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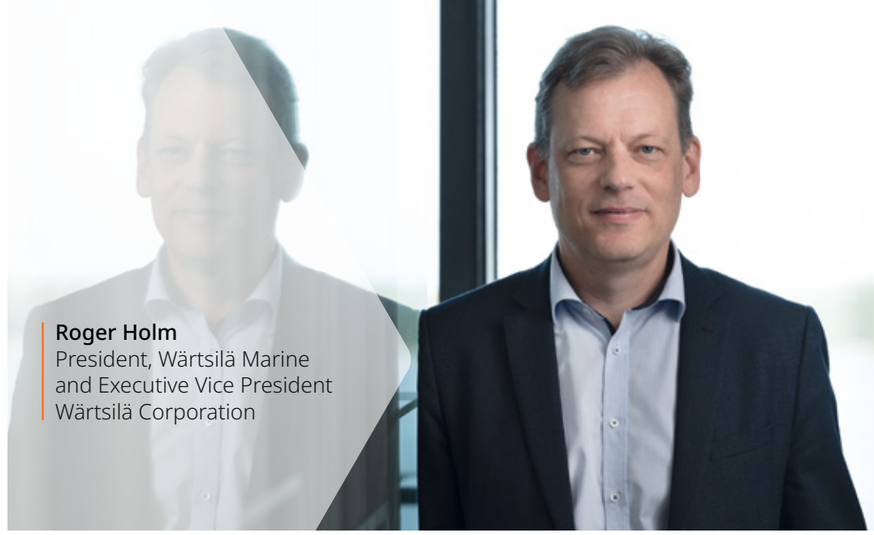
Sustainable fuels for shipping by 2050 – the 3 key elements of success

A report on future fuels in the marine industry

Contents

> We must act now and shape the future of sustainable fuels.



Roger Holm
President, Wärtsilä Marine
and Executive Vice President
Wärtsilä Corporation

Foreword - Roger Holm

The biggest transformation in the history of shipping is here.
Shipping is the 'engine room' of the global economy, transporting more than 80% of world trade. With such a large economic impact comes an equally heavy environmental footprint – around 2% of global emissions, which is equivalent to the annual emissions of Japan. Without action, these emissions could rise by around 45% by 2050, even as emissions from other sectors shrink.[1]

This trajectory is not going unnoticed. In 2023, the global shipping industry came together for the first time at the IMO's MEPC 80 to plot a course to achieve net zero shipping by mid-century. This means that in just 25 years – the lifetime of a single vessel – shipping must eliminate its entire contribution to climate change.

Adding to the pressure for change, shippers of goods are demanding more sustainable transport to meet their own climate goals. The number of companies approving emissions reduction targets in line with the Paris Agreement more than doubled every year between 2017 and 2021, with 96% adopting targets that cover supply-chain emissions.[2]

The need for action is clear.

Radical change is needed, and sustainable fuels are key.
Changes in vessel design, operation and power generation will be needed to comply with new regulations and to meet the growing demand for sustainable shipping. However, the biggest challenge and opportunity is fuel – the future sustainable fuels to power global shipping and the global actions necessary to scale their production and the infrastructure needed to replace fossil fuels.

Our latest analysis provides a picture of when each fuel type is likely to become available. LNG is well-placed to act as a transition fuel, followed by biofuels in the 2030s. 'Blue' fuels such as blue ammonia will then act as bridging fuels before green synthetic fuels become widely available at scale as the 'gold standard' in the late 2030s and early 2040s.

[1] Fourth IMO Greenhouse Gas Study 2020
[2] Driving decarbonization: Accelerating zero-emission freight transport

This analysis of the market was done to provide the most accurate picture of the future possible. However, nothing is certain and everything can change – something the last few years of supply chain disruptions, pandemics and global conflict have shown all too clearly.

The truth is, with the multitude of sustainable fuels to choose from, and costs in 2030 expected to be 3-5 times more than today's fossil-based fuels based on our modelling, shipping operators are understandably feeling overwhelmed and uncertain about when and how to decarbonise.

Adding to the uncertainty, none of this is happening in a vacuum. Shipping faces competition for low-carbon fuels from other sectors, including aviation, heavy transport and the chemicals industry, all of which are on their own course towards net zero.

Decisive policy, industry collaboration and individual action will be key for shipping to decarbonise

With such uncertainty, so many unanswered questions, and seemingly choppy waters ahead, the temptation can be to freeze. To wait. To delay action until a clearer path emerges, costs fall or technology advances. However, decarbonisation can only happen *with* action.

We have identified the key actions that policymakers, the collective shipping industry *and* individual shipping operators need to take *today* to scale availability of sustainable fuels, maintain a competitive advantage against other sectors, keep costs acceptable and guard against risk and uncertainty.

Policy is a major driver of change

Clear and stable signals of demand will be key in giving suppliers the confidence to invest in the necessary infrastructure and scale up production.

Clear, decisive policy that delivers certainty by setting an internationally agreed pathway for the phase-out of fossil fuels will therefore help to increase the availability of sustainable fuels; policy that **creates cost parity** with fossil fuels by adopting carbon pricing on marine fuels; and policy that **encourages collaboration** between governments on the innovation and infrastructure necessary to deliver sustainable fuels at scale, worldwide.

We have already seen how effective policy can be. For example, the EU introduced shipping into its Emissions Trading Scheme in January 2024. **Our modelling shows this, combined with FuelEU Maritime regulations, will double the cost of fossil fuels by 2030 and create cost parity between sustainable fuels and fossil fuels as early as 2035.**[3] At the same time, MEPC 80 has shown the importance of establishing an internationally agreed date for decarbonisation.

[3] **Based on fuel production cost estimate for 2035 (source: Maersk Mc-Kinney Møller Center for Zero Carbon Shipping – NavigaTE 2023).**

Collaboration is key

Industry collaboration will also be central to overcoming the barriers to sustainable fuels. **Pooling purchasing power** will help to minimise costs, facilitate industry-wide consensus on preferred fuels and outcompete other sectors in the race to secure limited supplies. **Sharing knowledge** with smaller operators – a significant portion of the global fleet – will support those that lack the dedicated innovation/sustainability teams required to plan for sustainable fuels.

At the same time, **collaboration with other sectors** can encourage fuel suppliers to optimise production methods to maximise the amount of fuel that is produced at grades suitable for each sector.

Change will happen, but only with urgent action

Individual operators – who can often feel powerless in the transition to sustainable fuels – have perhaps the most significant role to play. Protecting against the uncertainty of tomorrow and navigating decarbonisation with confidence requires just three qualities. **Efficiency. Flexibility. Responsibility.**

Efficiency because the first step to take, before even considering new fuels and engines, is simply to reduce how much fuel ships use. Every euro saved in fuel costs through efficiency measures at today's prices could be worth 2–5 times that by 2030, depending on the fuel used. That means a 5–10% efficiency gain (as achieved by Carnival Corporation's Service Power upgrade programme) could cut a company's fleetwide fuel costs by as much as $750 million per year in 2030.[4]

Flexibility because investing in fuel-flexible engines, fuel tanks and fuel handling systems that can operate on more than one fuel is the best tool for hedging against fast-changing legislation and global disruptions to fuel availability and cost. It also reduces the risk of stranded assets caused by potentially 'backing the wrong horse'.

Responsibility because with world-leading sustainable fuel engine experience – such as the container sector's dominance in methanol engines – shipping has a duty to apply its knowledge to upstream supply chains. By doing so, we can fast-forward the development of supporting infrastructure by years, boosting fuel availability, cutting costs and propagating confidence in those fuels right across the industry.

Policymakers, industry leaders and – importantly – shipping operators ultimately face just one simple choice. Act now and shape the future of sustainable fuels. Or delay and be shaped by it.

Marine technology, ship engines and other solutions from Wärtsilä are already helping lead the way to economical, resilient and low emission shipping. Get vessel-specific insights or the entire fleet point of view to define the best decarbonisation strategy for your business. View our portfolio of maritime solutions to discover how to navigate decarbonisation with confidence at wartsila.com/marine

[4] Carnival Corporation Upgrading Global Fleet with Fuel- and Energy-Saving Technology Annual fleetwide fuel costs savings estimated to be $150m due to efficiency measures. "2–5 times" figure assumes either a doubling of fossil fuel costs (if operating in the EU) or the adoption of future fuels (which are forecast to cost 3–5 times more than today's fuel by 2030). If 5 times more expensive, the $150m figure in 2030 would be $750m.

Executive summary

Shipping faces a number of conflicting challenges – it faces demands to increase capacity to support global economic growth, but as the source of 2% of all emissions, it is under intense pressure to decarbonise; and it must get to grips with the almost unfathomable pace of technological development.

The International Maritime Organization has mandated that the industry become net zero by mid-century. Solutions available today will enable significant progress towards this goal, but only to a certain point. To fully decarbonise requires the rapid scaling of sustainable fuels.

This report provides a roadmap for the future of sustainable fuels, identifying how the industry can more rapidly and affordably scale these fuels and achieve full decarbonisation by mid-century – within the lifetime of just a single vessel.

A roadmap to sustainable fuels

Our latest analysis of the market provides a picture of when each fuel type is likely to become available, while our modelling tool predicts their likely cost.

First we expect to see **biofuels**, produced from non-food or non-feed organic sources, with large growth predicted in the 2030s. This includes diesel-like biofuels, biomethanol and biomethane, but also bioethanol, which is already produced today in significant quantities, especially in Brazil and the US.

Next will be **'blue' fuels**, such as blue ammonia. Produced using fossil fuels, with CO_2 captured and stored, they are simpler to scale than synthetic fuels, and benefit from the upstream infrastructure of the oil and gas industry.

Green synthetic fuels will only arrive at significant volumes from the late 2030s. Produced from emissions-free 'green' hydrogen made using renewable electricity, they will likely be produced mostly in locations with high solar and wind resources.

By 2030, our modelling forecasts sustainable fuels will still cost 3–5 times more than today's fossil fuels. However, if strong regulation is introduced – similar to EU ETS and FuelEU Maritime in Europe – this cost gap could be much lower, and even create cost parity by 2035.

No one fuel is likely to dominate the market. Shipping needs a mix of fuels that can cater to different needs. Focus should be on co-ordinating action across policymakers, industry and individual operators to develop the production, infrastructure, supply chains and technology for a mix of sustainable fuels needs.

Every penny spent on preparing for sustainable fuels, every regulatory incentive, every new signal of increasing demand will stimulate supply and drive down costs. The future may seem uncertain, but it is in our hands.

How to accelerate the shift to sustainable fuels

Policy
Decisive and predictable policy measures are needed to switch to sustainable fuels. These measures will send a demand signal to industry, investors and operators, unlock the infrastructure and encourage innovation to bring down costs. Measures include carbon taxes and emission limits.

The IMO's MEPC 80 net zero target and the introduction of shipping into the EU's Emissions Trading Scheme have shown the way. MEPC has provided a timeline for decarbonisation, while FuelEU Maritime regulations and the EU ETS could create cost parity between fossil fuels and sustainable fuels in Europe by 2035.

To further accelerate progress, policymakers can:

1. **Deliver certainty:** Set and stand by a science-based pathway to phase out fossil fuels in line with IMO targets, to create a globally consistent timeline to plan investment decisions, and send clear demand signals to suppliers to accelerate sustainable fuel production.
2. **Boost cost competitiveness:** Adopt a global industry standard for marine fuel carbon pricing to encourage cost parity with fossil fuels and incentivise sustainable fuels.
3. **Collaborate:** Governments should collaborate on innovation and infrastructure to scale up sustainable fuels while avoiding regulatory arbitrage. Close work with international bodies such as the IMO should be promoted to set global standards.

Industry collaboration

Industry collaboration is fundamental to scaling sustainable fuels for shipping. The shipping industry and its partners should:

1. **Pool their buying power:** Sector-wide procurement agreements to pool demand from multiple shipping operators will reduce fuel prices, minimise supply chain costs, limit administrative burdens for individual operators, send clear demand signals to producers and maximise shipping's share of limited supplies in a competitive market.
2. **Collaborate with other sectors:** Convene with leaders in aviation, heavy transport and industry to establish a global framework for sustainable fuels. This will tell producers what fuel composition each sector requires and could optimise fuel production in each production pathway.
3. **Share skills:** Establish an industry knowledge hub to share expertise, skills and insights. This will help smaller operators (a significant segment of the global fleet) to access the resources required to plan for sustainable fuels.

Individual operators

For individual operators, the future can seem unclear and overwhelming. However, operators can prepare for the future by focusing on efficiency, investing in fuel flexibility and applying their sustainability expertise upstream to maximise fuel availability.

Scaling of sustainable fuels can only happen when policy, industry and individual actors combine to demonstrate clear and forecastable demand. Once that is achieved – and only then – supply will follow, and we can navigate decarbonisation with confidence. We have the lifecycle of just a single ship to get this right. Together, we can do it.

2%

Maritime transport's share of global GHG emissions

45%

Potential increase in CO_2 emissions without abatement steps

Roadmap to sustainable fuels

New global regulations have set a clear destination for shipping – net zero emissions by mid-century. The shipping industry must now seek to navigate decarbonisation with confidence. Efficiency measures can get us part way, but sustainable fuels will be essential to fully decarbonise shipping. Wärtsilä Marine's latest market analysis and unique modelling shows a timeline of which fuels to expect, when, and at what cost. However, these are forecasts only and it is clear that the cost and availability of sustainable fuels tomorrow will be shaped by our actions today: the future is in our hands.

We cannot fully decarbonise shipping without alternative fuels

As the most cost-effective way to move large volumes of goods over long distances, maritime transport has long been the backbone of international trade. But in spite of its efficiency, it also has significant environmental impacts, accounting for 2% of global greenhouse gas (GHG) emissions – if the shipping industry were a country, it would be the world's sixth-largest greenhouse gas emitter.

Most ship engines burn either heavy marine fuel oil or marine gas oil (MGO), which produces not only carbon dioxide (CO_2) but also other pollutants. Moreover, it is difficult to eliminate greenhouse gas emissions through full electrification because many ships must consume large amounts of energy over long distances without the opportunity to refuel.

A 2020 IMO study projected that the sector's CO_2 emissions could increase by more than 45% by 2050 without abatement steps.[5] If we are to reach net zero by 2050, shipping must invest around $5 trillion in newbuilding and equipment upgrades for renewal of the global fleet.[6]

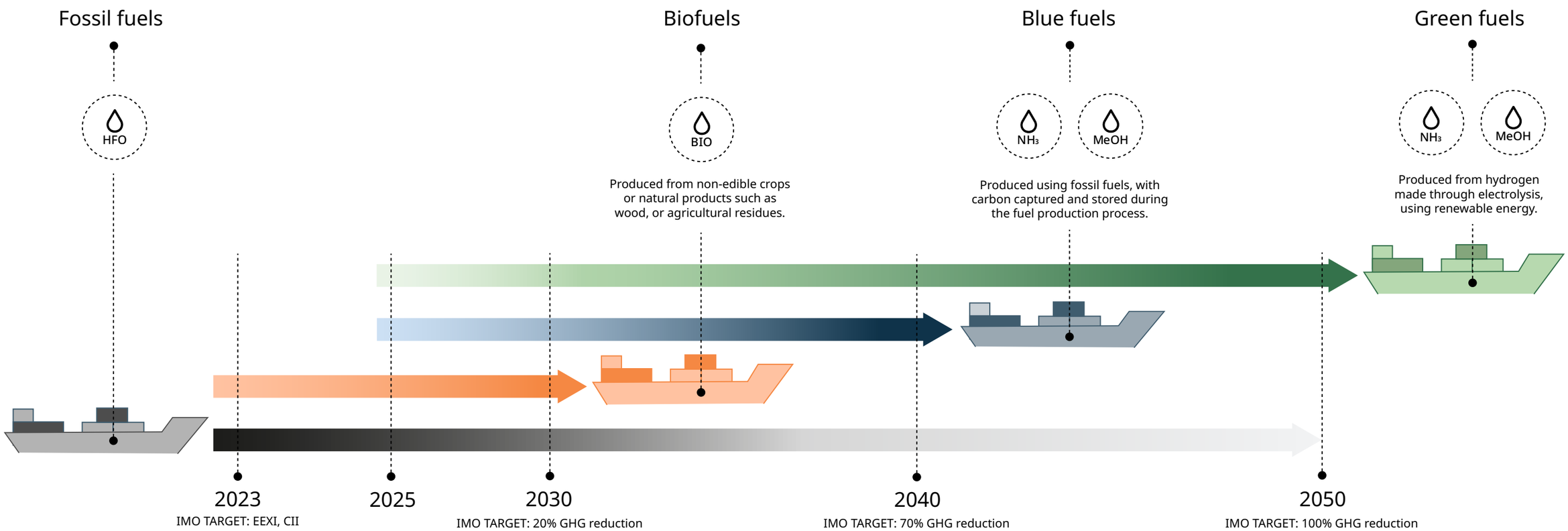
Cutting vessel speeds by 30% and implementing all available energy efficiency measures could reduce the sector's energy demand by 15–27%.[7] That's a good start, but shipping cannot fully decarbonise without sustainable fuels.

[5] https://www.imo.org/en/ourwork/Environment/Pages/Fourth-IMO-Greenhouse-Gas-Study-2020.aspx

[6] Clarksons: total newbuilding and equipment upgrades investment for fleet renewal in 2023–2050

[7] Ricardo: Update on the IMO Future Fuels & Technology Project (FFT Project)

Sustainable fuels roadmap to 2050



Targets based on latest MEPC80 regulation (referring to Well-to-Wake emissions)

HFO: Heavy fuel oil. NH3: Ammonia. MeOH: Methanol

- **Biofuels:** Produced from non-edible crops or natural products such as wood, or agricultural residues – biofuels are the first fuels to be available, with large growth predicted in the 2030s. This includes diesel-like biofuels, biomethanol and biomethane, but also bioethanol, which is already produced in significant quantities, especially in Brazil, the US and the EU. For these fuels to be sustainable they must use sustainable biomass feedstocks such as waste fats, oils and greases, which do not reduce food security and land availability.

  Example: Green methanol has emerged as an early leader. Methanol engines are a proven technology and ships can run on biomethanol and renewable e-methanol using currently available technology, while the fuel cuts emissions significantly compared to fossil fuels. This makes these advanced fuels a good short-term option that can make an immediate impact.

- **Blue fuels:** Next will be 'transition fuels' such as 'blue' ammonia due to simpler scalability than green zero-carbon fuels. These are produced using fossil fuels, with carbon captured and stored during the fuel production process. They are simpler to scale than synthetic fuels and will be backed by the infrastructure and resources of the oil and gas industry.

- **Green fuels:** Our market analysis indicates green synthetic fuels will become more widely available towards the late 2030s or early 2040s. These are produced from hydrogen made through electrolysis using renewable electricity, so they are likely to be produced mostly in locations with high potential and space for solar and wind.

  Example: Green ammonia is zero-carbon when produced from renewable sources, with no CO_2 emitted during production. However, there are safety issues to address before its use at scale due to its corrosive and toxic nature.

The cost of the transition

Up to 2030, fuel costs will double due to emission fees

The cost of emissions will close the price gap between fossil and sustainable fuels

By 2030, Wärtsilä's modelling forecasts that sustainable fuels are likely to cost 3–5 times more than today's fossil fuels, which are €400-€700/ton MGO equivalent today.

Synthetic fuels – made from either electrolysis or chemical processes powered by renewable energy – are likely to cost 3–5 times as much as fossil fuel counterparts in 2030, narrowing to 2–3 times as much in 2050, although they may reach cost parity with biofuels by then. Vessels that can run on alternative fuels are also typically more costly than the current standard. The OECD estimates that a new LNG-powered ship is around 10–20% more costly than a conventional ship. Dual-fuel vessels that can run on both methanol and conventional low sulphur fuel cost around 10–15% more, as do ammonia dual-fuel vessels. Much of the existing, conventionally fuelled fleet could be retrofitted to ammonia or methanol dual-fuel use at a similar cost to a dual-fuel newbuild, says UNCTAD.[8]

Comparing future sustainable fuel costs with today's fuel prices is a good way to assess the growing value of efficiency measures. However, it is important to keep in mind that new regulations that increase the cost of fossil fuels significantly are already coming into force.

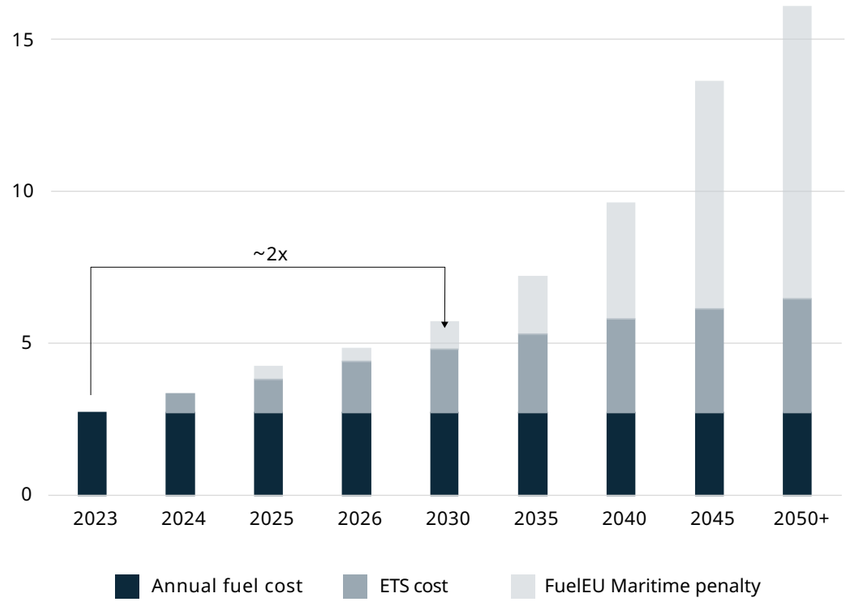
Policy can create future price parity between fossil fuels and sustainable fuels. This can be seen in Europe where cost parity will be achieved in 2035 thanks to the introduction of shipping into the EU ETS and FuelEU Maritime regulations, which increase the cost of fossil fuels for shipping annually.[9] Couple this with the impact of efficiency measures and greater investment in sustainable fuel supply chains and the cost equations will rapidly change.

[8] United Nations Conference on Trade and Development Review of Maritime Transport 2023

[9] Based on fuel production cost estimate for 2035 (source: Maersk Mc-Kinney Møller Center for Zero Carbon Shipping – NavigaTE 2023).

Up to 2030, fuel cost will double due to emission fees

Fuel-related costs for Handymax bulker operating in EU waters, EURm[1)]



1) Assuming 5 000 tons/year VLSFO (Very Low Sulphur Fuel Oil) consumption subject to EU Fit for 55, VLSFO at EUR 550/ton; EU allowances from EUR 100/ton in 2024 to EUR 230/ton in 2050 (source: Transport & Environment NGO).

Cost of emissions will close the price gap between fossil and sustainable fuels

Fuel type	Low Sulphur Fuel Oil	Liquified Natural Gas	Methanol	Ammonia	Liquid Hydrogen	Compressed Hydrogen	Marine Battery Rack
Fuel price factor (per GJ)[1)]	1x	1.1x – 4.6x[2)]	2.6x – 5.5x[3)]	2.4x – 4.3x[4)]	3.6x – 4.6x[4)]	2.1x – 3.1x[4)]	2.0x – 5.3x[8)]
Fuel price factor in 2035, incl. carbon tax[1) 5)]	1x	0.8x – 1.4[2)]	0.8x – 1.6x[3)]	0.7x –1.2x[4)]	1.2x – 1.5x[4)]	0.6x – 1.0x[4)]	0.8x – 2.0x[6)]

1) Fuel production cost estimate for 2025 and 2035; source: Maersk Mc-Kinney Møller Center for Zero Carbon Shipping – NavigaTE 2023.

2) Price range spans between fossil & electro-methane.

3) Price range spans between bio- & electro-methanol.

4) Price range spans between blue- & electro-ammonia/hydrogen.

5) Assuming 100% consumption subject to EU Fit for 55, EU allowances at EUR 159/ton (source: Transport & Environment NGO).

6) Shore energy price EUR 10–27/kWh.

Shipping needs a mix of fuels to cater to different requirements

To fully decarbonise by 2050, the industry will need around 270 million tons of the heavy fuel oil equivalent of alternative fuels.[10] As well as scaling supply of the fuels, the industry will also need to invest in fuel infrastructure. In total, if we are to reach net zero by 2050, shipping must invest around $5 trillion in newbuilding and equipment upgrades for renewal of the global fleet,[11] with DNV saying that $8 billion to $28 billion a year must be spent on ships and between $28 billion and $90 billion a year to scale up production, fuel distribution and bunkering infrastructure to supply the totality of carbon-neutral fuels by 2050.[12]

Which fuel will win?

It can be tempting to try and predict which fuel will dominate the industry. But "which fuel will win?" is the wrong question to ask. Shipping doesn't need a winner – it needs a mix of fuels to cater to the different requirements of the whole industry. The key to delivering this is co-ordinated action across policymakers, industry and individual operators to bring about the broad system change we need to mature the production, infrastructure, supply chains and technology required for a mix of sustainable fuels.

Shipping can learn from the transition to clean energy in the global power sector, where policy, industry and individual actors worked together to scale new solutions. Just one example. As recently as 2014, The Economist described solar PV as "the most expensive way to reduce carbon emissions".[13] Only six years later, the IEA acknowledged it as offering "the cheapest electricity in history". Change can happen – and fast.

Every penny spent on preparing for sustainable fuels, every regulatory incentive introduced, every new signal of increasing demand will stimulate supply and drive down costs.

The future may seem uncertain, but it is in our hands to shape.

[10] https://unctad.org/system/files/official-document/rmt2023_en.pdf

[11] Clarksons: total newbuilding and equipment upgrades investment for fleet renewal in 2023–2050

[12] https://www.dnv.com/expert-story/maritime-impact/Enhanced-modelling-of-maritimes-future-fuel-mix.html#:~:text=Decarbonization%20by%202050%20would%20need,neutral%20fuels%20by%20mid%2Dcentury.

[13] https://theconversation.com/an-energy-revolution-is-possible-but-only-if-leaders-get-imaginative-about-how-to-fund-it-172427#:~:text=Solar%20power%20%E2%80%93%20described%20as%20%E2%80%9Cthe,the%20cheapest%20electricity%20in%20history.

After many years of slow progress, shipping now has a clear strategy to cut emissions in place

How to accelerate the shift to sustainable fuels

With decisive policy, industry-wide collaboration and action from individual operators, shipping can navigate decarbonisation with confidence. Decisive policy will make sustainable fuels more cost competitive and send clear demand signals to help scale up production; industry collaboration will propagate skills and expertise; while individual operators can transform uncertainty and risk into competitive advantage and lower operational costs by investing in efficiency and fuel flexibility.

Policy is a major driver of change

To transition to sustainable fuels, strong policies such as carbon taxes and emission limits should be implemented to send a demand signal to industry, investors and operators. This will unlock the required infrastructure to bring down costs.

Due to its international nature, policy on shipping tends to be decided in the UN's International Maritime Organization (IMO). Despite positive efforts by the IMO, it can be difficult to reach agreement among its 175 members and meetings to ratify key decisions can come years after the decisions were made. As a result, the industry has found it more challenging than other sectors to decarbonise.

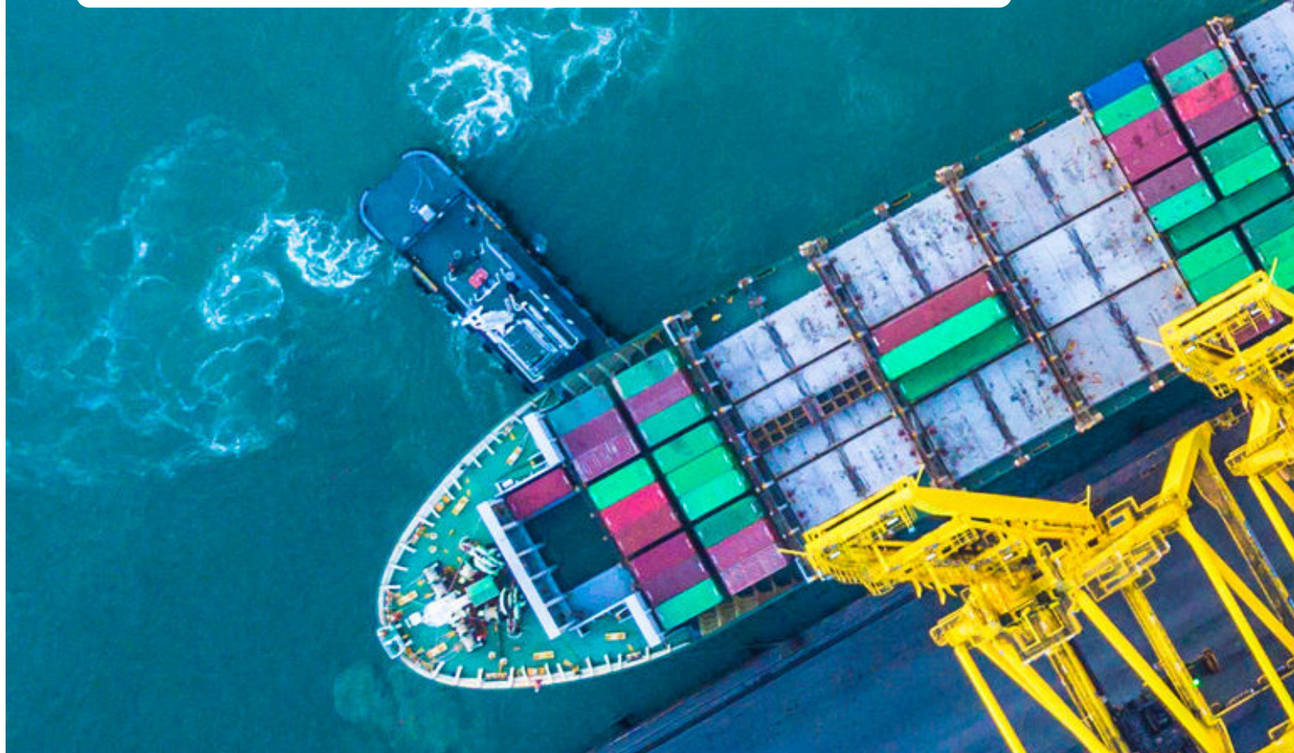
However, after many years of slow progress, shipping now has a clear strategy to cut emissions in place.

MEPC 80

The 80th session of the IMO's Marine Environment Protection Committee (MEPC 80) adopted a revised GHG Strategy to cut emissions from international shipping.[14] The industry must reduce emissions by 20% by 2030 from 2008 levels and by 70% by 2040, on the way to achieving net-zero emissions by, or around, 2050. New regulations to help meet these targets are expected to enter into force around mid-2027. A decision on whether to use market-based measures such as carbon pricing mechanisms is due in 2024.

MEPC 80 "represents a significant acceleration in the reduction of emissions compared to the strategy agreed only 5 years ago", says Lloyd's Register,[15] bringing the sector much closer to alignment with the Paris target of keeping global temperature increases within 1.5 degrees Celsius of pre-industrial levels.

Whereas the industry has broadly accepted new IMO ambition levels, the implementation effectiveness is still sparking mixed reactions. Currently, the IMO's Carbon Intensity Indicator (CII) merely grades ships from A to E. While ships that receive a D for three consecutive years or an E in any year must draft a plan of corrective actions, there are no requirements for what must be included in these plans, and environmental certificates are never revoked, no matter how many times the ship fails. The CII will be revised by January 2026, and is likely to get more stringent both in terms of thresholds (in line with net-zero targets) and the consequences of non-compliance. A basket of other measures is also expected, including a goal-based marine fuel standard to reduce marine fuel's GHG intensity, and a maritime GHG emissions pricing mechanism.



[14] https://www.imo.org/en/MediaCentre/MeetingSummaries/Pages/MEPC-80.aspx#:~:text=The%20revised%20IMO%20GHG%20Strategy,Read%20full%20details%20here.

[15] https://www.lr.org/en/knowledge/regulatory-updates/mepc-80-protect-future-fleets/#:~:text=With%20the%20adoption%20of%20a,agreed%20only%205%20years%20ago.

Policymakers must send clear demand signals and set industry-wide standards.

Shipping's efforts to decarbonise suffer from a 'chicken-and-egg' challenge. It is hard for operators to pick a fuel when it is only being produced in relatively small quantities and another technology may scale faster and cheaper. Meanwhile, fuel producers are reluctant to ramp up production without being sure the demand is there to deliver a return on their investment. Ship owners, fuel producers and all the other stakeholders related to the associated infrastructure of any new fuel are 'frozen' by this lack of certainty.

When policies deliver increased ambition, maximise certainty and stability and are implemented in the short term, production of sustainable fuels will follow,[16] breaking the 'chicken-and-egg' cycle.

Policymakers should aim to set an internationally agreed pathway to phase out fossil fuels from the maritime sector

While not a direct comparison due to different technical challenges, solar and wind technologies have progressed rapidly, becoming the cheapest and most cost competitive forms of new electricity generation within just one decade.[17] Wind has become an important and cost-effective source, increasing from under 1% to 10–15% of electricity supplies in Brazil and the EU respectively.[18] This was driven by clear policies that enabled large-scale development and deployment, leading to significant cost reductions through innovation and economies of scale.

To deliver certainty, policymakers should aim to set an internationally agreed pathway to phase out fossil fuels from the maritime sector. This would send clear demand signals to fuel producers to scale production more rapidly in line with industry targets, and provide shipping operators with a globally consistent timeline to plan investment decisions.

Policymakers can also use carbon pricing to accelerate the transition towards cost parity between fossil-based fuels and sustainable fuels. We are already seeing how this could work in Europe, where Wärtsilä modelling predicts cost parity could be achieved as early as 2035.

EU Emissions Trading Scheme

The EU plans to fully integrate marine transportation into the EU Emissions Trading Scheme (EU ETS) by 2026,[19] with 100% of CO_2 emissions from voyages between European ports included and 50% of emissions to and from ports outside the EU included. Methane and nitrous oxide emissions will also be included from 2026. Subjecting these emissions to the EU's carbon price should incentivise more efficient operation, a cut in emissions and the production of low carbon fuels.

Based on public EU MRV data the total emissions subject to EU ETS in 2022 was about 90.4 million tons. Assuming these remain at the same level and a EUA price of €90 per ton of CO_2 in 2024 and €100 per ton in 2026, this could cost shipping €3.3 billion in 2024, rising to €9 billion in 2026. Accordingly, at an EUA price of €90, ship operators can save about €270 for every ton of fuel saved (as 1 ton of marine fuel oil emits roughly 3 tons of CO_2).

In addition, from 2025, FuelEU Maritime will increase demand for renewable and low-carbon fuels in the fuel mix of international maritime transport in the EU.[20]

FuelEU Maritime sets GHG emission intensity requirements on ships trading in the EU from 2025 and mandates the use of shore power for container and cruise ships in certain EU ports from 2030. Over time, FuelEU Maritime is expected to have an ever larger impact than EU ETS (see the graph 'Fuel-related costs for Handymax bulker operating in EU waters, EURm' on page 17.)

[16] Ricardo - Update on the IMO Future Fuels & Technology Project (FFT Project)

[17] EEIST - THE NEW ECONOMICS OF INNOVATION AND TRANSITION: EVALUATING OPPORTUNITIES AND RISKS

[18] EEIST - THE NEW ECONOMICS OF INNOVATION AND TRANSITION: EVALUATING OPPORTUNITIES AND RISKS

[19] https://climate.ec.europa.eu/eu-action/transport/reducing-emissions-shipping-sector_en

[20] https://www.consilium.europa.eu/en/press/press-releases/2023/07/25/fueleu-maritime-initiative-council-adopts-new-law-to-decarbonise-the-maritime-sector/

Key steps for policy makers to scale sustainable fuels

1. **Deliver certainty and stability: Set an internationally agreed science-based pathway for phasing out fossil fuels from the marine sector, in line with IMO targets.**

   Why? To provide operators with a globally consistent timeline to plan investment decisions and send clear demand signals to suppliers to accelerate sustainable fuel production.

2. **Boost cost competitiveness: Adopt a global industry standard for marine fuel carbon pricing and reinvest any CO_2 tax revenue back into shipping to foster innovation.**

   Why? Over time, this will create cost parity with fossil fuels and incentivise the development and deployment of sustainable fuel solutions.

3. **Collaborate: Increase global collaboration between governments on the innovation and infrastructure necessary to deliver sustainable fuels at scale worldwide.** For example, through participation in the global Mission Innovation Zero-Emission Shipping Mission,[21] or working closely with the IMO to set global standards and measures.

   Why? To create a level playing field that avoids regulatory arbitrage.

[21] https://mission-innovation.net/missions/shipping/

The sector must collaborate with stakeholders from inside and outside shipping

Industry collaboration

No single ship operator can create enough demand alone to scale sustainable fuels, but together, the industry can move global markets.

Shipping operators need to work together to drive industry-wide consensus on the need for low-carbon options. But even then, shipping cannot decarbonise on its own. The entire ecosystem must be involved, from carriers, port and terminal operators, manufacturers and shippers to investors, energy producers and distributors.

To succeed in its goals, the sector must collaborate with stakeholders from inside and outside shipping. Smaller operators, many of which lack the resources and incentives to invest in sustainable fuels, make up a significant proportion of the shipping industry, but the owners and operators of larger fleets have the resources and expertise to invest in future fuel supply chains.

However, there is an opportunity to share resources to scale sustainable fuels right across the industry, not just in small, isolated pockets. Some smaller carriers, many of them ferries and coastal carriers, are making progress in areas such as electrification but the wider sector risks lagging behind if plans are not made to explicitly include them in the decarbonisation journey.

Wärtsilä is involved in a number of initiatives that are helping to speed the industry's transition, including:

ZEEDS
Wärtsilä is one of the core partners in the ZEEDS initiative, which envisions making zero-emission fuels available to the shipping industry. The work in the ZEEDS initiative is organised into four themes:

- Conversion of vessel to green ammonia propulsion
- Green ammonia bunkering vessel
- Offshore HUB production unit for hydrogen/ammonia
- Green ammonia onshore supply chain.

SeaTech
SeaTech[22] is an EU-funded project where Wärtsilä Finland leads the development of an advanced dual-fuel engine. The project aims to develop two symbiotic ship engine and propulsion innovations that will deliver 30% better fuel efficiency and radical emission reductions.

ZES
ZES - Zero Emission Services offers a new energy system to make inland shipping more sustainable: a product and services package for emission-free sailing based on exchangeable battery containers with green electricity, charging stations, technical support and an innovative payment concept for barge owners. Wärtsilä is one of the ZES shareholders.

Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping
Wärtsilä is Mission Ambassador at the Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping and worked as a project partner in the NoGAPS project. The goal was to develop a Nordic-based concept for an ammonia-powered gas carrier vessel that would both transport ammonia as cargo and utilise ammonia as a zero-emission fuel.

Green Ray
Green Ray, co-funded by the European Union, is a project to minimise methane slip from LNG vessels and reduce the environmental impact of maritime transport. Its objective is to develop three technologies to install on LNG engines of both existing and new ships.

ShipFC
The ShipFC project, co-funded by the European Union, aims to install the world's first ammonia-powered fuel cell onboard a converted offshore vessel. Wärtsilä will develop and deliver all electronic equipment, all control equipment, and systems for storing and distributing ammonia on board.

Zero Emission Marine
Zero Emission Marine (ZEM), co-funded by the European Union, is a four-year ecosystem project led by Wärtsilä. The project aims to create an economically compelling zero-emission marine ecosystem driving sustainable technology solutions and services. Its goal is to reach 60% greenhouse gas (GHG) reduction in the maritime sector by 2030.

[22] This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 857840.

The shipping sector must come together to build demand for sustainable fuels.

Shipping will face competition for these sustainable fuels from other sectors such as aviation (which is dominated by a smaller number of big players), industry and long-distance trucking, which all need to undertake their own decarbonisation journeys.[23] Not only will this limit the availability of the fuels for shipping, it could also keep costs higher for a long time.

The shipping industry has an opportunity to act quickly, collectively and proactively to establish itself as a leader, setting up infrastructure and supply chains, and using cleaner fuels in significant quantities.

Collaboration with other sectors will boost supplies for all

The relationship with other sectors need not be competitive and adversarial. There is a common need for low-carbon fuels, so different sectors should work together to build supplies and supply chains, while exploring opportunities to collaborate and leverage any synergies.

For example, aviation requires the highest grade fuel available. Shipping has much more leeway to accept lower grades of fuel while still decarbonising. So, with the right guidelines, producers may be able to make both grades of fuel simultaneously in the same production cycle.

This benefits both sectors and creates a stronger demand signal, giving suppliers the confidence to invest knowing demand from both shipping and aviation will be strong.

Key steps for industry to collaborate on sustainable fuels

1. **Pool buying power: Establish sector-wide procurement agreements to pool demand from multiple shipping operators.**

   Why? Buying in bulk will enable lower fuel prices, minimise supply chain costs, limit administrative burdens for individual operators, facilitate consensus on preferred fuels and send clear demand signals to producers, and maximise shipping's share of limited supplies.

2. **Collaborate with other sectors: Convene with leaders in aviation, heavy transport, and industry, through their equivalents of the IMO (such as the International Civil Aviation Organization) to establish a globally recognised framework for the production and allocation of sustainable fuels.**

   Why? Such a framework sends a clear message to producers on what fuel grade each sector requires, and it could optimise fuel production in each production cycle, boosting profits for producers and availability for all sectors in international markets.

3. **Share skills: Establish an industry-wide knowledge hub to share expertise, skills and insights.** This can best be achieved through industry-wide collaboration via existing global maritime bodies, such as the IMO or the Getting To Zero Coalition, aimed at getting commercially viable deep sea zero-emission vessels powered by zero-emission fuels into operation by 2030.

   Why? This will support smaller operators (which comprise a significant proportion of the global fleet) that lack the resources for dedicated innovation/sustainability teams to access the resources required to plan for sustainable fuels.

[23] https://unctad.org/system/files/official-document/rmt2023_en.pdf

Every euro saved at today's prices could be worth 3–5 times that by 2030

Individual operators

This report uses modelling to provide the most accurate picture of the future possible. However, nothing is certain and everything can change – something the last few years of supply chain disruptions, pandemics and global conflict have shown all too clearly. Individual operators can act today to minimise this uncertainty and navigate decarbonisation with confidence. This means Efficiency – minimising the amount of fuel used; Flexibility – investing in fuel-flexible engines and fuel tanks to hedge against fast-changing legislation and global disruptions to fuel availability; and Responsibility – pooling knowledge and expertise to advance upstream supply chains.

All operators can benefit from improving the efficiency of their vessels, which can immediately cut emissions and operating costs while also protecting against the long-term cost of transitioning to sustainable fuels.

"Short-term actions that improve the operational efficiency of existing vessels – saving fuel, money, and time through changes in ship speed and performance – can play a critical role in reducing emissions today, while also preparing for a more manageable long-term transition which will involve more expensive zero-emission fuels and eventually a price on carbon," says the Global Maritime Forum.[24]

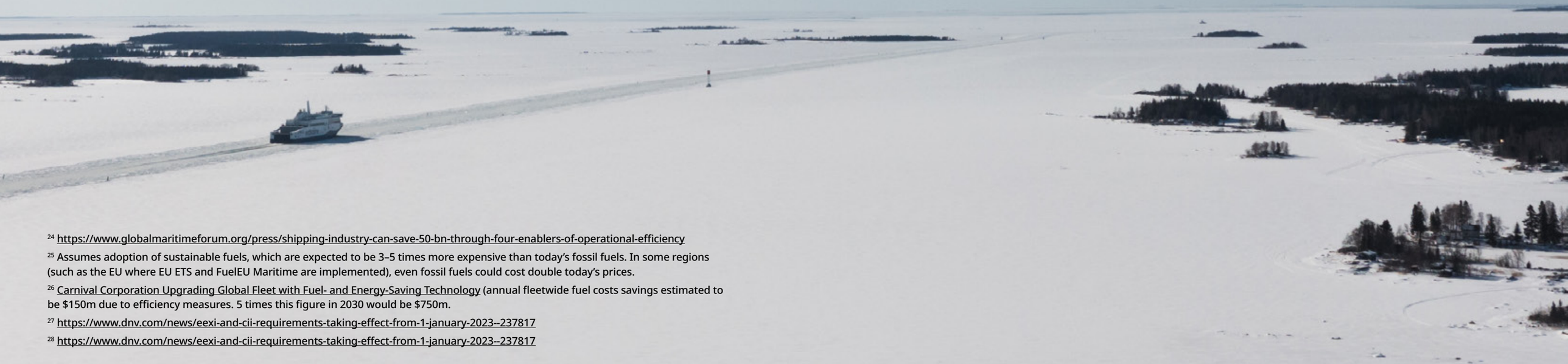
Maximising vessel and fleet performance through operational efficiency can reduce annual fuel costs by $50 billion at today's prices, saving up to 20% of fuel costs and more than 200 million tonnes of CO_2. Every euro saved at today's prices could be worth 3–5 times that by 2030.[25] That means a 5–10% efficiency gain – as achieved by Carnival Corporation's Service Power upgrade programme – could cut a company's fleetwide fuel costs by as much as $750 million per year in 2030.[26]

These savings will be increased if measures are combined with energy-efficient technologies. These include improving propulsion efficiency and using sails, kites or rotors to harness the power of the wind. Weather routing – using weather forecasts to steer a ship away from bad weather or benefit from favourable currents or wind directions – can lead to large savings, for example.

Efficiency has become even more important following the launch of the IMO's Carbon Intensity Indicator (CII) rating scheme. From 1 January 2023, owners and operators of vessels above 5,000 GWT must submit a rating annually, demonstrating the efficiency of their vessels. The rating is directly determined by fuel consumption, based on the amount of CO_2 emitted per cargo-carrying capacity and nautical miles travelled.[27]

A poor CII rating will reduce the commercial value of a vessel and its ability to win contracts, while the ship will also have higher fuel costs than its higher-rated rivals. A good CII rating, by contrast, makes it easier to maintain competitive vessel speeds and makes the ship more efficient.

At the same time, a new Energy Efficiency Existing Ship Index (EEXI) regulation stipulates the minimum level of energy efficiency that ships already in operation should provide, while its sister rule, the Energy Efficiency Design Index (EEDI), applies to newly built vessels.[28]



[24] https://www.globalmaritimeforum.org/press/shipping-industry-can-save-50-bn-through-four-enablers-of-operational-efficiency

[25] Assumes adoption of sustainable fuels, which are expected to be 3–5 times more expensive than today's fossil fuels. In some regions (such as the EU where EU ETS and FuelEU Maritime are implemented), even fossil fuels could cost double today's prices.

[26] Carnival Corporation Upgrading Global Fleet with Fuel- and Energy-Saving Technology (annual fleetwide fuel costs savings estimated to be $150m due to efficiency measures. 5 times this figure in 2030 would be $750m.

[27] https://www.dnv.com/news/eexi-and-cii-requirements-taking-effect-from-1-january-2023--237817

[28] https://www.dnv.com/news/eexi-and-cii-requirements-taking-effect-from-1-january-2023--237817

Data is becoming increasingly valuable to optimise operations

Wärtsilä Marine has deployed multiple energy saving technologies to cut fuel consumption, which when combined can deliver efficiency gains of over 20%.

There are clear steps that shipping operators can take today to cut emissions and save money:

Reduce the power needed for propulsion: There are several ways to reduce power requirements. For example, power derating can save fuel and emissions by tuning the engine's power to suit current operating profiles.

In 2022, a pilot installation onboard a container ship demonstrated that a vessel could save 2,000 tonnes of fuel and 6,000 tonnes of CO_2 emissions annually with the Wärtsilä Fit4Power radical derating solution.

Keep the ship hull clean: Some basic housekeeping on the hull can have a huge impact on a ship's efficiency and greenhouse gas emissions. Regular hull cleaning to remove biofouling – the build-up of micro-organisms, plants, algae or small animals – reduces the frictional resistance of the hull.

A report by GloFouling Partnerships estimates that a layer of slime as thin as 0.5 mm covering up to 50% of a hull surface could increase GHG emissions by as much as 25–30%.[29]

Leverage data to optimise port operations, engines and vessel route planning: As ships and shipping become more digitalised and connected, data is becoming increasingly valuable to optimise operations. A fleet optimisation solution (FOS) helps connect the digital dots between navigational data, operational processes and fuel efficiency, reducing environmental impact.

After rolling out Wärtsilä's FOS system in 2022, Carisbrooke Shipping reported a saving of over 600 tons of CO_2 in under a year, and an average fuel saving of 5–7% over a two-year period.[30]

Not only can these measures cut operating costs, they can also give operators a competitive advantage in a market that increasingly puts a premium on more sustainable products and services. A Boston Consulting Group (BCG) survey of 125 companies that ship cargo found that 82% of shipping customers were willing to pay a premium for zero-carbon shipping.[31]

[29] https://www.glofouling.imo.org/_files/ugd/34a7be_afd9d183df9a4526bd088007436c1079.pdf?index=true#:~:text=For%20example%2C%20a%20layer%20of,speed%20and%20other%20prevailing%20conditions.

[30] https://www.wartsila.com/media/news/15-11-2022-carisbrooke-shipping-significantly-reduces-co2-emissions-with-wartsila-s-fleet-optimisation-solution-3270465

[31] https://www.bcg.com/publications/2022/customers-willingness-to-pay-to-decarbonize-shipping

Efficiency measures are ‘no-regrets’ options that reduce operational costs, but it is sustainable fuels that will enable us to reach full decarbonisation.

Investing in the ‘wrong’ technology has the potential to create stranded assets at a later date if another, more competitive solution or fuel becomes dominant.

For companies looking to plot a course towards decarbonisation with the lowest risk, it is important to retain flexibility in the future choice of fuel. With limited supplies of alternative fuels currently available, many ship operators are seeking to invest in engines and fuel tank systems that can use sustainable fuels as well as fossil fuels with a view to running them on traditional fuels until they are required to switch.

Wärtsilä Marine’s industry-leading fuel flexibility technology

AMMONIA: In November 2023, Wärtsilä Marine launched the world’s first 4-stroke ammonia engine. Immediately cutting GHG emissions by more than 70%, this new engine will help ship operators address growing decarbonisation pressures from businesses, consumers and policymakers. As one of the leading alternative fuel options, the launch of this engine marked a major milestone in the transition to a clean shipping future.

METHANOL: Launched in 2022, the Wärtsilä 32 Methanol engine and Wärtsilä MethanolPac storage and supply system were the first commercially available solutions for using methanol as a maritime fuel. December 2023 saw the addition of another four methanol engines to the portfolio. Each of these engines is capable of delivering significant CO_2 emissions savings when compared to conventional LFO. They also drastically reduce NOx, SOx, and particulate emissions.

Key steps for individual operators to take

1. **Focus on efficiency: Map each vessel's capacity to deploy efficiency measures to reduce fuel consumption and emissions rapidly.**

   Why? This is the simplest move operators can make today to hit emissions targets. It could deliver *all* the 20% emissions reduction required by the IMO by 2030. It also protects against future fuel cost rises – for example, a 5–10% efficiency gain – as achieved by Carnival Corporation's Service Power upgrade programme – could cut a company's fleetwide fuel costs by as much as $750 million per year in 2030.[32]

2. **Invest in fuel flexibility: Protect against uncertainty by investing in fuel-flexible engines that can run on more than one fuel or be converted later.** When considering which engines to adopt, smaller operators should consider aligning strategies with major players and/or use fuels that are commoditized locally.

   Why? Multi-fuel capability is the best way to hedge against upcoming legislation, global disruptions in fuel availability and cost, and avoid stranded assets.

3. **Think 'upstream':** Apply world-leading future fuel expertise to supply-side challenges and commit to equal resourcing for on-vessel upgrades and upstream supply chains. For example, the container sector can apply its world-leading methanol engine experience to the supply chain to maximise fuel availability.

   Why? To maximise fuel availability and protect against stranded assets as well as give wider industry confidence in supply.

[32] Carnival Corporation Upgrading Global Fleet with Fuel- and Energy-Saving Technology (annual fleetwide fuel costs savings estimated to be $150m due to efficiency measures. 5 times this figure (i.e. the highest estimated costs of future fuels in 2030) would be $750m.

Together, we can make the transition a success

Sustainable fuels are coming – the IMO's new MEPC 80 regulations set the timeline for the shipping industry to fully decarbonise, and there is a clear imperative to start as soon as possible. Operators can achieve some quick wins by implementing energy efficiency measures, but these will not be enough to meet the sector's long-term targets.

The industry will need to start using sustainable fuels, fast. However, the mix of fuels, cost of deployment and operation, and the success of shipping at scaling infrastructure and utilisation will be determined by the actions taken by shipping stakeholders today.

When we look at other sectors, such as energy, where once-new technologies have transformed from "the most expensive way to reduce carbon emissions" to "the cheapest electricity in history" in less than a decade, it's clear that the industry can rapidly accelerate new energy sources at scale and drive massive cost reductions in a short space of time.

This can only happen when policy, industry and individual actors come together to create clear and forecastable demand. Once this is achieved – and only then – supply will follow, and we can navigate decarbonisation with confidence.

We have the lifespan of just a single ship to get this right.
But together, we can make it happen.

Work with Wärtsilä to navigate decarbonisation with confidence

Wärtsilä Marine is a global leader in power, propulsion and lifecycle solutions for the marine market. From end-to-end digital ecosystem planning to sustainable fuels development, Wärtsilä Marine is driving the shipping industry forward on its journey towards a decarbonised and sustainable future.

Its broad portfolio of engines, digital technologies, propulsion systems, hybrid technology and integrated powertrain systems delivers the efficiency, reliability, safety and environmental performance needed to support our customers.

Wärtsilä Marine offers real-time insights into operations, performance and energy use, performance-based agreements, lifecycle solutions and an unrivalled global network of maritime expertise. Find out more at: www.wartsila.com/marine

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Work with Wärtsilä to navigate decarbonisation with confidence.

Build your success on Wärtsilä's broad portfolio of engines, propulsion systems, hybrid technology, exhaust treatment, shaft line solutions and digital technologies, as well as integrated powertrain systems. These building blocks offer you efficiency, reliability, safety and world-class environmental performance.

The offering includes performance-based agreements, lifecycle solutions and an unrivalled global network of maritime expertise.

www.wartsila.com/marine

Wärtsilä is a global leader in innovative technologies and lifecycle solutions for the marine and energy markets. We emphasise innovation in sustainable technology and services to help our customers continuously improve their environmental and economic performance.