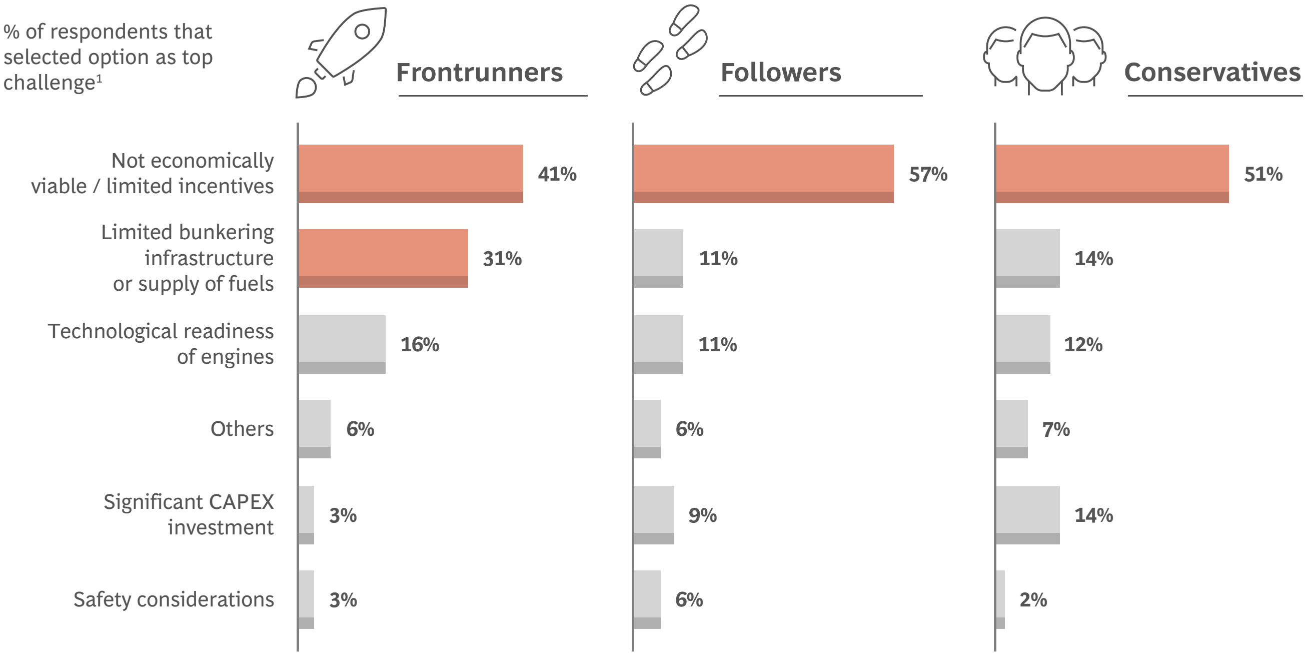
Today, sustainably sourced biofuels are constrained by a limited supply of second- and third-generation feedstocks. While first-generation feedstocks make up most biofuel supply today, these have high upstream emissions caused by induced land use changes and cultivation. As a result, second- and third-generation feedstocks are expected to drive the growth in biofuel production needed to meet 2030 targets. By 2030, 35% of biofuel production will come from second- and third-generation feedstocks, with this share increasing to 78% by 2050.[5] Today's second-generation feedstocks—primarily waste oils and animal fat—will soon reach their collection potential and are unlikely to meet this demand. While other feedstock options are available, such as agricultural residues (second generation) and crude algae oil (third generation), conversion technologies for these feedstocks are still in development, and commercial viability remains a challenge. In order to meet global biofuel demand by 2050, close to 30%[6] of the total addressable potential of second- and third-generation feedstocks will need to be unlocked.

The maritime sector will need to compete with other sectors that have parallel biofuel demand, like the aviation sector. Sustainable aviation fuel (SAF) will play a crucial role in long-term aviation decarbonization. Today, the most common type of SAF is hydrotreated esters and fatty acids (HEFA), which relies on biomass as feedstock. While SAF has higher production costs than marine biofuel due to the higher quality requirements, aviation's share of biofuel supply is likely to continue to increase due to the higher margins afforded by aviation compared to those of marine biofuels by shipowners and operators, the strong regulatory push to mandate SAF, and the potential for airlines to pass costs to their customers.

5. International Energy Agency (World Energy Outlook 2022)
6. International Renewable Energy Agency (Innovation Outlook: Advanced Liquid Biofuels), European Commission (JRC Science for Policy Report - JRC-EU-TIMES model)

Exhibit 14 - Lack of economic viability and limited commercial incentives are the biggest challenges for transition fuel adoption

Top challenges for adopting transition fuels (by 2030)



[1] N=128

Working with fuel providers and ports to secure near-term biofuel supply for maritime will thus be an important driver for adoption. Given that biodiesel and renewable diesel are shipped today, the maritime industry should also seek to opportunistically leverage shipped volumes for bunkering where viable.

Technical pilots and studies for bunkering of new second- and third-generation feedstocks, such as agricultural residues and crude algae oil, once they are available, can also help to accelerate their adoption and relieve supply pressure. There are also increasing opportunities for mini-biofuel refineries using domestic horticulture and organic waste to produce next-generation biofuels, which can be supplied to nearby bunkering ports. Doing so will help to improve the economic viability of biofuels by easing supply-side pressure on prices.

Economic viability is the other big challenge for drop-in fuels. While the industry is optimistic about biofuels, their green premiums may hinder near-term adoption. Roughly half of respondents across all archetypes identify the lack of economic viability and limited commercial incentives as the primary barriers to adoption (Exhibit 14). Biofuel blends (e.g., B20/B24), such as those comprising Fatty Acid Methyl Esters (FAME), which is one of the most used biofuels in maritime today, have commanded price premiums of 30%–50%[7] above traditional marine fuels in the last two years, with even higher premiums seen prior to this. However, as supply chains are more developed and little modifications are needed to existing infrastructure, it will likely still be cheaper to adopt biofuel blends in the near term compared to low-carbon methanol or ammonia.

While supply availability and economic viability are key factors in deciding on biofuels, the final, most critical piece of the puzzle is the abatement potential of biofuels. Creating transparency around the well-to-wake abatement potential will be critical to driving adoption and enabling shipowners and operators to understand which fuels to use. While emissions from fossil fuels are primarily generated from fuel combustion and are categorized as tank-to-wake emissions (Scope 1 emissions for shipping), emissions from biofuels are primarily well-to-tank in nature (upstream emissions incurred during production and transport of biofuels; Scope 3 emissions for shipping). Biofuels are considered to have a zero emissions factor for combustion and zero tank-to-wake emissions. However, the well-to-tank emissions of biofuels can vary widely depending on the feedstock used, where the biofuel is sourced, how far the product is transported before it is bunkered, etc. Enabling shipowners and operators to measure and understand the full life cycle assessment of emissions of these fuels is therefore key to their making educated choices about which fuels to adopt.

7. Based on UCOME prices from June 2021 to June 2023

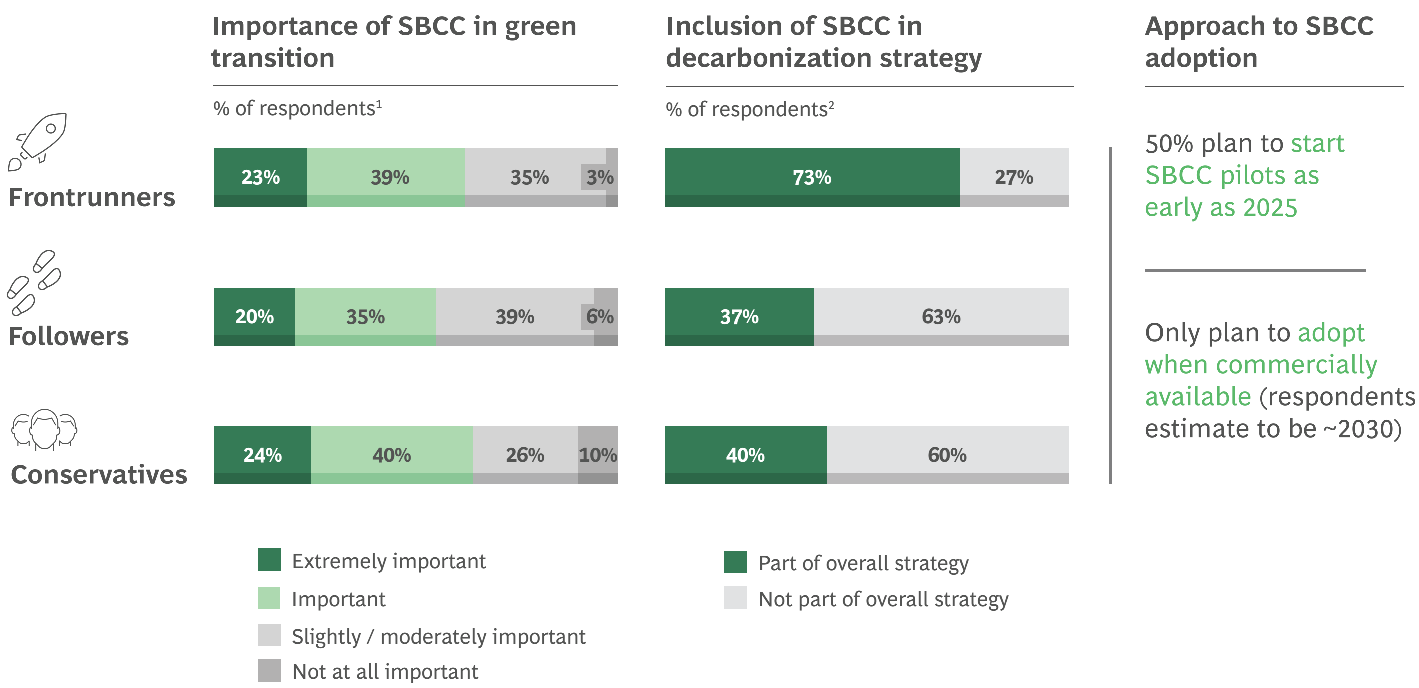
Shipboard carbon capture – an important step towards net zero

Shipboard carbon capture (SBCC) is poised to play a crucial role in both mid-term and long-term decarbonization efforts. It is a key interim solution while fossil fuels are still in use, but given that biofuels and methanol are still carbon-emitting fuels, SBCC will likely continue to be deployed when future fuels have reached widespread adoption. Capturing CO_2 beyond what is emitted into the atmosphere from a well-to-wake perspective can also lead to negative emissions, which could potentially translate into an additional source of income if accompanied with the right carbon pricing and accounting mechanisms.

SBCC adoption is still in its early stages, with industry pilots focused on marinizing land-based carbon capture technologies. Currently, the most mature solution is solvent-based (e.g., amines), with sorbent-, membrane-, and cryogenic-based approaches in the emerging stage. Capture technologies that use amine as a solvent are promising, as they are already available for land-based applications and have been tested by potential providers for maritime use.

Maritime use of amine-based systems can affect the performance of the system, and the overall CAPEX and OPEX involved. These considerations include: 1) the cleanliness of the onboard exhaust prior to capture, 2) the availability of waste heat to strip captured carbon dioxide from CO_2-saturated solvent, 3) the availability of additional energy to liquify captured carbon dioxide, and 4) the availability of additional space for the storage of liquified captured carbon dioxide.

Exhibit 15 - Shipboard carbon capture (SBCC) seen as an important solution by most, with Frontrunners looking to pilot by 2025



[1] N=124, [2] N=123

The cleanliness of the exhaust has a bearing on the ongoing OPEX costs required for amine-based SBCC systems. Impurities, such as particulate matter, soot, NOx, and SOx, can increase the frequency with which the amine solvent needs to be replaced, leading to higher costs. This is an important concern especially for vessels running on traditional marine fuels, as SBCC-deployment on such vessels will likely need pre-treatment of exhaust.

In contrast, an SBCC system built for vessels running solely on alternative fuels, such as LNG or methanol, would need much less exhaust pre-treatment. There may also be other synergies when using SBCC on LNG-fuelled vessels, as the cold energy available onboard can facilitate liquification of captured carbon dioxide without the need for additional electrical energy.

Amine-based SBCC systems can have high costs as they require extra heat, or more efficient boilers, to strip the captured carbon dioxide from the saturated amine solvent. A feasibility study commissioned by the Oil and Gas Climate Initiative (OGCI) and Stena Bulk on an HFO-fuelled SuezMax indicated that 22% additional fuel is needed to generate the extra heat and electrical energy to power an SBCC system at a 50% capture rate.

This fuel penalty rises with the capture rate—53% more fuel is needed for a 90% capture rate. Accounting for the extra emissions from the fuel penalty, the effective reduction in carbon dioxide for the systems running at 50% and 90% capture rates are 40% and 84%, respectively. These capture rates can help vessels achieve their interim indicative targets for 2030 and perhaps 2040, though at the expense of increased OPEX.

Liquified carbon dioxide (LCO_2) is typically stored under pressure at low temperatures, which require specialized tanks. This need will increase the costs associated with installation and maintenance of SBCC systems. Substantial storage space will also be needed, as each ton of HFO consumed generates three tons of carbon dioxide. Hence, the use of SBCC systems may lead to a substantial reduction in the amount of available cargo space, imposing an opportunity cost on operators and charterers.

Beyond these shipboard challenges, guidelines for offloading captured CO_2 currently do not exist. Port-side infrastructure will also need to be developed concurrently for wide deployment of the solution.

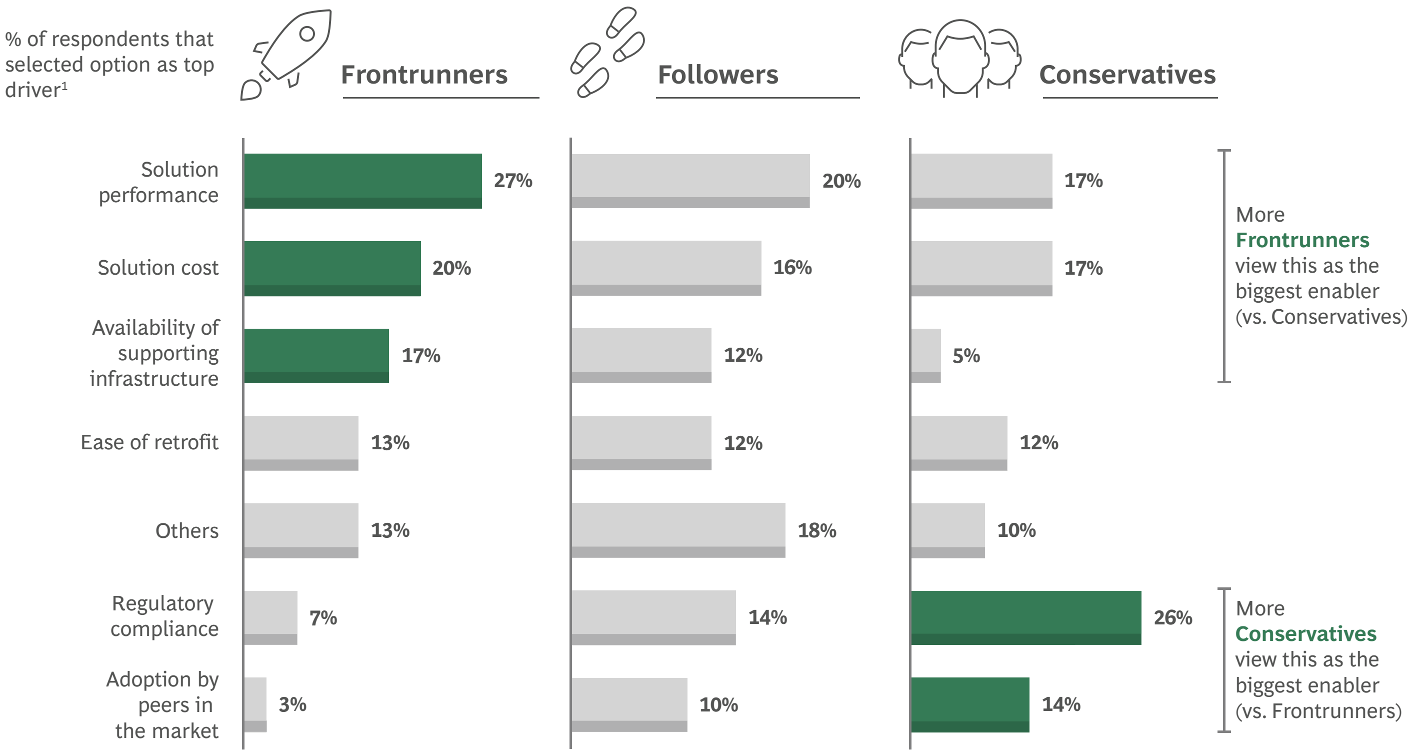
> **While SBCC systems are still at an early stage of development, most respondents (55%–65%) across archetypes see them as important to achieving net-zero emissions.**

The archetypes, however, differ in their outlook and approach to adoption (Exhibit 15).

Frontrunners are likely to lead the way in piloting and adopting SBCC solutions. Three-quarters of Frontrunners have included SBCC as part of their decarbonization strategy, with half aiming to initiate pilot projects by 2025. 25% of Frontrunners expect to pilot solutions before commercial availability. In contrast, Followers and Conservatives are cautious, planning to adopt SBCC only once it becomes commercially available, which they expect to be around 2030.

Exhibit 16 - External pressures likely needed to drive adoption of shipboard carbon capture amongst Conservatives

Top drivers for adopting shipboard carbon capture



[1] N=123

Frontrunners view technological improvements and infrastructure availability as key drivers for early adoption of SBCC.

Given their readiness to adopt SBCC and willingness to pilot the technology even ahead of commercial availability, the key obstacles for Frontrunners are largely related to execution and operationalization. 27% and 20% of Frontrunners identified improved solution performance and reduced solution cost as the top drivers to adoption, respectively. To drive adoption among Frontrunners, it is critical to address the capital and operational constraints of SBCC, including those highlighted in the earlier part of this section.

17% of Frontrunners also selected the availability of supporting infrastructure as the top driver for adoption. Infrastructure is needed at ports to offload and store captured carbon dioxide. This infrastructure needs to be tailored to the onboard storage conditions of the captured carbon dioxide (or vice versa), and the volumes that are offloaded. Hence, there is a need to holistically study processes that offload LCO_2 from different vessel types at different temperatures and pressures, and transfer them to different receptacles, including LCO_2-receiving vessels and intermediary storages sites.

In addition to the technical feasibilities and detailed procedures, studies must also review existing policy and regulation regimes that may prevent or enable offloading. Regional or local re-distribution models will need to be developed to facilitate the transportation of captured carbon to off-takers (utilization) and/or sequestration sites. Policies and standards governing cross-border transport of captured carbon as waste products, as well as transparency and documentation processes, will be essential in building industry confidence in the impact of SBCC on decarbonization.

Improved solution performance, reduced cost, and availability of infrastructure are necessary, but not sufficient conditions for the adoption of SBCC by other archetypes. 26% of Conservatives identify regulatory compliance as the top driver for SBCC adoption, while 14% identify adoption by peers as the top driver. This statistic reflects the need for external drivers, such as tighter regulation and widespread confidence in the solution, to drive broader adoption by Conservatives.

A call to action

Our survey of shipowners and operators found a general willingness to invest in decarbonization, but different needs depending on their state in the journey. In order to accelerate that investment, we need to support the industry with interventions tailored to those stages.

Frontrunners have high decarbonization ambitions and are willing to invest heavily. They are pushing boundaries, adopting even nascent and experimental decarbonization levers. It is critical to support them through technical pilots, and by building the necessary infrastructure for future fuels and shipboard carbon capture. Supporting them will push the frontiers of what the industry views as feasible and pave the way for broad-based adoption.

Followers, with stringent investment thresholds and a near-term outlook, are focused on solutions with immediate and certain value. Initiatives that collate and share data can increase their confidence in less-established solutions, while innovative financing mechanisms can de-risk adoption.

Regulations are needed to set the pace of decarbonization for Followers, pressing them to become fast Followers. This will close their adoption gap with Frontrunners and enable innovative and effective solutions to become entrenched in the industry quickly.

Conservatives are still in the early stages of decarbonization. They face intrinsic challenges, such as a lack of awareness and capabilities. Initiatives to help Conservatives will increase their understanding of the various decarbonization levers according to their specific context, while building the capabilities needed to support deployment. Accelerating low-carbon solutions for Conservatives is critical to ensure an inclusive and holistic green transition, as Conservatives form a large proportion of the global fleet. These initiatives are also “lower hanging fruit” that can be done more easily, especially when compared to the complex multi-party coordination needed to drive regulations, facilitate the fuel transition, and build infrastructure.

Five key actions to accelerate decarbonization across the shipping industry

Beyond the archetypes, we can lay out a variety of supports for maritime decarbonization: greater research and development, widespread industry pilots, financing of new technologies and infrastructure, tighter regulation, new and updated safety and operational standards, and industry-wide capability building.

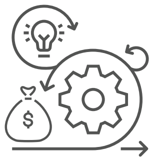
Five actions stand out in their importance, as they directly address the varying needs of each archetype, but also complexity, as they require close collaboration and partnership amongst stakeholders across maritime ecosystem.

01.

Conduct technical pilots and facilitate data sharing for more nascent levers

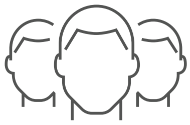
02.

Create innovative financing mechanisms to de-risk adoption of less-mature levers



03.

Support Conservatives to raise awareness, contextualize levers, and build capabilities

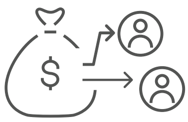


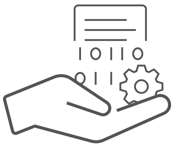
04.

Start to build out future fuel infrastructure and ensure supply at ports

05.

Develop mechanisms to share and equalize costs of adoption across the ecosystem





1 Conduct technical pilots and facilitate data sharing for more nascent levers

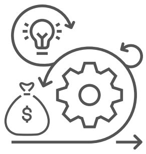
As Frontrunners push boundaries in adopting emerging solutions, solution providers and industry bodies must collaborate and conduct technical pilots that test, demonstrate, and improve the performance of these solutions. These pilots should take a “whole-of-value-chain” approach to uncover and address gaps that limit the adoption of a lever.

For example, even when shipboard carbon capture is proven to be commercially viable, adoption will hinge on the ability to offload, transport, and sequester the captured carbon dioxide safely and economically. Such pilots can pave the way for adoption by other archetypes as well as Frontrunners.

The large variance in performance of nascent levers, such as wind propulsion and air lubrication, can also deter shipowners and operators from adopting them, as it makes it difficult to formulate a business case to justify their adoption. This is exacerbated by low adoption levels, which keeps operational performance data by vessel type and route scarce.

Data from industry pilots, when shared with the broader industry, can offer valuable clarity to shipowners and operators on the benefits these levers yield. Such data will be especially valuable for Followers, who seek greater confidence in the performance and returns of a solution before adopting it.

Data on the performance of nascent levers need not come just from technical pilots. Industry bodies and classification societies can encourage stakeholders to pool data, which can then be aggregated and shared back with the industry as benchmarks, after removing commercially sensitive and/or proprietary information. Benchmarks that show performance on “sister ships”—ships of similar size or design—across key routes and operating conditions can provide shipowners and operators with added insight into which solutions would work for their fleet, and further drive adoption.



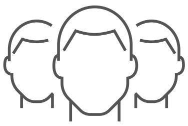
2 Create innovative financing mechanisms to de-risk adoption of less-mature levers

Followers are less likely to consider nascent levers, which are expensive with an unclear savings potential due to large variances in their performance.

Innovative financing mechanisms can promote nascent solutions by de-risking adoption. More than half of Frontrunners and Followers view “pay-as-you-save” models as de-risking the adoption of nascent levers, because these shift upfront CAPEX to OPEX and allow ship operators to repay the investment over time from realized fuel savings.

Such mechanisms are currently not common in the shipping industry, as current financing models focus on financing entire vessels and fleets, and are not designed with efficiency retrofits in mind. Yet such mechanisms will not only prompt adoption of nascent solutions by risk-averse Followers, but also accelerate adoption among Frontrunners.

Close collaboration between shipowners and operators, cargo operators, financial institutions, insurance agencies, and law firms is essential to create the necessary arrangements and leasing models.



3 Support Conservatives to raise awareness, contextualize levers, and build capabilities

Conservatives need to become familiar with the various decarbonization levers and understand which of these levers are suitable for their specific fleets and operating context. A quarter of the Conservatives cited this lack of awareness as the top challenge to the efficiency levers.

At the same time, Conservatives also need to develop internal capabilities to assess and deploy levers. A fifth of Conservatives reported a lack of capabilities to be their top challenge in adopting the efficiency levers.

Classification societies and other industry bodies have a significant role to play to uplift the long tail of smaller shipowners and operators. These groups can raise awareness of and help companies to contextualize the various solutions through channels, such as webinars and workshops, while also supporting the development of intrinsic capabilities for those who are keen to adopt.

4 Start to build out future fuels infrastructure and ensure supply at ports

Frontrunners aim to adopt methanol by 2026 and ammonia by 2029. Immediate action is needed to build future fuels infrastructure at ports and facilitate these ambitions.

Infrastructure build must not only proceed at a rapid pace, but also reflect the evolving bunkering landscape. Today's highly concentrated bunkering patterns must broaden with the transition to fuels with lower volumetric energy density. This transition will necessitate investments in storage and bunkering infrastructure at existing ports and the emergence of new ports, especially along lengthy routes. Bunkering investments for methanol and ammonia can draw on storage infrastructure built at ports geared towards transporting and trading these commodities, given their increasing use as export pathways for hydrogen. Such facilities allow aggregation of supply and can de-risk investment and lower the upfront cost of building infrastructure through economies of scale.

Catalytic financing from multilateral development banks, governments, and investment funds is required to kick-start the development of large-scale port infrastructure and green-fuel production facilities, and to crowd-in further private investment. Sectors requiring methanol and ammonia should aggregate demand and enter offtake agreements to provide demand certainty to financiers, port owners, and fuel suppliers. Doing so would enhance the investment case and unlock this financing.

5 Develop mechanisms to share and equalize costs of adoption across the ecosystem

Green premiums pose a significant challenge to the widespread adoption of decarbonization solutions, particularly for Followers and Conservatives in the maritime industry. Addressing the cost barrier is crucial to drive adoption, and a range of measures must be developed. Cost equalization through carbon pricing will help, but companies will need to share costs with stakeholders in the ecosystem, including cargo owners and end customers. A quarter of the respondents of the survey identify the ability to share costs as the most influential factor affecting their pace of future-fuel adoption.

Green-conscious cargo owners can establish buyers' clubs committed to procuring green volumes at a higher price to assure shipowners investing in decarbonization measures. But the shipping industry must devise other innovative strategies to encourage customers to share the costs of decarbonization. A promising approach is to increase transparency on Scope 3 (indirect) emissions per twenty-foot equivalent unit (TEU) or metric ton of cargo.

By leveraging the IMO's existing Carbon Intensity Indicator (CII) measures, shipowners and operators, cargo operators, regulators, and industry bodies can collaborate to establish standards and frameworks for calculating actual emissions per unit of cargo. This heightened transparency will enable customers to assess GHG emission reductions for their purchases and gain valuable clarity. Enabling customers to quantify their Scope 3 emissions would facilitate a better understanding of the cost of abatement and incentivize investments in higher-cost, green cargo volumes.

With bold steps and the right investments, we can set a course for a future where decarbonization and commercial success go hand in hand.

About the Authors

Professor Lynn Loo is Chief Executive Officer at the Global Centre for Maritime Decarbonisation. She is also the Theodora D. '78 and William H. Walton III '74 Professor in Engineering at Princeton University. You may contact her by email at lloo@gcformd.org.

Dr. Sanjay C Kuttan is Chief Technology Officer at the Global Centre for Maritime Decarbonisation. You may contact him by email at sckuttan@gcformd.org.

Michael Tan is a Managing Director and Partner in Boston Consulting Group's Singapore office. He is the Southeast Asia leader of the firm's Public Sector practice. You may contact him by email at tan.michael@bcg.com.

Sanjaya Mohottala is a Managing Director and Partner in Boston Consulting Group's Singapore office. He is the Asia Pacific leader of the firm's Logistics, Parcels and Shipping (LPS) practice. You may contact him by email at mohottala.sanjaya@bcg.com.

Seng Chiy Goh is a Principal in Boston Consulting Group's Singapore office. He is a core member of the firm's Public Sector and Climate and Sustainability practices. You may contact him by email at goh.sengchiy@bcg.com.

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For Further Contact

If you would like to discuss this report, please contact the authors.

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