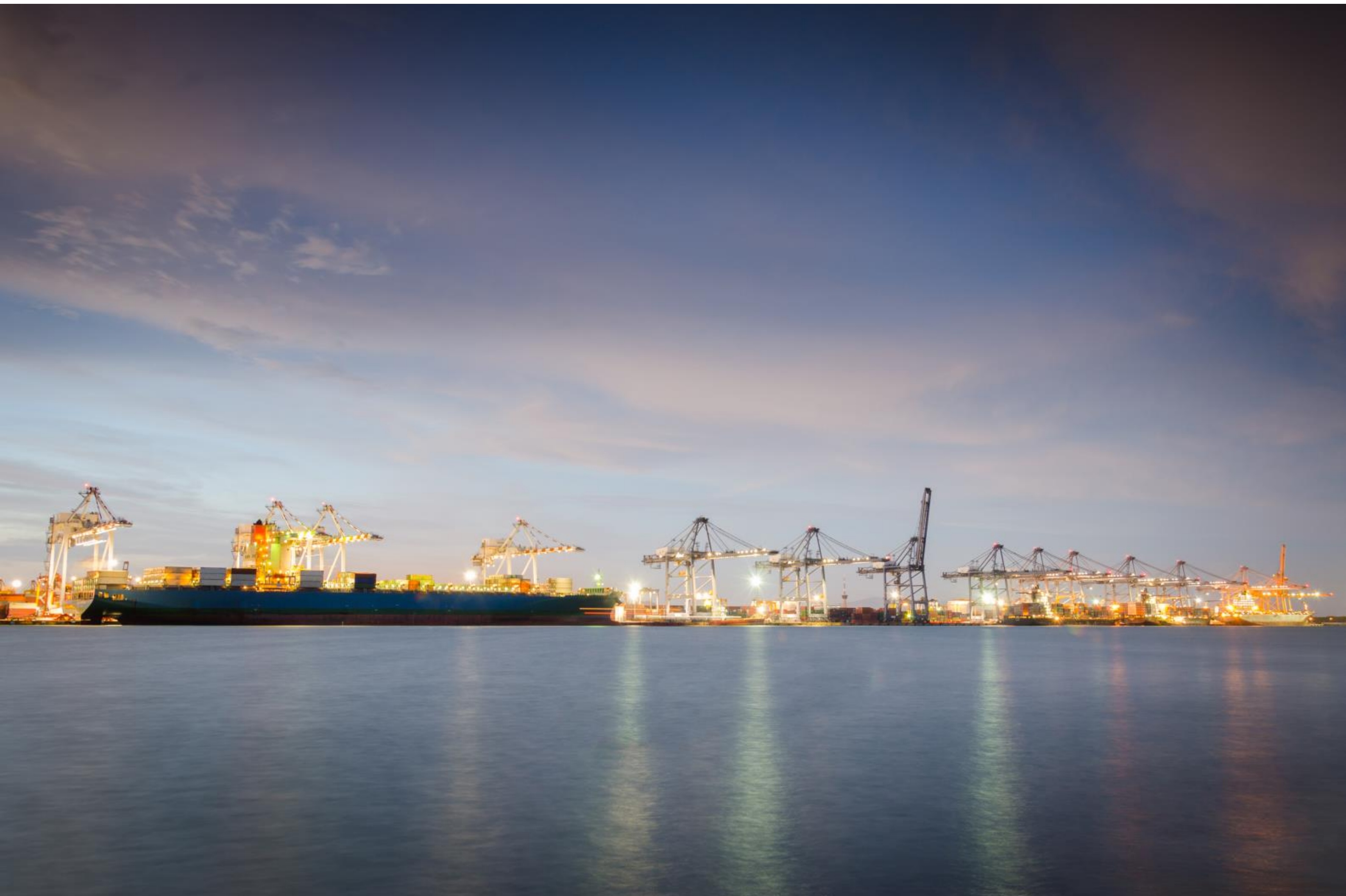
Harnessing the EU ETS to reduce international shipping emissions

Assessing the effectiveness of the proposed policy inclusion of shipping in the EU ETS to reduce international shipping emissions



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Preface

This report has been written by a team of experts from UMAS for the Environmental Defense Fund Europe with input on EU policy from Panos Spiliotis at Environmental Defense Fund Europe. The views expressed are those of the authors, not necessarily of the client.

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UMAS delivers consultancy services and undertakes research for a wide range of clients in the public and private sectors using models of the shipping system, shipping big data, and qualitative and social science analysis of the policy and commercial structure of the shipping system. UMAS's work is underpinned by state-of-the-art data supported by rigorous models and research practices, which makes UMAS world-leading on three key areas; using big data to understand drivers of shipping emissions, using models to explore shipping's transition to a zero emissions future and providing interpretation to key decision makers. For more information visit: www.u-mas.co.uk

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Contents

1 Executive summary

1.1 Introduction

The shipping sector's 1,076 million tonnes of GHG, which accounts for almost 3% of global anthropogenic emissions is on an increasing trajectory. To stay in line with the Paris Agreement's goals, total emissions need to peak within the decade to avoid much steeper subsequent cuts. The IMO has not made sufficient progress on global measures to reduce emissions in shipping. Despite agreeing on an Initial GHG Strategy to reduce emissions by at least 50% by 2050, peak emissions as soon as possible, and pursue pathways of GHG emission reductions consistent with the Paris Agreement temperature goals, the IMO has not enacted sufficient measures that will allow it to meet even its lowest ambition level. There is an urgency to implement measures able to bring shipping emissions onto a declining trajectory as soon as possible. As shipping is a long-life asset sector with an average life of a ship of around 25-30 years and dependent on fossil-fuel for propulsion, the creation of zero emissions marine fuel infrastructure and design of ships to accommodate these zero emissions fuels needs to be expedited.

To put shipping on a course to meet the IMO's Initial GHG Strategy, zero emissions vessels must be entering service by 2030, while owners of fossil-fuel ships operating during the 2020s need to consider mitigating the climate risk of a transition to a low carbon economy by maximising the energy efficiency of their vessels and switching to zero emissions fuels in the 2030s (Lloyds Register and UMAS, 2019) to avoid locking in fossil-fuel assets which need to be written off balance sheets ('stranded assets').

The EU Commission's proposal to include shipping in the EU ETS, which would cover maritime carbon emissions from intra-European Economic Area (EEA) voyages and half of the emissions from extra-EEA voyages[1] (the "Extra50" scope), is part of a wider policy package that besides maritime ETS includes a 'Fuel EU' standard[2] for the GHG intensity of shipping fuel. While there is a growing recognition that a combination of multiple climate policy instruments may be needed for shipping's transition to zero carbon fuels (Grubb, 2014; Mazzucato, 2018; IMO, 2021), the focus in this study is to assess some of the economic impacts most pertinent for understanding the potential for the EU ETS to reduce international emissions and stimulate investment in Scalable Zero Emissions Fuels[3] (SZEF). In light of the economic and climate impacts and the proposed policy design, it assesses the policy against the IPCC's effective decarbonisation policy criteria and discusses the elements needed to contribute to the decarbonisation of global shipping outside of the EU. The impact of other EU policies and potential future non-EU regional carbon policy scenarios are not considered in this report.

1.2 Key findings

1.2.1 Shipping needs a high carbon price this decade if it is to decarbonise by 2050

Emissions reductions can be achieved through a combination of energy efficiency technologies and zero emissions fuel use. To create a smooth transition in the 2020s which avoids carbon lock-in[4] and stranded assets in the future, policies should be created this decade to maximise uptake of energy

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[1] Voyages coming into, and out of, the EU from non-EEA ports) as well as emissions occurring at berth in an EEA port.

[2] The Fuel EU proposal will regulate the GHG intensity of fuel used by ships through maximum limits by year in relation to the fleet average in 2020.

[3] Scalable Zero Emission Fuels (SZEF) are a subset of fuels with the potential to have zero emissions (on a lifecycle basis) and that have scalable production processes capable of competitively supplying expected future demand, the scale of which is estimated to be around 2-300 million tonnes of HFO/LSFO equivalent energy per annum (Smith et al., 2021).

[4] Carbon lock-in can be defined as a path-dependent process, whereby initial conditions, increasing economic returns to scale, and social and individual dynamics act to inhibit innovation and competitiveness of low-carbon alternatives (Seto et al., 2016)

efficiency technology, stimulate early adoption of SZEF and prepare the industry for rapid scaling and roll-out of SZEF over the subsequent decade (UNEP, 2020; Smith et al., 2021).

Empirical evidence and modelling suggest that both operational and technological improvements are currently not taken up in the international shipping fleets to the extent that would be rational if the fuel savings that can be realised are efficiently passed back to the ship owner and operator (ISWG 8/3/3, 2021). This evidence indicates the existence of market failures and barriers and the need for policies that price carbon at a high enough level of around $120/tonne-carbon (2018 prices) to stimulate uptake of these improvements or require a command-and-control regulation such as a carbon intensity standard based on marginal abatement cost curve analysis[5] (Smith et al., 2019).

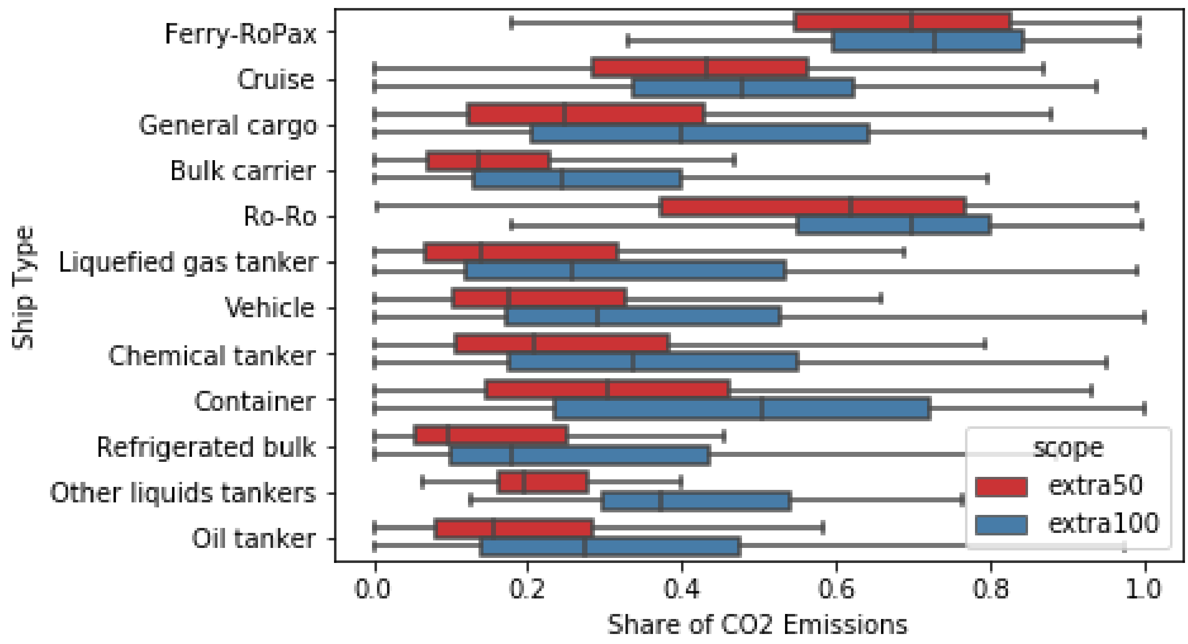
Ultimately, decarbonisation cannot occur without a transition away from fossil fuels (UNEP, 2020; Smith et al., 2021). To meet even the IMO's minimum GHG reduction requirements, a market for SZEFs and zero-ready ships must be created. As the Closing the Gap report (Baresic et al., 2021) (forthcoming) discusses, there exists a competitiveness gap between incumbent fossil fuels and zero emission alternatives. Zero-emission fuels will require the development of new land-based bunkering infrastructure, additional R&D, production scale-up, a fall in renewable electricity prices, development of new regulatory safety measures and ship designs, amongst other factors (Lloyd's Register & UMAS, 2019). This means that the creation of a zero-emissions fuel market is linked to the evolution of the global energy system which needs to grow its renewable energy capacity and continue to drive down the price of renewable electricity.

To achieve this transition, a significant amount of investment is needed; projected estimates suggest that between $1-1.4 trillion will be needed to meet the minimum IMO ambition (-50% by 2050) or $1.4-1.9 trillion to fully decarbonise by 2050, where the majority of funds need to be directed to land-based infrastructure (Raucci et al. 2020). The Closing the Gap report showed that in order to achieve the lowest ambition of the IMO's Initial GHG Strategy – i.e., reduce ships' GHG emissions by 50% by 2050 compared to 2008 - an average carbon price of US$173/tonne CO2 would be needed starting in the 2020s. To fully decarbonise shipping by 2050, the average carbon price would only need to be slightly higher: around US$191/tonne CO2 (Baresic et al., 2021).[6] This price is broadly consistent with the cost-effectiveness from the MACC analysis, which ranges between $150-$272 (2018 prices).

1.2.2 The choice of ETS scope is consequential, as the portion of carbon emissions in scope can vary significantly by ship types

Matching carbon emissions estimates derived from the Fourth IMO GHG Study to the EU MRV carbon emissions data using the unique IMO number per ship enabled a comprehensive picture of the carbon emissions coverage of the EU ETS scope as a share of its total annual emissions. This showed that the majority of EEA-related emissions (e.g., voyages with an EEA port) come from ships which spend a significant proportion of their time on non-EEA related voyages. For example, bulk carriers, the highest emitting ship type representing over 50% of EU MRV emissions, have under 20% of their emissions in the Extra50 scope as a percentage of annual emissions on average, and under 30% of emissions when considering full MRV scope. This is shown in Figure ES-1, which displays the distribution of CO2 emissions covered by the Extra50 and Extra100 scopes and as a share of total annual CO2 emissions by ship type. Each box represents the interquartile range with the median drawn as the line in the box.

[5] Based on a MACC for the UK international shipping fleet, representative of the ship types in the global international shipping fleet.
[6] Both scenarios assume no revenue is recycled from the carbon price in the form of subsidies to the sector.



ES-1: Extra50 and Extra100 emissions as a share of total annual CO2 emissions

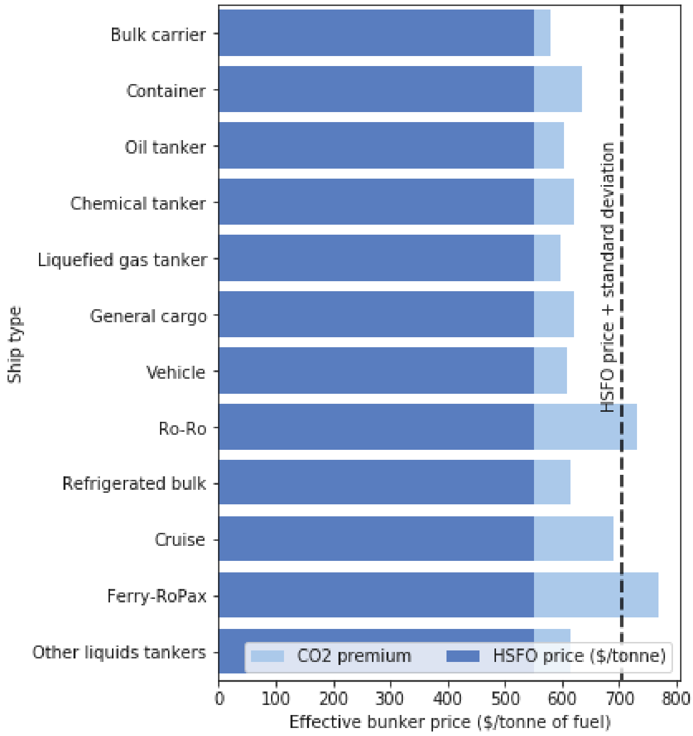
1.2.3 The effective carbon price experienced for globally trading ships is small relative to the historical variability in bunker price and the carbon price needed to incentivise investments in zero emissions fuels, even under full MRV coverage

The results of the analysis indicate that although some progress will be made to reduce GHG emissions regionally and internationally (e.g., mainly through operational efficiency), when the annual trading pattern of ships that trade with the EEA is taken into account (as shown above), the average "effective global carbon price" reduces significantly.

For example, under a $103/tonne-CO2 price scenario in 2030, the average effective global price reduces to $22/tonne-CO2 or about 20% of the ETS price level because the majority of EEA-related emissions come from ships which spend a relatively short period of time on EEA-related voyages during the year. This translates into a $69/tonne bunker price premium when considered as a weighted average across all ship types. When compared to a business-as-usual environment (defined as a fuel price that is within the standard deviation of the historical bunker price of $154 over 2008-2020), only ships which primarily trade within the EU (e.g., Ferry-RoPax and Ro-Ros) have an effective bunker price that exceeds the standard deviation of High-Sulphur Fuel Oil (HSFO) prices.

The effective global carbon price would only marginally increase from an average of $22/tonne-CO2 to $32/tonne-CO2 if the EU ETS increased its geographical scope from Extra50 to full scope (Extra100). Therefore, there is not a material impact on emissions, although the impact on slow steaming would increase under a full scope scenario. The marginal increase is due to the weight placed on ship types that trade with non-EEA ports which have a lower share of EEA-related trade.

Surveys and empirical evidence have shown that implementation of improvements with potential to reduce fuel consumption and emissions has remained low under a business-as-usual environment. Therefore, at this overall carbon price level, there is not a strong business case for additional investments in abatement technology (e.g., energy efficiency technologies or SZEFs) and therefore there would be no material impact on emissions beyond speed reduction on EEA voyages.



ES-2: Effective global bunker price (2030, $550/tonne of bunker fuel, $103/tonne of carbon)

1.2.4 Whilst environmentally and cost-effective in near term, when abatement is considered across all sectors in the ETS, the low effective global carbon price may contribute to carbon lock-in of LNG assets

A policy which focuses on reducing pollution at lowest cost across all sectors included in the EU ETS can be environmentally and cost-effective in the near term. However, because shipping's untapped energy efficiency technology and zero emission solutions require a higher carbon price than the EU ETS is expected to provide[7] (ETC, 2018), the ETS can only stimulate the lowest cost operational efficiency opportunities. On its own, the EU ETS is unlikely to stimulate the longer run investment the sector needs in technology and SZEF, until the slack in the rest of the economy's lower hanging fruit abatement has been realised. Given the long timescales needed for shipping's transition to SZEF, this may be too late.

Furthermore, the low effective carbon price could incentivise the uptake of LNG-propelled ships. The ETS' exemption of methane emissions, exacerbates the preferential treatment of LNG-propelled ships, which emit methane but have lower carbon emissions relative to HSFO ships and therefore are only marginally better at best than HSFO ships. This would create resistance to transition to SZEF because of the sunk investment costs in LNG assets. The uptake of LNG-propelled ships has several unintended consequences for both the environmental and cost-effectiveness of the policy over the time period required to decarbonise shipping:

- Environmental effectiveness risk due to carbon lock-in of marginal improvement solutions which then creates resistance to for shipping to contribute to the EU's aimed-for 2030 reduction timescale and to fulfil IMO's 2050 Initial Strategy; and
- Cost-effectiveness risk because the transition is much more expensive. Outlaying capital on LNG assets which then get stranded increases the cost significantly relative to a policy that is

[7] Sectors with relatively higher abatement costs than the rest of the economy. These include heavy industry sectors (cement, steel, chemicals) and heavy duty transport (heavy-duty road transport, shipping, aviation).

designed to have a much greater ability to stimulate early adoption of long-run solutions that avoid a marginal/incremental solution phase.

1.2.5 A significant amount of revenue will be raised from the ETS with Shipping as almost all abatement will come from out of sector allowance purchases. This creates an opportunity to stimulate early adoption of SZEF which should lead to a more cost-effective transition

The potential revenue generated from including maritime shipping in the EU ETS is shown in Figure 17: Maritime contribution to ETS revenueFigure ES-3 for the ETS carbon price scenarios. Assuming a $103/tonne carbon price (87 euros) by 2030 and an emissions baseline of 2018 (i.e., no reductions), the total revenue generated from shipping would be 9 billion in the Extra50 scope and 14 billion in the full MRV scope (Extra100). At current prices of about 50 euros (about $60/tonne), revenue from the Extra50 scope would be $5 billion in 2030. Compared to a required investment of about $1.4 trillion to at least meet 50% minimum reduction, this would contribute 0.6-1% of global investment if the revenues were re-invested back into the sector.

There is a range of speed reductions of that could occur as a result of higher effective bunker prices. Based on a literature review and case study analysis, a $100/tonne carbon price is likely to reduce speed in the range of 2-10% and 3-17% for emissions. Assuming linearity, a $22/tonne carbon price would lead to a <1-4% reduction in emissions and therefore almost all abatement will come from out of sector.[8]

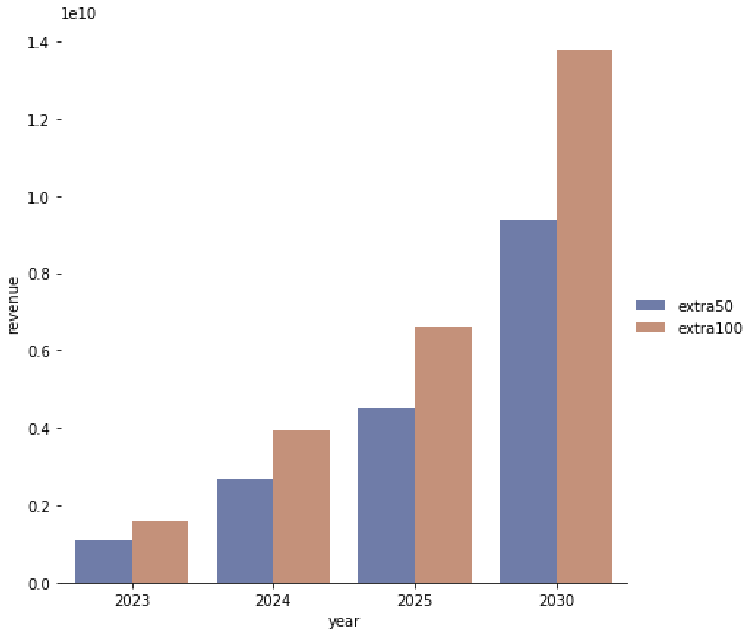


Figure ES-3: Maritime contribution to ETS revenue (all out of sector abatement)

Although the EU directs revenue raised from the ETS to an Innovation Fund for low carbon innovation projects, the current proposal does not ensure that adequate funds will be directed to shipping to stimulate R&D and scale-up production for zero carbon fuels in shipping through supply-side policies (e.g., tax credits, subsidies, loans, grants). Especially given the low ability of the EU ETS' effective

[8] The analysis has not considered the impact of more efficient ships from fleet turnover by 2030 and impact on lower transport demand due to increases in prices.

carbon price to a make a strong business case for SZEF investment this decade, supply-side policies are important for supporting a cost-effective and efficient transition in the short timescale needed to ensure zero emissions vessels are entering service by 2030.

Equally, with its current revenue and funding structure, the revenues generated, in part, relate to trade with non-EU countries but are collected in an EU-centric fund, which raises an issue around the capacity of the ETS to support fair, inclusive and equitable transition.

1.2.6 The inclusion of shipping in the EU ETS leverages an established carbon policy measure which could feasibly lead to further emissions reductions via indirectly pressuring the IMO for expedited action. Simultaneously, in a global context, the regulation's international reach raises issues around its distributional effects.

The move to include the shipping sector in the ETS is a positive push to ensure that a portion of the shipping industry is subject to a carbon price and MBM this decade which is a key time period for the decarbonisation of shipping. While global regulatory progress from the IMO has been slow, the Fit for 55 package, as a whole, should ensure the EU meets its emissions reductions starting this decade.

The ETS could itself lead to deeper emissions reductions in shipping if its policy design were better adapted to shipping's abatement profile. The EU cites heterogeneity in the abatement costs of different industries as justification for a stand-alone ETS for road transport and buildings (European Commission 2021a), while related considerations were behind the creation of special aviation ETS allowances. Setting up a similar system for shipping could place future limitations on out-of-sector abatement and accelerate emissions reductions.

Furthermore, this move may indirectly pressure the IMO for expedited action to develop and implement a global measure (Urrutia, Graichen & Herold, 2021). In general, the international shipping industry have been vocal on their preference for a global-level regulation as it maintains a level playing field and reduces administrative burdens (ICS & INTERTANKO. 2021). The analysis in this study treats non-MRV emissions as not subject to a carbon price, however major EU partners such as China and the US could also feasibly impose a carbon tax on the next few years. Such a development could also boost the carbon price felt by global shipping, as well as pave the way to a global IMO policy.

From a more global perspective, there has been criticism that this proposal is an extra-territorial tax on trade, constituting diplomatic overreach and could affect the trading costs between EU and non-EU trading partners (Thompson, 2021). Shipping is a global industry and therefore benefits from global regulatory mechanisms capable of decarbonising the industry while supporting Small Island Developing States (SIDS) and Least Developed Countries (LDCs), avoiding or addressing disproportionately negative impacts on States and ultimately stimulating an equitable transition. By generating revenues from global trade servicing the EU and recycling revenues within the EU, shipping's inclusion in the EU ETS risks increasing existing inequalities between the EU and the rest of the world especially the Global South. If revenues are not deployed to assist the decarbonisation of international shipping more generally as suggested in Section 1.2.5, but instead go to other purposes within the EU, this risk increases further. This is important to the perception of the EU and its ability to help the IMO reach a consensus on a global policy. The negative perception risk is further heightened if the EU member states do not support policy at the IMO that generates revenue or limits uses of revenue to in-sector purposes – e.g., if this remains in contradiction to the design of shipping's inclusion in EU ETS.

1.2.7 Conclusion

In conclusion, a regional carbon pricing policy such as the ETS with Shipping could be useful in helping at least a subset of international shipping, as well as for EU domestic shipping, to progress its required transition. But EU policy, and in this report's focus, EU ETS, needs to have its design improved to better achieve the required outcomes (maximise energy efficiency and stimulate the uptake of SZEFs). These design elements include a high enough effective carbon price for stimulating SZEF deployment this decade or a strong supply-side policy that recycles an adequate amount of the ETS revenue raised from shipping carbon allowances back into the sector to create a SZEF market. Without these design features (and in the absence of other global or regional GHG and carbon pricing policies in the first half of this decade), it will be left to national governments to create the infrastructure needed to kickstart the international SZEF market. A further justification for recycling significant portions of revenue use to in-sector uses is that this can improve the way the EU ETS is perceived outside of the EU.

2 Policy context

2.1 The need for decarbonisation policy in shipping

The shipping industry contributes significantly to global GHG emissions, accounting for around 2-3% of global CO2 emissions (Faber et al. 2020) and making the industry the 6th highest emitter if it was compared to countries (Olivier, Janssens Maenhout, Muntean, & Peters, 2016). Furthermore, shipping is widely seen as a hard-to-abate sector due to the energy density required to operate ships (Cho, 2021, IEA 2020). The IMO has, in 2018, adopted an Initial GHG Strategy which set a minimum target of reducing emissions by at least 50% by 2050 compared to the 2008 baseline year while generally pursuing the reduction of GHG emissions as a matter of urgency and consistent with the Paris Agreement temperature goal (IMO 2018). Despite this, emissions are projected to be between 90-130% of 2008 emissions by 2050 for a range of plausible long-term economic and energy scenarios (Faber et al. 2020). In order to meet the ambition consistent with the Paris Agreement, the industry will urgently need to decarbonise and begin emissions reductions in the 2020s, taking advantage of energy efficient technology in the short term and rapidly moving to SZEFs in the mid-to-long term.

To contextualise the inclusion of the shipping sector in the EU ETS, it is useful to consider the global policy landscape. Market-Based Measures (MBM) were part of IMO discussions from 2006 to 2013 (IMO, 2019a), during which time there were a number of proposals for economic instruments submitted, including suggestions of an ETS for shipping (60/4/12, 60/4/22, 60/4/26, 60/4/41). However, the discussion of MBMs for international shipping was paused in 2013 (IMO, 2019a). In lieu of pursuing MBMs, the IMO instead adopted the Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP), both of which then entered into force in 2013. Thereafter, the IMO adopted a Data Collection System (IMO DCS) for fuel oil consumption of ships, which entered into force in 2018 (ibid.). As part of the Initial IMO GHG Strategy, mentioned above, the IMO has set out a timeline for consideration of different policies. The Strategy offers a non-exhaustive list of short-, mid- and long-term policy measures, i.e., measures that could be finalised between 2018 and 2023, between 2023 and 2030, and beyond 2030, respectively (IMO 2018). The short-term measures focus primarily on energy efficiency improvements and in June 2021, MEPC 76 adopted regulations which will apply technical efficiency standards to existing ships (Energy Efficiency Existing Ship Index, EEXI) (IMO 2021b). Ships will also need to achieve a specified annual operational Carbon Intensity Indicator (CII) (ibid.). Discussions on mid-term measures will begin imminently with MBMs listed as a candidate measure for discussion. However, at present, the lack of regulation from the IMO with the stringency to make a material difference to GHG emissions in shipping has created somewhat of a regulatory void into which the EU has stepped.

A series of operational and technical interventions, including energy efficiency technology retrofits and slow steaming, can offer necessary reductions in carbon intensity and total emissions within this decade (Faber et al., 2020). If transport demand continues to grow as expected, then in the 2030s and 2040s the only way to ensure deeper emissions reductions is through a fuel switch to zero emissions fuels.

Recent work has highlighted the competitive disparity between fossil and zero emission fuels and the need for policy intervention to close this gap (Baresic et al., 2021). Fossil fuels are well established in this sector, with a global infrastructure designed for their production and use, a mature and stable market demand and negligible R&D requirements. Although ammonia and hydrogen are seen as the most viable SZEFs (Englert et al., 2020), there is still uncertainty, albeit decreasing uncertainty, around how the costs, efficiency, and environmental performance of these fuels will evolve. Therefore, it would be premature to conclude which one, and whether one, or several, will dominate the marine fuel landscape (Smith et al., 2019). In all cases, SZEFs still require significant support to enable investment, and benefit from more support for research, development and particularly deployment (RD&D).

SZEFs have both OPEX and CAPEX expenses. The figure below shows a renewable ammonia project specific to shipping. It describes the process to make ammonia, which is produced by creating hydrogen. The process of generating zero-carbon hydrogen requires renewable electricity and an electrolysis plant. Hence reducing the costs of ammonia and hydrogen would come from a reduction in electricity costs and electrolysis technology. The reduction in renewable electricity would be enabled by the wider energy transition (and deployment) of renewable electricity, while a reduction in the technology would be enabled by in-sector deployment.

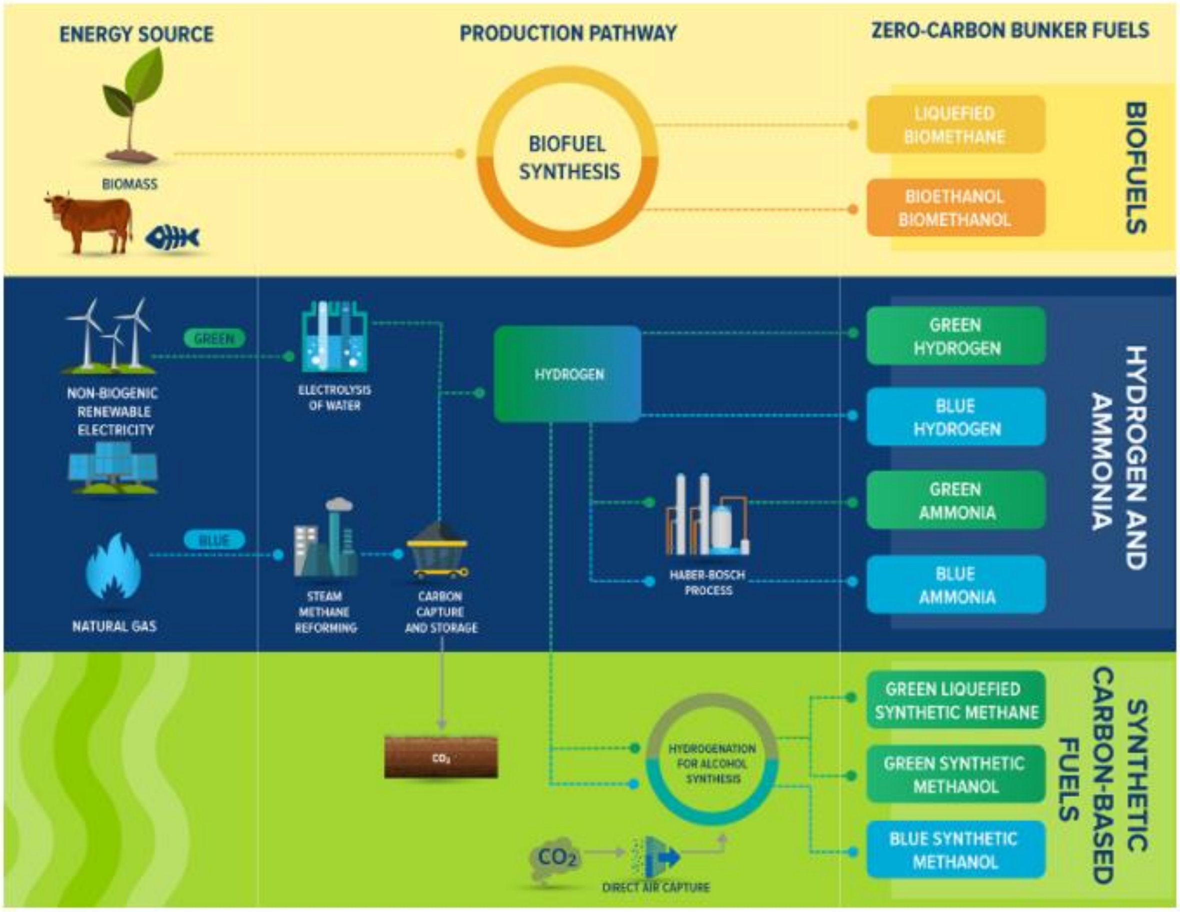


Figure 1: Zero and low-carbon bunker fuel options for shipping

Shipping is a long-life asset sector, dependent on a vast infrastructure to operate. As the average life of a ship is around 25-30 years before scrapping/recycling, there is an urgency to design ships to accommodate SZEFs as soon as possible. This means that significant investments are needed in terms of both finance and time for the transition (Grynzspan, 2021). Future investment will be required to create the infrastructure needed to provide zero-emission fuels to the shipping industry. Projected estimates suggest that between $1-1.4 trillion will be needed to meet the minimum IMO ambition (-50% by 2050) or $1.4-1.9 trillion to fully decarbonise by 2050 with 87% of this needed for land-based infrastructure in both cases (Raucci et al. 2020). Additionally, SZEFs must be promoted to foster their uptake which requires perception shifts, crew education and training and national capacity development.

The need for further decarbonisation policy in shipping is clear. In the absence of stringent global policy, the inclusion of shipping in the EU ETS represents a significant regional push towards decarbonising shipping and an application of an MBM to the shipping sector. The next section will introduce the recent development of the extension of the EU ETS to cover the shipping sector.

2.2 The EU's proposal to include shipping in the EU ETS

The EU's Emissions Trading System ("**ETS**"), is the Union's flagship cap-and-trade mechanism that has been in operation since 2005 to promote the reduction of certain greenhouse gases across the EU 27 countries, plus Iceland, Norway and Liechtenstein. The original ETS Directive 2003/87/EC applied to power generation and heavy industry, whereas an extension to intra-EU international aviation took place in 2012. The UK's exit from the EU has meant that UK emissions are no longer covered in the ETS.

As a cap-and-trade system, ETS has an overall emissions cap that applies to all sectors in the system. It is this 'hard cap' that ensures that across the ETS sectors, emissions decline at a linear rate consistent with the EU's climate targets. This is achieved in practice by reducing the number of allowances available to businesses each year. These allowances are known as European Union Allowances, or EUAs, and offer the holder the right to emit GHG equivalent to the global warming potential of 1 tonne of CO_2 equivalent (tCO2e). The gradual reduction, known as the 'linear reduction factor' allows companies to slowly adjust to meeting the increasingly ambitious overall target for emissions reductions. In the current phase 4 of the ETS (2021-2030) the cap is decreasing annually at a reduction factor of 2.2%.

Each year, a proportion of the allowances are given to certain participants for free, in sectors such as manufacturing and aviation, considered vulnerable to carbon leakage. The rest are sold, mostly through auctions. At the end of a year, participants must surrender an allowance for every tonne of CO2e they emit during that year. If a participant has insufficient allowances, they must either take measures to reduce their emissions or buy more allowances on the market.

The ETS includes additional design features that address potential imbalances in the supply and demand of allowances, when those arise. Through the Market Stability Reserve (MSR) that began operating in 2019, a significant portion of allowances can be transferred to the reserve by the regulator rather than be allocated. This happens when a surplus of allowances in the system risks undermining the ETS's price and investment signal, and MSR is expected to play a key role in the functioning of ETS over the next decade (Osorio B., et al 2021).

At the sectoral level, aviation, road transport, and buildings are all considered by the EU as subject to different reduction potentials and demand factors from the main stationary installations. As a result, aviation has dedicated allowances, whereas the 2021 Commission proposal put forward a "separate but adjacent" ETS system for road transport and buildings.

The proposed revision of the EU's Emissions Trading System (ETS)[9] forms part of a wider emissions reduction package known as 'Fit for 55', which aims to help European economies transition to the increased level of ambition for 2030 (55% net emissions reductions relative to 1990 levels). Like the package's other measures, the ETS revision is based on the principle that all economic sectors and policies will need to contribute to climate action.

[9]European Commission (2021a)

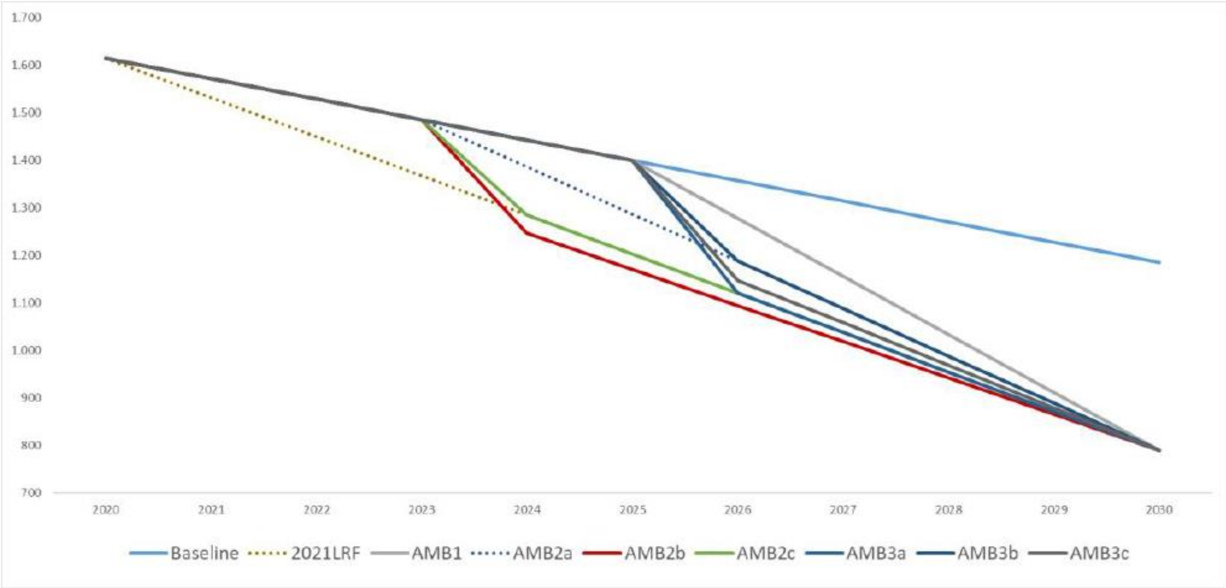


Figure 2: More ambitious ETS cap under different options[10]

This increased emissions ambition translates into a more aggressive emissions reduction from a 43% emissions reduction by 2030 to 61% (relative to a 2005 base), consistent with the headline EU target of a 55% reduction by 2030 (relative to 1990). This will mean reducing the total number of allowances issued by bringing down the overall number of allowances by 4.2% annually (up from 2.2%). The modified cap should apply from the current 2021-2025 period, even though it will not be implemented in practice before 2024. Once in effect, a steeper reduction rate as well as a one-off downward adjustment ('rebasing') may be required as a correction, as illustrated in Figure 1. It will also include an extension of the system to sectors that were previously not covered, including road transport, buildings, and maritime transport.

The annual reductions apply to the total emissions under the system, including maritime, but there would be no hard cap on individual sectors. Cost-efficiency across the ETS system would first prioritise reductions in other sectors where abatement is more cost-efficient, in the absence of corrective measures. Such measures could include auctioning shipping allowances following the aviation ETS model. This approach could offer more regulatory options that promote in-sector abatement, for example by requiring that general EUA allowances do not exceed a certain part of total allowances surrendered by shipping. Such systems have been described as a 'semi-open' system permitting the trade of allowances between sectors with some restrictions.

Under the maritime ETS proposal, the system would now cover carbon emissions from intra-EU voyages and half of the emissions from extra-EU voyages (voyages coming into, and out of, the EU from non-EU ports) as well as emissions occurring at berth in an EU port. This system is to be linked to the maritime EU MRV (Regulation EU 2015/757) for administration purposes, which exempts small ships under 5,000 gross tonnage and vessel types not covered by the EU MRV such as inland waterway vessels, small ferries and motorboats. In line with the EU MRV's focus on carbon dioxide emissions, the EU ETS for shipping will not cover other GHGs such as methane and nitrous oxides. The EU MRV regulation is also being reviewed with a possible outcome of the review being the inclusion of methane alongside carbon emissions for maritime.

The coverage of maritime emissions under the scheme will be gradually phased in during 2023 to 2025 after which shipping companies are required to surrender 100% of their verified emissions starting in

[10] Commission Staff Working Document SWD(2021)601, PART 1/4

2026.[11] The transition mechanism was proposed to address a wide stakeholder request for time to adapt described as necessary due to the shipping sector's complexity.

Each shipping company with vessels operating under the EU ETS will come under the responsibility of an administering authority, an EU Member State. For companies not registered in the EU, the administering authority will be the state where the company's vessels have had the most port calls in the last two years. These authorities will ensure that shipping companies monitor and report verified emissions consistent with the MRV regulation requirements.

Administering authorities will also handle enforcement that, in addition to the general EU ETS rules on penalties, will include ship detention and expulsion orders. As in the general ETS, companies not surrendering allowances face financial fines per tCO2 not surrendered as well as "name and shame" measures. Expulsion orders may be issued through the European Maritime Safety Agency (EMSA) against ships under the responsibility of a shipping company that has failed to surrender allowances for two or more consecutive annual periods. Member State authorities must detain non-compliant ships under their responsibility and deny entry to any ship facing an expulsion order.

The person or organisation considered responsible for compliance is the shipping company which is defined as the 'shipowner or any other organisation or person, such as the manager or the bareboat charterer, that has assumed the responsibility for the operation of the ship from the shipowner…'[1]. Although charterers who hire ships on time charter would not be responsible for acquiring and surrendering allowances, the regulation would allow shipping companies to hold charterers accountable through their contractual agreement. Such an arrangement would be better aligned with the polluter pays principle as the charterer is responsible for choice of fuel, route and the speed of the ship.

Maritime allowances will be auctioned, which is the general principle for allocation under the revised ETS. Auctions create revenues that are partly used for grant financing of deployment and demonstration activities through the Innovation Fund and acts as a safeguard against windfall profits from the sale of free allowances, as was observed during a previous extension of the system to aviation. Businesses or consortiums aiming to demonstrate zero-carbon shipping technology can apply for financial support under the EU Innovation Fund, which provides support for a wide range of new technologies and innovative projects that aim at decarbonizing Europe's economy.[12] The Fund includes Carbon Contracts for Difference, a type of subsidy program that offers investors in innovative low-carbon solutions a fixed price to reward CO2 reductions above that which would be stimulated by the ETS price. While the projected budget of the Fund is around €20 billion for the period of 2020-2030 financed from ETS revenues (hence potentially larger depending on the carbon price), it does not guarantee a fixed proportion will be dedicated to maritime shipping.

Revenue raised through the EU ETS also funds the Modernisation Fund, a dedicated funding programme to support 10 lower-income EU Member States in their transition to climate neutrality by helping to modernise their energy systems and improve energy efficiency. These Member States are Bulgaria, Croatia, Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania and Slovakia.

To ensure compatibility and to address any divergence between regional and global regulations, a reporting and review clause specifies that the Commission will consider amending this regulation in the event that the IMO agrees on a global market-based measure for shipping. By 2028 at the latest, the

[11] According to the proposal, shipping companies will need to surrender allowances in line with the following schedule: (a) 20 % of verified emissions reported for 2023; (b) 45 % of verified emissions reported for 2024; (c) 70 % of verified emissions reported for 2025; (d) 100 % of verified emissions reported for 2026 and each year thereafter.

[12] This includes several zero emission fuel shipping projects, such as DFDS hydrogen ferry, Chantiers de l'Atlantique ship and TS Laevad electric propulsion ferry.

Commission is committing to report on the development of such a measure at IMO, as applicable, including a legislative proposal to amend the EU ETS to reflect the development.

Beyond ETS: the EU's policy mix

The EU aims to decarbonise shipping through a policy mix that besides maritime ETS includes the following: the 'Fuel EU' carbon standard for shipping fuel (European Commission 2021d), the Alternative Fuels Infrastructure Regulation (AFIR) (European Commission 2021e) mandating onshore power supply and LNG bunkering infrastructure by 2025, and the Energy Taxation Directive (ETD)(European Commission 2021f) that will remove a ban on the taxation of bunkers for global shipping.

The Fuel EU proposal will regulate the GHG intensity of fuel used by ships through maximum limits by year in relation to the fleet average in 2020. These limits increase gradually as follows: 2% by 2025, 6% by 2030, 13% by 2035, 26% by 2040, 59% by 2045, and finally 75% by 2050. The targets concern the carbon content of fuel used, and not how efficient the vessel or its operation are, in contrast with measures proposed and discussed at IMO aimed at enhancing technical and operational efficiency. Because these reductions aren't in the short-term likely to enable a transition to SZEF, and because these do not directly incentivise energy efficiency, the focus in this paper is on the EU ETS and its detailed design for these purposes.

The amended AFIR is an EU-wide mandate for the deployment of sustainable fuel infrastructure across all transport modes. For shipping, it requires that a wider set of sea ports (TEN-T 'comprehensive' ports) will need to make Onshore Power Supply (OPS) available to container and ro-ro ships by 2030, mirroring the demand-side requirement in Fuel EU. The Commission's proposal has also maintained a 2025 LNG bunkering facility mandate for major seaports, a provision that could come under scrutiny in the forthcoming EU legislative review.

3 Assessing the economic and climate impact of the EU ETS with Shipping

This section provides an economic and environmental impact assessment of the EU ETS with Shipping. The objective of the economic impact analysis is to address the following questions:

- How would the EU ETS affect GHG emissions? What carbon price would be needed for a reduction in emissions?
- How does the EU ETS geographical scope (i.e., covering intra and 50% of extra voyages) affect the allocation of more efficient ships compared to a full coverage scope?
- How much ETS shipping revenue could be generated under different carbon price scenarios for the proposed EU geographical scope?

Figure 3 shows the approach used to answer the objective questions. The approach estimates the impact on transport supply, voyage costs, freight rates, emissions and revenue raised of including shipping in the EU ETS under an EEA intra and 50% extra-EEA voyages scenario and a full MRV scope (EEA intra and 100% extra-EEA voyages). In this report, we refer to emissions from voyages within EEA ports and at berth within the EEA as "intra" emissions, while voyages incoming to EEA or departing from EEA to a non-EEA port are considered "Extra" voyages.

The approach uses the bunker price and trend, ETS allowance price, the marginal abatement cost curve (MACC), freight rate elasticity with respect to the fuel price and the carbon price required to induce a shift to zero carbon fuels as exogenous inputs. By combining the MRV dataset to estimate emissions under each scenario and FUSE for the proportion of time spent trading in EEA ports, the effective carbon price, or the carbon price that takes into account trade with EEA ports and non-EEA trade over the year, can be estimated for all major ship types covered in the EU MRV under different carbon price scenarios.

Potential economic and climate impacts of the effective carbon prices on the shipping market are assessed using existing literature on the MACC and freight rate elasticities, combined with case studies to examine specific aspects such as impacts on operational efficiency (slow steaming) and port evasion.

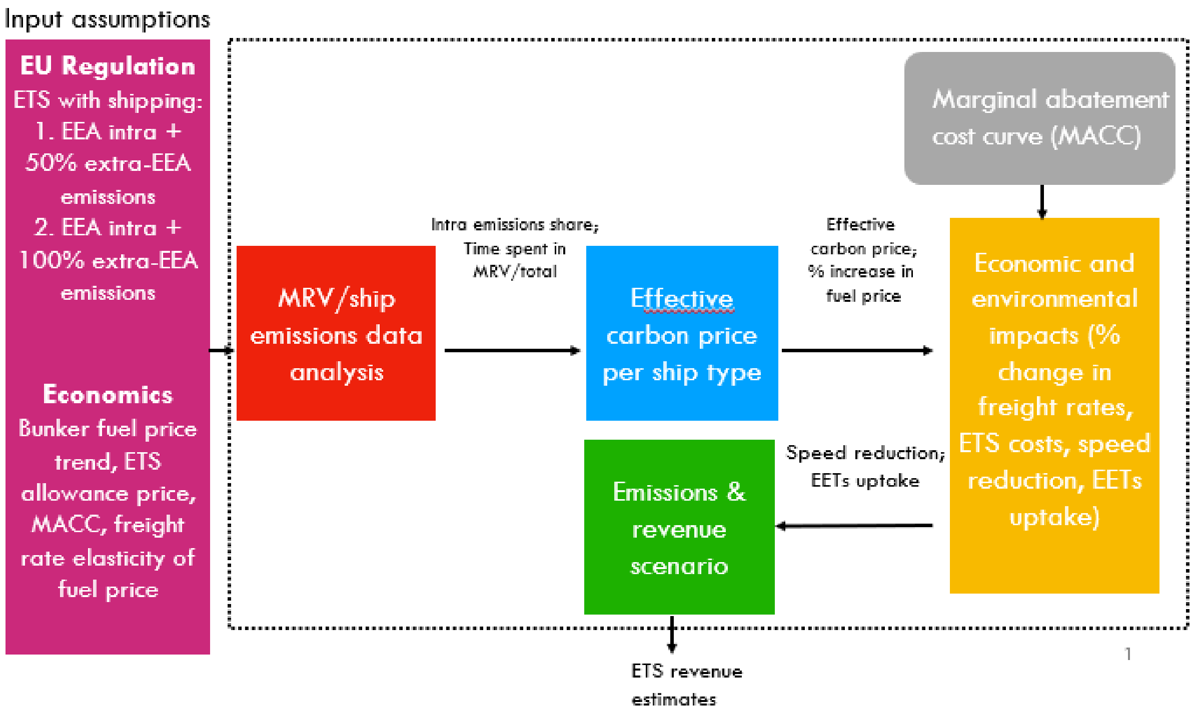


Figure 3: Approach for assessing economic and environmental impacts

3.1 Short-run impact of an EU ETS on shipping sector

A maritime EU ETS would affect costs (variable and fixed), prices and transport supply provided to the market and potentially impact the demand for transport. This section discusses these impacts in the short-term.

3.1.1 Marginal cost impacts

The maritime shipping sector will be added to the EU ETS, and as such, each shipping company will need to ensure that it purchases allowances to cover the amount of emissions emitted during the year. If it has more allowances than it needs, it can trade these in the carbon market. This would essentially add an additional cost to a company's variable costs (also known as ship running costs) equal to the allowance carbon price * the CO2 emissions from producing an additional unit of output (i.e., the additional voyage costs).

The marginal cost increase has an impact on a shipping company's profits in three ways:

- *The level of production is reduced* – as the costs of supplying transportation increase, it is no longer profitable to supply the same tonne-miles and speed will adjust to the new equilibrium.
- *The cost increase is shared with the customer* – some of the cost is passed on to customers in the form of higher prices. The extent that companies can pass on costs depends on the slope of the demand curve relative to the supply curve (Figure 4).
- *Quantity may be reduced* - The increase in price may lead to a decrease in quantity demanded and hence revenues, depending on how sensitive demand is to the price.

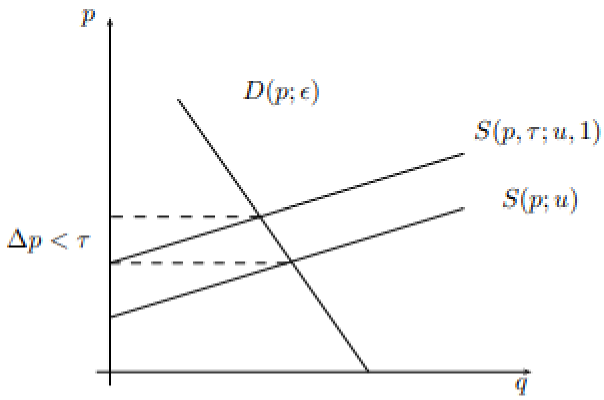


Figure 4: Cost pass-through when both supply and demand are elastic. Source: Fabra, 2013.

Figure 4 shows the impact of an increase in marginal cost due to allowance price of tau. As marginal costs increase, ships supply less to the market (by slowing their speed) and the supply contracts. This is shown in the Figure 4 which shifts to the left and the quantity supplied at the original price is reduced. This results in a deficit of supply relative to demand at the original price which causes the price to be bid up and to restore equilibrium, prices increase until demand equals supply. When the supply and demand curves are both responsive to price, the pass through is incomplete and the costs are shared between the shipping company and the charterer. The extent of the pass-through depends on the relative slopes of the two curves. In Impact on speed 3.4, we examine the sensitivity of speed to carbon price scenarios. This analysis will only consider the first-order impact of marginal costs. Reduction in transport demand as a result of an increase in price is not considered, although demand effects will be limited due to the inelastic nature of demand for shipping.

3.1.2 Fixed cost impacts

The final impact from auctioned carbon allowances is the impact of fixed costs on a shipping company's profits. The decision to invest in abatement technology depends on the cost of emissions relative to the cost efficiency of the abatement technology. Marginal abatement cost curves (MACC) can be used to assess whether it is economical to invest or buy allowance permits which relates the amount of abatement to the cost efficiency of the abatement option. Section 3.2.4 provides shipping specific MACCs.

3.2 Data assumptions

The data used for the impact assessment is comprised of emissions data, fuel consumption, fuel and carbon price assumptions and marginal abatement cost curves.

3.2.1 Emissions data

The European Union created a data collection system called EU MRV for vessels operating to, from and between ports located in the European Economic Area. Shipping companies are required to monitor data including each ships' CO2 emissions, fuel consumption, cargo transported and distance sailed and report their annual CO2 emissions disaggregated by incoming voyages to the EEA, departing voyages from the EEA to a non-EEA port, voyages within the EEA and at berth emissions within the EEA. Data is published annually and has been reported for the years 2018 and 2019.

There were 12,179 ships covered by the EU MRV dataset in 2018. Figure 5 shows the emissions for the intra, Extra50 and Extra100 (full MRV) scope. For passenger carrying ships (i.e., Cruise and Ferry-RoPax), Ro-Ro and Vehicle ships there is a small difference in emissions among the three options, as the majority of voyages are within the EEA. In contrast, the Bulk Carrier, Container, and Chemical Tanker ship types have the highest gain in emissions coverage between the Extra50 and Extra100 (Full

MRV) emissions scopes. In the segment of bulk carriers, the second most GHG emitting vessel type globally, extending ETS scope to full MRV would almost double the emissions covered.

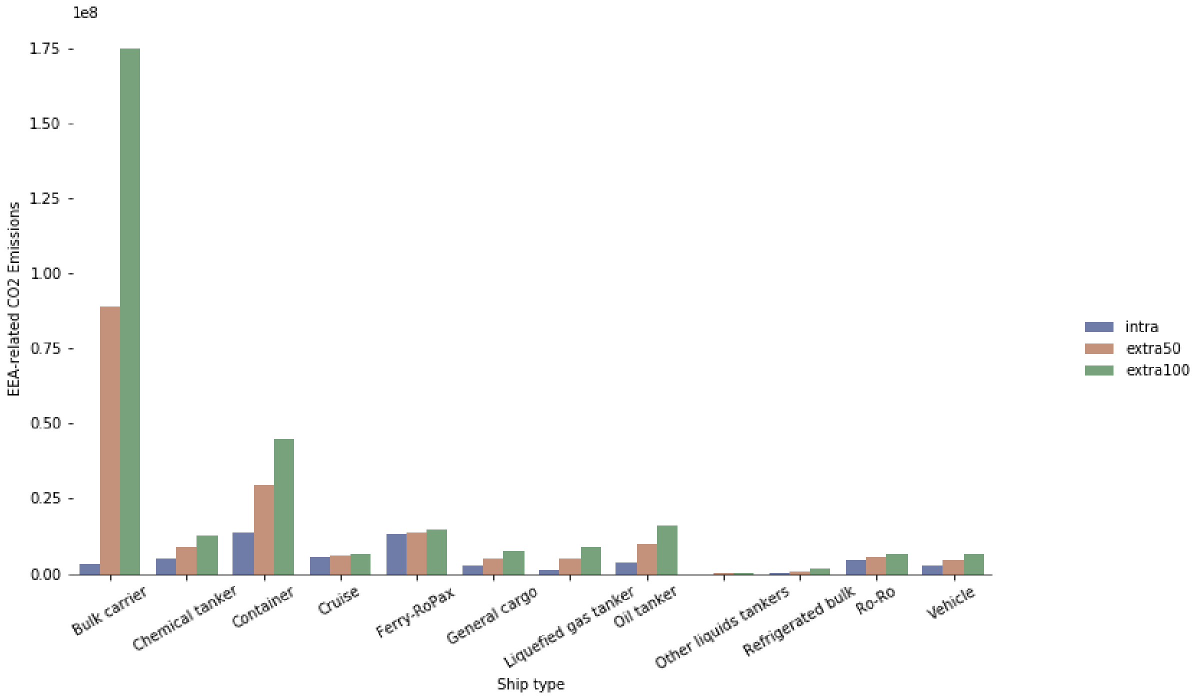


Figure 5: EEA-related CO2 emissions by scope. Source: EMSA, Thetis-MRV 2018

Because the MRV dataset only covers voyages that are connected to EEA ports, the time spent at sea reported by the majority of vessels is less than the entire year. The Fourth IMO GHG Study estimated emissions data for the global fleet between 2012-2018 by combining satellite data on ship movements with the technical characteristics of ships. EU MRV data was used to validate emissions estimates of the global fleet in the Fourth IMO GHG Study for the year 2018. The Study uses UMAS' FUSE model to estimate emissions and found good agreement in the emissions, distance travelled and carbon intensity estimates. The EU MRV data does not capture voyages outside of the EU. Large trading partners like the US and China would therefore not be covered. The analysis performed matched the FUSE carbon emissions estimates to the EU MRV carbon emissions data using the unique IMO number per ship. This enabled a comprehensive picture of the carbon emissions coverage of the EU ETS scope as a share of its total annual emissions. In Section 3.4.2, the carbon emissions cost is analysed in relation to the total fuel consumption expenditure.

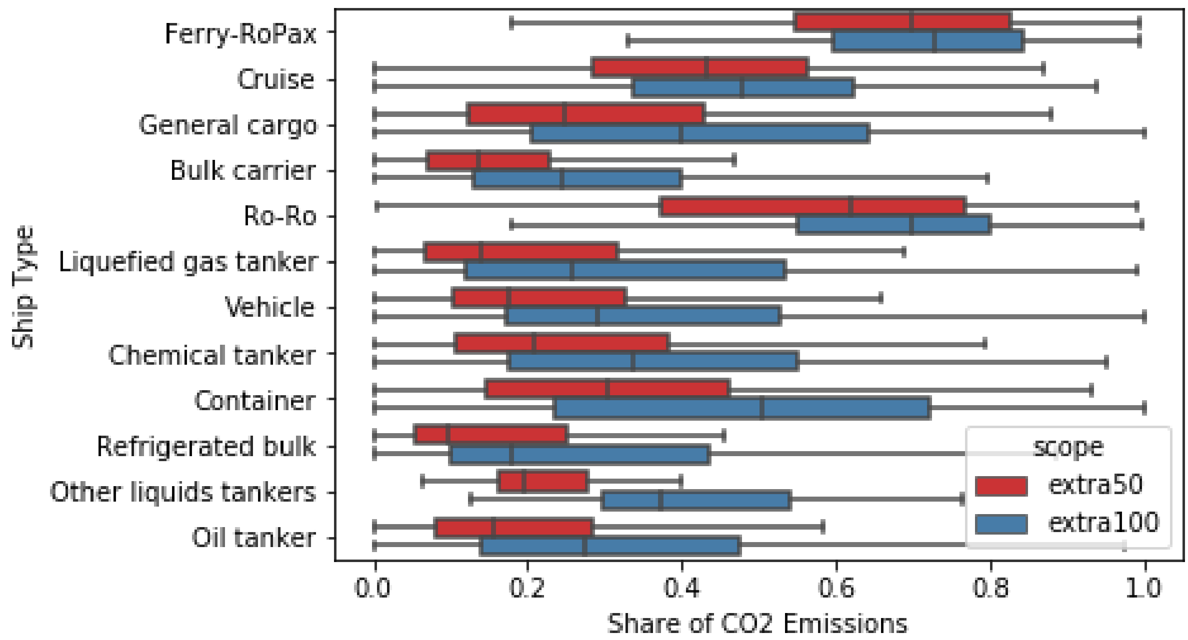


Figure 6: Extra50 and Extra100 emissions as a share of total annual CO2 emissions

Figure 6 shows the distribution of CO2 emissions covered by the Extra50 MRV scope as a share of total annual CO2 emissions by ship type. Each box represents the interquartile range with the median drawn as the line in the box. Ferry-RoPax, Ro-Ro and Cruise ships have the highest share of emissions covered in the Extra50 and Extra100 scopes. There is a marginal increase in emissions when moving from the Extra50 to Extra100 scope for these ship types because the majority of emissions are covered in the intra scope. In contrast, for ships which have a large portion of international voyages, the coverage in emissions increases much more for ship types which trade more internationally (e.g., Bulk Carrier, Chemical Tanker, Container, Oil Tanker). Consequently, the economic impact between the Extra50 and Extra100 would be greater, the larger the gap between the Extra50 and Extra100 shares.

3.2.2 Fossil fuel price assumptions

After the global financial crisis of 2008, fuel prices recovered and the sector experienced high fuel prices (Figure 7), and therefore a stronger and sustained business case to improve efficiency up until 2014, when oil prices fell significantly relative to their levels 2008-2014. The period 2015 to 2019 has been a consistently low oil and fuel price environment with low market forces and policy incentive on efficiency. Bunker prices have edged up in 2021 to $550/tonne of fuel for HSFO, comparable to levels seen in the 2008-2014 period, following the re-opening of economies after Covid lockdown. Figure 7 illustrates the volatility in the fuel price which had a standard deviation of $154 over the time period 2008-2020. This study will base its analysis on a current bunker price of $550/tonne.

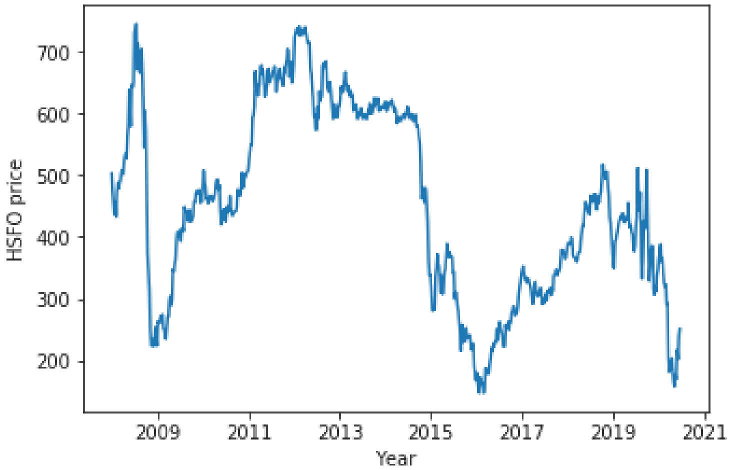


Figure 7: Singapore HSFO prices (Source: Clarksons)

3.2.3 Carbon price assumptions

Carbon price forecasts for the EU ETS are provided by Carbon Pulse and the EU Commission's impact assessment report (EU, 2021). The Carbon Pulse Survey surveys experts periodically about their expectations for carbon pricing in the EU ETS. Table 1 shows a summary of the analysts' carbon price forecasts between 2023 and 2030 for the median, low (10^{th} percentile) and a high scenario (90^{th} percentile). Median values were an average 63 euros over the time period 2023-2030, rising from €51 in 2023 to €87 in 2030. The EU Commission's impact assessment report uses a lower carbon price assumption. It assumes an average price of €45 for 2021-2025 and €55 for 2026-2030 based on multiple sources (Carbon Pulse, PRIMES energy system model, and Vivid Economics).

Year	*Median*	*10th Percentile*	*90th Percentile*
2023	51	35	65
2024	56	35	74
2025	60	33	78
2030	87	60	108

Table 1: Summary of analysts' carbon price forecasts (€/tonne of carbon). Source: Carbon Pulse April 2021 Survey.

As discussed in Section 2.2, the EU ETS will be phased-in for shipping companies and as such, during the first few years (2023-2025), shipping companies will only need to cover a portion of their emissions in the EU scope. The phase-in assumptions are shown in Table 2.

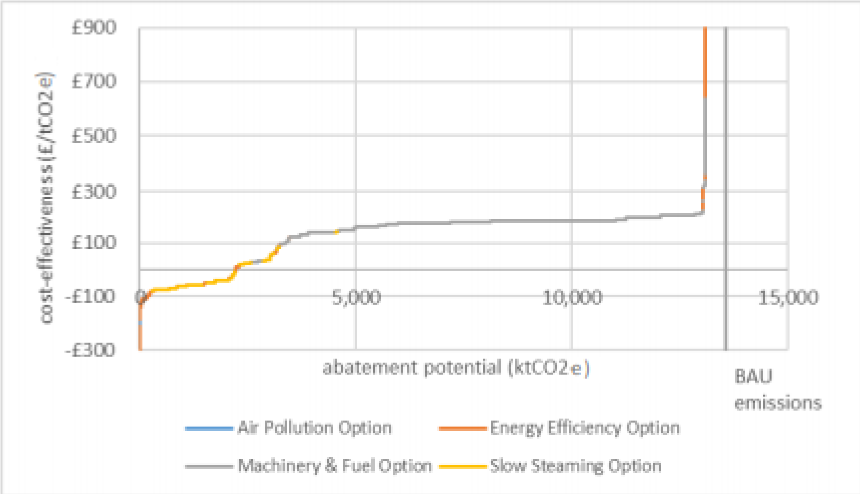
Year	*Emissions covered (%)*
2023	20
2024	45
2025	70
2026 onwards	100

Table 2: Emissions phase-in assumptions

3.2.4 Marginal abatement cost curves and market barriers to implementing abatement measures

The marginal abatement cost curve for 2031 is shown in Figure 8 which includes energy efficiency technologies, speed reduction and alternative fuels (Smith et al., 2019). Although the MACC shown represents UK international shipping, the estimated savings can be used to infer abatement reductions for international shipping because it is a representative sample of global shipping based on the types of ships covered. The horizontal axis represents the CO2e abatement potential (ktCO2e) if the abatement options were applied to the baseline ship and the y-axis shows the cost-efficiency in $/ton-CO2e. The MACC can therefore be used to understand CO2e reductions at different carbon prices.

Figure 6 MACC of UK international shipping in 2031 (2018 prices)



Note: BAU emissions include both operational emissions and emissions at port.

Source: CE Delft analysis of UMAS modelling

Figure 8: Marginal abatement cost curve (2031). Source: CE Delft analysis of UMAS modelling

The figure shows that more than 2.6 Mt CO2e could be saved by implementing options with a negative net cost per tonne of CO2e saved. Given that UK international shipping emissions under BAU are projected to be 13.6 Mt CO2e, this represents a savings of 19% of total UK international shipping emissions. In addition, it is estimated that 1.0 Mt CO2e (7%) could be saved at a net cost of less than £88/tCO2e or about $120/t CO2e (2018 prices). Most of these savings would come from operational (slow steaming) and energy efficiency improvements.

Empirical evidence and modelling (including the MACC curve in Figure 8) suggests that both operational and technological improvements are currently not taken up in the international shipping fleets to the extent that would be rational if the fuel savings that can be realised are efficiently passed back to the ship owner and operator. In many studies into both shipping markets and other similar markets, market failures, which include split incentives and informational problems, are shown to impact the implementation of both operational and technological improvements, whereas non-market failures, which include access to capital, risks and hidden costs, mainly impact the implementation of technological improvements. The MACC shown in Figure 8 incorporates these barriers.

Split incentives arise because of contractual or organizational arrangements, while the latter two barriers (imperfect information, and asymmetric information) are associated with informational problems (e.g., the access and quality of information, especially on performance and cost, that is used in commercial decision making). A large proportion of shipping contracts are arranged on time charter, in which the charterer hires the ship and pays for the fuel. In this case, the charterer is in control of the operations, while the shipowner makes the decisions over implementing technical efficiency measures. Empirical evidence has shown that the premium charterers pay does not pass back the savings to the owner (Prakash et al., 2016), though this could likely be corrected through regulatory action. This challenge lies in an informational asymmetry about the efficiency of the ship and the characteristics of the market, which can tilt the bargaining power in the charterer’s favour (Agnolucci et al., 2014).

Implementation of improvements with potential to reduce fuel consumption and emissions has remained low. A survey performed in 2013, on implementation of cost-effective operational improvements showed that on average, the implementation across all the operational improvements was around 50%, and some degree of speed reduction, as one of the most cost-effective operational improvements, had an implementation rate of around 60% amongst the respondent companies. In another study conducted in 2015, data derived from a cross-sectional survey of 275 shipowners and operators covering around 5,000 ships (Rehmatulla et al., 2017) shows that, despite being considered as mostly mature and commercially ready technologies, there was a low level of implementation of technologies across the different categories and only a small number of improvements in each of the categories are implemented at scale (e.g., bulbous bows, pre/post swirl devices). Those devices that had been implemented had only small energy efficiency gains at the ship level. Devices that have the largest potential to improve efficiency and reduce fuel cost (e.g., wind assistance, air lubrication) were and have remained at very low levels of implementation in international shipping.

As discussed in the fossil fuel price assumptions section, the period 2015 to 2019 has been a consistently low oil and fuel price environment with low market forces and policy incentive on efficiency. This is evidenced in the 4th IMO GHG Study (IMO, 2020) which shows only a 1-2% improvement in energy efficiency and carbon intensity in the 2017-2018 period.

3.2.5 Carbon prices required to close the price gap between fossil fuel and zero-carbon fuels

Section 2.1 outlined that SZEFs are required to meet the IMO's levels of ambition and the price gap, which is at best approximately double the price of LSHFO across the 2030s and 2040s (Lloyds Register & UMAS, 2020). One mechanism to close this price gap is to set a price on the carbon content of fossil fuels. To determine carbon price levels needed to meet the IMO's levels of ambition, this report draws on the forthcoming report "Closing the Gap" (Baresic et al., 2021). The report, which builds on scenario and techno-economic modelling conducted by Smith et al. (2019) for the UK Department for Transport, finds that in order to achieve the lowest ambition of the IMO's Initial Strategy – i.e., reduce ships' GHG emissions by 50% by 2050 compared to 2008 - an average carbon price of US$173/tonne CO2 would be needed. To fully decarbonise shipping by 2050, the average carbon price would only need to be slightly higher: around US$191/tonne CO2. This price is broadly consistent with the cost-effectiveness from the MACC in Section 3.2.4, which ranges between $150-$272 (2018 prices).

Figure 9 shows the assumed carbon price trajectory, which begins in the mid-2020s at a relatively low carbon price of US$11/tonne CO2 in order to phase-in carbon pricing. This would not lead to overall decreases in emissions, though some owners may find it economical to invest in energy efficiency technology. To incentivise the switch to low- and zero-carbon fuels/energy, the global carbon price would need to ramp up to close to US$100/tonne CO2 in the early 2030s and be around US$230-260/tonne CO2 between 2035-2045. To reach full decarbonisation by 2050, the carbon prices in the more ambitious scenario would need to increase even further to around US$360/tonne CO2 whereas it could largely stay the same (US$264/tonne CO2) in the minimum ambition scenario.

These two climate policy scenarios illustrate the range the carbon price levels would need to be in if carbon prices were the only policy measures put in place to achieve the IMO's levels of ambition and decarbonise shipping. However, as Section 4.3 discusses, it is recommended that a demand-side policy such as emissions trading be accompanied by supply-side measures to stimulate investment in zero carbon fuels. The next section will discuss how revenue recycling in the form of subsidies can be used to temper high carbon prices.

Scenario E: Target of 50% absolute reduction in operational shipping GHG emissions globally by 2050 (compared to 2008); zero operational shipping GHG emissions globally by 2070.

Scenario D: Target of zero operational shipping GHG emissions globally by 2050

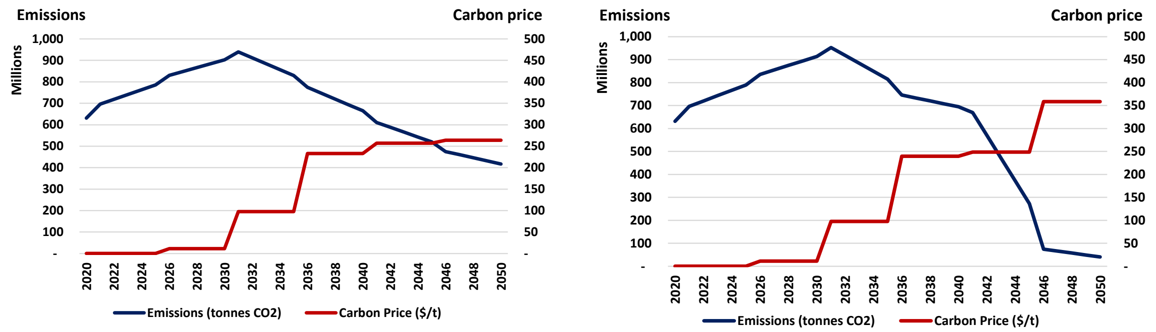


Figure 9: Carbon price trajectories and associated emissions projections for two decarbonisation scenarios. Source: based on Scenarios E and D in Smith et al. (2019)

3.2.6 Implication of Revenue Recycling for Carbon Pricing Levels

Revenue recycling can be used to achieve the same environmental outcomes whilst mitigating the economic burden on the sector. Whilst having a carbon price that is higher than necessary earlier on sends a signal to industry that it needs to slam the breaks on its BAU trajectory, there are still R&D challenges to overcome, and the revenue recycling approach provides a cushion to allow zero carbon fuels to take off. In the context of the EU ETS, revenue 'recycling' would use the revenue raised from shipping company allowances to further support closing the competitiveness gap between SZEFs and fossil fuels through various subsidies to the industry. Such subsidies could for example be used to fund R&D into alternative fuels and technology, finance construction of fuel bunkering infrastructure or to directly subsidise alternative fuels prices. By combining a carbon pricing mechanism with revenue recycling in the form of subsidies, the competitiveness gap can be narrowed or even closed by simultaneously increasing the costs of using fossil fuels (carbon pricing) and reducing the costs of SZEFs (revenue recycling).

The Closing the Gap report provides the carbon price which would be needed to close the competitiveness gap between fossil fuels and SZEFs considering varying degrees of revenue recycling (shown in **Figure 10**). The '0% carbon price' in **Figure 10** below is the carbon price which would be needed if there was no revenue recycling and consequently no subsidy. On the other end of the scale is the '100% carbon price' which assumes that all the revenue collected from a carbon pricing mechanism would be recycled through subsidies to support zero-carbon marine fuels.

Based on Scenario E which has a target of 50% absolute reduction in operational shipping GHG emissions globally by 2050 (compared to 2008); zero operational shipping GHG emissions globally by 2070.

Based on Scenario D which has a target of zero operational shipping GHG emissions globally by 2050

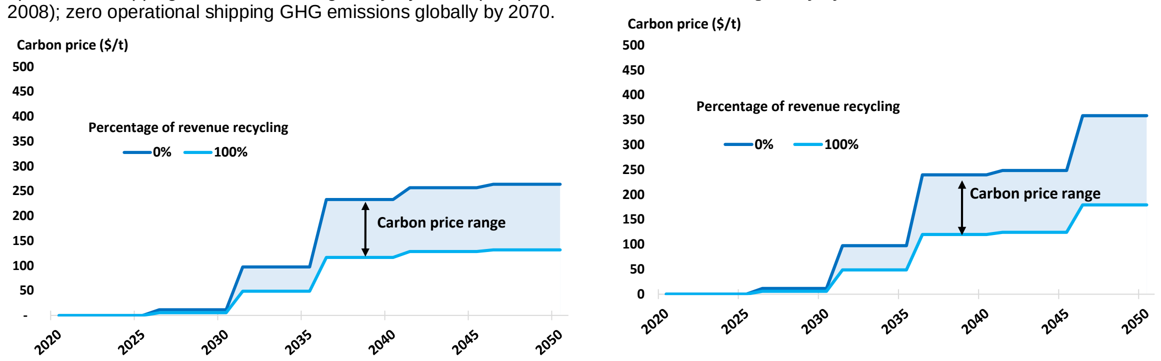


Figure 10: Carbon price trajectories based on % of revenue recycling for two decarbonisation scenarios Source: Based on Scenarios D and E in Smith et al. (2019).

As shown in **Figure 10** above, if 100% of the revenue generated by a carbon pricing mechanism was reinvested into the industry through subsidising SZEFs and associated infrastructure, the carbon price necessary to close the competitiveness gap between fossil fuels and SZEFs could in theory be halved. In the scenarios shown here, this would mean that to reduce emissions by 50% by 2050 compared to 2008 emissions, the average and maximum carbon price needed would be US$86/tonne CO2 and US$132/tonne CO2, respectively. Zero operational shipping emissions could be achieved globally by 2050 with an average and maximum carbon price of US$96/tonne CO2 and US$179/tonne CO2, respectively.

3.2.7 Cost-pass through

Three approaches have been taken in the literature to assess cost-pass through: (1) regression analysis relating the freight rate to bunker prices, as a proxy for carbon costs, controlling for other economic variables (Dinwoodie and Chauwdry, 2011; Vivid Economics, 2010); (2) a cost structure approach that calculates the increase in total costs as a result of carbon costs (Faber et. al., 2010); (3) a structural model that estimates freight rates and the impact of higher bunker costs on supply and equilibrium freight rates in the tanker market (Parker, 2014).

This study employs cost-pass through elasticities from the Vivid Economics 2010 study prepared for the IMO, which is the most comprehensive empirical study to determine the elasticity of the freight rate with respect to the bunker price over the period 1990-2010. During the period 1990-2008, bunker prices exhibited a fivefold steady increase, until they crashed as a result of the global financial crisis. This provides a large variation in bunker prices from which to study their impact on freight rates. Table 3 shows the elasticities for different sectors in the study (the percentage change by which freight rates increase in response to a 1 percent increase in the bunker price). The study found a range of pass-through elasticities, from near unity in the Capesize iron ore market to .11 in the Container market.

Transport segment studied	Implied cost pass-through elasticity
Capesize iron ore	0.96
VLCC crude oil	0.37
Panamax grain	0.25
Container	0.11

Table 3: Implied cost-pass through elasticities of a carbon price (Source: Vivid Economics, 2010)

3.3 Results

The set of results for the economic and environmental impact is discussed in the following sections. In all cases, the results refer to the estimated effect of the EU ETS on the particular variable holding all else constant, i.e., not taking into account changes in other factors such as transport demand.

3.3.1 Effective carbon prices

The cost of carbon emissions depends on the:

- Carbon price
- Percentage of emissions covered in the phase-in period (2023-2025)
- Share of emissions classified as intra and extra for MRV voyages
- Proportion of time spent on MRV voyages

The "effective" carbon price that applies to carbon emissions will be lower, the lower the phase-in coverage percentage, the share of emissions classified as extra voyages and/or the proportion of time spent on MRV voyages. For example, a carbon price would apply to all carbon emissions for ships which trade 100% of the time within the EEA, whereas ships which trade on routes which involve non-EEA ports incur carbon costs on only 50% of their emissions, all else equal. The average effective carbon price for MRV voyages for one tonne of carbon can be estimated as:

$$EC_{t,j}^{ETS} = .50C_tP_t(1 + intra\_sh_{t,j})$$

where:

C_t : carbon price in the year *t*

P_t : phase-in percentage

$intra\_sh_{t,j}$: the median share of intra emissions in year *t* for ship type *j*

The $intra\_sh_{t,j}$ was calculated using the MRV dataset for 2018 as shown in Figure 6.

As most ships do not sail 100% of the time on EEA-related voyages, this carbon price reduces by the proportion of the year spent on MRV routes. Therefore, the effective global carbon price (assuming no ETS in other regions) can be calculated as:

$$EC_{t,j} = mrv\_sh_{t,j}EC_{t,j}^{ETS}$$

where:

mrv_sh: the median proportion of year spent on MRV routes

$EC_{t,j}^{ETS}$: effective ETS carbon price

Data from the FUSE model, which was used to estimate annual emissions for the global fleet in the Fourth IMO GHG Study, was used to match estimated data for 2018 to the IMO number contained in the MRV dataset. Figure 11 shows that for the main ship types, Ferry Ro-Pax and Ro-Ro ships spend the most time in the MRV scope while Bulk Carriers and Oil Tankers spend the least amount of time.

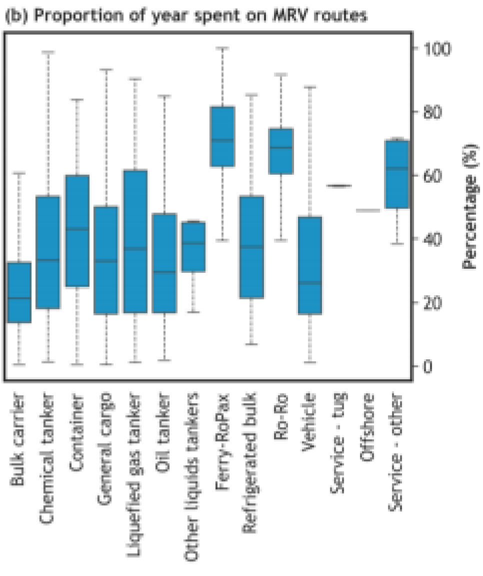


Figure 11: Proportion of year spent on MRV routes. Source: Fourth IMO GHG Study (2020)

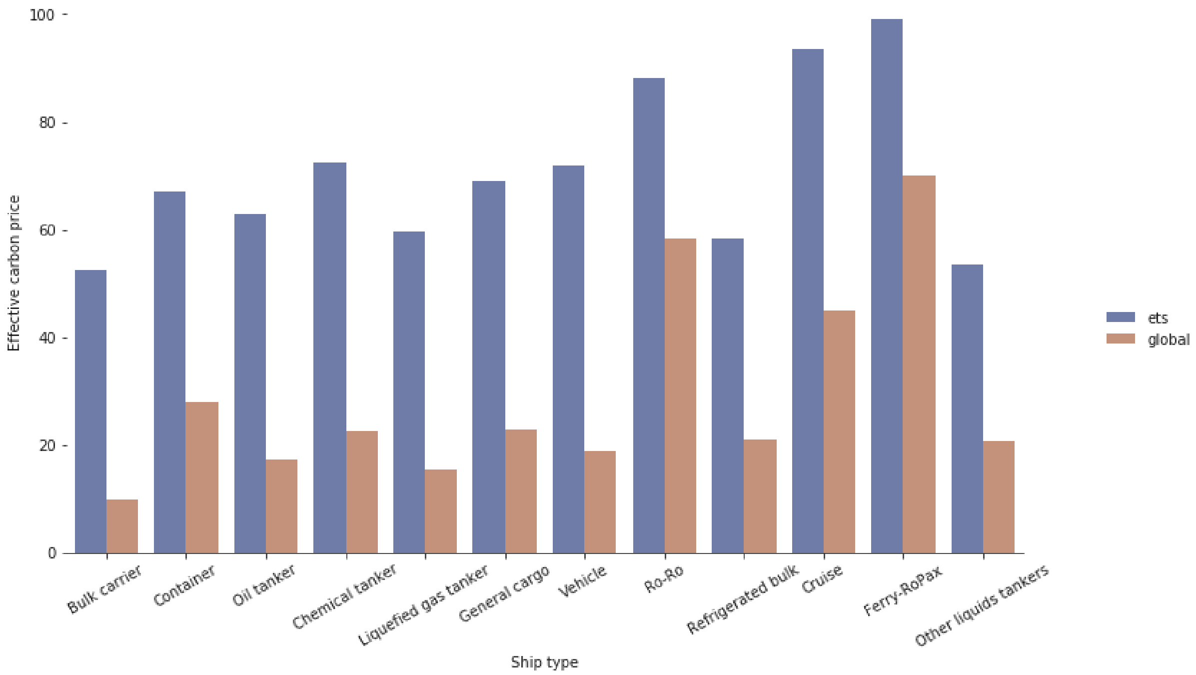


Figure 12: Average effective carbon price in 2030 (ETS vs. global) for Extra50 scenario

Figure 12 shows the effective carbon price that would be applied to carbon emissions on ETS voyages compared to the global carbon price in 2030. The Ferry-RoPax, Ro-Ro, Cruise and Container ship types maintain the highest prices on both an ETS and global basis, with all other ship types incurring an annualised (global) carbon price of about $20/tonne or lower. However, as a large proportion of emissions are accounted for by ship types that travel internationally, when weighted by its contribution to MRV emissions, the aggregate effective annual carbon price is $22/tonne-CO2 under the Extra50 scenario. Under a full emissions scope, this price would increase to $32/tonne-CO2.

At a current HSFO price of $550/tonne, a carbon price of about $100/tonne would add approximately $300/tonne to the price of HSFO. Figure 13 shows the global effective carbon price per ship type in 2030 in $/tonne of HSFO. The median carbon price premium is $60/tonne of fuel, ranging from $31 to $218. This compares to a standard deviation of $154 over the time period 2008-2020. At the volatility of HSFO prices, only Ferry-RoPax and Ro-Ro's have an effective bunker price that exceeds the standard deviation in HSFO prices. This represents an increase in bunker prices in the range of 6-40%, with most of the increases falling in the 10-18% range based on the interquartile range.

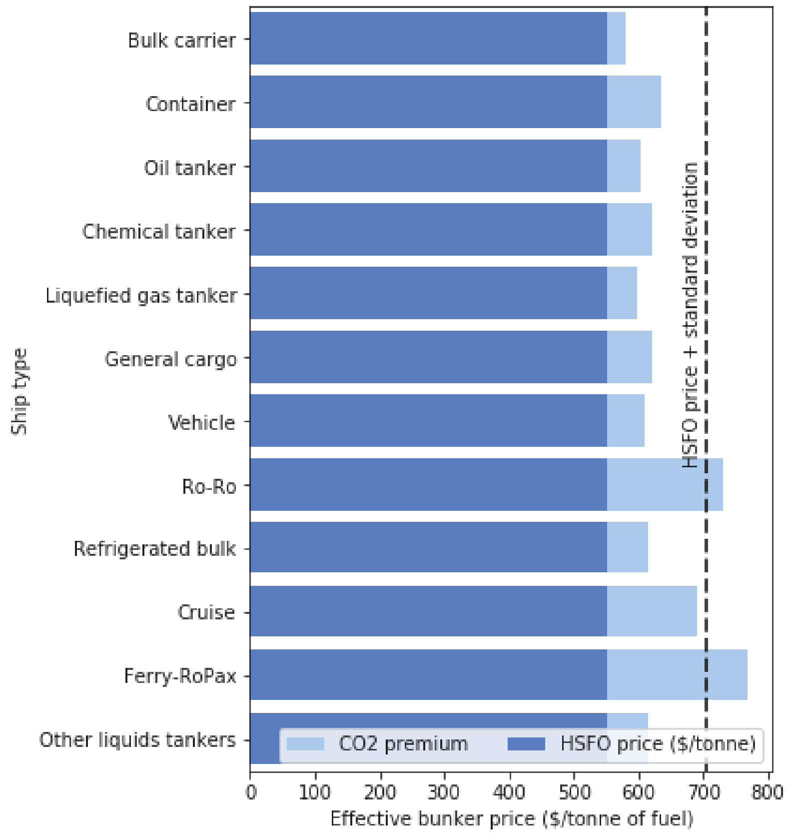


Figure 13: Effective global bunker price (2030, $103/tonne of carbon)

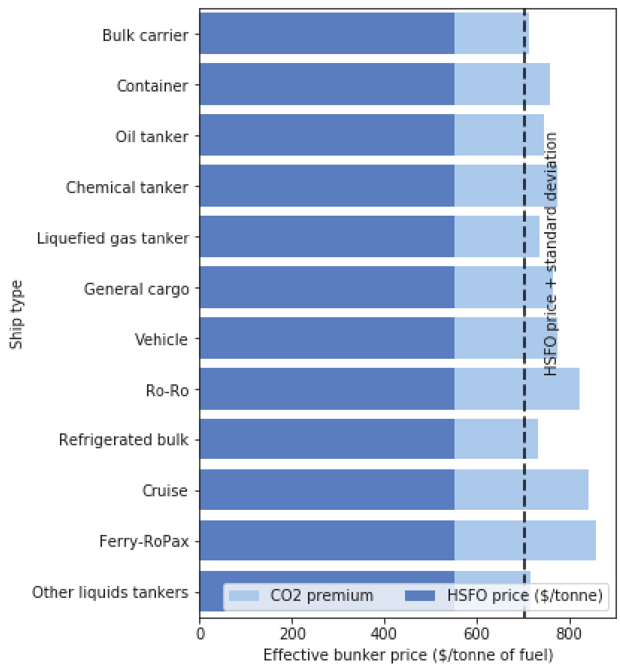


Figure 14: Effective bunker price on ETS routes (2030, $103/tonne of carbon)

Figure 14 shows the effective bunker price on ETS voyages in 2030. The increase in bunker prices from a price of $550 ranges between 29-56%.

3.4 Impact on speed

One of the impacts of the allowance price is that by increasing marginal costs, the amount of production a shipping company is willing to supply to the market is reduced, as it is no longer profitable to supply the same tonne-miles and hence run at the same speed at the same freight rate. Other papers have examined the optimal speed of a vessel and the impact of higher fuel prices (Ronen, 1982, Evans and Marlow, 1990, DNB Markets, 2012, Euronav, Gkonis and Psaraftis, 2012, Psaraftis and Kontovas, 2013, Adland and Jia, 2018, Adland et al., 2018, DfT, 2019, Faber, 2019, Adland, 2020) through a profit maximisation of Time Charter Equivalent Earnings (**TCE Earnings**) or the minimisation of charterer's costs. Considering the charterer's costs is important in shipping markets where a relatively higher proportion of transport demand is on time charter because the charterer controls the ship speed and is responsible for paying the fuel.

This section explores the impact of carbon pricing on a shipping company's Time Charter Equivalent Earnings (**TCE Earnings**) for deploying a Capesize ship on the Colombia to Belgium route. The TCE Earnings per day formula can be expressed as:

$$E_d = \frac{R - C_v}{D}$$

where:

- R is the lumpsum freight rate paid by the cargo owner and calculated by multiplying the freight rate in $/tonne by the cargo quantity; and
- C_v are the variable costs of the voyage incurred between positioning the ship from the last port it discharged a cargo to the port where it will take a new cargo. In this analysis, the variable cost equals the fuel cost, which accounts for the lion share of the variable cost (Stopford, 2009) of a voyage; and
- D is the number of days on the voyage, a function of the route's distance, time in port and the ship's speed.

The variable costs and number of days for the voyage are both dependent on speed, while it is assumed that the lumpsum freight rate is independent of speed. While sailing slower minimises the fuel costs, there is an opportunity cost as it also increases the number of days it takes to complete the journey and thus decreases the daily earnings. In a competitive market such as the bulk carrier market, firms are price-takers and choose the optimal speed that maximises profits. Therefore, the owner will choose the speed at which the marginal benefit from speeding up equals the marginal cost. Figure 15 shows the owner's income over a range of operating speeds for different fuel price scenarios. The optimal speed is represented as the black dot on each fuel price scenario where income is the highest.

Under a Extra50 scenario, a carbon price of 55 euros/tonne-CO2 ($65/tonne-CO2) would increase bunker fuel by $100 leading to a speed reduction of about 8% and a 24% decrease in fuel consumption and emissions. At $100/tonne-CO2, the speed would reduce by 10% and 30% reduction in fuel consumption and emissions. If the increase in bunker fuel were to double (e.g., if the EU were to move to full scope or under a higher carbon price scenario), a $200 increase would produce a 12% reduction in speed or 38% reduction in emissions. Appendix A provides the selected values used for determining the optimal speed.

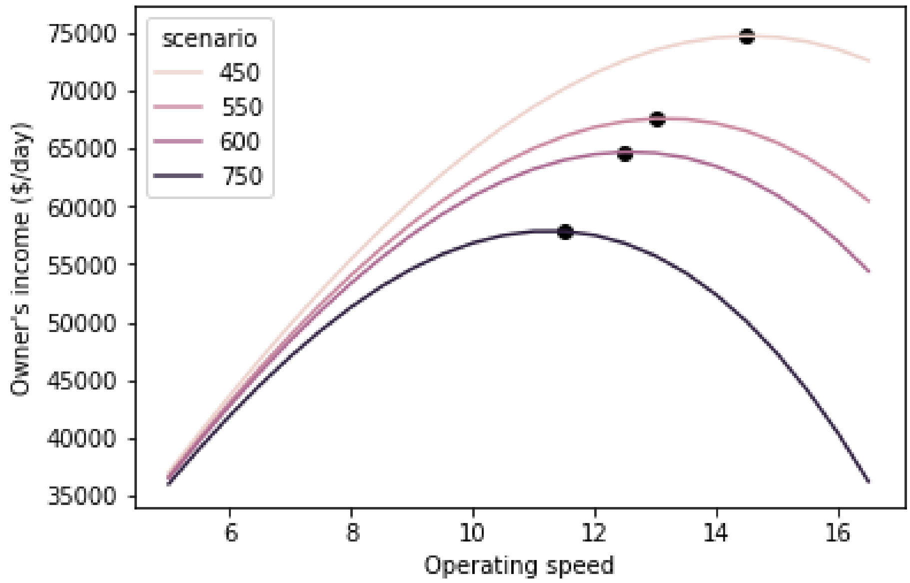


Figure 15: Owner's income for a Capesize ship on a Colombia to Belgium voyage under different fuel price scenarios

There is a range of modelling results on the impact of higher fuel prices on speed in the literature. The variation in results is due to the modelling approach, the TCE formula used (e.g., assumptions about the relationship between fuel consumption and speed, definition of voyage used) and whether the objective function is optimised from the owner or charterer's perspective. In Smith et al. (2019), optimal speed is modelled using a MACC approach, whereby a ship owner's profit is maximised for different combinations of energy efficiency technologies (EETs) and fuels at different speeds and the optimal speed is chosen to maximise the NPV of the bundle of technologies. Since the fuel savings of EETs are speed-dependent, this can result in a different optimal speed compared to assessing the optimal speed for a baseline ship. The report, which assessed the impact of carbon pricing scenarios on decarbonisation of the UK fleet, showed a reduction of 5-6% in operating speed. Adland and Jia (2016) estimate the empirical relationship between speed and other factors including freight rates, fuel prices, age, and other operational factors for bulk carriers using AIS data. The authors find that owners do not appear to adjust vessel speeds based on freight market conditions and fuel prices, as would be implied by economic theory. Instead, vessel-specific variables such as age and design speed, as well as operational factors such as loading conditions, show some explanatory power (Adland and Jia, 2016).

The type of operator also impacts ship speed. DNB (2019) performs an optimal speed analysis which includes the optimal speed when operated by the charterer in the tanker market. They find that neglecting the cargo financing cost aligns the charterer and owner's speeds, but the inclusion of a finance cost results in a higher speed preference. At a TC rate of 20,000 per day, $550 base fuel price and 5% interest rates, an increase to $650 per tonne and $700 per tonne leads to a 2% decrease in speed.

To meet the transport demand required, additional ships may need to be added to meet transport demand. The extent to which additional ships are required depends on the slack that can be taken up from the existing fleet. In fact, many shipping companies used slow steaming in times of overcapacity and high bunker prices when rates were low. When there is not overcapacity however, additional ships would need to be added as ship types like containers and ferries operate on schedules. Their speed optimisation decision also depends on the cost of adding more vessels to a service and the inventory costs for shippers (Cariou, 2011). Faber (2019) performed analysis of the impact of a slow steaming limit. Under a scenario where speed is reduced by 20%, fuel consumption decreases by up to 34%, when taking into account the additional ships that are needed to meet transport demand. Thus, for a 10% reduction in speed, this would lead to a 17% reduction in emissions.

In summary, optimal speed models produce a range of results in the range of 2-10% reduction in speed for an increase in bunker fuel price of $100 for the case studies that were examined. The sensitivity of speed reductions and hence fuel consumption reduction to increases in bunker prices depends on the type of model considered (MACC vs. TCE maximisation only), the type of operator and the specific assumptions about the relationship between speed and fuel consumption, and the supply response (e.g., additionality of ships required). When additional ships are taken into account in the global fleet, a 10% reduction in speed would result in up to a 17% decrease in emissions. Therefore at a range of 2-10% speed reduction in the literature, this implies a reduction in emissions of 3-17% for a $100/tonne carbon price and, assuming linearity, <1-4% reduction in emissions for a $22/tonne carbon price.

3.4.1 Impact on freight rates

The implied freight rate increase on ETS voyages is calculated using the implied cost pass-through elasticities from the literature and the increase in effective bunker price on ETS voyages. Bulk carriers have nearly the same increase in freight rates as costs, while container freight rates are the least impacted.

Transport segment studied	Implied cost pass-through elasticity	Increase in effective bunker price	Implied freight rate increase (%)
Capesize iron ore	0.96	29.7	28.5
Container	0.11	37.9	4.2
VLCC crude oil	0.37	35.6	13.2

Table 4: Implied freight rate increase for major transport segments on ETS voyages (2030)

3.4.2 Average annual carbon costs

The annual carbon emissions costs are shown in the following table according to the median carbon price.

Ship Type	2023	2024	2025	2030
Ferry-RoPax	399,646	988,233	1,661,894	3,458,322
Cruise	373,554	923,715	1,553,394	3,232,539
Ro-Ro	236,999	586,043	985,538	2,050,858
Container	155,382	384,225	646,144	1,344,595
Other liquids tankers	98,740	244,161	410,601	854,441
Vehicle	75,139	185,801	312,458	650,211
Liquefied gas tanker	66,695	164,920	277,344	577,139
Oil tanker	62,617	154,838	260,388	541,856
Chemical tanker	50,662	125,275	210,672	438,399
General cargo	37,486	92,695	155,884	324,387
Refrigerated bulk	35,056	86,685	145,777	303,356
Bulk carrier	26,157	64,680	108,771	226,347

Table 5: Average annual carbon costs

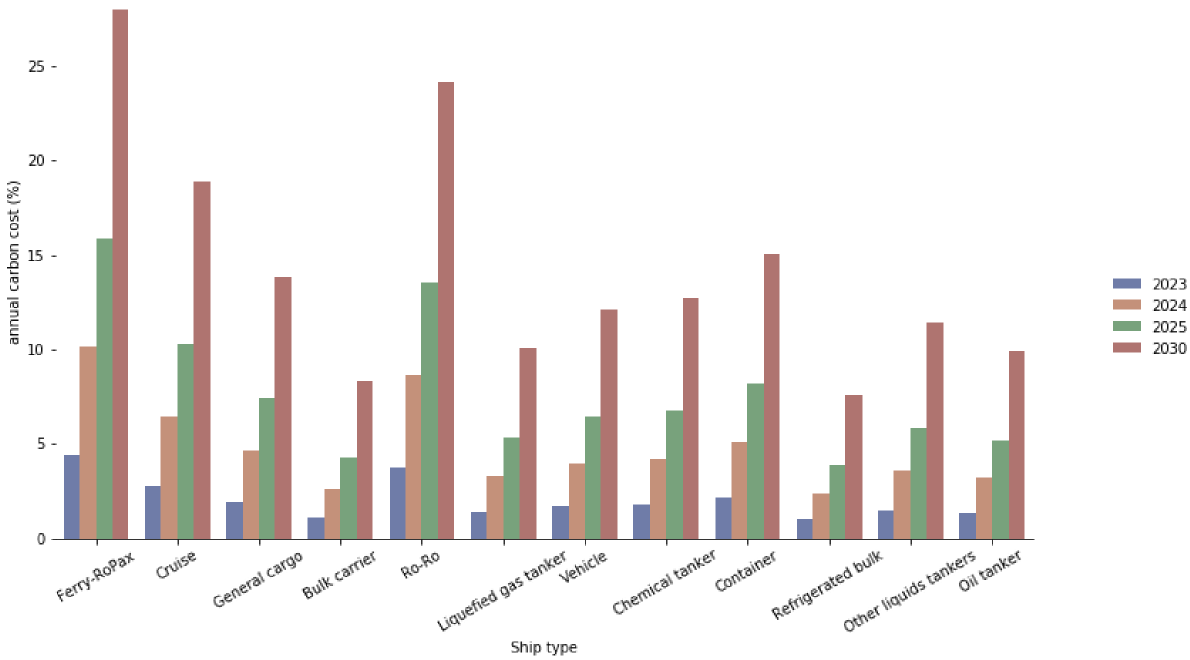


Figure 16: Annual carbon costs as a share of total fuel and carbon costs

As a percentage of total annual fuel/carbon costs, Ferry-RoPax, Ro-Ro, Cruise and Container ship types all have the highest shares (greater than 15%), representing over 20% for Ferry-RoPax and Ro-Ro by 2030.

3.4.3 Impact on maritime emissions

Section 3.2.4 showed that at carbon prices of less than $120/tonne-CO2, savings of 7% by 2031 would be achieved. When compared to the MACC, an effective carbon price of $22/tonne-CO2 in the Extra50 scenario and $32/tonne-CO2 in Extra100 therefore has a negligible impact on the uptake of abatement technology for ships trading with EEA ports. This assumes that no other region or the IMO imposes a carbon tax and no additional mitigation measures in shipping. Under rational expectations, it may be argued that shipowners would factor in a rising carbon price in the future that is higher than the carbon price forecasted in 2030. Should the shipping industry not bring expectations into their investment decisions and use the 2030 carbon price for future periods, then an average price gap of $151/tonne-CO2 exists between the required carbon price (as discussed in Section 3.2.5) of $173/tonne-CO2 and the average effective global carbon price.

3.4.4 Maritime ETS revenue

The potential revenue generated from including maritime shipping in the EU ETS is shown in Figure 17: Maritime contribution to ETS revenueFigure 17 for the ETS carbon price scenarios. Assuming a $103/tonne carbon price (87 euros) by 2030 and an emissions baseline of 2018 (i.e., no reductions), the total revenue generated from shipping would be 9 billion in the Extra50 scope and 14 billion in the full MRV scope (Extra100). At current prices of about 50 euros (about $60/tonne), revenue from the Extra50 scope would be $5 billion in 2030. Compared to a required investment of about $1.4 trillion to at least meet 50% minimum reduction, this would contribute .6-1% of global investment if the revenues were re-invested back into the sector. Section 4.3 will discuss how to stimulate investment in zero carbon fuels.

Section 3.4 discussed that there is a range of speed reductions of that could occur as a result of higher effective bunker prices. Based on the literature and a case study, a $100/tonne carbon price is likely to reduce speed in the range of 2-10% speed reduction and 3-17% for emissions. Assuming linearity, a

$22/tonne carbon price would lead to a <1-4% reduction in emissions. Therefore almost all abatement will come from out of sector.[13]

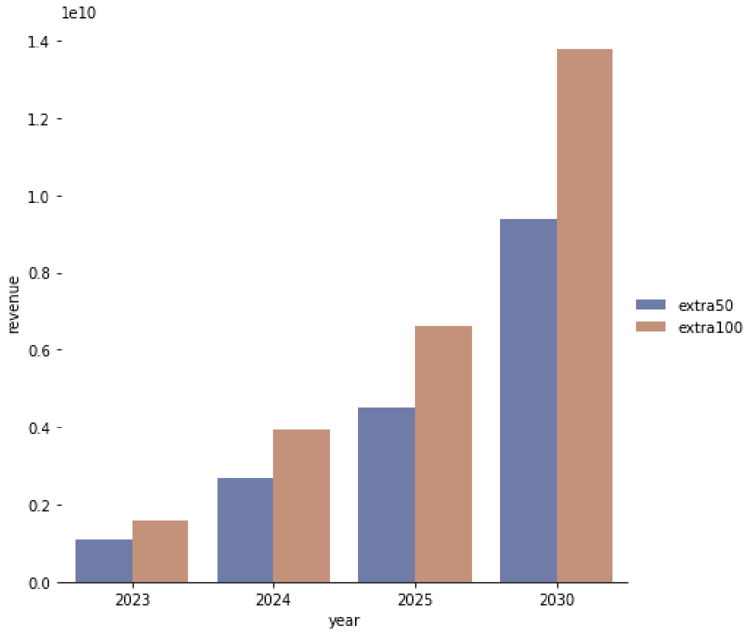


Figure 17: Maritime contribution to ETS revenue (all out of sector abatement)

3.5 Summary of key economic and environmental findings

This section concludes with the key findings from the assessment of the economic and environmental impact of the EU ETS policy in terms of the objectives that were set in Section 0.

3.5.1 How would the EU ETS affect GHG emissions? What carbon price would be needed for a reduction in emissions?

The majority of carbon emissions reductions (the scope of emissions for the shipping's inclusion in the EU ETS) would come from operational efficiency (slow steaming), as shipowners and operators would reduce their transport supply in response to a higher effective bunker price on voyages that include the EEA. Although comprehensive modelling of the impact of higher fuel prices on speed was not performed for this study, the results from the case study analysis and literature review suggest that there is a range of outcomes for speed reduction.

When the annual trading pattern of ships that trade with the EEA is taken into account, the *effective* average global carbon price reduces significantly. For example, under a $103/tonne-CO2 price scenario in 2030, the effective global price reduces to $22/tonne-CO2 or about 20% of the ETS price scenario. This translates into a $69 carbon price premium overall, and ranges from $31 to $218 across different ship types. When compared to a standard deviation in the bunker price of $154 over the time period 2008-2020, only Ferry-RoPax and Ro-Ro's have an effective bunker price that exceeds the standard deviation in HSFO prices. Therefore, at this overall carbon price level, the analysis shows that there is not a strong business case for investments in abatement technology (e.g., energy efficiency

[13] The analysis has not considered the impact of more efficient ships from fleet turnover by 2030 and impact on lower transport demand due to increases in prices.

technologies) or SZEFs and therefore there would be no material impact on emissions beyond speed reduction voyages within the MRV scope.

The Closing the Gap report (Baresic et al., 2021) showed that in order to achieve the IMO's Initial Strategy, an average carbon price in the range of US$173-191/tonne CO2 would be needed, depending on the ambition level (50% - 100% absolute reduction). However, as Section 4.3 discusses, when such large investment is required to transform an entire sector from fossil fuels to zero carbon fuels, demand-side policies that raise revenue have the benefit that revenue raised from the ETS can be recycled back into the sector in the form of subsidies (e.g., to fuel suppliers).

3.5.2 How does the EU ETS geographical scope (i.e., covering intra and 50% of extra voyages) affect the allocation of more efficient ships compared to a full coverage scope?

The effective global carbon price would only marginally increase from an average of $22/tonne-CO2 to $32/tonne-CO2 if the EU ETS increased its geographical scope from Extra50 to full scope. Therefore, there is not a material impact on emissions, although the impact on slow steaming would increase under a full scope scenario. The marginal increase is due to the weight placed on ship types that trade with non-EEA ports which have a lower share of EEA-trade.

3.5.3 How much ETS shipping revenue could be generated under different carbon price scenarios for the proposed EU geographical scope?

Assuming a $103/tonne carbon price (87 euros) by 2030 and an emissions baseline of 2018 (i.e., no reductions), the total revenue generated from shipping would be 9 billion in the Extra50 scope and 14 billion in the full MRV scope (Extra100). At current prices of about 50 euros (about $60/tonne), revenue from the Extra50 scope would be $5 billion in 2030. Compared to a required investment of about $1.4 trillion to at least meet 50% minimum reduction, this would contribute .6-1% of global investment if the revenues were re-invested back into the sector.

As discussed, there is a range of speed reductions that could occur as a result of higher effective bunker prices. There is a range of speed reductions of that could occur as a result of higher effective bunker prices. Based on the literature and a case study, a $100/tonne carbon price is likely to reduce speed in the range of 2-10% speed reduction and 3-17% for emissions. Assuming linearity, a $22/tonne carbon price would lead to a <1-4% reduction in emissions and therefore almost all abatement will come from out of sector. Section 4.3 will discuss how this revenue could be used to stimulate investment in zero carbon fuels.

4 Assessing the EU ETS with Shipping policy

The objective of this section is to discuss:

1. How does the inclusion of shipping into the EU ETS (the "**ETS with Shipping**") measure against effective decarbonisation policy criteria?
2. What policy elements are needed for EU ETS with Shipping to contribute to the decarbonisation of global shipping outside of the EU?

4.1 Key elements of a decarbonisation policy

The primary aim of any decarbonisation policy should be to produce a substantial and measurable reduction in GHG emissions. However, in practice, decarbonisation policy is often assessed against a number of considerations. The Intergovernmental Panel on Climate Change (IPCC), for example, suggest the following four criteria for both evaluating and choosing a mitigation policy:

	IPCC criteria detail
Cost-effectiveness and economic efficiency (excluding environmental benefits but including transaction costs)	A policy is cost-effective if it reduces pollution in line with a climate target at lowest cost with marginal compliance costs equal among parties. Transaction costs should also be considered and limited. A policy is economically efficient if allocation of resources is optimal i.e., it is not possible to reallocate resources for a positive impact without also creating a negative impact for an individual or group. The extent to which a policy encourages investment in research, innovation and technological change to reduce emissions is also a factor of its efficiency.
Environmental effectiveness	A policy is environmentally effective if it achieves its expected environmental target. Environmentally effective policies can also generate co-benefits while ineffective policies can generate carbon leakage whereby a national policy for one country can result in increased emissions in another.
Distributional effects	Distributional effects refer to the likelihood that gains and losses generated by a policy may not be equal across society and includes aspects such as fairness and equity.
Institutional feasibility	Institutional feasibility covers both the administrative burden and the likelihood of political acceptance.

Table 6: IPCC criteria for assessing decarbonisation policy, created from Kolstad et al., 2014

These four elements can be taken as the baseline criteria for designing or assessing decarbonisation policy. The following section discusses the EU ETS in relation to these four criteria.

4.2 What aspects of those principles does the ETS fulfil that can lead to decarbonisation, if only regionally?

This section will assess whether the EU's proposal to extend the ETS to cover the shipping sector fulfils the four IPCC criteria laid out in Section 4.1: *cost-effectiveness and economic efficiency, environmental effectiveness, distributional effects* and *institutional feasibility*.

4.2.1 Cost-Effectiveness and Economic Efficiency

According to the IPCC criteria, a policy is cost-effective if it reduces pollution in alignment with a climate target at the lowest cost with limited transaction costs and marginal compliance costs equal among parties. A policy is economically efficient if the allocation of resources is optimal in that any change of allocation would cause a negative impact on an individual or group and the policy encourages investment in research, innovation and technological change (Kolstad et al., 2014). The EU Commission highlights the advantageous features of the EU ETS as follows:

- Certainty about quantity of emissions through the cap-and-trade mechanism
- Cost-effectiveness: emissions are cut where it costs least
- Revenue is generated to support decarbonisation
- Risk to Member States budgets is minimised

Being an extension of the EU ETS, the move to cover shipping should therefore share these features. In this sense, the proposal could be considered to be relatively cost-effective, especially if it leads to emissions reduction at low cost to Member States. An analysis performed on ten relevant commodities in the EU Commission impact assessment report suggests that an open ETS covering 50% of extra-

EEA emissions would have relatively small impacts on prices[14], even by 2050 (EU Commission, 2021). While there may be certainty about the quantity of emissions through the EU targets, the price itself is not certain and will be set by market forces. The lack of price certainty may discourage in-sector investment.

4.2.2 Environmental Effectiveness

Under the criteria from the IPCC, a policy is environmentally effective if it achieves its expected environmental target. Within this, the generation of co-benefits and avoidance of carbon leakage is important. Generally speaking, ETS systems have a high certainty of impact (Eden et al., 2018). As the proposal is extending the ETS over shipping, the certainty of impact on emissions is relatively high compared with other possible policy instruments as it places a limit on emissions in line with wider EU goals.

In alignment with the EU goals, the proposal is a significant change for the shipping industry from business-as-usual, particularly as it covers not only intra-EU voyages and emissions at berth, but because it applies to half of extra-EU voyages. This may have the effect of decarbonising shipping internationally, beyond the borders of the EU, assuming that rerouting does not occur in order to avoid direct coverage. This proposal, therefore, may contribute to the decarbonisation of a variety of ships and trade routes and create first mover incentive beyond the EU member states. The proposal is also likely to have some co-benefits, particularly in relation to reduction of air pollution in ports. The Innovation Fund will be used to stimulate research and innovation which may have spill over effects for the shipping industry, depending on the projects funded.

This proposal may also be indirectly environmentally effective if it puts pressure on the IMO to develop and implement a global measure which stimulates the shipping sector to decarbonise as part of an equitable transition (Urrutia, Graichen & Herold, 2021). Within the maritime sector, there is a clear history of regional activity on environmental issues putting pressure on the IMO to act at a global level in the interest of maintaining what it refers to as ‘the level-playing field’ and the uniformity desired by the shipping sector as a whole (ICS & INTERTANKO, 2021). This can be seen from the development of double-hull regulations for oil tankers, whereby the US imposed its own regulation, which then stimulated action at the IMO and the development and adoption of a global regulation. This effect was also supported by the threat of unilateral action at EU level. The sulphur regulations and restriction of TBT in anti-fouling paint are further examples of regional activity causing a global response (van Leeuwen 2010). It is therefore feasible that this proposal at EU level may serve to expediate the development and implementation of a global measure for decarbonisation. At the very least, it will set a precedent for a carbon price for the shipping sector.

While there are clearly elements of the proposal which suggest environmental effectiveness, there are also several issues which may undermine its effectiveness. Shipping is often classed as a hard-to-abate sector (ETS, 2018) which must undergo an entire fuels transition. The effective carbon price generated by this proposal may not be high enough to stimulate the necessary change and in particular, without use of companion measures such as subsidies or contracts for difference, will struggle to close the price difference between incumbent fossil fuels and new SZEFs for shipping. Additionally, in order to transition to alternative fuels, the shipping industry will need substantial investment in assets and infrastructure. Depending on the trajectory in question, this investment is projected at between $1-1.9 trillion with around 87% of that needed for infrastructure (Raucci et al., 2020). With revenues generated from shipping activity not being recycled directly back to the industry and instead going into the EU

[14] The analysis showed that even in the case of full cost pass-through, prices of commodities such as iron ore and cereals would rise by less than 2% by 2050. Goods such as crude oil, organic chemicals or perishable goods would largely be unaffected by an increase in shipping costs.

Innovation Fund for cross-sector use, first movers, innovation and the fuels transition will be limited in the sector.

Other features of the proposal which potentially undermine its effectiveness include the phase-in period (covered in Section 2.2) which is overly lax, the exemptions on size, and the emissions in scope. The proposal currently only covers ships of 5000GT and above and does not apply to inland waterway vessels, small ferries and motorboats. These exemptions could allow for carbon leakage in the system. Carbon leakage is also possible if, as a response to the regional regulation, ships are re-routed around the EU Member States or dock out with the EU with goods subsequently transported by road and rail. At the same time the impact assessment of the EU proposal found that only 5% of routes may be vulnerable to leakage.

In terms of revenue generation, while there will be significant funds to stimulate innovation and technological change, the ETS may not directly tackle some barriers to long-run investments, particularly those unique to shipping (split incentives) (Rehmatulla & Smith, 2015). Indeed, Hoffman (2007) surveyed managers in the German power sector and found that although the EU ETS had become a main driver for small-scale investment decisions with short amortisation times, there had been little impact on large scale investment decisions in power plants or R&D.

Lastly, the scope of the EU proposal includes only carbon dioxide and not methane, nitrous oxide or other GHG emissions which undermines its environmental effectiveness and could possibly lead to bias for low-carbon but not low-GHG measures being taken, for example a higher ordering and use of LNG powered ships (T&E, 2020).

4.2.3 Distributional Effects

Distributional effects refer to the likelihood that gains and losses generated by a policy may not be equal across society and includes aspects such as fairness and equity (Kolstad et al., 2014). Indeed, shipping is a keystone industry and many nations around the world are dependent on the sector for their basic and most essential needs, meaning that in terms of distributional effects, there are significant risks and uncertainties around the impact of a carbon price on these nations.

The revenue generated from the ETS will be largely collected in the Innovation Fund and which is then used to finance projects which are aimed at achieving significant emissions reductions. Additionally, the Innovation Fund also feeds into the Modernisation Fund which supports 10 lower-income Member States to reach their 2030 climate targets. In this way, the ETS can be seen as having positive distributional effects, however, at the same time, there may be an issue with the fairness and equity of the policy coverage and revenue generation. Rather than applying to, and generating revenue from, only intra-EU voyages, the EU ETS covers half of extra-EU voyages. This key element of the policy means that the revenue generated comes, in part, from trade beyond the scope of the EU alone, i.e., the EU ETS covers also non-EU trade and while the effective carbon price may be initially low there is the potential that the EU ETS could have impact (including negative ones) on non-EU countries. These non-EU countries cannot apply to the EU funding, so won't be able to benefit from the revenues, despite having to pay into the system.

The Innovation fund feeds into another fund called the Modernisation Fund which supports 10 lower income EU Member countries however neither of these funds specifically address projects or mechanisms to assist the globally climate vulnerable. This contrasts with a global policy from the IMO which would need to assess and address disproportionately negative impacts, incorporate and apply important guiding principles[15], and would most likely specifically promote knowledge transfer and

[15] In the Initial IMO GHG Strategy there is a need to be cognizant of the principle of non-discrimination, the principle of no more favourable treatment, the principle of common but differentiated responsibilities and respective capabilities. Other guiding principles of the strategy include – 'the requirement for all ships to give full and complete effect, regardless of flag, to implementing

capacity development. In light of this, there are potential issues of fairness and equity with the current EU ETS proposal.

The current focus points of the EU Innovation Fund are – low-carbon technology, carbon capture and storage and energy storage and renewable energy[16]. While this list may not preclude investment in alternative zero emissions fuels, such as hydrogen or ammonia, or zero emission vessels, these are not listed as a specific priority for the Fund but are required for the shipping sector to make its decarbonisation transition. This means that while the shipping sector must pay into the Fund, as a stakeholder of the Fund, it does not necessarily receive the support it requires (i.e., the Fund may favour other sectors' use more than it does shipping's).

4.2.4 Institutional Feasibility

According to the IPCC criteria, institutional feasibility relates to the administrative burden and the political acceptability of policy (Kolstad et al., 2014). The EU ETS extension will be hitched to the MRV system and involve Member States, Flag administrations in implementation and enforcement. It also makes use of the existing Innovation Fund. As such, there is a clear attempt to reduce administrative burdens through the use of pre-established structures, and relevant organisations. For shipping specifically, the ETS may not substantially expand the requirements already placed on ships to maintain records of fuel bunkered and to carry appropriate related documentation (IMO, 2010b). At the same time, due to the complexity of ETS systems in general, there will most likely be a significant administrative burden in the short term and an increase in transactional costs or even hidden transactional costs. For example, Hintermann and Ludwig (2019) find permit trading was much higher within national borders than across national borders, which suggests higher transaction costs when trading across borders. Thus, even small deviations in transactions costs can create large changes in the trading patterns.

In terms of political acceptability, it is yet unclear how politically acceptable the proposal is beyond the EU. Generally, the shipping industry as a whole, support global mechanisms as the most suitable for the sector (ICS & INTERTANKO, 2021). While the EU have built into the proposal a commitment to review and amend the EU ETS in line with developments at the IMO, how the proposal is viewed at a global policy level will become clearer after MEPC77 in November 2021. For the moment, there has been some support for the proposal (Hakirevic Prevljak, 2021), but there has also been criticism that the proposal is a unilateral and extra-territorial tax on trade which constitutes diplomatic overreach. Even though the EU Commission's impact assessment suggests only moderate impact on certain commodity prices, there is still the potential that the ETS could, depending on the carbon price, raise the cost of shipping for EU trading partners, which is in turn could be passed on to the consumer (Thompson 2021). Thus, this extension of the EU ETS could affect the EU's credibility in global diplomatic fora, such as IMO MEPC discussions. If we look at the inclusion of aviation in the ETS as an example, there may yet be amendments to the ambition of the proposal, particularly in terms of coverage. This was the case with the inclusion of aviation as a result of international pressure. As such, it is fair to say that the political acceptability of this proposal is yet to be seen at the global level.

While the IPCC criteria is cross-sectoral and broad stroke, it is worth noting that a global decarbonisation policy, applicable to all ships regardless of flag registration, would need to align with the principles and aims set out by the IMO in the Initial IMO GHG Strategy, in order to be both cost and environmentally effective and to be politically acceptable. In other words, to achieve the international consensus and political buy-in at a global level, and therefore to be fully institutionally acceptable, the policy would need to be designed in a similar way to a global policy proposal. The following section

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mandatory measures to ensure the effective implementation of this strategy', the need to consider impacts on States, especially LDCs and SIDS and the need for evidence-based decision making (IMO 2018).

compares the EU ETS proposal to a recent submission to IMO MEPC76 in order to give an example of the differences between the regional EU ETS proposal and a globally-orientated proposal[17].

4.2.4.1 Comparison of EU ETS to IMO Developments

In terms of the global policy landscape at the IMO level one concrete proposal was submitted to the IMO at MEPC76 in June 2021. The co-sponsors were the Republic of Marshall Islands and Solomon Islands, both climate vulnerable Small Island Developing States (SIDS). The submission contains a proposal for a MBM in the form of a GHG levy for shipping. The starting carbon price suggested is \$100/tCOe2. Having a price floor of \$100/tCO2e and reinvesting the revenues in the shipping industry could enable take-up of alternative technology and fuels as part of shipping's transition (MEPC 76/7/12). The price would then be ratcheted upwards on a 5-year review cycle (ibid). The Co-sponsors share the view that a levy such as this will send and unequivocal signal to the industry that decarbonisation in line with the Paris Agreement goals is imperative. At MEPC76, this proposal was forwarded for further discussion at the 10th session of the Intersessional Working Group on Greenhouse Gas (ISWG-GHG 10), scheduled for October 2021.

The table below summarises some key features and compares this proposal with the EU ETS for shipping.

	Carbon Levy Proposal (MEPC 76/7/12)	**EU ETS for shipping**
MBM type	Carbon Levy	Emissions Trading System
Applicability	For ships over 5000GT • Global coverage • Exemptions discouraged	For ships over 5000GT • All Intra-EU voyages • All emissions at berth in EU ports • Half of extra-EU voyages
Price level	Price floor \$100/CO2e	Set by the market response to target
Where is revenue collected?	• A climate fund administered under the UNFCCC, for example the Green Climate Fund (at least 51%) • International Maritime Research Fund (around 33%) • Administration 16%	The EU Innovation Fund The Modernisation Fund
Revenue Use	• A fund to support climate change mitigation and adaptation efforts in vulnerable countries administered under the mandate of UNFCCC • A fund to subsidize Research Development & Deployment of new technologies and fuels administrated under the mandate of IMO. Administration costs	• The Innovation Fund focuses on highly innovative technologies and large flagship projects within Europe, aimed at achieving significant emissions reductions. • The Innovation Fund also supports cross-cutting projects to lead emissions reduction in multiple sectors as well as small-scale projects with total capital costs under €7.5 million[18].

[17] It should be noted that this proposal has been forwarded for consideration in the MEPC process and has not, as of yet, achieved widespread support. It is presented merely as an example of an international proposal in order to highlight the differences between a proposal which is global-facing compared to the EU ETS which is a regional policy.

[18] https://ec.europa.eu/clima/policies/innovation-fund_en

		• The Modernisation Fund is dedicated to supporting 10 lower-income EU Member States in their transition to climate neutrality. The beneficiary Member States are Bulgaria, Croatia, Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania and Slovakia[19].
Emissions covered	• All GHG emissions from ships	Carbon Dioxide (CO2)

Table 7: Compiled for report based on source material from (MEPC76/7/12) and (EC 2021)

Aside from the difference in geographical emissions coverage, a key distinction between the systems is that the EU ETS, being an emissions trading system, will cap emissions over a certain period and allow the market to determine the carbon price within that limit. On the other hand, with a carbon levy the regulator sets a price, however the absolute reduction of emissions will be unknown as it is the market's response to the price which creates said reduction (PMR & ICAP 2016). ETS carbon prices have been known to be volatile in the past (Feng, Zou & Wei, 2011), which makes it challenging for firms to make a clear business case for investing in low- or zero-carbon technologies. Without the ability to confirm payback periods or return on investment it is difficult for companies to de-risk investing activities.

A second key difference that the levy covers all GHG Emissions from international shipping, which includes methane, while the EU ETS covers only CO2 (MEPC76/7/12, EC 2021). Methane is a gas with a much greater global warming potential. Indeed, projections suggest that Methane emissions in 2020 will cause half the global warming over the next 20 years[20] (S van Renssen, 2020). By not covering methane, the EU ETS may allow methane emissions to increase and create a bias for LNG ships. Methane slip from LNG ships can make them equally as harmful as current diesel ships in the context of global warming (T&E 2020). After CO2 and methane, nitrous oxide is the most important GHG to reduce due to its potency (Garthwaite 2020) and should also therefore be addressed under GHG emissions policies.

The proposal at MEPC76 by the Marshall Islands and Solomon Islands is cast at a global level and is part of the IMO MEPC discussions. It has been constructed to be cognizant of the Initial IMO GHG Strategy and the principles therein. As such, this represents a proposal which is more aligned to enabling an equitable transition and addressing disproportionately negative impacts on states than the extension of the EU ETS. While it is not necessary for the EU ETS to apply guiding principles of the IMO, the difference in orientation between these proposals can be seen in the collection and use of revenue. There are two main issues with the EU approach to revenues. Firstly, the funding collected from shipping goes into a central fund which can be accessed by multiple sectors. Unfortunately, this leaves the shipping sector in competition with other sectors for much needed financial support for the decarbonisation transition. Secondly, as discussed above in Section 4.2.4, the generation of funds is, in part, based on portions of voyages external to the EU, and yet it appears that the EU Fund will largely be supporting EU-based projects. At present, a large amount of R&D and pilot projects are already based in the EU, which may give them first mover competitive advantages in the transition. However, decarbonisation on a global level should be an equitable and fair process with inclusive innovation a

[19] https://ec.europa.eu/clima/policies/budget/modernisation-fund_en
[20] This is referring to total methane emissions, rather than shipping-specific.

key part. This is an element which is better captured in proposal from the Marshall and Solomon Islands but is largely absent from the EU proposal.

This section does not intend to suggest that the EU ETS is expected to capture all of the elements of a globally-orientated proposal. Instead, the point being made here is to put the EU ETS proposal into the context of a global fuels transition for shipping and to compare the features of these two levels of policy. In doing so, the elements of the EU ETS that could be strengthened to further fulfil IPCC policy effectiveness criteria are highlighted. The following section moves on to discuss in more detail the best use of ETS funds as part of the transition.

4.3 Best use of ETS funds to support shipping's SZEF transition

The findings from the Section 3.4.4 show that the majority of shipping companies would purchase allowances rather than reducing emissions in sector. While the Commission's proposal states that the Fund should be used to "decarbonise the maritime transport sector, including investments in sustainable alternative fuels, such as hydrogen and ammonia that are produced from renewables, as well as zero-emission propulsion technologies like wind technologies," it does not include a sector-specific Ocean Fund, as previously considered. The focus of the Fund would not therefore considerably produce the type of climate innovation which can assist shipping, leaving shipping companies in the position of paying for pollution and reducing transport supply without the true benefit of transition support. This section discusses how the European Union can best make use of the auction revenues raised from shipping in terms of stimulating innovation and achieving an equitable transition.

The varying success of energy policies to foster renewable electricity in different countries provides some insight into how the market for zero carbon marine fuels could be developed. The rapid decline in the cost of solar and wind power over the past decade to the point where they are competitive with fossil fuels was the consequence of good policy decisions (Krugman, 2021). In all of the countries that created a sustainable renewable electricity policy (at the international, national, state and local level), both demand and supply-side policies were used to foster the growth of wind and solar power (e.g., in Germany, Netherlands, US and China) (Mazzucato, 2018). In the case of Germany, its Federal Ministry for Research & Technology combined a programme to develop wind power electricity plants with a feed-in-tariff, which provided above-market prices for wind power and a 70% tax credit to small producers. The government created long investment time horizons (20 years), twice as long as those in the U.S., creating assurance to investors that reduced the upfront risk of investment. This aggressive public financing push is the most direct support possible for business development, given that all existing demand-side policies assume that a 'dynamic private sector' will readily respond to a call for reduced pollution. While demand-side policies are critical for signalling to the industry that change is needed, they "too often become pleas for change" (Mazzucato, 2018). Supply-side policies for increasing renewable electricity were successful because they incentivised producers to increase production, which in turn, gave technologies like solar the chance to learn about the production process ("learning by doing"). In the case of solar, a niche project for deploying the technology in outer space provided a first use case to kick start the learning process. Once started, a virtuous cycle was created whereby increasing demand and falling prices occurred with more deployment (Roser, 2020).

The Closing the Gap report (Baresic, 2021) questions whether the implementation of one single measure to decarbonise shipping and close the competitiveness gap is even desirable as economists and political scientists increasingly point to the benefits, or even necessity, of a policy mix approach (Baresic, 2021). Grubb et al. (2014), for example, argue that multiple policy instruments are needed for different purposes. For sectors which require innovation to decarbonise such as in the maritime shipping sector, the uncertainty and cost behind the innovations must be addressed which are required to meet the IMO 2050 decarbonisation target. Existing evidence (EEA, 2017) refers to a 'chicken and egg' problem whereby no shipowner wants to invest in abatement options, such as alternative fuel technologies, until other actors, such as ports, put in place the supporting infrastructure. However, ports may not want to invest in the supporting infrastructure until the demand can be credibly demonstrated.

Supply-side policies such as tax credits, subsidies, loans, grants etc. support the technologies that complement and provide a solution to demand-side policies. One of these policies mentioned in the EU's proposal is the use of Carbon Contracts for Difference (CfD), which offer investors in innovative low-carbon solutions a fixed price to reward CO2 reductions above that which would be stimulated by the ETS price. A CfD is a type of subsidy, which could be used to stimulate investment in low carbon fuels infrastructure. CCfDs have been a successful policy to increase the renewable electricity supply in the UK. In this context, potential generators of electricity bid for contracts to supply renewable electricity and contracts were awarded based on the lowest price bid. Generators who win the CfD contract are guaranteed a premium above the market "reference" price of electricity based on the difference between their bid (strike price) and the reference price which changes based on supply and demand in the market. Clark et al. 2021 put forward two proposals for a shipping specific CfD – a fuel-only CfD and a TCO CfD for delivering a net-zero-carbon vessel. They find that the fuel-only CfD is the most viable option complemented by sufficient CapEx support. The fuel-only CfD could be administered to fuel suppliers or shipping companies.

Although the wind industry has had success with CfDs, there was already an established market for renewables as a result of the Renewables Obligation (RO) policy. The RO policy kickstarted the market by requiring electricity suppliers to source an increasing proportion of their electricity from renewable sources. Clark et. al. 2020 discusses the issues of introducing a CfD policy without a market established for zero-carbon fuels. The uncertainty about the costs of SZEFs could cause bidders to under or overestimate the strike price, leading to higher costs for bidders or the government compared to a more stable market. It is therefore important that any subsidy policy is considered within the context of the industry and its stage in the low-carbon energy transition. It may therefore be appropriate to fund specific projects, which kick start the learning process, though more research is needed to conclude on the appropriate supply-side policies.

Section 3.2.6 discussed the implications of revenue recycling in terms of lowering the carbon price required to close the gap between fossil fuels and SZEFs. If the EU ETS revenue were re-invested back into the maritime sector for zero carbon fuels, the required carbon price would be lowered to $87/tonne-CO2, reducing the gap to $65/tonne-CO2. For some ship types that have a higher intra coverage, the gap would be much smaller – e.g., for Ferry Ro-Pax, which has an effective global carbon price of $70/tonne-CO2.

Achieving an equitable transition is the best way to accelerate decarbonisation. If the EU use ETS to stimulate their commercial advantage relative to rest of the world and then sell their technology to the developing countries, whilst taxing trade from/to developing countries, there is a risk of losing credibility in the multilateral negotiating space and globally. Therefore funds should be earmarked, not only for stimulating innovation and supply-side production, but also for addressing disproportionately negative impacts on states and enabling a fair, equitable and inclusive transition as discussed in Section 4.2.4.1.

5 Concluding remarks

The need for further decarbonisation policy in shipping is clear. To meet the IMO's Initial Strategy goal of at least 50% reduction in GHG emissions by 2050 and be aligned with the Paris Agreement, zero emissions vessels must be entering service by 2030, while owners of fossil-fuel ships operating during the 2020s need to consider the climate risk of a transition to a low carbon economy by maximising the energy efficiency of their vessels and switching to zero emissions fuels in the 2030s (Lloyds Register and UMAS, 2019) to avoid locking in fossil-fuel assets which need to be written off balance sheets ('stranded assets').

The EU Commission's proposal to include shipping in the EU ETS, which would cover maritime carbon emissions from intra-EEA voyages and half of the emissions from extra-EEA voyages (the "**Extra50**" scope), is part of a wider policy package that besides maritime ETS includes a 'Fuel EU' standard for the GHG intensity of shipping fuel. While there is a growing recognition that a combination of multiple climate policy instruments may be needed for shipping's transition to zero carbon fuels (Grubb, 2014; Mazzucato, 2018; IMO, 2021), this study focused on assessing some of the economic impacts most pertinent for understanding the potential for the EU ETS to reduce international emissions and stimulate investment in Scalable Zero Emissions Fuels (SZEF). In light of the economic and climate impacts and the proposed policy design, it assessed the policy against the IPCC's effective decarbonisation policy criteria and discussed the elements needed to contribute to the decarbonisation of global shipping outside of the EU. The impact of other EU policies and potential future non-EU regional carbon policy scenarios were therefore not considered.

A regional carbon pricing policy such as the ETS with Shipping could be useful in helping at least a subset of international shipping, as well as for EU domestic shipping, to progress its required transition. But EU policy, and in this report's focus, EU ETS, needs to have its design improved to better achieve the required outcomes (maximise energy efficiency, stimulate the uptake of SZEFs and minimise carbon lock-in in the shipping industry). These design elements include a high enough effective carbon price or a strong supply-side policy that recycles an adequate amount of the ETS revenue raised from shipping carbon allowances back into the sector to create a SZEF market. Without these design features, it will be left to national governments to create the zero-emissions fuel infrastructure needed to kickstart the international zero emissions fuel market.

The carbon price level and the inclusion of all GHG pollutants (e.g., in CO2-equivalent terms) is crucial for determining what abatement technology becomes cost efficient (on a $/tonne basis) and for avoiding 'carbon lock-in'. To maximise the uptake of energy efficiency technologies, there is a need for policies such as carbon pricing that price carbon at a high enough level of around $120/tonne-carbon (2018 prices) to stimulate uptake of these improvements based on MACC analysis (Smith et al., 2019) due to the existence of market failures and barriers that inhibit both operational and technological improvements in international shipping fleets to the extent that would be expected under rational expectations.

However, decarbonisation cannot occur without a transition away from fossil fuels (UNEP, 2020). To meet even the IMO's minimum GHG reduction requirements, a market for SZEFs and zero-ready ships must be created. In order to achieve the lowest ambition of the IMO's Initial GHG Strategy – i.e., reduce ships' GHG emissions by 50% by 2050 compared to 2008 - an average carbon price of US$173/tonne CO2 would be needed starting in the 2020s (Baresic et al., 2021). To fully decarbonise shipping by 2050, the average carbon price would only need to be slightly higher: around US$191/tonne CO2.[21] This price is broadly consistent with the cost-effectiveness from the MACC analysis, which ranges between $150-$272 (2018 prices).

The majority of EEA-related emissions (e.g., voyages with an EEA port) come from ships which trade globally. Therefore, when the annual trading pattern of ships that trade with the EEA is taken into account, the average effective global carbon price reduces significantly. For example, under a $103/tonne-CO2 price scenario in 2030, the average effective global price reduces to $22/tonne-CO2 or about 20% of the ETS price level because the majority of EEA-related emissions come from ships which spend a relatively short period of time on EEA-related voyages during the year. This translates into a $69/tonne bunker price premium when considered as a weighted average across all ship types. When compared to a business-as-usual environment, only ships which primarily trade within the EU have an effective bunker price that exceeds a BAU bunker price environment in which there is low implementation of operational and technological improvements. Therefore, at this overall carbon price level, there is not a strong business case for investments in abatement technology (e.g., energy efficiency technologies) or SZEFs and therefore there would be no material impact on emissions beyond speed reduction on EEA-related voyages.

[21] Both scenarios assume no revenue is recycled from the carbon price in the form of subsidies to the sector.

There is a range of speed reductions of that could occur as a result of higher effective bunker prices. Based on a literature review and case study analysis, a $100/tonne carbon price is likely to reduce speed in the range of 2-10% and 3-17% for emissions. Assuming linearity, a $22/tonne carbon price would lead to a <1-4% reduction in emissions and therefore almost all abatement will come from out of sector.

Whilst environmentally and cost-effective in near term when abatement is considered across all sectors in the ETS, the low effective global carbon price may lead to carbon lock-in of LNG-propelled assets. Furthermore, the ETS' exemption of methane emissions, exacerbates the preferential treatment of LNG-propelled ships, which emit methane but have lower carbon emissions relative to HSFO ships and therefore are only marginally better at best than HSFO ships, would create resistance to transition to SZEF because of the sunk investment costs. The uptake of LNG-propelled ships therefore has several unintended consequences for both the environmental and cost-effectiveness of the policy over the time period required to decarbonise shipping.

As a result of almost all abatement occurring out of sector, a significant amount of revenue will be raised from the ETS with Shipping. Assuming a $103/tonne carbon price (87 euros) by 2030 and an emissions baseline of 2018 (i.e., no reductions), the total revenue generated from shipping would be 9 billion in the Extra50 scope and 14 billion in the full MRV scope (Extra100). The revenue recycling feature of the ETS adds a layer of potential for the ETS with Shipping to be economically efficient by having the revenue created by the mechanism channelled towards decarbonisation and addressing disproportionate impacts on non-EU trading partners.

The ETS with Shipping therefore has a much greater potential to create a cost-efficient transition to SZEFs by recycling more of these funds for supply-side policies (e.g., tax credits, subsidies, loans, grants) in the short timescale needed to ensure zero emissions vessels are entering service by 2030. More research is needed to conclude on the appropriate supply-side policies for the early stage of zero carbon fuels (e.g., specific grants for public-private partnerships of fuel projects and CfDs) to maximise private sector investment. Equally, with its current revenue and funding structure, the revenues generated in part relate to trade with non-EU countries but are collected in an EU centric fund, which raises an issue around the capacity of the ETS to support fair, inclusive and equitable transition.

From a more global perspective, there has been criticism that this proposal is an extra-territorial tax on trade, constituting diplomatic overreach and could affect the trading costs between EU and non-EU trading partners (Thompson, 2021). Shipping is a global industry and therefore benefits from global regulatory mechanisms capable of decarbonising the industry while supporting Small Island Developing States (SIDS) and Least Developed Countries (LDCs), avoiding or addressing disproportionately negative impacts on States and ultimately stimulating an equitable transition. By generating revenues from global trade servicing the EU and recycling revenues within the EU, shipping's inclusion in the EU ETS risks increasing existing inequalities between the EU and the rest of the world especially the Global South. If revenues are not deployed to assist the decarbonisation of international shipping more generally as suggested in Section 1.2.5, but instead go to other purposes within the EU, this risk increases further. This is important to the perception of the EU and its ability to help the IMO reach a consensus on a global policy. The negative perception risk is further heightened if the EU member states do not support policy at the IMO that generates revenue or limits uses of revenue to in-sector purposes – e.g., if this remains in contradiction to the design of shipping's inclusion in EU ETS.

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Appendix A Parameter values used for Capesize speed case study

Spot freight rate ($/tonne)	14.3
Quantity demanded (tonnes)	201,334
Design speed	14.6
Tonnes per day fuel consumption	84
Distance	8966
Port days	2