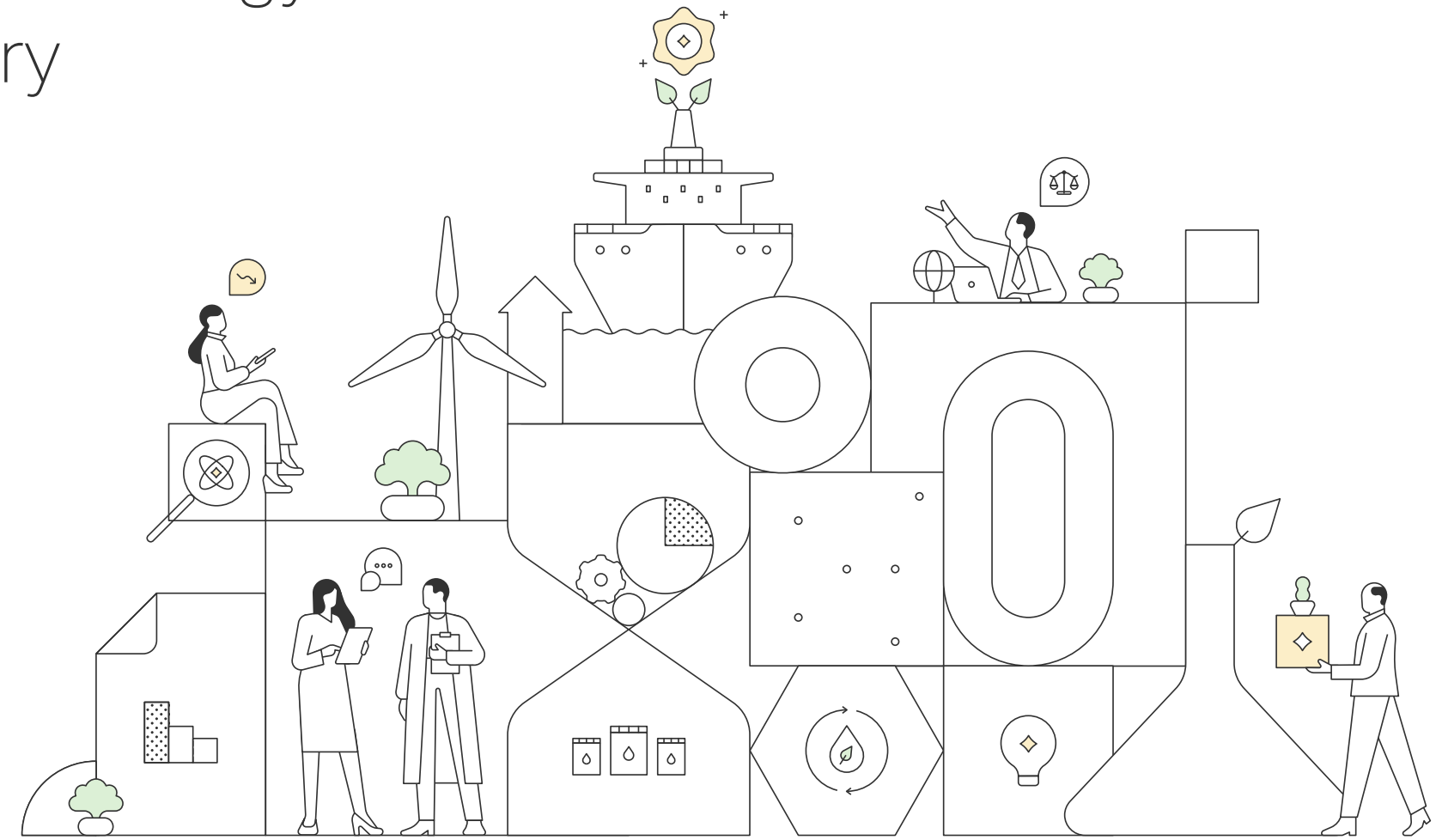
Industry Transition Strategy
Executive Summary

October 2021

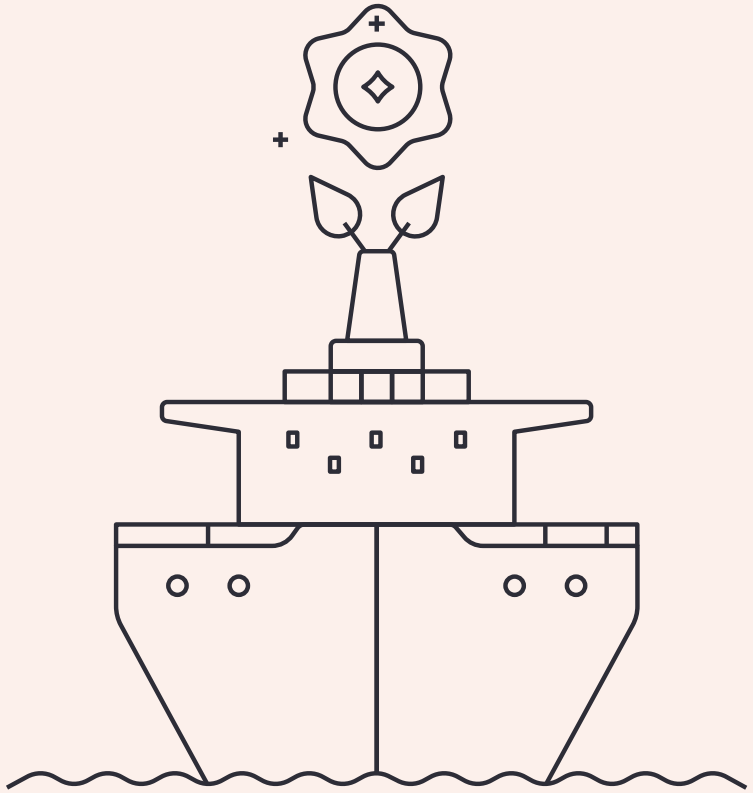


Mærsk Mc-Kinney Møller Center
for Zero Carbon Shipping

Preface

The maritime industry's approach to fighting climate change has changed dramatically over the past two to three years. Ship owners have set decarbonization targets, vessels with alternative propulsion are being ordered and much more is planned. But the current Green House Gas (GHG) emissions from the maritime industry are enormous and time is scarce. In our Transition Strategy we discuss the development in the maritime industry and ways for it to decarbonize.

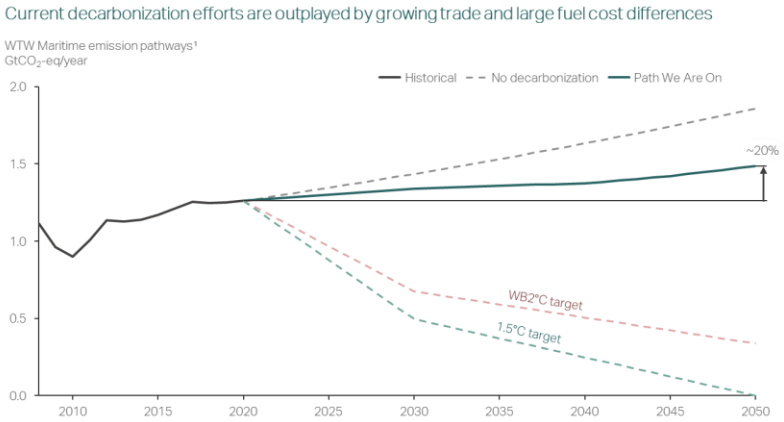
Despite some of our data being given by the laws of physics there is still considerable uncertainty around the future pathways. We will therefore not speculate and try to predict the future. We will discuss what our current data shows and what we are able to model at this point. Based on this we will outline the critical levers we have available to impact the direction, and what needs to happen over the coming years to get the maritime industry on the path towards zero carbon shipping.



The path we are on

The modelling of 'the path we are on' includes realistic forecasts for the growth of shipping, implementation of energy efficiency measures, cost and availability of renewable energy, consumer behavior, finance cost and all relevant regulation that has been implemented. It shows that if we do not change course the path we are on will lead to around 20% more GHG emissions by 2050. This is very far from the 1.5-degree and the well below 2-degree pathways outlined by the IPCC.

Industry leadership is gaining momentum but even if all current shipowner decarbonization commitments are delivered as promised only 22% of global maritime transportation will be net zero carbon by 2050. This momentum would almost exclusively be driven by the container industry. Tanker and dry bulk are more fragmented, and leadership is only just emerging. The main risk is that industry leadership could lead to margin erosion for the front runners if customer willingness to pay is weak and the substantial cost gap between fossil and alternative fuels (e.g. e-methanol, e-ammonia or biofuels) is not closed by regulatory intervention.



If the path we are on materializes, the global maritime fuel mix would consist almost exclusively of LSFO and LNG by 2050. Energy demand from the maritime industry would grow because improved energy efficiency cannot offset transport demand growth. Although long-term trade volume forecasts are uncertain by nature, we use an estimate for global trade growth of 1.3% p.a. on average, which if realized would increase industry trade volumes by 50% over the next three decades.

In short:

- The path we are on may lead to more GHG emissions in 2050 compared to today
- Industry leadership on its own cannot drive the transition and must be supported by customers willing to pay more for zero-carbon transportation and from regulation

Sources: IMO, IEA, Clarksons and Techno-economic model MMM Center for Zero Carbon Shipping
1 WTW = well to wake.
2 Referencing the IPCC, 2018: Summary for Policymakers, In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty.

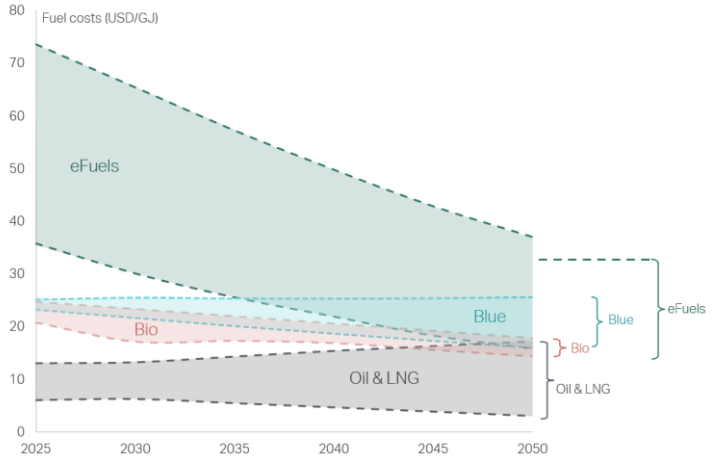
The challenge

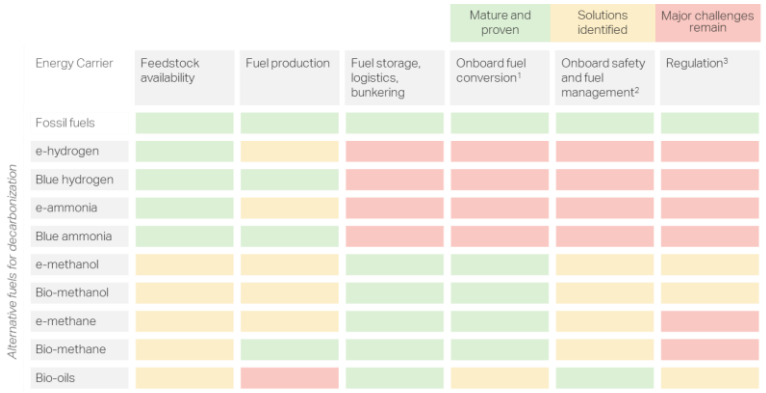
Fuel cost is a major part of overall cost of ownership in the maritime industry, ranging from 20% in dry bulk to 35% in container. Today and in the near term, alternative fuels will be much more costly to produce than fossil fuels, by a factor of 2-8 times. The gap is projected to narrow over time, but likely not close through market forces before 2050.

Fossil fuels are the least costly, they are easy to handle, energy dense, well understood and regulated, and available in most all ports globally. This makes fossil fuels a tough competitor to beat.

Alternative fuels include a large number of energy carriers: hydrogen, methanol, ammonia, methane, bio-oils etc. They can all be produced in several different ways – some use fossil feedstock combined with carbon capture and storage; some are made from renewable primary sources such as solar, wind and biomass. How the fuels will make its way into commercial scale up depends on parameters like global availability at scale, total cost of ownership, maturation of new safe and reliable technology, carbon emissions intensity, and the regulatory framework, as illustrated below for some of the most referenced alternative fuels.

Energy efficiency technology and improved operational practices utilizing digitalization and analytics are available, but not widely implemented. The segmentation and structure of the shipping business where charterers and owners carry different types of cost (fuel vs technology for example) makes it hard to optimize the entire shipping system. Potential reduction of emissions through stricter energy efficiency regulation remains a very significant opportunity.





In short

- Fuel cost is a major part of total cost of ownership of the shipping operation
- Fossil fuels are and will likely remain cheaper than alternative fuels without a carbon levy
- Energy efficiency has significant potential to reduce energy consumption

Source: MMM Center for Zero Carbon Shipping Note: Emissions reduction impact from direct electrification of ships and nuclear-powered vessels is not modelled in NavigaTE 1.0 1 Considers onboard fuel supply and storage, fuel conversion and emissions control systems 2 Considers fuel toxicity, flammability and explosiveness 3 Includes regulatory framework supporting onboard regulatory aspects, and market mechanisms supporting adoption

What is needed to accelerate the transition?

We have identified five critical levers that all must be activated to reach zero carbon shipping in 2050.

Energy and fuel advancements on shore is required to scale up production and over time push down the cost curves for alternative fuels. Technical readiness levels for production of alternative fuels are already relatively high, but commercial readiness is low, and today mainly first-generation biofuels are commercially available as marine fuels, and only on a limited scale.

Advancements on ship technologies are under constant development with relatively high technical readiness levels. Propulsion technologies for bio-oil, methane and methanol are already in commercial operation. Ammonia systems are projected for initial operation in 2024, subject satisfactory emissions- and safety standards being implemented. Dual fuel systems for fossil/alternative fuels are currently being ordered albeit in a very low proportion of total newbuilding orders. Future-fuel-prepared ship designs are under development.

Several existing energy efficiency technologies are being integrated into vessel newbuildings. Adoption of newer energy efficiency technologies e.g., Flettner rotors, air lubrication and digit-/optimized vessel operations are gaining traction, but the overall potential for higher energy efficiency in the global fleet remains large.

Customer demand/pull - Customer willingness to pay for zero-carbon shipping services is emerging, particularly in the container segment. Global consumer companies commit to scope-3 decarbonization targets and demand zero carbon container transportation. In segments like dry bulk and tanker the situation is different, and price remains one of the main purchase criteria. Here corporate customer's climate targets do not yet seem to make it into the scorecards of their chartering staff. On average and by 2030 we assume that less than a third of all maritime customers may be willing to pay a just below 10% premium for transportation with alternative fuels.

What is needed to accelerate the transition?

Finance sector mobilization is required to finance the transition. Banks and other capital providers are already deeply engaged in reducing their carbon footprint, but on a global scale the effects have not yet been seen in shipping. We believe that over time zero carbon vessels can be financed at a lower cost of capital than fossil vessels. The spread can increase to more than 2% towards the end of this decade as both banks and equity investors reallocate their portfolios

The major critical lever with the highest potential is **policy and regulation**. Policy and regulation can not only level the global playing field, but also entirely close the cost gap between fossil and alternative fuels. The International Maritime Organization has implemented short term measures e.g., in the form of energy efficiency regulation and will soon initiate the discussion of market-based measures such as carbon pricing. The European Union has launched its ambitious Fit-for-55-plan. Several countries have called for a decarbonized global shipping sector by 2050, including the US and UK.

In short:

- Zero carbon shipping by 2050 requires activation of all 5 critical levers:
    - Energy and fuel advancements on shore
    - Technological advancements on ship
    - Customer demand/pull
    - Finance sector mobilization
    - Policy and regulation

What does it take to reach net-zero in 2050?

Market forces will likely not be able to drive decarbonization of the entire maritime industry alone – more is needed. The main missing piece to the puzzle is effective regulation that will level the playing field between early adopters of zero carbon technologies and shipowners who want to use fossil fuels.

Market based measures such as a carbon levy can be very effective in closing the cost gap between fossil and alternative fuels. A flat levy of USD 230 per ton of CO2 implemented in 2025 and activation of the critical levers would close the fuel cost gap sufficiently to bring the maritime industry close to net zero by 2050. It would also generate an accumulated almost USD 4 trillion of proceeds and add much less to the cost of maritime transportation.

Introducing a carbon levy where funds are earmarked and returned to the early adopters of alternative fuels could close the fuel cost gap at a much lower levy. The accumulated funds collected could be reduced to approximately USD 2 trillion hence add much less to the cost of zero carbon maritime transportation compared to a flat levy with no recycling of proceeds.

Alternatively, an incrementally increasing carbon levy starting at USD 50 per ton CO2 and increasing to USD 150 per ton CO2 can generate additional proceeds. These proceeds can not only compensate the early adopters of alternative fuels, but also accumulate up to USD 300 billion earmarked for developing countries. This mechanism can serve to ensure a wider consensus in the IMO around a global carbon levy.

With critical levers activated and a global carbon levy shipping can reach close to net zero GHG emissions by 2050. In order to reach the 1.5- or Well-below-2-degree targets of the Paris agreement all the way between today and 2050 would require alternative fuel supplies and retrofitting of existing fleet beyond the scope of the current study – it will be covered in future updates.

In our central scenario, biofuels such as bio-oil, bio-methane and bio-methanol are part of the mix due to their projected low production cost. In combination with high readiness level on vessel technologies makes biofuels great opportunities for first movers already now.

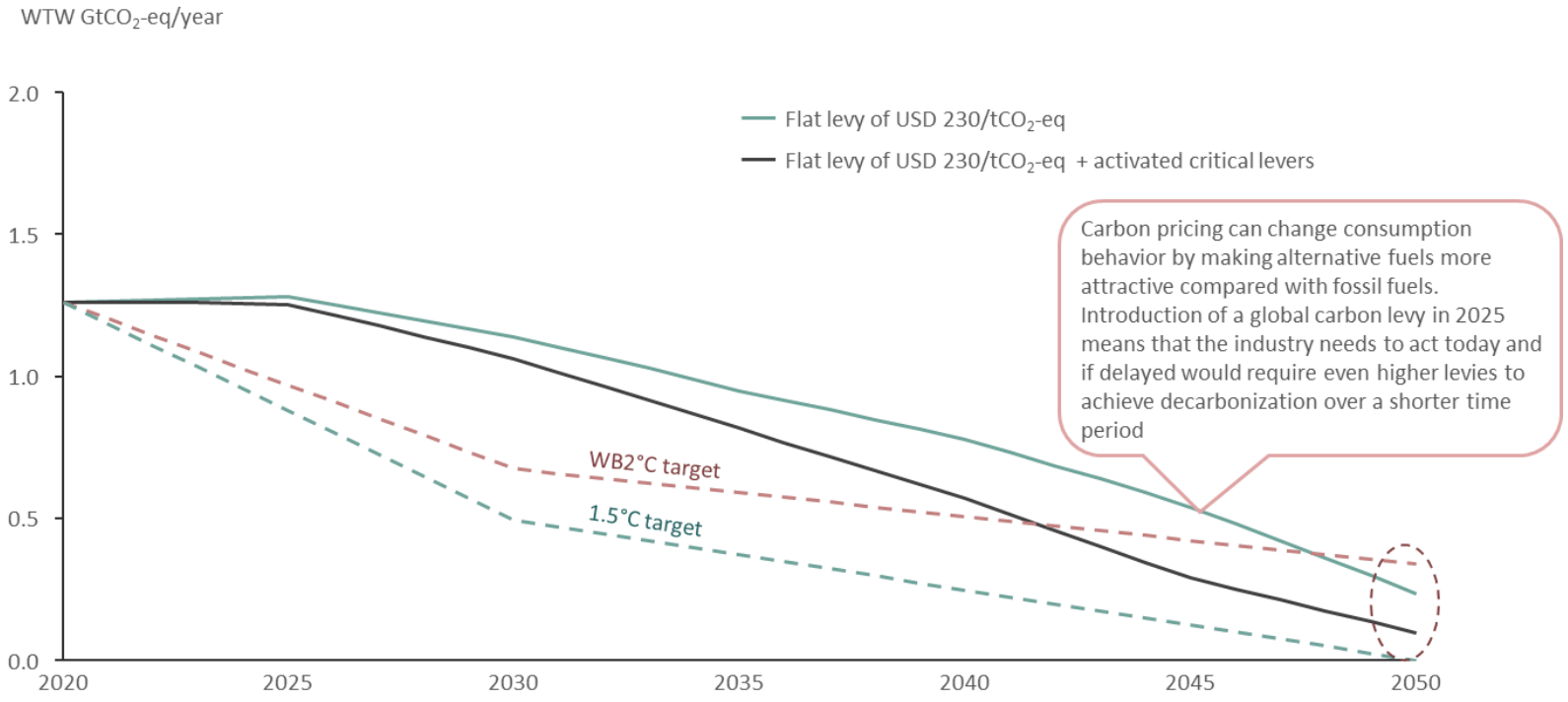
The main constraint longer term may be the ability to source feedstock and scale up production. Among the e-fuels we estimate that e-ammonia will be the cheapest e-fuel to produce and that rapid scale up can be done, provided that the safety and environmental concerns can be addressed. We see blue ammonia as a potentially important transition fuel.

The amount of carbon neutral fuel needed to propel the entire shipping fleet is gigantic and it is critical that we maximize fuel optionality. No one fuel solution is likely to be able to satisfy the needed demand fast enough.

The central scenario is subject to considerable uncertainty and particularly sensitive to assumptions around how fast production can be scaled up, biomass availability, cost of renewable energy and regulatory risk.

What does it take to reach net-zero in 2050?

Introducing a significant flat global levy by 2025 can take us to net-zero in 2050



Source: NavigaTE

In short

- Zero carbon shipping by 2050 can be done, but it requires strong regulation
- It matters how a carbon levy is implemented. If proceeds from a levy are earmarked and returned to early adopters of alternative fuels, decarbonization can be done at a much lower cost to consumers. Practical implementation must be carefully addressed
- The future fuel mix will likely consist of several alternative fuels including both e-fuels and biofuels
- Regardless which pathways materialize, it will require significant scaling of alternative fuels, cost-down of fuels and technology maturation for efficiency, cost-down, reliability and safety

What needs to happen over the next decade?

Maritime decarbonization is a systemic change. Ensuring timely end-to-end zero-carbon shipping requires fundamental changes across the entire business ecosystem. This is a truly complex task that requires innovation, regulation and industry wide action. Action must be taken now, and real progress must be made within this decade.

We have identified four areas that are key to success in zero-carbon shipping. The Center will devote the main part of its resources and build its program structure to support:

Tighter energy efficiency (EE) regulation is needed to reduce overall industry energy demand. Focus on energy efficiency can maximize primary energy conversion to new energy carriers. The maritime industry should focus on: (1) resolving current challenges preventing wider EE technology adoption; (2) effective regulation; and (3) fostering new EE technology innovation.

Availability and cost reduction of alternative fuels is a prerequisite for decarbonization. Production and supply chains of alternative fuels need to mature through technology innovation and scaling. Developments of permits, licenses, standards and regulation are urgently needed.

A level playing field with global regulation is critical for managing safety, inspiring investor confidence and accelerating technological developments. For example, a carefully designed global carbon pricing structure has the potential to create a level playing field for industry participants and nations.

Support to first movers includes implementing demonstration projects, establishing initial collaboration platforms to enable the market for zero carbon transportation with 'green corridors' between selected cities and ports. It will involve industry leaders and public sector engagement with financing and regulatory support. The projects should bring together shipowners, technology providers, customers, ports, fuel providers i.e., the entire maritime ecosystem. This would showcase first-mover solutions and leverage learnings to build scalable long-term solutions.

In short

Zero-carbon shipping can be achieved by 2050 and requires:

- Effective energy efficiency regulation to reduce overall energy demand
- Alternative fuels made available through scaled-up production and at reduced cost
- A well-designed global carbon pricing mechanism
- Support to first movers, green corridors and large demonstration projects