Carbon pricing options for international maritime emissions

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Summary

Emissions from international shipping accounted for an average of 2.4% of global annual greenhouse gas (GHG) emissions between 2007 and 2012 and are expected to increase by 50-250% by 2050 in a Business as Usual scenario. However, in order to stay within the 1.5ºC global average temperature increase threshold, it is necessary that all sectors reach net-zero emissions by 2050. International shipping can significantly reduce GHG emissions using existing technical and operational measures, while a full decarbonisation requires further research and development and rapid deployment of technology.

In April 2018, the International Maritime Organization (IMO), the UN regulatory body for international shipping, adopted an Initial Strategy to reduce GHG from ships with a number of objectives. One of these objectives is "to peak GHG emissions from international shipping as soon as possible and to reduce the total annual GHG emissions by at least 50% by 2050 compared to 2008 while pursuing efforts towards phasing them out […] on a pathway of CO_2 emissions reduction consistent with the Paris Agreement temperature goals." The IMO lists market-based measures as a candidate measure to help reach these goals. While a definition of market-based measures within the IMO context is not clear, previous discussions included, among others, tradable permits and pollution charges. A market-based measure that puts a robust price on greenhouse gas emissions, as part of a broader policy package, could efficiently help speed up adoption of these measures to reach the goal of decarbonising the sector by 2050.

A number of questions are common to any kind of market-based measure: questions regarding Measuring, Reporting, and Verification (MRV); who the compliance entity should be, and who and how to enforce the regulation. A robust MRV system is necessary to collect the required data on individual ship's emissions. Although there are now MRV frameworks for international shipping (one from the IMO and one from the EU), it is likely that these would require further reform and transparency for effective use for a market-based measure. Applying a market-based measure upstream (i.e. fuel suppliers) is in theory the simplest way to implement a market-based measure however, there is no precedence for MARPOL to directly mandate enforcement action on fuel suppliers for non-compliance. A number of fuel suppliers are likely to oppose a pricing measure for ships, therefore, without universal participation, making fuel suppliers responsible for the implementation of a market-based measure could pose a carbon leakage risk. Making shipping companies the compliance entity instead is a more promising approach with enforcement to be checked as part of port state control. In part a lack of capacity among flag states means that a market-based measure that relies on flag state enforcement is unlikely to be effective.

In this paper we explore three different options for a market-based measure for international shipping:

1. An offsetting scheme, which would require ships to compensate for their GHG emissions by buying emission reduction credits;
2. A maritime emissions trading scheme, which would place a cap on the total GHG emissions for international shipping and allow shipping companies to buy and sell allowances under the cap; and
3. A climate levy, which would place a set price on each tonne of GHG emitted by ships.

These three measures are not necessarily mutually exclusive and hybrid options, in conjunction with other policy instruments, are possible, but are beyond the scope of this paper.

We propose four criteria to evaluate the choice of a market-based measure and apply them to the three options:

1. Effectiveness in reducing GHG emissions and steering the shipping sector towards decarbonisation;

2. Compatibility with the IMO principle of No More Favourable Treatment (NMFT), which provides that any measure should be applied to all ships within the waters of a Party that has ratified a measure, regardless of whether the flag state of the ship has ratified the measure;
3. Adherence to the UNFCCC principle of Common But Differentiated Responsibilities and Respective Capabilities (CBDR-RC), which recognises the different historical responsibility for climate change and the different resources and capacities to address it; and
4. The market-based measure's efficiency in minimising transaction costs and administrative burden.

Based on the assessment of the three options within the scope of this paper, we conclude that a climate levy would be the most appropriate measure to reduce emissions in the maritime sector. A climate levy at an appropriate price level, is most likely to steer the shipping sector towards decarbonisation, can adhere to both the principle of NMFT and CBDR-RC, and has comparatively low transaction costs. Compared to an ETS, a climate levy has the potential to provide predictable and stable price signals and can offer greater certainty to investors investing in low-carbon technologies. Further, an ETS is more complex and prices fluctuations are less likely to provide investors with a clear carbon price incentive to invest. As uncertainty – both in general and regarding the return on investment in particular – is a major investment barrier to even negative and low-cost measures, further uncertainty in terms of future carbon price trajectories is likely to constitute a suboptimal approach. Finally, a carbon emission offsetting scheme is the least desirable alternative. There is a great deal of uncertainty over the future market conditions for offset credits and a material risk that credit prices remain low. If it is cheaper to buy offset credits than to reduce in-sector emissions it is possible that shipping emissions continue to increase through 2050. Furthermore, considering that the shipping sector has significant potential to decrease its GHG emissions and that global emissions should be reduced to net-zero by 2050, the shipping sector should not rely on offsetting its own emissions with reductions in other sectors.

We recommend that a climate levy is accompanied by some form of compensation for developing countries. Both an ETS and a climate levy can generate revenues that could be used for compensation, as well as for in-sector R&D.

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Abbreviations

AGF	High-Level Advisory Group on Climate Change Finance
AOC	Air Operator Certificate
BAU	Business As Usual
CBDR-RC	Common But Differentiated Responsibilities and Respective Capabilities
CCS	Carbon Capture and Storage
COP	Conference of the Parties
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
EEDI	Energy Efficiency Design Index
ETS	Emissions Trading Scheme
EU	European Union
DCS	Data Collection System
GCF	Green Climate Fund
GHG	Greenhouse Gas
GRT	Gross Registered Tonnage
GT	Gross Tonnage
HFO	Heavy Fuel Oil
ICAO	International Civil Aviation Organization
IFO	Intermediate Fuel Oil
IMO	International Maritime Organization
ISWG-GHG	Intersessional Working Group on Greenhouse Gas Emissions
IPCC	Intergovernmental Panel on Climate Change
ITCP	Integrated Technical Cooperation Programme
LDC	Least Developed Country
LIC	Low Income Country
LLDC	Landlocked Developing Country
MARPOL	International Convention for the Prevention of Pollution from Ships
MEPC	Marine Environment Protection Committee
MFN	Most Favoured Nation
MGO	Marine Gas Oil
MRV	Monitoring, Reporting, and Verification
NDC	Nationally Determined Contribution
NMFT	No More Favourable Treatment
NO_x	Nitrogen Oxide
ODS	Ozone Depleting Substances
SARP	Standards and Recommended Practices
SBSTA	Subsidiary Body for Scientific and Technological Advice
SEEMP	Ship Energy Efficiency Management Plan
SIDS	Small Island Developing States
SO_x	Sulphur Oxides
UN	United Nations
UNFCCC	United Nations Convention on Climate Change
VOC	Volatile Organic Compound

1 Introduction

The Paris Agreement sets the global objective to limit global average warming to well below 2ºC, with efforts to keep it to 1.5ºC. The IPCC's Special Report on Global Warming of 1.5ºC showed that a temperature increase of more than 1.5ºC compared to pre-industrial levels could cross critical thresholds and cause irreversible damage to ecosystems (IPCC, 2018). In order to stay within the 1.5ºC limit, it is necessary that global CO_2 emissions peak as soon as possible; are reduced by 45% by 2030, compared to 2010 levels; and reach net zero in 2050 (IPCC, 2018). International shipping makes up a significant portion of global emissions. Although robust monitoring, reporting, and verification (MRV) measures for international shipping have yet to yield detailed numbers, the sector is estimated to have been responsible for approximately 816 million tonnes CO_2eq in 2012; 2.1% of global greenhouse gas (GHG) emissions (Smith *et al.*, 2014). This is comparable to annual emissions of countries like Japan and Germany. A function of global trade patterns, emissions went down after the 2008 global economic crisis but are assumed to have been rising again since 2012. Without robust climate measures, Smith et al. (2014) expect maritime emissions to grow by 50-250% between 2012 and 2050. Hoen et al. (2017) predict emissions growth of a more modest growth of between 20 and 120%. Either way, such a trajectory is not reconcilable with the goals of the Paris Agreement.

The 1992 United Nations Framework Convention on Climate Change (UNFCCC) does not specifically mention maritime GHG emissions. At the first meeting of the Conference of the Parties (COP) in 1995, the COP asked the Subsidiary Body for Scientific and Technological Advice (SBSTA) to address the issue of the allocation and control of emissions from international bunker fuels (UNFCCC, 1995). In 1997, the COP adopted the Kyoto Protocol, specifying that the reduction of GHG emissions from international shipping should be pursued through the International Maritime Organization (IMO) (Kyoto Protocol, Article 2.2). The IMO is a specialised United Nations (UN) Agency and is responsible for measures relating to the safety and security of international shipping, as well as the prevention of marine pollution (IMO, 2016a). In 1973, Parties to the IMO agreed to the International Convention for the Prevention of Pollution from Ships (MARPOL), which consists of six annexes. Annex VI on the Prevention of Air Pollution from Ships is mostly focused on SO_X, NO_x, and particulate matter (PM) but also covers other GHGs.

Unlike the Kyoto Protocol, the Paris Agreement does not explicitly mention the IMO as the primary forum to address maritime GHG emissions. The Paris Agreement does however to cover all anthropogenic GHG emissions from all sectors. At the same time, parties to the Paris Agreement are encouraged to define Nationally Determined Contributions (NDC) that cover economy-wide emissions and the shipping sector makes up a significant part of many countries' economies. At present however, despite the relative lack of clarity of many NDCs, one can assume that NDC's generally do not include emissions from international shipping. Indeed, the nature of international shipping makes it difficult to attribute the sector's emissions to a specific country: a single ship may be registered with one flag state, have crew members and captains from different countries, be owned by a company in another country, be chartered by another, and run routes between yet others.

In February 2017, in the absence of tangible progress on climate measures in the IMO, the European Parliament adopted an amendment to the Directive on enhancing cost-effective emission reductions and low-carbon investments. Although there was a clear preference for a multilateral approach through the IMO, the amendment called for shipping to be included in the EU ETS (and perhaps by extension in the EU NDC) starting in 2023 if the IMO fails to take action before 2021 (European Parliament, 2017). This amendment was however not in the final EU directive on the emissions trading scheme.

In April 2018, the IMO adopted an Initial Strategy on the Reduction of GHG Emissions, setting out three objectives (IMO, 2018b):

1. ***Reduce ships' carbon intensity*** *through the implementation of further phases of the energy efficiency design index (EEDI) for new ships;*

2. ***Reduce carbon intensity of international shipping*** *(i.e. CO_2 emissions per transport work[1]) by at least 40% in 2030 and pursuing efforts towards 70% in 2050, compared to 2008 levels; and*
3. ***Peak international shipping GHG emissions as soon as possible****; reduce total annual GHG emissions by at least 50% by 2050, compared to 2008; pursue efforts to phase out emissions (decarbonise) on a pathway of CO2 emissions reduction consistent with the Paris Agreement temperature goals.*

Among a number of other measures, the Initial Strategy includes market-based measures as a potential medium- to long-term measure (IMO, 2018b). Exactly what the IMO considers to be a "market-based" measure is not entirely clear. Stavins (1998) defines market-based environmental policies as "regulations that encourage behaviour through market signals rather than through explicit directives regarding pollution control levels or methods" – for example "tradable permits or pollution charges". The OECD defines market-based instruments as those that "seek to address the market failure of 'environmental externalities' either by incorporating the external cost of production or consumption activities through taxes or charges on processes or products, or by creating property rights and facilitating the establishment of a proxy market for the use of environmental services" (OECD, 2007). A workstream on market-based measures in the IMO previously explored a number of measures including levies, an ETS, and subsidies (IMO, 2010a).

By putting a price on carbon, a market-based measure can complement other emission reduction policy tools by providing the shipping sector a broad economic incentive to reduce GHG emissions and develop low-carbon technologies and products. The inclusion of market-based measures in the Initial Strategy has restarted the debate on the portfolio of measures to address GHG from international shipping that has been going on since the adoption of Annex VI on the Prevention of Air Pollution from Ships to the MARPOL Convention in 1997 (O'Leary and Brown, 2018). Market-based measures were discussed in the IMO as early as 2006 but Parties failed to agree on the design of such a measure and discussions were suspended in 2013. Figure 1: Timeline of decision-making events related to maritime GHG emissions provides an overview of relevant decision-making processes at the IMO, UNFCCC, and European Parliament with regard to market-based measures for international shipping.

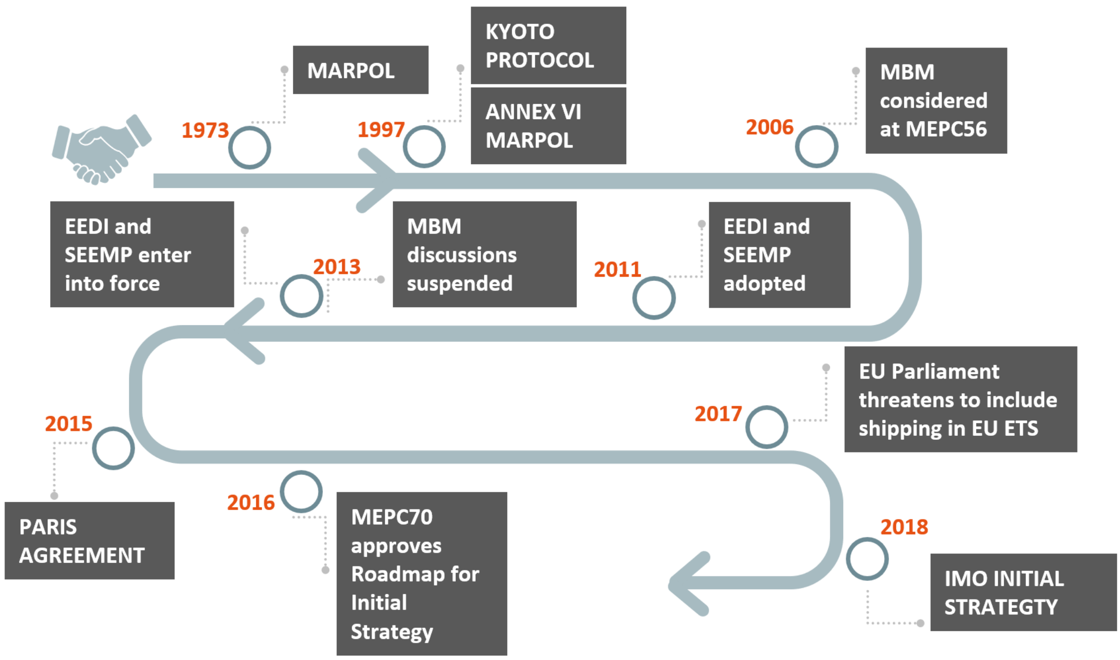

Figure 1: Timeline of decision-making events related to maritime GHG emissions

[1] Emissions per tonne kilometre or emissions per person kilometre or similar

A body of research already exists on the potential of market-based measures to address the climate impact of shipping. Psaraftis (2012) and Parry *et al.* (2018) considered market-based measures for international shipping in general and a carbon levy for international shipping, respectively. Psaraftis (2016) analysed the different market-based measure proposals that IMO Members put forward in 2010 and 2011, and found that a market-based measure could contribute to CO_2 reductions from shipping, but does not provide a clear recommendation for further steps given the stalled IMO talks after 2013. Parry et al. (2018) made a strong argument for a carbon tax, but only briefly discussed an ETS and an offsetting scheme as alternative options. An in-depth exploration the shipping sector's unique characteristics and what they mean for the application of an market-based measure has however not so far been covered in scientific literature.

In this paper we build on this existing research and explore three different options for a market-based measure: an offsetting scheme, a maritime emissions trading scheme, and a climate levy. We propose four criteria to evaluate the choice of a market-based measure in the international shipping sector, apply these criteria to the three options, and make recommendations as an input into discussions on carbon pricing for international shipping emissions.

2 Carbon pricing and the international maritime sector

To reach the temperature goals of the Paris Agreement, the world must drastically reduce GHG emissions. In certain sectors, a carbon price can play an important role in providing an economically efficient incentive to reduce GHG emissions (Nordhaus, 2013). According to Nordhaus (2013), a carbon price can achieve four goals. First, if high enough, it shows consumers which goods and services are more-carbon intensive and should therefore be used less. Second, it provides a signal to producers about which fuels are carbon-intensive (e.g. coal and oil) and which are less carbon-intensive or zero-carbon (e.g. renewables). This incentivises firms to invest in efficiency and switch to cleaner resources. With regard to the shipping sector, a carbon price would make clean energy sources more attractive compared to fossil fuels, in particular Heavy Fuel Oil (HFO). HFO, a residual fuel obtained from crude oil distillation, is inexpensive and widely available. Consequently, HFO is the most widely used fuel in international shipping, but its price does not reflect its environmental impacts. In fact, while HFO is not taxed, cleaner energy sources, such as electricity, are often subject to high taxes (OECD/ITF, 2018a).

Third, a carbon price incentivises inventors and investors to develop and fund low-carbon products. Faber et al. (2016) found that most important factors driving efficiency improvements are fuel prices and freight rates (i.e. the price to move a certain commodity from one port to another). High fuel prices increase the relative attractiveness of more efficient vessels and decrease the payback period required of the additional capital expenditure of energy efficiency expenditures (Faber et al., 2016). When freight rates are high however, shipping companies have a high profit margin, so from an economic perspective, energy efficiency is relatively less important. Moreover, when freight rates are high, transporting goods is more profitable, so demand for new ships increases. As a result, yards can build standard designs with a high profit margin. Conversely, when freight rates are low, shipyards compete for clients and are therefore more willing to build more efficient vessels (Faber et al., 2016). A carbon price which is applied based on the carbon content of the fuel, increases the competitiveness of lower carbon fuels and especially fossil fuel alternatives like hydrogen. This is likely to result in: increased investments in energy efficient ships, as well as operational improvements including speed reduction, hull cleaning, and weather routing (ICCT, 2011). A carbon price would therefore give a competitive advantage to technology firms and ship builders who invest in technology to reduce emissions.

Fourth, a carbon price will convey these three signals on the marketplace for wider adoption. Currently, carbon taxes/levies and ETSs cover only 14% of global GHG emissions (World Bank and Ecofys, 2018), but the carbon prices in these systems are generally too low to have a large mitigation effect (OECD, 2018). Furthermore, no carbon price initiative yet exists for international shipping. Options for a market-based measure for international maritime transport include an offsetting scheme, an ETS, or a climate levy.

In addition to reducing GHG emissions, a carbon price can also generate revenues that can be used to address disproportionate impacts (e.g. a food price increases for remote countries and islands that depend on imports for their food security), finance climate adaptation efforts in developing countries, and fund R&D in the shipping sector.

3 Current status and future scenarios

3.1 Current status and trends

International maritime traffic has increased significantly in the past decades (IMO, 2014). As a result, fuel consumption and GHG emissions from international shipping have also grew significantly.

GHG emissions from international shipping peaked in 2008 and declined for several years due to the reduced economic activity and corresponding reduced demand for commodities caused by the global financial crisis. Although GHG emission levels were still below 2007 levels in 2015, they have been increasing since 2010 (Olmer *et al.*, 2017). The exact future pathway for GHG emissions from shipping depends on economic conditions, but the Third IMO GHG Study 2014 expects an increase of 50-250% between 2012 and 2050 in a BAU scenario (Smith *et al.*, 2014), resulting from economic and population growth and consequently a higher demand for maritime shipping (Bodansky, 2016).

Factors affecting the BAU scenario for GHG emissions include the decarbonisation efforts of countries worldwide. Fossil fuels are one of the most traded commodities, both in weight (44% of the international seaborne trade) and value (16% of the US$18.8 trillion global trade) (Sharmina *et al.*, 2017). Thus, even partial decarbonisation efforts worldwide will reduce demand for international trade of fossil fuels and therefore their transport via international shipping. Sharmina *et al.* (2017) analysed the effect of different energy and emission pathways and their effect on maritime GHG emissions. Their analysis led to the following conclusions:

1. Trade in fossil fuels is likely to be lower under the <2ºC than under the >3ºC scenario;
2. Trade in oil and coal will almost certainly decrease under the <2ºC scenarios by 2050 compared to 2012, but trade in natural gas will likely increase; and
3. Although bioenergy supply and Carbon Capture and Storage (CCS) are likely to grow, it is unlikely that the trade in bioenergy and transportation of the CO_2 in a gas form is likely to be much higher under <2ºC compared to 2012 levels or >3ºC scenarios.

The implementation of a market-based measure in the form of a carbon price for international shipping would be relatively new to the sector, which has traditionally primarily relied on standards in its environmental policy making. For example, to address local air pollution from ships, a new global fixed limit for sulphur oxides (SO_X) in fuel oil will enter into force in 2020. Current regulations allow ships to use fuel on board with a sulphur content of 3.5% m/m (mass by mass), except in a number of SO_x Emission Control Areas (ECAS) were the limit is 0.1% m/m. Under the new cap, ships must use fuel oil on board with a sulphur content of 0.5% m/m or less. Ships can comply with the new limit by switching to low-sulphur oils, for instance marine gas oil (MGO). Depending on oil prices and refining capacity development, the sulphur cap is likely to increase fuel prices as low sulphur fuels currently trade at a premium to high sulphur fuel oil (HSFO) (Halff, Younes and Boersma, 2018). Such a price increase could lead to ships slowing down to conserve fuel and therefore reduce emissions. This price increase could also further to incentivise the shipping sector to develop and implement technical and operational measures that will improve ship efficiency.

Thus, decarbonisation of other sectors as well as the new sulphur limit are likely to decrease maritime GHG emissions compared to a scenario without these factors. Nonetheless, even with a decreasing demand for oil and coal, and the limit for SO_X in fuel oils, shipping and shipping-related GHG emissions are likely to grow in the future. Therefore, the shipping sector must make drastic changes to further decrease its GHG emissions in order to meet the goals listed in the IMO's Initial Strategy and ultimately decarbonise the shipping sector.

3.2 Reduction potential

Depending on when shipping emissions peak, there are various possible pathways for the sector's contribution to staying below the 1.5°C temperature increase. If emissions peak or start to decline early, the pathway could be longer, reaching zero carbon emissions in 2050. If emissions peak late, the sector must quickly decrease its emissions afterwards, reaching zero carbon emissions as early as 2035 (OECD/ITF, 2018a). The shipping sector is, however, currently not following either of these pathways.

A key IMO initial strategy objective is "*to peak GHG emissions from international shipping as soon as possible and to reduce the total annual GHG emissions by at least 50% by 2050 compared to 2008 whilst pursuing efforts towards phasing them out as called for in the Vision as a point on a pathway of CO2 emissions reduction consistent with the Paris Agreement temperature goals*" (IMO, 2018b).

A reduction of 50% in 2050, compared to 2008 levels, would allow the maritime transport sector to emit a total of 28 to 43 Gt CO_2eq over the period to 2100. However, according to the IEA, the shipping sector can emit no more than a cumulative 17 Gt CO_2eq in total from 2015 onward in order to reach the "well below 2°C" goal of the Paris Agreement. Thus, a 50% reduction would significantly overshoot the Paris Goal of well below 2°C (IEA, 2017; ICCT, 2018).

Aligning international shipping with the Paris Agreement and decarbonising the sector before 2050 is not an easy task, but possible. According to a study from the OECD/ITF (2018a) it is technologically feasible to reach almost zero carbon emissions by 2035 using existing technologies, although such a scenario is ambitious in practice. A large part of the emissions reductions could be realised by technological and operational measures, including propeller polishing, water flow optimisation, weather routing, hull cleaning, and speed optimisation (ICCT, 2011). Switching from HFO to renewable energy, such as rotor sails providing ships with auxiliary wind propulsion, and alternative fuels, such as hydrogen are further potential measures (OECD/ITF, 2018a). With the rapid fall in the cost of renewable energy and battery technology, much of this abatement potential is likely to have become cheaper still.

A number of assessments find that around 22 analysed measures have an annual abatement potential of 350 million metric tonnes at almost zero marginal abatement costs or less, representing about 30% of emissions from the shipping sector (Buhaug *et al.*, 2009; Faber *et al.*, 2009, 2011; Rehmatulla and Smith, 2015b). A further study carried out for the European Commission found that 25% to 60% of emissions in the shipping sector could be reduced at negative or zero overall cost depending on vessel category and fuel prices (Lindstad *et al.*, 2015). An important question is how to develop a policy and incentive framework so that these technological and operational measures are implemented and mainstreamed into the shipping industry to quickly decarbonise the sector in line with the Paris Agreement goals.

Box 1: Technical and operational measures to reduce GHG emissions

Technical measures:

- **Hull cleaning:** foul hulls decrease a ship's efficiency, increases fuel consumption and consequently emissions. If the hull is regularly cleaned and its surface smooth, ship efficiency improves, leading to a decrease in emissions.
- **Propeller polishing:** the surface of a ship's propeller becomes less smooth over time, as a result of strain and cavitation damage as well as the accumulation of dirt. Polishing the propeller regularly, i.e. twice per year, increases the propeller's efficiency and therefore reduces GHG emissions.
- **Hull design:** the hull's size, shape, and coating can be designed to optimise the ship's position in the water and to make the ship as efficient as possible.

- **Wind propulsion:** rotor sails, installed on a ship's deck, can provide the ship with auxiliary wind propulsion, leading to a decrease in fuel consumption and emissions.
- **Alternative fuels:** potential alternative fuels include electric batteries (more feasible for short sea shipping), hydrogen, methanol, power to gas, and ammonia.
- **Air lubrication:** a layer of bubbles generated between a ship's hull and the water can reduce friction as the ship moves through water.
- **Alternative propulsion:** other alternative propulsion options have been proposed, for instance replacing propellers with flapping foils that mimic a dolphin's movement through water.
- **Waste heat recovery:** a significant proportion of energy from fuel is lost to heat in the conversion to mechanical work by the main engine, such heat can be reconverted to electricity via heat recovery systems linked to turbine generators
- **Solar power:** Photovoltaics can be installed on ships to generate electricity en route.
- **Other ship design measures:** A number of other ship design measures, such as lightweight design and gyro stabilisers can also increase fuel and emissions efficiency.

Operational measures:

- **Slow steaming:** speed reduction is an effective measure to reduce emissions. By reducing speed with 10%, a ship can decrease its emissions by 27% (Faber *et al.*, 2012).
- **Weather routing:** by taking into account weather conditions, a shipping company can decide the most optimal route, save fuel, and reduce emissions.
- **Route planning:** shipping company can plan their route in such a way that they sail as few miles as possible, with as much cargo as possible.
- **Cold ironing / on shore power:** provision of on shore electricity to ships while in port reduces the need for ships to run engines for electricity.
- **Port and cargo handling and logistics:** reduced waiting time for port access and unloading and loading also could improve efficiency.

3.3 Climate policy measures to reduce maritime GHG emissions

Although the UNFCCC discusses emissions from "bunker fuels", the development and implementation of measures to address these emissions were historically left to the International Civil Aviation Organization (ICAO) for aviation and the IMO for shipping. While the Paris Agreement does not preclude countries from covering international shipping emissions in their Nationally Determined Contributions (NDCs), the IMO remains the main forum for discussion with regard to addressing shipping's climate impact.

The legal mandate for IMO discussions on GHGs does not come from the UNFCCC, but rather from the IMO's International Convention for the Prevention of Pollution from Ships (MARPOL). Originally focussing mainly on water pollution, MARPOL Annex VI regarding the prevention of air pollution from ships came into force in 2005. Discussions on the prevention of air pollution from ships, including GHGs are held in the IMO's Marine Environment Protection Committee (MEPC). Regulatory work originally focused mainly on SOx, NOx, Ozone Depleting Substances (ODS), Volatile Organic Compounds (VOC), and shipboard incineration, but the MEPC recognises MARPOL to include "emissions of any substances that originate from fuel oil and its combustion process" (IMO, 2011) and therefore greenhouse gases. Because the committee sessions must cover several issues in a limited amount of time, additional Intersessional Working Groups on Greenhouse Gas (ISWG-GHG) are held, often in the week before MEPC meetings.

While discussions on market-based measures continue, the IMO has promoted technical and operational measures in the past decade, most notably through the Energy Efficiency Design Index (EEDI) and Ship Energy Efficiency Management Plans (SEEMP). In addition, the IMO established a data collection system (IMO DCS) applying to ships larger than 5,000 gross tonnage (GT) that will enter into force in January 2019. All ships larger than 5,000 GT combined emit approximately 85% of maritime GHG emissions (IMO, 2016b).

3.3.1 Existing policy measures: the EEDI and SEEMP

The IMO has to date focused on improving energy efficiency to reduce maritime GHG emissions by encouraging the shipping sector to take both technical and operational measures. In 2011 the IMO adopted changes to MARPOL Annex VI, making the EEDI mandatory for all ships (IMO, 2018a). Another instrument adopted in 2011, SEEMP, applies to all ships and imposes planning, instead of substantive requirements for operational efficiency.

The EEDI was "intended to stimulate innovation and technical development of all elements influencing the energy efficiency of a ship from the design phase" (IMO, 2009). It is the only regulatory instrument promoting technical solutions to decrease GHG emissions from new vessels.

The EEDI, however, has been the subject to a number of critiques that in its current form, its impact in decreasing GHG emissions is modest at best. First, technical measures not only require engineering progress, but also a rapid adoption by the shipping industry, which is notably slow to react. Since ships have a lifespan of 25 to 30 years, a large share of the existing global fleet does not fall within the scope of the EEDI. Also, the early adoption phase in the shipping industry can be expensive, which hampers the uptake of certain technical measures (Wan *et al.*, 2018). For these reasons, it is highly unlikely the EEDI alone will achieve a significant reduction in GHG emission by 2050. Second, the energy efficiency of vessels that were subject to the EEDI are only slightly better than the average energy efficiency of vessels entering the fleet in the same period but which were not covered by the EEDI (Cichowicz, Theotokatos and Vassalos, 2015). Third, the EEDI focuses on technical measures to improve the energy efficiency of ship design, but does not address operational factors that determine actual ship energy efficiency (Cichowicz, Theotokatos and Vassalos, 2015).

Operational measures are supposed to be addressed by the SEEMP, which in theory requires both new and existing ships to develop a plan to maximise operational efficiency according to best practices for fuel efficient operation as well as guidance for voluntary use of the Energy Efficiency Operational Indicator (IMO, 2009). The requirement to develop such a plan can increase awareness of energy efficiency among shipping companies but is unlikely to significantly reduce GHG emissions (Wang, 2012), partially because SEEMP does not set efficiency targets that ships must meet. In addition, it lacks crucial features, such as requirements on policy and management reviews (Johnson *et al.*, 2013).

One of the most important operational measures that a ship can take to reduce fuel consumption and emissions is speed reduction. The financial crisis of 2007-2008 resulted in a decline in demand and the associated reduction in freight rates and fuel prices. Consequently, shipping companies decreased ships' speed in order to save money in the short term (Faber *et al.*, 2012). Since 2012 however, ships have sped up again. Indeed, although the speed of most ships did not change between 2013 and 2015, the largest oil tankers and container ships increased their speed. Consequently, the carbon intensity of these large ships increased. This, in combination with a significant increase in distances travelled, led to an increase of total maritime CO_2 emissions (Olmer *et al.*, 2017).

3.3.2 Market-based measures and future maritime climate policies

The IMO recognised that technical and operational measures may not be enough to address GHG emissions from shipping given expected growth of the global population and world trade and the urgent need to reduce emissions (IMO, 2009). Importantly, the IMO's Initial Strategy objectives (i.e. reduce individual ships' carbon intensity, reduce the carbon intensity of the shipping sector, and reduce GHG emissions) are unlikely to be reached through implementation of the EEDI and SEEMP alone. Additional measures are needed to incentivise ship owners, charterers, builders, and financiers to invest in low- and zero-carbon ships and operate them in ways that minimise emissions. IMO Members named various further candidate measures to reduce GHG emissions in the short-term, as well as in the medium- and long-term (Table 1: Candidate measures mentioned in the IMO Initial Strategy (IMO, 2018b). Market-based measures are included as a medium-term measure.

Table 1: Candidate measures mentioned in the IMO Initial Strategy (IMO, 2018b).

Short-term measures (finalised and agreed 2018-2013)	**Medium- and long-term measures (finalised and agreed 2020-2023 and beyond)**
Further improvement of the existing energy efficiency framework with a focus on the EEDI and SEEMP	Implementation programme for the effective uptake of alternative low-carbon and zero-carbon fuels
Technical and operational energy efficiency measures for both new and existing ships	Operational energy efficiency measures for both new and existing ships
Establishment of an Existing Fleet Improvement Programme	**New/innovative emission reduction mechanism(s), possibly including market-based measures to incentivise GHG emission reduction**
Speed optimisation and speed reduction	Further continue and enhance technical cooperation and capacity-building activities such as under the ITCP
Measures to address emissions of methane and further enhance measures to address emissions of Volatile Organic Compounds	Development of a feedback mechanism to enable lessons learned on implementation of measures to be collated and shared
Encourage the development of national action plans to develop strategies to address GHG emissions from international shipping	Pursue the development and provision of zero-carbon or fossil-free fuels to enable the shipping sector to assess and consider decarbonisation in the second half of the century
Continue and enhance technical cooperation and capacity-building activities under the Integrated Technical Cooperation Programme (ITCP)	Encourage and facilitate the general adoption of other possible new/innovative emission reduction mechanisms
Measures to encourage port developments and activities such as shore-side/on-shore power supply from renewable resources	
Initiate research and development activities addressing marine propulsion, alternative low carbon and zero-carbon fuels, etc.	
Incentives for first-movers to develop and take up new technologies	
Develop robust lifecycle GHG/carbon intensity guidelines for all types of fuels	
Actively promote the IMO's work to the international community, in particular to highlight that measures could support the Sustainable Development Goals	
Undertake additional GHG emission studies and consider other studies to inform policy decisions	

A carbon price generated through a market-based measure can send a signal (over and above fuel costs) and help steer the shipping sector towards decarbonisation. As mentioned, there are already a number of mitigation measures that could be taken in the sector at negative or low costs. The exact costs of different measures and their associated pay-back periods is currently dependent on the cost of the measures, fuel prices and freight rates (Faber *et al.*, 2016). The fact that there is such negative cost abatement potential seems to point to a number of barriers that prevent the implementation of these measures, even though they would save the shipping industry money. Maddox Consulting (2012) conducted a study on these barriers and found a number of market failures. Of these market failures, *uncertainty* is the single most significant obstacle to the shipping industry implementing cost effective abatement measures and presents a number of challenges for cost effective mitigation (see Table 2: Barriers to the implementation of cost-efficient measures).

Table 2: Barriers to the implementation of cost-efficient measures

Barrier	Could a carbon price help?
Economic uncertainty with regard to future fuel prices, future freight rates, the costs of technologies, future cost of capital affect if and how fast a mitigation measure will yield a return on the investment	Yes
Regulatory uncertainty for example what, when, and how regulatory measures will be enforced	Could help indirectly depending on a number of factors
Split incentives between ship owner, who makes ship investment decisions and ship operator who benefits from increased efficiency	Could help indirectly
Lack of accurate information on the energy efficiency of existing vessels, lack of accurate fuel consumption information	Could help indirectly
Commercial practices in the maritime industry where for example ships are compensated to wait for a berthing slot, but not if it arrives on time because it slowed down	No, a carbon price is unlikely to address this barrier
Timing barriers where if there is high demand vessel owners are unwilling to take a ship out of service for retrofitting, when demand is low there may be a lack of capital to make efficiency improvements	Could help indirectly
Administrative issues where there are management or staff resourcing issues or personal lack awareness of the efficiency measure	Could help indirectly

The implementation of a carbon price can help address some of these issues. A carbon price is likely to raise ship owners' and charterers' awareness about their emissions. In order to implement a carbon price, an MRV system to track individual ships' emissions is required. Such an MRV system will give owners and charterers more information of the energy efficiency of ships, as well as on fuel consumption. EU Regulation 2015/757 cites that: "public access to the emissions data will contribute to removing market barriers that prevent the uptake of many cost-negative measures which would reduce greenhouse gas emissions from maritime transport" (EU, 2015). Such transparent and accessible information can help charterers be more discriminating in their selection of ships to charter. With better information and choice, the split incentive barrier to more emission reductions when the owner and operator are not the same entity is reduced. It will also make the opportunity cost of not taking efficiency measures clearer to ship owners, as well as better motivate management and staff to inform themselves about efficiency measures in order to improve profitability. With more transparency and awareness about emissions as well as the investment options to reduce emissions, it is also likely that finance will be more readily available for shipping companies to finance these investments.

Second, a carbon price, depending on the price level, can drive investment in efficiency by creating an additional factor to take into consideration when making decisions about investments in efficiency or lower carbon alternatives. The impact on that behaviour depends on the current and future price level and crucially the shipping companies' expectation and confidence that price levels will continue to provide the price signal in the future. A stable or stably rising carbon price will reduce uncertainty in terms of payback periods for investments in efficiency or lower carbon alternatives. Uncertainty about future carbon prices will less effectively incentivise such investments.

Although the IMO Convention does not specifically give the IMO the power to establish economic instruments or an independent body, nothing in the Convention prevents the IMO from doing this (O'Leary and Brown, 2018). In fact, the IMO already implemented an economic measure and established an independent body. The International Oil Pollution Funds provide financial compensation for oil spills resulting from oil spills or persistent oil from tankers that occur in waters of states that ratified the Fund Convention[2].

Moreover, the IMO is not starting from scratch in considering market-based measures. The IMO has implicitly assumed the mandate to consider economic instruments and specifically market-based measures in the past. Market-based measures for the international maritime transport sector were first mentioned at the IMO in 2003 (IMO, 2003) and have been considered since MEPC 56 2006. In 2010, Members were invited to submit proposals for market-based measures. The proposed measures included *inter alia* an emissions trading scheme (United Kingdom, France, Norway, and Germany); a port levy based on ships' emissions (Jamaica); and a GHG Fund that would establish a global GHG emission reduction target for shipping that would require the purchase of offsets for emissions above the threshold (Cyprus, Denmark, the Marshall Islands, Nigeria, and the International Parcel Tanker Association). An Expert Group reviewed the ten submissions and concluded that all proposals could be implemented. However, all proposals lacked sufficient details to consider issues such as carbon leakage, international harmonisation in implementation, as well as enforcement and fraud. In 2013, discussions on market-based measures were put on hold because Members failed to reach consensus. Now, the IMO Initial Strategy has given rise to renewed discussions on market-based measures within the IMO which can start where previous discussions left off.

[2] More information can be found at: https://www.iopcfunds.org/.

4 Prerequisites for a market-based measure

A number of important decisions need to be made regardless of the market-based measure implemented. These include the how emissions are measured, reported, and verified, definition and selection of compliance entities, and enforcement entities.

4.1 MRV

Regardless of the market-based measure that is selected, transparent and publicly available data on GHG emissions from each individual ship and individual voyage, will be necessary to implement the measure. Currently, there are two data collection systems for international shipping: the EU MRV that entered into force in January 2018 and applies to all ships equal to or larger than 5,000 GT sailing to and from EU ports; and the IMO Data Collection System (IMO DCS) that will start in January 2019 and has global coverage. The IMO DCS also applies to large ships (≥ 5,000 GT) only. The EU selected the threshold of 5,000 GT because it covers 90% of emissions from ships calling into EU ports and thus covers the most relevant emitters. An impact assessment carried out by the European Commission found that a lower threshold would result in an unreasonably high administrative burden for small ships, while a higher threshold would limit the environmental effectiveness of the MRV system (European Commission, 2013).

Data collected under the EU MRV regulation becomes publicly available and port states thus have access to it, but the reporting obligation only applies to ships entering EU ports. Data collected under IMO DCS – while global, remains confidential. IMO Members could decide to disclose individual ship data to port states and ship owners, so port states could enforce any market-based measure and ship owners can settle their payment to the port state with the different ship operators who come into port, but this is not currently a requirement.

4.2 Compliance entities

An important consideration in the implementation of any market-based measure is the compliance entity that pays the carbon price generated by the market-based measure. This can be done “upstream” at the point of fuel suppliers, or “downstream” at the point of the shipping company.

In theory, the simplest way to enforce a market-based measure is upstream, i.e. charge the carbon price on fuel suppliers, which would then pass on the cost of the levy to shipping companies.

Setting the compliance entity point of regulation “upstream” at the refinery gate as an extension of existing fuel tax administration procedures would involve collection from a limited number of large easily identifiable taxpayers (Parry *et al.*, 2018). There are, however, two obstacles. First, although there are no legal obstacles to taxing fuels, countries refrain from doing so as a result of international tax competition and HFO is currently not taxed. Second, ships can travel long distances without refuelling, which means that the sector is highly competitive and without universal participation (which is unlikely from the start), the measure would be vulnerable to “carbon leakage” where ships would divert refuelling to ports that do not participate in a port fuel tax regime. Also, refuelling can happen at sea, in which case no port state would be responsible for charging the levy. The risk of carbon leakage means that a narrowly imposed carbon tax on maritime fuel is unlikely to have any effect if some fuel suppliers do not participate (Keen, Parry and Strand, 2013). Third, there is no precedence for MARPOL to directly take enforcement measures on fuel suppliers directly.

Parry *et al.* (2018) found that setting the compliance entity point of regulation downstream at the point of the ship “operator” is the most promising option for regulation. Although ship owners may ship cargo themselves, in which case they would be the ship operator, many contract out use of their ships to charterers who are then the considered the ship operator. Charterers in turn sometimes ship cargo themselves or they can sub-charter the vessel to a third party. The divergent incentives of these different actors is an important market barrier to efficient shipping (Rehmatulla and Smith, 2015a; Rehmatulla *et al.*, 2017; Scott *et al.*, 2017). Making ship operators the market-based measure compliance entity would go some way to helping address the principal agent problem between ship owners and charterers. The 2019 proposal to amend EU Regulation 2015/757 on MRV on emissions from ships defines the "company" responsible for reporting as "the shipowner or any other organisation or person such as the manager or the bareboat charterer, which has assumed the responsibility for the operation of the ship from the shipowner" (European Commission, 2019). Such a definition would also be suitable to define the compliance entity to be subject to a carbon price. Defining a different entity as responsible for the carbon price than that which is subject to MRV would create parallel structures and unnecessary regulatory burden.

A size and weight threshold of 5,000 GT and larger appears to be a reasonable cut off for compulsory participation in the market-based measure. Ships above this threshold account for 85% of global maritime GHG emissions (IMO, 2016b). The IMO DCS as well as the EU MRV use this threshold of 5,000 GT.

As discussed, emissions from ships are a function of both technical design measures and operation/behaviour. While ship owners bear the investment decision for or against fuel efficiency technologies, charterers pay for the fuel and profit from increased efficiency. Since most of the financial gains associated with increased energy efficiency flows to the operator, ship owners have little direct incentive to invest in cleaner ships. The extent to which a ship owner has an incentive to invest in cleaner ships depends on the availability and competition between ship owners for charterer business and the awareness and confidence of charters that certain kinds of ships. Although charterers are starting to include energy efficiency into their commercial decision-making (Rehmatulla *et al.*, 2017), the incentive is not yet enough to make ship owners make large investments in more efficient ships, which in turn means that there is not sufficient research and development invested into new efficient technology options among ship builders (see section 3.3.2 on barriers).

With increased information on emissions from the implementation of a transparent and publicly available emissions report, a market-based measure with the shipping "company" as per the EU definition as the compliance entity would increase the incentive of ship operators to include efficiency into their decision-making both in the operational efficiency of the ship (slow steaming) as well as to select the most fuel-efficient ship available. This would contribute to competition among ship owners to invest in more fuel-efficient ships (See Figure 2). The extent of the increased incentive will depend on the price level, awareness of the relative efficiency options, and the relative certainty that that price level will continue at the same or a higher price level in the future.

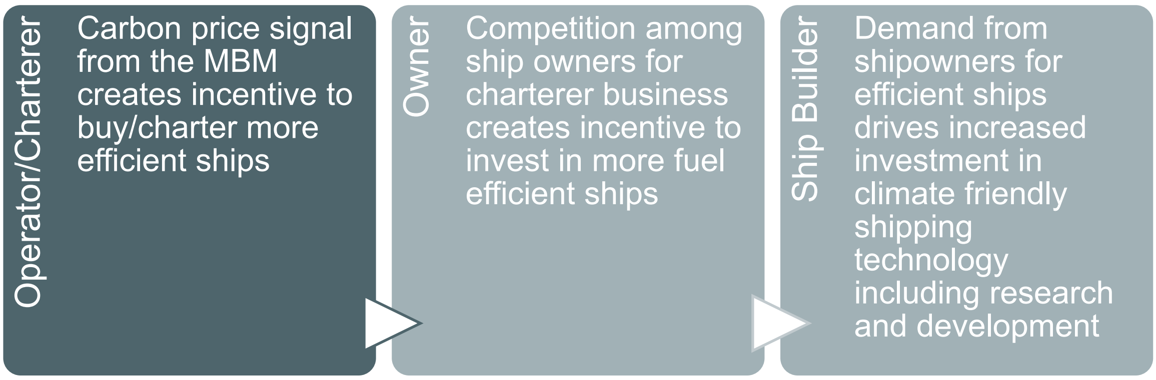

Figure 2: Idealised market-based measure carbon price influence on the shipping industry.

4.3 Enforcement authorities

Both flag states and port states could enforce a market-based measure. Under the United Nations Convention on the Law of the Sea (UNCLOS), flag states have the duty to exercise jurisdiction and control over administrative and technical matters (UNCLOS, article 94), and the IMO Monitoring, Reporting, and Verification (MRV) provisions will be reported via flag states. Many environmental and safety measures are however enforced via port states (GEF *et al.*, 2018). UNCLOS specifically provides port states with the right to take actions against vessels that violate international rules and standards if the vessel is voluntarily in the port of that state (UNCLOS, article 218). MARPOL Annex VI on the prevention of pollution from ships grants port states the power to carry out inspections related to operational requirements (Regulation 10).

Flag states enforcement may encounter a number of challenges however as, various flag states “open registries” are known for weak enforcement of international standards. Since it is easy for ships to change their flag registration to another country, a market-based measure that relies on flag state enforcement may be prone to carbon leakage. Given the fact that for a certain route, the use of a certain port is unavoidable, port state control is likely the preferred option. Port state enforcement in keeping with the NMFT principle would ensure that a ship flying under the flag of a state that does not participate in the global market-based measure still pays for its GHG emissions when entering the port of a state that participates.

Approximately 28 of the 100 largest ports in terms of total volume handled already apply environmentally differentiated port fees, where more efficient ships or ships willing to reduce speed in their approach pay a reduce docking fee (OECD/ITF, 2018b). Combined with MRV data (see above) a port could check that a shipping company is up to date with its obligations under the market-based measure as it does with bunker delivery notes. Compliance would have to include emissions from the vessel since the last time the vessel entered a participating port. This would require a ship charterer to verify that previous market-based measure obligations have been paid for previous voyages to avoid having to pay for previous charterers’ emissions.

To improve port state efficiency and improvement, various port states have grouped together under regional memoranda of understanding on port state control[3]. (Bang and Jang, 2012). Also, the European Union Regulation 2015/757[4] requires all ships sailing to and from EU ports to report their emissions to the European Commission. In the event that a shipping company does not comply with the regulation, enforcement measures take place through port state authorities.

[3] For more information see Paris MoU (https://www.parismou.org/) and Tokyo MoU (http://www.tokyo-mou.org/)

[4] For more information, see: https://ec.europa.eu/clima/policies/transport/shipping_en#tab-0-1

5 Assessment criteria based on sectoral structure and characteristics

In order to decarbonise the shipping sector, various technical design and operational efficiency measures must be developed and widely adopted in the sector. A market-based measure could be implemented to enhance these technical and operational changes. To inform a potential evaluation process in selecting an appropriate market-based measures to implement a carbon price, we propose the following four criteria to evaluate market-based measure options:

1. Effectiveness in reducing GHG emissions and steering the shipping sector towards decarbonisation;
2. Compatibility with the IMO principle of No More Favourable Treatment (NMFT);
3. Adherence to the UNFCCC principle of Common But Differentiates Responsibilities and Respective Capabilities (CBDR-RC); and
4. The market-based measure's efficiency in minimising transaction costs and administrative burden.

5.1 Effectiveness

The rationale behind designing a market-based measure for the maritime sector is to drive GHG emission reduction. Therefore, we assess how effective different instruments would be in incentivising in-sector emission reductions on the way towards decarbonisation. In the assessment of various options, it is important to consider what impact the carbon pricing option will have on investment behaviour, with the goal of moving towards lower carbon technologies and operational measures to reduce emissions. This is a function of current and expected carbon price levels, expectations of future price volatility, as well as correlation with output prices – freight rates for the shipping sector, and fuel prices (Kiriyama and Suzuki, 2004; Laurikka, 2006; Laurikka and Koljonen, 2006; Blyth *et al.*, 2007). Given that freight rates and fuel prices are exogenous factors not under the control of the IMO, we examine carbon pricing options and their influence on investment behaviour and carbon pricing option to improve efficiency independent of changes in these factors. We therefore assess the effectiveness of offsetting, emissions trading, and a climate levy to drive emission reductions in the international maritime sector in both the short and long term.

5.2 Non-discrimination and NMFT

IMO regulations follow the principle that measures should be non-discriminatory and that there should be No More Favourable Treatment (NMFT) of ships. This means that port states that have ratified a convention (including a potential convention with a market-based measure), are obliged to apply the rules laid down by this convention not only to ships flying the flag of a party to that convention, but also to vessels flying the flag of non-party states if they the port (UNCLOS, article 218). Thus, the NMFT principle ensures that, if countries do not universally agree to the implementation of a measure, such a measure can still be successfully enforced by port states to all ships coming into their ports.

Without application of the NMFT principle, a market-based measure that exempts certain flag states is very likely to be ineffective as 75% of the world shipping tonnage (by deadweight) is registered in developing countries, a number of which may opt to not participate in the scheme (UNCTAD, 2018). We therefore assess the ability of offsetting, emissions trading, and a climate levy to adhere to the principle of NMFT.

5.3 Impact on states and CBDR-RC

The IMO Initial Strategy calls for the principle of Common But Differentiated Responsibilities and Respective Capabilities (CBDR-RC) to be considered as a guiding principle of the strategy and for any measure to consider "Impacts on States". It further notes that "disproportionately negative impacts should be assessed and addressed, as appropriate" (IMO, 2018b). Since CBDR-RC and impact on states both address some level of differentiation for states, we assess them together. Because CBDR-RC is not included in the IMO convention or MARPOL, it is not a requirement for a market-based measure on the same level as NMFT. However, as a guiding principle and with the precedent established under the UNFCCC, any market-based measure is unlikely to attract widespread support if it does not implement this principle in some way. The fact that assigning responsibility for emissions from international maritime traffic is not straight forward, represents a challenge unique to international shipping[5] especially in the application of both the NMFT and the CBDR-RC principle.

The CBDR–RC principle stems from the 1992 Rio Declaration on Environment and Development (United Nations, 1992). The principle has been widely recognised in the climate regime, but was implemented differently under the Kyoto Protocol, the Paris Agreement, and the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) of ICAO.

Whereas the Kyoto Protocol only requires developed countries that historically contributed most to the emission of GHG (the so-called Annex I countries) to reduce their emissions, the Paris Agreement provides that all Parties must act, though on a nationally determined basis.

The international transboundary nature of international air and maritime transport makes the application of the CBDR-RC principle difficult. Although there are similarities, there are important differences between international aviation and international shipping (see Table 3: Main differences between international shipping and international aviation). These differences affect how a market-based measure could be implemented and mean that options for international aviation are likely to be less appropriate for international shipping.

With the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), ICAO took an approach to CBDR-RC that is different from the approaches under the Kyoto Protocol and the Paris Agreement. CORSIA is meant to help the aviation sector approach the global aspirational goal of carbon neutral growth after 2020 by offsetting emission in other sectors[6]. Under CORSIA, compliance with the scheme is stipulated by route. Routes between participating Parties are covered regardless of the country that issued the Air Operators Certificate (AOC)[7] of the airline flying the route. For example, if Belgium and Canada participate in CORSIA, then flights between Brussels and Montreal are covered regardless if the route is flown by Air India (with an Indian AOC) or Air Canada (with a Canadian AOC). Flights between participating parties and non-participating parties, and between non-participating parties, are not covered by CORSIA, regardless of the airline. The CBDR–RC principle is reflected in CORSIA in that the ICAO Assembly Resolution creating CORSIA, decided to use "a phased implementation for CORSIA to accommodate the special circumstances and respective capabilities of States, in particular developing States" and to make participation voluntary until 2027. From 2027 onward, international flights will generally be subject to these requirements, except flights to and from countries with a small share of international flight emissions, Least Developed Countries (LDCs), Small Island Development States (SIDS), and Landlocked Developing Countries (LLDCs), unless they volunteer to participate (ICAO, 2018). In practice, there is a strong correlation between the AOC countries and the routes operated by airlines between those countries. This is because under the

[5] International aviation has a related concept to NMFT, set in the Chicago Convention as "non-discrimination" but applied differently.

[6] Although there are two CDM methodologies in the aviation sector, the eligibility of the CDM in the CORSIA is still unclear, as is the future of the CDM after 2020.

[7] An AOC country is the ICAO equivalent to the registration of ships under a country flag in the IMO.

Chicago Convention of 1944, no international air service is permitted unless it specifically agreed that operations between countries are governed by air transport agreements, sometimes called open skies agreements (Puscinska, 2018). This means that the vast majority of flights between, for example, Europe and the United States are operated by airlines with an AOC from either the US or a European country, and only very rarely from a third country in cases where a specific special agreement has been negotiated.

Table 3: Main differences between international shipping and international aviation

International shipping	International aviation
International Maritime Organization (IMO)	International Civil Aviation Organization (ICAO)
No More Favourable Treatment (NMFT)	Non-Discrimination
Low correlation between flag state and routes sailed	High correlation between the country of an airline's Air Operator Certificate (AOC) and flight routes
Flag of a ship easily changed	Complicated procedure to change country of an AOC
Majority of ships sails under the flag of a developing country	Largest airlines are in developed countries
Common separation between ship operator / charterer and ship owner, loose relationship	Airline operator and airplane owner are usually the same entity, where airplanes are leased, these are usually longer-term contracts
Significant GHG abatement potential in the sector, much of which can be accessed at negative cost	Limited in sector abatement potential

Although not necessarily according to the CBDR-RC principle, the way CORSIA is implemented and enforced may lead to differences between countries. CORSIA is implemented through a regulatory tool called a SARP (Standards and Recommended Practices). Countries that have volunteered for CORSIA implement and enforce the SARP for airlines to which they have granted an AOC. Whether a country agrees to a SARP, generally determines if airlines with their AOC in that country follow that SARP. When a country disagrees with a SARP, it can file a "reservation" and if countries intend to implement a SARP differently they can file "differences". This leads to various levels of implementation and enforcement for different airlines depending on the country of their AOC (Mendes de Leon, Correia and Erling, 2015). With regard to the CORSIA SARP, Argentina, Brazil, China, India, the Russian Federation, Saudi Arabia, the United States, and Venezuela have all submitted reservations on various parts of the SARP text[8]. It is not possible to force a country to enforce SARPs on airlines for which it has issued an AOC, and there is a lack of publicly available information of SARP compliance in general. Rather, when non-compliance with SARPs is judged to pose a danger to safety, such airlines are generally banned from operation within certain airspace.[9]

The ICAO approach to CBDR-RC where there is a phased approach where countries either participate or not, and where there is a high correlation between an airline's AOC and the international routes it flies, is largely inappropriate for international shipping. First, making a definitive association between a particular ship and a particular country for the purposes of CBDR-RC is complicated because a ship's flag; the routes it sails on; where it refuels; and the registration or nationality of the ships' owners, charterers, and ship financers are not necessarily related. Thus, it is possible that a US logistics

[8] Reservations on the CORSIA SARP can be found at: https://www.icao.int/Meetings/a39/Pages/resolutions.aspx
[9] A list of airlines that are banned from operation in the EU can be found here: https://ec.europa.eu/transport/sites/transport/files/air-safety-list_en.pdf.

company charters a ship that was built in South Korea, is registered in Panama and owned by a Greek ship owner, refuels in Singapore, with an Indonesian crew, and gets finance from Germany for cargo shipments between Chile and the EU. This multi-country dimension of the international shipping sector makes application of the NMFT principle particularly important for international regulatory measures, but CBDR-CR especially challenging. Figure 3 gives a schematic overview of the main actors involved in maritime transport between two countries (in this case Chile and Germany).

Exempting ships flying the flag of LDCs and SIDS is also not desirable, because of the tentative relationship that a ship's emissions have to the flag of the ship and the large share of the global fleet that is registered in developing countries including a number in SIDS and LDCs. Panama, the Marshall Islands, Liberia, Hong Kong (China), Singapore, and Malta are the largest shipping flag states. Together, they account for 63% of overall tonnage (UNCTAD, 2018) and 52% of global CO2 emissions from shipping (Olmer *et al.*, 2017). Other prominent global shipping fleets are also registered in countries outside the OECD and include Hong Kong, the Bahamas, Indonesia, Antigua and Barbuda, Tanzania, Bermuda, Malaysia, Vietnam, Russia, the Philippines, Kuwait, Thailand, and Taiwan (UNCTAD, 2015). Most of these are Non-Annex 1 countries for UNFCCC purposes. Moreover, exempting certain states from the offsetting scheme, would violate the principle of NMFT.

Further, within this complex sector, the IMO Initial Strategy calls for the development of any measure to pay special attention to the needs of SIDs and LDCs in general, with respect to *inter alia* a country's geographic remoteness and connectivity to main markets, transport costs, and food security (IMO, 2018b). Indeed, the economic impact of a carbon price is likely to differ between regions, with a modest but proportionally higher impact on the GDP of remote small island states, depending on their geographic location. We therefore assess the ability of offsetting, emissions trading, and a levy system to take the principle of CBDR-RC into consideration, paying particular attention to options to address the impact on SIDS and LDCs.

Figure 3: Whose emissions? Schematic overview of different actors in the shipping sector.

5.4 Transaction costs and administrative burden

Lastly, a market-based measure should maximise efficiency and minimise transaction costs, including administrative costs. Efficiency and transaction costs are relevant both for the administrator of a market-based measure and for the emitters subject to the regulation (Den Butter, De Graaf and Nijsen, 2009). Minimising transaction costs is good policy making. An undue administrative burden would waste resources and elicit significant stakeholder resistance. We therefore assess the administrative implications of offsetting, emissions trading, and a levy system.

6 Assessment of various market-based measure options

There are at least three prominent market-based measures options for international shipping emissions: an offsetting scheme, an emissions trading scheme, and a climate levy. These three options were discussed at the IMO between 2010-2013, but as countries failed to reach consensus, the discussions were stalled in 2013. In this chapter we provide an overview of how these three market-based measures might function; how effective they are likely to be in driving emission reductions in the shipping sector in the short and long term; how they comply with the NMFT and CBDR principles; and to what extent they minimise transaction costs and administrative burden.

Other market-based measures are possible, for example an in-sector intensity trading scheme that sets an emissions intensity for emitting activities against a baseline. Participants with an emissions intensity below the baseline would earn credits that they can sell to participants with a higher emissions intensity. Because a baseline-and-credit system sets a target for emissions intensity, rather than for total GHG emissions, there is less certainty about reaching a certain emission reduction target (e.g. -50% by 2050 compared to 2008 levels). Therefore, we focus in this paper on an offsetting scheme, cap and trade scheme, and a climate levy for international shipping.

6.1 Offsetting

An offsetting scheme requires compliance entities / participants to purchase offset credits to compensate for all or a portion of GHG emissions covered by the measure. These offset credits are generated by reductions elsewhere and would lead to investments outside the sector covered by the scheme. Given the nature of the goals set by the IMO for itself, it is not entirely clear that offsetting is an option for the shipping sector. In contrast to ICAO's CORSIA, the IMO strategy specifically calls for GHG emissions *from international shipping* to peak and decline, not for the net effect of GHG emissions to peak and decline. The ICAO Assembly Resolution that served to set the aspirational target for CORSIA refers to "net" emissions. *The Assembly […] resolves that, […] ICAO and its Member States with relevant organizations will work together to strive to achieve a collective medium term global aspirational goal of keeping* ***the global net carbon emissions*** *from international aviation from 2020 at the same level.* (ICAO, 2013).

Such a target specifically allows for increased in-sector emissions growth well beyond – something that the IMO target does not specifically allow for.

Despite the relative clarity of the IMO Initial Strategy's goals that exclude offsetting by their nature, we assess the hypothetical option of offsetting international maritime emissions with a focus on what impact such a scheme would have on emissions in the shipping sector.

The IMO Initial Strategy sets the target of reducing GHG emissions by *at least* 50% by 2050, compared to 2008 levels (IMO, 2018b). This target does not lend itself particularly well to an offsetting target. Although "at least" is an undefined quantity, an offsetting scheme could be based on a percentage target at a value below the 50% target. This would require further negotiations to set the offset target beyond 50%. The IMO could then set yearly targets for emission reductions that increase annually to reach a 50+% reduction by 2050. Emissions above this level could be:

1. Distributed to shipping companies based on their own emissions in relation to sectoral emissions above a 50% reduction pathway, or a pathway towards zero emissions in 2050; or
2. Through a formula distributing emissions over the threshold to all actors in the sector; or
3. A mix of the two approaches.

Since with the latter two options, there is only a weak relationship between the emitters offsetting obligation and its own emissions they would not effectively incentivise individual emitters (shipping companies) to reduce their own emissions.

For the international aviation sector, the CORSIA also sets a sectoral target, but unlike the 50% emission reduction target of the IMO, ICAO sets a target of neutral growth after 2020. According to Paragraph 11 of the Assembly Resolution A39-3 that establishes CORSIA, the offsetting obligation starts out with a 100% sectoral approach from 2021-2029 and moves to a mixed approach where an airline offsetting obligation is determined by its own growth for at least 20% of the offsetting obligation for 2030 to 2032; and then moves to an approach where 70% of the aircraft offsetting obligation is determined by the individual growth for the period 2032-2035 (ICAO, 2016).

Alternatively, a ship emission efficiency benchmark could be applied and routinely strengthened to align a ship's emissions with a 50% reduction or a net zero carbon trajectory in 2050.

An offsetting scheme requires clear eligibility criteria to ensure environmental integrity. Parties to the Paris Agreement are still in the process of establishing rules for tradeable emission units. It is unclear exactly what provisions will come out of this negotiation process. The IMO could also establish its own system. Accounting, however, would have to be harmonised with the UNFCCC and CORSIA systems to avoid double counting. Other approaches could also be considered, for instance, an IMO body could be established to develop these guidelines and approve offset credits as, for example, the ICAO Council is in the process of doing. However, neither ICAO nor the UNFCCC have finalised criteria or decided on the rules for a mechanism after 2020 and it is very likely such a process would be at least as complicated in the IMO as in these other fora.

6.1.1 Effectiveness

Generally, a mandatory offsetting requirement is not a particularly effective tool to reduce emissions in the shipping sector. Rather, the rationale behind offsetting is to compensate for non-abatement or an increase of emissions in one sector with reductions in other sectors. Ongoing discussions on global rules for offsetting continue under the UNFCCC and need to ensure environmental integrity (further discussed in Box 2).

An offsetting scheme could have an impact on emissions from ships depending on the price level of eligible offsets. This introduces a high level of uncertainty for the shipping sector as supply and prices of offset credits depend on a number of factors, possibly including: provisions for carbon markets in the UNFCCC, credit eligibility discussions in the IMO, the mitigation opportunities in other countries, the ambition of NDCs, demand from CORSIA, as well as the future of existing projects, and mechanisms such as the CDM after 2020 (Schneider *et al.*, 2017; Fearnehough *et al.*, 2018). Low prices will not incentivise the industry to reduce emissions in the shipping sector if buying offset credits is cheaper than reducing their own GHG emissions. Current Certified emission reduction (CER) credits from the CDM are €0.26[10], because of the large supply and currently limited demand related to the mechanism's uncertain future after 2020. Forthcoming research on potential offset supply from existing projects for the period 2013-2020 suggest that without further criteria, potential supply could be up to 18 billion credits (Fearnehough, *et al.*, forthcoming), far outstripping current likely demand scenarios. Depending on eligibility criteria, such supply and demand interactions are not likely significant enough to lead to offset price levels that provide an incentive to reduce emissions in the shipping sector rather than buy offsets. Thus, it is possible that shipping emissions do not decrease by at least 50% by 2050, but instead continue to increase in the coming decades, undermining the temperature targets of the Paris Agreement.

Further, depending on how the sectoral growth is distributed to individual shipping companies, another element of uncertainty could be the emissions growth of other ships. If the offsetting scheme were to require shipping companies to offset emissions based on sectoral trends, then, shipping companies may be required to purchase offsets even if they themselves did not grow. This is the case under CORSIA

[10] CE ECX CER Futures December 2018 from https://www.marketwatch.com/investing/future/cerez8?countrycode=uk

where an airline will not know its offsetting obligation until the end of a compliance period when overall sectoral growth has been determined.

Moreover, in order to stay below the 1.5ºC temperature target, it is necessary for *all sectors* to decarbonise. The shipping sector has many opportunities to reduce GHG emissions, and could radically reduce emission using existing technology and operational measures (OECD/ITF, 2018a). Many mitigation opportunities in the shipping sector are relatively inexpensive with low or negative overall costs. Focusing on offsetting emissions, rather than investing in mitigation measures and innovation would be a lost opportunity for the shipping sector.

Box 2: Factors affecting environmental integrity of offsets

To preserve environmental integrity, a mitigation project only fully compensates for increased emissions elsewhere if the reductions are real, measurable, permanent, additional, independently verified, avoid double counting, and do not leak elsewhere (California 2018; ICROA 2018; ICAO 2017). Further considerations may include the vulnerability of existing projects, and the kinds of incentives for ambition that the project may set in the future (NewClimate 2018).

- **Real**: all emission reductions and the projects activities generating those reductions must have genuinely take place.
- **Measurable**: all emission reductions must be quantifiable.
- **Permanent**: carbon credits must represent permanent emission reductions.
- **Additional**: Mitigation projects should produce some "extra good" in the future relative to a reference scenario (Gillenwater, 2012). Or in the language of the Paris Agreement, emission reductions should produce emission reductions that are additional to any that would otherwise occur.
- **Independently verified**: an independent verifier must verify all emission reductions.
- **Avoid double counting**: double-counting must be avoided such that no single reduction credit can be used towards more than one climate mitigation goal.
- **Leakage**: projects should not cause emissions to materially increase elsewhere (ICAO, 2017)
- **Vulnerability**: A further proposed criteria, could be that credit purchases should support projects that are dependent on further revenue to continue reducing emissions. (Warnecke *et al.*, 2017).
- **Ambition**: In the context of the Paris Agreement, where all countries have emission reduction contributions to make, a further possible criteria for market-based mechanisms could be that credits should promote further ambition of the host country where the project is located and avoid perverse incentives against further ambition (NewClimate Institute, 2018).

6.1.2 Non-discrimination and NMFT

In order to comply with the NMFT principle, an offsetting scheme would have to apply to all ships calling port in a state that participates in the scheme, regardless of flag state. Port states could force ships flying a foreign flag to comply with the offsetting scheme, so the NMFT principle can be applied.

6.1.3 Impact on states and CBDR-RC

In the case of an offsetting scheme, adherence to the NMFT principle would complicate adherence to the CBDR-RC principle. An offsetting scheme cannot easily incorporate the CBDR-RC principle, because it does not raise (significant) revenues that can be used to compensate developing states[11].

ICAO's approach to CBDR-RC, where LDCs and SIDs are excluded from the offsetting scheme, would undermine the system because ships often load and unload cargo in different ports during one single journey.

Conceivably, the IMO could limit offset purchases to credits from projects in specific developing countries adversely affected by the scheme or another sub-group, for example LDCs. The European Union (EU) for example restricted offset eligibility for the EU ETS for the period 2012-2020 to credits from projects in LDCs (European Commission, 2012). Such an approach would not necessarily help LDCs, however, because the Paris Agreement principle of no double counting for market mechanisms means that host countries cannot count emission reductions carried out in their countries their own targets. This means that every emission reduction sold will make it harder for the host country to achieve their own NDCs (NewClimate Institute, 2018). Further, SIDS and LDCs have relatively low emissions, so even if offset project eligibility were to be limited to these countries, the mitigation opportunities are likely not large enough to provide a sufficient supply of offsets for international shipping.

6.1.4 Transaction costs and administrative burden

An offsetting scheme would come with a relatively high overall system administrative cost and impose relatively high transaction costs on small shipping companies or owners. Large shipping companies, like Maersk and MSC, that have existing trading departments could trade and hedge credits at a relatively lower cost than smaller shipping companies as their administrative costs per credit will be lower. Although only six liner shipping companies have a market share of 50% (UNCTAD, 2018), a large share of the global fleet is operated or owned by small companies, for whom it may be relatively expensive to carry out the administration involved in buying and trading offsets (Wang, 2010). Some of the administrative and transaction costs could be reduced for smaller emitters if they were to not hedge and were only to buy directly through a broker. This would however leave them comparably more exposed to price volatility. The higher relative cost for small emitters raises questions of fairness. Although in a different sector, Jaraite, Convery, & Di Maria (2009) found that small firms (allocation share up to 0.1%) incur transaction costs that are 40 times as large as the costs for large firms (larger than 2% share).

6.2 Emissions trading

A cap-and-trade system sets an overall cap on GHG emissions within a certain time period. Emission allowances (i.e. the right to emit a certain amount of GHGs) are distributed freely among participants or sold. Scarcity of available allowances creates a carbon price. Based on the price level, participants can choose to either reduce their own emissions (i.e. by investing in low-carbon technologies or through operational measures such as slow steaming) or purchase additional allowances. The main benefit of an ETS is that it provides greater certainty that a certain target will be reached, compared to an offsetting scheme or a levy.

[11] Under the CDM, a share of proceeds from the sale of certified emission reductions is used to fund the Adaptation Fund. One could theoretically follow the CDM Adaptation Fund approach, where a share of proceeds of offset trading flows to the Fund. It is however unlikely that such a fund would generate sufficient revenues to satisfy CBDR demands.

Four IMO Members (Norway, the United Kingdom, Germany, and France) have proposed the establishment of a global maritime emissions trading scheme (ETS) that would require ships to acquire emission allowances for their GHG emissions (France, Germany and Norway, 2008; France *et al.*, 2010; United Kingdom, 2010).

By setting a cap, the IMO can predefine the reduction goal of maritime GHG emissions to be achieved in a certain period leaving the price levels to fluctuating market demand. Shipping companies could receive or buy allowances that allow them to emit a certain amount of GHG. If they want to emit more, they would have to purchase additional allowances from other shipping companies or through an auction. Important issues to consider include cap setting; allocation of allowances; and administrative system and market oversight.

Similar to the offsetting baseline in the example above, the IMO's Initial Strategy target of reducing GHG emissions by *at least* 50% by 2050, compared to 2008 levels (IMO, 2018b) does not lend itself particularly well to an emissions trading scheme. While emissions trading schemes are comparatively well suited to achieve a certain target, they generally do not work well to *overachieve* a target: in an ETS reducing emissions below the cap drives down prices and weakens the price incentive to further abate emissions. Alternatively, the cap could be set at a nominal number of tonnes below the 50% target, or potentially for zero in 2050. This would require further negotiations to set the cap beyond the negotiations that led to the Initial Strategy target. Allowances could then be allocated on a yearly basis and be reduced each year according to a linear reduction factor to reach a >50% or 100% reduction by 2050.

Allowances could be allocated for free, based on historic emissions (grandfathering); auctioned, or sold for a fixed price on a first come first served basis. Auctioning and selling allowances would raise revenues that could either flow back to the industry or be used to compensate developing countries for the adverse impacts that an ETS would have on their economies. Part of the revenues could also be used to cover administrative costs related to the emissions trading scheme. Allocation of the emissions could theoretically happen at a global scale, as proposed by Norway (Norway, 2009) or on a national level, as proposed by the United Kingdom (United Kingdom, 2010).

An ETS requires robust system oversight. Since maritime shipping is a globalised industry, it would be necessary to have an international body market monitoring and oversight, including for the financial transactions that would result and rules to guard against market manipulation (Kachi and Frerk, 2013). Because the six largest shipping companies have a market share of 50% (UNCTAD, 2018), a particularly large amount of market power is concentrated in a few hands leading to increased danger of market manipulation where, for example, large market players could "corner" or "squeeze" the market (Jarrow, 1992; Pirrong, 1995, 1996, 2009). Moreover, the complexity of a global scheme and the international nature of IMO pose significant challenges to the implementation of a maritime ETS.

Indeed, if all ships are to be included in the ETS, the scheme would represent a very high administrative burden for smaller shipping companies. However, if the ETS is restricted to large ships, there is a significant risk of carbon leakage, though other measures could be developed for ships below the threshold. Suppose for instance that only ships exceeding 10,000 gross registered tonnage (GRT) are included in the ETS. Without comparable measures for smaller ships, this could result in new ships that are 9,900 rather than 10,000 GRT to avoid the ETS. Such a result would not be a desirable outcome because per tonne kilometre, larger ships are generally more efficient than smaller ships (Psaraftis, 2016). Thus, the threshold should be set at a level where it includes relatively small ships (so it makes no sense for ship owners to switch from large to small vessels) and covers most of the maritime GHG emissions. The threshold for both the IMO DCS and the EU MRV is set at 5,000 GT, covering about 85% of global maritime emissions and 90% of emissions related to voyages from or to European ports respectively (IMO, 2016b, European Commission, 2013). A maritime ETS should set a similar threshold to avoid carbon leakage.

Furthermore, an ETS should cover all states, including SIDs and LDCs. Exempting those countries from the scheme is likely to result in them becoming hubs for maritime traffic and thus in carbon leakage (Psaraftis, 2016).

6.2.1 Effectiveness

The effectiveness of an ETS depends on the cap and the price level generated. The idea of an emissions trading scheme is to control the total amount of GHG emitted, but not the price for allowances. While an ETS provides a higher degree of certainty for the overall environmental outcome, the incentive to invest in more efficient technology is variable and, depending on banking and borrowing provisions, an ETS may not meet a certain target (such as decarbonisation) in a certain year (for example 2050). Demand for allowances and prices in an ETS depends on a large number of factors including overall demand for shipping transport services, and technological progression.

With an economic slowdown and a corresponding reduction in demand for world trade, carbon prices would fall, and the opposite would happen if economic activity accelerates. Such volatility causes unpredictability for investors. In making an investment decision, important factors are not only current fuel, output and allowance prices, but also future expectations as to their development. Uncertainty and volatility mean that higher prices would be required to induce the same emission reduction investment behaviour than if future prices rise predictably (Laurikka and Koljonen, 2006; Blyth *et al.*, 2007). For instance the global financial crisis that started in 2007 led to a sharp drop in demand for international shipping transport (UNCTAD, 2017), which was associated with a drop in both bunker fuel prices and emissions from international shipping (Smith *et al.*, 2014). With an ETS, without robust market support measures or intervention, the allowance price would likely have dropped significantly, leading to a reduced incentive to take emission reduction measures or buy more efficient ships.

Price fluctuations can also be caused by technological breakthroughs. For instance, the Japanese NYK Group has developed a zero-emission concept ship (NYK, 2018) and Maersk started testing rotor sails that provide auxiliary wind power in August 2018 (World Maritime News, 2018). Such technological progress, if adopted by a number of shipping companies, would reduce demand and therefore allowance prices for other shipping companies, reducing the incentive to reduce emissions for the fleet as a whole – the so called *waterbed effect*. Several ETS have features to address such challenges, for example an auction floor price in California, Quebec, and the Regional Greenhouse Gas Initiative (RGGI) in the United States. California and RGGI also have price containment reserves, which consist of a pool of allowances that are made available to the market at certain price thresholds constituting a kind of price ceiling. A system price floor or ceiling, depending on their thresholds, may reduce some uncertainty. The closer the floor and ceiling are to each other, the more an ETS resembles a tax (see discussion on tax). The EU has opted for what it has called a Market Stability Reserve to address excess allowance accumulation, which some scholars have found may increase price volatility and uncertainty (Richstein, Chappin and de Vries, 2015). The IMO could also reduce the cap of the ETS, but as in other emissions trading schemes, such adjustments are likely to require repeated lengthy political debates, which would provide further uncertainty to market participants.

Moreover, the price of allowances may rise rapidly depending on rapid trade expansion or potentially speculative trading behaviour, which is likely to severely distort trade in goods transported by ships (Psaraftis, 2016). It is in the interest of the shipping industry and a global economy to avoid severe trade distortions.

For these reasons, an ETS may be a suboptimal policy measure to incentivise investments in more efficient low carbon shipping technology.

6.2.2 Non-discrimination and NMFT

An ETS could apply the NMFT principle by applying to all ships, regardless of flag state. This is important to prevent carbon leakage by ships registering in a state that does not enforce the ETS.

6.2.3 Impact on states and CBDR-RC

Similar to the challenges of an offsetting scheme adherence to the NMFT principle, would complicate adherence to the CBDR-RC principle by way of exemptions because exempting developing countries, or even only LDCs and SIDS, would significantly undermine the effectiveness of the scheme (see discussion in the offsetting section). Further, exempting certain states from the offsetting scheme, would violate the principle of NMFT.

An ETS could, however, potentially be implemented in such a way that it recognises the principle of CBDR-RC through compensation. For instance, while allowances could be allocated freely to ships serving routes between developing states, they could also be sold auctioned to raise revenue. Such revenue could be used for various purposes, e.g. to compensate developing countries for the negative effects of the ETS, to assist the shipping industry in decarbonisation efforts, or to finance climate adaptation measures. We further discuss potential uses of raised revenue to address impacts on states and CBDR-RC in section 6.5.

6.2.4 Transaction costs and administrative burden

Transaction and administrative costs are inherent to an emissions trading scheme. These costs are relatively high for small emitters, which raises questions of fairness. Jaraite, Convery, & Di Maria (2009) found that small firms (allocation share up to 0.1%) incur transaction costs that are 40 times as large as the costs for large firms (larger than 2% share). Although only six liner shipping companies have a market share of 50% (UNCTAD, 2018), many companies use fewer than five ships. An ETS would impose relatively high transaction costs and a large administrative burden on those companies. Furthermore, the implementation of a global ETS is an extremely complicated task with large data requirements and high administrative costs, which would include market oversight of trading activity. No global regime for market oversight of commodity markets exist, rather commodity exchanges are subject to financial regulation in the country where they are located. Existing ETS all have detailed rules for market oversight, and ETS linking negotiations have so far all included significant discussion of market oversight provisions (Tänzler *et al.*, 2018). Such deliberations would also increase administrative costs and force the IMO to enter into a new regulatory role with which it is not familiar.

6.3 Climate levy

The third option for a maritime market-based measure that we assess in this paper is a climate levy. A climate levy would impose a fee or tax tied to the ship's GHG emissions.

As mentioned in section 4, a designated payment matched to emission reporting and verification could be paid directly to the IMO, or integrated into the berthing fee structure that shipping companies already pay to port authorities on a per voyage basis. UNCLOS provides port states with the right to take actions against vessels that violate international rules and standards, if the vessel is voluntarily in the port of that state (UNCLOS, article 218). The NMFT principle builds on port state jurisdiction, as it implies that ships calling into a port are subject to inspection with regard to international instruments, even when the flag state is not party to those instruments. In other words, a ship flying under the flag of a state that does not participate in the global market-based measure, would still be required to pay the climate levy for its GHG emissions when entering the port of a state that is participating.

6.3.1 Effectiveness

As for the other measures, the climate impact of a climate levy depends on its price level. Unlike an ETS and offsetting scheme, a levy allows the regulator to set the price. A low levy is unlikely to incentivise the shipping sector to sufficiently reduce GHG emissions to achieve the 2050 target and align the sector with the goals of the Paris Agreement. However, a carbon price that is high enough to make renewable energies and low-carbon technologies competitive with fossil fuels, will be effective in contributing to the decarbonisation of the international shipping sector. A climate levy for shipping may be the most effective and cost-efficient potential policy instrument to reduce maritime GHG emissions (Parry *et al.*, 2018).

The levy price level could be set equal to the carbon price necessary for the shipping sector to align with the 2ºC or 1.5ºC Paris Agreement targets. According to a survey undertaken by Lloyd's Register and UMAS (2017), a carbon price as high as US$250 per tonne of fuel makes zero-emission alternatives highly competitive and would likely lead to complete decarbonisation by 2035. However, an immediate levy in that price range is unlikely to attract widespread support from industry and governments. Moreover, if the levy is so high that shipping loses competitiveness compared to other modes of transport, this may result in a shift from shipping to e.g. rail or road transport on certain routes with a viable land alternative, which, depending on their fuel could increase global GHG emissions (Psaraftis, 2018). Another option is to start with a relatively low carbon price, which prevents market distortion or a shock to world trade. The levy could then be increased on an annual basis to provide certainty for investors and make the transition to zero-carbon fuels and technologies attractive such that fossil fuels are phased out by around 2050. By increasing the levy each year, the IMO is able to react on technological changes in the shipping sector. Several jurisdictions with carbon prices have taken this approach of gradually increasing the carbon price, for example in British Columbia (British Columbia, 2018).

The price level at which a carbon levy would be effective partially depends on cost differences between renewable options for marine fuels and prices for incumbent fossil fuels[12] while also factoring in the cost of alternative fuelling infrastructure development and the turnover cost of ships.

The price of alternatives and therefore the price difference and required carbon price to induce change depends on a number of factors. Renewable fuels, for example for hydrogen or ammonia, are tied to the cost of renewable electricity (See Table 4: Renewable electricity prices, associated price of hydrogen as marine fuel compared to incumbent fossil fuel prices (Lloyds Register and UMAS, 2017 and Philibert, 2017, Ship and Bunker, 2018a). If these costs are low, costs for e.g. hydrogen decrease too, making this fuel more attractive for the shipping sector (Lloyd's Register and UMAS, 2017; Philibert, 2017). In an assessment of converting renewable power to hydrogen, Glenk and Reichelstein (2019) expect industrial scale supply to become competitive within a decade and by 2023 in areas with large renewable resources and a high market penetration such as wind in Texas. For shorter distances, electric shipping is a promising option, especially because of the comparatively high amount of energy lost in conversion from electricity to hydrogen. Prices of batteries dropped by 73% between 2010 and 2016 (BNEF, 2017) and are expected to fall by another 66% between 2017 and (BNEF, 2018). Currently however, electricity sales are taxed in most jurisdictions, while bunker fuel is not. Depending on electricity tax regimes, developments in renewable energy prices and batteries will likely make electrification of short sea shipping more economically attractive.

Table 4: Renewable electricity prices, associated price of hydrogen as marine fuel compared to incumbent fossil fuel prices (Lloyds Register and UMAS, 2017 and Philibert, 2017, Ship and Bunker, 2018a).

Renewable energy price ($/MWh)	**Hydrogen price in energy equivalent Heavy Fuel Oil / Marine Fuel Oil ($/t)**	**Range of intermediate fuel oil prices from December 2017-December 2018 (global 20 ports average) ($/t)**
60	945	High: 514.50
30	450	Low: 372.00

As an alternative to impose a fee tied to the fuel's carbon content or ship's emissions, Parry *et al.* (2018) suggest setting a benchmark level and taxing the difference between this level and a ship's emissions.

[12] Prices for marine fuels are likely to increase after 2020 due to the new IMO sulphur cap.

This, however, does not incentivise ships that emit less than the benchmark level to reduce their emissions. Unless the benchmark were to rapidly drop to zero emission ships, it would not lead to a fully decarbonised shipping sector which is necessary to align the sector with the 1.5ºC global temperature increase target.

A robust climate levy is the most effective market-based measure that we assessed in this paper. A levy would incentivise shipping companies to sail at lower speed on the short term, thereby reducing fuel costs and GHG emissions (Psaraftis, 2018). In the long run, a climate levy is likely to contribute to the decarbonisation of the shipping sector.

6.3.2 Non-discrimination and NMFT

A climate levy could be implemented in line with the NMFT principle by applying to all ships coming into a certain port, regardless of flag state. If a critical mass of port states that represent a majority of global trade demand participate, then it would have an important impact on the shipping sector as a whole. As with any other environmental measure associated with the IMO, this is important to prevent carbon leakage that would occur when ships register in a state that does not enforce the levy.

6.3.3 Impact on states and CBDR-RC

Like an ETS, a levy could raise revenue that could then be redistributed to help address CBDR-RC. Generally, administrative costs associated with an ETS are higher than those associated with a levy or tax, because the institutional structure to collect levy usually already exists in the form of port fees. Therefore, revenues for redistribution are higher in case of a climate levy than with an ETS, assuming price levels are the same. We further discuss distributing these revenues in section 6.5.

6.3.4 Transaction costs and administrative burden

A climate levy is relatively straightforward to implement, especially compared to an offsetting or emissions trading scheme. Administrative and transaction costs are also likely to be lower than for an offsetting or ETS, because ship owners and charterers do not have to engage with an allowances or offset credits markets. However, a levy implies similar costs for shipping companies and regulators for MRV and levy collection as under an ETS.

6.4 Option assessment overview

Table 5 provides an overview of how the three market-based measure options (offsetting scheme, ETS, climate levy) perform against the different criteria (effectiveness; non-discrimination and NMFT; Impact on states CBDR-RC; and transaction costs and administrative burden).

Table 5: Assessment of different market-based measures: an offsetting scheme, an emissions trading scheme, and a climate levy.

	Offsetting scheme	Emissions trading scheme	Climate levy
Effectiveness	Some potential in-sector GHG emission reduction incentive, depending on offset credit price levels. However, price levels are highly uncertain as they depend on a number of additional external factors. Consequently, offsetting could allow emissions to continue to increase within the sector.	A cap gives high certainty regarding overall emissions. However, an ETS is unsuited to deliver on targets such as "at least" 50% since price incentives diminish the more emissions are reduced. Further, an ETS is unlikely to provide ship owners / investors certainty for investment in more efficient technology. This uncertainty of future price levels would lead to unpredictable responses from shipping companies in terms of operational measures and is unlikely to incentivise shipping companies to invest in technological changes.	A clear climate levy provides investors with more certainty and is therefore, depending on prices and future trajectories, most likely to incentivise the decrease of GHG emissions in the maritime sector. Though also a function of fuel prices and freight rates, a climate levy is the most likely to incentivise both ship operators to take operational measures to reduce emissions such as reducing speed; and ship owners / investors to invest in technical measures. The lack of price volatility and uncertainty mean that lower price levels are necessary than under an ETS for the same incentive towards more efficient technology.
NMFT	Possible	Possible	Possible
CBDR-RC	Significant challenges, because the scheme does not raise revenues that can be redistributed. Neither exemption, nor nationally determined contributions represent an option for CBDR-RC in an environmentally effective scheme.	Possible if allowances are sold or auctioned and revenues are used to compensate states along the lines of impact of the scheme and CBDR-RC. Neither exemption, nor nationally determined contributions represent an option for CBDR-RC in an environmentally effective scheme.	Possible if climate levy revenues are used to compensate states along the lines of impact of the scheme and CBDR-RC. Neither exemption, nor nationally determined contributions represent an option for CBDR-RC in an environmentally effective scheme.
Transaction costs and administrative burden	High. All ships must be monitored to determine individual GHG emissions and ship owners must purchase offset credits. Also, small ship owners with relatively low GHG emissions incur relatively high transaction costs.	High. All ships must be monitored to determine individual ships' GHG emissions. Further, shipping companies must participate on the carbon market. Also, small shipping companies that emit relatively little GHG emissions incur relatively high transaction costs.	Medium. All ships must be monitored. Unlike under the offsetting scheme and ETS, shipping companies do not have to trade allowances or buy offset credits. With the same carbon price as under those schemes, transaction costs are lower for a levy than for an offsetting or emissions trading scheme.

6.5 Compensation

As discussed, an offsetting system would not generate (significant) revenues that could be used to address CBDR-RC. Both a climate levy and an ETS, however, could generate significant revenues that can be used for various purposes, e.g. further research and development for low carbon shipping, construction of alternative fuelling infrastructure, emission reductions outside the shipping sector, compensation for top-performing vessels, or compensation for developing countries that are disproportionately affected by the measure (Chircop, Doelle and Gauvin, 2018).

By allocating revenues to the shipping industry for mitigation purposes, the IMO could stimulate the adoption of new, cleaner technologies and mitigate the negative impact on ship owners, especially in less established markets (Kosmas and Acciaro, 2017). Alternatively, revenues could be used to financially support several specific countries that are vulnerable to climate change, e.g. SIDSs, or countries that are negatively affected by the market-based measure, for instance because import prices increase significantly.

At MEPC 61 (2010) India and China argued that a maritime market-based measure does not respect the CBDR-RC principle. In their submission to the MEPC, these countries argue that in order for a market-based measure to comply with the CBDR-RC principle, all participating countries should be at the same level of technological and economic development. If this is not the case, a market-based measure favours developed countries and impairs developing countries (China and India, 2010). The perception of the extent to which such a carbon price would favour certain countries over others may be larger than reality. A low levy ($25/tonne of CO_2) is expected to have a small impact on commodity prices (AGF, 2010). Halim, Smith and Englert (2019) find that a carbon price in the range of US$10 – 50/tonne of CO_2 would increase maritime transport costs by only 0.4 – 16%, so the impact on transport mode choices would be minimal. Also, the impact on countries' GDPs would be minor, with a carbon price of US$90/ tonne of CO_2 having an effect of -0.002% of GDP for large developing countries. Comparatively, a US$30/ tonne of CO_2 could have an economic impact of -1% of GDP for a remote small island developing state (Halim, Smith and Englert, 2019).

Nonetheless, regardless of the exact magnitude of economic impacts, a scheme without some form of compensation for developing states is unlikely to receive widespread acceptance. Therefore, we recommend that any market-based measure is accompanied by some sort of compensation for developing states, for instance by creating a fund that allocates money to developing countries. This ensures that the measure respects both the principle of CBDR-RC and the principle of NMFT.

The design of a compensation fund raises several issues, including the question of which countries or actors should be compensated and to what extent. Several non-exclusive options present themselves including finance for climate change mitigation and adaptation in general, compensating for the impact of the market-based measure in developing countries, other kinds of technical support for developing countries themselves or for the shipping industry. It has been suggested that the revenues of an IMO levy could flow to help mitigation and adaptation in general, for example into the Green Climate Fund (GCF) (Parry *et al.*, 2018). However, the GCF does not currently consider the impact of a maritime market-based measure on different countries when making financing decisions. Further, several developing countries see the GCF as an institution that should be the main distribution mechanism for climate finance mobilised by developed countries, rather than a distribution mechanism for carbon pricing that developing countries have also paid into. Thus, it is unclear if developing states would agree to use a climate levy to generate revenues for the GCF.

Another option could be to establish a new fund in order to disburse (a portion of) the revenues from a maritime market-based measure to compensate countries particularly impacted by the measure, which implies a number of further questions. Should only LDCs and SIDs be compensated or also other low-income countries? Should compensation be based on import volumes (as an increase in fuel price is generally transferred to the final consumer) or should a decrease in exports also be considered? How should compensation for landlocked developing states be calculated? Should compensation be a form of climate finance or can countries also use it for non-climate related issues?

One option would be to redistribute some of the revenues through a fund that provides technical expertise and financial support to developing countries impacted by the market-based measure. Cambodia, China, Ecuador, Georgia, Iran, Jamaica, and Kenya advocated the establishment of a *Capacity Building for Climate Mitigation in the Maritime Shipping Industry* (GMN) fund at MEPC 73 (Cambodia *et al.*, 2018). The GMN initiative for example bring furthers maritime technology cooperation centres worldwide. These centres support the decarbonisation of the shipping sector in developing states (GMN, 2018). The IMO and the EU provide technical and financial support, but this is scheduled to end in December 2019. There is a growing sense among IMO Members for continuing support to the GMN. A revenues from a carbon price in shipping could help fill this gap.

Another option, though not necessarily helping to address CBDR, would be to use part of the revenues from a market-based measure to directly support the shipping industry with development and uptake of technological measures. For instance, promotional lending for shipping companies in developing countries to help them upgrade to the best available technology.

Further discussion of the questions above falls outside the scope of this paper, but they will likely need to be addressed if IMO Members are to agree on a compensation measure related to a market-based measure.

7 Implementation and next steps

The IMO often needs up to seven years or more to implement policy measures between the decision to develop a new mandatory IMO instrument, e.g. a market-based measure, and its entry into force (IMO, 2010). Considering the urgency of addressing the sources of climate change, the IMO should take concrete action soon. Amending an existing treaty (e.g. MARPOL) or adopting a new instrument with minimal ratification requirements is therefore preferable (O'Leary and Brown, 2018). The earliest opportunity for IMO Members to further discuss market-based measures and consider proposals is at MEPC74 in 2019. Parties could theoretically adopt a measure at MEPC77 in 2021. Soon after, decisions on the price level, point of application and enforcement, collection of required data, and compensation for developing states could be made (Figure 4). By 2030 the carbon price should be high enough so that it is economically more attractive to invest in low- or zero-carbon ships than in conventional fossil fuel ships.

In the meantime, the IMO should also consider additional measures to decarbonise the shipping sector, including fuelling infrastructure development and speed restriction standards.

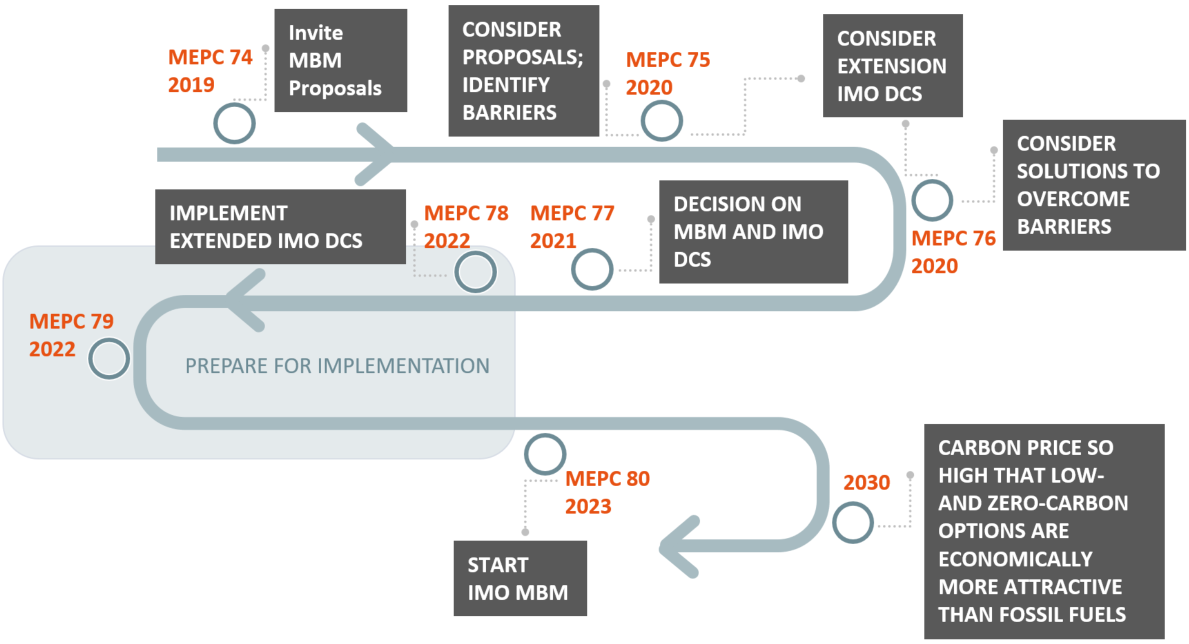

Figure 4: Timeline showing potential steps to be taken in the period 2019-2030.

8 Conclusion

International shipping has a 2.4% share of global GHG emissions and BAU scenarios project a 50-250% increase in GHG emissions between 2012-2050. Even if other sectors decarbonise and demand for coal and oil declines, shipping will continue to cause significant GHG emissions unless drastic action is taken. In the past years, the IMO has mostly focused on energy efficiency requirements, e.g. by implementing the EEDI. These efficiency measures alone, however, are very unlikely to lead to decarbonisation of the shipping sector.

A carbon price can enhance the development and application of technical and operational measures by incentivising actors in the shipping industry to invest in alternative – low-carbon – fuels and renewable energy, to improve ship design efficiency, to improve the logistic supply chain, etc.

We analysed three potential market-based mechanisms: an offsetting scheme, an emissions trading scheme, and a climate levy. Offsetting is unlikely to lead to sufficient in-sector reductions. The future rules for carbon markets under the Paris Agreement are still under negotiation after a lack of consensus that has continued at least since COP24 in Katowice Poland in 2018. Moreover, prices of emission offset credits are highly uncertain and depend on several factors, including technological progression, the ambition of NDCs, and other sources of demand such as the CORSIA. When prices are low, the shipping industry is not incentivised to reduce in-sector emissions. Since the shipping sector can take various technical and operational measures to reduce GHG emissions, a robust carbon price that would provide an incentive to realise this emission reduction potential would be a preferred option instead of offsetting. In addition, offsetting would not raise significant revenues to compensate developing countries or financially support R&D in the shipping sector. Unlike ICAO, the IMO cannot opt for a route-based approach that exempts certain developing countries from the scheme, because ships usually make several stops on one single journey and the relationship between flag state and routes are not closely linked. Further, excluding certain states from the scheme would likely lead to ships registering in countries that are not participating in the scheme, leading to carbon leakage.

The second market-based measure option, emissions trading, is complex and faces challenges of cap setting and system oversight. Moreover, without price management measures, the price of allowances would be volatile and therefore not provide a robust incentive to reduce emissions and drive innovation. Low price levels would not provide a robust incentive to reduce emissions. Speculative price spikes could rapidly disrupt trade patterns and have knock on effects for global commerce. Unlike an offsetting scheme, an ETS can generate revenues to compensate developing states and meet the CBDR-RC criterion.

A climate levy equally applied by all states is likely the best option for the international maritime sector. The carbon price under a climate levy should follow a defined pre-set trajectory, providing investors with certainty and therefore incentivising investments in technical and operational measures. Furthermore, a levy raises revenues that can be used to compensate developing countries, thereby implementing the CBDR-RC principle. To attract wider support and prevent a shock to the industry, the levy can start at a relatively low level and be raised over time. The climate levy could rise increasingly so that by 2030, the price could make zero-carbon technologies economically more attractive than high-carbon technologies and fossil fuels for new ships, and so that by 2050, fossil fuel powered vessels are economically unattractive to operate.

We recommend linking the climate levy with a compensation mechanism, so the levy can address disproportionate impacts on states and the CBDR-RC principle. Such a compensation mechanism could take the form of a fund, and the IMO has already set precedent with the development of a fund with the International Oil Pollution Funds. Another model could be the GMN Fund as advocated by Cambodia, China, Ecuador, Georgia, Iran, Jamaica, and Kenya at MEPC73.

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