Decarbonizing Container Shipping

Alternatives to fossil fuels and what container carriers need to know about them

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Abstract

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Container shipping is one of the top global emitters of CO_2 due to the routine use of fossil-fuel propulsion technology. Given the strict regulatory framework, the industry is under serious pressure to act fast and become more sustainable. Deloitte is using its expertise to contribute to the sustainable transformation of the industry with this in-depth assessment of available vessel fuels. By providing a concise overview of the (current and future) available fuel technologies in this heavily asset-driven business, our goal is to help container carriers make sound investment decisions based on objective criteria, and hopefully accelerate the industry's transformation to sustainable shipping.

When it comes to fuel options for ocean freight carriers, we distinguish between short-, medium- and long-term options. In Horizon 1, we compare the current options, namely heavy fuel oil (HFO) and liquified natural gas (LNG). In Horizon 2, we look at biofuels, green hydrogen, green ammonia and green methanol, comparing the pros and cons of these alternative fuels. In Horizon 3, we analyze innovative strategies for the long-term future, such as kite sails and electric ships. We conclude our analysis with an in-depth outlook based on three future scenarios for container shipping companies that will highlight different paths to sustainable transition as well as investment options based on the insights of the three horizons. Container carriers today have the power to make the leap from one of the most polluting industries to a pioneer in sustainability, working in collaboration with other ecosystem players and with the support of government incentives.

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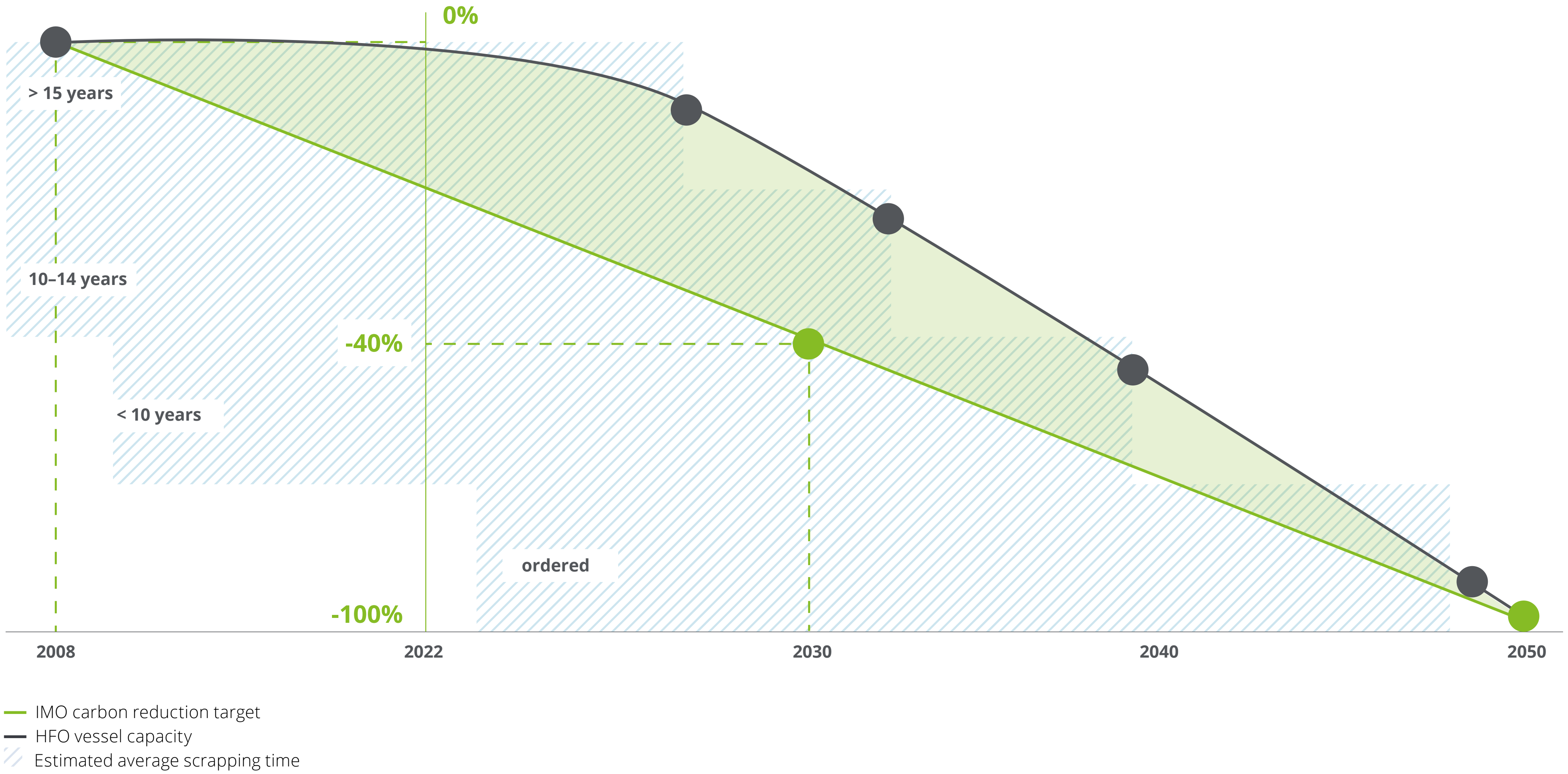
The sustainability challenge for today’s container carriers

At around two percent of global CO_2 emissions in 2018 (IMO, 2020), fossil-fuel propulsion technology has made voyage-based shipping one of the world’s biggest polluters.

Indeed, the vast majority of vessels currently in operation run on fossil fuels, with more than 50% expected to continue to do so in 2050 [Det Norske Veritas (DNV)]. One of the key reasons for this is the relative youth of the fleet: 36% of vessels are less than 10 years old while 33% are less than 15 years old. With an average scrap age of 27.7 years, most of these vessels still have one-half to two-thirds of their useful life ahead of them (see Figure 1). Based on current economic trends, a large percentage of these vessels will continue to run on fossil fuels for 15 to even 20 years before it makes financial sense to replace them with sustainable alternatives. When we look at the order books for container ships, the prospects for sustainability in container shipping are even worse: only a fraction of new vessels ordered are equipped to accommodate sustainable fuels and propulsion technologies, even as the volume of orders continues to grow.

Fig. 1 – Lifespan of the global fossil-fuel based fleet of container ships



Source: Deloitte visualization based on data from UNCTAD (2020), Danish Ship Finance (2021) and Alphaliner (2022).

The circumstances illustrated contradict the industry's regulatory framework.

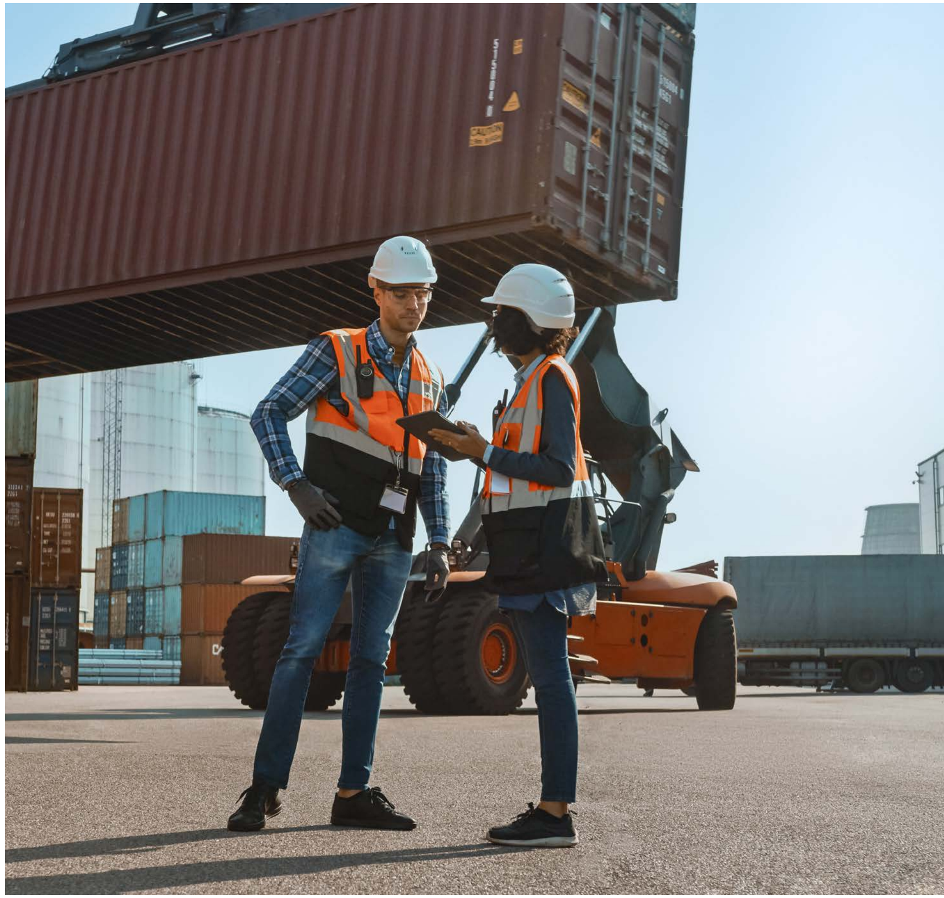
- At the global level, the International Maritime Organization (IMO) has set the ambitious goal of reducing greenhouse gas (GHG) emissions by 50% by 2050 and carbon dioxide (CO_2) emissions by 40% by 2030 and by 70% by 2050 (compared to a 2008 baseline).
- At the European level, the Fit for 55 package provides a set of regulatory proposals designed to meet the goals of the European Green Deal, aiming to reduce the EU's GHG emissions by 55% by 2030 vis-à-vis a 1990 baseline, and to be fully carbon neutral by 2050.
- In the US, legislators are currently debating the Clean Shipping Act, which calls for reduced emissions of all vessels calling at US ports. The bill intends to go beyond the already ambitious targets of the IMO and specify a 20% reduction in vessel emissions by 2027, 45% by 2030, and 80% by 2035, with the goal of full carbon neutrality by 2040.

EU Fit for 55 package

One of the measures in the Fit for 55 package known as the FuelEU Maritime proposal will apply to all vessels departing from and arriving at European ports (100% of energy used within the EU and 50% to and from third countries). It also introduces a fuel standard for ships and a requirement that the most polluting ships use onshore electricity when at berth. There are also proposals on including the maritime sector in the EU Emissions Trading System (ETS), on alternative fuels infrastructure and on energy taxation that impacts vessel operators in particular.

The huge discrepancy between the emission levels of today's ocean freight carriers and official emission targets and regulations is an urgent call for carriers to rethink their propulsion technology and fuel options.

If carriers intend to comply with the targets for 2030 and beyond, they need to look at new propulsion technologies and consider converting or scrapping vessels before the end of their useful lives. Numerous logistics companies reported outstanding profits during the last two years of the pandemic, which means they have the necessary funding to transform rusty industry technology. However, investing in fleet renewal before the end of the lifespan of vessels in operation, opting for one specific fuel over another, and purchasing advanced technologies are costly and challenging endeavors. Today's container ships have an average lifespan of 27.7 years, so vessel owners and charterers must be prudent in their financial decision-making. It is still unclear which technology will prevail in the future and live up to the sustainability requirements of consumers as well as regulators. Some ecologically-promising technological innovations will take decades of research to reach maturity, while others are available now but have only limited decarbonization potential.



Deloitte supports the container shipping industry's move toward sustainability with our evaluation table on vessel fuels that highlights the advantages and challenges of the different options

(Table 1 Overview of the carbon neutrality of different fuel types). Our concise overview presents current and future fuel technologies for this heavily asset-driven business, including three future scenarios to provide insight into the key issues, possible approaches, and potential costs of transitioning to a more sustainable fleet. This overview will help container carriers make sound investment decisions based on objective criteria and hopefully accelerate the industry's journey towards sustainable shipping.

Tab. 1 – Overview of the carbon neutrality of different fuels used in ships

		(Combustion) Engine & Fuel Cells						E-Motor	Sails
Fuel Source	**Energy Carrier**	**Heavy Fuel Oil**	**LNG**	**E-Fuel Biofuel**	**Hydrogen**	**Methanol**	**Ammonia**	**Battery**	**Wind**
Fossil Energy Sources	**Crude Oil**	▽		▽	▽	▽	▽		
	Natural Gas		▽	▽	▽	▽	▽		
Renewable Energy Sources	**Biomass & Waste**			△	△	△	△		
	Electricity			△	△	△	△	△	
	Wind								△

△ Carbon neutral

▽ Fossil based

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Fuel options for container carriers today, tomorrow and beyond

Looking at fuel options for ocean freight carriers, we distinguish between short-, medium- and long-term options. In the first instance, efficiency improvements, fuel additives, and technical devices such as scrubbers are the most meaningful ways to improve the emission balance of a container vessel. In the medium term, we need alternative fuels and new types of propulsion technology, particularly as combustion engines emit nitrogen oxides (NOx) even when they run on zero-carbon alternative fuels.

The boxes in the sections that follow show the different fuel types and their sources relevant to the maritime industry and the different types of (propulsion) technologies available.

For simplicity when assessing fuel types and technologies, we assume that the electricity used to generate synthetic fuels and to power electric motors comes from renewable sources such as water, wind, and sun. However, it is clear that today's energy mix includes a large share of coal, natural gas and other fossil fuels as well as nuclear power. Determining which source is considered renewable is also a hotly-debated topic at various political levels.

In the next chapter, we assess the fuel types listed in the table above based on a range of ecological, operational, and financial factors relevant to the maritime industry and categorize them based on the assumed time to maturity (Horizon 1 to Horizon 3):

- **GHG balance –** absorbing and emitting carbon during both production and consumption, including relevant byproducts such as nitrogen oxides (NOx), sulfur oxides (SOx) and particulate matter (PM)
- **Applicability –** density and storage conditions, particularly for managing long distances at sea, infrastructure for transportation, and fueling and feedstock availability
- **OpEx and CapEx –** compatibility with propulsion technology used in vessels today and total cost of the fuel

Today's Fossil Fuels (Horizon 1)

Heavy fuel oil (HFO) is the most common fuel used in container ships today. It is a very efficient source of power for container ships and experts believe that the advantages of HFO will make it difficult to find a viable alternative capable of fulfilling the IMO's 2050 targets. We also look at liquified natural gas (LNG) from fossil sources, which emits up to 25% less CO_2 and almost no SOx, but only as a short-term fix.

Heavy Fuel Oil (HFO)	
Absorbs carbon during production	▽
Carbon-free when used in engine or motor	▽
No toxic byproducts when used in engine or motor	▽
Availability and scalability of source	△
Competitive cost with growing demand	△
Compatibility with existing vessels	△
Existing infrastructure for trading fuel	△
Practicality i.e., power, density, temperature	△

Heavy Fuel Oil (HFO)

HFO, also known as “Bunker C”, became the most widely used marine fuel in the mid-20th century, gradually replacing coal. In terms of quality, HFO is inferior to marine diesel, and even more so to the gasoline and diesel used in road transport. Its many advantages range from low price and high energy density to versatility, but a key disadvantage is that it is a very polluting fuel with high CO_2, SOx and NOx emissions. Today, 85% of the fuel used in the shipping industry is HFO, accounting for most of the 740 million tons of CO_2 emitted by voyage-based international shipping,or 2.0% of all global CO_2 emissions caused by humans in 2018 (IMO, 2020), including 15% of the world’s NOx and 13% of SOx emissions. The International Maritime Organization (IMO) issued emission control regulations in response, calling for general SOx thresholds that are higher than those of recent years, in addition to specific regulations for particularly sensitive areas.

Compared with the maximum sulfur content in HFO of 3.5% set in 2010, the current limit was reduced to 0.5% in 2020. This requires carriers to operate ships either on marine diesel or to install exhaust aftertreatment systems known as scrubbers. Another option is the use of very low sulfur fuel oil (VLSFO) with a maximum sulfur content of 0.5%, which complies with IMO specifications and still has good cleanliness, lubricity, ignition and combustion properties.

The industry has achieved significant efficiency gains, lowered fuel consumption, and improved emission monitoring in recent years. But it is difficult to beat HFO’s winning combination of globally available infrastructure, low prices, and high energy density, which enables long-range voyages with moderate tank sizes. If legislators fail to introduce regulatory requirements and a targeted incentive and subsidy scheme for alternative fuels, it is hard to imagine carriers switching to climate-neutral and environmentally-friendly fuels. The lack of viable medium-term alternatives means that the industry will have no choice but to consider various forms of compensation to meet regulatory requirements.

Liquified Natural Gas (LNG)

Liquified natural gas (LNG) is the liquid that forms when natural gas is cooled to minus 162 degrees Celsius. The cooling process also has the advantage of shrinking the gas to less than 1% of its original volume. In this form, LNG has a slightly higher weight-specific energy density than HFO but a lower volumetric energy density. To achieve the same range as existing ships, LNG-powered vessels would need a tank 2.3 times larger and much more complex in its design than HFO tanks. LNG may have a role as a transitional fuel, however, as it is readily available. LNG prices are competitive to HFO prices, while its emissions are significantly lower than those of HFO. Used in combustion engines, it is 15 to 25% less carbon intensive than HFO, reduces pollution from NOx and particulate matter, and is nearly SOx free.

LNG combustion engines are commercially available and carriers can retrofit existing internal combustion engines for the fuel, for instance by modifying the fuel injection system. Both in practice and in our future scenarios, LNG provides a good opportunity to cut CO_2 emissions and, more importantly, of NOx and SOx in the short term. Many companies are looking at transitioning to LNG, a technology that is relatively mature compared to alternatives. Current challenges range from the time required to retrofit existing vessels, which will then have to remain in service longer to the loss of storage capacity for larger LNG tanks. However, measures designed to reduce storage loss and retrofitting timelines have the added benefit of cutting costs and may also simplify the retrofitting and operation of these new systems. LNG can be used in both combustion engines and fuel cells. The development of LNG-based fuel cells is still early-stage, but as fuel-independent fuel cells are adopted, industry players can opt for LNG until green hydrogen and other zero-carbon fuels are available at scale. Fuel cells are an obvious solution for LNG-powered carriers in particular, and the first prototypes have already been approved.

Storage infrastructure for LNG is widespread and improving, but insufficient. The industry needs more LNG bunkering infrastructure, particularly in the southern hemisphere, to ensure global supply. Carriers are currently transporting LNG around the world and are well versed in its handling and risks.

Liquified Natural Gas (LNG)

Absorbs carbon during production	▽
Carbon-free when used in engine or motor	▽
No toxic byproducts when used in engine or motor	—
Availability and scalability of source	—
Competitive cost with growing demand	△
Compatibility with existing vessels	△
Existing infrastructure for trading fuel	△
Practicality i.e., power, density, temperature	△

Sustainable Fuels (Horizon 2)

Experts agree that the best way to decarbonize transportation in the medium term is to leverage today's advanced combustion technology with alternative fuels.
Various types have emerged, though each is at a different stage of maturity in terms of production, as we will outline below. The availability of green hydrogen and carbon from carbon capture and utilization (CCU) and from industrial or biogenic point-source capture (Ind-PSC/Bio-PSC) is crucial to sustainable propulsion. Hydrogen itself can be used as a fuel, but has limited viability and lends itself to processing into e-fuels with better combustion properties such as e-methanol or green ammonia. Besides ammonia, which is carbon-free, methanol can be a practical zero-carbon alternative, depending on the origin of the carbon used in the production process (IMO 2021).

Biofuel is the umbrella term for fuels obtained from biomass and from waste oils and fats. It is produced using different technologies and processes depending on the feedstock. While some feedstocks are widely available, such as oil crops and cellulosic biomass, the supply of other materials such as waste oils and fats is limited. The limited availability of fertile farmland under current agricultural practices could, however, lead to a conflict of interest if producers move to develop new farmland for the targeted cultivation of biomass. Biofuels are considered a renewable energy source because they return carbon that was previously absorbed through photosynthesis to the atmosphere, without adding to atmospheric carbon dioxide. That said, the type and origin of the feedstock will determine whether biofuels are ultimately deemed sustainable.

Biofuels and E-Fuels

Absorbs carbon during production	—
Carbon-free when used in engine or motor	▽
No toxic byproducts when used in engine or motor	—
Availability and scalability of source	—
Competitive cost with growing demand	▽
Compatibility with existing vessels	△
Existing infrastructure for trading fuel	△
Practicality i.e., power, density, temperature	△

Used as a “drop-in” fuel (i.e., a fuel that can directly substitute existing fuels with minimal equipment adjustment) or blended with existing fossil fuels, biofuels have huge potential to support the short-term GHG emission reduction targets, not least because they work with existing technology and infrastructure. Ocean carrier Hapag-Lloyd, for example, teamed up with several freight forwarding firms in 2022 and signed contracts for advanced biofuels with DHL Global Forwarding, Bolloré Logistics, and Forto, among others.

E-fuels are synthetic fuels based on converting electricity to liquid hydrocarbons. The two different types available are carbon-based e-fuels made with electricity, water, and a carbon source, and carbon-free e-fuels made with electricity, water, and air. Electrolysis can also produce hydrogen, which is either used directly as a fuel or converted into other fuels like ammonia. With carbon-based e-fuels, hydrogen produced by electrolysis is combined with carbon to create a synthetic fuel or methanol using Fischer-Tropsch synthesis.

For e-fuels to be considered climate-neutral, the electricity must come from renewable energy sources and the CO_2, if used, must come from sustainable biomass or from the atmosphere (direct air capture). E-fuels are very versatile, but production is very energy intensive, with only about 10% to 35% of the original electricity converted into useful energy. One company active in this space is CMA CGM, which recently joined the Jupiter 1000 project in France, the first power-to-gas demonstrator to produce hydrogen and e-methane at industrial scale.

The potential is obvious: biofuels and e-fuels produced from renewable energy do not emit any additional CO_2. These fuels are versatile, have similar characteristics to conventional fuels and are able to use existing infrastructure. These advantages are offset by significant disadvantages, however, in particular the immense costs associated with the energy-intensive production process as well as the limited supply of the resources required to produce them, such as renewable energy or biomass.

Green Hydrogen

H_2 – Hydrogen can be generated from fossil sources, from renewable sources such as biogas, from residual waste or synthetically through electrolysis. Depending on the method used, the end product is classified as gray, blue, or green hydrogen. Gray hydrogen is produced by splitting natural gas into hydrogen and CO_2. Natural gas-based hydrogen produced with carbon capture and storage is referred to as blue hydrogen. Green hydrogen, which uses electricity generated from renewable energy to split water into hydrogen and oxygen, can be used in a fuel cell or in specialized combustion engines.

Hydrogen has a higher weight-specific energy density but a lower volumetric energy density than HFO. As a result, container ships either have to make more refueling stops or eliminate cargo space to accommodate the larger fuel tank. To liquify hydrogen at ambient pressure, it must be stored in cryogenic conditions (below -240°C), which adds cost. An alternative would be to store it as compressed gas under high pressure, but a combination of these two solutions is also possible. Hydrogen storage is so difficult that producers often use it to make methanol and ammonia instead, which have more practical properties and may provide a good alternative for shipping.

Most ships can be retrofitted for hydrogen fuel cells using technology that already exists. Fuel cells have the advantage that they are quiet, have no moving parts and are easily scalable for larger ships since the individual cells can be stacked. Although hydrogen fuel cell technology exists, the industry is still looking for solutions to apply this technology to maritime applications on a larger scale.

Green Hydrogen

Absorbs carbon during production	▽
Carbon-free when used in engine or motor	△
No toxic byproducts when used in engine or motor	—
Availability and scalability of source	—
Competitive cost with growing demand	▽
Compatibility with existing vessels	—
Existing infrastructure for trading fuel	—
Practicality i.e., power, density, temperature	—

Current trends suggest that hydrogen is still likely to play an important role in reducing emissions, both through existing processes for producing green methanol and through future innovations as a range extender or as an add-on for use within coastal and short-sea shipping. Using energy converters such as fuel cells is the only way to avoid the toxic byproducts of hydrogen such as NOx. A crucial factor here is the price competitiveness of hydrogen. At present, gray hydrogen is the only competitive form at a cost of about $1–$2/kg, though it does not make a significant contribution to reducing CO_2 emissions. Blue hydrogen is currently 30%–80% more expensive than gray hydrogen, while green hydrogen costs about four times as much. Experts believe that the cost of blue and green hydrogen will go down in the near future, but for hydrogen to become a real alternative and help reduce shipping emissions, the industry will have to invest more in fueling and transport infrastructure.

There is not enough electricity generated from renewable sources today to produce the amount of green hydrogen the maritime industry needs. But numerous countries are making a real effort to ramp up green hydrogen production: Germany, for example, plans to build hydrogen generation plants with a total capacity of up to 10 gigawatts by 2040. The required (sorted) waste and raw materials are also in limited supply, especially since the space needed to produce them is in direct competition with farmland for food production. Yet there are distinct advantages to green hydrogen that offset its complicated storage, lack of infrastructure, and low energy density. Hydrogen is a very clean fuel that can be produced using renewable energy and has a virtually unlimited feedstock.

Green Methanol

CH3OH – Methyl alcohol or methanol is a versatile substance used as a component of many products in the chemical industry. As of today, 99% of the 100 million metric tons of methanol produced each year comes from natural gas, coal and other fossil fuels. There are two ways to produce methanol from renewable resources, either by using green hydrogen and CO_2, known as e-methanol, or by using biomass, e.g., biogases from garbage or agricultural waste, known as bio-methanol. Production costs for renewable methanol are currently 10 to 25 times higher than for conventional methanol, depending on the availability and price of feedstock. Experts agree that achieving a cost on par with fossil methanol will be feasible in time, depending on the availability and price of biomass, renewable hydrogen, and extracted CO_2.

In addition to its use in fuel cells, methanol is of particular interest as a combustion fuel. Not only is the energy yield higher, it can also use existing technology and infrastructure with little to no modifications. For example, combustion engines built for methanol also run on diesel or mixed fuels. In 2022, Danish ocean carrier Maersk announced a strategic partnership with six leading companies to scale green methanol production by 2025. Maersk has also ordered twelve 16,000 TEU vessels that operate on green methanol.

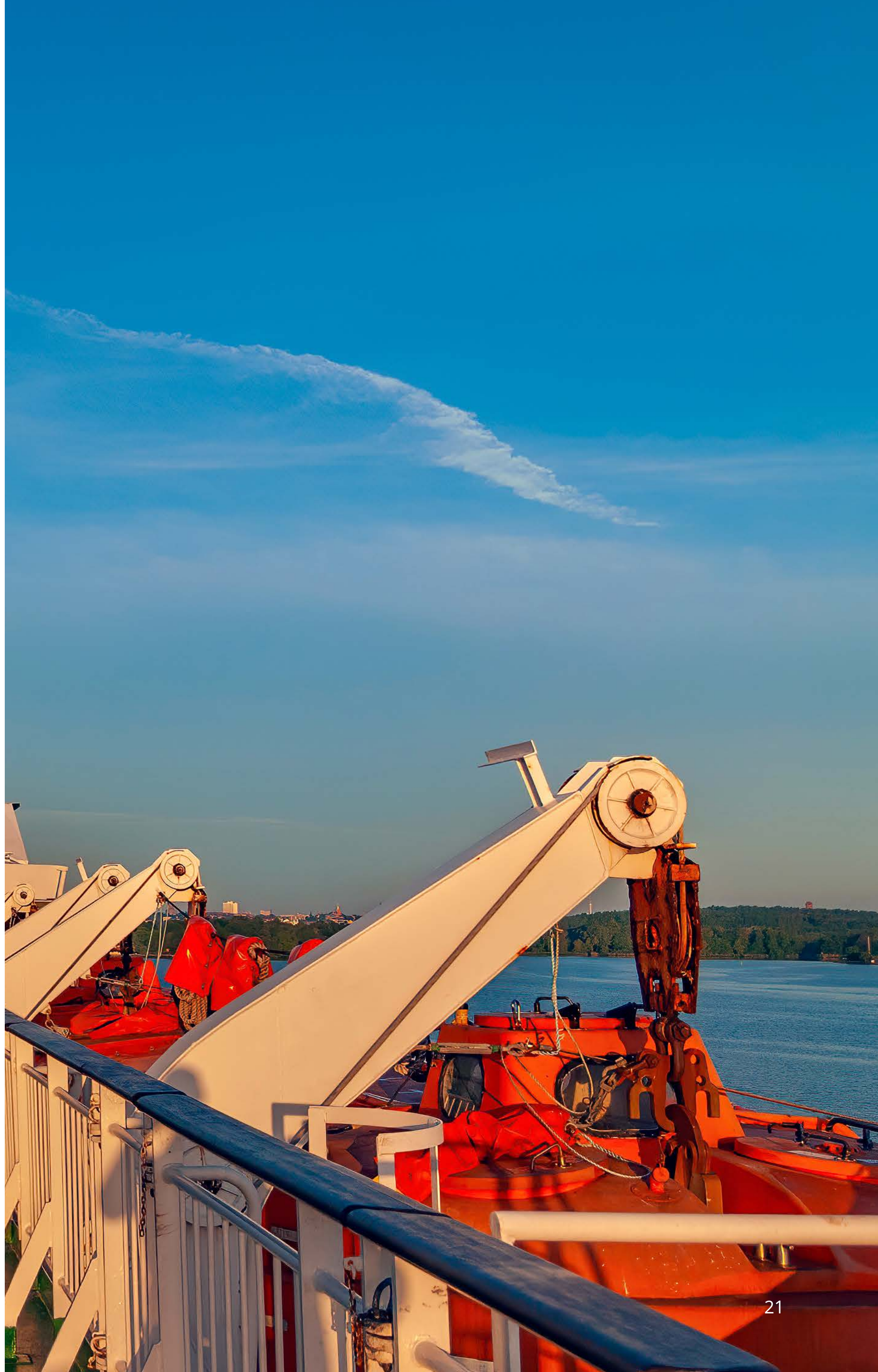
Methanol is liquid at ambient temperature and pressure, which enables convenient handling. One disadvantage of methanol is that its energy density is higher than that of ammonia and hydrogen but significantly lower than that of HFO, so vessels running on methanol rather than HFO would need larger fuel tanks for the same range. The conversion effort, as with other alternative fuels, varies based on the space available for tanks and other equipment. Current conversion projects focus primarily on a combination of methanol and diesel, but there have also been successful prototypes using hydrogen and methanol injection as well as purely methanol-powered ships.

Green Methanol	
Absorbs carbon during production	△
Carbon-free when used in engine or motor	▽
No toxic byproducts when used in engine or motor	—
Availability and scalability of source	—
Competitive cost with growing demand	△
Compatibility with existing vessels	—
Existing infrastructure for trading fuel	—
Practicality i.e., power, density, temperature	△

03 | Fuel options for container carriers today, tomorrow and beyond

While we know that converted vessels operating on methanol/diesel are similarly if not more efficient than HFO-powered ships, it is a safe assumption that engines specifically designed to run on methanol are likely to be even more efficient. Major ocean carriers have a number of these vessels ordered, indicating that the trend towards methanol as an alternative fuel is likely to continue.

When produced with renewable feedstock, pure methanol combustion emits up to 95% less CO_2 and up to 80% less NOx, with no SOx emissions at all and very low particulate matter. The upsides of methanol range from its simple technical implementation to potentially massive emissions reduction; the only downside being the uncertain availability of renewable methanol. Some experts in the industry seem hesitant to embrace methanol, although individual companies have invested heavily in shifting at least part of their future fleet to methanol-powered engines. Our three scenarios discuss the challenges related to methanol and show how carriers can harness current developments to transform their fleets and find new solutions.



Green Ammonia

Ammonia is a versatile compound which occurs in nature and is mainly used to produce agricultural fertilizers. In a method known as the Haber-Bosch process, three ingredients are needed to produce ammonia: hydrogen, nitrogen, and energy. Ammonia produced using renewable energy from nitrogen and green hydrogen as feedstock is considered carbon-neutral.

However, experts expect the lack of green hydrogen feedstock to severely limit the supply of green ammonia in the near future. To become a viable source for the maritime industry green hydrogen, as well as solar and wind power to generate the energy needed for production, must increase. It is now cheaper to produce green ammonia than green methanol, and experts believe the price of green ammonia, currently around $700 per metric ton, will decrease by half in the next few years.

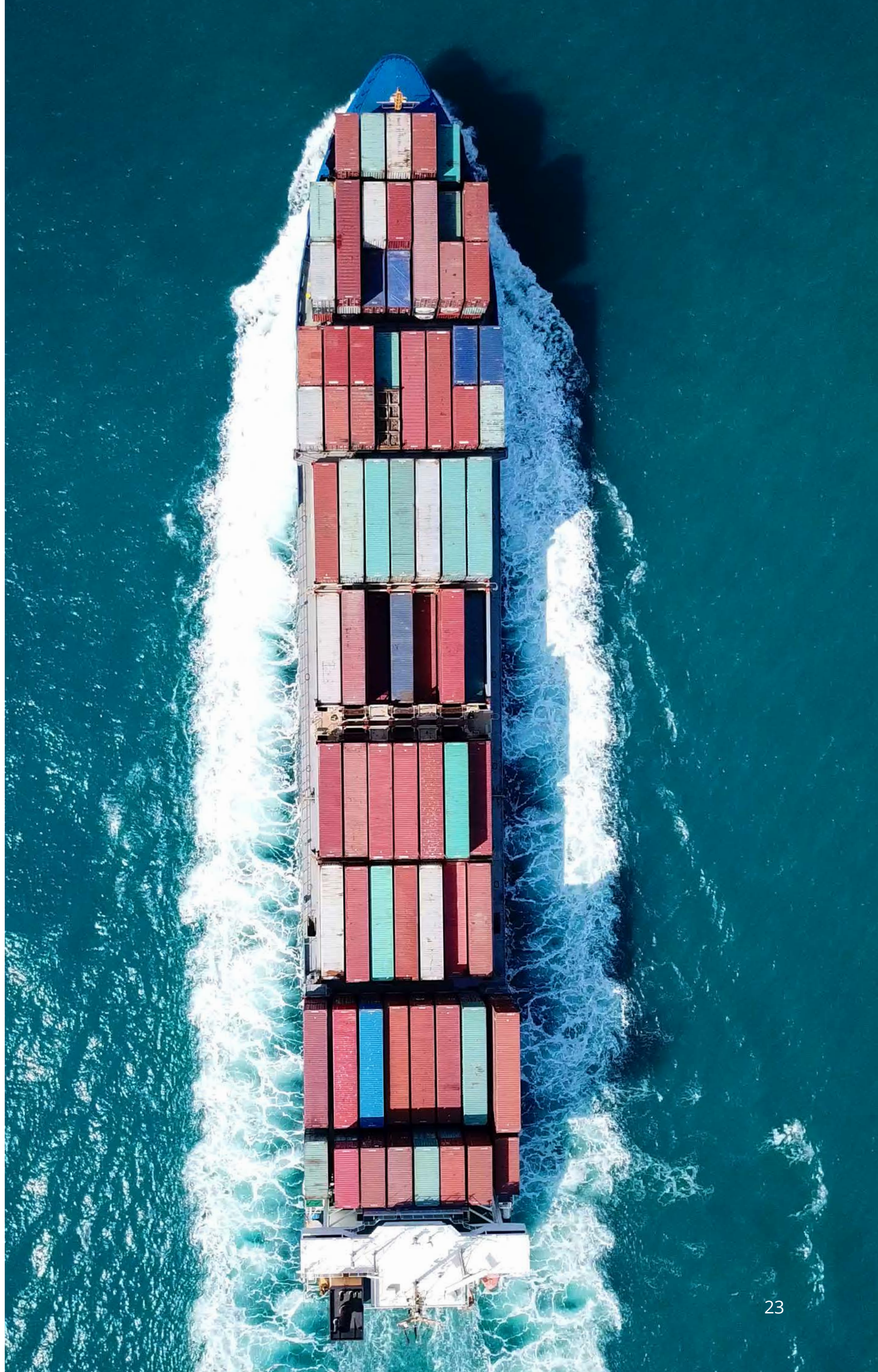
Ammonia liquefies at -33°C and does require cooling, but no high-pressure tanks for storage onshore or offshore. The infrastructure needed to transport ammonia in high volumes and over long distances already exists. It has a similar energy density as methanol, though it is higher than that of hydrogen and significantly lower than that of HFO, so vessels running on ammonia would need larger fuel tanks to achieve the same range as their conventional counterparts. We have seen some rather experimental projects recently emerge to promote green ammonia production. In 2021, for example, Maersk announced that it would back the plan to build Europe's largest green ammonia plant in Denmark. Swiss-based shipping giant MSC has also listed ammonia as an alternative fuel to explore.

Green Ammonia	
Absorbs carbon during production	—
Carbon-free when used in engine or motor	△
No toxic byproducts when used in engine or motor	—
Availability and scalability of source	—
Competitive cost with growing demand	△
Compatibility with existing vessels	▽
Existing infrastructure for trading fuel	△
Practicality i.e., power, density, temperature	—

Ammonia can be used in fuel cells, but its commercial use in the maritime sector is not realistic any time soon due to the relative immaturity of the technology. Because it is difficult to burn, ammonia will require specialized combustion engines for use as a marine fuel. Various carriers currently have prototypes under development, which will likely run on ammonia mixed with hydrogen or other fuels due to its complex combustion properties.

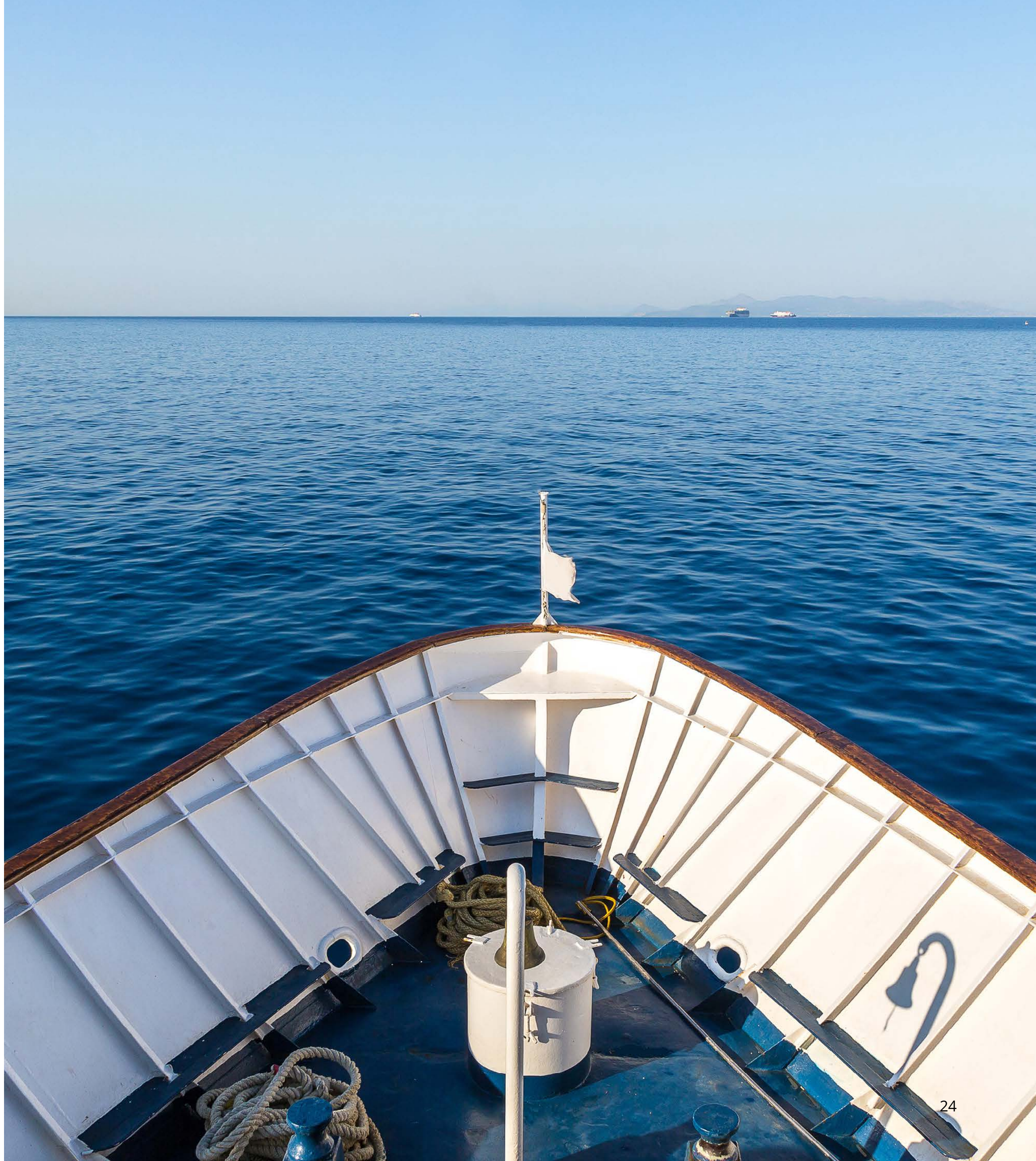
The first tankers powered by green ammonia are expected to launch soon and major engine manufacturers are also planning to expand retrofit options by the mid-2020s. The current approach focuses on dual-stroke engines running on an ammonia-fuel blend. Such combustion may emit NOx and unburned ammonia and is at present no solution to reduce or avoid these emissions in marine engines. Clear reduction of N_2O emissions is vital to ensure the climate benefit of green ammonia.

Due to its toxicity, on par with that of HFO, vessels that operate on ammonia as a fuel are subject to strict requirements for storage and safety, which may or may not be feasible for some maritime segments.



Maritime Innovation (Horizon 3)

Innovative options for the medium- to long-term, from electrification to sailing, are worth considering. Neither of these options are mature enough yet to be viable, and seem to be a better fit for short-haul voyages and smaller vessels.



E-motors running on renewable energy

Absorbs carbon during production	—
Carbon-free when used in engine or motor	△
No toxic byproducts when used in engine or motor	△
Availability and scalability of source	△
Competitive cost with growing demand	△
Compatibility with existing vessels	▽
Existing infrastructure for trading fuel	△
Practicality i.e., power, density, temperature	▽

E-motors running on renewable energy

For the battery option to become viable, carriers would have to pivot to smaller ships with space for 3,000 to 4,000 containers and more quick stops along the voyage to swap batteries. The benefits of this new technology are evident: no CO_2 emissions at sea thanks to the electric propulsion and battery system. With an estimated annual reduction in CO_2 of 1,000 tons for every mid-sized ship, electric cargo ships can significantly improve the industry's sustainability outlook.

Some smaller carriers have announced projects for testing electric cargo vessels for container shipping. There is, in fact, already one completely electric cargo ship operating today: the zero-emission vessel christened Yara Birkeland. Its maiden voyage, a short haul along the Norwegian coast from Horten to Oslo, took place in February 2022. Current battery technology allows for a capacity of 120 TEU which, compared to existing container vessels, is extremely small. In addition to the Yara Birkland, there are prototype batteries for shipping container vessels that have passed the first regulatory hurdle for safety standards at the American Bureau of Shipping. Plans are underway for testing of the first retrofitted ship which, according to relevant market players, is expected to begin operating on a small scale in 2023. With new technical challenges and limitations emerging every day, carriers will need to find a creative approach to solutions in this area. In our Scenario Outlooks, we offer some ideas on how carriers can make the most of battery technology benefits and potential emission cuts, despite existing issues.

Sailing

Using sails or rotor sails to travel across the ocean is clearly one of the most sustainable ways to harness a natural power like wind. It also makes other power supplies more cost-efficient. Over the past few years, various players have invested in wind power for cargo vessels as a propulsion aid in addition to fuel. AirSeas, a subsidiary of the European aircraft manufacturer Airbus, has developed a wind propulsion system for its own fleet and ordered its first kite, known as SeaWing, in late 2018. According to the manufacturer, SeaWing kites measure up to 1,000 square meters and can provide around 20% of the propulsion energy required, reducing fuel consumption by the same amount. This could mean a significant reduction in CO_2 emissions for cargo vessels equipped with sails.

Vessels equipped with kites, however, travel at slower speeds and have less space in the cargo hold. Despite these downsides, sail technology pioneer SailCargo is about to finalize the production of two new sailing vessels: Veiga and Ceiba. Ceiba will be finished and ready to set sail transporting sustainable goods and produce in 2023. With a capacity of 250 tons, Ceiba is relatively small compared to traditional fossil-fuel based vessels. Other solutions are also evolving, as we will discuss in more detail in the Outlook Scenarios. While sails definitely have the potential to help reduce emissions in container shipping, most of the innovations in this space, and in most of the forward-looking projects in the pipeline, focus on their role as a propulsion aid.

E-motors running on renewable energy

Absorbs carbon during production	—
Carbon-free when used in engine or motor	△
No toxic byproducts when used in engine or motor	△
Availability and scalability of source	△
Competitive cost with growing demand	△
Compatibility with existing vessels	▽
Existing infrastructure for trading fuel	△
Practicality i.e., power, density, temperature	▽

04

Scenario Outlook

As shown in the previous sections, carriers have a lot of options when it comes to preparing their fleets for the future and advancing their efforts to reduce emissions. This section highlights near-term scenarios that could transform the shipping business as we know it.

The purpose is to outline possible applications of the technologies and fuels discussed above. We have selected our scenarios on the basis of various assumptions about political, technological, and economic developments that are likely to influence the speed and scale of fleet transformation. In these scenarios the current status quo provides the baseline; in other words, we work under the assumption that most of the fleets in question run on heavy fuel oil and that these companies are seriously pursuing economical and sustainable alternatives.

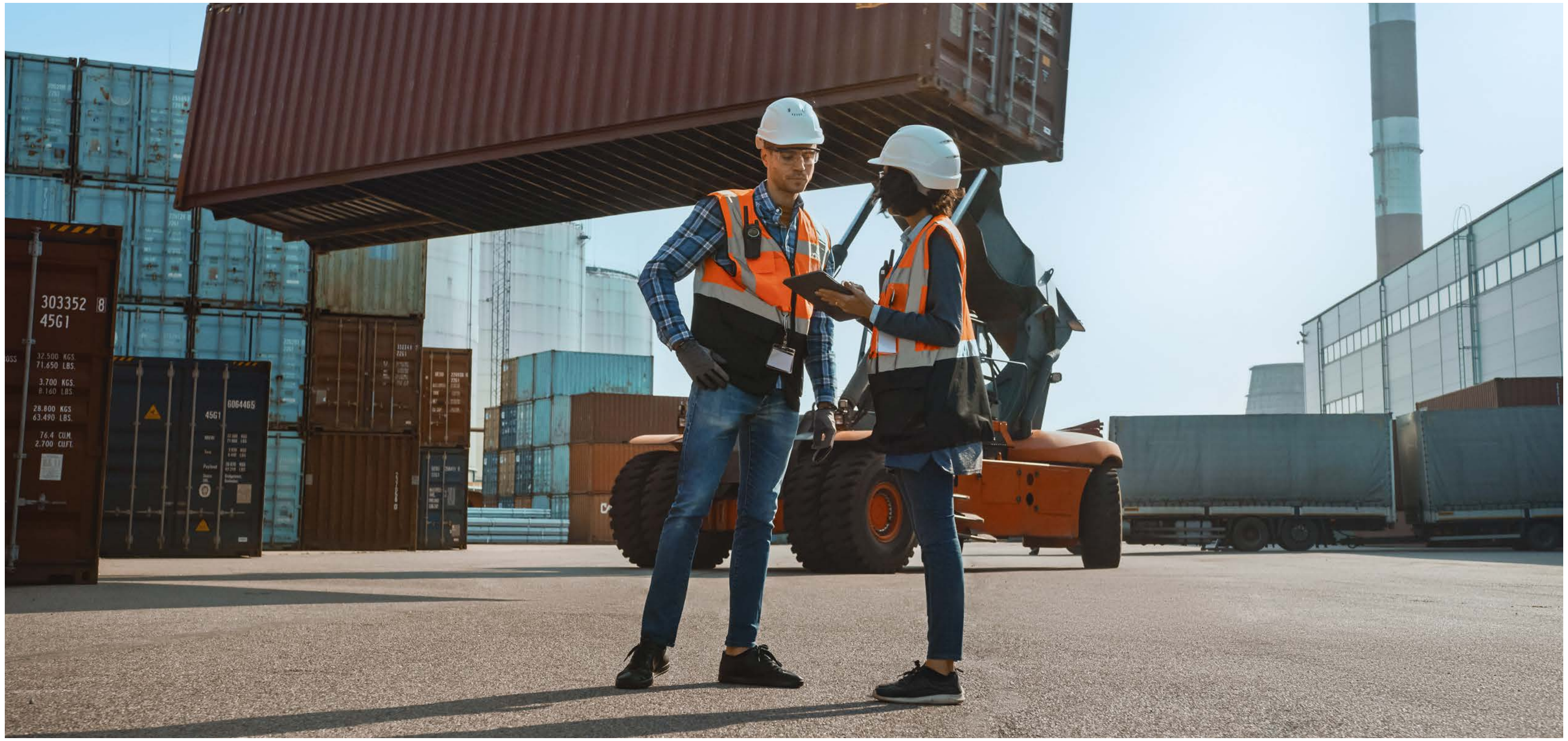


Fig. 2 – Company Profiles

	Cautious Container Company **Focus on legal requirements**	Fit for Future Company **Follows a specific strategy**	Clean Shipping Company **Takes the lead – is a sustainable pioneer**
Perspective on sustainability	• **Would like to reduce the effort as much as possible** • Neatly meet requirements from the regulator • **Does not see sustainability as a differentiator**	• **Is convinced that sustainability should have a fundamental impact on company strategy** • Wants to define and implement concrete measures to make the company a sustainable company • **However, does not believe that sustainability should be a central driver for corporate decisions (profitability is central)**	• **Sees sustainability as a leading element of company strategy** • **Believes that sustainable products and services can generate more business in the future** • Believes that the company must position itself as a front-runner in sustainability to generate the full benefits
Driver for decision	• Minimize effort • Meet minimum requirements of the group	• Importance of sustainability is acknowledged • Maintain profitability at all costs • Do not fall behind competitors	• Importance of sustainability is acknowledged • An understanding that sustainability is the basis for successful actions
Target	All innovations and changes will still be based on fossil energy sources. CO_2 emissions are to be reduced under personal responsibility	55% reduction of EU GHG emissions by 2030 compared to a 1990 baseline and to be fully carbon neutral by 2050.	Reduce vessel emissions 20% by 2027, 45% by 2030, and 80% by 2035, with the goal of full carbon neutrality by 2040

In the first transformation scenario, the "Cautious Container Company" has set itself fairly ambitious emission reduction goals. However, the company is cautious about investing in new technologies and only wants to meet the minimum legal requirements for sustainable shipping. The company is aligned with the FuelEU Maritime initiative and plans to reduce greenhouse gas intensity six percent by 2030, 26% by 2040 and 75% by 2050 compared to the 2020 fleet average.

The "Fit for Future Company" in our second scenario is focused on the Fit for 55 plan, planning to reduce emissions considerably by 2030 and to be fully climate neutral by 2050. Sustainability is not a major focus, but the company is aware that sustainability plays an increasingly important role and will continue to do so in the future. With this in mind, the company is looking to renew its fleet and sees its efforts to become more sustainable as key to standing out from the competition. In the third scenario, the "Clean Shipping Company" has made sustainability a core element of all future operations and intends to position itself in the market accordingly. The company considers the Clean Shipping Act to be an innovation driver and has therefore set itself the goal of reducing vessel emissions 20% by 2027, 45% by 2030 and 80% by 2035, with the goal of full carbon neutrality by 2040. The company believes that increased sustainability will give it a decisive competitive edge and considers itself prepared for any future legislative requirements with regard to sustainability.

Transformation Path 01:
Cautious Container Company

Since the Cautious Container Company (CCC) is aligned with the FuelEU plan, its first stated goal is to reduce fleet emissions by six percent to meet what it considers the minimum policy requirements. The company has not committed itself to a sustainability strategy but intends to take a flexible approach to complying with legal regulations.

With its order books full, CCC believes smart near-term investments will drive continued growth. The new regulatory requirements promise lower operational costs for natural gas-powered vessels, **so the company decides to convert some of its 15,000 TEU container ships to LNG power for 35 million euros each.** The LNG tank capacity of the converted ships will be approximately 6,700 m3, which means they will have to refuel twice on each round trip from Asia to Northern Europe. After the conversion, most of the ships will be powered by LNG but can also still run on conventional fuels. CCC plans to convert the ships successively over a 12-month period, with all ready to set sail by 2025. The converted ships will emit 15% less CO_2 and as much as 90% less SOx and particulate matter.

With some of ts large vessels being phased out over the next few years, the company decides to order new ships that are also LNG-capable. These 23,000+ TEU container ships are expected to be operational by 2026 and 2028, respectively, and will emit 15% to 25% less CO_2 than the retired vessels. The price tag for each ship is between 170 and 255 million euros, which is higher than the budgeted cost to buy conventional vessels. Management approves the investment neverthe-less as part of its efforts to reach the company's sustainability targets.

The IMO has introduced regulations lowering the permitted sulfur content of fuel from 3.5% to 0.5%, so the company must look for alterna-tives. These new laws could cost the container shipping industry anywhere from 15 to 25 billion euros due to retrofitting work on the fleet and the switch to alternative fuels. **The company decides to retrofit part of their fleet with exhaust-gas cleaning systems known as scrubbers** to enable the current fleet to continue to run on conventional fuels despite the new rules.

04 | Scenario Outlook

Scrubbers cost between seven and ten million euros per vessel. The company also intends to operate the rest of its fleet with very low-sulfur fuel oil (VLSFO) or with permitted fuel blends selected on the basis of current market price trends. It is unclear whether these resources will be sufficient for CCC to comply with legal requirements, but the company feels these efforts have prepared it well for the years to come and decides to make further plans based on future political developments.

As the chart shows, companies that do not take sufficient action on climate issues could lose market share, resulting in stagnation and even reduction of fleet size. The lack of a sustainability strategy to transition the fleet away from fossil fuels toward more sustainable alternatives could thus endanger the business operation in the long term.

Fig. 3 – Cautious Container Company

Transformation Path 02: Fit for Future Company

The Fit for Future Company (FFC) has been in the process of transforming its fleet for several years and started developing a sustainability strategy as soon as legislators announced stricter regulations. The strategy envisages a combination of LNG and e-methanol, with major investments planned to future-proof the fleet and make it climate-neutral by 2050. The company believes that it is important to communicate its sustainability strategy clearly to the outside world in an effort to involve all stakeholders in the process, but above all the investors. The sustainability strategy calls for determined, rapid action to decisively reduce SOx and NOx over the next few years. **The FFC has identified LNG as the right technology for the short term.** The company also intends to **invest in the development of alternative fuels, with a longer-term focus on e-methanol.** At the same time, it will use the transition phase to **ramp up storage and logistics infrastructure** that can be used with both LNG in the short to medium term and e-methanol in the medium to long term.

As part of the modernization and retrofitting of the fleet, FFC has decided to **remove hull fouling from affected vessels and apply a coat of antifouling paint that also reduces frictional resistance,** resulting in **energy savings of up to 15%.** The company has also determined that several **of its vessels could be fitted with an energy-efficient propeller to reduce fuel consumption and thereby emissions between 10% and 13%.** Carefully selected vessels will be **equipped with a fuel-saving, flow-optimized bulbous bow.** The cost of all these retrofitting initiatives will be in the three-digit million range for a fleet of around 250 ships of assorted sizes.

The company also plans to invest heavily in making the fleet LNG-capable, equipping some vessels with dual fuel engines. Initial projects are expected to cost between 30 and 35 million euros, though the steep learning curve and economies of scale will likely bring that price down rapidly. FFC also plans to acquire several TEU 23,500+ vessels for approximately 165 million each, which will be ready for operation by the mid-2020s according to current project status. By retrofitting and modernizing the fleet, FFC is confident that it can achieve its goals of reducing CO_2 emissions by 30% by 2030. Funding for these substantial investments in sustainability comes from green loans. The active participation of all stakeholders has made this transition possible. With its sustainability strategy, the company is confident that it can unlock a fast-growing market as large global companies and their customers drive demand for more sustainability.

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FFC is certain that its consistent, long-term sustainability strategy and partnerships will enable it to refinance the investment and additional costs. Its transition path has already had a positive impact on risk management thanks to investment, stabilization of LNG prices through long-term partnerships, and a better supply situation via expanded infrastructure.

In the medium term, the company hopes to gather enough resources and knowledge to develop a concrete full decarbonization plan. **The company intends to stop using HFO as of 2025, and VLSFO by 2050.** To reach that goal, FFC is building stronger infrastructure and partners with other companies to secure future LNG supply. The company will focus on the transition to zero-carbon fuels in the next phase, with plans to purchase e-methanol-powered ships and develop the necessary infrastructure. By 2030, the fleet and infrastructure should be ready to launch the first e-methanol vessels, leading to a further reduction in overall emissions and a better competitive position in this constantly evolving market.

Yet whether the measures will suffice to meet the company's sustainability targets given the forecasted growth in container shipping is questionable, as shown in Fig. 4. And since the company does not yet have a concrete plan for a complete shift away from fossil fuels, it could miss its climate goals.

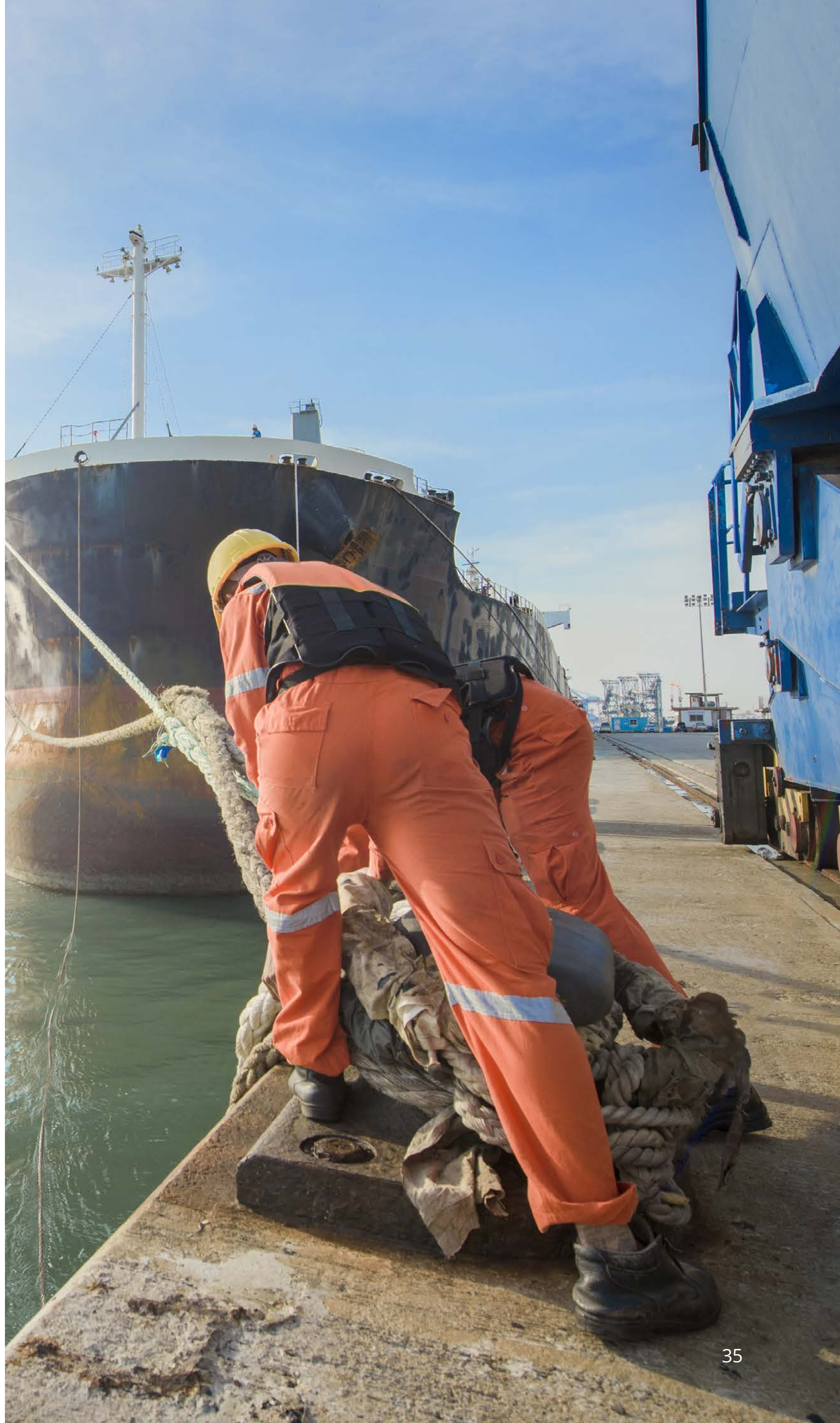
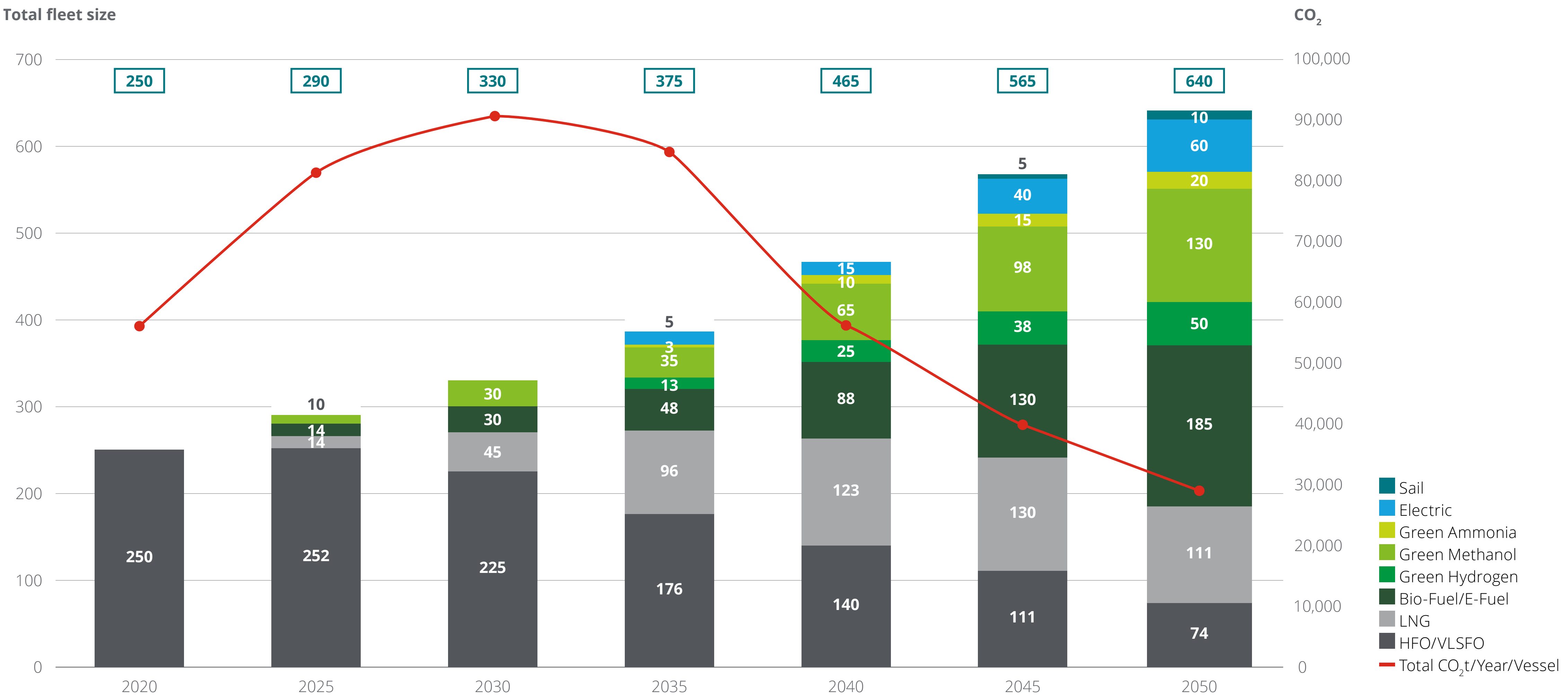


Fig. 4 – Fit for Future Company



Transformation Path 03: Clean Shipping Company

The Clean Shipping Company (CSC) wants to be a pioneer in the sustainable shipping transformation and has recently announced a large-scale modernization and expansion plan of its fleet. The goal is to **move away from fossil fuels as quickly as possible** and CSC has announced the **switch to e-methanol** in an effort to be fully **climate neutral by 2040.** New acquisitions and a modernization of the current fleet, similar to those made by the Fit for Future Company, are also on the agenda. CSC also plans to enter new markets in **inland shipping with battery-powered ships and to adjust both routes and speeds by making additional changes to the use of wind power.**

The core of its sustainability strategy will be the switch to sustainable e-methanol-powered ships. The company has announced **the construction of new e-methanol vessels** to replace those being retired in the next few years. With an initial investment package, **the company will acquire 16,000 TEU ships for about 175 million euros each.** They will be launched from the beginning of 2024 until the end of 2025, and will be equipped with dual-fuel engines that run on e-methanol and low sulfur fuel. **The acquisition costs are approximately 10% to 15%** higher than for conventional ships. Following further developments in shipbuilding and the e-methanol industry, **CSC plans to order 17,000 TEU ships** that are expected to set sail in 2026 and **will cost approximately 200 million euros each.** Compared to conventional ships, the investment costs are about 8% to 12% higher, and a smaller upcharge than the previous acquisition. Twenty new e-methanol ships would save approximately 2.3 million tons of CO_2 over conventional HFO ships.

CSC's focus is not only on transforming its fleet, but also on building partnerships with other companies to secure reliable sources of green methanol, currently in short supply. The plan is for **CSC to join forces with six other companies and build a worldwide production network with sites for bio-methanol and e-methanol across Asia, Europe, South America, and North America.** The projected output is a total of 130 metric tons per year by the end of 2024. Capacity for up to 700 additional metric tons per year will be added by the end of 2025, with a long-term goal of around 1,300 metric tons per year. With this initiative, CSC aims to ensure a steady, secure supply of green methanol and a competitive price.

The company is also interested in **testing vertical airfoils to assess the potential of wind power.** These sails are mounted vertically on the deck and operate much like the wings of an airplane. The system being tested uses AI technology to trim in the direction of the wind and can be folded into a 40-foot container when not in use to avoid interfering with the cranes. The sails could **cut emissions by between 6% to 8% depending on route and weather.** Testing is scheduled to begin in 2023 with the first deployments planned in 2025.

CSC has also identified a market for **lower speed shipping.** The fuel consumption of a container ship, which mainly depends on the size and cruising speed of the ship, follows an exponential curve. Slowing cruising speeds could therefore save large amounts of fuel and in turn also emissions. **Vessels could use 33% less fuel simply by reducing speed from 24 to 21 knots.** After initial experience with extra slow steaming between 15 and 18 knots, CSC intends to develop further markets in **super slow steaming** with speeds of 12 to 15 knots. CSC expects that despite longer voyage times, there will be high demand for this form of more sustainable shipping. The company will offer **lower speed shipping services as of 2025, with plans to use battery-powered ships by 2030 in this segment.** These vessels will have replaceable battery containers that they can exchange for charged ones in port. One of the biggest challenges will be the planning of routes and distribution of ships and batteries so that as many ships as possible use the available batteries as efficiently as possible to scale the system as quickly and profitably as possible. While acquisition costs are expected to be higher than normal, CSC expects its operational expenses to go down thanks to lower maintenance and personnel costs. Distance and size are the key limiting factors for battery-powered vessels, so CSC is adapting its strategy accordingly and looking to deliver to ports that cannot accommodate large container vessels. This will enable more precise deliveries, while also speeding up last-mile delivery to the customer. As a first step towards implementation, CSC plans to start deploying these battery-powered ships in 2030 for distances of up to 1,500 km, meaning they could become economically feasible very soon.

CSC is confident that it is well positioned for the future and has a determined and sophisticated sustainability strategy that will enable the company to achieve its ambitious goals. In future, CSC will have what it takes to develop new markets and penetrate more existing markets.

Fig. 5 – Clean Shipping Company

05

Other factors driving sustainability in shipping

When it comes to investing in sustainable fuel options, the preferences and decisions of today's container carriers will make a huge impact on the industry's sustainability outlook – but it is not up to the carriers alone.

For the sector to decarbonize in a timely manner, all stakeholders must be on the same page in terms of technology and extremely clear in their decision-making.

- Industry associations also need to work closely with regulators and legislators to synchronize the future initiatives of various players in the ecosystem pursuing alternative fuels and engines. This will help reduce the extreme uncertainty about which technologies to support, and incentivize investments in sustainable solutions by both vessel owners and operators.
- Both refineries and shipbuilders need to invest in alternative solutions.
- Despite constraints on the maturity of the technology and the availability of raw materials, the petroleum companies producing heavy fuels from crude oil today must be prepared to switch to producing alternative, more sustainable fuels.

Regulation and market interventions including certificates and claims can incentivize all players in the container shipping ecosystem to put decarbonization on par with cost and viability when it comes to selecting new vessels and propulsion technologies.

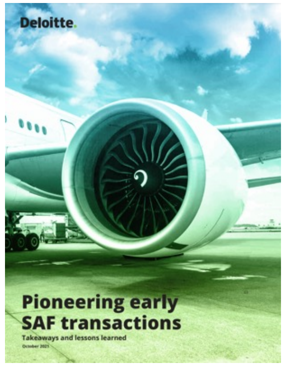
Governments can incentivize progress by using policy instruments like price subsidies on the demand side, and by granting subsidies for the construction of alternative fuel production plants on the supply side. Forthcoming non-financial reporting mandates will increase transparency around sustainability, while legislation regarding sustainable supply chains will increase peer pressure to develop or adopt pioneering technologies at a faster pace. Carriers that exceed mandatory emissions reduction targets and present innovative solutions will have a competitive edge. This will help them avoid client churn as consumers become more environmentally conscious, with demand largely aggregated through logistics service providers.

Container carriers have the power to make the leap from one of the most polluting industries to a pioneer in sustainability, working in collaboration with the ecosystem players mentioned above.

In the short term, the key steps are investing in efficiency through digitalization, carbon insetting and offsetting projects as well as drop-in biofuels. To mitigate risk, carriers need to maintain a modern fleet of container ships, ensuring that they can adopt technological advances in novel fuels and propulsion technologies quickly. Vessels on order today should be constructed with a modular design to enable carriers to exchange the propulsion technology with minimal effort and allow for flexibility with any of the above-mentioned sustainable fuel options. In the medium term, it might be worthwhile to scrap vessels early or replace the propulsion technology. In the long run, the container shipping ecosystem should set standards for propulsion and fuel technology to ensure that the decarbonization of the container shipping sector succeeds.

Other related whitepapers

Decarbonizing Shipping
All Hands on Deck



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Issue 02/2023