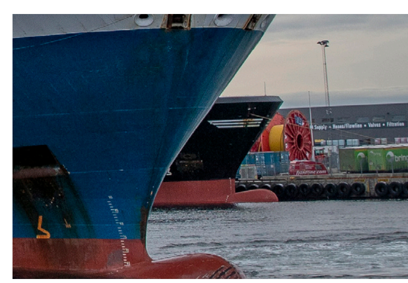
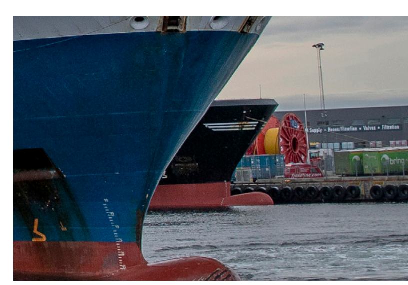
Carbon Pricing in Shipping



Case-Specific Policy Analysis

Carbon Pricing in Shipping



Case-Specific Policy Analysis

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Abbreviations and acronyms

CII	Carbon Intensity Indicator
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
EC	European Commission
ECTS	Emissions cap and trade system
EEDI	Energy Efficiency Design Index
EEXI	Energy Efficiency Existing Ship Index
EP	European Parliament
ETS	Emission trading system
EU	European Union
GHG	Greenhouse gas
GT	Gross tonnage
HFO	Heavy fuel oil
ICS	International Chamber of Shipping
IMO	International Maritime Organization
LCA	Life cycle analysis
LDC	Least developed countries
LNG	Liquified natural gas
MEPC	Marine Environmental Protection Committee
MRV	Monitoring Reporting and Verification
NAP	National action plan
NDC	Nationally Determined Contributions
NO_x	Nitrogen oxides
RD&D	Research development and deployment
SEEMP	Ship Energy Efficiency Management Plan
SEU	Ship emission units
SIDS	Small Island Developing States
TTW	Tank-to-wake
UNFCC	United Nations Framework Convention on Climate Change
VLCC	Very large crude carrier
WTW	Well-to-wake

Executive summary

What we did

This report reviews the effectiveness of carbon pricing, how it might be applied to the shipping sector and with what effects. It also evaluates recent proposals by countries to introduce a price on shipping's carbon emissions and examines related policy issues. The analysis draws on interviews and exchanges with stakeholders and experts who participated in the ITF's Common Interest Group on Decarbonising Shipping from June 2021 to November 2022.

What we found

The lack of commercial viability of zero-emission ships is a significant challenge for decarbonising maritime transport. A price gap between conventional and zero-emission ship fuels hinders the adoption of known and sometimes available technological solutions. The result is a bottleneck for the uptake of zero-emission energy sources for ships. A price on shipping carbon could help bridge the gap and accelerate deployment by making conventional ship fuels more expensive and zero-emission fuels and energy sources competitive.

Worldwide, 68 generic carbon pricing schemes exist on supra-national, national and sub-national levels. They cover around 23% of global greenhouse gas emissions, according to the World Bank. Only one scheme, Norway's national carbon tax, encompasses emissions from maritime shipping. Studies indicate that carbon pricing on its own is often insufficient because prices are too low to trigger full decarbonisation. They are most effectively applied in tandem with other instruments, such as regulations and standards. Carbon pricing schemes can generate significant revenues and thus provide funds for investing in zero-emission technologies and infrastructure. These could have a long-lasting impact by lowering the costs of zero-emission shipping.

Circumstances are favourable for a productive global discussion on carbon pricing for shipping. At a regional level, the European Union (EU) is advancing its proposal to include shipping in the EU emission trading system (ETS). At the global level, a growing number of countries and shipping industry stakeholders consider carbon pricing a promising measure to decarbonise the sector.

These developments make it more likely to reach a global agreement on carbon pricing in shipping at the International Maritime Organisation (IMO). Five proposals for global carbon pricing schemes for shipping have been submitted to the IMO: levies, a "feebate" system, an emission trading system for shipping and a reward/penalty system. In addition, there has been a proposal for a maritime fuel standard. Despite differences in approach, there are also considerable overlaps and possible complementarities among the proposals.

Full decarbonisation of maritime shipping by mid-century will require building a substantial number of vessels capable of operating on zero-emission energy sources in the coming years. To stay on a clear decarbonisation pathway, an immediate transition to zero-emission ship fuels is preferable to including an intermediary phase in which vessels run on low-emission fuels before switching to zero-emission propulsion systems. Carbon pricing mechanisms could encourage such leapfrogging through adequate support for emission-free fuels or other clean energy sources.

Mitigating the negative impacts of carbon pricing and facilitating an equitable transition is the key to securing an agreement at the global level. Directing some of the revenues from a shipping carbon pricing scheme towards broader climate change mitigation and adaptation appears to be a way forward.

What we recommend

Introduce carbon pricing in shipping as part of a broader set of decarbonisation measures

A global carbon pricing scheme for shipping would accelerate the decarbonisation of maritime transport. Such a scheme should combine elements of the five different carbon pricing proposals put forward to the IMO. Regulatory instruments such as technical design requirements for ships and a low-emission fuel standard should accompany it.

Consider designing a carbon pricing mechanism for maritime shipping as a "feebate" system

Under a “feebate” system, all ships emitting greenhouse gas emissions pay a levy that is used to subsidise zero-emission fuels and energy sources. Ships operating with zero emissions receive a rebate that covers the price difference between conventional fuels and zero-emission fuels or energy sources. This rebate is funded by increased levies for vessels that still burn fossil fuels. In this way, the “feebate” system incentivises operators to adopt emissions-free energy sources early while burdening late movers with higher costs and increasing pressure to convert. The “feebate” system should be introduced as soon as possible.

Complement carbon pricing with a technical design requirement and a low-emission fuel standard

Governments should agree on a technical design requirement for “zero-emission readiness” for new vessels. This standard would require all new vessels to be capable of running on zero-emission fuels or other zero-emission energy sources. Governments should also consider introducing a low-emission fuel standard that would become progressively stricter and so help to phase out fossil fuels in shipping.

Use carbon pricing revenues from maritime shipping to facilitate an equitable transition to zero emissions

A substantial share of revenues from the carbon pricing mechanism would need to be reserved for general climate mitigation and adaptation projects in Small Island Developing States (SIDS) and least developed countries (LDCs), including projects related to decarbonising maritime transport. Using carbon-pricing revenues in this way helps balance potentially increased transport costs and negative impacts on trade. Retrofitting ships to make them zero-emission ready or adapting port infrastructure to accelerate the uptake of zero-emission energy sources are other potential uses.

Make sure that these pricing schemes and standards cover well-to-wake emissions

Well-to-wake covers emissions from the entire process of fuel production, delivery and onboard use. The well-to-wake life-cycle view of greenhouse gas emissions in shipping will maximise emission reductions. Moving to a well-to-wake basis requires reliable data on emissions from the entire energy production process of alternative ship fuels.

The decarbonisation imperative

The planet is in a state of climate emergency. In 2022 alone, climate change resulted in a range of catastrophic weather events. Extreme weather is expected to worsen as global temperatures rise. In 2022, the average temperature rise above pre-industrial levels was around 1.2°C. At the current rate of greenhouse gas (GHG) emission increases, the world will likely reach a 1.5°C-temperature rise by the early 2030s, and most likely before then (IPCC, 2021).

Maritime transport is a significant emitter of greenhouse gases. Shipping's annual GHG emissions increased by 9.6% in 2018 compared to 2012. In 2018, the shipping sector – including international and domestic shipping and fisheries – emitted 1 076 million tonnes of GHG emissions (in carbon dioxide equivalent, CO_2e), of which 1 056 million tonnes were CO_2 emissions. This represented 2.89% of the total global anthropogenic CO_2 emissions in 2018. (IMO, 2020)

Maritime transport is also one of the main facilitators of the continuing use of fossil fuels. The transport of fossil fuels accounts for around one-third of maritime transport volumes: 11% is coal transport, 16% is crude oil and 5% is gas (UNCTAD, 2021). In addition, maritime transport has allowed developed economies to outsource manufacturing to developing countries – hence pushing a significant share of their emissions to developing countries.

Decarbonising maritime transport is necessary for mitigating the global climate emergency. However, there are no indications that maritime shipping's emissions have peaked. According to the International Maritime Organization's (IMO) *Fourth IMO Greenhouse Gas Study*, shipping's CO_2 emissions are expected to grow by up to 50% by 2050, depending on assumptions of future maritime trade growth (IMO, 2020).

Reducing shipping's emissions: Strategies and measures

The IMO is the international organisation mandated to develop international regulations for the shipping sector. This includes measures to reduce GHG emissions from international shipping. This role was explicitly mentioned in the 1977 Kyoto Protocol and is left implicit in the 2015 Paris Agreement. One of the legal instruments at the disposal of the IMO is the International Convention for the Prevention of Pollution from Ships (MARPOL), adopted in 1973 and amended several times since (IMO, 2022). In particular, Annex VI deals specifically with air pollution from ships.

The "Initial IMO GHG Strategy on Reduction of GHG Emissions from Ships" (IMO, 2018), adopted in 2018, lays out the direction towards decarbonising international shipping. It sets out the vision, levels of ambition, guiding principles and a list of candidate measures to reduce ships' GHG emissions. The levels of ambitions in the Initial IMO Strategy cover the carbon intensity of an individual ship, the carbon intensity of international shipping and the absolute GHG emissions from international shipping. The level of ambition related to absolute emissions is to reduce the total annual GHG emissions by at least 50% by 2050 compared to 2008 (IMO, 2018). The Initial IMO Strategy provides a timeline for three types of candidate measures: short-term, mid-term and long-term.

The current global measures aim to improve ships' energy efficiency. Since 2015, all newly delivered ships must meet a minimum design energy efficiency standard – the Energy Efficiency Design Index (EEDI). The EEDI regulation requires that new ships meet minimum energy efficiency levels based on the ship type and size segment. These energy efficiency levels become more stringent every five years (ITF, 2020a). At the same time, the IMO also introduced voluntary guidance on the operational efficiency of ships, the Ship Energy Efficiency Management Plan (SEEMP). These voluntary measures apply to both new and existing ships and aim to improve energy efficiencies via operational measures such as optimising routes and speeds (ITF, 2020a). However, the emission reduction impacts of these measures are fairly limited.

Since the adoption of the Initial IMO Strategy in 2018, other measures have been adopted. The EEDI reduction factors became more stringent so to accelerate the expected emission reductions from energy efficiency. IMO members agreed on two additional measures in 2021: the Energy Efficiency Existing Ship Index (EEXI) and the Carbon Intensity Indicator (CII). EEXI is a technical requirement that aims to improve the energy efficiency for existing ships that are in service. The CII consists of a set of operational carbon intensity reduction requirements. The idea of the measure is that ships are rated according to their carbon intensity on an A to E scale: A indicates a major superior performance level; B, a minor superior performance level; C, a moderate performance level; D, a minor inferior performance level; or E, an inferior performance level. If a ship is rated D or E for three consecutive years, its owners must submit a corrective action plan to improve the rating to at least C. Administrations, port authorities and other stakeholders could provide positive incentives to A- or B-rated ships (IMO, 2020c). The EEXI and CII measures will likely be insufficient to reach the Initial IMO Strategy's ambition levels. It is particularly doubtful they will reduce the total annual GHG emissions by at least 50% by 2050, compared to 2018. CII reduction post-2026 has not been adopted yet.

Some countries have developed national shipping decarbonisation policies. Nineteen of the 194 Nationally Determined Contributions (NDC) mention maritime transport or define concrete measures to decarbonise maritime transport (ITF, n.d.). Most countries that mention maritime transport in their NDCs come from Asia, Pacific Island States and Sub-Saharan Africa, according to the ITF's Transport NDC Tracker (ITF, n.d.). The Initial IMO GHG Strategy lists developing national action plans (NAP) to deal with the decarbonisation of international shipping as a short-term candidate measure. Moreover, IMO's Marine Environmental Protection Committee (MEPC) adopted a resolution in 2020 to encourage member states to develop and submit voluntary National Action Plans to address GHG emissions from ships; the resolution included a number of areas that such NAPs could cover (IMO, 2020b). Seven countries have submitted a national action plan to the IMO: Finland, India, Japan, Marshall Islands, Norway, Singapore and United Kingdom. The main policy measures in these NAPs relate to research and development, demonstration projects and capacity building.

Supra-national organisations, such as the European Union, have also developed strategies for decarbonising maritime shipping. The EU's Fit for 55 package is an overarching strategy to reduce GHG emissions by 55% by 2030 compared to 1990 levels. Five of the Fit for 55 proposals have an impact on CO_2 emissions from shipping (European Council, n.d.):

- The inclusion of shipping in the EU emission trading system (ETS) which would mean that GHG emissions from ships that call at EU ports would start to be priced. This measure will be discussed in more detail in later sections.
- A new regulation on sustainable maritime fuels, called FuelEU Maritime. The proposal is essentially to introduce annual average targets for the GHG intensity of energy used by ships. These reductions would start in 2025 with a 2% improvement compared to a 2020 baseline. Requirements would become increasingly stringent over time, with a 6% improvement required

in 2030 and an improvement in 2050 that would lead to a 75% cut in reductions compared to the baseline. This fuel standard would apply to all energy used on board ship voyages between EU ports and to 50% of the energy used for voyages between EU and non-EU ports.

- A revised directive on alternative fuels infrastructure that aims to raise the availability of liquified natural gas (LNG) by 2025 and shore-side electricity in main EU ports by 2030.
- A revised directive on energy taxation that aims to end the tax exemptions for conventional marine fuels and incentivise the uptake of alternatives.
- A revised renewable energy directive (RED III) that sets up the new EU economy-wide target of a share of at least 40% of energy from renewable sources by 2030 and a new target of GHG intensity reduction of at least 13% by 2030 in the transport sector, including shipping.

The potential role of carbon pricing and fuel standards

There are various potential challenges to decarbonising maritime transport. These include access to technology, the commercial viability of new technologies, renewable energy production, on-shore infrastructure for alternative transport fuels and transition costs.

Full decarbonisation of maritime shipping requires that:

- zero-emission fuels are available at scale
- all ships have access to these fuels
- there is demand for zero-emission fuels and related on-board technology so both are commercialised
- there is sufficient production and onshore infrastructure for refuelling or recharging and
- there is some mitigation of transition costs related to zero-emission shipping.

The greatest barrier to zero-emission shipping is the lack of commercial viability (Netherlands and OECD, 2021). A basket of measures, including carbon pricing in shipping, could resolve zero-emission shipping's lack of commercial viability. Certainty of demand will create supply. Creating a market for zero-emission shipping – stimulating commercial viability – will, in turn, drive the resolution of other barriers to zero-emission shipping (Baresic et al., 2022):

- Decarbonising technologies will only develop or mature if there is a market for zero-emission shipping or a credible perspective that a substantial market will emerge shortly. There will be no market if shipowners and operators find conventional shipping operations more attractive (cost less) than zero-emission shipping operations.
- Zero- or low-emission shipping will require onshore infrastructure. However, the presence of onshore infrastructure alone will not spur zero- or low-emission shipping unless it comes with an obligation to use it. This is, for example, the case in the US state of California, where ships are obliged to use the onshore power facilities installed in its ports (ITF, 2020). Ideally, investment in low-emission ships takes place simultaneously with investment in the appropriate onshore infrastructure; for example, in Norway the simultaneous government subsidies for battery-powered ships and electric charging systems in ports have facilitated the quick uptake of battery-powered ships there (ITF, 2020). The costs for shore-based infrastructure are estimated to be

almost seven times higher than the costs for on-board infrastructure (Krantz, Sogaard and Smith, 2020).

- Transition costs can be mitigated with new revenue sources from carbon pricing.

Carbon pricing is controversial. Some countries fear that carbon pricing will affect the prospects of their fossil fuel industries. Others fear potential price impacts on imported and exported goods.

Nevertheless, there seems to be growing momentum for introducing carbon pricing in shipping. Several industry leaders and representative organisations have come out in favour of carbon pricing schemes for shipping. Various countries have submitted proposals for carbon pricing schemes for shipping. The need for renewable energy to produce zero-emission ship fuels creates potential economic opportunities for various countries. In addition, impact studies have shown the trade effects to be limited, as will be elaborated later in this report. Despite what seems to be emerging support for the principle of carbon pricing in shipping, the momentum is fragile.

In that context, it is very important to get the design and process right. This report aims to contribute to the emerging global debate by assessing the merits of carbon pricing, analysing current proposals and addressing policy issues relevant to its effective introduction.

Carbon pricing: What it is and how it works

Climate change presents the largest potential for market failure from an economic standpoint (Stern, 2006; Stiglitz et al., 2018). Carbon pricing corrects that market failure by pricing the social costs of carbon, which are the negative externalities related to the use of fossil fuels, including the damages that result from emitting additional carbon dioxide into the atmosphere. If the social costs of carbon were fully priced, producers would have a stronger incentive to invest in low-emission production factors. Similarly, consumers would have a stronger incentive to buy low-emission products. The social costs of carbon – the economic damage of emitting one additional tonne of carbon dioxide into the atmosphere – have been calculated to be in the range of USD 44 to USD 805 per tonne of CO_2e (Rennert et al., 2022; Ricke et al., 2018).

Carbon pricing can have short-term and long-term effects. The short-term effects of carbon pricing are related to operational changes in existing assets, e.g. a switch within a power plant fleet from coal to gas power (Vogt-Schilb, Meunier and Hallegatte, 2018). Longer-term effects are when carbon pricing triggers investments in new low- or zero-emission assets or when it induces innovation in new low- or zero-emission technologies or practices.

Conceptually, there are two principal ways to design carbon pricing: a carbon tax (or levy) or emissions cap-and-trade schemes (or emissions trading systems). Under the carbon tax, there is a set carbon price but no decreasing limit on emissions – although the carbon price provides incentives for emissions to fall and can be adjusted to meet climate targets. Under emissions cap-and-trade schemes, there is an established maximum cap on emissions that will decrease over time, but the price of carbon emissions can fluctuate. In other words: carbon taxes ensure the price, whereas emissions cap-and-trade schemes ensure the quantity (Green, 2021).

There are conceptual merits for both measures. Emission trading provides governments with certainty over emission reductions, which cannot exceed the cap. Emission trading is thus an effective measure, provided that the emissions cap is well calibrated and initial allowances are auctioned instead of provided freely to companies. The downside of emission trading systems is their administrative complexity; they require a lot more investment in design and human capital. In addition, their price volatility may delay investments in green technologies and zero-emission systems. In comparison, carbon taxes are simpler to design and implement and reduce uncertainty over carbon prices.

In practice, the distinction between carbon taxes and emission trading schemes is sometimes blurred (Hepburn, 2006). This is the case, for instance, when a form of price regulation – e.g. a maximum and minimum carbon price – is introduced in emission trading systems to limit price volatility.

Theory favours a global universal carbon-pricing scheme that covers all sectors. Including as many sectors as possible would increase the potential allocative efficiency of the market mechanism. At the same time, including sectors with very different levels of abatement potential into the same ETS could make it difficult to achieve emission reductions from all, which is essential for a successful transition to net zero emissions. In addition, including many sectors with very different abatement potential has given rise to offsetting schemes (e.g. tree-planting schemes to compensate for aviation emissions) that have, in many cases, proved ineffective.

Ideally, considering that various sectors compete beyond country borders, carbon pricing schemes should be global. Global carbon pricing schemes limit the opportunity for shipping companies to evade the carbon pricing scheme, which would result in carbon leakage (wherein entities may evade paying carbon prices or carbon taxes in a jurisdiction with a carbon pricing scheme by moving operations into a jurisdiction without one). A second-best option would be to link national or sub-national carbon pricing schemes to each other, resulting in a network of stitched-together carbon pricing schemes. That said, carbon prices are likely to continue to differ substantially across countries and sectors.

Overview of existing carbon pricing schemes

In 2022, 68 carbon pricing schemes were operational worldwide. Thirty-seven of these were explicit carbon taxes, and 34 were emission-trading schemes (WB, 2022). The 68 carbon-pricing schemes covered around 23% of global GHG emissions in 2022, and their revenues reached approximately USD 84 billion in 2021 (WB, 2022). In addition, almost all countries levy fuel excise taxes, which effectively price carbon (OECD, 2022). Fuel excise tax rates on road fuels often exceed carbon tax rates and tradable permit prices. However, their rates are not aligned with the carbon content of fuels and often do not extend beyond fuels used in the road transport and building sectors.

Most of the carbon pricing schemes are implemented at the national level. However, there are also supra-national schemes (the EU ETS) and various sub-national schemes, e.g. in Canadian provinces and territories, Mexican sub-national governments and US states. The oldest schemes are from the Nordic countries and the European Union. Denmark, Norway and Sweden introduced their schemes in the early 1990s. The EU introduced the EU ETS, the world's first compulsory emission trading system, in 2005. People's Republic of China hosts the world's largest carbon market by emissions, whereas the largest carbon market by traded value is the EU ETS.

The price of carbon in these schemes is generally lower than the social cost of carbon and the carbon prices needed to meet climate targets. Only eight carbon pricing schemes had a carbon price of USD 80 per tonne of CO_2e or higher in 2021, the largest of which are the EU ETS and the UK ETS. The highest carbon prices are in the carbon taxes in Uruguay (USD 137 per tonne) and in Liechtenstein, Sweden and Switzerland (all at USD 130 per tonne). Even these carbon prices are on the lower end of the USD 44-805 range of the social costs of carbon calculated by Rennert et al. (2022) and Ricke et al. (2018). Carbon prices have generally risen over time, and various countries have established more ambitious price trajectories for the coming years. However, recent energy commodity price hikes might delay this timing.

There is significant pressure from citizens and businesses to exempt certain sectors from carbon pricing schemes or reduce the schemes' scope. Citizens are most likely to oppose carbon pricing when it impacts the cost of consumer goods, as is the case of fuel prices for private cars. Industries that depend on energy prices and are highly exposed to global trade, e.g. export-oriented commodity businesses, are also sensitive to carbon pricing. A global carbon pricing measure would minimise the effects of carbon pricing on relative competitiveness. Firms that trade in local jurisdictions will be less sensitive to cost changes, so less likely to oppose carbon pricing.

Almost all major carbon pricing schemes include the electricity sector because it is the most inward-looking, the least trade-sensitive and the most manageable through existing regulatory structures. Fewer carbon pricing schemes include industrial sectors because they are more trade-sensitive. Forestry and agriculture are almost excluded from carbon pricing. Although fuel taxes frequently apply to the transport sector, relatively few carbon pricing schemes include transportation (Cullenward and Victor, 2020), where fuel excise taxes dominate (OECD, 2022).

Tax instruments in many political systems require qualified or super-majority votes to pass into legislation. This is not the case for emission trading systems, which is one of the practical political reasons why some jurisdictions choose to introduce ETS instead of carbon taxes. For instance, when the EU did not get universal support for a European carbon tax in the early 1990s, it decided to introduce a cap and trade system.

Does carbon pricing alone effectively reduce emissions?

Surprisingly few *ex-post* impact studies on carbon pricing exist. Green's (2021) overview study of *ex-post* evaluations of the performance of carbon pricing policy found 37 studies that can be considered rigorous, as they isolate the amount of emission reductions attributable to the carbon pricing policy. There are also impact studies that do *not* isolate the effect of carbon pricing; the emission reductions in those studies might be caused by factors other than the carbon pricing policy.

Green's overview study shows that the overall effect on emissions reductions for carbon pricing is quite small: generally between 0% and 2% of emission reductions per year (Green, 2021). Incremental solutions, including fuel switching, enhanced efficiency and reduced consumption of fuels, are driving these modest reductions (Tvinnereim and Mehling, 2018). Such operational shifts are helpful because they rapidly decrease emissions and increase the remaining carbon budget. However, they do not help to reach full decarbonisation. Even in the few jurisdictions with high carbon prices, such as Sweden and Finland, the emission reduction estimates are relatively modest (Shmelev and Speck, 2018; Andersson, 2019; Fernando, 2019; Lin and Li, 2011). The limited effectiveness of carbon pricing might be caused by carbon leakage and the wide-spread use of offsets (Green, 2021). However, these studies were conducted on historical data for periods where carbon prices were very low and free allocation of allowances in emissions trading systems pervasive (OECD, forthcoming).

Carbon taxes appear to perform slightly better than emission trading systems in generating reductions, but the evidence is not altogether convincing. Carbon taxes in European nations have resulted in emission reductions of up to 6.5% over several years; however, countries without a carbon tax reduced emissions faster than those with a carbon tax, suggesting that other policies may have contributed more to reducing emissions than carbon taxes (Haites, 2018). On the other hand, another study found that for every EUR 10 increase in the price of carbon, emissions decrease by 7.3% (Sen and Vollebergh, 2018).

Studies also show that carbon pricing has not resulted in more technological innovation that could drive decarbonisation. Seven studies looked into the effect of carbon pricing on low- or zero-emission investment, according to Liliestam et al. (2021). All seven concluded that carbon pricing did not have an effect on zero-emission investment, and six of them found no effect for low-carbon investment. Liliestam et al.'s (2021) overview study was contested by Van den Bergh and Savin (2021), who identified the study's shortcomings. Their assessment showed "that carbon pricing has had a small but positive and significant effect on low-carbon innovation" (Van den Bergh and Savin, 2021). In response, Liliestam and his co-authors expanded their review and found that carbon pricing has triggered weak innovation increases but "that there is no evidence that carbon pricing has triggered zero-carbon investments" (Lilliestam, Patt and Bersalli, 2022).

The studies describe three main reasons for the limited impact of carbon pricing on technological innovation. First, schemes might have suffered from design and implementation problems, such as over-allocation of certificates leading to a low carbon price and excessive exemptions. Second, other price developments could have masked or eliminated the price signal effect from carbon pricing. Third, other policy instruments, such as renewable energy support schemes, were much better at stimulating rapid innovation and development of zero-emission technology. Other studies agree with the last of these: other measures than carbon pricing seem to have had impacts that are more fundamental to decarbonisation. Particularly substantive GHG emissions reductions are often achieved via regulatory instruments (Cullenward and Victor, 2020; Tvinnereim and Mehling, 2018). These studies on the impact of carbon pricing have important implications for the appropriateness of carbon pricing as a policy measure: the design and introduction of carbon pricing schemes directly impact the schemes' effectiveness.

Carbon pricing schemes: Lessons learned

The extensive literature on carbon pricing seems to converge in many respects. The following lessons from that literature could be drawn that might be relevant for the discussion on carbon pricing in shipping:

- **Carbon pricing schemes have been notoriously difficult to introduce.** Australia, Canada and the United States have faced fierce political fights over carbon pricing, often because many citizens and businesses opposed it. Part of successfully introducing carbon pricing schemes is in the presentation. The schemes' design parameters must be accurate and realistic. Observers also recommend calling carbon taxes "carbon levies". (Carattini et al., 2018; Carattini et al., 2017)
- **Most successful carbon pricing schemes have gradually increased their ambitions.** The Center for Climate and Energy Solutions (C2ES, n.d.) explains, "Economic theory suggests a carbon tax should be set equal to the social cost of carbon, which is the present value of estimated environmental damages over time caused by an additional ton of carbon dioxide emitted today. The tax rate should also rise over time to reflect the growing damage expected from climate change. An increasing price over time also provides a signal to emitters that they will need to do more and that their investments in more aggressive technologies will be economically justified." Carbon prices could increase over a certain period: schemes could provide free allowances and exemptions in the first phase, for example, and withdraw them over time. However, the transition phase with generous allocations and exemptions should not last. Were it to, stringent and effective carbon pricing would never be reached. The EU ETS is an example of a carbon pricing scheme that becomes more stringent and effective over time (Cullenward and Victor, 2020).
- **Carbon pricing should be part of a package of measures**. Studies indicate that carbon pricing alone is often insufficient to reach full decarbonisation. For carbon pricing to be effective, it should be enacted in tandem with other instruments, including regulation, such as fuel standards and technical requirements. (Baranzini et al. 2017)
- **Carbon pricing is a significant revenue-raising mechanism**. Carbon pricing has generated a significant amount of revenue. Countries such as France have used the additional income to invest in zero-emission technologies and infrastructure that could have a positive, long-lasting impact on the climate (Carattini et al., 2018). However, governments must safeguard against the politically-oriented spending of carbon pricing revenues, and there appears to be limited transparency on the impacts of spending programmes for decarbonisation.

Carbon pricing in shipping: Is it applicable?

While carbon pricing schemes are becoming more common, very few cover shipping. The question arises: Can carbon pricing be applied to the shipping sector, or do characteristics of shipping make that difficult or even impossible?

One of the obvious characteristics of shipping is its global reach. Even if some shipping activity is foremost local or regional, the largest part of shipping activity takes place at a global level. So, how could regulators design an effective carbon pricing scheme that does not result in massive evasion? The answer to this question depends on the carbon pricing scheme's geographical scope, who pays the carbon price and who receives the carbon price revenues.

Carbon pricing's geographical scope: When different carbon pricing schemes are applied to limited geographical zones, the risk of evading carbon pricing rises. Attempts at evasion are less likely if the costs of evasion for shipping companies outweigh the benefits of evasion. A global carbon pricing scheme for shipping would provide a level playing field for all taxed entities and eliminate any incentive for evasion. A global measure would require international agreement on the specific terms. Achieving consensus on such terms could result in a lowest-common-denominator scenario and a low carbon price. An alternative but less desirable option consists of a supra-national scheme – for example, at the level of the EU. A supra-national scheme could be linked to regional schemes. However, one must acknowledge that such links are hard to realise. The appropriateness of such a constellation depends on who pays the carbon price and who benefits from the revenue.

Who should pay the carbon price? The overarching idea of carbon pricing is the "polluter principle". In the case of shipping, this would mean that the more polluting ship would pay more. A structure would need to be established that ensures that each ship pays the appropriate carbon price. This could be collected by flag administrations (the marine regulator under which the ship operates), by port state administrations, or centrally by an international institution. It has also been suggested that carbon levies could be collected at the level of ship bunker facilities (Parry et al., 2018). Energy-efficiency depends on both the technological and operational specifications of the vessel. For the technological specifications, the responsible entity is the shipowner. In contrast, the operational specifications fall to the shipowner if the vessel is chartered in the spot market and the charterer if it is chartered in the time charter market.

Who receives the revenues from carbon pricing? If one accepts that shipping activity is predominantly global, it stands to follow that there would be constraints on the amount of revenue that states could automatically claim for themselves. An international institution or mechanism charged with allocating and distributing carbon pricing revenues may be necessary. This could be a mechanism under the auspices of the IMO or another UN organisation (such as the Green Climate Fund under the auspices of the UNFCCC) or a distribution mechanism to allocate carbon revenues to countries (Dominioni and Englert, 2022).

The shipping sector is disintegrated into many different parts. For example, a ship can be owned, operated, managed and crewed by four different companies, each tasked with a different responsibility and having different commercial interests. This makes it difficult to establish who has the most leverage to reduce shipping emissions. It also makes it hard to define which actor should pay the carbon price and what part of it.

Any discussion on carbon pricing in shipping will need to take account of the well-established international principle of equal treatment of ships. This rule of no more favourable treatment, which ensures that all ships – regardless of the flag under which they sail – are held to the same standards, is enshrined in IMO Conventions, including the Marpol Convention. Respecting this principle limits the possibilities for regional carbon pricing schemes, as it discourages regional authorities from introducing a carbon pricing scheme that only applies to ships registered under certain flags.

Shipping facilitates global trade. As such, its character is slightly different from other sectors that compete in global markets. A carbon price for shipping would increase the cost to customers of traded goods transported by sea. For long-distance shipping, there is no real alternative to ships, whereas short-sea shipping might have land-based transport alternatives. One must assume that economies that are farther from export and import markets would suffer more than less remote ones. In turn, their trade-sensitive sectors would be harder hit than those in the parts of the world that are closer to consumer markets. However, historical fuel price fluctuations have shown very few practical impacts. Although one of the objectives of carbon pricing might be to discourage carbon-intensive supply chains, these potential global distributional impacts could present an obstacle to implementing carbon pricing in shipping.

Such discussions on global distributional impacts of measures to decarbonising maritime transport have often become linked to discussions on common but differentiated responsibilities, a principle formalised in the United Nations Framework Convention on Climate Change adopted in 1992. The common-but-differentiated-responsibilities principle acknowledges that every state has a shared obligation to address climate change but also stipulates that this responsibility is differentiated considering that not all states are at similar stages of economic development or have similar mitigation capabilities. Many discussions on decarbonising maritime transport have to deal with reconciling the no-more-favourable-treatment and common-but-differentiated-responsibilities principles. (Aidun, Metzger, Gerrard, 2021; Dominioni, Heine, Martinez Romera, 2018; Psaraftis, Zis, and Lagouvardou 2021).

Various actors could push for carbon pricing in shipping: countries highly exposed to climate change, efficient shipping companies, and countries and companies that might benefit from producing renewable fuels. There are, however, at least three main stakeholders that may oppose carbon pricing in shipping:

- Governments from countries at the periphery of global trade routes may be concerned about the public backlash from potential impacts on trade costs from increases in maritime transport costs. Private citizens are not directly impacted by the costs of maritime transport, unlike those of other sectors. For example, they are highly sensitive to increases in fuel costs for private cars and heating and tend to blame their governments for the rising prices. One can assume that citizens will not raise concerns against carbon pricing in shipping, but their governments likely will, fearing the ripple effect of carbon pricing on trade.
- The shipping industry will generally oppose high carbon prices; high carbon prices in shipping might reduce the amount of global trade, hence the amount of maritime transport. International shipping is highly energy-intensive and trade-sensitive. Carbon pricing only makes sense if the geographical coverage is global – or if carbon leakage effects can be minimised, in the case of regional coverage. There are exceptions within the shipping industry, however, where representatives of some high-profile shipping companies favour high carbon levies for the shipping sector. Some shipping companies might consider carbon pricing an opportunity to increase their

competitive advantage. For instance, if they have already invested in energy-efficient and zero-emission ships, they will be able to adapt to the new situation faster than their competitors.

- Fossil fuel companies also maintain interest in seaborne trade. They charter considerable parts of the dry and liquid bulk fleet and manage to have their governments represent their interests in international fora.

In the design and introduction of carbon pricing schemes, concerns from engaged parties should be addressed, such as the predictability of the policies, scalability of the infrastructure and the technical readiness of zero-emission GHG technologies.

The practice of carbon pricing in shipping

The greenhouse gas emissions from shipping are currently not priced in most parts of the world. Fuels for shipping are generally exempted from taxation, in particular for international shipping, but also for domestic shipping in many countries. Despite the emergence of carbon taxes and emission trading schemes, the shipping sector is generally not included in these schemes, with a few notable exceptions. Finally, there are a few pricing schemes that are applied to the shipping sector, although these schemes do not price carbon emissions but other emissions, such as nitrogen oxide (NO_x) emissions.

Fuel tax exemptions for shipping

Fuels for international shipping are generally exempted from taxation. The reason is that ships could very easily circumvent ship fuel taxation in one jurisdiction by getting ship fuel in a jurisdiction where it is not taxed. So any attempt to tax ship fuel would need international co-operation.

Taxation of ship fuel that is used for domestic shipping is somewhat easier. Consequently, there are several countries that have taxes for domestic shipping, including Canada, Colombia, Switzerland and the United States. Estonia taxes marine fuels used inside its territorial waters (OECD, 2019). The State of California applies a partial exemption of the sales and usage tax (SUT) on ship fuel required to get from California to its first out-of-state destination (ITF, 2019).

The EU aims to facilitate the taxation of fuels for domestic and intra-EU shipping by changing its Energy Taxation Directive. This directive currently states that shipping shall be exempt from taxation on “energy products supplied for the use of fuel for the purposes of navigation within Community waters” and, as such, explicitly forbids taxation of ship fuels (European Council, 2003). As the alternatives to conventional ship fuels, for example electricity, are not benefitting from the same tax exemption, the directive provided a disadvantage for low-carbon technologies and shore power in comparison with conventional fuels. The EU has allowed various member states to provide tax exemptions for electric charging systems for ships, to take away this disadvantage. The revised EU directive on energy taxation being proposed by the European Commission aims to end the tax exemptions for conventional marine fuels, which will reduce the competitive disadvantage for alternative fuels and energy sources.

Carbon pricing schemes that cover shipping

Shipping is not included in the scope of carbon taxes of most countries, with a few exceptions. The carbon tax applies to domestic shipping in Norway. In Norway, the carbon tax rates for inland transport depend on the energy source, with the highest rates for petrol and the lowest rates for heavy mineral oils, such as ship fuels. Since 2018, Norway has applied the standard carbon tax rate also to LNG and liquefied petroleum gas (LPG) for domestic shipping (ITF, 2020).

International shipping is excluded from all emission trading schemes in the world, but domestic shipping is included in some. A notable example is the case of Shanghai. This is one of the Chinese regional pilots on emission trading schemes, introduced in 2013. In the scheme of Shanghai, both ports and domestic shipping are included (ITF, 2020).

Other pricing schemes for shipping

There are examples of pricing schemes for shipping emissions, other than greenhouse gas emissions. One of the most referenced examples is Norway's NO_x Fund. In this scheme, firms that operate ships in Norwegian waters can pay a NO_x fee related to the NO_x emissions of the ship instead of paying the regular NO_x tax. The revenues of the scheme fund innovative projects aimed at reducing NO_x emissions from ships. The rates of payment to the NO_x Fund in 2020 were NOK 10.5 (EUR 1) per kg for the shipping sector. Companies need to report their emissions to the NO_x Fund based on a defined methodology and have them approved by an accredited firm (ITF, 2020). Not only domestic shipowners and operators can apply for this financial support, but also foreign owners that operate their ships in Norwegian waters. For example, various Swedish shipowners indicated that approximately 80% of the additional costs of LNG ships related to equipment were covered by the NO_x Fund (ITF, 2018).

Impacts of carbon pricing in shipping

There are essentially three ways to reduce GHG emissions from shipping: improve energy efficiency (by reducing the energy needed per tonne-mile); use lower carbon-intense fuels (measured in GHG emissions per unit of energy used) and; reduce the demand for maritime transport (the total amount of tonne-miles carried out by the shipping sector). There are different ways to achieve these decarbonising objectives. For example, ships are more energy-efficient when travelling at slower speeds, and shipping companies can deploy more energy-efficient ships and adapt their operations to become more energy-efficient.

Table 1. Decarbonisation goals and possible ways to achieve them

Objectives for decarbonisation	Possible levers
Energy efficiency	Lower ship speed More energy-efficient ships More efficient shipping operations
Carbon intensity	Bridge the price gap between conventional and alternative fuels Advance in zero-carbon technologies
Reduced demand	Shorter shipping routes Fewer goods transported by sea

Carbon pricing could be instrumental in decarbonising efforts. It can make shipping more energy-efficient, spur a transition to less carbon-intensive ship power, and reduce the demand for shipping altogether. Carbon pricing can also influence trade costs, trade flows, carbon leakage and competition. The following assessment of these impacts comes from studies that have modelled the likely effects of introducing carbon pricing in shipping. Currently, there are practically no carbon pricing schemes for shipping. With this in mind, these assessments are not based on real-life experiences and should be interpreted with caution.

Carbon pricing's potential effects on ship speed

Carbon prices could potentially influence a speed reduction for ships, which translates directly into emission reductions (Wang, Fu and Luo, 2015). Studies indicate up to 50% potential emission reductions, depending on the carbon price level and the prevailing fuel price (Table 2).

The effect on ship speed depends on fuel prices. High fuel costs create incentives for slow steaming (sailing at slow speeds), leaving little room for carbon pricing to trigger further speed reductions (Gu, Wallace and Wang, 2019; Giovannini and Psaraftis, 2019). The emission-reducing effects of carbon pricing are more significant if the geographical coverage of the carbon price is global. In the case of regional schemes, ships slow down in the region where a carbon price is applied but make up for lost time by speeding up outside that region. This carbon leakage effect could undo the emission reductions intended by the regional carbon pricing scheme. Carbon pricing might also be the necessary incentive for shipping companies to optimise ship speed and just-in-time-operations via digitalisation and data-sharing between actors within the transport chain.

Slow steaming's potential in liner shipping is limited by the company's commitment to provide a regular service. For them to maintain the same service on a route, additional ships would need to be added if the fleet were to travel below a certain average speed.

Table 2. Studies on the emission-reduction potential of slow steaming induced by carbon pricing

Study	Potential CO_2 emission reductions	Carbon price (USD per tonne CO_2)	Fuel price (USD per tonne)	Ship type
Devanney (2010)	6% 12%	USD 50 USD 150	USD 465	VLCC
Gkonis and Psaraftis (2012)	50%	USD 400-1 000	USD 370-480	VLCC
Psaraftis (2019)	50%	USD 500	USD 500	Containerships
Lagouvardou, Psaraftis and Zis (2022)	43%	USD 400	USD 400	Tankers

Note: VLCC=Very large crude carrier.

Ship speed also depends on charter rates and freight rates. When charter rates are high, operators will sail at high speeds to complete the trip quickly and save costs. Carbon pricing is not very effective. However, when charter rates are low, shipping companies will fully utilise idle ships and slow shipping speeds to save fuel costs. Here, the additional costs of carbon pricing can hardly push the speed to an even lower level (Gu, Wallace and Wang, 2019). Similarly, introducing a carbon levy in periods with high freight rates will have a limited effect on emission reductions in the short term. In these conditions, only a significantly higher levy would counterbalance the profit incentive to sail faster. At low freight rates, ships are often already slow steaming, and the margin for achieving a significant speed reduction – and thus CO_2 emission reductions – is much lower (Lagouvardou, Psaraftis and Zis, 2022).

Carbon pricing and a move to more energy-efficient ships

Carbon pricing could provide incentives for retrofitting ships to make them more energy-efficient and replacing high-energy ships with more energy-efficient ones. In depressed shipping markets, shipping companies tend to store less energy-efficient ships. In such market conditions, carbon pricing incentivises shipping companies to lay up less energy-efficient ships earlier, particularly when bunker costs are high (Zhu et al., 2018). Huang et al. (2015) found that installing a waste heat recovery system is one of the most profitable measures for improving containerships' energy efficiency; carbon pricing in shipping might stimulate the deployment of this measure.

Carbon pricing and the adoption of zero-emission fuels technologies

Carbon pricing schemes could raise the price of conventional fuels to such an extent that zero-emission fuels or energy sources become economically competitive. In that case, the carbon pricing scheme would have bridged the price gap between conventional fuels and zero-emission fuels.

Marginal abatement cost curves (MACC) could help to estimate the carbon price needed to bridge the price gap. A MACC plateaus at a value representing the carbon price required to make zero-emission technologies competitive with conventional propulsion. A carbon price between USD 100 and USD 500 per tonne CO_2 would be necessary to achieve the Initial IMO Strategy's objective of at least 50% absolute reductions in GHG emissions by 2050 (Smith, 2020). Much depends on assumptions. For example, in a hypothetical scenario with ample availability of biofuels, significant absolute reduction emissions could be achieved even at a low marginal cost of carbon (USD 50 per tonne) because it is available at the same price as the fossil fuel equivalent and not dependent on the carbon price to stimulate its uptake (IMarEsT, 2018; Smith, 2020).

The carbon price could be lower than the USD 100 and USD 500 per tonne CO_2 range if the carbon pricing scheme's revenues were used to offset the cost of alternative fuels. Were those revenues fully re-invested in zero-carbon fuels and technologies, the magnitude of the carbon price needed to achieve the level of ambition of the Initial IMO Strategy would drop to between USD 50 and USD 250 per tonne CO_2 (Smith, 2020). Carbon pricing will increase the attractiveness of zero-carbon fuels and, as such, require adjustments in ports, such as zero-carbon fuel bunkering facilities, energy supply infrastructure, potentially to be developed in ports.

The effectiveness of carbon pricing depends to a large extent on the level of the bunker fuel price. Zhu et al. (2018) modelled the impacts of different maritime emissions trading systems. Their calculations show that in scenarios with high bunker fuel prices (up to USD 583 per tonne), even emission trading schemes with loose allowance rules and moderate initial CO_2 prices could motivate an emissions reduction of around 8%. However, CO_2 price increases in low bunker price scenarios (USD 348 per tonne) would not lead to noticeable improvements in emission mitigation. Shipping operators indicate that costs, risks and volatility of CO_2 allowances in existing emission trading regimes are of much less importance to them than bunker costs (Koesler, Achtnicht and Köhler, 2015).

Bridging the price gap might not be enough to stimulate the uptake of zero-carbon fuels. It could be argued that zero-carbon fuels will need to be less expensive than conventional fuels, because shipping companies will have to incur costs related to shifting fuels. For example, for some fuels, shipping companies will have to retrofit or renew their fleets to accommodate these new fuels. The costs for retrofits could be spread out over many years – and investment in new ships usually implies cost savings through enhanced energy-efficiency, but these costs might still constitute a barrier for shipping companies.

Carbon pricing and shipping routes

Higher fuel costs increase the voyage costs of ships. Shipping companies will generally use shorter shipping routes to reach the destination. One can reasonably expect similar results from carbon pricing in shipping: likely raising the voyage cost and potentially changing the shipping routes. For example, were shipping included in carbon pricing schemes, the Cape of Good Hope route would become less attractive than the Suez Canal route. The Cape of Good Hope route between Asia with Europe is much longer than the Suez Canal route, leading to greater fuel consumption and higher carbon emissions. Carbon pricing would thus make this route more costly (Wang et al. 2021). The drop in fuel prices at the beginning of 2020 resulted in more container ships taking the Cape of Good Hope route and, thus, higher GHG emissions.

A more or less similar logic applies to perspectives of Arctic shipping. As the Northern Sea Route is much shorter than the Suez Canal route, carbon pricing makes the Northern Sea Route a more attractive option – despite additional costs related to this route, such as the need to use ice-breaking ships at certain periods of the year. The higher the carbon tax, the higher the cost difference between the Northern Sea Route and the Suez Canal route (Ding et al., 2020).

Carbon pricing and shipping demand

With hardly any carbon pricing schemes in the shipping sector, there is no empirical evidence to illustrate how carbon pricing may change the demand for shipping. However, factual, observable changes in the price of ship fuels provide indications of shipping's price elasticity and a potential means of assessing carbon pricing's impacts on shipping demand due to the rise in fuel costs. Existing studies suggest that the rise in fuel costs (that are likely to result from carbon pricing) could affect, to some extent, the demand for maritime transport of low-value goods.

Price elasticities differ substantially across products and industries, with effects ranging from -0.03 to -0.42 in a study that looked at goods at a highly disaggregated level (Mundaca, Strand and Young, 2021). In general, the largest impacts of carbon taxes on tonne-nautical miles were on low-value goods: products with low trade values relative to their weight. For such products, a global maritime carbon tax of USD 40 per tonne CO_2 would stimulate reductions in tonne-nautical miles (so, more regional trades or less trade), resulting in reductions of carbon emissions in the order of 8.1% for fertilisers, 8.3% for iron and steel, 8.4% for cereals, 10.5% for ores and 11.5% for fossil fuels (Mundaca, Strand and Young, 2021).

Such effects could be more significant for certain parts of the world. For example, the per-unit transport costs for Pacific Small Island Development States (SIDS) are, on average, 6% higher than the rest of the world; they might also face more severe impacts from further increases. An increase of 10% in per-unit transport costs would result in a reduction of exported units of 8.3% to 18.5% for these countries, with particularly considerable impacts on Fiji Exports of coffee were the most sensitive to changes in per-unit transport costs for the region, with a decrease between 20% and 30% for every 10% increase in transport costs. (Rojon et al., 2021)

Carbon pricing, shipping costs and trade flows

A variety of studies analyse the extent to which carbon pricing may increase maritime shipping costs. In an overview of the literature on the subjet, Rojon et al. (2021) showed that – depending on chosen assumptions – carbon pricing would increase maritime freight costs by between 0.4% and 16%.

Increases in maritime transport costs could differ according to the ship segment. In the case of an emission trading scheme in which emission allowances are fully auctioned or partially freely allocated on the basis of a uniform benchmark, Roll-on/Roll-off and Roll-on/Roll-off/Passenger ships would face relatively high impacts due to their high fuel consumption per transport activity, compared to oil tankers and bulk carriers (Christodoulou et al., 2021).

Higher costs for shipping companies do not necessarily translate into higher maritime trade costs for freight shippers. It depends on whether or not the carriers pass those costs on to their customers: the shippers and, ultimately, the final buyer or consumer.

The extent to which a carbon price will be shared between producers and consumers depends on the supply-and-demand balance, specifically, the extent of competition in the market. When market conditions are favourable to shipping companies with high freight rates, a higher share of the carbon pricing scheme's costs can be transferred to shippers. A modelling exercise of a potential fuel tax levy for shipping showed that the cost pass-through rate (the percentage of the levy costs borne by the consumer) would have been 52% in 2007 when market conditions were favourable to the shipping sector, but only 10% in 2013 when conditions were less favourable (Kosmas and Acciaro, 2017). The long-term effects on pass-through from a carbon tax could be expected to be higher than the pass-through from short-term fluctuations in oil prices.

The existing literature seldom considers the general equilibrium effects and the changes in trade flows that could result from carbon pricing in shipping. However, these effects are important. A carbon price raises the cost of importing commodities and, therefore, encourages domestic production. As this import substitution expands production, prices of primary inputs, such as land, labour and natural resources, could rise due to their increased scarcity. This, in turn, could push up the price of exporting commodities. The magnitude of the net impact depends on the overall change in import prices, primary input prices and the commodities' responsiveness to the price change related to carbon pricing (Sheng, Shi and Su, 2018).

The few studies that applied computable general equilibrium (CGE) modelling found that carbon pricing in shipping would have a minimal impact on global trade and production. Carbon pricing in shipping reduces the trade of low-value, high-volume commodities from relatively distant sources while encouraging the trade of high-value, low-volume commodities. However, Sheng, Shi and Su (2018) estimated the impact on real GDP (assuming a bunker emissions charge of USD 18 per tonne of CO_2) at less than -0.5% and demonstrated that less-developed countries would not be disadvantaged with a properly designed revenue distribution mechanism. Lee, Chang and Lee (2013) found that even a high global maritime carbon tax (USD 90 per tonne CO_2) would not lead to significant economic impacts: the highest loss in real GDP was modelled to take place in China, but even there, the reduction in real GDP would be small, around 0.02%. The same study found that a maritime carbon price would discourage distant trade but promote trade with neighbouring countries in Asia and Europe.

A study for the European Commission (EC, 2021) typically found carbon pricing's effects to be much less than 0.1% for most countries and regions. The reason for the relatively small impact is that imports and exports often constitute a small share of GDP, and changes in import and export values are often partly offset by changes in domestic production, consumption and investments. In this study, middle and emerging economies had predominantly net-positive impacts, whereas most Small Island Developing States (SIDS) and least developed countries (LDC) had negative impacts. The most significant net-negative impact among SIDS and LDCs was up to -3% of GDP. (EC, 2021)

Carbon pricing and the potential for carbon leakage

Carbon pricing schemes face the risk of carbon leakage when their coverage is not global and universal, e.g. with regional carbon pricing schemes. In the case of shipping, shipping companies could evade carbon pricing schemes by changing the ship's flag (if the carbon pricing is connected to a country flag) or by changing ports and routing (if the carbon pricing applies to specific ports or territorial waters). Most of the studies on carbon leakage in shipping focus on the possible effects of including shipping in the EU's emission trading scheme (Hermeling et al. 2015; Lagouvardou, Psaraftis and Zis 2020). They will be described in more detail in the following sections. However, it is important to note here that the EU proposal's scope not only includes shipping emissions between EU ports but also 50% of the emissions from voyages from a non-EU to an EU port and 50% of the emissions from voyages from an EU port to a non-EU port.

Studies show mixed assessments on the possibility of carbon leakage from the inclusion of shipping in the EU ETS. According to CE Delft (2022), there are at least seven different ways in which shipping companies could avoid cost increases related to the EU ETS, but the report considers only two of them realistic: adding an extra port call just outside the EU and feeding to EU ports from a non-EU hub port. The report's cost-benefit analysis generally considers the changes in EU ETS costs, container handling costs, fuel costs, charter costs, port costs and opportunity costs. Its general assessment is that the impact of such carbon leakage would be limited (CE Delft, 2022). The *ex-ante* impact assessment for the EU proposal to include shipping in the EU ETS indicated that the potential for shipping companies to engage in evasive port calls is only expected to be significant for options with high carbon prices in 2030 or full geographical scope (100% coverage of voyages from non-EU to EU ports and from EU ports to non-EU ports). It indicates that the risk for evasion could increase with higher carbon prices in 2040 but will likely be mitigated by further decarbonisation policies adopted by countries outside the EU (Pons et al., 2021a, 2021b). This assessment is in line with those from Transport and Environment (2020). A more pessimistic assessment than the three studies cited above finds that evasion via a non-EU hub will become attractive for container shipping operators when the carbon prices in the EU scheme would be well below EUR 25 per tonne CO_2 (Lagouvardou and Psaraftis, 2022).

Carbon pricing and competition

Carbon pricing for the shipping industry could raise competition concerns. Carbon pricing schemes could discriminate against smaller operators, most of which have smaller and older ships and might have less access to allowance trading markets.

There are concerns that carbon pricing schemes could accelerate the trend towards market concentration. Large global carriers have the necessary financial capability to renew their fleets and adapt shipping services. Smaller companies would face the risk of being squeezed out (Franc and Sutto, 2014). This effect could be particularly significant when freight rates are low and the advantage of larger, more energy-efficient ships is more evident (Luo, 2013).

There is also a risk of two-tier shipping markets – with more energy-efficient vessels operating on international routes and less energy-efficient vessels on regional or domestic routes – or secondary markets, likely to be located in developing or emerging economies.

The rate of concentration in the different shipping segments could impact the price of carbon emission allowances in shipping-specific emission trading schemes. When carriers compete more intensively, the emission allowances will be traded at a higher price, as carriers are more geared towards the growth of output and thus require more emission allowances (Wang, Fu and Luo, 2015). It is generally assumed that the container shipping sector will be buyers of emission allowances, as they are more fuel-intensive than the dry and liquid bulk sector. At the same time, the container sector is more concentrated and increasingly so. This loss in competition intensity of buyers of emission allowances could translate into lower emission allowance prices.

Proposals for carbon pricing in shipping

Over the last decades, academics, international organisations, shipping companies and governments have developed multiple proposals for carbon pricing in shipping. This chapter focuses on recent government proposals put forth as part of the IMO's discussion on decarbonising shipping. It also covers the European Union's carbon pricing proposal for shipping and possible initiatives in other parts of the world.

Carbon pricing proposals at the International Maritime Organization

From 2006 to 2013, IMO member countries discussed introducing market-based measures (MBMs) to help reduce GHG emissions in shipping. Eleven different proposals were submitted to the IMO in 2010. These ranged from essentially doing nothing to a carbon levy, emission trading schemes for shipping and various hybrid proposals. In 2010, the IMO installed an expert group to assess the proposals. The resulting report, released in 2010, evaluated each proposal according to specific criteria that included the impacts on trade and developing countries (IMO, 2010). However, the report contained no horizontal comparison of the proposals and no recommendations on which proposals should be further pursued (Psaraftis, 2012). The meetings that followed did not lead to a decision, and the discussions on MBMs were suspended in 2013.

Table 3. Proposals for carbon pricing or fuel standards submitted to the International Maritime Organization, 2021-22

Proposal	Submitted by	Year	IMO reference
Universal mandatory greenhouse gas emission levy	Marshall Islands, Solomon Islands	2021	MEPC 76/7/12
Levy-based market-based measures	International Chamber of Shipping, Intercargo	2021	ISWG-GHG 10/5/2 ISWG-GHG 12/3/7
Zero-Emission Vessels Incentive Scheme	Japan	2022	MEPC 78/7/5
International Maritime Sustainability Funding and Reward mechanism	Argentina, Brazil, China (People's Republic of), South Africa, United Arab Emirates	2022	ISWG-GHG 12/3/9
Emission Cap and Trade System	Norway	2022	ISWG-GHG 12/3/13

Note: The different documents referenced under "IMO reference" are available to delegates of IMO meetings (IMODOCs) on a password-protected part of IMO's website. They are referenced in the Reference section of this report, though they are not publicly available. This report refers to the documents with the names used in IMO meetings, for example: "Argentina et al." refers to the proposal by Argentina, Brazil, People's Republic of China, South African and United Arab Emirates. MEPC refers to IMO's Marine Environment Protection Committee; ISWG-GHG to IMO's Intersessional Working Group on Reduction of GHG emissions from Ships. The IMO reference is the numbering used in the IMO meetings to identify the documents.

Source: Marshall Islands and Solomon Islands (2021), ICS and Intercargo (2021), Japan (2022a), Argentina et al. (2022), Norway (2022).

A decade later, circumstances are more favourable for a fruitful discussion on carbon pricing at the IMO. The Initial IMO Strategy formulates a level of ambition related to GHG emissions from shipping that provides a common base that did not exist ten years ago. The European Union is advancing its own carbon pricing proposal (by including shipping in the EU ETS) that puts pressure on the IMO to move forward on carbon pricing. A growing number of representatives from the shipping industry have called for carbon pricing in the shipping industry, either individually (e.g. Trafigura, 2020) or via organisations like the Global Maritime Forum. The International Transport Forum has hosted workshops on market-based mechanisms for the shipping sector. Finally, a growing number of countries – including many developing countries – consider carbon pricing for shipping a promising measure. The Dhaka-Glasgow declaration, issued during COP26, is an example of the emerging political support for carbon pricing in shipping. In the declaration, 55 climate-vulnerable countries call for "urgent discussion, study and work of the IMO for establishing a mandatory GHG levy on international shipping to ensure that IMO emission measures are fully aligned with a 1.5ºC pathway" (CVF, 2021).

Since 2021, five proposals related to carbon pricing have been submitted to the IMO. These include proposals for global carbon levies (one put forth by Marshall Islands and Solomon Islands and another by the International Chamber of Shipping and Intercargo), a global feebate system (from Japan), a global emission trading system for shipping (proposed by Norway), and a reward and penalty system (by Argentina, Brazil, People's Republic of China, South African and United Arab Emirate and hereby referred to as Argentina et al., in alignment with IMO practice). The proposals are outlined in Table 3. In addition, all EU27 countries, Norway and the European Commission submitted a proposal for a global GHG fuel standard (ISWG-GHG 12/3/3 hereafter referred to as Austria et al., in alignment with IMO practice). This proposal is not a carbon pricing proposal, but will be included in our analysis below, as it is closely related to carbon pricing.

The following sections explain the different proposals. Although there are differences between their approaches, there are also considerable overlaps and even ways for them to complement each other.

Carbon pricing mechanisms

In the proposal by Marshall Islands and Solomon Islands, the carbon price is set at an amount that would create a level playing field between heavy fuel oil and zero-emission fuels. The proposal suggests that a carbon price of USD 250-300 per tonne of CO_2e by 2030 (Table 4) achieves this goal. The proposal also acknowledges that setting this price at the outset is difficult, so it proposes an entry-level of USD 100 per tonne by 2025, with upward ratchets on a five-year review cycle. The suggested mechanism is a levy collected at the point of bunkering (refuelling for ships). All ships pay the carbon levy, but ships that are more energy-efficient or use less carbon-intensive fuels pay relatively less for the same transport activity. The proposal foresees that part of the revenues from the levy will be spent on research development and deployment (RD&D), and suggests that the cost-effectiveness of this could be improved by a feebate mechanism to reward first movers. However, the proposal does not elaborate on this suggestion. (Marshall Islands and Solomon Islands, 2021)

The proposal by the International Chamber of Shipping (ICS) and Intercargo is similar in its basic premise of a global fuel levy. However, it does not indicate the carbon price it wants to set. Its objective is to bridge the price gap, but it also states that "it will be premature to impose a disproportionally high carbon price on shipping". The likely implication of this statement is that the carbon price will not be high enough to bridge the price gap between heavy fuel oil (HFO) and zero-carbon fuels. As a result, the main emission-reduction effect is not likely to come from the carbon price but from how revenue is distributed. The proposal indicates that the revenues from the fuel levy could be used to accelerate R&D and deployment of new bunkering infrastructure. It assumes that this will decrease the price gap between HFO and zero-carbon fuels. (ICS and Intercargo, 2021)

Japan's proposal is an explicit feebate system. It uses revenues from a carbon levy as rebates for zero-emission fuels. In this proposal, the carbon price corresponds to the funds needed to provide enough rebates to zero-emission fuels to make the transition to them commercially viable. The price gap between conventional fuels and zero-emission fuels is then bridged, but since there will initially be few zero-emission ships, revenues from the levy will be limited. Consequently, the rate of the levy can be relatively low initially and then increase with the uptake of zero-emission vessels. (Japan, 2022a)

Table 4. Design mechanisms of proposals submitted to the International Maritime Organization, 2021-22

Proposal	Carbon price	Which ships benefit?	Which ships pay?
GHG levy (Marshall Islands, Solomon Islands)	USD 100 per tonne CO_2e (2025) USD 250-300 per tonne by 2030	Dependent on re-investment of revenues from levy	All ships, according to their CO_2e emissions
Levy (International Chamber of Shipping, Intercargo)	Not defined	Dependent on reinvestment of revenues from levy	Ships according to carbon intensity of their fuels
Feebate (Japan)	USD 56-73 per tonne CO_2 (2025) USD 135-176 per tonne by 2030	Zero emission ships	All the other ships
Reward and penalty system (Argentina et al.)	n.a.	Ships with emissions below reward benchmark	Ships with emissions above contribution benchmark
Cap and trade (Norway)	Market price of cap and trade	Ships with low GHG emissions	Ships with high emissions
Global fuel standard (Austria et al.)	Cost compliance with standard		

Note: Argentina et al. refers to Argentina, Brazil, People's Republic of China, South Africa and United Arab Emirates. Austria et al. refers to all EU27 countries, Norway and the European Commission.

Source: Marshall Islands and Solomon Islands (2021), ICS and Intercargo (2021), Japan (2022a), Argentina et al. (2022), Norway (2022), Austria et al. (2022a).

Japan's proposal contains model calculations showing that a feebate of USD 56 per tonne of CO_2 from 2025-2030 would close the price gap between low-sulphur fuel oil and zero-emission fuels. This would lead to a 17% deployment of zero-emission ship fuels by 2030. At some point, the levy required to finance the rebate would be so high that fossil-based shipping would become impossible. Japan's proposal also considers it necessary to introduce technical requirements, such as mandating newbuild ships and existing ships to use zero-emission fuels. (Japan, 2022a)

The International Maritime Sustainability Funding and Reward mechanism set forth by Argentina and like-minded countries bears superficial resemblance to the Japanese proposal in that the taxes collected from high CO_2 emission-emitting ships are paid to ships that emit less CO_2. The specificity of this proposal, though, is that it uses the IMO Carbon Intensity Indicator (CII) mechanism to define the upper and lower benchmarks. As described earlier, the CII consists of a set of operational carbon intensity reduction requirements wherein ships are rated on an A-E scale according to their carbon intensity. The proposal indicates that the upper benchmark would be the upper boundary of the "C" rating ("moderate performance") in the CII mechanism, and the lower benchmark, the lower boundary of the "C" rating. In normal circumstances, this would roughly mean that ships that are rated D and E would have to contribute to the system, ships rated A and B would get rewarded, and ships rated C would neither contribute nor be rewarded. (Argentina et al. 2022)

However, the proposal mentions that contributions and rewards will be based on a ship's actual annual CO_2 emissions average. This clause provides a loophole in which certain ships could get rewarded even if they are not rated A or B. For example, a ship could be unduly rewarded when it operates in an energy-efficient way, uses LNG or operates with a very low-capacity utilisation (hence realising actual CO_2 emissions below the lower benchmark). Another clause is that the benchmark levels will be adjusted for ships that have consumed "a certain proportion of alternative low/zero-carbon fuels (to be defined in LCA guidelines) and/or has served one or more ports of developing countries likely to be negatively impacted." (Argentina et al. 2022)

The reward rate – the amount of money rewarded per tonne of CO_2 emission reductions below the reward benchmark level – will likely vary from year to year. If a large number of ships were to emit more CO_2 than the upper-level benchmark (and only a few ships emit less than the lower benchmark), the reward rate would be high. In this scenario, there would be a lot of revenue available to reward the ships with low CO_2 emissions. The high reward rate would incentivise shipping companies to invest in decarbonisation. In the proposal, the share of revenues from the system is fixed at 40%; the rest should be used for capacity building, RD&D and administration costs. The proposal provides for a reward ceiling to avoid an excessively high reward rate. The proposal does not specify the benchmark levels and reward rates; it is not clear whether the incentives will be sufficient to phase out GHG emissions from shipping.

Norway's proposal is an emissions cap and trade system (ECTS). Central to the proposal is a cap on emissions that will ensure an annual reduction of total GHG emissions along an agreed pathway aligned with the ambitions of the Initial IMO Strategy and the revised GHG Strategy, still to be agreed upon and slated for adoption in 2023. This cap determines the total amount of allowances available for ships; Norway's proposal calls these allowances ship emission units (SEUs). The annual amount of SEUs made available to ships would be defined for the whole period until 2050. These SEUs would be regularly distributed to ships via auctions. Ships should surrender an amount of SEUs equal to the actual GHG emissions of that ship. These are the verified annual GHG emissions reported via the IMO Data Collection System (DCS). When a ship surrenders the required number of SEUs, it receives a certificate. Ships would not be able to sail without such a certificate; they would be able to resume sailing when they have surrendered the required amount of SEUs and received the certificate. SEUs could be traded freely between ships but valid only for one specific calendar year; unused SEUs would be cancelled after the completion of the calendar year. (Norway, 2022)

The Norway proposal conceives the ECTS as a closed system specific to the shipping sector. However, it indicates that opening the system to other sectors could be considered at a later stage so ships could acquire allowances from outside sources. The Norway proposal suggests price control to avoid large price fluctuations. Norway has indicated that its cap and trade system could be combined with a global fuel standard. Norway has co-sponsored the submission of such a proposal by the EU27 countries and the European Commission (Austria et al., 2022a) referred to in Table 4.

Austria et al. propose a global fuel standard requiring all ships to use fuels or energy sources with a GHG intensity below a specific limit value. GHG intensity is here defined as GHG emissions per unit of energy used onboard a ship (Austria et al. 2022a). The global fuel standard would be strengthened over time to decrease the GHG intensity of ship fuels in line with the Initial IMO Strategy or a stronger ambition, such as phasing out GHG emissions in maritime fuels by 2050. In the proposal, shipping companies would need to monitor the GHG intensity of the fuel their ships consume and demonstrate compliance with the global fuel standard to their administration. The administration would issue a document of compliance for compliant ships, which would be retained onboard. The proposal does not specify which administration would issue the compliance document. The proposal anticipates a transitional period, during which not all ships may be capable of sailing on low- and zero-GHG fuels, and proposes “flexibility mechanisms” to deal with this situation. The two flexibility mechanisms identified are: 1) surplus rewards for overachievers that could be transferred to non-compliant ships or carried over to the next year, and 2) paying a higher price than the price differential to an IMO GHG fund to avoid non-compliance.

How carbon pricing mechanisms can develop over time

Global fuel standards must develop over time to ensure that the emission pathways are declining. Austria et al. propose GHG fuel intensity reductions that decrease by five-year increments. For example, in a high-ambition scenario, the fuel GHG intensity relative to 2008 would need to have decreased to at least 95% by 2025, 85% by 2030, 70% by 2035, and so forth. The degree by which GHG intensity must drop per five-year period has not been defined in the proposal.

Similarly, in cap and trade systems, the system is designed so that a declining cap ensures emission reduction. Norway’s proposal indicates that the cap should be established every year and decrease in accordance with the pathway outlined by the Initial IMO Strategy and the pending 2023 Revised Strategy. The proposal also envisages a gradual phase-in of the costs related to the scheme, implementing a unit price ceiling that will gradually increase. This phase-in method is preferred over the free allocation of SEUs, free market pricing, and reducing the emissions subject to the cap-and-trade system.

Japan’s proposal presumes a step-based increase of the carbon price so the revenues of the carbon levy minimise the price gap between conventional and zero-emission fuels. In the proposal’s model calculations, the carbon price would increase every five years. By 2040, the required carbon levy would be USD 673-874 per tonne of CO_2; by 2045, it would rise to USD 1 284-1 682 per tonne. The proposal hints at the need to terminate the scheme in the long term when the penetration of zero-emission vessels have advanced.

The proposals by Marshall Islands and Solomon Islands and the ICS and Intercargo foresee a similar five-year adjustment to the carbon price. However, the motivation behind these proposals is the perception of the measure’s political feasibility, not their design, as in the case of Japan’s proposal. The Marshall Islands and Solomon Islands’ proposal assumes that the desired level of USD 250-300 per tonne of CO_2e can only be achieved gradually via the first step of USD 100 per tonne by 2025.

Types of emissions covered in the proposals to the International Maritime Organization

The Marshall Islands and Solomon Islands proposal hints at the possibility of exempting shipping routes to countries facing potentially disproportionately negative impacts from carbon pricing. It prefers to compensate these countries via the revenues from carbon pricing rather than exemptions. The proposal made by Argentina, Brazil, China, South Africa and the United Arab Emirates indicates that the benchmark levels that play a significant role in the reward system should be adjusted for ships that have “served one or more ports of developing countries likely to be negatively impacted” (Argentina et al. 2022). As such, they introduce a differentiated approach to MBMs.

An essential difference between the five proposals is the coverage of only CO_2 emissions or all greenhouse gas emissions and whether they cover well-to-wake (WTW) emissions or tank-to-wake (TTW) emissions. TTW emissions only take into account the emissions from ship operations; they do not account for emissions from the production of ship fuels. WTW emissions cover emissions from the entire process of fuel production, delivery and onboard use. WTW emissions should be assessed when a ship's fuels do not emit emissions when used (e.g. hydrogen-powered ships), but their production process could emit more or less GHG emissions depending on whether renewable energy is used in that process.

Table 5. Types of emissions covered in the proposals to the International Maritime Organization, 2021-22

Proposal	Ship size	Carbon emissions (CO_2) or all greenhouse gas (GHG) emissions?	Well-to-wake emissions or tank-to-wake emissions?
GHG Levy (Marshall Islands, Solomon Islands)	Not defined	GHG	Well-to-wake
Levy (International Chamber of Shipping, Intercargo)	Ships > 5 000 GT	CO_2	Tank-to-wake, open to expanding to well-to-wake
Feebate (Japan)	Ships > 5 000 GT	CO_2	Tank-to-wake, but exclusion from scope if WTW of zero-emission fuels are higher than WTW from fossil fuels.
Reward and penalty system (Argentina et al.)	Not defined	CO_2	Tank-to-wake
Cap and trade (Norway)	Ships > 400 GT	GHG	Tank-to-wake, open to expanding to well-to-wake
Global fuel standard (Austria et al.)	Ships > 5 000 GT or 400 GT	GHG	Well-to-wake

Note:GT= gross tonnage. Argentina et al. refers to Argentina, Brazil, People's Republic of China, South Africa and United Arab Emirates. Austria et al. refers to all EU27 countries, Norway and the European Commission.

Source: Marshall Islands and Solomon Islands (2021), International Chamber of Shipping and Intercargo (2021), Japan (2022a and 2022b), Argentina et al. (2022), Norway (2022), Austria et al. (2022a).

The proposals by ICS and Intercargo, Japan, and Argentina and like-minded cover only CO_2 emissions. Those from Marshall Islands and Solomon Islands, Norway and Austria et al. cover all GHG emissions (Table 5). Of the six proposals, the proposal by Marshall Islands and Solomon Islands and Austria et al. explicitly cover WTW emissions. Norway's proposal would cover TTW emissions but is open to expanding to WTW emissions if solid methods of measuring WTW emissions were available. In refinements to its proposal, Japan indicates that zero-emission fuels that have higher WTW GHG emission factors than fossil fuels should be excluded from the scope of the reward (Japan, 2022b). In the proposal by Argentina and its partner countries, WTW emissions are, to a certain extent, taken into account, as benchmark levels would be adjusted for ships that have consumed "a certain proportion of alternative low/zero-carbon fuels (to be defined in LCA guidelines)" (Argentina et al. 2022). Table 5 shows that two proposals do not define which ships will be covered by the scheme, two proposals cover all ships larger than 5 000 GT, one proposal covers all ships larger than 400 GT and one proposal leaves this boundary open.

Covering WTW emissions would require transparent and harmonised reporting of WTW emissions. The IMO created a Correspondence Group to develop and finalise the life cycle analysis (LCA) guidelines before the July 2023 meeting of the Marine Environment Protection Committee (MEPC 80). It is expected these guidelines will support the upcoming basket of measures for the decarbonisation of maritime transport.

What to do with the revenues?

Table 6 outlines how revenues from the proposed carbon pricing schemes might be used. Two of the six proposals provide indicative numbers on revenues from their carbon pricing proposal. ICS and Intercargo mention that a levy of USD 50 per tonne of CO_2 emitted would generate almost USD 40 billion per year. The Norway proposal would generate USD 130 billion to USD 140 billion annually from 2030. Extrapolating the ICS and Intercargo numbers to the Marshall Islands and Solomon Islands proposal suggests revenues in that scheme of USD 80 billion per year by 2025. The freely available revenues in the proposals of Japan and Argentina and its partner countries will likely be smaller, if only because, by design, they will use a large share of the contributions to reward lower-emission ships. Argentina and its partner countries put this share at 40%, while Japan leaves it undefined. In principle, Austria et al.'s proposal would not generate any revenues. However, it mentions the possibility of "flexibility mechanisms", one of which would be contributions of under-complying ships to an IMO GHG fund.

Table 6. Revenue use in carbon pricing proposals submitted to the International Maritime Organization, 2021-22

Proposal	Main spending categories	Administered by
GHG Levy (Marshall Islands, Solomon Islands)	Climate change adaptation/mitigation (at least 51%) Research development and deployment (up to 33%) Administrative costs (16%)	Green Climate Fund[1] International Maritime Research and Development Board (to be established)
Levy (International Chamber of Shipping, Intercargo)	Research and development, new bunkering infrastructure, assist maritime GHG reduction of developing countries	IMO Climate Fund (to be established)
Feebate (Japan)	Incentives for first movers, technical co-operation, carbon offset credits	IMO's Integrated Technical Cooperation Programme[2]
Reward and penalty system (Argentina et al.)	Rewards to ships with emissions below benchmark (40%) Capacity building (30%) Research development and deployment (20%) Administration costs (10%)	An International Maritime Sustainability Funding and Reward Board (to be established) within the IMO structure
Cap and trade (Norway)	Address disproportionate impacts on states, uptake low- and zero-emission fuels, production of zero-emission fuels, infrastructure, R&D	Green Climate Fund

Notes: 1. https://www.greenclimate.fund/; 2. https://www.imo.org/en/OurWork/TechnicalCooperation/Pages/ITCP.aspx; IMO= International Maritime Organization; Argentina et al. refers to Argentina, Brazil, People's Republic of China, South Africa and United Arab Emirates.

Source: Marshall Islands and Solomon Islands (2021), International Chamber of Shipping and Intercargo (2021), Japan (2022a), Argentina et al. (2022), Norway (2022), Austria et al. (2022a).

In the Japan proposal, the main spending category – in addition to the rebates for zero-emission vessels that form the essence of the proposal – is technical co-operation to facilitate an equitable transition. The proposal singles out IMO's Integrated Technical Cooperation Programme, which could be up-scaled to assist maritime GHG reduction efforts in vulnerable states. They suggest that this could help mobilise more significant amounts of external resources for projects, such as establishing new bunker fuel infrastructures.

Capacity building also is a major spending category in the Argentina group's proposal. This could be allocated to an International Maritime Sustainability Funding and Reward Board under the IMO's purview.

Other major spending categories in this proposal are RD&D and administration costs. Similar spending categories feature in the Marshall Islands and Solomon Islands' proposal. There, the funds for RD&D could be allocated by a structure similar to the International Maritime Research Board suggested by shipping associations and discussed in various IMO meetings. The Marshall Islands and Solomon Islands' proposal foresees channelling spending for climate change adaptation and mitigation through the Green Climate Fund of the UNFCCC. Norway's proposal suggests the same: the Green Climate Fund would collect and allocate the revenues to mitigate disproportionate impacts on states and stimulate the uptake of low- and zero-emission fuels, the production of zero-emission fuels, infrastructure maintenance and R&D.

How effective these proposals might be

At current price levels, the Marshall Islands and Solomon Islands' proposal only manages to bridge the price gap between HFO and zero-emission fuels when fully implemented in the second phase, wherein the levy rises from USD 100 to USD 250-300 per tonne CO_2e. In the meantime, the measure's effectiveness depends on reinvestment in the decarbonisation of shipping via RD&D. The proposal suggests that part of the RD&D could be in the form of feebates. However, it does not detail how to do so. It is thus unclear which ships would qualify for the feebate and the compensation amount. Subsidies on R&D might bring down the costs for zero-emission vessels, but this will likely be a long-term process dependent on how targeted these subsidies will be. It is unlikely they will create a market for zero-emission fuels in the short term.

Such an assessment is even more relevant for the ICS and Intercargo proposal. The carbon price of the levy in this proposal is likely lower than the one proposed by Marshall Islands and Solomon Islands. The lower the carbon price, the less likely the levy will be effective in itself. The effectiveness of the ICS and Intercargo proposal depends largely on its character as a revenue-generating mechanism. However, the assumption that more spending on RD&D for new bunker infrastructure will reduce the price gap between HFO and zero-carbon fuels has not been demonstrated. New bunker infrastructure for alternative fuels is important, but it will not reduce the price gap by itself. Certain design features of the fuel levy – as proposed by ICS and Intercargo – risk hindering the measure's effectiveness, even to the point of making it counter-productive. The principle drawback is the proposed exemption for fuels with zero TTW emissions, such as ammonia and hydrogen: "…it is suggested that when a levy system is first established it should not initially differentiate, for example, between green and grey hydrogen" (ICS and Intercargo, 2021). Such design features risk creating incentives for the use and lock-in of fuels that are wholly undesirable from a well-to-wake perspective. Similar counterproductive elements form part of the proposals of Japan and the Argentina group.

The Japan proposal promises to be considerably more effective than the two levy proposals. It is designed to bridge the price gap. As such, it makes zero-emission vessels commercially viable via a carbon levy that does not dissuade the use of non-zero-emission vessels. This might seem paradoxical, but it might be exactly this feature that makes the proposal politically palatable at the initial stage. That said, the scheme's effectiveness will decrease in later decades. As the pool of zero-emission vessels grows and the base of non-zero-emission vessels to finance the rebate falls, an ever-larger levy will be needed to finance a feebate. For this reason, it will probably make sense to reconsider the sensibility of the scheme once a certain penetration rate of zero-emission vessels has been reached.

The Argentina country group's proposal aims to set a predictable pathway towards decarbonising international shipping. However, the proposed system does not do so and is not likely to provide a sufficient incentive for bridging the price gap between conventional and zero-carbon fuels. In Japan's proposal, the base of contributing ships is substantial, and the number of rewarded ships is initially quite small. As such, the proposal's measures manage to create a strong incentive for change (for first movers) while minimising the impacts on the other vessels.

In comparison, the Argentina country group's proposal has a much smaller base of contributing vessels and a much larger number of potential beneficiaries in the initial phase. The only way to create a significant incentive in this system is to charge a substantial fee to the contributing vessels. However, the proposal claims that the negative impacts on the fleet are moderate. The incentive created will thus be insufficient to bridge the price gap. This is inherent to the way the proposal is designed: if many ships emit less CO_2 than the reward benchmark levels and only a few ships emit more than the contribution benchmark, the reward rate would become very low. The proposal's design provides incentives to decarbonise to a level just below the reward benchmark.

In theory, the target pathway for GHG emissions in the Norway proposal guarantees its effectiveness. Similarly, the target pathway for GHG fuel intensity in Austria et al.'s proposal ensures its effectiveness. In practice, however, the extent to which these targets will result in emission reductions will depend on enforcement mechanisms. Specifically, incompliant vessels must be removed from operation. The targets in both proposals refer to all ships and decline gradually over time. In the Norway proposal, the price gap between conventional and zero-emission fuels will likely only be bridged after a certain period. Considering the long lifetime of ships, full decarbonisation by 2050 would require that a substantial share of new ships be capable of running on zero-emission fuels or other zero-emission energy sources in the next five years. It is not clear how both proposals would be able to stimulate this development.

Carbon pricing proposal in the European Union

The European Union is at an advanced stage of decision-making on including shipping in EU ETS. Different proposals from the European Commission (EC), the European Parliament (EP) and the EU Council of Ministers (EU Council) will have to be merged into a compromise. The European Union believes that the IMO has not enacted sufficiently stringent measures to decarbonise shipping. As a result, its different decision-making bodies have joined to implement carbon pricing measures for ships calling EU ports.

The general idea is to include shipping in the existing EU ETS. The aim is to include shipping in a wider, open system in the EC proposal, not create a separate, closed system for maritime shipping. To do so, the EU ETS would apply to ships with tonnage over 5 000 GT, in alignment with the EU Monitoring Reporting and Verification (MRV) regulation. The EU Council retains this size threshold for all ships except general cargo ships, which would report in the MRV and pay in the ETS above 400 GT. The EC, EP and EU Council all have similar stipulations on the coverage of the system, namely voyages between EU ports, 50% of every voyage between a non-EU port and an EU port, and 50% of every voyage between an EU port and a non-EU port. The EP (2022) has proposed that this scope rises to 100% from 2027, but may remain at 50% for countries with equivalent measures on shipping, or for voyages to and from LDCs and SIDS. This applies to all ship flags, so is flag neutral. CO_2, N_2O (nitrous oxide) and CH_4 (methane) emissions are included in the extension of the EU ETS to maritime transport activities in the EP proposal (EP, 2022).

The inclusion of shipping in the EU ETS is embedded in a larger package of measures, Fit for 55, briefly described above. The FuelEU Maritime fuel standard is the most relevant Fit for 55 package shipping measure for this discussion. The proposal essentially introduces annual average targets for the GHG-intensity of energy used onboard ships. Reductions would start in 2025 with a 2% improvement compared to a 2020 baseline. Requirements would become increasingly stringent over time, with a 6% improvement required in 2030 and an improvement in 2050 that would lead to a 75% cut in emissions compared to the baseline. This fuel standard would apply to all of the energy used onboard ship voyages between EU ports, but to 50% of the energy used for voyages between EU and non-EU ports (European Council, n.d.). The design of the EU fuel standard resembles the global fuel standard proposed by (Austria et al, 2022a).

An element of the EP and EU Council proposals covers the relationship between shipowners and ship operators. The proposals suggest the commercial operator should be responsible for the final payment of the EU ETS price. When the commercial operator is not the compliant entity, shipowners' costs should be passed to the ship operators. To ensure this, the EP proposal requires that contractual agreements between shipowners and operators include a binding clause explicitly stating so. When the commercial operator is not the compliant entity, the EU Council proposal requires that national jurisdictions ensure that contracts between owners and operators provide the right to pass on costs. (EP, 2022)

In principle, shipowners and ship operators both have a responsibility to decarbonise. Ship operators are responsible for the choice and purchasing of ship fuel and the operation of the ship (e.g. the routing and the ship speed). However, shipowners also have an important role in decarbonising through, for example, investing in zero-emission propulsion technologies, implementing energy-efficiency measures on board and retro-fitting ships. The argument for passing on costs could be that it provides the incentive to charterers to look for more efficient ships. In this constellation, owners will benefit from improving their ships and making them more attractive to charterers.

The EP proposal foresees the creation of an Ocean Fund to facilitate the transition to zero-emission shipping. This Ocean Fund would consist of revenues generated by auctioning allowances related to maritime transport activities (at least 75% of the auction revenue) and revenues earned from penalties imposed under the FuelEU Maritime. The Ocean Fund could support projects and investments related to energy efficiency, innovative technologies and infrastructure (including short-sea shipping and ports), deploying sustainable alternative fuels, zero-emission propulsion technologies (including wind), and deploying innovative technologies and fuels for ice-class ships. The proposal suggests that the European Commission engages with third countries (countries that are not members of the European Union) to explore options as to how they, too, could use the Ocean Fund. (EP, 2022)

Special treatment is provided for ice-class ships in the EP's and EU Council's proposals; for example, there is specific support for the innovation and decarbonisation of ice-class ships through the Ocean Fund in the EP (2022) proposal. The motivation for this special treatment is that certain northern European countries depend on ice-class ships for navigation in the winter months, which can generate additional emissions due to higher fuel consumption.

An important issue for certain ports is the potential risk of evasion, resulting in fewer EU port calls. The EC (2021) proposal believes there is a limited risk of evasive port calls and a shift of transhipment activities to non-EU ports. However, both the EP and EU Council have adopted amendments to tackle carbon leakage, whereby third country container ports within a certain distance of EU ports will, in some cases, be considered part of the EU system (EP, 2022). More simply put, when ships call at an EU port before or after calling at those non-EU ports, the net leg past or before that non-EU port shall be considered part of the MRV and ETS.

Carbon pricing proposals in other parts of the world

Carbon pricing parameters for shipping could be included in various carbon pricing schemes throughout the world. The UK Climate Change Committee has suggested that shipping could be subject to a carbon tax or included in the UK ETS, which largely mirrors the EU ETS. The UK government is currently discussing the possibility of including domestic shipping in the UK ETS by the mid-2020s, based either on vessel activity, fuel supplied, or a combination of the two. (Bakhsh, 2022)

The national emission trading system launched in China in 2021 only covers the power generation sector. All companies covered by the system "are allocated their emission allowances free of charge. This allocation is based on a national benchmarking method, whereby the average carbon intensity of key sectors and products is calculated and compared with that of individual emitters. Each emitter will be allocated allowances equal to its verified emissions" (Roldao, 2022). Roldao continues to say that the China ETS does not have a declining cap on emissions. Chambers (2021) reports that the ultimate aim of the system is to include any company that discharged over 26 000 tonnes of CO_2e in any year between 2013 and 2019, which could well include shipping companies.

Policy implications of carbon pricing

There is ample experience with carbon pricing in a variety of sectors. Research shows both the potential and the limitations of carbon pricing. The lessons learned thus far should be considered when designing an appropriate carbon pricing scheme for the shipping sector. Three central policy issues emerge from the current discussions on carbon pricing in shipping: reaching a compromise on global carbon pricing for shipping; tackling the interference of global and regional or national carbon pricing schemes; and addressing competition issues related to carbon pricing in shipping.

Towards a global solution on carbon pricing for shipping

A core challenge to decarbonising maritime transport is the lack of commercial viability of zero-emission ships. The technological solutions are known and sometimes available, but zero-emission fuels and technologies are not yet cost-competitive with conventional fuels. This hampers the uptake and deployment of cleaner operating solutions. Carbon pricing could help bridge the price gap: it would increase the price of conventional fuels to stimulate the uptake of zero-emission fuels and technologies.

Carbon pricing in shipping is most effective as a global measure. The IMO has been investigating the introduction of global carbon pricing measures for shipping since 2021. This report has outlined the six different proposals currently under consideration. Stakeholders must find ways to combine the best parts of these proposals to advance the discussion on carbon pricing in shipping.

The differences between the six proposals might seem more significant than they actually are. Both Japan's and Austria et al.'s proposals provide potential extensions that make them more hybrid. Austria et al.'s proposal, a regulatory measure in essence, is a fuel standard. However, the proposal suggests combining it with an MBM and hints at the possibility of "flexibility mechanisms", namely a surplus reward for over-compliant ships and a contribution to an IMO GHG fund for non-compliant ships. Such mechanisms resemble the incentives that are part of the other proposals, in particular, the proposal by Argentina, Brazil, China, South Africa and the United Arab Emirates. Japan's proposal is a feebate, but it also opens the possibility of trading CO_2 allowances between ships, increasing the proposal's similarities with Norway's.

Despite the hybrid character of some of the proposals, there are obviously real choices to be made as to the design of a compromise proposal. Three essential questions are:

- What is the pathway's vision to decarbonising shipping?
- What is the best use of carbon pricing revenues?
- Should carbon pricing be combined with regulation and standards?

What is the pathway's vision to decarbonising shipping?

The distinctive difference between Japan's proposal and the others is the vision of how to fully decarbonise shipping. In Japan's proposal, full decarbonisation is achieved through the early deployment of zero-emission ships by first movers. The deployment of zero-emission ships will increase over time and this will drive the decarbonisation of the shipping sector. All the other proposals assume – more or less explicitly – that decarbonisation will initially take place via low-emission ships; they do not exclusively focus on stimulating zero-emission ships. As such, there is a transition period in which ships will be low-emission before they become zero-emission. The fuel standard's flexibility mechanism intends to promote first movers and early uptake. The mechanism levels out the disadvantage of being a first mover.

Considering the long lifetime of ships, full decarbonisation by mid-century would require that a substantial share of the new ships could operate on zero-emission fuels or other zero-emission energy sources in the next five years. Technology for zero-emission ships is known and, in some instances, already available (e.g. battery-powered ships, wind-propulsion and alternative fuels like bio/e-methanol, bio/e-diesel, bio/e-ammonia). A decarbonisation pathway that takes an immediate leap to zero-emission fuels or other zero-emission energy sources is preferable to one that creates an intermediary phase wherein shipping companies operate on low-emission fuels before operating on zero-emission fuels or other zero-emission energy sources.

Global carbon pricing could help to facilitate this leap to zero-emission shipping if it is well-designed and targeted. Japan's feebate-proposal, for example, provides for a relatively modest carbon levy on all ships that could help level the playing field for zero-emission ships, provided that the eligible fuels are limited to renewable fuels and not TTW zero-emission fuels. A similar leap to zero-emission shipping could also be achieved by the Marshall Islands and Solomon Islands' proposal, as long as in-sector revenue spending bridges the price differential between conventional fuel and zero-emission fuels and other zero-emission energy sources.

What is the best use of carbon pricing revenues?

Of the carbon pricing proposals, those by Marshall Islands and Solomon Islands and the Argentina country group provide the most detail for using carbon pricing revenues. These proposals list the specific shares of revenues that should be allocated to certain spending categories (see Table 6). At the other extreme, Austria et al.'s proposal does not generate revenues, so it does not address infrastructure investment needs or requirements to mitigate disproportionate impacts on states. However, Austria et al. intend that the proposal be implemented in conjunction with an MBM, which could potentially address this issue.

The central questions to answer here are: to what extent should carbon pricing revenues be allocated to decarbonising maritime transport; and what support should wider adaptation and mitigation measures receive? In addition, what spending priorities would there be for decarbonising maritime transport not already provided for by private actors in the market?

Carbon pricing revenues should stimulate the decarbonisation of maritime transport. In a feebate mechanism like the one proposed by Japan, the automatic rebates for zero-emission ships would be the main lever for stimulating the deployment of zero-emission fuels. In addition, carbon pricing revenues could be used to support developing countries that, with their renewable energy resources, have considerable potential for producing zero-emission shipping fuels (WB, 2021). Revenues from shipping's carbon pricing could help finance the necessary bunkering and recharging infrastructure in those countries.

IMO members are unlikely to agree on any global carbon pricing mechanism that does not provide the possibility of mitigating disproportionate negative impacts on states. There are two ways in which negative impacts could be mitigated: via in-sector spending or out-of-sector spending. In-sector spending would use carbon pricing revenues to invest in projects within the maritime transport sector. An example of in-sector mitigation spending would be when carbon pricing revenues fund the improvement of port infrastructure to reduce transport costs or the build-up of renewable energy infrastructure that could be used to produce zero-emission energy for shipping. Such projects would mitigate negative impacts because they would likely generate local economic development.

An advantage of spending carbon revenues out of the shipping sector is that it may allow for greater climate outcomes. It is unlikely that all the most cost-effective opportunities for climate change action relate to international shipping, so out-of-sector spending of carbon pricing revenues might be more effective from the perspective of general climate mitigation or adaptation (Dominioni and Englert, 2022). Furthermore, spending carbon revenues for non-shipping related activities can guarantee that countries with limited opportunities for in-sector projects (e.g. those with limited potential to produce zero-emission bunker fuels) can receive some revenues. This not only makes implementing carbon pricing more equitable but also more politically feasible.

Should carbon pricing be combined with regulation and standards?

Which regulatory measures would be most complementary in carbon pricing schemes for shipping? The combination of carbon pricing with regulation and standards is explicitly foreseen in the proposals by Japan (2022a), Norway (2022), Marshall Islands and Solomon Islands (2022), and Austria et al. (2022b). Carbon pricing alone does not drive long-term emission reductions or technological advances, according to findings from the general literature on carbon pricing and research on shipping-specific carbon pricing schemes. The positive effects of carbon pricing are often in the revenues it raises. However, they are even greater when carbon pricing is part of a larger package of measures, including regulation and standards.

In the leap forward to a zero-emission shipping pathway underlying Japan's proposal, combining monetary incentives for zero-emission ships with a regulatory stick may make sense. Japan's proposal describes this as "technical requirements, such as mandating newbuild ships and even existing ships to use zero-emission fuels" (Japan, 2022). The strength of Japan's carbon pricing proposal is its "all-or-nothing" character. However, that could also have a downside, as the proposal would not support ships with partial emission reductions. This could be problematic if shipping companies decided not to pursue low-emission solutions because they would only get incentives for zero-emission solutions. The right regulation could help solve this eventuality by, for example, introducing a fuel standard that becomes gradually more stringent, such as those proposed by the World Shipping Council (WSC, 2022), Austria et al. and – on a regional level – the EU's FuelEU Maritime standard.

A way forward

To accelerate maritime transport's decarbonisation, a global carbon pricing scheme for shipping should be considered. It should combine elements of the five different carbon pricing proposals put forward to the IMO, and be accompanied by regulatory instruments such as a technical design requirement and a low carbon fuel standard:

- A feebate system to finance zero-emission vessel operations consists of a carbon levy paid by all ships lacking zero-emission operations; the revenues will be used as an automatic rebate to ships operating with zero emissions. This rebate will be high enough to completely bridge the price gap between conventional and zero-emissions fuels and energy sources, based on assumptions on fuel price developments and the price of zero-emission fuels and energy sources. This feebate system should be introduced as soon as possible.

- In addition to introducing carbon pricing for shipping, policy-makers would need to agree on a "zero-emission vessel readiness" technical design requirement for newbuilds that would require all new vessels to be capable of running on zero-emission fuels or other zero-emission energy sources. In addition, policy makers would need to consider introducing a low-emission fuel standard with gradually more stringent targets that would help phase out the use of fossil fuels in shipping.
- A substantial share of revenues from the carbon pricing mechanism would need to be reserved for general climate-mitigation and adaptation projects in SIDS and LDCs, including specific in-sector projects related to decarbonising maritime transport. Doing so will foster decarbonisation and an equitable transition for those countries. In-sector use of revenues preferentially spent in developing economies can help balance out the potential increase in transport costs and negative trade impacts. Other in-sector use of revenues could support retrofitting ships to make them zero-emission ready or through projects that private-market actors would not be able to provide for themselves, such as adapting or building port infrastructure that accelerates the uptake of zero-emission fuels and other zero-emission energy sources.
- A carbon pricing scheme would need to cover GHG emissions from well to wake. Well-to-wake emissions cover the emissions from the entire process of fuel production, delivery and onboard use. The well-to-wake life cycle view of GHG emissions in shipping will maximise emission reductions. Moving to a well-to-wake basis requires the availability of reliable data on emissions from the entire energy production process of the alternative ship fuels.

Addressing the interference of global and regional measures

The EU ETS is likely to cover shipping by 2024. The proposed EU directive foresees the possibility that a global market-based measure will be adopted at the IMO level. If the IMO's measure turns out to be at least comparable to the EU's measure, in the EU Council proposal the EU would consider a proportionate reduction in its measure's scope to avoid creating a double burden. In the EP proposal, if the IMO measure were not ambitious enough, the EU could extend its own measure to cover 100% of the emissions from ship voyages from non-EU to EU ports or from EU ports to non-EU ports. This assessment shall take place upon adoption by IMO of its measures and, in any event, no later than 2028. The IMO discussion on global pricing for shipping should have concluded by then.

In the absence of a global carbon pricing mechanism for shipping, it would make sense to try to link the EU ETS's measures for shipping to other carbon pricing mechanisms in the world. The EU proposal to include shipping in the EU ETS covers 50% of the emission from voyages from non-EU ports to EU ports and 50% of the emissions from ship voyages from EU to non-EU ports. The EP has proposed that this scope rises to 100% from 2027 but stays at 50% for countries with equivalent measures on shipping or for voyages to and from LDCs and SIDS. The EP proposal suggests that the European Commission will reach out to other countries to establish bilateral agreements on market-based mechanisms to bring the coverage up to 100%. One obvious link would be with the UK ETS, should it decide to include shipping in its ETS. This link appears feasible, considering that the UK ETS mirrors the design of the EU ETS. Other linkages would be more complicated, considering the differences between EU ETS and other emission trading systems in the world.

Addressing competition issues

Carbon pricing could increase industry consolidation and concentration in shipping. This competition concern should be addressed. There are various ways to design carbon pricing schemes that guarantee access for small operators. In emission trading schemes, this could, for example, be done by holding frequent auctions to reduce buyers' risk, a threshold on the number of allowances which can be bought by each body to reduce the risk of a cornering strategy, and the implementation of a specific non-competitive platform for small carriers with a fixed price based on the equilibrium price identified at the previous auction (Franc and Sutto, 2014). A more general consideration relates to the need for upgrading the knowledge and resources of competition authorities regarding shipping, as also highlighted in ITF (2022).

References

Aidun, H., D. Metzger, M. Gerrard (2021), "Principles of International Law and the Adoption of a Market-Based Mechanism for Greenhouse Gas Emissions from Shipping", Columbia Law School, New York, https://scholarship.law.columbia.edu/cgi/viewcontent.cgi?article=3753&context=faculty_scholarship (accessed 23 November 2022).

Andersson, J. (2019), "Carbon Taxes and CO_2 Emissions: Sweden as a Case Study", *American Economic Journal: Economic Policy*, Vol. 11/4, pp. 1-30, American Economic Association, Pittsburgh, https://doi.org/10.1257/pol.20170144.

Argentina et al. (2022), "Proposal to establish an International Maritime Sustainability Funding and Reward (IMSF&R) mechanism as an integrated mid-term measure", International Maritime Organisation, Intersessional Working Group for the Reduction of GHG emissions from Ships, ISWG-GHG 12/3/9 (accessible to IMO delegates).

Austria et al. (2022a), "Proposal for a GHG Fuel Standard", International Maritime Organisation, Intersessional Working Group for the Reduction of GHG emissions from Ships, ISWG-GHG 12/3/3, (accessible to IMO delegates).

Austria et al. (2022b), "Combination of technical and market-based mid-term measures illustrated by combining the GHG Fuel Standard and a levy", International Maritime Organisation, Intersessional Working Group for the Reduction of GHG emissions from Ships, ISWG-GHG 13/4/8, (accessible to IMO delegates).

Bakhsh, N. (2022), "UK risks breaching climate obligation with focus on domestic shipping in ETS", *Lloyds's List*, Informa UK, London, https://lloydslist.maritimeintelligence.informa.com/LL1142440/UK-risks-breaching-climate-obligation-with-focus-on-domestic-shipping-in-ETS (available by subscription).

Baranzini, A. at al. (2017), "Carbon pricing in climate policy: seven reasons, complementary instruments, and political economy considerations", *Wiley Interdisciplinary Reviews: Climate Change*, Vol. 8/4, https://doi.org/10.1002/wcc.462.

Baresic et al. (2022), "Closing the Gap: An Overview of the Policy Options to Close the Competitiveness Gap and Enable an Equitable Zero-Emission Fuel Transition in Shipping", University Maritime Advisory Services, London, https://www.globalmaritimeforum.org/content/2021/12/Closing-the-Gap_Getting-to-Zero-Coalition-report.pdf.

Carattini, S., M. Carvalho and S. Fankhauser (2018), "Overcoming public resistance to carbon taxes", *Wiley Interdisciplinary Reviews: Climate Change,* Vol. 9/5, e531, https://doi.org/10.1002/wcc.531.

Carattini, S., M. Carvalho and S. Fankhauser (2017), "How to make carbon taxes more acceptable", Policy report, Grantham Research Institute in Climate Change and the Environment and Centre for Climate Change Economics and Policy London School of Economics and Political Science, London, https://www.lse.ac.uk/granthaminstitute/wp-content/uploads/2017/12/How-to-make-carbon-taxes-more-acceptable.pdf (accessed 23 November 2022).

C2ES (n.d.), "Carbon Tax Basics", Center for Climate and Energy Solutions, Arlington, www.c2es.org/content/carbon-tax-basics/ (accessed 24 October 2022).

CE Delft (2022), "Maritime shipping and EU ETS: An assessment of the possibilities to evade ETS costs", CE Delft, Delft, https://www.portofrotterdam.com/sites/default/files/2022-03/ce-delft-maritime-shipping-eu-ets.pdf.

Chambers, S. (2021), "China looks at adding shipping to the world's largest emissions trading scheme", *Splash 24/7*, 9 March 2021, https://splash247.com/china-looks-at-adding-shipping-to-the-worlds-largest-emissions-trading-scheme/ (accessed 23 November 2022).

Christodoulou, A.; D. Dalaklis, A. Ölçer and P. Ghaforian Masodzadeh (2021), "Inclusion of Shipping in the EU-ETS: Assessing the Direct Costs for the Maritime Sector Using the MRV Data", *Energies*, Vol. 14/13, 3915, https://doi.org/10.3390/en14133915.

Cullenward, D. and D. Victor (2020), *Making Climate Policy Work*, Polity Press, Cambridge.

CVF (2021), "Dhaka-Glasgow Declaration of the Climate Vulnerable Forum", Climate Vulnerable Forum, https://thecvf.org/our-voice/statements/dhaka-glasgow-declaration-of-the-cvf/ (accessed 23 November 2022).

Devanney, J. (2010), "The impact of bunker price on VLCC spot rates", *Third International Symposium on Ship Operations, Management and Economics*, Athens, Greece.

Ding, W. et al. (2020), "Does a carbon tax affect the feasibility of Arctic shipping?", *Transportation Research Part D: Transport and Environment*, Vol. 80, 102257, https://doi.org/10.1016/j.trd.2020.102257.

Dominioni, G. and D. Englert (2022), "Carbon Revenues From International Shipping: Enabling an Effective and Equitable Energy Transition", Technical Paper, World Bank, Washington, DC, https://openknowledge.worldbank.org/handle/10986/37240 (accessed 23 November 2022).

Dominioni, G., Heine, D., Martinez Romera, B. (2018), "Regional Carbon Pricing for International Maritime Transport: Challenges and Opportunities for Global Geographical Coverage", *Carbon and Climate Law Review*, Vol. 12/2, pp. 140-158, Elsevier, https://ssrn.com/abstract=3494819.

EC (2021), *Study on Assessment of Possible Global Regulatory Measures to Reduce Greenhouse Gas Emissions From International Shipping: Final Report*, European Commission, Directorate-General for Climate Action, Brussels, https://data.europa.eu/doi/10.2834/330363.

EP (2022), "Report on the proposal for a directive of the European Parliament and of the Council amending Directive 2003/87 establishing a system for greenhouse gas emission allowance trading within the Union, Decision (EU) 2015/1814 concerning the establishment and operation of a market stability reserve for the Union greenhouse gas emission trading scheme and Regulation (EU) 2015/757", Report-A9-0162/2022, European Parliament, Strasbourg, www.europarl.europa.eu/doceo/document/A-9-2022-0162_EN.html.

European Council (n.d.), "Fit for 55", https://www.consilium.europa.eu/en/policies/green-deal/fit-for-55-the-eu-plan-for-a-green-transition/ (accessed 05 December 2022).

European Council (2003), "Council Directive 2003/96/EC of 27 October 2003 restructuring the Community framework for the taxation of energy products and electricity", Article 14c, *Official Journal of the European Union*, L. 283/51-70, EUR-Lex - 32003L0096 - EN - EUR-Lex, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32003L0096.

Fernando, S. (2019), "The environmental effectiveness of carbon taxes: a case study of the Nordic experience", in World Bank (ed.), *The First International Research Conference on Carbon Pricing,* 349-368, World Bank, Washington, DC, https://doi.org/10.1596/32746.

Franc, P., L. Sutto (2014), "Impact analysis on shipping lines and European ports of a cap- and-trade system on CO_2 emissions in maritime transport", *Maritime Policy and Management*, Vol. 41/1, pp. 61-78, https://doi.org/10.1080/03088839.2013.782440.

Giovannini, M. and H. Psaraftis (2019), "The profit maximising liner shipping problem with flexible frequencies: Logistical and environmental considerations", *Flexible Services and Manufacturing Journal*, Vol. 31, pp. 567-597, Springer, https://doi.org/10.1007/s10696-018-9308-z.

Gkonis, K. and H. Psaraftis (2012), "Modelling tankers' optimal speed and emissions", Paper number SNAME-SMC-2012-A08, Paper presented at the SNAME Maritime Convention, Providence, Rhode Island, USA, October 2012, SNAME Maritime Convention, https://doi.org/10.5957/SMC-2012-A08.

Green, J., (2021), "Does carbon pricing reduce emissions? A review of ex-post analyses", *Environmental Research Letters*, Vol. 16/4, 043004, IOP Publishing, Bristol, Philadelphia, https://doi.org/10.1088/1748-9326/abdae9.

Gu, Y., S. Wallace and X. Wang (2019), "Can an Emission Trading Scheme really reduce CO_2 emissions in the short term? Evidence from a maritime fleet composition and deployment model", *Transportation Research Part D: Transport and Environment*, Vol. 74, pp. 318-338, Elsevier, https://doi.org/10.1016/j.trd.2019.08.009.

Haites, E. (2018), "Carbon taxes and greenhouse gas emissions trading systems: What have we learned?", *Climate Policy*, Vol. 18/8, pp. 955-966,Taylor and Francis, https://doi.org/10.1080/14693062.2018.1492897.

Hepburn, C. (2006), "Regulation by Prices, Quantities, or Both: A Review of Instrument Choice", *Oxford Review of Economic Policy*, Vol. 22/2, pp. 226-247, Oxford University Press, Oxford, https://doi.org/10.1093/oxrep/grj014.

Hermeling, C. et al. (2015), "Sailing into a dilemma: An economic and legal analysis of an EU trading scheme for maritime emissions", *Transportation Research Part A: Policy and Practice*, Vol. 78, pp. 34-53, Elsevier, https://doi.org/10.1016/j.tra.2015.04.021.

Huang, Z., et al. (2015), "Optimal annual net income of a containership using CO_2 reduction measures under a marine emissions trading scheme", *Transportation Letters*, Vol. 7/1, pp. 24-34, Taylor and Francis, https://doi.org/10.1179/1942787514Y.0000000030.

ICS (2022), "Use of funds raised by a levy on CO_2 emissions", International Maritime Organisation, Intersessional Working Group for the Reduction of GHG emissions from Ships, ISWG-GHG 12/3/7 (accessible to IMO delegates).

ICS and Intercargo (2021), "A levy-based MBM, per tonne of CO_2 emissions, to expedite the uptake and deployment of zero-carbon fuels", International Maritime Organisation, Intersessional Working Group for the Reduction of GHG emissions from Ships, ISWG-GHG 10/5/2 (accessible to IMO delegates).

IMarEST (2018), "The costs of GHG reduction in international shipping", ISWG-GHG 3-3, International Maritime Organisation, London (accessible to IMO delegates)

IMO (2010), Reduction of GHG Emissions From Ships: Full Report of the Work Undertaken by the Expert Group on Feasibility Study and Impact Assessment of Possible Market-based Measures, MEPC 61/INF.2, Marine Environment Protection Committee, 61st session, 13 August 2010, International Maritime Organization, http://martrans.org/documents/2009/air/MEPC61-INF2.pdf.

IMO (2018), "Note by the International Maritime Organization to the UNFCCC Talanoa Dialogue: Adoption of ohe Initial IMO Strategy on Reduction of GHG Emissions From Ships and Existing IMO Activity Related to Reducing GHG Emissions in the Shipping Sector", Annex 1: Resolution MEPC.304(72), International Maritime Organisation, London, https://unfccc.int/sites/default/files/resource/250_IMO%20submission_Talanoa%20Dialogue_April%202018.pdf.

IMO (2020a), *Fourth IMO Greenhouse Gas Study 2020: Full Report*, International Maritime Organisation, London, https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/Fourth%20IMO%20GHG%20Study%202020%20-%20Full%20report%20and%20annexes.pdf.

IMO (2020b), "Resolution MEPC.327(75), Encouragement of member states to develop and submit voluntary national action plans to address GHG emissions from ships", adopted on 20 November 2020, International Maritime Organisation, Marine Environment Protection Committee, London, https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/Air%20pollution/Resolution%20MEPC.327(75).pdf.

IMO (2020c), "IMO working group agrees further measures to cut ship emissions", International Maritime Organisation, https://www.imo.org/en/MediaCentre/PressBriefings/pages/36-ISWG-GHG-7.aspx.

IMO (2022), "MARPOL Consolidated Edition 2022", IMO Publications, International Maritime Organisation, London.

IPCC (2021), *Climate Change 2021: The Physical Science Basis*. Contribution of Working Group 1 to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge and New York, https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_FullReport.pdf

ITF (n.d.), "ITF Transport NDC Tracker", website, International Transport Forum, https://www.itf-oecd.org/ndc-tracker/en (assessed 17 October 2022).

ITF (2022), "Performance of Maritime Logistics", *International Transport Forum Policy Papers*, No. 106, OECD Publishing, Paris, https://doi.org/10.1787/8e06fcd1-en.

ITF (2020), "Navigating Towards Cleaner Maritime Shipping: Lessons From the Nordic Region, *International Transport Forum Policy Papers*, No. 80, OECD Publishing, Paris, https://doi.org/10.1787/ab3d3fbc-en.

ITF (2019), "Maritime Subsidies: Do They Provide Value for Money?", *International Transport Forum Policy Papers*, No. 70, OECD Publishing, Paris, https://doi.org/10.1787/919d4222-en.

ITF (2018), "Decarbonising Maritime Transport: The Case of Sweden", *International Transport Forum Policy Papers*, No. 46, OECD Publishing, Paris, https://doi.org/10.1787/99514381-en.

Japan (2022a), "Proposal for a Market-based Measure (MBM) to incentivize GHG emission reduction and to make equitable transition with an overview of mid- and long-term measures", International Maritime Organisation, Marine Environment Protection Committee, MEPC 78/7/5, (accessible to IMO delegates).

Japan (2022b), "Refined proposal on Zero-Emission Shipping Incentive Scheme (ZESIS) to incentivize GHG emission reduction and to make an equitable transition", International Maritime Organisation, Intersessional Working Group on the Reduction of GHG Emissions from Ships, ISWG-GHG 13/4/6, (accessible to IMO delegates).

Koesler, S., M. Achtnicht and J. Köhler (2015), "Course set for a cap? A case study among ship operators on a maritime ETS", *Transport Policy*, Vol. 37, pp. 20-30, https://doi.org/10.1016/j.tranpol.2014.10.009.

Kosmas, V. and M. Acciaro (2017), "Bunker levy schemes for greenhouse gas (GHG) emission reduction in international shipping", *Transportation Research Part D: Transport and Environment*, Vol. 57, pp. 195-206, Elsevier, https://doi.org/10.1016/j.trd.2017.09.010.

Krantz, R., K. Sogaard and T. Smith (2020), "The scale of investment needed to decarbonize international shipping", Insight Brief, Getting to Zero Coalition, https://www.globalmaritimeforum.org/content/2020/01/Getting-to-Zero-Coalition_Insight-brief_Scale-of-investment.pdf.

Lagouvardou, S. and H. Psaraftis (2022), "Implications of the EU Emissions Trading System (ETS) on European container routes: A carbon leakage case study", *Maritime Transport Research*, Vol. 3, 100059, Elsevier, https://doi.org/10.1016/j.martra.2022.100059.

Lagouvardou, S., H. Psaraftis and T. Zis (2022), "Impacts of a bunker levy on decarbonizing shipping: A tanker case study", *Transportation Research Part D: Transport and Environment*, Vol. 106, 103257, Elsevier, https://doi.org/10.1016/j.trd.2022.103257.

Lagouvardou, S., H. Psaraftis and T. Zis (2020), "A Literature Survey on Market-based Measures for the Decarbonization of Shipping", *Sustainability*, Vol. 12/10, 3953, MDPI, Basel, https://doi.org/10.3390/su12103953.

Lee, T., Y. Chang, P. Lee (2013), "Economy-wide impact analysis of a carbon tax on international container shipping", *Transportation Research Part A: Policy and Practice*, Vol. 58, pp. 87-102, Elsevier, https://doi.org/10.1016/j.tra.2013.10.002.

Lilliestam, J., A. Patt and G. Bersalli (2022), "On the quality of emission reductions: Observed effects of carbon pricing on investments, innovation, and operational shifts. A response to van den Bergh and Savin (2021)", *Environmental and Resource Economics*, Vol. 83, pp. 733-758, Springer, https://doi.org/10.1007/s10640-022-00708-8.

Lilliestam, J., A. Patt and G. Bersalli (2021), "The effect of carbon pricing on technological change for full energy decarbonization: A review of empirical ex-post evidence", *WIREs Climate Change*, Vol. 12/1, e681, Wiley Interdisciplinary Reviews, https://doi.org/10.1002/wcc.681.

Lin, B. and X. Li (2011), "The effect of carbon tax on per capita CO_2 emissions", *Energy Policy*, Vol. 39/9, pp. 5137-5146, Elsevier, https://doi.org/10.1016/j.enpol.2011.05.050.

Luo, M. (2013), "Emission reduction in international shipping—the hidden side effects", *Maritime Policy and Management*, Vol. 40/7, p. 694-708, Taylor and Francis, https://doi.org/10.1080/03088839.2013.851462.

Marshall Island and Solomon Islands (2021), "Proposal for IMO to establish a universal mandatory greenhouse gas levy", International Maritime Organisation, Marine Environment Protection Committee, MEPC 76/7/12 (accessible to IMO delegates).

Marshall Island and Solomon Islands (2022), “Proposal for a GHG levy as a component in a basket of measures”, International Maritime Organisation, Marine Environment Protection Committee, MEPC 76/7/12 (accessible to IMO delegates).

Mundaca, G., J. Strand and I. Young (2021), "Carbon pricing of international transport fuels: Impacts on carbon emissions and trade activity," *Journal of Environmental Economics and Management*, Vol. 110, 102517, Elsevier, https://doi.org/10.1016/j.jeem.2021.102517.

Netherlands and OECD (2021), “Reduction of GHG Emissions from Ships: Importance of starting work on mid-term measures (carbon pricing, fuel standards)”, International Maritime Organisation, Marine Environment Protection Committee, MEPC 76/7/42 (accessible to IMO delegates).

Norway (2022), “Proposal for an Emission Cap-and-Trade System (ECTS)”, International Maritime Organisation, Intersessional Working Group for the Reduction of GHG emissions from Ships, ISWG-GHG 12/3/13 (accessible to IMO delegates).

OECD (2019), *Taxing Energy Use 2019: Using Taxes for Climate Action*, OECD Publishing, Paris, https://doi.org/10.1787/058ca239-en.

OECD (2022), *Pricing Greenhouse Gas Emissions; Turning Climate Targets into Climate Action*, OECD Series on Carbon Pricing and Energy Taxation, OECD Publishing, Paris, https://doi.org/10.1787/e9778969-en.

Parry, et al. (2018), “Carbon Taxation for International Maritime Fuels: Assessing the Options”, *IMF Working Paper No. 18/203*, International Monetary Fund, Washington, DC, https://ssrn.com/abstract=3267230.

Pons, A. et al. (2021a), *Study on EU ETS for Maritime Transport and Possible Alternative Options of Combinations to Reduce Greenhouse Gas Emissions: Final Report*, European Commission, Directorate-General for Climate Action Publications Office of the European Union, Luxembourg, https://data.europa.eu/doi/10.2834/27271.

Pons, A. et al. (2021b), *Study on EU ETS for Maritime Transport and Possible Alternative Options of Combinations to Reduce Greenhouse Gas Emissions: Annexes*, European Commission, Directorate-General for Climate Action Publications Office of the European Union, Luxembourg, https://op.europa.eu/en/publication-detail/-/publication/120c5d5c-353d-11ec-bd8e-01aa75ed71a1/language-en.

Psaraftis, H. (2012), “Market-based measures for greenhouse gas emissions from ships: A review”, *WMU Journal of Maritime Affairs*, Vol. 11, pp. 211-232, Springer, https://doi.org/10.1007/s13437-012-0030-5.

Psaraftis, H. (2019), “Speed optimization versus speed reduction: Are speed limits better than a bunker levy?”, *Maritime Economics and Logistics*, Vol. 21/4, pp. 524-542, Springer, https://doi.org/10.1057/s41278-019-00132-8.

Psaraftis, H., T. Zis, and S. Lagouvardou (2021), “A comparative evaluation of market based measures for shipping decarbonization”, *Maritime Transport Research*, Vol. 2, 100019, Elsevier, https://doi.org/10.1016/j.martra.2021.100019.

Rennert, K. et al. (2022), “Comprehensive evidence implies a higher social cost of CO2”, *Nature*, Vol. 610, pp. 687-692, Springer, https://doi.org/10.1038/s41586-022-05224-9.

Ricke, K. et al. (2018), “Country-level social cost of carbon”, *Nature Climate Change*, Vol. 8/10, pp. 895-900, Springer, https://doi.org/10.1038/s41558-018-0282-y.

Rojon, I. et al. (2021), "The impacts of carbon pricing on maritime transport costs and their implications for developing economies", *Marine Policy*, Vol. 132, 104653, Elsevier, https://doi.org/10.1016/j.marpol.2021.104653.

Roldao, R. (2022), "Carbon trading the Chinese way", *Energy Monitor*, 5 January 2022, www.energymonitor.ai/policy/carbon-markets/carbon-trading-the-chinese-way (accessed 23 November 2022).

Sen, S. and H. Vollebergh (2018), "The effectiveness of taxing the carbon content of energy consumption", *Journal of Environmental Economics and Management*, Vol. 92, pp. 74-99, Elsevier, https://doi.org/10.1016/j.jeem.2018.08.017.

Sheng, Y., X. Shi and B. Su (2018), "Re-analyzing the economic impact of a global bunker emissions charge", *Energy Economics*, Vol. 74, pp. 107-119, Elsevier, https://doi.org/10.1016/j.eneco.2018.05.035.

Shmelev, S. and S. Speck (2018), "Green fiscal reform in Sweden: Econometric assessment of the carbon and energy taxation scheme", *Renewable and Sustainable Energy Reviews*, Vol. 90, pp. 969-981, Elsevier, https://doi.org/10.1016/j.rser.2018.03.032.

Smith, T. (2020), "The Cost of Reducing Greenhouse Gas Emissions in Shipping", *International Transport Forum Discussion Papers*, No. 2020/18, OECD Publishing, Paris, https://doi.org/10.1787/f7846c27-en.

Stern, N. (2006), *The Stern Review: The Economics of Climate Change*, Cambridge University Press, Cambridge, https://webarchive.nationalarchives.gov.uk/ukgwa/20100407172811/https:/www.hm-treasury.gov.uk/stern_review_report.htm.

Stiglitz, J. et al. (2018), *Report of the High-Level Commission on Carbon Prices*, Carbon Pricing Leadership Coalition, www.carbonpricingleadership.org/report-of-the-highlevel-commission-on-carbon-prices.

Transport and Environment (2020), *All Aboard! Too Expensive for Ships to Evade EU Carbon Market*, https://www.transportenvironment.org/wp-content/uploads/2021/07/ETS_shipping_study.pdf.

Trafigura (2020), "A proposal for an IMO-led global shipping industry decarbonisation programme", https://www.trafigura.com/brochure/a-proposal-for-an-imo-led-global-shipping-industry-decarbonisation-programme (accessed on 23 November 2022).

Tvinnereim, E., Mehling, M. (2018), "Carbon pricing and deep decarbonisation", *Energy Policy*, Vol. 121, pp. 185-189, Elsevier, https://doi.org/10.1016/j.enpol.2018.06.020.

UNCTAD (2021), "Review of Maritime Transport 2021", United Nations Conference on Trade and Development, United Nations Publications, New York, https://unctad.org/system/files/official-document/rmt2021_en_0.pdf.

Van den Bergh, J. and I. Savin (2021), "Impact of Carbon Pricing on Low-carbon Innovation and Deep Decarbonisation: Controversies and Path Forward", *Environmental and Resource Economics,* Vol. 80/4, pp. 705-715, Springer, https://doi.org/10.1007/s10640-021-00594-6.

Vogt-Schilb, A., G. Meunier and S. Hallegatte (2018), "When starting with the most expensive option makes sense: Optimal timing, cost and sectoral allocation of abatement investment", *Journal of Environmental Economics and Management*, Vol. 88, pp. 210-233, Elsevier, https://doi.org/10.1016/j.jeem.2017.12.001.

Wang, K., X. Fu and M. Luo (2015), "Modeling the impacts of alternative emission trading schemes on international shipping", *Transportation Research Part A: Policy and Practice*, Vol. 77, pp. 35-49, Elsevier, https://doi.org/10.1016/j.tra.2015.04.006.

Wang, S. et al. (2021), "Implications of the EU's Inclusion of Maritime Transport in the Emissions Trading System for Shipping Companies", *Engineering*, Vol. 7/5, pp. 554-557, Elsevier, https://doi.org/10.1016/j.eng.2021.01.007.

WB (2021), *Potential of Zero-Carbon Bunker Fuels in Developing Countries*, International Bank for Reconstruction and Development, World Bank, Washington DC, https://openknowledge.worldbank.org/handle/10986/35435 (accessed 23 November 2022).

WB (2022), "State and Trends of Carbon Pricing 2022", International Bank for Reconstruction and Development, World Bank, Washington DC, https://openknowledge.worldbank.org/handle/10986/37455 (accessed 23 November 2022).

WSC (2022), "Integrating a Low GHG Fuel Standard (LGFS) with IMO's GHG Strategy", World Shipping Council, International Maritime Organisation, Intersessional Working Group for the Reduction of GHG emissions from Ships, ISWG-GHG 12/3 (accessible to IMO delegates).

Zhu, M. et al. (2018), "Impact of maritime emissions trading system on fleet deployment and mitigation of CO_2 emission", *Transportation Research Part D: Transport and Environment*, Vol. 62, pp. 474-488, https://doi.org/10.1016/j.trd.2018.03.016.

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This report reviews the effectiveness of carbon pricing, how it might be applied to the shipping sector and with what effects. It also evaluates recent proposals by countries to introduce a price on shipping's carbon emissions and examines related policy issues.

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