In partnership with

NAVIGATING SHIPPING TO A DECARBONIZED FUTURE

Why 2025 is the critical year to accelerate the decarbonization of the backbone of the global economy and how this can be achieved

A joint white paper from Reuters Events, Supply Chain and the World Shipping Council

CONTENTS

ACKNOWLEDGEMENTS

We would like to extend our enormous gratitude to the following participants for participating in this research:

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EXECUTIVE SUMMARY

Shipping is highly efficient and critical to global economic activity

Shipping acts as an engine for economic growth, allowing access to markets and has helped lift hundreds of millions out of poverty. It has done so by being reliable and low-cost. The relative cost of shipping declined nearly continuously from 1940 to 2019, while the energy efficiency of the global fleet rose by almost 4% annually between 2008 and 2022.

Low-cost, reliable shipping at scale allows countries to rapidly integrate into the global economy and move up the value chain. Consequently, the number of people living in the most extreme poverty has fallen from two billion to 713 million since 1990, even as the global population increased by 2.9 billion.

Shipping sector Greenhouse Gas (GHG) emissions rose in recent years and this needs to be rapidly reversed

Even though it is energy efficient, shipping still accounts for 2-3% of GHG emissions and container freight GHG emissions rose 11.9% between Q1 2019 and Q3 2019. The direction needs to rapidly shift towards GHG emission reductions. Grams of CO2 produced per tonne-kilometer must fall 94% from 2022 to 2050 to hit 1.5oC warming targets, while shippers are increasingly interested in contracting low emissions freight to help hit their own targets.

Technologies and investments have come together to make low-to-zero emission fuels a possibility

A scenario of rapidly falling emissions in shipping would have seemed extremely difficult even five years ago, but emerging technologies have dramatically shifted the landscape. The precursor is the dramatic expansion of clean energy capacity, the scale of which has allowed rapidly falling production and installation costs.

That power can be directed into electrolysis to make the hydrogen necessary for the e-fuels e-methane, e-methanol and e-ammonia. The final component is the engines. Order books for vehicle and container carriers were devoid of ships capable of burning clean fuels at the beginning of 2020, but by January 2025 79% of ships on order in this segment have engines that can utilize one of these renewable marine fuels.

Clean fuels are not yet widely available and are much more expensive than conventional counterparts

However, the production facilities and fueling infrastructure to supply these fuels remain limited and the price differential makes the economics challenging.

Clarkson research noted that as of Q1 2025, methanol bunkering was present in 35 ports and 276 ports had LNG bunkering, a very small part of the global network of over 45,000 ports.

The price increase from 0.5% Very Low Sulfur Fuel Oil (VLFSO) to alternatives was 31% for Liquid Natural Gas (LNG), 53% for grey methanol, 111% for bio-LNG, and 274% for green ammonia according to Platts' global bunker fuel cost calculator in January 2025 for Rotterdam.

The sector needs clear, measurable and enforceable global fuel standards and economic measures to reduce pricing disparity

While there is positive momentum behind clean fuels, growth needs to be accelerated via a legally binding global fuel GHG standard that is enforceable and measurable. That needs to be accompanied by a mechanism that makes clean fuels economically viable.

Successfully introducing measures could allow shipping to decarbonize over the next 25 years

Shipping, once seen as a particularly hard sector to abate, now has multiple pathways to reduce, and eventually eliminate, GHG emissions. To make that a reality, and to do so within the 25-year timeframe currently desired, requires committing to clear regulations and continued investment into supporting infrastructure and the ships themselves.

THE ROLE OF GLOBAL TRADE AND THE IMPACT SHIPPING HAS ON THE GLOBAL ECONOMY

The incredible scale, reach and volume of modern maritime trade drives the globalized economy. It provides access to international markets, propelling economic growth, especially in the Global South, where a reliable, cost-effective means of exporting goods often provides the surest route towards long-term improvements in living conditions.

1.1 The success of shipping and the global economy are intertwined

Ocean freight remains the engine of modern economies, even though manufacturing's share of the global economy has declined and services have become a greater part of the world's Gross Domestic Product (GDP).

We can see that relationship clearly when we plot global GDP growth against port throughput of containers, in this case measured in the industry standard Twenty-foot Equivalent Units (TEUs).

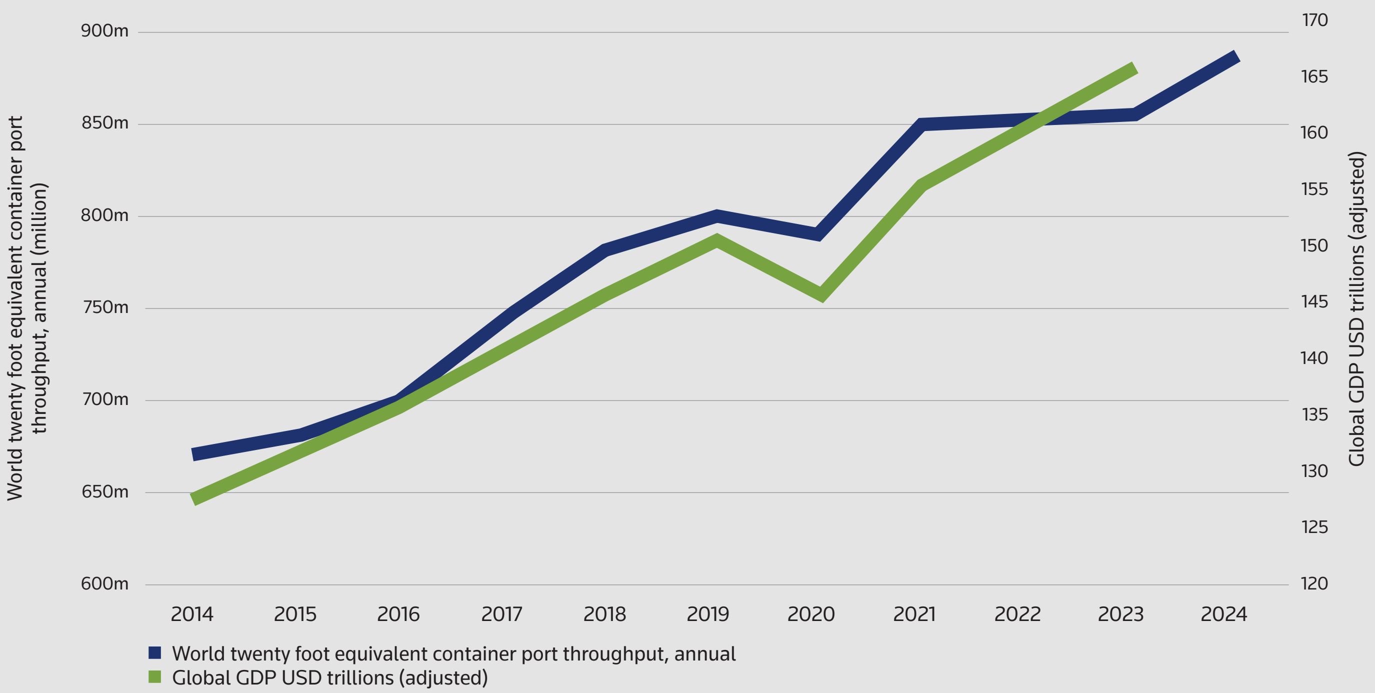
Since 2014 the two measures have been in near lockstep in times of both expansion and recession. Global inflation-adjusted GDP rose from $128 trillion in 2014 to $167 trillion in 2023, or a 30% rise, while the volume of container throughput closely tracked this expansion at 27%.

In this admittedly small sample period, the two have a near perfect correlation coefficient of 0.97, underscoring how modern economies are driven by reliable and efficient ocean freight.

1.2 Container shipping remains cost effective

What's more, modern container cargo trade remains incredibly low-cost on a broad historical basis, even after

Annual container throughput, 2014-2024, and global GDP (USD trillions), 2014-2023



Sources: UNCTAD, 2023, UNCTAD, 2024 *estimated; Our World in Data, 2025 recent dramatic, and headline grabbing, price rises.

From 1940 to 2002 the relative cost of shipping via maritime freight fell every single year. Those 62 years of consecutive pricing declines meant that by the latter date, shipping goods cost around a fifth of what it had been at the outbreak of World War II in real terms.

Even as the global economy continued to grow during the globalization of the 2000s, and supply chains became more complex and internationally intertwined, the cost of shipping still repeatedly fell.

Analysis by the Federal Reserve Bank of St Louis found that prices continued to be behind inflation and shipping freight grew relatively cheaper across the period 2007-2019, marking the COVID-19 Pandemic and subsequent period as a major break with the norm.

Even with that sudden spike in rates, ocean freight via containers continues to be a remarkably cost-efficient way to transport goods globally. The ability to position thousands, or even tens of thousands, of TEUs onto a single ship with a crew of just a few dozen to a vast array of ports gives immense economies of scale and flexibility. Drewry noted in its 27 February 2025 World Container Index assessment that the average $2,629 price to move a 40ft container was 75% below the pandemic peak of $10,377,

"THE TRANSFORMATION IS JUST REMARKABLE BECAUSE IT WASN'T THAT LONG AGO THAT AN 8,000 TEU SHIP WAS UNUSUAL ... NOW WE'RE SEEING SHIPS THAT ARE 24,000 TEU AND LARGER"

indicating a return towards historical norms, especially when inflation post 2020 is included.

"The efficiency gains are staggering in terms of mode," exclaims Bryan Wood-Thomas, Vice President for the World Shipping Council. "In the container trades we have seen both economic and environmental improvements that have significantly improved the per-unit cost of moving a container both in real dollars and the associated GHG emissions." Over the last few years "the amount of fuel it took to move a container on a larger ship on a per unit basis has dropped so significantly," he continues, notably driven by bigger vessels. "Carriers very quickly realized 'if I don't build larger ships like this, I will be so inefficient and my operating cost profile will be so high compared to somebody running the larger ships that I have to do this, or I will not even exist.'" Consequently, "we saw this incredible wave of building, which was good for efficiency and for the

environment. The transformation is just remarkable because it wasn't that long ago that an 8,000 TEU ship was unusual, then it became 12,000, then 13,000. Now we're seeing ships that are 24,000 TEU and larger" being built he notes.

That trendline should continue as there is substantial ongoing investment in larger ships and the ports to handle them, alongside the deployment of more efficient engines, especially on large Panamax and post-Panamax vessels. This should continue the long-term trend of improving energy efficiency of the global fleet, which increased "by almost 4% annually between 2008 and 2022" according to Danish Ship Finance.

1.3 Maritime freight is the key to unlocking economic development

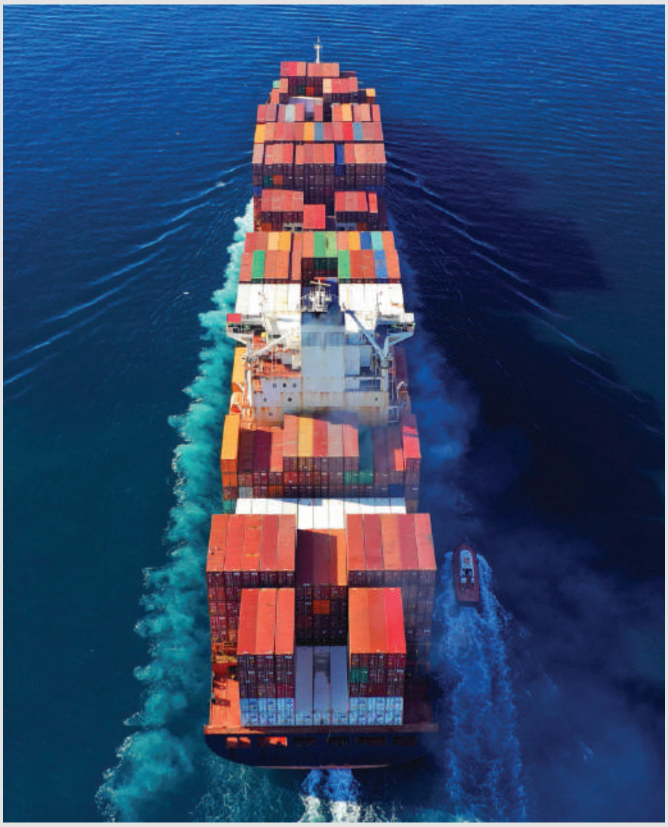
The deep relationship between economic growth and the ability to easily and cheaply access international markets via maritime freight has been the underpinning for remarkable explosions in economic fortunes around the world.

China, India and Vietnam have moved, or are all moving, from rural economies to major producers of high-tech goods and are doing so in extremely short time spans. These are three prominent examples, but the effect is now widespread, raising living standards dramatically for populations in multiple countries in the Global South.

Containerized shipping "enabled countless countries around the world to participate in the world economy in a way that they hadn't before," says Wood-Thomas.

Whereas many less economically developed countries traditionally had to focus "mainly on raw material resourcing," Wood-Thomas points out that "now you have countries manufacturing goods and supplying those in a market in the context that hadn't existed before."

"NOT ONLY DID THE STANDARD OF LIVING FOR MILLIONS OF PEOPLE AROUND THE WORLD INCREASE, BUT EXTREME POVERTY ALSO AMAZINGLY DROPPED"



The end "result of that was not only did the standard of living for millions of people around the world increase, but extreme poverty also amazingly dropped," he states. Since 1990, the number of people living in the most extreme poverty has fallen from two billion to 713 million according to the World Bank, even as the global population has increased from 5.3 billion people to 8.2 billion.

While we are now entering an era of heightened protectionism and localization, alongside increasing risks to trade from conflict and climate change, the long-term trend should still be for a wider foundation of economic activity underpinned by global maritime trade.

The intensifying risks are pushing manufacturers to look for new sourcing locations, relying on maritime access in locations closer to their end markets or that have favorable terms of trade or labor costs. In 2025, the fastest growing economies in the world are expected to be in these emerging destinations for sourcing manufacturing. The IMF expects emerging Asia and Sub-Saharan Africa to be the fastest growing locations globally, led by countries like Ethiopia, India, the Philippines, Senegal and Vietnam.

THE FIGHT AGAINST EMISSIONS IN GLOBAL SHIPPING

Even though modern shipping is the most efficient means to move goods in terms of both unit cost and emissions, it still accounts for an estimated 2-3% of the Greenhouse Gases (GHG) emitted annually from human fossil fuel consumption.

Those GHG emissions, alongside its prominent position as one of the key engines in the global economic system, mean that moving the sector to a carbon neutral basis would be a huge marker of the possibilities of decoupling economic activity from carbon emissions.

The WSC's Wood Thomas spells it out thusly: "To go to net zero in a period of less than 25 years in one of the hardest-to-abate commercial-industrial sectors would provide an incredible signal."

2.1 The relative carbon cost of shipping today

"Compared to trucks' usage of fossil fuel, it's a huge differential, and compared to aviation on a per-tonne basis it is off the charts," says Wood-Thomas with regards to the carbon cost of ocean freight.

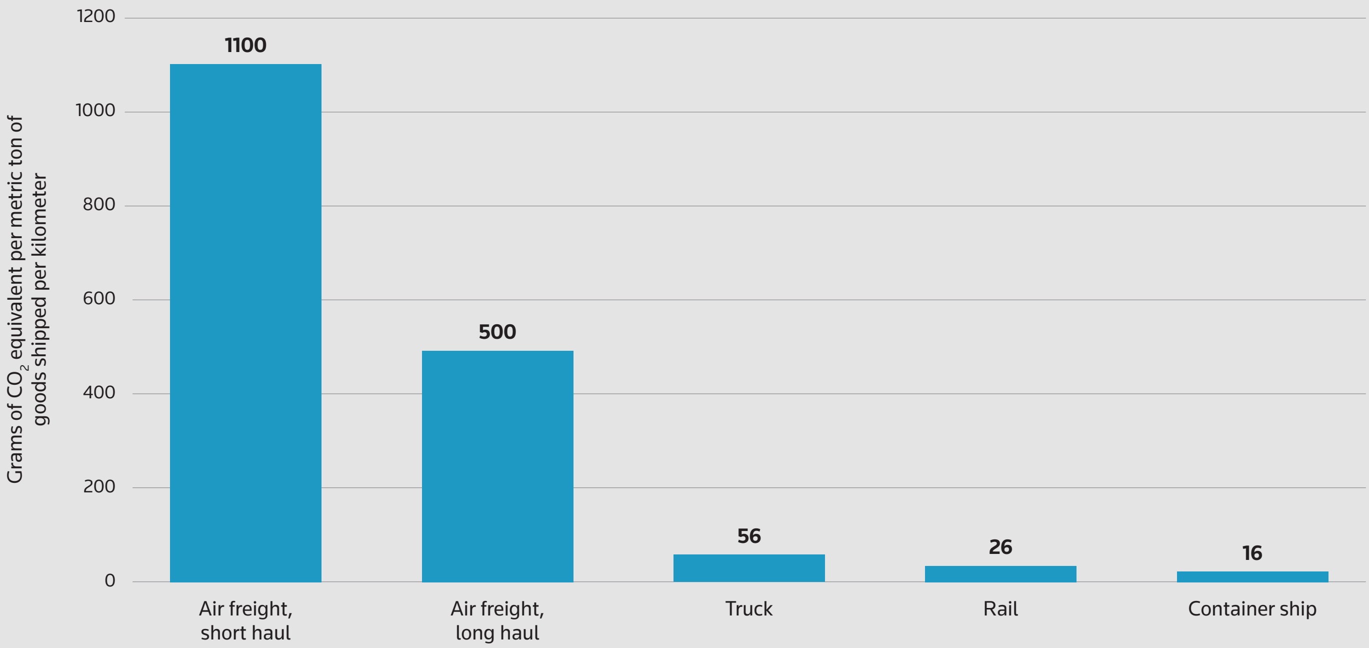
Although comparisons can be tricky given variables in different geographies, their regulations and how they generate power, shipping currently comes out as clearly more efficient than other modes of freight transport. Comparing UK figures for emissions of CO_2 equivalent per metric ton of goods shipped per kilometer, we can see rail produces nearly two-thirds more carbon than container freight. That rises to three-and-a-half times for a typical European truck, and air freight generates between 30 and 60 times as much CO_2 equivalent!

2.2 Powering ahead to lower emissions

If shipping is already such an efficient sector, then why the need to rapidly transition and what have been the main barriers thus far?

In terms of urgency, there are compelling arguments from

Grams of CO_2 equivalent per metric ton of goods shipped per kilometer across different transport modes



Sources: UK Department for Business, Energy & Industrial Strategy, 2022; ICCT, 2023; UK Office of Rail and Road, 2024; Statista, 2024 all sides. Environmentally, the goal of trying to keep GHG emissions down enough to limit global warming to 1.5ºC could already have already passed, leaving the world on a perilous path with enormous potential costs. This, alongside increasing scrutiny from both consumers and regulators, is pushing businesses to focus on their complete GHG emissions footprint, of which shipping is a core component.

IKEA's Sustainability Manager for Supply Chain Operations, Elisabeth Munck af Rosenschöld, notes that transportation "is about 5% of the total carbon footprint of IKEA," of which "about 50% comes from ocean shipping, 48% from our land transportation part and about 2% from warehousing. So that means that the ocean shipping part is "a little bit more than 2% of the total IKEA carbon footprint." While "the transportation footprint itself might seem small in the bigger context, it's a critical footprint to reduce," she says. "Transportation touches the everyday lives of many people. It's our responsibility as one of the largest shippers globally to reduce this footprint, encourage the industry, and [last but not] least contribute to clean air for the people touched by our transportation."

When it comes to why maritime trade remains a major emitter there are "a long list of related challenges," says Ingrid Irigoyen, Senior Director, Ocean and Climate at the Aspen Institute and President and CEO of the Zero Emission Maritime Buyers Alliance (ZEMBA). However, "when you boil it right down, it's the cost differential between sustainable fuels and the high emission fuels on the water today that is the major barrier," to shifting the sector over to a lower emissions basis.

"TRANSPORTATION TOUCHES THE EVERYDAY LIVES OF MANY PEOPLE. IT'S OUR RESPONSIBILITY AS ONE OF THE LARGEST SHIPPERS GLOBALLY TO REDUCE THIS FOOTPRINT"

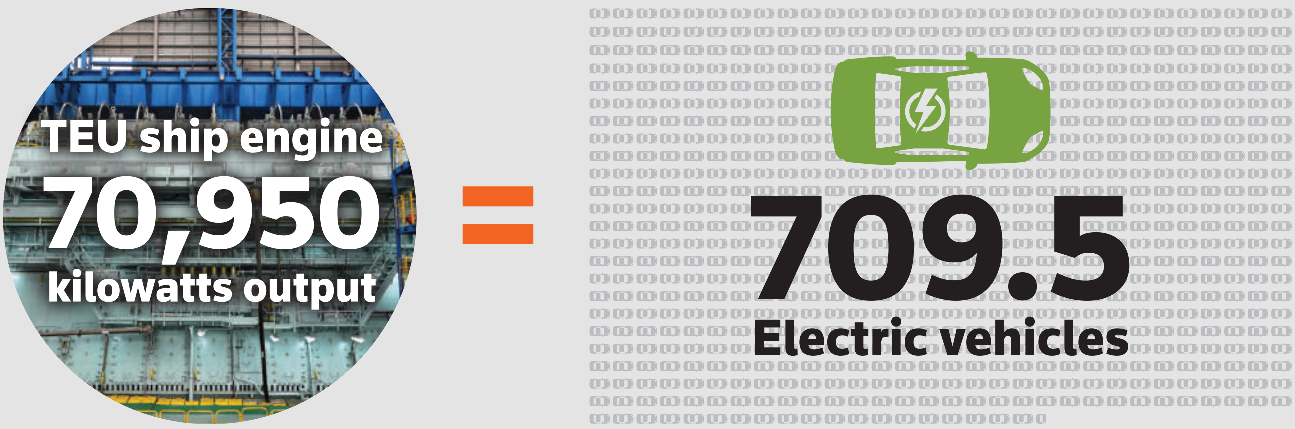
While the sector is beginning to transition, as we will see, Very Low Sulfur Fuel Oil (VLSFO) is by far the main fuel used today and it is easily accessible, versatile and comparatively low-cost in comparison to low-to-zero emissions fuel.

Those alternative fuels also need matching powerplants, and these are substantial pieces of engineering that typically consume a considerable amount of fuel on each voyage.

The Evergreen A-class of container ships represent well the larger scale of vessels that are being constructed today. Weighing in at 235,579 gross tonnes, they can handle a maximum of 24,000 TEUs if fully laden. They are powered by a WinGD X92-B engine. This is the size of a large multistorey building with 11 cylinders, each of which the average man could comfortably fit in, allowing a peak output of 70,950 kilowatts. That is equivalent to a huge 709.5 Renault Zoe electric vehicles operating at full throttle.

Additionally, that engine needs to drive the ship over thousands of miles for each journey. For the very largest vessels like the A-class, that route typically flows between

The power output of a 24,000 TEU ship engine compared to an electric vehicle



East Asia and Europe. That journey covers 10,600 nautical miles from Shanghai to Rotterdam via the Suez Canal, or 13,800 nautical miles travelling via the Cape of Good Hope.

Therefore, the sector needs reliable alternative fuels bunkered around the world in significant quantities. This is a substantial change requiring investment in infrastructure, as well as the ships themselves.

"You could think about it in terms of moving from sail to steam motor and steel ships 125 years ago," says the World Shipping Council's Environmental Director for Europe Jim Corbett.

He explains that decarbonizing shipping is "very different to the global switch to sulfur, which could happen on every existing ship overnight on January 1st 2020 because all those engines were capable of burning the fuel. A switch to methane, a switch to methanol, a switch to ammonia or a switch to any of the other fuels you see ... requires a change in where we buy our fuel, a change in what kind of fuel we buy (including certifications that verify that the fuels we're buying provide the reductions we need) and ... depending on how fast how we phase it in, it will require retrofitting or replacing existing technologies."

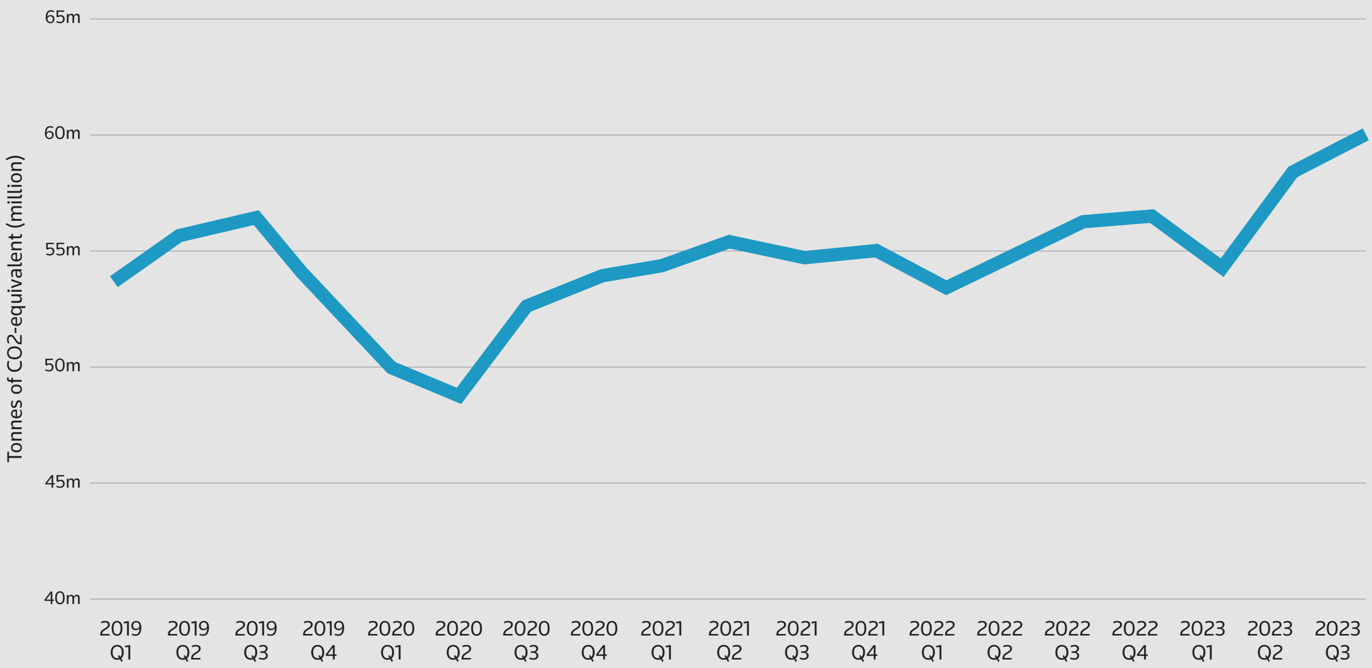
"YOU COULD THINK ABOUT IT IN TERMS OF MOVING FROM SAIL TO STEAM MOTOR AND STEEL SHIPS 125 YEARS AGO"

2.3 What are current emissions from container shipping and what is required to cut them?

Critically, even with increasing efficiencies via improvements to the ships, their engines and their capacity utilization, GHG emissions continue to rise in the sector. Furthermore, GHG emissions can increase notably due to changes to shipping patterns, knocking back efficiency gains as geopolitical events or supply chain disruptions cause longer routes or delays.

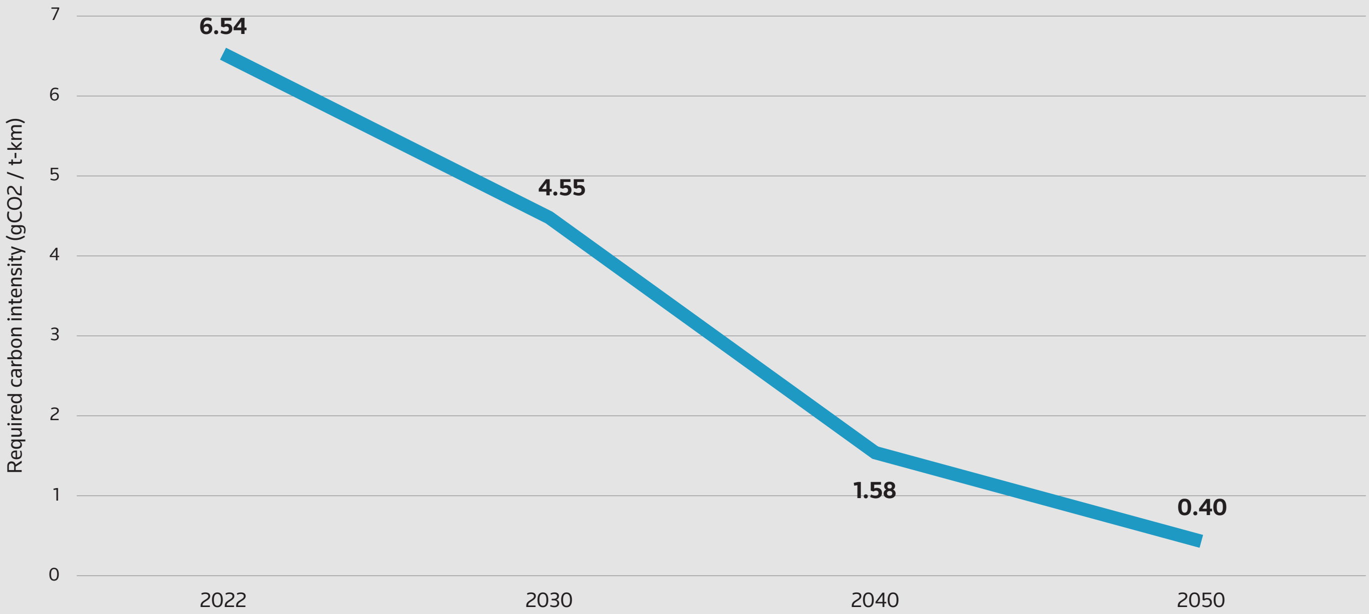
While container throughput rose 6.8% between 2019 and 2023, container freight GHG emissions rose 11.9% between Q1 2019 and Q3 2019 (the last available data) to just over 60 million tonnes of CO_2-equivalent.

Tonnes of CO_2-equivalent emitted from container shipping Q1 2019 to Q3 2023 (OECD estimation)



Source: OECD, 2023

Carbon intensity cuts required in shipping sector to meet 1.5°C Paris Agreement scenario (grams CO_2 per tonne-km)



Source: LSE Transition Pathway Initiative Centre (TPI Centre), 2024

GHG emissions notably increased at the end of the period as ships travelled further due to improving global demand and low water levels in the Panama Canal. A further dramatic increase not captured by this data occurred due to ships rerouting to avoid the Red Sea in Q4 2023 onwards, causing double-digit percentage increases in TEU miles travelled in 2024 compared to 2023.

Therefore, even with more efficiencies within the industry, there remain substantial carbon costs, and these can be worsened by events around the world, meaning a shift in the fuels used is mission critical to lowering emissions in the future.

That future is now just a few decades away as ambitious goals to cut emissions have been set by the IMO, and the levels of reduction are substantial.

According to the LSE Transition Pathway Initiative Centre (TPI Centre) meeting existing commitments would require the carbon intensity of the shipping sector to reduce by 30% from 2022 to 2030, after which it would need to fall 65% again from 2030 to 2040 and by 75% from 2040 to 2050, for a total cut in grams of CO_2 per tonne-kilometer of 94% between 2022 and 2050.

THE MEANS TO GET TO ZERO EMISSIONS

The route to low, and then zero, GHG emission shipping is now clear due to several major advancements in technologies that are coalescing to make 2025 an inflection point, after which change can accelerate.

These are principally: the ability to produce clean electricity cheaply and at massive scale; a growing consensus on the alternative fuels needed for the global fleet and the technical know-how on how to produce them; and ship order books filling up with vessels fitted with engines capable of utilizing those alternative fuels.

3.1 The clean energy revolution is here

The precursor to bringing the latest fuels into the marketplace is abundant clean energy.

This is necessary to produce the hydrogen required for the main low emission fuels, with cleanly generated electricity used to split apart water via electrolysis to get the necessary hydrogen, which is then bonded to carbon, oxygen or nitrogen to make e-methane, e-methanol or e-ammonia.

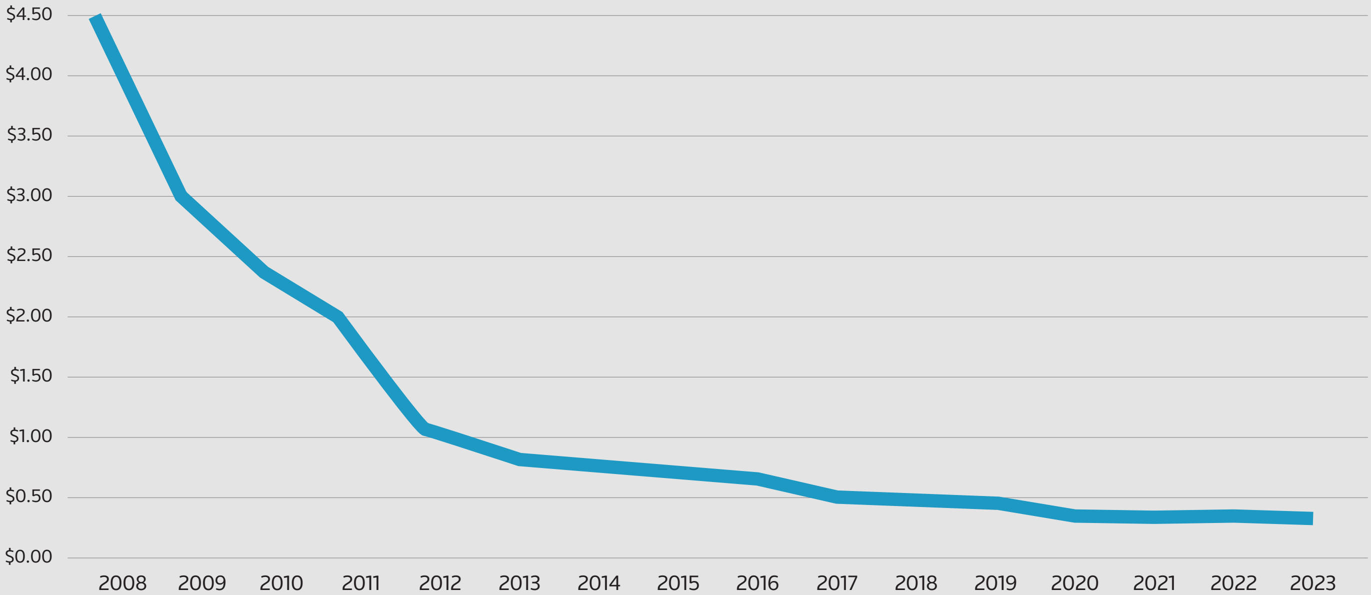
Without large scale provision of clean energy at competitive rates, low carbon fuels would be largely dead in the water and the means to produce them would rely on fossil fuels, bringing the industry back to square one.

In this arena, the global energy sector has experienced a massive change in just the last decade. The price of solar panels has plummeted to unprecedented lows on the back of massively expanding production, meaning solar projects breaking ground currently are the cheapest means of producing grid scale energy in most cases.

That economic argument is part of why S&P expects 2025 to be the first year that clean technology investments will top those of oil and gas, reaching a staggering $670 billion.

This level of investment is expected to push solar power production above coal for the first time within the EU, while China alone added 374.8 gigawatts of zero emission power production in 2024, equivalent to 10 times the typical energy demand of the entire UK.

Solar PV panel prices in US dollars per watt, 2008-2023



Source: Our World in Data, 2025

The change in how we produce our energy, and the relative cheapness at which it can be installed and generated, is a gamechanger for the global economy and how the maritime sector is powered.

It now needs to be coupled to a coherent policy with regards to maritime fuels.

"Just having an achievable, rational, consistent clean fuel standard makes a lot of sense and can lead to innovation and economic growth and opportunities in new parts of the world that aren't traditionally big fuel producers or bunkering hubs," Irigoyen thinks in the event of an agreement being forged.

"For some governments, particularly in developing countries, they now recognize that there is an opportunity here to … become net exporters of energy," concurs Dr Edmund Hughes, IBIA Representative to the International Maritime Organization (IMO). "Where countries have access to, or are exposed to, surplus capacity renewable energy, what's better than turning that surplus capacity into potential energy through turning green electrons into e-fuels?" he asks, citing Namibia as an example of a country with surplus wind and solar energy and an industrial strategy to turn that into hydrogen.

There are also potentially sources of 'white hydrogen' or geological hydrogen, which would have lower emissions than fossil fuels or hydrogen taken from fossil fuel production and would help bridge the gap while completely green sources are built up. A major reserve has been discovered in France, with an estimated 46 million tons, and the number of firms exploring for white hydrogen has dramatically increased in the last few years, with projects from Albania to South Korea.

"The combination of clean energy and new fuels" potentially means "we could see some really new opportunities flourish," in Irigoyen's opinion.

3.2 The main contenders to replace marine fuel oils

Currently, there are three viable, long-term routes to reduce reliance of marine fuel oils, each with their own advantages and disadvantages:

"Starting on one end of the spectrum, we see growing use of fossil LNG, which is an alternative fuel, but becoming more mainstream all the time," explains the Aspen Institute's Irigoyen. "From a decarbonization perspective, that one's a bit challenging because while we see a lot of local air pollution benefits … unfortunately, from a greenhouse gas point of view ... [it] can only get us, at most, a 20% emissions reduction on a lifecycle basis.

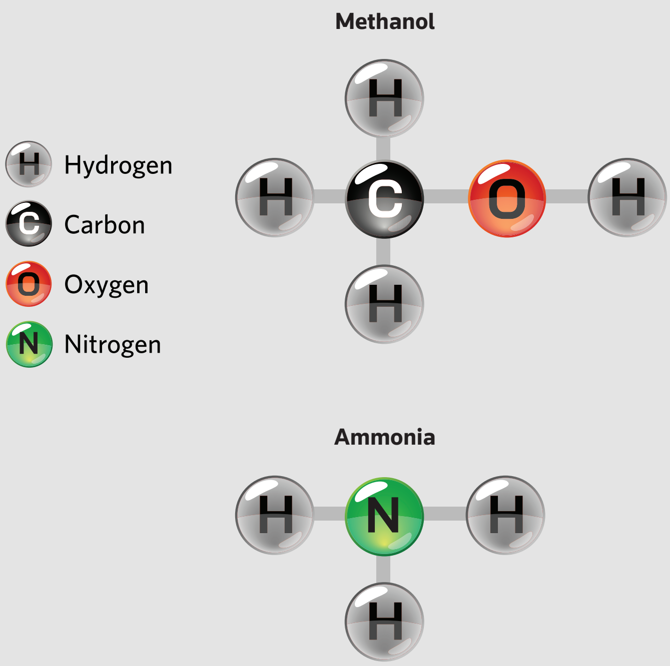
"The next category over would be biofuels of which there are many different kinds," but largely they are "bio-oil-based fuels or bio-LNG that's made from waste gases," she explains. Biofuels are "certainly making some inroads in the market," she notes, but due to their need for sustainable waste feeds, they "have a real scalability challenge, and of course as you start to reach the scalability ceiling, you start to get real price increases and [the shipping] sector is lower margin than other sectors that will be competing for those biofuels. So, while an important bridge solution, they are not really a long-term solution for decarbonizing the entire sector," in her opinion.

One piece of analysis from the European Federation for Transport and Environment estimated that "a biofuel-dependent shipping industry would need around 35 million hectares" of farmland to supply the needed crops, which is equivalent in land area to Germany.

The other main contenders are therefore the e-fuels e-ammonia, e-methanol and e-methane.

These represent different advantages and disadvantages. For ammonia, it is "the one e-fuel that doesn't have any carbon

Chemical formulas of e-fuels ammonia and methanol



"WE NEED TO GET MORE [AMMONIA-POWERED] VESSELS ON THE WATER TO TEST THE SAFETY PROCEDURES AND MAKE SURE THAT SOCIETY IS COMFORTABLE WITH THE USE OF THAT FUEL"

at all," says Irigoyen as it is composed of three hydrogen molecules and one nitrogen molecule. That makes it the least carbon-intensive option, but it is currently costly to produce, when burnt it produces nitrous oxide, which is also a GHG, and it is toxic, corrosive and flammable, requiring specialized regulations to transport safely.

From a safety perspective, "We need to get more [ammonia-powered] vessels on the water to test the safety procedures and make sure that society is comfortable with the use of that fuel," Irigoyen says. If that barrier can be overcome, we potentially could "have an e-fuel in the market that is incredibly scalable. We move ammonia all over the world already all the time," as a bulk cargo in either liquid or gas form, "so it's a substance that we know well how to handle. We just need to handle it appropriately as a maritime fuel." Indeed, Hanwha Ocean and Naftomar Shipping announced in late 2023 a class of dual-fuel bulk ammonia carriers that would eventually be converted to consume their cargoes as fuel, potentially pointing to a strong proof-of-concept.

Methanol, on the other hand, does produce some carbon emissions, but is more adaptable and stable at ambient temperatures.

"From an emissions perspective, methanol is a much more environmentally benign fuel than diesel bunkers in that methanol is an alcohol," says the CEO of the Methanol Institute Gregory A. Dolan.

It's chemical formula of CH_3OH means that "when it combusts, it will produce carbon dioxide," explains WSC's Corbett, especially as it often requires a small amount of diesel fuel for initial ignition in marine engines, "but that amount of carbon dioxide from one carbon [in methanol] instead of the typical 16 to 20 carbon atoms in a complex fossil hydrocarbon," means that it burns cleaner.

Dolan says that there is "a 95% reduction in particulate matter when you're using methanol compared to conventional fuels," and that it is safer in the eventuality of spills.

Broadly, its biggest advantage as a future fuel is its adaptability, as it is a liquid at ambient temperatures, so "you can easily grow your storage and bunkering capability as demand ramps up for the fuel," claims Dolan. "You have a lot more flexibility where you put the storage tanks on a vessel," which is key as the lower energy density of methanol compared to VLSFO means "you need to be able to upload twice as much of that fuel onto a vessel."

Critically, the ability to adapt existing engines for methanol means there is a comparatively low barrier to widespread adoption, and existing production of methanol means that "you can use a conventional methanol blend, some bio-methanol blend, some e-methanol and meet those carbon reductions over time as the supply of the renewable product increases its share into the fuel pool," according to Dolan.

Similarly, e-methane can be utilized inside existing LNG engines and can be blended with existing fossil fuel stock to reduce the carbon emissions of ships. However, it too requires clean sources of CO_2 and clean energy to be produced sustainability and releases carbon emissions when burnt, albeit far less than conventional fuels.

So, what will be the fuel of the future?

"We think there will be more than one, maybe more than two or three fuels that will find a way successfully and sustainably into the market and that the combination of those fuels will meet the demand for energy use in the world fleet and achieve the GHG reductions," says the WSC's Corbett. Overall, they "think it will require dual-fueled ships, which are able to operate under emergency conditions on traditional liquid, but that operate for most of their life on fuels that would be incompatible with the fuels used today."

Irigoyen agrees that "a real range of different technologies in our view," will be utilized. However, "what matters is can we get pretty close to zero emissions on the lifecycle basis and is that fuel or technology vastly scalable so that we can actually get the per unit cost down as fast as possible?

"If I were a betting gal," she says she would put her money on e-fuels, as they "have really significant potential because we see the cost of clean energy has dropped so much faster than anyone could have predicted," and that they "could be vastly scalable and actually solve the sector's emissions problem in the long run in an economically viable way."

3.3 A sea change in ship power plants

Alongside alternative fuels, the industry needs to have engines that can utilize those fuels and for the global fleet to adopt them.

According to the Methanol Institute's Dolan, "we don't have technical hurdles because the engine technology is all mature and available" in the case of methanol. "Pretty much all the OEM's have methanol compatible engines, and with some like MAN or Wärtsilä their entire fleet of different size dimensions are methanol capable."

Similarly, LNG engines are now proven systems, while ammonia-capable engines are the newest of the alternatives, with Wärtsilä looking to make its first deliveries for commercial use within 2025.

With that technology maturation a huge change is on the horizon for global fleets.

While for something like methanol, "I think it's officially 41 methanol field vessels that are on the water today," says Dolan, and for LNG it is in the region of 600 – a pretty tiny amount of the global fleet of around 60,000 large vessels – the real change is within the order books of major carriers.

Among container and vehicle carriers, the order book has shifted dramatically in the last four years. While in January 2020, the ships on order were all conventionally powered, with 2.3 million TEU capacity in this segment, by January 2025 the situation was drastically different.

Jumping forward five years and purely conventionally powered ships comprised a little over 400,000 TEUs in order books, alongside 1.4 million TEUs of capacity using standard engines with scrubbers fitted to capture pollutants. That is now dwarfed by the capacity liner carriers have ordered using alternative fuels. Some 4.5 million TEUs worth of capacity is under order that can be powered by liquified methane natural gas and 2.3 million TEUs will be carried in methanol-capable vessels.

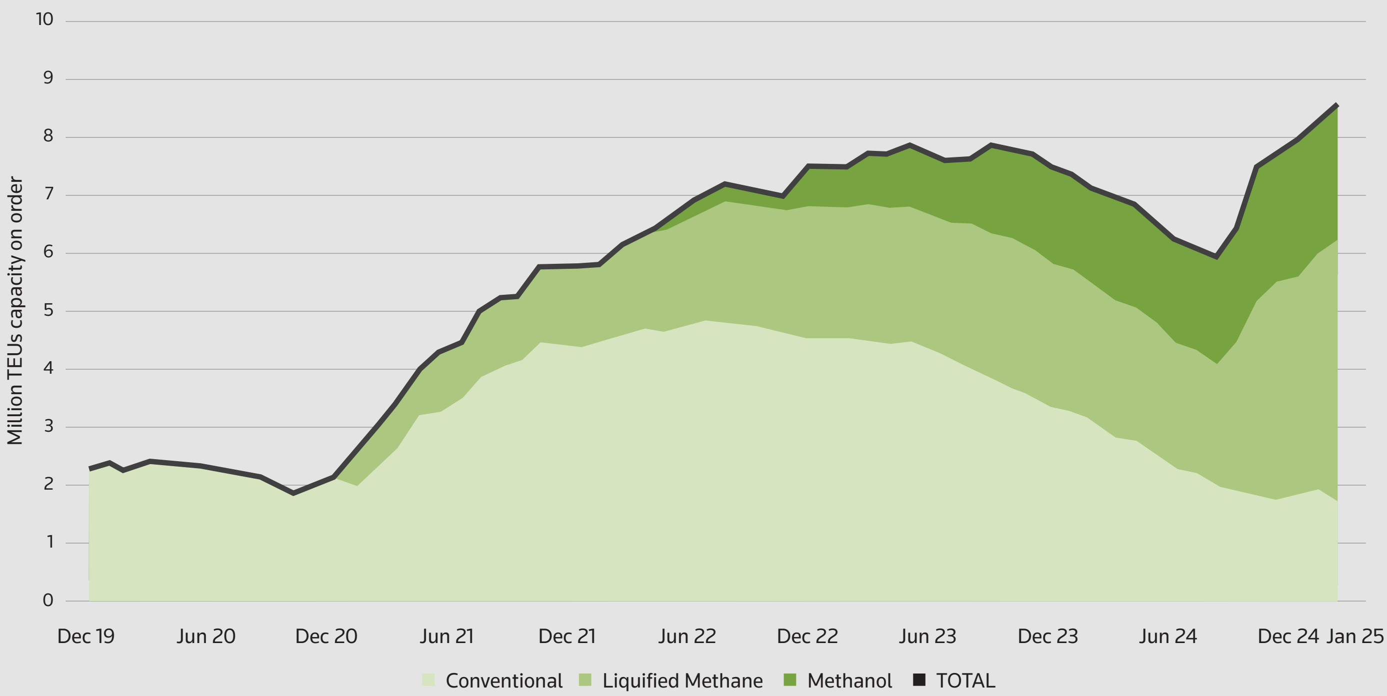
That is a transition from an order book comprised of 100% conventional vessels to 79% fitted with alternative-fueled engines in the space of half a decade.

Confirming this transition, Dolan notes that according to Clarksons registry of ships there are 351 dual-fuel vessels on order, a further "694 methanol ready vessels have been ordered ... and then we've probably got beyond that another 100 methanol retrofits ordered ... so we're looking at more than 1,000 vessels," on the water or in order books that can utilize methanol.

Clarksons reported that there is record investment in alternative fuels, alongside a major investment into fleets overall. Orders and shipyard output in 2024 was the highest in over 15 years and alternative fuels comprised 50% of all tonnage ordered in 2024.

We are then at a milestone for fleet transition. Consequently, governments and industry must look at adopting industry-wide standards to facilitate and speed up this ongoing transition with availability of economically competitive zero-to-no emission fuels.

World Shipping Council member vessel order book (TEU capacity) by fuel type, January 2025



Source: World Shipping Council, 2025, based on Alphaliner data as of January 2025

FUELING GROWTH IN ALTERNATIVES: CHALLENGES, COSTS AND POTENTIAL

While technologies are coalescing to provide the technical framework for a shift to new fuels for vessels, there are economic and infrastructure challenges that must be addressed urgently to make a fully functioning global market that shipping can rely upon.

4.1 Kickstarting the market

Fundamentally, shipping "can't start in 2040 and create these changes," states Corbett. "You just couldn't get enough fleet modernization and you couldn't produce enough of these fuels," and position them to supply a truly global market.

Instead, clean marine fuels, and all their attendant infrastructure, need a jump start to dramatically speed up the transition.

While there is "evidence that renewable fuels are being produced in places around the world," says Corbett, "that commitment is insufficient to the targets and it's even less than our ability to use the fuels, so we're lagging," creating a situation where carriers and fuel producers look at the near horizon and hedge their bets rather than take the leap and commit to new fuels.

Corbett estimates that there already exists an approximately "20% decarbonization potential" if the price of fossil and new fuels were near-equal in price.

The fact that this capacity to utilize alternatives is already extant in the shipping sector illustrates the need for effective policy to help guide the market: "There is a very weak market incentive to switch from less expensive fuels that are readily available to new fuels that will require these new ships," Corbett says. "If the rest of the fleet [outside the liner sector] doesn't invest, there will be no opportunity for them to use the fuels that are coming on board. The timing is not up to the economics of the operators. It needs a policy driver. We need policy to define the targets, make the requirements, monitor the pace, and be sure that the pace is also part of a policy commitment."

> ***"THE TIMING IS NOT UP TO THE ECONOMICS OF THE OPERATORS IT NEEDS A POLICY DRIVER"***

4.2 Creating the renewable bunker breakthrough

One of the issues around moving to new fuels is that "the bunker infrastructure is catching up" to the emerging realities notes Dolan.

While there is expansion, it is coming from a relatively small base. Clarkson research found that in January 2024 that only 10 sites had methanol bunkering facilities, with another 11 in the pipeline. By July 2024 that had grown to 29 ports with methanol bunkering available or planned and, at the time of writing, in Q1 2025 had increased to 35 ports. They also noted in their January 2025 analysis that there were "276 ports with LNG bunkering and 275 ports with shore power connection in place or planned." This remains a small share of the global maritime system, with over 45,000 sea ports worldwide.

Although these numbers show rapid expansion in infrastructure, most of that capacity to supply low GHG emission fuels is currently on paper only. That reality underscores why a clean energy transition needs improvement from multiple angles simultaneously, as carriers need confidence in available fuel supplies, ports need to know that there will be enough ships calling, and shippers need to know that there will be adequate capacity along their routes.

Dolan is confident that the bunkering issue will continue to move quickly though. "We know that there is methanol storage capacity at 120 of the world's leading ports," and there are flexible options to provide supply.

"Some of the bunkering that we've seen done, for example in the port of Savannah and the Port of Houston, has been taking existing methanol bunker barges, as we move a lot of methanol by barge up the Mississippi and East Coast using those standard methanol barges," he outlines. That provides some "low hanging fruit in using that existing large infrastructure. We are now seeing dedicated methanol fueling vessels or bunker barges being ordered in the big ports – Shanghai, Singapore – and they're operating dedicated methanol bunker vessels today, so the bunkering infrastructure is beginning to expand," even if the rate is behind the potential total demand that could come from new dual-fuel and pure methanol vessels.

4.3 Creating confidence and cutting costs for the fuels of the future

Although there are clearer routes to decarbonization than ever from a technological perspective, the fact remains that current market prices for alternative fuels are substantially above that of conventional VLSFO.

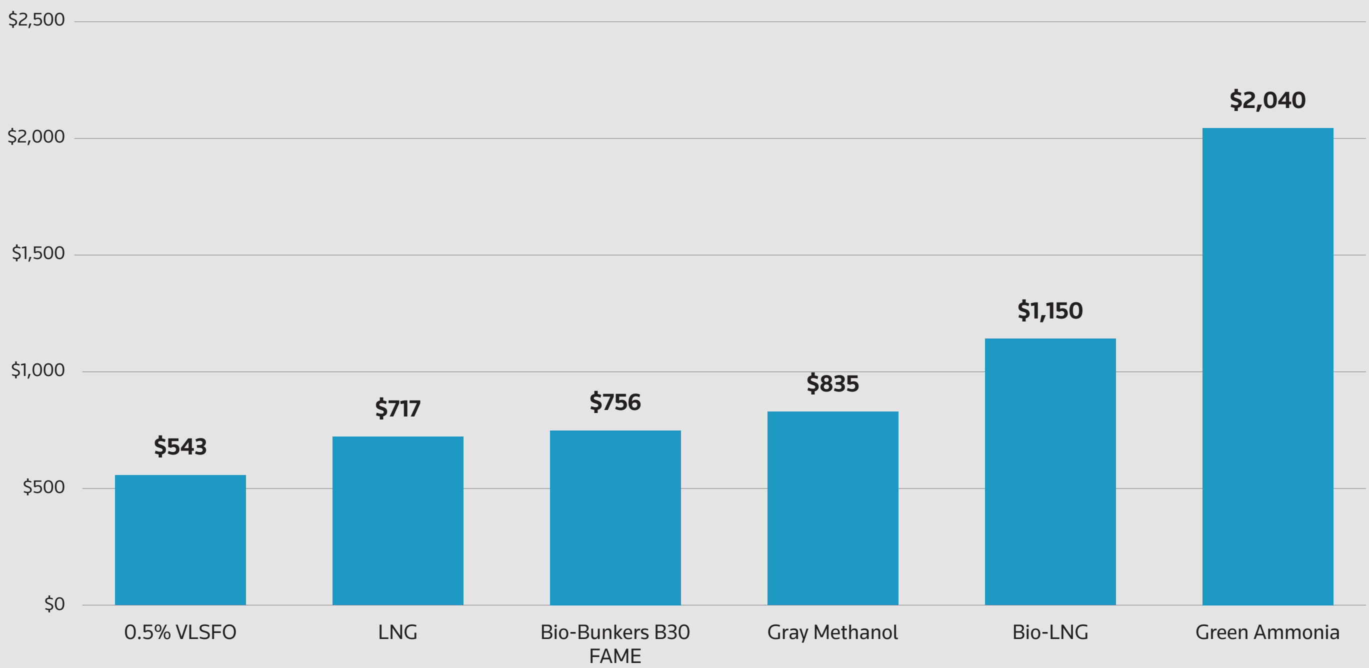
Looking at prices for bunkered fuel in Rotterdam in January 2025, 0.5% VLFSO was the cheapest fuel by some margin, at $543 per metric tonne. LNG was 31% more costly, followed by blended biodiesel (38%), grey methanol (53%), bio-LNG (111%) and finally green ammonia, which was 274% more expensive.

Those big differences in pricing for cleaner fuels are clear barriers to growth.

"What any innovation in technology and any new market needs and wants in order to thrive is an even playing field," comments Irigoyen. That levelling "means the right kind of science-based global fuel standards for the maritime sector that will offer clarity to the market and allow producers to know what on earth they're supposed to be producing, how much of it and by when, and will [therefore] take out the race-to-the-bottom element."

As part of her role as President and CEO of the Zero Emission Maritime Buyers Alliance (ZEMBA), Irigoyen also sees the need for shippers to work actively to provide

Price for marine fuels in Rotterdam or Northwest Europe, January 2025, S&P Global



Source: Platts global bunker fuel cost calculator, 2025

some of this clarity and demonstrate demand through contracting low emissions shipments. Principally, the alliance seeks to introduce some of the scale and transparency needed for the sector to catalyze maritime's clean energy transition by running forward tenders for the environmental attributes associated with sustainable fuels. "When we bring corporate buyers together, they can do much more to help create these new competitive markets, be clear on what it is they're looking for from these alternatives, and demonstrate not just some willingness to pay, but also a really strong interest in bringing that cost down over time.

"The whole theory of change behind our collaboration is in gaining economies of scale right out of the gate" she outlines.

"There is a need to collaborate with different stakeholders across the industry to make this transformation happen," agrees Ikea's Munck af Rosenschöld, which is why the company is a ZEMBA member.

"What we really want is for this to scale up and to really ensure that our goods are moved on the vessels that use the zero emission fuels," she concurs, noting that contracting these movements is challenging due to "limited availability of these fuels right now."

"On 25th of February, ZEMBA opened our second tender and for a pretty significant volume over three-to-five years and we're looking specifically for bidders to offer us shipping with clean energy generated e-fuels," explains Irigoyen.

The tender signals a strong and growing "group of corporate customers that are demanding these kinds of solutions from the market and are interested in getting good, competitive bids," she says, underscoring that there is movement to generate scale on the demand side and significant interest among shippers to get goods moved on low-to-no emission vessels right now.

FUELING GROWTH IN ALTERNATIVES: THE ROLE OF REGULATION AND FINANCIAL INCENTIVES

Rapidly maturing technologies, new fuels, and greener grids give a degree of clarity on how the shipping sector is to decarbonize. The central question now is how to create a functioning global market where alternative, clean fuels can compete and are widely available?

A transition will require clear, consistent and enforceable standards that create a floor of demand, ensure supply and reduce the pricing differential over time. These need to be agreed upon and adopted at a global level, and this could happen within 2025, potentially making this year a vital inflection point.

5.1 Setting a new set of standards

The two fundamental "building blocks we need are availability of renewable fuels and a mechanism that allows the price in a competitive marketplace to be very similar to the price of the option of not buying that fuel," outlines Dr Hughes.

"People will not adopt these fuels until they can see an economic case," asserts Corbett, especially as major "investment decisions can take five years or more, particularly if you look at the large-scale production" required to supply and reconfigure the global fleet, which will require decades.

> ***"PEOPLE WILL NOT ADOPT THESE FUELS UNTIL THEY CAN SEE AN ECONOMIC CASE... INVESTMENT DECISIONS CAN TAKE FIVE YEARS OR MORE"***

However, "shipping companies and operators will hedge, and they'll work out what's the best strategy for them based on the current economics, not what the economics are likely to be in five- or ten-years' time," agrees Dr Hughes.

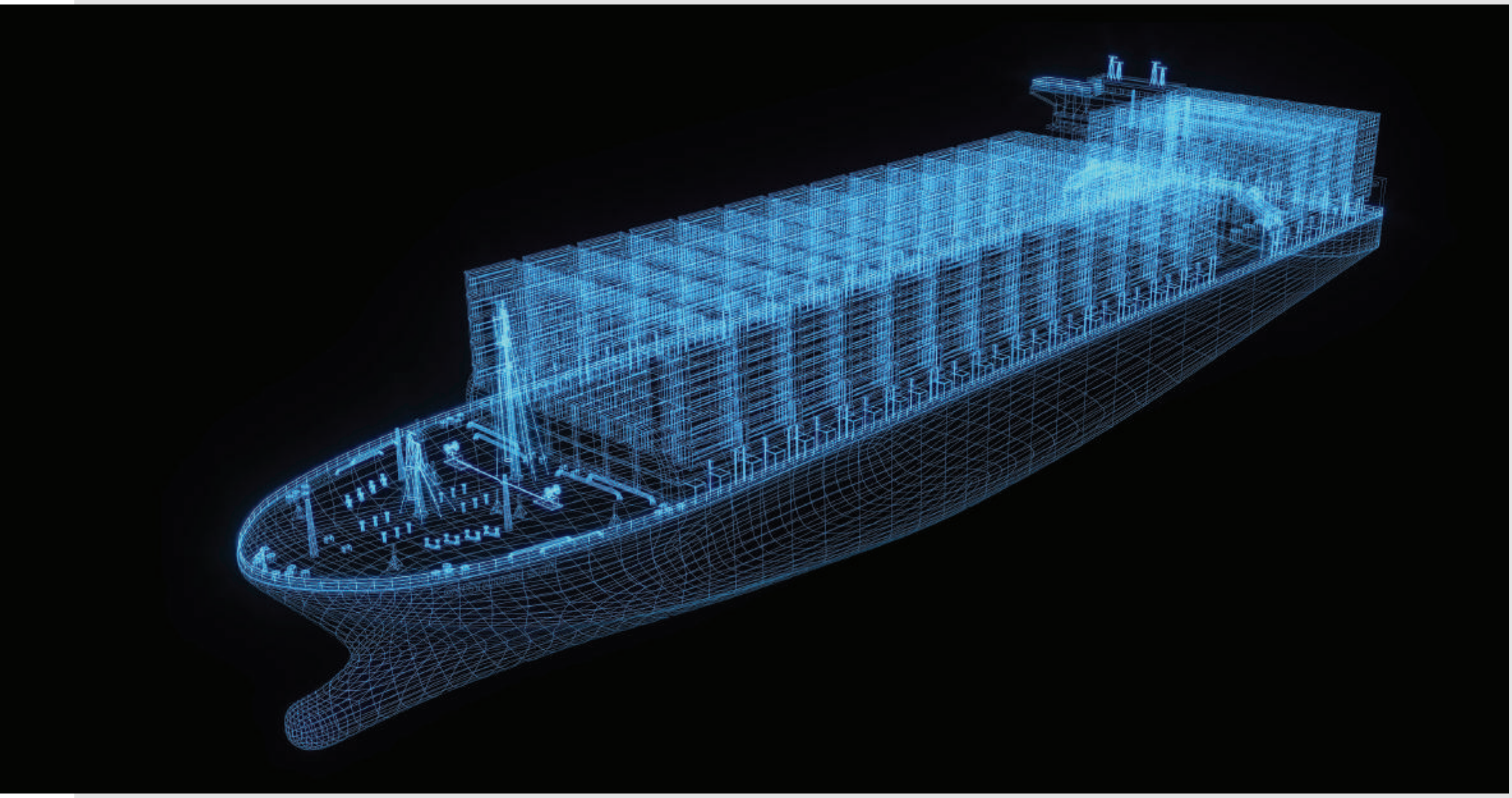
That means a new set of fuel standards that can cover the entire industry is needed immediately to spur on change, but is even more important in the long term to give strategic direction and security for organizations.

Any standard should consist of a requirement "that these fuels be used, which helps create the readiness for the market," says Corbett, alongside an "economic measure, either directly or indirectly, that will create the economic conditions for accelerated uptake of the better fuels."

He thinks that any measure "has to be fuel inclusive. It needs to include any fuels that can meet the performance standards – so it's performance-based regulation – and that fuel standard has to incrementally make the requirements more and more strict, so that there is a shift."

Doing so will introduce higher costs, at least in the short term. However, "we as a society historically supported high [GHG] emission [fossil] fuel production because we deemed it good for society, good for economic growth, good for nations that were able to extract and produce those energy sources," comments Irigoyen. Indeed, the IMF estimated that in 2022 global fossil fuel subsidies amounted to $7 trillion, or 7.1 percent of GDP. "We need to make the same assessment about these new, more sustainable fuels to put the tools in place to facilitate their rapid uptake," she concludes.

In practice, support could mean both a contracted floor price for e-fuels and the ramping up of charges on conventional hydrocarbon fuels.



"We've seen in energy supply sectors, like renewables for example, contracts for difference emerge to enable and provide a stable market," Dr Hughes points out. Contracts for difference provide a guaranteed price per unit produced, giving long-term stability and predictable revenues to the producer. A similar mechanism could be utilised for alternative fuels, guaranteeing a set amount will be bought at a set price, with different auctions occurring every few years with lower fuel prices as volume scales.

This would be the carrot, while the proverbial stick would be introducing pricing mechanisms that account for GHG emissions generated from shipping.

Dolan points out that this already exits, as the EU moved to include maritime emissions within its Emissions Trading Scheme (ETS) from January 2024, whereby companies must include 50% of emissions generated from voyages by ships over 5,000 gross tonnes that started or ended outside of the EU or 100% of emissions for intra-EU transport in their emissions allowance.

"Under ETS, there are real cost-to-compliance penalties that are going to be imposed on shippers that continue to use diesel bunker fuel," he says, especially as the FuelEU Maritime Regulation also came into force in January 2025. Through this, penalties for continuing to use fuels completely derived from fossil sources "go to as much as €2,400 a tonne" of VLSFO by 2050 for failing to comply with GHG intensity reduction requirements.

Already, this goes some way to the overall goal of reducing the pricing differential, as "that means that if you're using methanol as an alternative for compliance, and as long as you're underneath those [GHG intensity requirements], there's a value in bringing methanol in and that value can [eventually be] be as much €1,000 per metric tonne for biomethanol, or €2,000 per metric tonne for e-methanol," as the latter offsets more GHG emissions explains Dolan, with that value extending to all low-to-no GHG emission fuels.

> ***"UNDER THE EMISSIONS TRADING SCHEME , THERE ARE REAL COST-TO-COMPLIANCE PENALTIES THAT ARE GOING TO BE IMPOSED ON SHIPPERS THAT CONTINUE TO USE DIESEL BUNKER FUEL"***

5.2 Clarity is key

While agreements within countries or blocs are important, shipping is a global industry. The experts interviewed for this research unanimously agree that clear, consistent regulation that the industry can follow across the board will underpin the transition to renewables.

"Global policy is the key – it's about certainty," states Corbett. "If you have that certainty, then you can make the investments into the ships, you can make the investments in the production and the supply lines."

"We have to be able to give the market confidence that there will be a demand for these fuels and once that demand is there then people will have confidence to invest in their provision," agrees Hughes.

All of this means that for the industry to meet stated goals, 2025 is a vital year for agreement and ratification.

The expectation is for an extraordinary session to ratify the proposed amendments to Annex VI of the International Convention for the Prevention of Pollution from Ships, otherwise known as MARPOL, in autumn 2025.

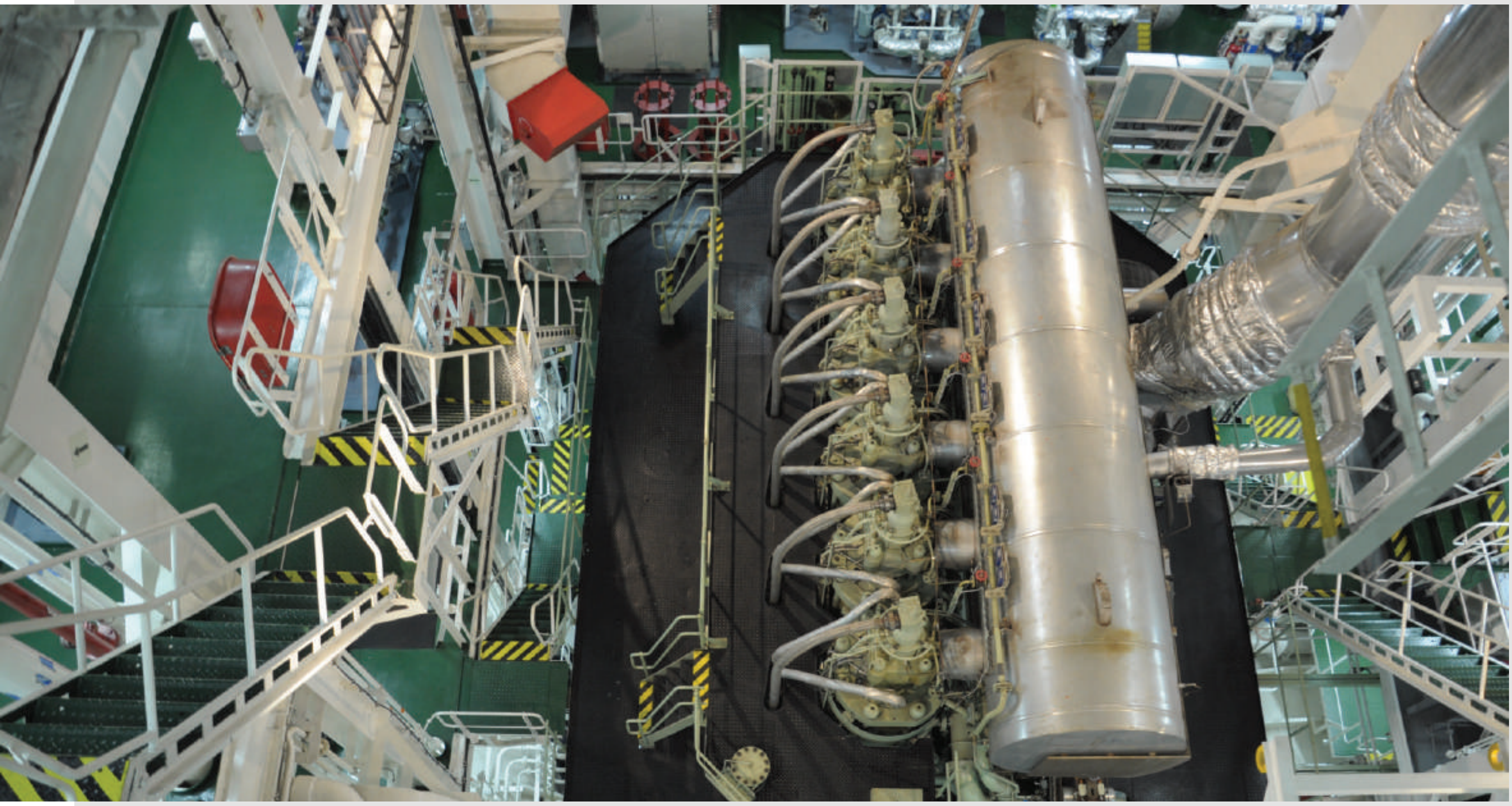
While urgency and clarity are required from bodies such as the IMO on standards and from governments on local support and incentives, the industry also needs to move towards more transparency.

"We have to see transparent reporting and good enforcement and good evidence of compliance," for any GHG agreement to function well asserts Dr Huges.

Irigoyen agrees that the shipping needs "better data management so that if freight buyers are paying a premium, they can feel confident that what they've paid for is actually going to result in the impact that they want, and also to ensure that for any regulatory measures we can monitor progress and feel confident in that progress.

"We've seen plenty of economies around the world where data of all kinds is manipulated and there's nothing more corrosive to investor confidence than unreliable data, so for shipping, and it's energy transition, I believe fostering transparency is another arena where IMO regulators can make a big impact," she concludes.

On a wider basis a reliable chain of information "will



also serve Scope 3 requirements," points out Dr Hughes. Scope 3 emissions include all GHG emissions within an organization's value chain and are increasingly becoming part of required reporting practices.

Additionally, "if we can certify the trade routes that are being served by vessels with higher performance, [those carriers] may actually be more attractive to the cargo shippers who are looking to reduce their Scope emissions," he notes.

Ikea's Munck af Rosenschöld thinks that this kind of foundation will mean "increased efficiencies in how we operate things due to improved data quality and the application of new digital tools like AI."

Looking out "even further, I believe we will see a consolidation of these different tools," she says and "we will see a more standardized way of how we work across [supply chains]. By doing that I think our ability to spot efficiencies from an end-to-end perspective will improve a lot ... and from our perspective, we will be able to secure the physical connectivity with our goods on the actual ship using these fuels," and the associated reporting measures that hopefully will come with any agreement.

5.3 Closing the gap

"Ships are the largest machines on the planet.... They require enormous amount of energy to move," comments Dr Hughes. "To take that whole sector and transition it away from hydrocarbon fuels within the space of a generation would be remarkable, frankly, but technically there is the possibility of doing that. It's now a case of thoughtfully putting in place the policy instruments that can enable that."

For Munck af Rosenschöld "the momentum is there in the industry right now," to push the transition forward.

"Many of us see the clean energy economy as the inevitable future," agrees Irigoyen. "We can get there the easy way or we can get there the hard way.... We can suffer all the consequences of taking too long, or we can be efficient and get right down to work and achieve our goals."

While this can seem intimidating, "we should remember that we have managed to do this in the past where we've seen an inherent threat and we've managed to then find a way to mitigate that," points out Dr Hughes, noting that when aerosolized chlorofluorocarbons were found to be damaging the ozone, there was rapid international consensus, followed by negotiations and then a binding agreement.

"We need to really keep in mind that this is not a sprint," believes Dolan. "This is a marathon, so we need to look at the steps that we can be taking now and the transition that will position us to 2050, but we need to be making incremental improvements over the next two decades."

From his perspective, "we've got the engine technology as mature as available ... vessels are being launched, we're expanding the bunkering infrastructure, we have technical guidelines for the safe handling," of alternative fuels and the foundations are being built. "Now we just need to make sure that there's regulatory certainty and that we're essentially facilitating the expansion" of alternative fuels via mechanisms that support them in the global marine fuel marketplace.

CONCLUSION

Technology and investment progress since 2020 has set the scene for massive potential change in the shipping industry, its energy usage and its emissions through investment into rapidly maturing technologies and new vessels that can run on alternative fuels. However, until policy decisions are hopefully agreed in 2025 that address the imbalances in pricing and availability of these fuels, it still largely remains just that: potential.

The next step is to light a fire under the alternative fuels market through clear regulatory standards and support for globally bunkering these fuels, especially e-fuels.

Instituting that framework requires dialogue, coordination and consensus, followed by monitoring and reporting.

While reaching a global consensus might seem like a major challenge, especially with the fractious political climate surrounding the discussion of decarbonization, it has never been more achievable.

Already, the template for change exists. Policy bodies of different size, stature and jurisdiction, such as the EU and the IMO are already leading the world in both technical regulations and the recognition that a market pricing structure is needed for the energy transition to succeed in the commercial maritime fleet.

The IMO is now entering the final stages of securing a global GHG agreement and many are confident that the IMO will deliver agreement.

However, Wood-Thomas stresses "that agreement alone will not be the measure of whether the IMO has been successful." Instead, he asserts "success requires a legally binding global fuel GHG standard that is accompanied by an economic measure (i.e. a fee-based system) applied to selected emission zones. [Doing so] will provide a predictable pool of revenue that can enable the use of zero and near-zero fuels early in the transition and to fund other core needs deemed critical by the Parties."

Wood-Thomas emphasizes that any agreement and regulatory structure needs to be truly global, avoiding "treating numerous voyages and trade routes differently. If we go down this path, we will find ourselves with an agreement that effectively limits its impacts to a minority of the voyages made by the global fleet."

If the IMO and its member countries can avoid these pitfalls, Wood-Thomas believes it "will have demonstrated that one of the hardest to abate sectors can provide a model for what is possible in other sectors. That would not only be effective policy, it would be impressive!"

World Shipping Council

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The World Shipping Council is the united voice of liner shipping, working with policymakers and stakeholder groups to shape the future growth of a socially responsible, environmentally sustainable, safe, and secure shipping industry. We are a non-profit trade association with offices in Brussels, London, Singapore and Washington, D.C.

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