A Global Maritime Emissions Trading System

Design and Impacts on the Shipping Sector, Countries and Regions

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Further information on this study can be obtained from the contact person Jasper Faber.

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CE Delfts solutions are characterised in being politically feasible, technologically sound, economically prudent and socially equitable.

Preface

This report was commissioned by the Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety). It has been written by a team of experts from CE Delft, DLR and Fearnley Consultants.

Interim results of this project have been discussed at a workshop 'Emissionshandel im Schiffsverkehr' in Berlin on 19 May 2009 and a side-event at MEPC 59 on 14 July 2009. The report has benefited from comments made by participants of these events. Furthermore, over the course of this project, several experts from a number of stakeholder groups kindly provided inputs to this report.

All errors, of course, can only be attributed to the authors.

Jasper Faber

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Summary

It is feasible to implement a cap-and-trade scheme for greenhouse gas emissions in the maritime transport sector. Such a scheme requires that the emissions of each ship are monitored and that an equivalent amount of emission allowances is surrendered to the scheme administrator. This obligation can either be imposed on the ship owner, or not assigned to a specific legal entity, in which case onboard documentation would have to demonstrate a ship's compliance status. Allowances can be acquired at an auction, in the marketplace and/or partly for free, if so decided by the international community. An administrative organisation would receive and administer emission reports and allowances, maintain records of the compliance status of all ships and inform Flag States regularly. Flag States would enforce the scheme on ships in their register and Port States have the right to inspect the compliance status of ships in their ports and enforce the scheme on non-compliant vessels.

A cap-and-trade scheme can guarantee a reduction in net maritime emissions. The cap would ensure that emissions are indeed reduced. Because the allowances are tradable, moreover, the scheme will reduce emissions in the most cost-effective manner. Furthermore, auction of the allowances can provide a funding mechanism. The price of the allowances will incentivise ship owners and operators to increase the efficiency of their vessels.

Shipping can continue to grow despite a cap on the emissions of the shipping sector. By allowing ships to use credits or allowances from other sectors, emission growth in maritime transport is possible, as long as emissions are offset by reductions in other sectors. Some positive economic aspects would result for ship builders, the engine manufacturers and classification societies due to a stimulation of demand of emission reduction technologies.

A cap-and-trade scheme can generate funds for climate change finance. The revenues of the auction of allowances can be used to mitigate undesired impacts and to finance climate change.

This study assesses the impacts of a maritime emissions trading scheme on the shipping sector and on the economies of regions and country groups. The impacts are assessed assuming full auctioning of allowances, as this would give rise to the greatest costs and also provide the largest funds available for compensating developing countries**.**

The costs of allowances would constitute a small fraction of total vessel operating costs. The size of the impact depends on vessel type and size, fuel price, allowance price and the proportion of allowances auctioned. Assuming full auctioning and using 2007 cost figures and an allowance price of USD 15 per tonne of CO_2 the cost increase for six different vessel types ranges from 4 to 8% of total operating costs. The share in overall costs is proportional to the allowance price, so that higher allowance prices increase the share in total costs. Conversely, higher fuel prices lower the share in total operating costs. A fuel price of USD 500 per tonne of fuel lowers the relative cost increase to 3 to 7%.

The volatility of the existing CO_2 allowance price has been similar to that of HFO prices. In the past two years, the price of allowances in the major market has varied from 13 to 33% of the price of HFO**.** The volatility of allowance prices has thus been approximately the same as that of fuel prices.

Under most market conditions, a major share of the cost increase can be passed on to consumers. When demand for maritime transport is lower than supply, prices are set by marginal costs and costs are passed on to the shipper and ultimately to the consumer. On the other hand, when demand is higher than supply, prices are not cost-related but are set by marginal demand and the profit margins are high. In that case, the introduction of additional costs will not affect the price; the costs will be borne partly by the ship owner, reducing his profit margins. Ship owners in developed countries own over 60% of the world fleet in terms of deadweight tonnage. About two-thirds of imports (by value) are to developed countries. Since both consumers and ship owners are located mainly in developed countries, these countries will bear the major share of the costs.

If costs are passed on, higher transport costs result in a small increase in import values. On aggregate, maritime transport costs represent less than 10% of import value for some developed countries and 5-15% for some developing countries. These costs include items that would not be affected by a maritime emissions trading scheme, such as port handling charges. These transport costs suggest that the value of imports would increase by less than 2% on aggregate. Disaggregating cargo types, we find that the value of imports of crude oil and manufactured products is least affected, increasing by less than 1%. Ores and coal are most affected, and their import value could increase by a little under 3%.

The overall impact on regions and groups of states is low, but differences can be observed. Assuming that costs are passed on to consumers, these costs will be related to emissions en route to the countries concerned. While emissions on routes to developing countries are lower than those on routes to developed countries, they are higher relative to GDP. As a result, developing countries face higher costs relative to GDP than developed counties. Table 1 provides a first order estimate of the cost increase of maritime transport to various regions and country groups. Because of improvements in vessel fuel efficiency, actual cost increases are likely to be lower than this. For many developing countries, moreover, costs are likely to be lower, as shipping companies will allocate costs to shipping routes where demand is highest, and these are typically routes to developed countries.

The revenues from the auctioning of allowances can be used to compensate for undesired impacts on developing countries and accelerate emission abatement in the maritime sector. There are several ways to mitigate the impact of the cost increase on developing countries. Some ways, such as exempting certain routes, ship types, ship sizes and cargo types, have the disadvantage that they could distort markets and potentially lead to higher emissions. However, a size threshold might be implemented in order to lower the administrative costs. Using part of the auction revenue to offset cost increases has the advantage that it would not distort markets. At a price range of USD 15–30, and assuming that all allowances are auctioned, revenues could amount to USD 15–30 billion annually. Table 1 provides a quantitative synopsis of how compensation might work if developing countries were compensated on the basis of their share in global imports. There are also other options for compensating certain (groups of) countries, including those taking into account the need for climate-related funding.

Table 1 **Emissions, costs and benefits for different regions and country groups**

Region of destination	CO_2 emissions on routes to regions Mt CO_2	First order estimate of cost increase of maritime transport, in USD bln. (CO_2: USD 15-30 per tonne)	First order estimate of cost increase of maritime transport, as % of GDP (CO_2: USD 15-30 per tonne)	Benefits from using 67% of auction revenues to compensate developing countries, based on value of imports
Region				
North America	120	1.8-3.6	0.01-0.02%	Almost none1)
Central America and Caribbean	53	0.8-1.6	0.01-0.01%	0.9-1.8
South America	59	0.9-1.8	0.05-0.09%	0.7-1.4
Europe	277	4.2-8.3	0.02-0.05%	Almost none1)
Africa	68	1.0-2.0	0.1-0.2%	0.7-1.3
Middle Eastern Gulf, Red Sea	62	0.9-1.9	0.08-0.15%	1.0-2.1
Indian Subcontinent	24	0.4-0.7	0.03%-0.06%	0.6-1.1
North East Asia	194	2.9-5.8	0.03-0.06%	5.1-10.2 2)
South East Asia	116	1.7-3.5	0.17-0.35%	1.5-3.1
Australia	35	0.5-1.0	0.06-0.13%	Almost none1)
World	1006	15.1-30.2	0.03-0.06%	
Country groups				
Annex I countries	469	7.0-14.1	0.02-0.04%	None
Non-Annex I countries	582	8.7-17.5	0.08-0.15%	10-20
G77	465	7.0-13.9	0.07-0.14%	6.7-13.4
Least Developed Countries	13	0.2-0.4	0.06-0.12%	0.3-0.5
Small Islands and Developing States	99	1.5-3.0	0.45-0.89%	0.7-1.5

1) Comprises mainly but not exclusively developed countries.

2) Comprises mainly but not exclusively developing countries.

In summary, it is feasible to implement a cap-and-trade scheme for greenhouse gas emissions in the maritime transport sector. Such a scheme ensures that the environmental target is met, while allowing the sector to grow and ensuring that the target is met in the most cost-effective way. An emissions trading scheme would result in an increase in the costs of shipping of less than 10%, depending on the price of allowances. As this increase would impact similar ships in the same way, markets would not be distorted. The increase in import values is likely to be less than 1% for most commodity groups, the impact on consumer prices even lower. The additional costs for most regions and country groups are estimated to be less than 0.2% of GDP, with a few exceptions. Undesired impacts can be mitigated by using the auction revenue to compensate countries.

1 Introduction

1.1 Policy context

The inclusion of international shipping emissions in a global climate policy framework has proved to be a difficult issue. In the run-up to the Kyoto Protocol, different options were studied to allocate emissions to countries and thus include them in the national totals, but no agreement could be reached. Instead, the Kyoto Protocol calls on Annex I countries to limit or reduce emissions ‘working through the International Civil Aviation Organisation and the International Maritime Organisation’ (KP, Article 2.2).

In 2003, the International Maritime Organisation (IMO) adopted resolution Resolution A.963(23) on ‘IMO Policies and Practices related to the Reduction of Greenhouse Gas Emissions from Ships’, which, ‘urges the Marine Environment Protection Committee (MEPC) to identify and develop the mechanism or mechanisms needed to achieve the limitation or reduction of GHG emissions from international shipping’. In doing so, the MEPC should give priority to, among others, technical, operational and market-based solutions.

To date, the Annex I countries have not been successful in limiting or reducing greenhouse gas emissions from international transport.

The main reason for this lack of progress is the seemingly conflicting principles of the IMO and the United Nations Framework Convention on Climate Change (UNFCCC). IMO policies are based on equal treatment of all ships, regardless of their nationality. IMO has regionally differentiated policies but even these apply to all ships in the specified regions. In contrast, the UNFCCC’s Kyoto Protocol is based on the principle of Common but Differentiated Responsibilities. Under this principle, developed or Annex I countries have to limit their emissions while non-Annex I countries do not. Simply applying this principle to shipping, e.g. by specifying that ships flying an Annex I flag would have to reduce their emissions while other ships do not, is widely agreed to be ineffectual as ships can easily change flag.

The seemingly conflicting principles, together with the fact that the Kyoto Protocol only instructs Annex I countries to reduce emissions (though not necessarily only *their* emissions) have resulted in a discussion on the governing principle of possible instruments, perhaps delaying the discussions about the design and impacts of instruments.

MEPC 58 and 59 discussed market-based instruments for shipping. At MEPC 59, the discussion focused on two instruments, viz. the ‘International Fund for Greenhouse Gas Emissions from Ships’, proposed by Denmark (MEPC 59/4/5), and the ‘Global Emissions Trading Scheme for International Shipping’, proposed by France, Germany and Norway (MEPC 59/4/25). While the discussion focused on a large number of issues, there seemed to be little convergence between States on the subject. It was decided to continue work on market-based instruments at the following sessions of the MEPC (MEPC59/24).

The UNFCCC discussed bunker fuels under the Ad-Hoc Working Group on Long-term Cooperative Action under the Convention (AWG-LCA) during several sessions in 2009. At the COP15 in Copenhagen, no final position was reached. The Copenhagen Accord (FCCC/CP/2009/L.7) does not mention emissions from bunker fuels.

This report aims to contribute to the discussion on the design and impacts of market-based instruments. It focuses on emissions trading, building on a few reports that have previously been written on this subject (CE et al. (2006)[1], Kågeson (2008)[2], CE (2008)[3], Buhaug et al. (2009)[4] and CE (2009)[5].

1.2 Scope of the report

The phrase Maritime Emissions Trading Scheme was coined by Kågeson (2008)[6]. In his paper, he proposed the following characteristics of such a system:

- It is an open emissions trading scheme, i.e. its emission allowances are exchangeable with allowances from other schemes.
- All emissions on voyages of ships larger than 400 Gt would be included in the scheme.
- The scheme would cover CO_2 emissions which would be calculated on the basis of fuel consumption data.
- The initial allocation of allowances would be done by auctioning them.
- Initially, a certain share of the revenues of the auction would be ploughed back into the sector, e.g. by awarding ships for tonne-kilometers of transport work provided or dwt-kilometers.
- The revenues could be partly used to feed UN funds intended for adaptation to climate change or reducing emissions from deforestation.
- IMO would create a special authority or subsidiary unit for the administration of the scheme.

This study builds on Kågeson (2008) and the German submissions to the MEPC based on it (GHG WG 1/5/7, MEPC 58/4/25, MEPC 59/4/25 and MEPC 59/4/26). It sets out to further design the scheme in chapter 2. Chapter 3 presents new data on the geographical distribution of ship emissions. The impacts on the shipping sector are assessed in chapter 4, while chapter 5 assesses macro-economic impacts on regions and country groups. Chapter 6 analyses whether a global emissions trading scheme would distort markets. In chapter 7, design options are discussed to minimize undesirable impacts on developing countries. Chapter 8 concludes.

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[2] Kågeson, Per (2007): The Maritime Emissions Trading Scheme (METS), Stockholm.

[3] CE (2008): Left on the High Seas: Global Climate Policies for International Transport: October 2008 update, Delft : CE Delft, 2008.

[4] Buhaug, Ø.; Corbett, J.J.; Endresen, Ø.; Eyring, V.; Faber, J.; Hanayama, S.; Lee, D.S.; Lee, D.; Lindstad, H.; Markowska, A.Z.; Mjelde, A.; Nelissen, D.; Nilsen, J.; Pålsson, C.; Winebrake, J.J.; Wu, W.-Q.; Yoshida, K. (2009): Second IMO GHG study 2009; International Maritime Organisation (IMO) London, UK.

[5] CE (2009): Impacts of proposed MBIs on the competitiveness of the Dutch maritime sector, Delft : CE Delft, 2009.

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2

Design of a Global Maritime Emissions Trading Scheme

This chapter proposes a design for a global maritime emissions trading scheme (METS). It analyses several design options in sections 2.2 through 2.9. but before doing so, it outlines the way in which a METS affects ship owners, states and the organisation(s) administrating the METS in section 2.1.

2.1 How does a maritime emissions trading scheme work?

This section describes briefly how a METS affects ship owners, the registry and states. It focuses exclusively on the main obligations for the actors involved. A more elaborate description and argumentation is provided in subsequent sections.

2.1.1 Obligations on the ship, the ship owner or operator

In the Maritime Emissions Trading Scheme, two responsibilities are placed on ships:

1. CO_2 emissions must be monitored and reported in a verified report to the METS Registry.
2. An amount of allowances equal to the emissions reported must be surrendered.

Monitoring of CO_2 emissions could be done in a number of ways. They would all be based on monitoring fuel consumption, as this is directly related to emissions. The least complex would be to make a fuel inventory per ship. This can be done by establishing the amount of fuel on board the ship at the beginning of the reporting period, establish the amount of fuel bought during the reporting period and establish the amount of fuel on board at the end of the reporting period. These data suffice to calculate the amount of fuel consumed during the reporting period, which can be multiplied by the emissions factor of that fuel to calculate emissions.

Allowances can be acquired at the auction, at carbon markets and possibly by registering for free allocation.

2.1.2 Obligations on the registry

The METS Registry has administrative tasks to guarantee the functioning of the METS. These are:

- Receive and administer emission reports.
- Receive and administer surrendered allowances.
- Maintain records of compliance status of all ships.
- Sends statement of account to Flag State on yearly basis.

In this way, the registry will keep track of the actual compliance status of each ship under the scope of the scheme. Flag States and Port States can make use of this registry to enforce the METS.

In addition, the registry may be assigned with the following tasks:

- Auctioning of allowances.
- Manage fund.

However, these tasks can also be fulfilled by different organisations.

2.1.3 Obligations and rights of States

Flag States have several obligations in the METS:
- Annual survey: control of account balance once a year on basis of bunker delivery notes (BDNs), fuel flow meters or other methods.
- Communication with the METS Registry: receive statement of account of ships flying the flag of that state.
- Enforcement of requirements of ships flying the flag of that state.

Port States have the following rights in the METS:
- Control:
  - Ships flying flag of Party State.
  - Ships flying flag of non-Party State (no more favourable treatment).
- Inspect record books and documentation of allowances and be informed by the METS Registry about a ship's compliance status.
- Take action against a ship that is not in compliance.

This enforcement regime is common with most other maritime conventions, such as MARPOL and SOLAS.

2.2 General principles of emissions trading

Emission trading is an incentive-based instrument to help achieving environmental objectives. In a cap-and-trade scheme, the total emissions are limited by a cap. All actors in the scheme need allowances to be able to emit. Since the total amount of allowances is limited, allowances have a value which creates an incentive to reduce emissions. Since allowances are transferable, emission reductions take place where they are the most cost-effective, consequently, a cap-and-trade scheme is a very cost-effective policy instrument.

When the general principles of emissions trading are applied to the maritime transport sector, a number of choices can be made on the design of such a scheme that takes the specific characteristics of the shipping sector into account. A successful implementation requires that:
- The scope of the scheme has been established.
- It has been decided whether or not to link the scheme to other systems and if so, how.
- A cap has been established.
- The responsible entity for handing in allowances has been identified.
- The cap has been divided into allowances which are allocated to responsible entities or auctioned off.
- The administrative organisation has been set up.
- The monitoring, reporting and verification requirements have been established.

Each of these design choices is discussed in more detail below. In addition, section 2.1 provides a short overview of the main tasks and responsibilities for ship owners, states and the administrative organisation.

2.3 The scope of the scheme

The scope of the scheme is one of the factors that determine its environmental effectiveness. The larger the amount of emissions in the system, the more emissions can be abated. The fewer exceptions, the fewer possibilities exist to avoid the scheme and thus reduce its environmental effectiveness. Hence, the scheme should ideally include all emissions from all ships worldwide. However, there may be reasons to exclude some emissions. This section discusses the impacts of various ways to exclude emissions on the environmental effectiveness.

When only certain flags would be included, it is generally acknowledged that the scheme would not be environmentally effective, as it would result in the flagging out of ships to states that are not included in the METS (CE et al., 2006). In that case, only ships that are required to fly a certain flag, e.g. ships engaged in cabotage, would be affected by the METS.

Limiting the scope geographical to certain routes also opens up the potential for avoidance, albeit to a lesser extent than flags. The reason is that the cargo needs to be delivered in a port near the final destination. There are two ways to avoid a geographically limited scheme. One is to offload the cargo in a port of a state outside the geographical scope and use another transport mode to bring it to the final destination. The other is to change routes in order to limit emissions in the geographical scope. So in the case where ports of parties to the METS are close to ports of non-Parties, avoidance may occur, but as long as the Parties are a geographical block, the impact of this is likely to be small. The second way to avoid a geographically limited system may have a larger impact. It depends to some extent on the definition of a route. If routes are simply defined by two port calls, an additional port call could be added to a voyage that would normally have been sailed without interruption in order to limit the emissions under the scheme. Although making an additional call entails costs like expenditures for harbour dues and opportunity costs for time lost, it could still be profitable on many routes (CE et al., 2009). However, if routes are defined as the distance from the port of lading to the port of destination, emissions under the scheme can only be reduced by transhipping the cargo. This would considerably increase the costs of avoidance for bulk shipping, as transhipment is time-consuming. However, the concept of a port of laden makes little sense for some kinds of shipping such as container transport.

One could imagine excluding certain ship types such as research vessels. As long as these vessels have a small amount of emissions and don’t compete with other vessel types, this would not have a large impact on the scheme. Hence, cargo ships cannot be excluded, as they account for a large share of emissions and different cargo ship types compete to some extent with each other. Excluding all non-cargo ships would reduce the amount of emissions under the scheme by 16% (see chapter 3). Excluding research, patrol and rescue vessels would reduce emissions under the scope of the scheme by less than 1% (Buhaug et al., 2009).

A size threshold could be introduced for two reasons. First, if there are many small vessels which collectively have fewer emissions than large vessels, having a size threshold would reduce the number of ships more than the amount of emissions. This would limit the administrative burden. However, if ships over and below the threshold operate in the same market, a threshold could distort the market. Moreover, since small ships are generally less fuel efficient than larger ships, a size threshold could at the margin have an environmentally perverse effect by shifting cargo from larger to smaller ships. Furthermore, as long as there are no other instruments to limit international maritime emissions, exclusion rules should be designed carefully, as small ships also compete with other transport modes. Second, a size threshold could be introduced as a way to reduce the impact on small and remote economies (CE, 2008). Chapter 7 looks into the feasibility of this concept.

To summarise, the scope should ideally be global and cover CO_2 emissions of all ships above a certain size threshold. A global scheme would be more environmentally effective since it would cover all shipping emissions. Moreover, it would not suffer from avoidance and avoid thus distortion in competition. However, the instrument would allow modifications in order to avoid undesirable negative impacts.

2.4 Possible links with other emissions trading schemes

The scheme should allow for the use of emission allowances and credits from other schemes to comply. Such an ‘open’ system has several advantages. It enables the shipping sector to buy allowances from other emissions trading schemes – and thus from other sectors that may allow to reduce emissions at a lower price compared to the abatement costs in the shipping sector - or sell allowances in these trading schemes. Of course, the allowances of credits from other schemes should be of sufficient quality and really represent an emission allowance or an emission reduction. Currently, the largest emissions trading scheme is the EU ETS which has a cap of over 2,000 Mt of CO_2. The proposed US ETS will probably be even larger. The Australian and New Zealand ETS are several hundreds of Mts. In addition to current cap-and-trade schemes, project based credits from CDM and JI projects amounted to 500 Mt in 2007 and their potential is expected to amount to several thousands of Mt in the future.

In a ‘closed’ system, emission allowances could only be traded within the system, i.e. within a clearly defined shipping sector. This could have the advantage that all the costs and the benefits are borne by the sector. However, a closed system would limit growth of the sector if mitigation measures within the sector cannot be developed at the same pace as traffic growth. This issue would become worse when the cap is reduced. Moreover, a closed system is likely to have more volatile prices than an open system as it depends solely on the business cycle of the shipping industry. Price volatility has several negative impacts, for example they increase the risk in investments and thus lower the speed of innovation.

By opening the METS to allow the use of allowances from other sectors, the price volatility would be significantly reduced as more sectors with different business cycles would be included. Insofar as other sectors have lower marginal abatement costs, the average allowance price would decrease. The volume of allowances and the number of potential participants would also be much larger in an open system, which should be beneficial for market transparency and liquidity. Therefore an open system appears to be the more effective solution.

2.5 Setting the cap

A scheme for mitigating greenhouse gas emissions requires the definition of a specific level of emissions: a cap. Usually, a cap is set using a historic level of emissions and a reduction path. This allows a system to gradually adapt to a new situation. One way to set the reduction path is to base it on the available carbon budget (WBGU, 2009). The carbon budget for the shipping sector can be determined by taking a share in the total available budget equal to shipping's historical share or equal to its present share (Lee et al., 2009). However, other methodologies are also possible.

Emissions of international maritime transport have been estimated at 843 Mt CO_2 in 2007 (Buhaug et al., 2009). The uncertainty margin in this estimate is ± 20%. Lee et al. (2009) have quantified a cumulative emissions cap based on a climate stabilisation scenario. If the share of shipping in the future climate budget would be set equal to the share in the emissions since pre-industrial times, the cumulative cap for shipping would be 40 Gt CO_2 in the period 2006-2050 for a stabilisation at 450 ppm CO_2 scenario. If the share of shipping would be set equal to its current share in emissions, the cumulative cap would be 36 Gt CO_2. When the cap is lowered gradually at a constant rate, the global annual cap for 2030 would be 765-815 Mt CO_2. Both the total budget and the 2030 cap have the same range of uncertainty as the present day estimate.

The cap should be set by the Party States, e.g. within the framework of the UNFCCC. In view of the uncertainty in the estimate the Party States that agree on the METS could consider a first phase with a price floor and a price cap in the auction. This would prevent the risk of very high prices if the cap is set too high or zero prices if the cap is set too high. After a few years in which accurate emission data will have been gathered, the price floor and the price cap can be eliminated. It should be noted that a price floor and a price cap may make linking the METS to other systems more complicated. It could then be contemplated to start with a closed system in the first phase as the disadvantages would be reduced by the price floor and the price cap.

Another way of dealing with the uncertainty is to precede the implementation of an emissions trading scheme with a year or a couple of years of collection of emissions data. If an accurate figure of maritime emissions data exists, a cap can be established. In principle this would create an incentive to increase emissions in the years in which the cap is established. However, increasing emissions means consuming more fuel. It is costly. Each ship operator has to weigh these costs to the benefits. Since the cap is a sectoral cap, the whole sector will benefit if an operator increases his emissions. Consequently, the individual benefits are small. Only if all operators collectively decide to increase emissions would this be worthwhile, but this would be unlawful in most countries. Setting a cap in this way would postpone the implementation of the scheme by several years.

2.6 Identifying the responsible entity

The choice of the responsible entity is a crucial one in any emissions trading scheme (CE et al., 2005). It determines to a large extent the enforceability of the scheme and thus its environmental effectiveness; and its administrative burden and thus its cost-effectiveness. This section first lists the potential responsible entities. It then derives a number of assessment criteria and assesses the potential entities against these criteria.

In principle, all entities engaged in shipping and partly responsible for a ship's use can be assigned with the responsibility to surrender allowances for the ships emissions. There are many of these entities, as is clear from the overview in section 4.1:

- Ship owner or disponent owner.
- Ship operator.
- Ship technical manager or DOC holder.
- Ship crew.
- Shipper.
- Charterer.
- Cargo owner.
- Cargo buyer.
- Cargo seller.
- Ship builder.
- Engine manufacturer.
- Fuel supplier.
- The ship itself.

In order for a system to be effective, it is essential that a responsible entity is clearly identifiable. Moreover, the entity has to be a legal entity, otherwise a system cannot be enforced.

As there are many factors that affect a ship's emissions, and not all of these can be defined contractually, the transaction costs of a system will be lower when a responsible entity has direct control over as many factors as possible that affect emissions. Moreover, the smaller the number of entities involved, the lower the administrative burden. Finally, enforcement is easier to organise when it is aligned with current enforcement mechanisms.

Hence, we derive five criteria to assess the potential responsible entities:

1. The entity is identifiable.
2. The entity is a legal entity
3. The entity has control over factors affecting emissions of a ship.
4. The number of entities is not too high.
5. The entity is currently responsible for compliance with maritime conventions

On the basis of these criteria, we rule out the shipper, cargo owner, buyer or seller as these may change during the voyage of a ship or may own or ship only a share of the cargo on board so they cannot be considered to have control over factors affecting emissions of a ship.

We also rule out the ship crew as it acts on instructions of the owner and/or the operator and has limited direct control over emissions. Moreover, the number of crews or masters is higher than the number of ships or ship owners, so this would complicate the administration of a scheme.

The following paragraphs discuss the extent to which the various actors satisfy the four criteria identified above.

Ship:

- The ship is identifiable as it has an IMO number.
- In some but not all jurisdictions, the ship is considered to be a legal entity. However, this would probably not be a problem if the ship is obliged to carry a copy of the verified emissions report and a certificate showing an equal amount of allowances has been surrendered.
- A ship as such has no control over emissions.
- In 2007, there were just over 100,000 ships larger than 100 Gt (Buhaug et al., 2009).
- Currently, many IMO regulations apply to the ships. This is certainly true of technical standards. MARPOL standards all apply to ships, not to ship owners or operators. For example, MARPOL Annex I requires new tankers to have double hulls, and Annex IV requires ships to have engines that comply with certain standards for emissions of NO_x. Compliance is enforced through inspection of the ship.

Ship owner

- The ship owner is identifiable and linked to a ship by SOLAS regulation XI-1/3-1. Under this regulation, each registered owner has a mandatory company and registered owner identification number. Ships' certificates identify the owner, so that the owner can be identified by visiting a ship.[7]
- A ship owner is either a company or a natural person and as such a legal entity.
- A ship owner has direct control over the technical factors determining a ship's emissions. He may choose, for example, to apply a low-friction painting to an existing ship or order a new ship with a waste heat recovery system. He also has control over many operational factors determining emissions. He can, for example, increase the maintenance frequency. If a ship is chartered he may warrant a lower than maximal speed. If the owner also operates the ship he may instruct the crew to sail slow, optimise trim, etc.
- The number of ship owners is smaller than the number of ships, as many ship owners own more than one ship.
- Operational procedures, management systems, and liability rules often hold the ship owner responsible. For example, the ship owner is obliged to comply with the International Safety Management (ISM) Code. The owner can transfer this obligation to another person or organisation. The code specifies that the responsible entity is 'the owner of the ship or any other organisation or person such as the manager, or the bareboat charterer, who has assumed the responsibility for operation of the ship from the ship owner and who, on assuming such responsibility, has agreed to take over all duties and responsibility imposed by the Code'. Likewise, the International Convention on Civil Liability for Oil Pollution Damage places the liability for oil pollution damage resulting from maritime casualties involving oil-carrying ships on the owner of the ship.

Ship operator

- The ship operator can refer to both the commercial operator and the technical operator. The commercial operator is not required to have an IMO number and may not be immediately identifiable.
- A ship operator is either a company or a natural person and as such a legal entity.
- A ship operator is contracted by the ship owner and acts as his agent. That limits his control over factors that impact emissions. In practice, he may

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[7] http://www.imo.org/Facilitation/mainframe.asp?topic_id=388.

have control over operational measures to reduce emissions. These include measures like slow steaming, weather routing and in some cases maintenance. But in general they do not include measures like the installation of wind power, retrofits to hull and engine, and they certainly do not include measures integrated in the design of new ships.
- The number of ship operators is smaller than the number of ships as many ship operators operate more than one ship.
- The ship operator is not named directly as an entity responsible for complying with conventions such as SOLAS, MARPOL or CLC. However, he may assume the responsibility for the ISM code from the ship owner. In that case, the operator becomes the holder of the Document of Compliance (DOC).

Ship technical manager
- The DOC holder holds the document of compliance of the International Safety Management (ISM) Code 2002. In most cases, this is the ship technical manager. This entity is responsible for the technical management of the ship. It is a clearly identifiable entity as it also has an IMO identification number.
- A ship technical manager is either a company or a natural person and as such a legal entity.
- The ship technical manager has control over the same measures as the ship operator.
- The number of ship technical managers is smaller than the number of ships as many technical managers manage more than one ship.
- The ship technical manager is not named directly as an entity responsible for complying with conventions such as SOLAS, MARPOL or CLC. However, he may assume the responsibility for the ISM code from the ship owner. In that case, the operator becomes the holder of the Document of Compliance (DOC).

Charterer
- The charterer is the party hiring a vessel. The charterer has a contract with the ship owner and is identifiable. However, during a certain period, a ship can have different subsequent charterers. Moreover, not every ship is chartered as some are operated by the owner. Therefore, it would be hard to assign responsibility to the charterer.
- The charterer is always a legal entity as it is the party that signs a charter contract.
- Depending on the contract, the charterer can take many responsibilities. These can include the operation of the ship and as such the charterer can have control over operational factors affecting a ship’s emissions.
- We have no estimate of the number of charterers. As the same ship can be on several charters at the same time, such an estimate would be hard to make.

Ship builder and engine manufacturer
- The ship builder and engine manufacturer are clearly identifiable. However, during the life of a ship, these companies may cease to exist which would make it impossible to hold them responsible for the emissions of a ship.

Fuel supplier

- Such a scheme would have many design aspects in common with the Danish proposal on an international compensation fund, with the additional feature that it would have a cap. Making the fuel supplier responsible for surrendering allowances would mean that fuel suppliers in Parties to an emissions trading scheme would have to charge more for their fuel than fuel suppliers in non-Parties. There is a clear indication that the bunker market can shift easily to other countries. In 1991, California introduced an 8.5 percent sales tax on bunker fuel at the same time the US Oil Pollution Act increased the costs of bunker fuel suppliers by raising their insurance and adding operational constraints. The bunker market in LA Long Beach collapsed to about one fifth of its original volume. At the same time, the market in Panama, where no tax was levied, soared (Michaelis, 1997). Hence, the fuel supplier could only be made the responsible entity if all states would become party to the convention or if ships could be made responsible for paying the levy in case fuel suppliers had not. The latter option would mean that two entities would be responsible: the fuel supplier and the ship.

Based on the analysis above, we conclude that the ship owner has control over the largest number of factors that determine emissions, either directly or through contracts with the ship operator, the DOC holder and crew. Ship owners are legal entities and are clearly identifiable and linked to the ship. In many cases, the ship owner may also act as the operator and hold the DOC, but often the operator or DOC holder is a different company.

In order to improve the enforceability of the scheme, it should be considered to have the ship as the accounting entity, and assign the responsible entity with the task of surrendering emissions for each ship he owns in accordance with its emissions. Thus, not only responsible entities could be non-compliant, but also ships, and it would be more effective to enforce a policy both on the ship owner or DOC holder and on the ship than on just one of these two. Moreover, if the owner sells a ship for which no allowances have been surrendered, the new owner becomes liable for surrendering them.

The ultimate penalty for non-compliance would probably be detention of a ship and/or a denial of entry of a ship into a port. This would significantly reduce the flexibility of a vessel trading and could, depending on the regions where it cannot trade, reduce the economic value of a ship. Also, in this way, enforcement could be based on Port State Control or other enforcement agencies in ports.

An alternative arrangement would be not to define the entity which is responsible for monitoring emissions and surrendering allowances, but to place an obligation on the ship to carry a copy of a submitted emissions report and a certificate from the administrative organisation specifying an amount of allowances has been surrendered equal to the emissions reported.

In summary, it appears that the ship owner is the preferable responsible entity to monitor emissions and surrender allowances. The accounting entity will be the ship. This ensures that the ship can be held liable if a ship is not compliant. An alternative arrangement is to place an obligation on each ship to carry documents that show compliance. In that case, there is no need to specify a responsible entity.

2.7 Monitoring, reporting and verification

The effectiveness of the scheme depends on the accuracy by which emissions can be monitored and verified. Emissions can be calculated on the basis of fuel consumption. Ship owners can monitor fuel consumption and report it to the METS administration. To ensure that the report is correct, the METS administration can require that it is verified by an independent third party. This section outlines the methods for monitoring and verification.

The effectiveness of any scheme depends on the ability of both the responsible entity and the administrative organisation to monitor emissions. This section discusses current practices of fuel monitoring in shipping and potential monitoring, reporting and verification requirements.

There are a number of sources a ship owner or operator can use to monitor a ship's fuel consumption, such as:

- Fuel purchases in a given period, e.g. on the basis of bunker delivery notes (BDN).
- Internal records of fuel consumption such as the daily 'noon report' which logs a ship's position, course, and fuel consumption amongst others.
- Commercial records of fuel billed to the charterer (only for time chartered ships).

The method by which fuel purchases or fuel consumption is determined can either be tank soundings or fuel flow meters. The first source is based on measuring the amount of fuel bunkered by sounding the tanks. Such a method may be accurate up to 1-5%.[8] The latter two methods can be based on fuel flow meters, tank soundings or other instruments to measure fuel consumption. The accuracy of these measurements is at least as good as the accuracy of tank soundings. In case of commercial records, the measurements may be done by an independent third party.

Based on the fuel consumption CO_2 emissions can easily be calculated by using the default emission factors. The CO_2 emissions would have to be reported to the authority which administers the scheme.

We note that the method of choice of fuel consumption monitoring depends on the actual equipment on board a ship. As there are currently no international regulations on this, the method of choice cannot be prescribed. If the accuracy of current methods is considered to be inadequate, international standards on fuel monitoring can be contemplated.

Under Regulation 18 of MARPOL Annex VI, all ships engaged in international transport over 400 Gt are obliged to keep bunker delivery notes on board for a period of three years. There are currently no obligations to monitor fuel use, although it is common practice to do so and a commercial necessity for ships in time charter.

Hence we conclude that all ships over 400 Gt engaged in international transport have at least one way in which fuel consumption can be monitored and in most cases at least two ways.

The existence of two independent sources of fuel records makes it possible to use one to verify the other. This is the task of the verifier. If a ship is to report its fuel consumption over a certain period, e.g. a year, it can do so by recording the amount of fuel on board at the beginning of the year, calculating

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[8] Bunkerspot, Vol. 6, No.1, Feb/March 2009.

the total amount bunkered during the year from the BDNs, and recording the amount of fuel on board at the beginning of the year. The amount of fuel can be calculated from these data. This can be compared to the sum of amounts of fuel consumed in all the noon reports over the year.

The verification of the fuel consumption can further be improved by cross-checking noon reports with voyage information from the log-books, shipping companies internal records on fuel purchases, commercial databases on ship movements and port calls and other available sources.

To guarantee the environmental integrity of the scheme, the authority will only accredit an organisation as a verifier if it can prove sufficient knowledge and qualification for monitoring a ship's CO_2 emissions. Verifiers are responsible for checks and the quality of their work will therefore be subject to regular assessments.

As in most existing emissions trading schemes, emissions need to be reported regularly to the competent authority. These reports need to be accompanied by a report from an external independent verifier who ascertains that the reported data is correct. Several classification societies currently act as verifiers in land-based emissions trading schemes and these could be envisaged to assume the role of independent verifier in such a scheme, although other organisations may also qualify.

Given the diversity in equipment on board ships, we propose to have each ship owner file a monitoring and verification plan for each ship to the competent authority before the start of the scheme. This plan should outline in detail the method by which it will monitor fuel use and which data will be used to verify the emissions. The competent authority will need to approve of the plan before a ship is allowed to enter the scheme. The alternative to approval of a plan beforehand would be to issue detailed guidelines that monitoring and verification should meet and penalising ship owners that submit reports that do not follow these guidelines.

2.8 Initial allocation

There are several options to initially allocate allowances to the individual ships:

- Selling or auctioning allowances.
- Free allocation based on former emissions of individual ships.
- Free allocation on the basis of a benchmark.
- A combination of the above.

Auctioning the allowances is most efficient economically as it ensures that the allowances are allocated to the actors for whom they have the largest value. Auctioning rewards early action since ships that have taken measures to reduce their emissions would need to buy fewer allowances; it guaranties equal treatment of incumbents and new entrants; and it is fairly straightforward administratively. After all, auctioning would require less historic data because the data is only needed to determine the overall cap but not to calculate the allocation to individual ships. Still, auctioning all the allowances to the sector would increase the costs of shipping significantly and therefore it may be desirable to phase-in auctioning rather than implement it completely from the start.

Note that there are many ways to organise auctions (open or closed bid; ascending or descending prices; price floors, price caps or both; etc., (Klemperer, 2004). Moreover, the auctioneer can set rules on the entities that can bid (only ship owners or also other parties), the maximum amount of allowances available to each bidder, etc. In this way, manipulation can be prevented, the costs of the auction can be kept down and an efficient price setting can be ensured (Charpin et al., 2009).

Free allocation on the basis of former emissions means that inefficient ships would receive more allowances than efficient ships. This is undesirable since it would penalise ships that have taken early action to reduce emissions and reward ships that have been inefficient.

In principle, a better way to freely allocate allowances would be to use an output benchmark, e.g. tonne-miles produced in a certain year. However, the shipping sector is complex and it would be hard if not impossible to design a benchmark that would be applicable to bulkers, tankers, gas tankers and container ships alike. And even within one ship type, an output benchmark could have inequitable results. Consider for example two dry bulk sister ships, one carrying iron ore and one carrying grain. The amount of iron ore is restricted by weight, the amount of grain is restricted by the size of the ship. As a result, if both are Panamax class, the first transports 74,500 tonnes of iron ore and the second 46,500 tonnes grain. Meaning that the two sister vessels, each emitting approximately the same amount of CO_2 (the iron ore ship may emit a bit more) would receive very different amounts of allowances. In addition, output benchmarks would have to be calculated, verified and reported, thus increasing the administrative burden.

A combination of auctioning and free allocation would be economically less efficient than full auctioning yet could be desirable to limit the immediate financial impact on the sector in the initial phase of the scheme. There are a number of limitations for such a scheme. First of all, if the scheme would be open, i.e. if trading would be allowed with other schemes, a buy-one-get-one-free rule would not work, since this would merely double the price of the allowances at the auction. Second, if the scheme is to be environmentally effective, a rule that allowances have to be surrendered for a share of the total emissions only would reduce the effectiveness as it would abolish the cap. A combination of free allocation based on historical emissions and auctioning, in which the share of auctioning would gradually increase, could be a way to reduce the financial impact on the shipping sector yet have a cap and allow an open scheme.

In summary, there are several ways to initially allocate the allowances. While auctioning is preferable from an economic point of view, the financial impact on the sector could be considered to be undesirable. If so, a share of emissions can initially be allocated on the basis of historical emissions. However, since free allocation lowers the incentive to reduce emissions, it should be phased out after a certain period. In choosing a way, a balance can be struck between ecologic efficiency, economic efficiency, administrative burden and impact on the sector.

2.9 Regulatory and administrative organisation

There are at least six tasks for regulators and administrative bodies:

1. Set a cap.
2. Distribute allowances.
3. Manage allowance registries for ships.
4. Monitor compliance.
5. Enforce compliance.
6. Manage the fund in case of full or partial auctioning of allowances.

The organisation that sets the cap would have to be an international body in which all relevant states are represented and which can set the cap based on scientific input and economic analysis. The UNFCCC would be ideally suited for such a task. It also sets caps for Annex I countries and possibly for more countries and/or sectors in the future. It could issue emission units to the shipping sector.

The initial distribution of allowances can be organised in several ways. A central organisation can be assigned with this task or the allowances can be allocated to states. In the first case, a decision would have to be made on how to use the revenue generated by auctioning allowances. In the second, a key for allocating allowances would have to be determined. As most of the emissions are generated on the high seas, there seems to be no natural owner of them. One way to allocate allowances would be on the basis of need for climate finance. The states with the largest needs could then use the auction revenue to fund adaptation and mitigation.

The management of allowance registries and the monitoring of compliance could both be done by the same organisation. IMO would be in a good position to take responsibility for setting up such an organisation. It would need to register which entity holds allowances and how many, and how many allowances are traded between which entities. It also would need to receive and approve of emission reports and cancel the surrendered allowances. Obviously, this organisation would have to have strong administrative skills.

The organisation enforcing the system would need to have the legal instruments to effectively do so. Flag States can enforce compliance for ship owners that have registered ships in these states or, in case the ship is the responsible entity, on ships flying their flag. Port States can enforce against ships in their port. They can inspect a ship's compliance status, for example on the administrative organisation's website. If a ship is not in compliance, it can be denied access to ports or be detained until compliance has been achieved.

The organisation managing the fund would need to be accountable to states whose entities contribute to the fund and to states that are benefiting from the fund. It would therefore have to be a multinational organisation such as the IMO or the UNFCCC or perhaps the proposed Copenhagen Green Climate Fund.

The total emissions from international maritime transport are estimated at 847 Mt in 2007 and 1,013 Mt for all transport including domestic. So at a price of USD 10-50 per allowance to emit one tonne of CO_2, the auctioning revenues could increase to USD 50 billion once all the allowances would be auctioned.

2.10 Summary and conclusion

The proposed Maritime Emissions Trading Scheme would have the following design features:

- The scope should ideally be global and cover CO_2 emissions of all ships above a certain size threshold. A global scheme would be more environmentally effective since it would cover all shipping emissions. Moreover, it would not suffer from avoidance and avoid thus distortion in competition. However, the scope can in principle be limited in order to reduce undesirable negative impacts on some countries or country groups.
- The METS would ideally be an open system and allow responsible entities to surrender allowances or credits from other emissions trading schemes or from the wider carbon market as long as they are of sufficient quality, i.e. represent real emission reductions. By opening the METS to allow the use of allowances from other sectors, the price volatility would be significantly reduced as more sectors with different business cycles would be included. Insofar as other sectors have lower marginal abatement costs, the average allowance price would decrease. The volume of allowances and the number of potential participants would also be much larger in an open system, which should be beneficial for market transparency and liquidity.
- The responsible entity for surrendering allowances could be the ship owners. The owner has directly or indirectly (through contracts with operators, crew, etc.) control over the emissions of a ship. The owner is clearly identifiable and linked to the ship. The accounting entity will be the ship. This ensures that the ship can be held liable if a ship is not compliant. An alternative arrangement is to place an obligation on each ship to carry documents that show compliance. In that case, there is no need to specify a responsible entity.
- Monitoring, reporting and verification is essential for the effectiveness of the METS. Given the diversity in equipment on board ships, we propose to have each ship owner file a monitoring and verification plan for each ship to the competent authority before the start of the scheme. This plan should outline in detail the method by which it will monitor fuel use and which data will be used to verify the emissions. The competent authority will need to approve of the plan before a ship is allowed to enter the scheme.
- There are several ways to initially allocate the allowances. While auctioning is preferable from an economic point of view, the financial impact on the sector could be considered to be undesirable. If so, a share of emissions can initially be allocated on the basis of historical emissions. However, since free allocation lowers the incentive to reduce emissions, it should be phased out after a certain period. By combining auctioning with free allocation for a limited time period, a balance can be struck between economic efficiency, administrative burden and impact on the sector.

3 Global Shipping CO_2 Emissions

3.1 Introduction

While a number of estimates of global maritime emissions have been published, there are no reliable estimates of emissions on different route groups. This reports presents such estimates for the first time, using a purpose built activity-based model.

Section 3.2 describes the model; section 3.3 presents the emission estimates on different route groups and section 3.6 validates the model results using independent data sources. Section 3.7 concludes.

3.2 Method to Estimate Global Shipping CO_2 Emissions

A ship movement database is used to calculate fuel use and CO_2 emissions on different routes. The basic parameter in this calculation, fuel use (or equivalently emissions) on specific routes, is the hardest one to come by. The existing top-down approaches do not allow the easy allocation of emissions to countries, as they calculate energy use and emission totals without respect to location by means of quantifying the worldwide fuel consumption by power production first and then multiplying the consumption by emission factors (Corbett and Köhler, 2003; Endresen et al., 2003, 2007; Eyring et al., 2005a)[9]. Therefore, a bottom-up method is needed where fuel use and emissions are directly estimated within a spatial context and can be linked to ship movement data. Such a bottom-up approach has been developed by Paxian et al. (2009), hereafter referred to as SeaKLIM algorithm. A brief model description is given below. For further details it is referred to Paxian et al. (2009).

The SeaKLIM algorithm uses ship movements and actual ship engine power per individual ship from Lloyd's Marine Intelligence Unit (LMIU) ship statistics of six months in 2006 and further mean engine data from literature serve as input. The SeaKLIM algorithm automatically finds the most probable shipping route for each combination of start and destination port of a certain ship movement by calculating the shortest path on a predefined model grid while considering land masses, sea ice, shipping canal sizes and climatological mean wave heights.

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[9] Corbett, J. J., Köhler, H. W., 2003. Updated emissions from ocean shipping. Journal of Geophysical Research 108, doi:10.1029/2003JD003751.

Endresen, Ø., Sørgård, E., Sundet, J. K., Dalsøren, S. B., Isaksen, I.S.A., Berglen, T. F., Gravir, G., 2003. Emission from international sea transportation and environmental impact. Journal of Geophysical Research 108, 4560, doi:10.1029/2002JD002898.

Endresen, Ø., Sørgård, E., Behrens, H.L., Brett, P. O., Isaksen, I. S.A., 2007. A historical reconstruction of ships fuel consumption and emissions. Journal of Geophysical Research 112, D12301, doi:10.1029/2006JD007630.

Eyring, V., Köhler, H. W., van Aardenne, J., Lauer, A., 2005a. Emissions from International Shipping: 1. The last 50 Years. J. Geophys. Res., 110, D17305, doi:10.1029/2004JD005619.

For the purpose of this project, several improvements and extensions over the method described in Paxian et al. (2009) have been made in order to allow the calculations that were required for this project:

1. The focus of the Paxian et al. (2009) study was on global emissions rather than regional estimates. Therefore, as part of this project the SeaKLIM algorithm had to be extended to allow the calculation of emissions for arriving/departing ships for certain regions (see Table 1), certain ship type classes (see Table 2) as well as for emissions calculations between the LMIU regions.
2. Large uncertainties are associated with the main engine power of each ship. For this study, LMIU provided an updated file for the main engine power for each ship that is registered in the LMIU movement database. This file included 16,494 instead of 16,642 missing values out of 90,840 ships that are registered. However, from the 90,840 ships that were registered in 2006, only 40,055 are included in the LMIU movement database, and from those ships that are included in the LMIU movement database, 2,527 ships have missing entries for the main engine power in the new file. In addition to using this new file, compared to Paxian et al. (2009) two further changes have been made: (a) the main engine power has been multiplied with the number of engines as instructed by Lloyds, and (b) instead of using the average main engine power for missing values in this file, a new method was developed that considers the actual ship size. For the ships with missing engine power the vessel's dead weight tonnage (DWT), the vessel type and the vessel subtype was extracted from the Lloyds file that included the vessel information. The vessels were divided into ten subgroups considering type and subtype. Within each of these groups the vessels were further selected by classes related with the vessels DWT to match the IMO classification (Buhaug et al., 2009). Once the class of the ship had been determined the IMO main engine power was assigned for this particular ship. After this method was applied, the main engine power of only 338 ships could not be corrected (because size, subsize or DWT was missing from the LMIU file on vessels). In this case the mean value for the ship class was used as in Paxian et al. (2009).
3. All intermediate stops not important for trading but only for passing like Strait of Dover, Gibraltar, Suez/Port Said and Panama Canal have been skipped in the algorithm by Paxian et al. (2009). This is only possible if the corresponding ship continues to navigate in the same direction after leaving this port, i.e. the start port of the first movement and the end port of the second movement lie in different LMIU regions on both sides of the intermediate port. This skipping can be redone for four times until the final ship movement is determined from start port and sailing date of the first movement to end port and arrival date of the last movement in this row. This skipping method has been improved in this project. First of all, the selection of regions of start ports (before the skipped port) and of the end ports (after the skipped port) is redefined. Then, the choice of any particular category of routes (by regions, by country, etc.) was postponed with respect to the evaluation of the correct start and end port through the 'skipping algorithm'.
4. As a reference for the total we use the fuel consumption and emission totals that were calculated in the 2nd IMO GHG study (Buhaug et al., 2009). In other words, we sue the SeaKLIM algorithm only to calculate the regional shares and the shares for the various ship size categories, but we scale the resulting fuel consumption and emissions to the IMO totals.

The final algorithm that was then used in this study with the changes described above calculated a total fuel consumption of 237 Mt instead of 221 Mt as in Paxian et al. (2009). This shows that overall the total fuel consumption is not very sensitive to the above outlined changes, which proofs the robustness of the algorithm against these changes. With this revised highly flexible SeaKLIM algorithm, global energy use and emissions can be calculated considering a variety of different allocation methods.

This report has SeaKLIM to calculate emissions from ships sailing to and from the following regions.

Table 2 **Regions for which emissions have been calculated**

Region ID	Description
1	North America
2	Central America and Caribbean
3	South America
4	Europe
5	Africa
6	Middle Eastern Gulf, Red Sea
7	Indian Subcontinent
8	North East Asia
9	South East Asia
10	Australasia

Source: This report.

A precise list of countries in each group can be found in Annex A.

Moreover, this report has calculated emissions on ships sailing to and from the following groups of countries, which are relevant in the climate policy negotiations.

Table 3 **Groups of countries for which emissions have been calculated**

Group ID	Description
A	Annex I countries
B	Non-Annex I countries
C	G77
D	Least Developed Countries
E	Small Islands and Developing States

Source: This report.

Annex I and non-Annex I countries are depicted in Figure 1. Figure 2 shows the G77 group, while Figure 3 shows the LDCs. SIDS are not presented as most members are small and hardly visible on a world map of this scale. A precise list of countries in each group can be found in Annex A.

Figure 1 Annex I and non-Annex I countries – country groups A and B

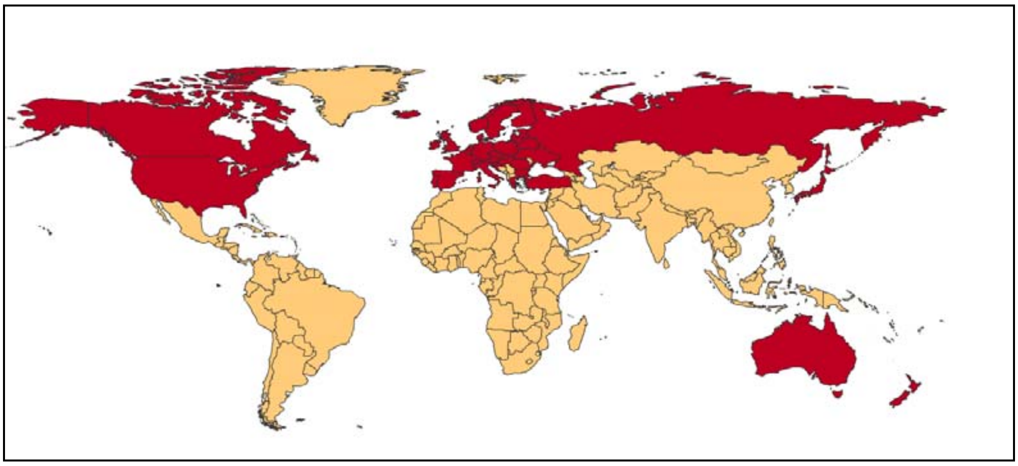


Figure 2 G77 countries – country group C

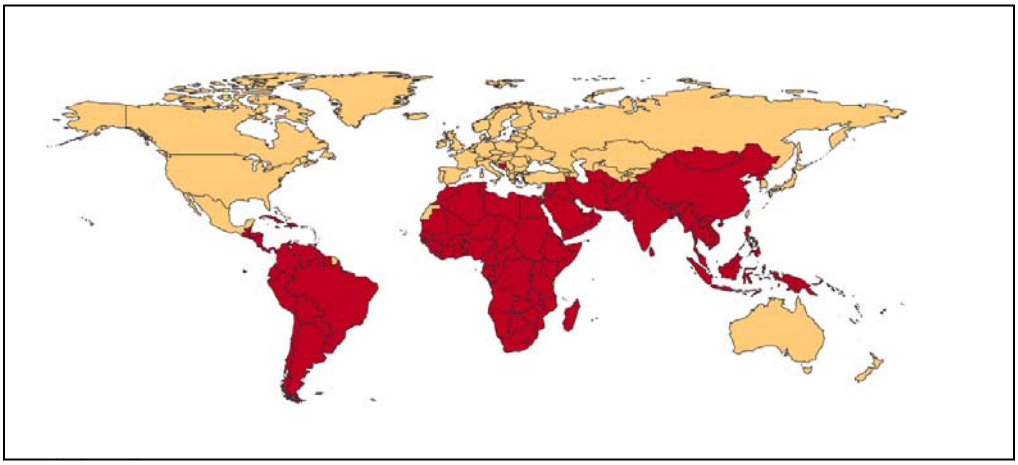
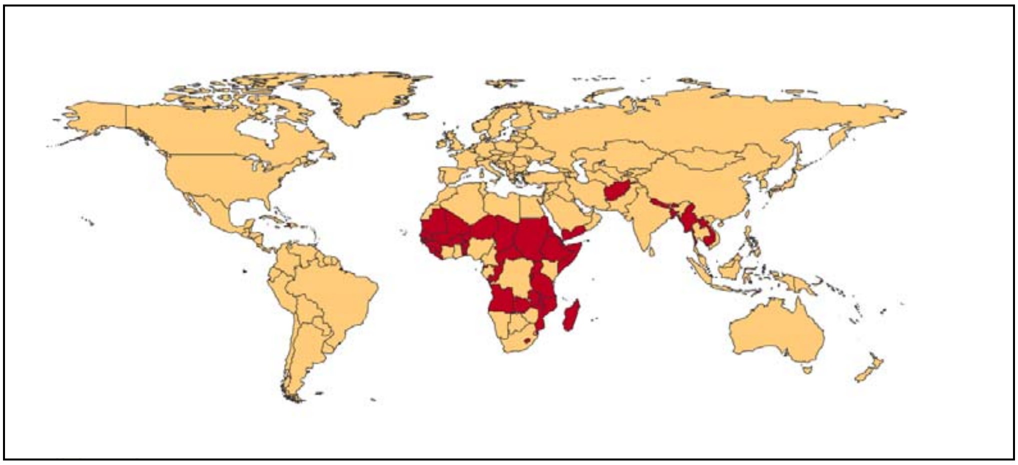


Figure 3 Least developed countries – country group D



3.3 Input data

3.3.1 Ship Movement Data

Spatially resolved ship movements from three databases of LMIU are used. These three databases are linked by unique LMIU ship IDs and LMIU port IDs (see further details in Paxian et al. (2009).

1. The ship movement database available for this study contains movements of the international commercial fleet larger than 100 Gt leaving the start port in February, April, June, August, October or December in 2006. Purchasing the full year of data from LMIU was not possible due to financial reasons. However, the six months of ship movements are considered representative for the whole year of 2006 and thus extrapolated. The dataset includes the ship IDs, start and end ports, arrival and sailing dates (d) and partly also times (h) of 1,001,123 ship movements from 40,055 vessels.
2. The ship database contains information on ship name, size, main engine power, average speed, flag and type of 90,840 ships. Besides main engine power (see section 1.2) no further engine data were available from LMIU.
3. The port database includes names and locations in geographical coordinates of 8,541 ports.

Table 4 shows a comparison of the ship numbers per ship type that are included in the LMIU movement database (half a year in 2006) in comparison to recent global top-down studies from Buhaug et al. (2009) and Eyring et al. (2005a). This comparison shows that ship movements of non-trading vessels like tugs, pleasure craft, fishing and small coastal vessels are undercounted in the LMIU ship movement database because these non-IMO vessels are registered but not monitored. In contrast, container ships, bulk carriers and reefers are well covered in the LMIU database, whereas general cargo, tankers and roll-on-roll-off ships are covered only to around 60%. This undercounting of certain ships leads to biases in the derived regional emissions.

Table 4 **Ship number per ship type of this study from LMIU ship movement database (2006) in comparison to Buhaug et al. (2009) for 2007**

Ship type	Ship numbers from six months LMIU movement database in 2006	Ship numbers from Buhaug et al. (2009) in 2007	Percentage
General cargo	8,988	17,234	52.2
Tanker	7,751	12,905	60.1
Container	4,744	4,137	114.7 1)
Bulk carrier	6,233	7,391	84.3
Reefer	1,080	1,238	87.2
Roll-on-Roll-off	1,480	2,445	60.5
Passenger	1,221	6,912	17.7
Fishing	2,332	23,848	9.8
Miscellaneous	6,226	24,101	25.8
All ships	40,055	100,214	40.0

Note 1) the high percentage is due to a different classification of ships.

From Paxian et al. (2009), their Table S2.

3.3.2 Ship Characteristic and Engine Data

Since no further engine data are available from LMIU, we use mean ship characteristic for ship speed, auxiliary engine power and main and auxiliary engine load factors from Wang et al. (2007) grouped into nine different ship classes (see Table S3 in Paxian et al., 2009). From Eyring et al. (2005) we derive further information on specific fuel oil consumption and emission factors for main and auxiliary engines. Finally, Entec UK Limited (European Commission and Entec UK Limited, 2005b) provides CO_2 emission factors and main and auxiliary engine load factors, engine running hours, specific fuel oil consumption and emission factors for harbour activities. CO_2 emission factors in harbours are not included.

3.3.3 Model Grid Data: Land Masses, Sea Ice, Shipping Canals and Sea State

Several input datasets describe the model grid characteristics. The distribution of land masses is derived from a 0.5°x0.5° land-sea mask of the Data Collection of the International Satellite Land Surface Climatology Project Initiative II (ISLSCP2, 2009). Three grid boxes are defined representing the shipping canals Panama, Suez and Kiel Canal. These canals only allow certain ship sizes to pass and furthermore act as delay areas for passing ships due to reduced ship speeds compared to open sea voyages. Therefore, shipping canal data like average canal ship speed and ship length, breadth and draft restrictions are gathered from canal authorities (see Supporting Information of Paxian et al. 2009, their Table S1). Finally, significant wave heights (m) are obtained from ECMWF ERA 40 data (ECMWF, 2009). A 2.5° sea state climatology for 1958-2001 is derived and scaled to the 0.5° model grid in order to present further delay areas for shipping routes.

3.4 Shipping CO_2 Emissions on Routes to geographical regions and country groups

The resulting present-day ship activity agrees well with observations (see Figure 3 of Paxian et al., 2009). The global fuel consumption of 221 Mt in 2006 lies in the range of previously published inventories when undercounting of ship numbers in the LMIU movement database (40,055 vessels) is considered. If we increase the fuel consumption per vessel category to match the number of ships in that category, also taking into account that maritime transport has increased 3.7% from 2006 to 2007, we arrive at a fuel consumption of 349 Mt. This figure is in good agreement with the IMO result of 333 Mt ± 67 Mt as reported in Buhaug et al. (2009).

We allocated emissions to countries on a route bases, where a route has been defined as the voyage from the port of departure to the port of destination. Thus, emissions of a ship sailing from Hong Kong to LA Long Beach are allocated to ships arriving in North America and to ships departing from Asia (since emissions of departing ships are similar to emissions of arriving ships, another way to allocate emissions would not significantly change results).

Table 5 shows how global shipping emissions are distributed geographically. The largest share of emissions, 27% of the world total, are on ships sailing to European ports, ships to North East Asia account for 19% of global emissions and ships to North America for 12%.

Table 5 **Shipping emissions on routes to geographical regions, 2006**

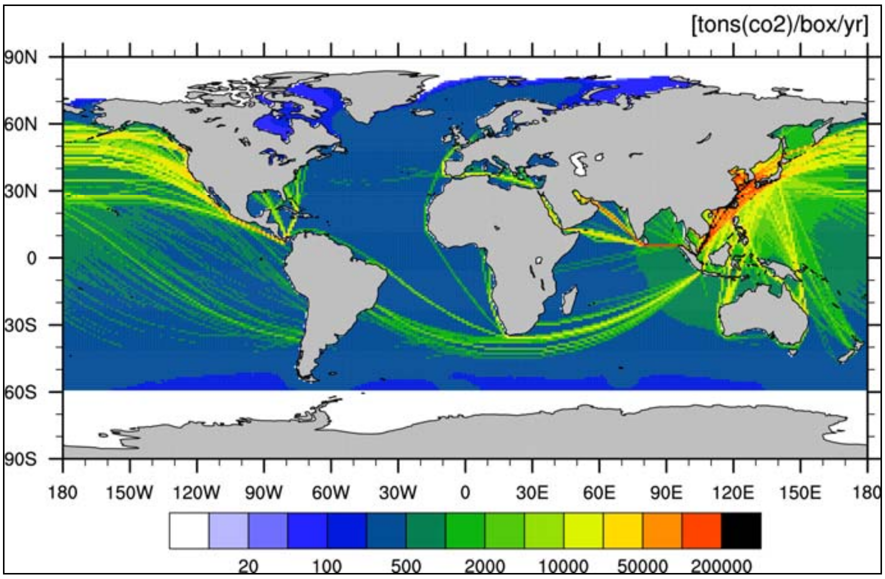
Region	Arriving ships			Departing ships		
	Fuel use (Mt)	CO_2 emissions (Mt)	Percentage of global CO_2 emissions (%)	Fuel use (Mt)	CO_2 emissions (Mt)	Percentage of global CO_2 emissions (%)
North America	38.3	120.2	12%	37.5	117.5	12%
Central America	17.2	53.3	5%	16.6	51.6	5%
South America	18.5	58.5	6%	20.2	64.2	6%
Europe	88.6	276.7	27%	90.9	284.1	28%
Africa	21.5	67.6	7%	21.9	69.2	7%
Middle Eastern Gulf	19.5	62.4	6%	20.5	66	7%
Indian subcontinent	7.5	23.6	2%	7.07	22.3	2%
Far East Asia	36.8	115.8	12%	36	113.1	11%
North East Asia	61.6	193.6	19%	58.8	184.6	18%
Oceania	11.0	34.8	3%	11.3	36	4%
Totals	**320.4**	**1,006.5**	100%	**320.8**	**1,008.6**	100%

Source: This report.

The emissions can be plotted on a world map. These plots clearly show the major trade routes. One illustration is presented in Figure 4 which shows emissions on voyages to North East Asia. Figure 4 shows that there is a high density of emissions in the region, stemming from both voyages within the region and from voyages from other regions to North East Asia. Major shipping routes are clearly recognizable, such as routes from the Middle Eastern Gulf to North East Asia, From Europe and North America to North East Asia, and from Australia to North East Asia.

More plots are presented in Annex B.

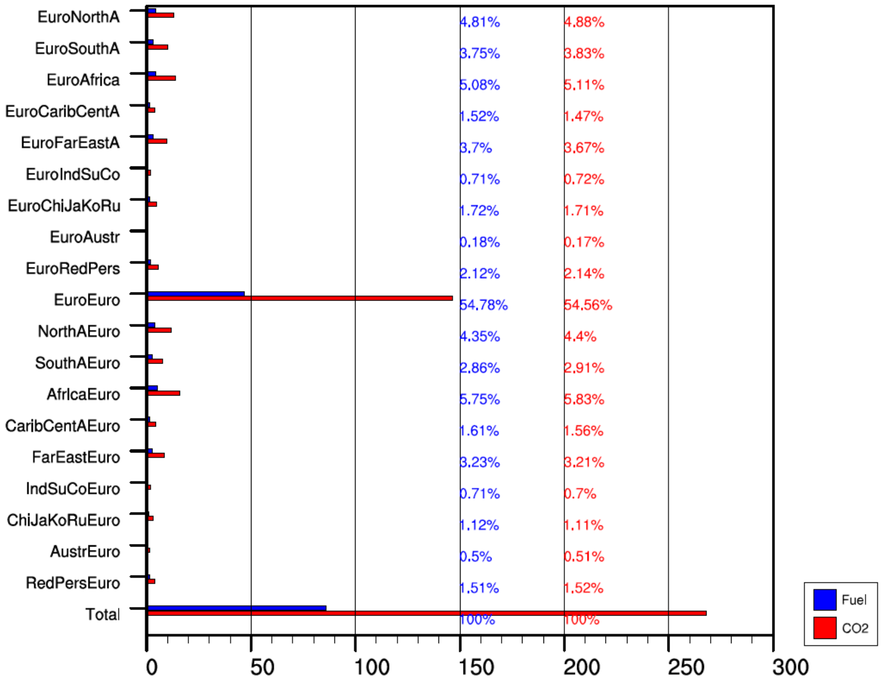
Figure 4 **Emissions on voyages to North East Asia**



Source: This report.

Although the model is capable of breaking down emissions further, this was considered to be outside the scope of this project. CE et al. (2009) analyses emissions on ships sailing to European ports in greater detail. It finds that the majority of emissions are on voyages between two European ports. Of the intercontinental routes, voyages to and from North America and Africa generate most emissions (see Figure 5).

Figure 5 **Geographical breakdown of emissions on voyages to and from European ports**



Source: CE et al. (2009).

Table 6 shows emissions to country groups. Emissions on voyages to non-Annex I countries are slightly higher than emissions on voyages to Annex I countries. Emissions to LDCs are a small share. Emissions on voyages to SIDS are 10% of global emissions, which is at least partly attributable to the fact that Singapore is a SIDS member.

Table 6 **Emissions on routes to and from groups of countries, 2006**

Region	Arriving ships			Departing ships		
	Fuel use (Mt)	CO_2 emissions (Mt)	Percentage of global CO_2 emissions (%)	Fuel use (Mt)	CO_2 emissions (Mt)	Percentage of global CO_2 emissions (%)
Annex I countries	149.4	468.5	45%	148.9	466.3	46%
Non-Annex I countries	185.2	581.7	55%	171.2	538.9	54%
G77	147.6	464.7	44%	148.8	468.8	47%
Least Developed Countries	5.6	13.0	1%	5.3	16.5	2%
Small Islands and Developing States	31.5	98.8	9%	29.9	93.7	9%

Source: This report.

Note that emissions to Small Islands and Developing States include emissions on voyages to Singapore, which is a major maritime hub.

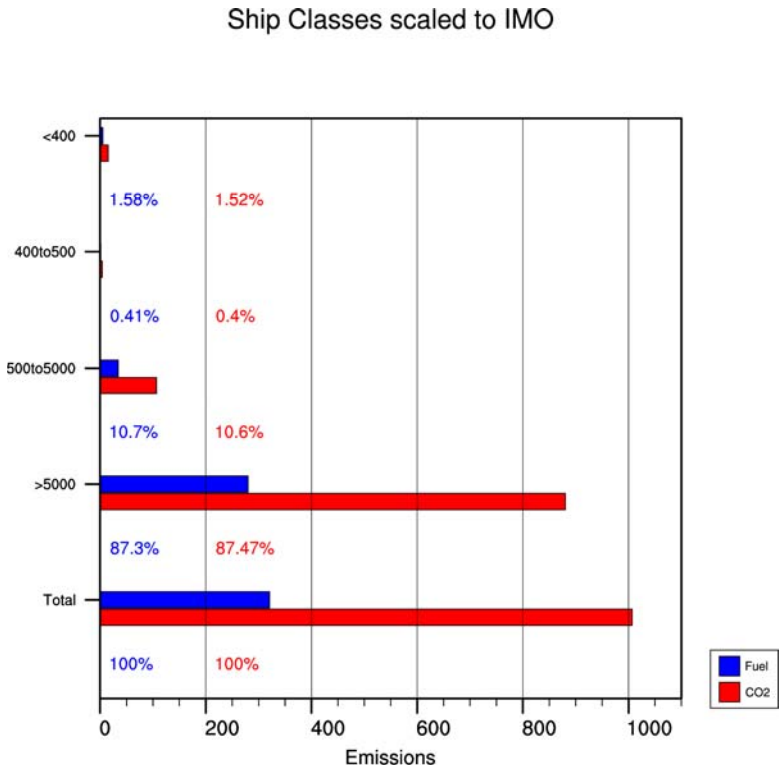
3.4.1 Emissions for different ship size categories

The SeaKLIM algorithm was also used to calculate ship emissions and fuel consumption for the various ship size categories. The results are summarized in Table 7 and in Figure 6. In addition the geographical distribution for CO_2 for the different size categories for total shipping is shown in Figure 6 and for Europe in Figure 7. The majority of the total fuel is consumed by ships with sizes greater than 5,000 Gt (87%). Similarly, this size category is the largest contributor for the European fuel consumption (78,8%), though it is notable that there is a slight shift to the smaller size category (500 to 5,000 Gt) for the European fuel consumption and CO_2 emissions.

Table 7 **Fuel use and CO_2 emissions for different ship size categories, totals and ships arriving in Europe, 2006**

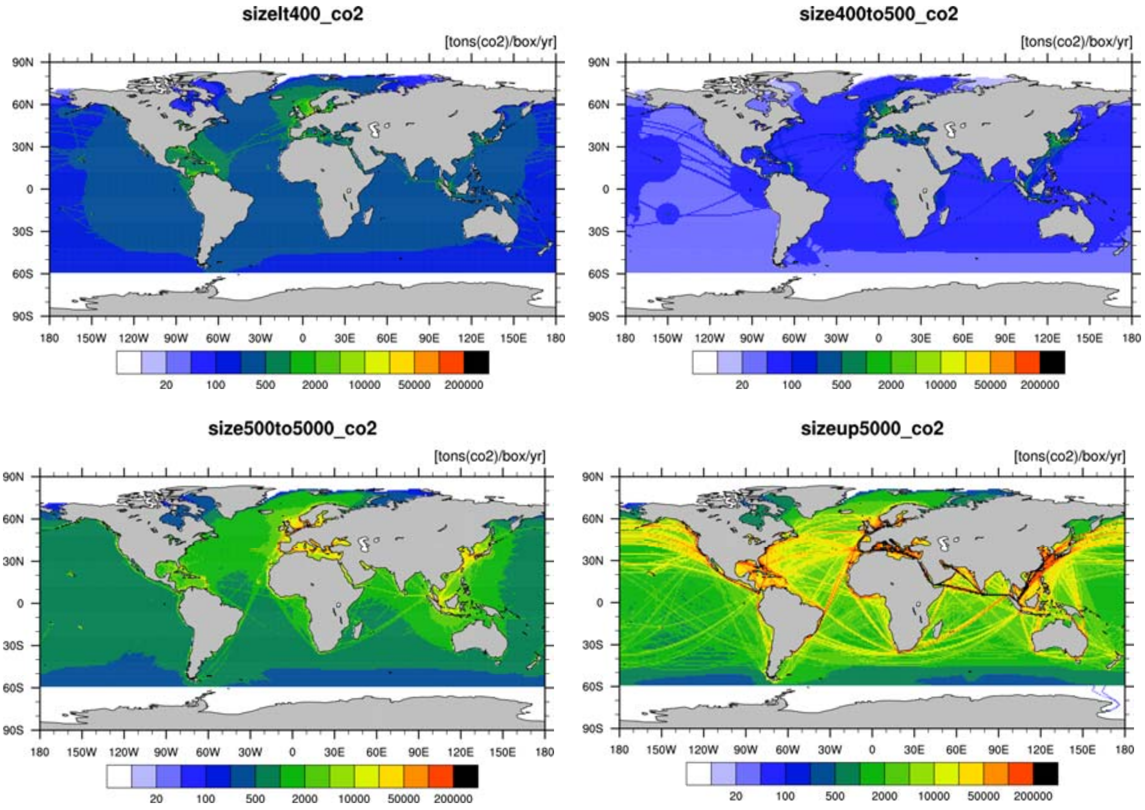
Size (GT)	Total fuel use (Mt)	Total CO_2 emissions (Mt)	Percentage of global CO_2 emissions
<400	5.1	15.3	1.5%
400 to 500	1.3	4.1	0.4%
500 to 5,000	34.3	106.7	10.6%
>5,000	279.8	880.5	87.5%
Total	**320.5**	**1006.6**	1.5%

Figure 6 Emissions for four different ship size classes for the year 2006



Source: This report.

Figure 7 Geographical distribution of total CO_2 emissions for the four different ship size classes



Source: This report.

3.5 Discussion and uncertainties in emission estimates

The emissions calculations presented in this section are based on a global bottom-up method. An automatic path-finding algorithm between start and end port on a 0.5°x0.5° model grid developed by *Paxian et al.* (2009) has been further improved and extended to allow the calculation of fuel consumption and emissions for several policy relevant allocation criteria. The results yield a better spatial resolution than global top-down approaches and represent the first global bottom-up approach. The totals of fuel consumption and emissions lie in the range of recent global top-down and regional bottom-up approaches. This algorithm is used to calculate fuel consumption as well as CO_2 emissions for ten LMIU regions and additionally for five country groups. Fuel consumption and CO_2 emissions can be calculated for ships arriving in these regions, as well as for ships leaving these regions, allocating all emissions on arriving voyages to these regions. Changing the allocation method would only marginally affect the results, since emissions on departing voyages are very similar to emissions on arriving voyages (see Table 6 and Table 7).

Overall, the results are reasonable. However, the quality of the results strongly depends on the input data and the completeness of the movement database. Table 4 shows that while the number of container ships, bulk carriers and reefers are well represented in the half year of 2006 LMIU movement database, general cargo, tankers and roll-on-roll-off ships are covered only to around 60%, and smaller ships like passengers, fishing and miscellaneous ships are not well covered. In addition, a bias in the coverage of the movement database (e.g. higher coverage of movements over Europe than over China) cannot be excluded and might bias the results. These uncertainties in the input data cannot be overcome as part of this project. Effective monitoring and reliable emission modelling on an individual ship basis is expected to improve if data from the Long Range Identification and Tracking (LRIT) technology and the Automatic Identification System (AIS) are more widely used. LRIT is a satellite-based system with planned global cover of maritime traffic from 2008. AIS transponders automatically broadcast information, such as their position, speed, and navigational status, at regular intervals. Since 2004, all ships greater than 300 Gt on international voyages are required by the IMO to transmit data on their position using AIS. The LRIT information ships will be required to transmit the ship's identity, location and date and time of the position.

The LMIU movement data that were bought for the purpose of this project included only half a year of 2006 because of financial limitations. Improvements could be achieved by improved information for engine data per individual ship and by an underlying ship movement database that covers at least a whole year of movements to avoid averaged values per ship type and extrapolations. It would be desirable if the movement data could be made freely available for research purposes in order to allow the analysis of several years to get more robust results.

The path-finding algorithm itself could be improved by a model grid with higher resolution and an optimisation following shipping routes’ costs in addition to distances. In general, the SeaKLIM algorithm finds the shortest path and thus always calculates a lower bound for the fuel consumption of a certain port combination. The method that was used in this study shows the flexibility to integrate all these improvements.

3.6 Comparison of emission estimates with other data

3.6.1 Comparison of total emissions

The improved SeaKLIM algorithm calculates a total fuel consumption of 221 Mt in 2006 which corresponds to 695 Mt CO_2. This is higher than bunker fuel sales as reported by the IEA and the EIA, but lower than most other bottom-up estimates (see Table 8). When corrected for underreporting of ships in the LMIU movement database, assuming the underreported ships have the same emissions as the reported ships, emissions are 1,090 Mt CO_2. This difference may be due to the underreporting of ships (see Table 4).

Table 8 **Estimates of global maritime fuel consumption**

Reference	Base year	Total fuel consumption (Mt)	Remarks
Eyring et al., 2005	2001	280	Boilers not included
Corbett et al., 2003	2001	289	Boilers not included
Endresen et al., 2007	2000	195	Military, auxiliary engines and boilers not included
IMO Expert Group	2007	369	Military not included
IEA total marine sales	2005	214	Military not included
EIA bunker sales	2004	225	Military not included
This report	2006	221	Military not included
This report, corrected for underreporting of movements	2007	349	Military not included
Buhaug et al., 2009	2007	333	Military not included

Source: This report and Buhaug et al., 2009.

We consider Buhaug et al. (2009) to be the most accurate estimate to date of global maritime fuel consumption. Hence, we have scaled the results of the improved SeaKLIM algorithm to the fuel consumption and CO_2 emissions for total shipping as estimated by Buhaug et al. (2009): 321 Mt of fuel and 1,008 Mt of CO_2 in 2006.

3.6.2 Comparison with trade data

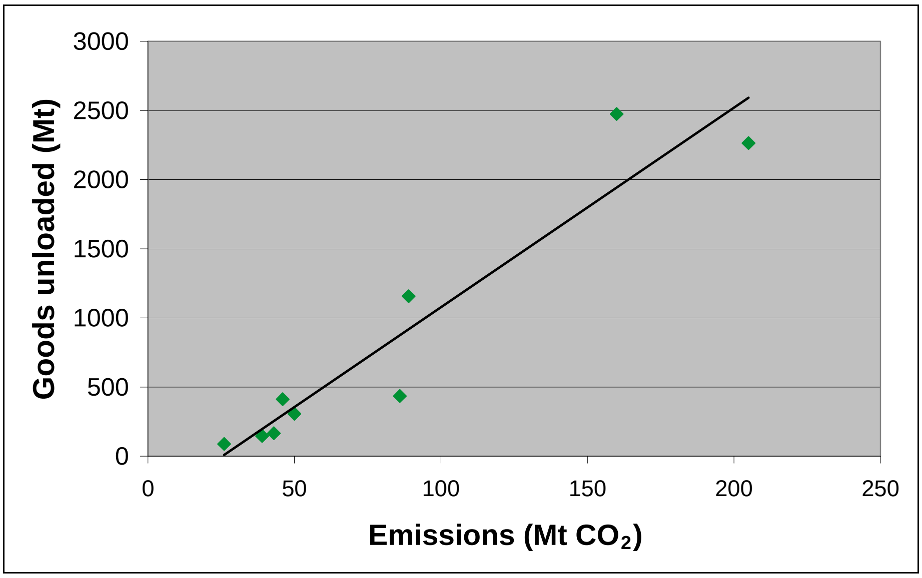
Most emissions are associated with cargo ships and thus with the movement of cargo. This section explores the relationship between emission estimates and trade data.

One would expect there to be a reasonably good correlation between emissions and data on tonne-miles of transport performance, at least as long as the structure of the fleet is similar in all regions and trade is balanced. If, moreover, the average distances over which freight is transported is similar for all regions, we would expect there to be a good correlation between the volume of trade (in tonnes) and emissions.

In reality, we know that these assumptions are not all true. Trade is not balanced. Developed countries, with the exception of Australia and New Zealand, import more (in tonnes) than they export (UNCTAD, 2007). Developing countries, with the exception of South and East Asia, export more than they import.

Nevertheless, we find that there is a good correlation between trade (total goods unloaded) and emissions on voyages to regions. Using trade data from UNCTAD (2007) and emissions on voyages to regions as reported in Table 5, we find that there is a good correlation between them ($R^2 = 0.9$).

Figure 8 **Good correlation between trade data and emissions estimates**



Source: UNCTAD, 2007 and this report.

3.7 Conclusion

This chapter uses a new model to estimate ship emissions based on activity data. It uses ship movement data from Lloyds MIU. The model is used to estimate emissions to and from ten geographical regions and to and from five country groups. A comparison with data on maritime trade volumes shows a good correlation between maritime trade volumes and emissions. We are therefore confident that the emissions presented here are an accurate representation of 2006 maritime emissions.

4 Impacts on the shipping sector

4.1 Introduction

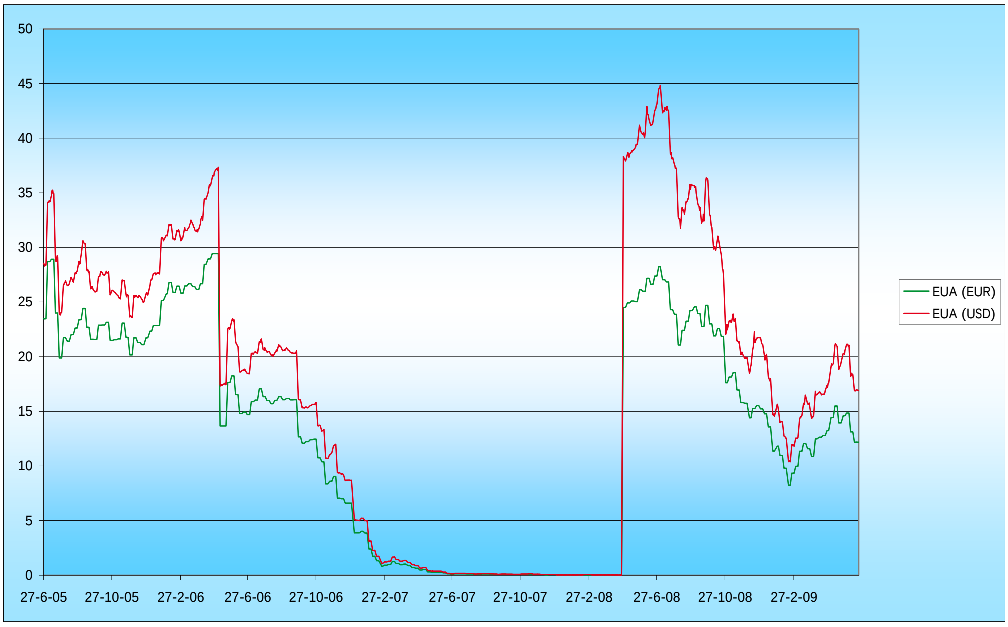
This chapter assesses the impacts of an emissions trading scheme on the shipping sector. As the impacts depend on the price of allowances, section 4.2 provides a background on the allowance price in the major carbon market. Section 4.3 discusses the various actors in the shipping sector and how they are affected. It also addresses the issue of which actor is likely to assume responsibility to surrender allowances on behalf of the ship owner. Section 4.4 focuses on the cost structure of the shipping industry and section 4.5 on the resulting increase in the costs of imports. Section 4.6 assesses likely behavioural responses in the shipping sector to an METS. Conclusions are drawn in section 4.7.

4.2 Price of allowances

The quantitative impacts of a METS depend on the price of the allowances, which, in turn, depends on the cap, the marginal abatement cost curve and the possibilities to use allowances from other systems and credits. All these factors are uncertain and to a large extent outside the scope of this project.

In the largest emissions trading scheme, the EU ETS, allowance prices have varied between EUR 8 and EUR 28 in 2008 and 2009 (USD 10-44) - see Figure 9. In a socially optimal damage cost approach, prices should increase in the next decades. This report uses a range of USD 10-50 to assess the impacts, with central values of USD 15 and USD 30.

Figure 9 **Spot prices of allowances in the EU ETS**



Source: Bluenext (allowance prices); DNB (USD/EUR exchange rate).

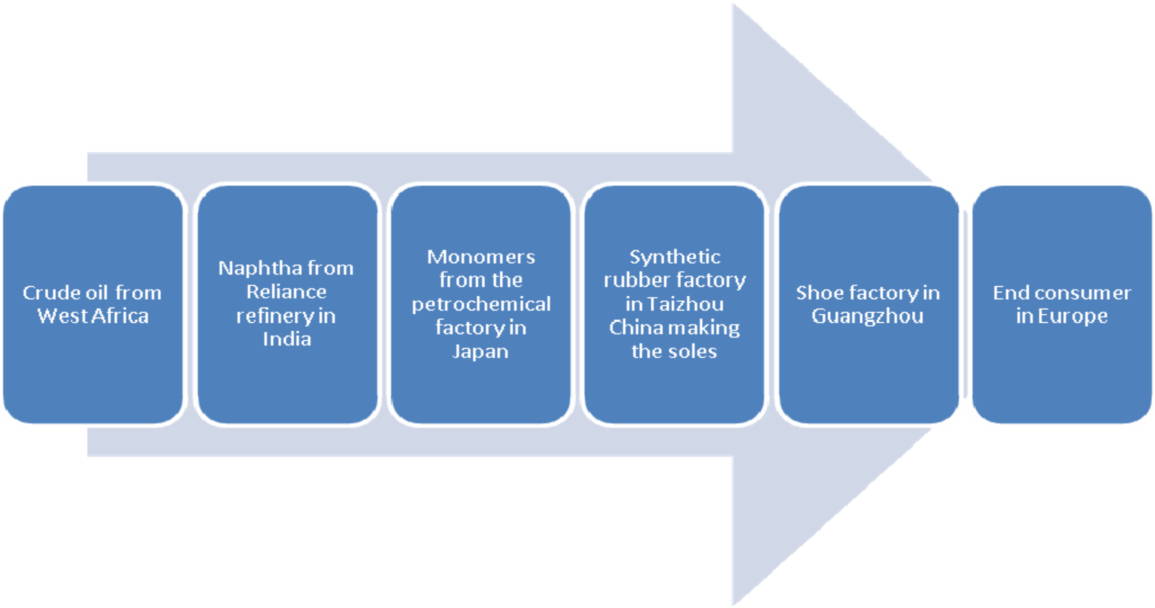
Over the past two years, the volatility of allowance prices in the EU ETS (when expressed in USD) has been about the same as the volatility in fuel prices, as can be seen in Figure 10.

Figure 10 **The volatility in allowance prices has been similar to the volatility fuel prices**

Source: EIA (Singapore spot prices); Bluenext (allowance prices); DNB (exchange rates).

4.3 Impacts on actors in the shipping sector

In this part of the report we will look at the economic impact an emissions trading scheme will have on the shipping sector in general. As shipping is a very diverse and heterogeneous sector, the impact will be very different among segments and sizes, but we will try to derive some general patterns. Since about 90% of all commodities transportation is done by ships, a global emissions trading scheme would of course affect the shipping sector and also the whole logistics chain from raw material to consumer. Some products or commodities are never transported by sea, and will therefore not be impacted by any policies towards shipping. On the other hand, some products are transported across multiple legs on ships on their way from a raw material to the end customer. Taking the example of a shoe with a synthetic rubber sole, the process from raw material to the end product in the consumer market could be as follows.



The crude oil is extracted from an oil well on the coast of West Africa, from where it is transported on a Very Large Crude Carrier, VLCC, to an oil refinery on the East Coast of India. The refinery cracks the crude oil into different oil products, including naphtha. Naphtha is transported in a product tanker, a so called Long Range version 2, LR2, to a petrochemical factory in Japan. In this factory the naphtha is used in the making of monomers, the monomer is then transported in a chemical tanker to a synthetic rubber factory in China where the rubber 'chumps' are manufactured. The 'chumps' are loaded into containers which are shipped further down the coast to a shoe factory in Guangzhou, where the rubber is moulded into outer sole for shoes. The shoes are then packed into containers again before they are heading on a container vessel again for the end user in Europe or United States.

In this example there are five transportation legs which are performed by different types of ships. It is obvious that a CO_2 emissions trading scheme will affect each of the actors involved and the end user. The question is how much? Let us first look at the different players in the industry.

Participants in the shipping industry

Flag State

The role of the Flag State is to approve, implement and enforce conventions coming from the International Maritime Organisation (IMO) and also rules they formulate themselves. This means that the Flag State plays an important role if IMO is to ratify an emission policy. A few countries are not IMO members and are therefore not required to impose IMO conventions[10]. However, the tonnage in their registries is small (UNCTAD, 2009).

Port States

Port States have jurisdiction over ships visiting their ports. Moreover, they have the right to inspect ships in order to establish whether they comply with the requirements established in international maritime rules and regulations.

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[10] The countries are: Bahrain, Costa Rica, Eritrea, Fiji, Grenada, Iraq, Kuwait, Thailand, and Turkmenistan.

Ship owner or disponent owner
The ship owner is the true owner of the ship. Very often a ship owning companies are organized as single purpose or 'one ship' companies, this is to protect the parent company from claimants if something happens to an individual ship.

Ship operator
A ship operator is in most cases an operating company, which operates ships without owning them. Ship operator and ship manager is often used for the same purposes.

Ship technical and commercial manager
Often divided between commercial and technical manager functions. Technical managers take care of technical issues, maintenance and also sometimes crewing of the vessel. Commercial manager is more or less the same as a ship operator. Some companies are ship owners, ship managers and also act as ship operator.

DOC holder
The DOC holder holds the Document of Compliance of the ISM Code (see section 2.6). according to the Code, it is 'the owner of the ship or any other organisation or person such as the manager, or the bareboat charterer, who has assumed the responsibility for operation of the ship from the ship owner and who, on assuming such responsibility, has agreed to take over all duties and responsibility imposed by the Code' (IMO, 2009).

Ship crew
The crew of the vessel, which runs the ship on a daily basis. They will not directly be affected by an emission policy, but indirectly there might be more paperwork, registrations of emission data and new working routines for the crews.

Shipper
The shipper is the one shipping the cargo.

Charterer
The charterer is the party hiring the vessel, or paying freight to the disponent owner to transport a certain amount of cargo between certain ports; it could be the cargo owner, the shipper, the cargo buyer, or any person/company designated by any of the former parties to arrange for the transportation.

Cargo owner
The owner of the cargo during transit. In some trades, it is not uncommon that the cargo is sold multiple times during the voyage, so that the cargo owner may change during the voyage. The ultimate owner of the cargo upon the ship's arrival in the discharging port is the one presenting and/or appearing in the bills of lading. The cargo owner can be either the cargo buyer or the seller, or a trader.

Cargo buyer
Depending on the contract, the cargo seller or cargo buyer has ultimately to pay for the shipment. The cargo is in most cases sold FOB (Free-On-Board) or CIF (Cargo-Insurance-Freight). In case of a FOB sale, the ownership of the cargo changes from the seller to the buyer once the cargo arrives onto the ship. In case of a CIF sale the ownership of the cargo changes from the seller to the buyer once the cargo is taken off the ship. So for a FOB contract the buyer has to arrange the freight, whereas for a CIF contract the cargo is

delivered to the buyers designated location. FOB contracts are often used if the buyer thinks he can do a better job than the seller to secure the freight at a lower level.

Cargo seller
This is the complementary role to that of the cargo buyer. Realistically the cargo seller would only be exposed to emissions related costs under CIF contracts.

Ship builder
Since a ship normally has a life time of around 25 years, many sail even longer, the design and engine choices are crucial for how much CO_2 a vessel emits during its lifetime. It is very costly to significantly alter the design or change the engine after the ship has been built, although small modifications and retrofits are possible. A ship can be compared to an advanced commodity, and, as for all commodities price is important. Therefore the standard ships a yard offers are normally built to standards that are just sufficient to comply with class (rules and regulations from class societies). Any additional equipment or modifications will increase the cost of the vessel. Yards want to offer as cheap as possible prices to secure buyers, and for their part ship owners also want the cheapest price available (keeping investment costs down), so, unless the ship owner requires more efficient engines or other emission reducing measures and pay for them, the vessels will not be delivered outside the standard specifications. What we have observed however when the bunker prices have been high, the ship owners have made demands for more fuel efficient ships to save operation costs, and with less bunker consumption there will be less emissions.

Engine manufactures
An engine manufacturer's incentive is to deliver what the ship builders order. More innovative and fuel saving engines will have a higher price than the standard ones and, unless the ship builders are required to deliver to meet specification in excess of the standard design, they will not. This has, of course, to do with margins and making profit.

Classification society
Classifications societies are entities that make sure that vessels satisfy certain standards. This way a buyer knows that his ship is fit for purpose according to class rules and also provides comfort to insurance companies that a vessel is seaworthy.

Insurance
One of the most important documents when a ship is either hired out for a trip or for a longer period is its insurance documentation. It is established on a common basis across all classification certificates, and shows what is covered by the insurance. The maritime insurance market is a rather small market with relatively few companies. There are mainly two types of insurances that are relevant in this report, that is P&I, which stands for Protection and Indemnity, and the other is H&M, which stands for Hull and Machinery.[11]

Consumers
The end of the logistical chain. As will be argued below, when there is a large supply of ships, any increase in the costs along the logistical chain will be absorbed by the end user or the consumer. In contrast, when ships are short in supply, costs will not be passed on but absorbed in the profit margins of ship owners or charterers.

Impact on players in the shipping industry

The METS will have a direct impact on the actors that need to acquire and surrender allowances, i.e. the ship owners or, in case the ship is the responsible entity, the ship operator. Other actors will be affected by changes in prices – these are considered to be indirect impacts. Till others may be impacted because they have to fulfil certain tasks.

The Flag States and Port States would get an increased administrative burden with implementing and executing the emission policy. The administration burden also goes for the ships' crew as they have to monitor the actual emissions and report these to the controlling administration.

As for the ship builder, engine manufacturer, and equipment maker they will be indirectly affected by an emission policy. The demand for fuel efficient ships will increase.

Looking at the impact for the players, Table 9 summarises the impacts based on the definitions earlier.

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[11] The P&I insurance are for owners and charterers and are structured in mutual clubs, where the owners are the members. The members are collectively responsible for the entire fleet of vessels insured by the club. This is to spread the risk and also cost in case of large claims. However the members have to approve of new vessels entering a club. The P&I cover: Cargo; Damage; Shortage; Equipment; Personnel, as in crew, passengers, stevedores; Injuries; Illness; Death; Belongings and effects; Stowaways, refugees, shipwrecked; Pollution; Cargo; oil, chemicals, soot, dust; Fuel; Damage to other third party; Vessels; Quays, breakwaters; Cranes and Equipment; Fines; and wreck removal.

The H&M insurance is more a 'normal' insurance that is related to the insurance companies. The H&M covers all risks subject to the normal exclusions for wear and tear and similar causes such as lack of maintenance, for the ship, its equipment on board and spare parts, and also bunkers and lubrication. The following factors are assessed for the H&M premium: Loss record (five years); Classification society; Management; Crew; Trading area; Place of building; Maintenance; Nationality; Age of vessel; Experience with the owner in question; The wider market.

Table 9 **Overview of impacts on the shipping sector**

	Direct cost impact	Indirect cost impact	Possible administrative burden
Flag States	No	No	Enforce compliance for owners of ships in their registry or on ships in their registry.
Port States	No	No	Enforce compliance on ships visiting ports
Ship owners Ship operator Ship manager Ship disponent owner	Yes, because the direct operating costs of a ship will be affected	No	Yes, will have to report emissions and, depending on the contractual arrangement, surrender allowances.
Ship crew	No	No	Yes, because emissions have to be monitored.
Shipper Charter Cargo owner Cargo buyer Cargo seller	No	Yes, because the transport costs will increase.	No
Ship builder Engine manufactures	No	Yes, if the policy results in higher demand for more efficient ships.	No
Classification Society	No	Yes, because of a new market appearing in verification and certification on emission measurements.	No
Insurance	No	No	No
Consumers	No	Yes, because they will ultimately pay a share of the cost increase.	No

Which entity is most likely to assume responsibility for compliance?

The ship owner is the responsible entity for surrendering allowances and the ship is the accounting entity for calculating the number of allowances in an emissions trading scheme. In principle, the ship owner can pass on the obligation to surrender allowances or the associated costs to another party, e.g. the charterer, the disponent owner or the operator. The large variety of contractual arrangements in the shipping sector will likely result on actors passing on the responsibility to others in some cases. For example, in time charter arrangements it is common for the charterer to pay for the voyage costs. It is very well possible that in these cases the responsibility for acquiring and surrendering allowances will be contractually imposed on the charterer. Whether or not this happens in practice depends on the contracts the owner and the charterer agree upon. Whether this will happen in practice, and how often this will happen, will depend on market circumstances.

An analogy may be drawn with the over-age insurance premium, i.e. the insurance premium on either the ship, or the cargo, due to the age of the ship. Currently, time charter contracts may contain a clause stating that 'the overage insurance premium on ship and/or cargo to be for X's account', where X may be either the ship owner or the charterer. What this means that if, due to the age of the shipping carrying out the transportation, the insurance company(ies) increase the extra cost. They shall be paid by a) the owner or, b) the charterer or, c) the cost is split between the parties. A typical compromise is that the owner takes the additional cost for the ship whereas the charterer takes the cost for the cargo. However, when demand for ships is high many owners will impose the costs on the charterers. Equally, when demand for ships is very low, the charterer will be in a position to have the owners accept taking the entire cost. We also understand that something similar is the case for bunkers cost in SECA areas.

Which entity is most likely to bear the costs of compliance?

It should be noted that the actor who is held responsible by the regulator for surrendering allowances is not necessarily the actor that bears the costs: a ship owner can, in principle, pass on the costs to the shipper who, in turn, can pass on the costs to the consumer. Theoretically, when supply of ships and demand for transport services are in equilibrium and there are no market failures, prices are determined by marginal costs and all the costs are borne ultimately by the consumer. In practice the shipping market is very volatile and hardly ever in equilibrium because supply of ships is inelastic – it takes a long time to build a ship and when there is a high demand for ships yards' order books may last several years.

In order to assess which actor bears the costs, it is therefore necessary to consider two situations:

1. The demand for shipping is higher than the supply of ships.
2. The demand for shipping is lower than the supply of ships.

In the first case, freight rates are not determined by marginal costs but rather by the marginal benefits, in other words by the shippers' willingness to pay for transport. In these cases, shipping companies will be able to reap scarcity rents (sell their services above costs). The introduction of a new cost item, CO_2 costs and higher costs will in general not affect rates in this case.[12] However, existing market institutions such as charter contracts in which the charterer pays for the voyage costs may occasionally or temporarily allow shipping companies to pass on some of the additional costs (like currently Bunker Adjustment Factors sometimes allow shipping companies to pass on higher bunker costs even in times of high freight rates (Cariou and Wolff, 2006). The new cost item will, however, reduce the scarcity rents.

In the second case, freight rates are set by marginal costs, the costs of operating the ship (or more precisely, at the costs of operating the ship minus the costs of laying her up – after all, if it costs more to operate a ship than it does not to operate it, a shipping company would decide to lay her up). Investment costs, which are sunk costs, will typically not be recovered under

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[12] Some readers may feel this is counter-intuitive. They may argue that in a market where demand for maritime transport is higher than supply, suppliers are in a good negotiating position (a 'sellers market') and may negotiate contracts in which the demand side pays for the additional costs. While this may happen in some cases, it is unlikely to be the norm. After all, if suppliers are able to raise their prices even more in a market where freight rates are already well above marginal costs, one could ask why they had not increased their rates without the additional costs, thus maximising their profits even more. The answer is that if they would have increased their rates, they would have lost demand as shippers would choose other modes of transport or decide not to transport at all.

these circumstances. Since voyage costs are typically costs of operating a ship, and since allowance costs are part of the voyage costs, ship owners will be able to pass them on to shippers (see also Stopford, 2009).[13]

A special case may occur when one ship operates in two markets with different price elasticities of demand. This is often the case in shipping, and container lines are an excellent example. Demand for transport from Asia to Europe and the US is high and the elasticity of this demand is lower than the elasticity of the return voyage. Under such circumstances, it is rational for ship operators to allocate more costs to the least price sensitive market. This is known as Ramsey pricing. So while the costs for shipping a container from Singapore to Rotterdam are the same as the costs for shipping it back, ship operators charge higher prices for the trip to Europe.

For developing countries, more factors are important. Hummels et al. (2009) show that shipping companies are able to charge higher prices not only when demand is less elastic, but also when the cargo is more valuable, when tariffs are higher and when there are fewer competitors on a trade route. The latter is especially relevant for smaller developing countries.

In summary, the costs of climate policy are not always borne by the actor that surrenders allowances. When demand for shipping is high, costs are borne by the shipping companies, leading to lower scarcity rents and thus lower profit margins. Conversely, when demand for shipping is low, the costs will be passed on to the shipper and ultimately to the consumer. However, not all consumers will be equally affected, as the least price sensitive consumers – typically consumers in developed countries, are likely to pay a higher share of the costs.

Geographical distribution of responsibilities and costs

The previous section analysed which actor group is most likely to assume responsibility for compliance and who bears the costs of climate policies. This section analyses where these actors are located, hence where the responsibilities and costs are borne geographically.

While the ownership of a vessel can be unequivocally determined, the country where the owner is located is not necessarily the country that is impacted. The reason is that the owner may be a legal entity established in one country which, in turned, is owned by a shareholder or shareholders in another country. Ultimately, the shareholders reap the benefits from a ship, and they may be considered the true owner. UNCTAD assesses the geographical distribution of ownership, where '(t)he country of ownership indicates where the true controlling interest (i.e. parent company) of the fleet is located.' (UNCTAD, 2009). Table 10 shows the ownership of the World fleet. At least 63% of the world fleet is controlled by nationals from Annex I countries (in terms of deadweight tonnage). At least 33% is controlled by non-Annex I nationals. This implies that the responsibilities for surrendering allowances will probably be predominantly assumed by Annex I nationals.

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[13] It should be noted that there have been reports of ship owners operating at a loss. It is not clear whether they are really operating below marginal costs, or whether they have other sunk costs, e.g. crew costs that they cannot adjust immediately because of labour contracts, or that they operate below marginal costs on one voyage hoping to recoup some of the losses on the next voyage. Whatever the case, it is clear that ships cannot be sustainably operated below marginal costs.

Table 10 Ownership of the world fleet

Country	Fleet (1,000 DWT)*	
Greece	174,570	
Japan	161,747	
Germany	94,223	
Norway	46,872	
United States	39,828	
Denmark	27,435	
United Kingdom	26,002	
Canada	18,748	
Russian Federation	18,038	
Italy	17,740	
Turkey	13,160	
Belgium	12,155	
Netherlands	8,636	
Sweden	6,918	
France	6,526	
Spain	4,498	
Switzerland	3,579	
Croatia	3,065	
ANNEX I Total		683,740
China	84,882	
Korea, Republic of	37,704	
Hong Kong, China	33,424	
Singapore	28,633	
Taiwan Province of China	26,150	
India	16,053	
Saudi Arabia	12,946	
Malaysia	11,169	
Iran, Islamic Republic of	10,257	
United Arab Emirates	8,925	
Cyprus	7,313	
Indonesia	7,258	
Kuwait	5,301	
Vietnam	4,586	
Brazil	4,421	
Thailand	4,022	
Bermuda	3,217	
NON-ANNEX I Total		306,261

* Data represent 95% of the world fleet.

Source: UNCTAD, 2009.

The previous section concluded that the costs of climate policy will be borne by the charterer or the consumer, and in case of unbalanced markets, predominantly by the charterer or consumer with the lowest price elasticity of demand.

In terms of tonnage, about equal quantities of goods are offloaded in developing countries and developed countries (according to UNCTAD (2009), 53% of goods were offloaded in developed economies, 46% in developing economies and the remainder in economies in transition). The share of developed countries in the total of goods unloaded is declining monotonously. In 1970, developed market economy countries, a group which comprised Western European countries, the USA, Canada, Japan and South Africa, accounted for 80% of goods unloaded. By 1980, this share had declined to 71%, declining further to 67% in 1990 and 63% in 2000 (UNCTAD, 2004). With the current economic slowdown appearing less severe in Asia than in Europe and North America, it is likely that the share of goods unloaded in developed countries will decline further (there are no global statistics of the value of maritime trade).

Because the share of goods offloaded in developed countries is larger than the share of goods offloaded in developing countries, it can be expected that developed countries will pay a larger share of the costs. Moreover, as argued before, shipping companies will allocate costs to routes to developed countries, increasing the share that developed countries will pay.

4.4 First order impacts on the cost structure of the shipping industry

We have now identified which players will be impacted by enforcement of a climate policy. We will move on further to look at the cost structure for those players that are directly impacted, namely the ship owner and the cargo owner.

Cost structure for operating a ship

The cost structure for running a ship is the cost either the ships' owner or operator will bear. Based on Stopford (2009), the cost structure for running ships can be presented as in Figure 11. The general cost categories are indicated in the dark blue and individual cost items are listed below.

The magnitude of individual costs will vary across segments and the size of the vessels and also over time as variables in the individual cost items undergo changes e.g. fuel costs. To give a very crude impression: operating and maintenance costs are typically in the order of millions of dollars per year (see next section). Fuel costs depend on fuel price, of course, but are also mostly in the millions of dollars range.[14] New build ships typically cost several tens of millions of dollars (UNCTAD, 2009), so at an interest rate of 10% and a lifetime of 25 years, the annual interest payment and depreciation is also in the order of millions of dollars. In other words, annual operational costs and maintenance, annual voyage costs and annual capital costs are of the same order of magnitude.

A CO_2 emission cost will fall under the general cost classification group Voyage costs, since it directly linked to the voyages.

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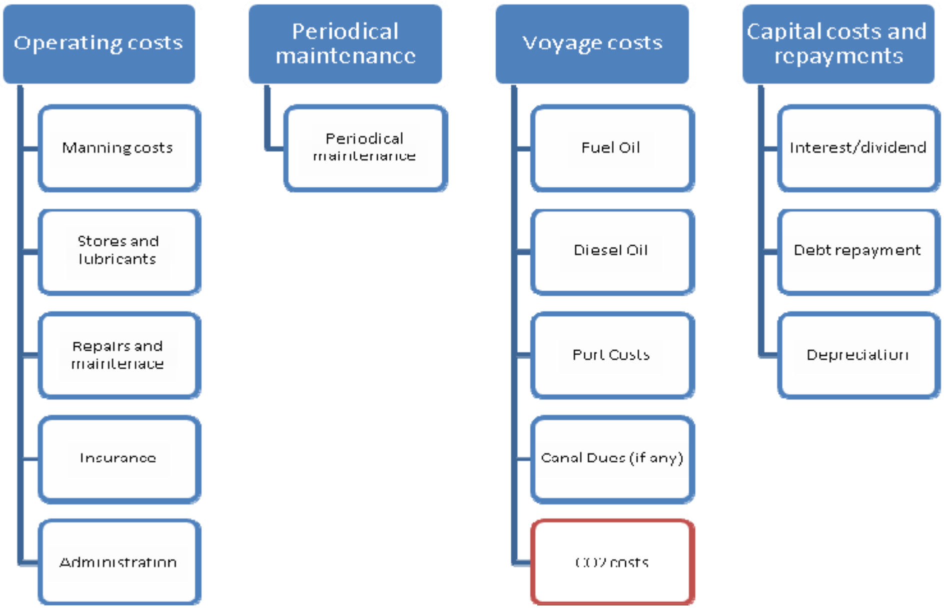
[14] Buhaug et a;. (2009) estimate total fuel consumption of international shipping in 2007 at 277 million tonnes. For a fleet of approximately 36,000 vessels (UNCTAD 2008), the average consumption per vessel is about 8,000 tonnes. The fuel price has ranged from USD 250 per tonne to USD 600 per tonne over the past years.

Figure 11 Analysis of the major cost of running a ship



Quantitative Cost Examples

Below we are going to present six cost examples for different segments and vessels sizes to show an estimated cost for the CO_2 emitted compared to today's costs. The operation costs are based on Moore Stephens' OpCost 2008 report, where samples from a selection of vessels that are used to give an average cost overview for the operational costs for different segment and sizes. The examples are based on the vessel types:

- Handysize Bulker (a small bulk carrier with a deadweight of 15,000–35,000 tons).
- Capesize Bulker (the largest category of bulkers with a deadweight exceeding 150,000 tons).
- Handysize Product Tanker (a small tanker with a deadweight of 15,000–35,000 tons).
- VLCC Tanker (a Very large Crude Carrier with a deadweight of 150,000–320,000 tons).
- Container Main Liner (a container ship with a capacity of transporting 2,000–6,000 TEUs).
- RoRo (a vessel designed to transport wheeled cargo).

Let's first look at the Handysize Bulker.

Table 11 **Operating costs of a handysize bulker, 2007**

Handysize Bulker		
	DWT:	**20,000-40,000**
	World Fleet:	**2,103 (62,796,658 dwt)**
	Average Size:	**29,861 dwt**
	Average Age:	**September 1987**
	Sample size:	**123 vessels**
	Sample average size:	**28,708 dwt**
	Sample average age:	**August 1989**
OpCost report		
All figures are for 2007		
Item	**USD (per year)**	**USD (per day)**
Crew Wages	504,541	1,382
Provisions	55,703	153
Crew Other	90,083	247
Crew Costs Total	650,327	1,782
Lubricants	114,223	313
Stores Other	116,760	320
Stores Total	230,983	633
Spares	128,930	353
Repairs & Maintenance	126,276	346
Dry docking[15]	150,638	413
Repairs & Maintenance Total	405,844	
P&I Insurance	94,469	259
Insurance	90,228	247
Insurance Total	184,697	506
Registration Costs	10,301	28
Management Fees	163,053	447
Sundries	60,765	166
Administration Total	234,119	641
Total Operating Costs 2007	**USD 1,705,970**	**USD 4,674**

Source: Moore Stephens LPP, 2008.

We have added the dry docking expenses into the cost overview and the results cover more or less the total Operating costs and Periodical Maintenance costs. The last cost items are the Voyage costs. This however is the difficult task as these cost elements are not static but varies on a daily basis or just on a specific voyage. The bunker cost (both HFO and MDO) will vary with the consumption and the price of the bunkers. Bunker prices, for Heavy Fuel Oil, HFO, development during the five last years is as follows, on a weekly basis.

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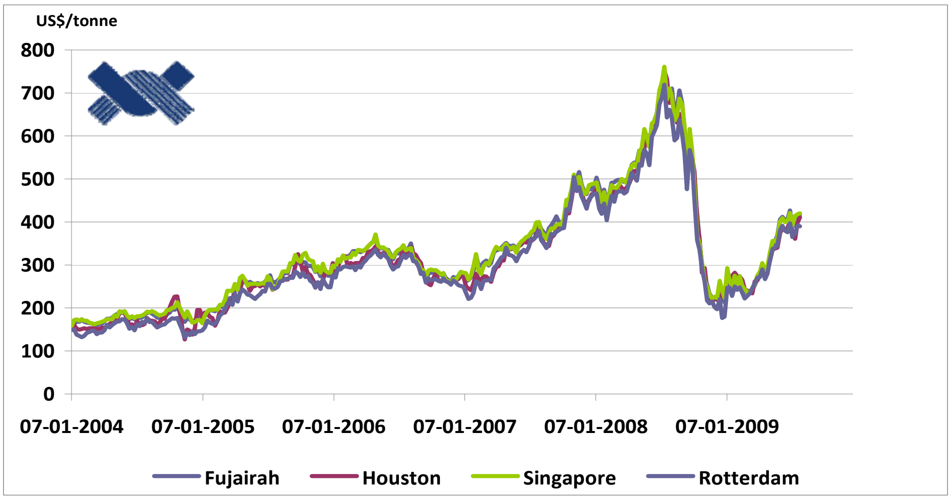
[15] Dry docking costs are based on Moore Stephens' Average dry dock costs for year ending 31 December 2007 and divided by 5, assuming that ships dry dock every five years

Figure 12 Bunker fuel price development



Furthermore port cost varies for almost every port. As for the canal costs it will depend on if there are any canals on the voyage. There are basically only two places where a large vessel has to pay canal dues and that are in Panama or through the Suez Canal. For the CO_2 cost it will be a function of the operation, i.e. fuel consumption and emission, and the price for the CO_2. To be able to show any quantitative analyses we have to set some of the variables in the functions. Since we have used 2007 numbers for the operation cost we will use fuel price data for the same year.

First of all the average bunker price was in 2007 USD 360.5 per tonne. A Handysize bulk vessel burns about 22 tonnes of bunkers per day of normal operation. From the 'Second IMO GHG study 2009' a bulk vessel between 10,000-34,999 DWT operates on average 258 days at sea per year. This gives us the following bunker cost of USD 2,046,198 per year or USD 5,606 per calendar day.
The consumption of one tonne of HFO generates 3.09 tonnes of CO_2, which gives us that a Handysize will estimate emit approximately 68 tonne CO_2 per day or approximately 17,539 tonne CO_2 per year in operation. If we assume a USD 30 per tonne price for the CO_2, this would mean a yearly cost of USD 526,170 or USD 1,442 per day. The actual costs are proportional to the price of the allowances.

The capital costs are highly variable. They depend first and foremost on the price of a ship, which is highly variable. Moreover, the financial structure for the ship, age, equipment, specifications etc, all are variable. Here, in order to give a crude estimate of capital costs, we estimate that capital costs are the annuity of the loan for a new built ship with an economic life of 25 years. Following VROM (1998), we take the private interest rate to be the 10-year rate on government bonds plus a risk surcharge of 5 percentage points. From 2004 through 2008, Euro area and US 10-year bonds yield averaged 4%[16], hence we use a private interest rate of 9%.

The average handysize new built price from 1992 through 2007 was 22 million USD (Fearnley Consultants), hence our estimate of the annual

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[16] http://www.statistics.dnb.nl/index.cgi?lang=uk&todo=Rentes, accessed September 10, 2009.

capital costs were 2.25 million USD. Note that actual capital costs may be higher or lower, depending on factors described above.

Summarizing the cost for the handysize bulker we get the following.

Table 12 **Annual and daily cost structure of a handysize bulker**

	USD (per year)	USD (per day)
Total Operating & Maintenance Costs	1,705,970	4,674
Capital costs	2,250,000	6,320
Bunker costs (USD 360 per metric tonne of fuel)	2,046,198	5,606
CO_2 cost (USD 15-30 per tonne of carbon)	**263,085-526,170**	**720-1,442**
CO_2 cost % of other costs	**4-9%**	**4-9%**

The CO_2 cost with the used assumptions represents a 4-9% increase in costs (and a 7-14% increase in operational costs).

We have done similar calculations for a capsize bulker, a handysize product tanker, a VLCC tanker, a container main liner and a RoRo vessel. Details can be found in Annex C. The results are summarized in Table 13.

Table 13 **Cost structure of different vessel types (annual costs, 2007, USD million)**

	Handysize bulker	Capesize bulker	Handysize product tanker	VLCC	Container main liner	RoRo
Operating & Maintenance	1.71	2.68	2.76	3.81	2.13	2.13
Capital	2.25	5.06	3.47	9.37	4.81	5.55
Bunker (USD 360.5 per tonne)	2.04	6.03	3.17	8.88	12.15	3.07
CO_2 (USD 30 per tonne)	0.53	1.55	0.82	2.29	3.13	0.79
CO_2 cost % of total costs	9%	11%	9%	10%	16%	7%
CO_2 cost % of operating and voyage costs	14%	18%	14%	18%	22%	15%

Note: Cost increase ratios depend on fuel price and allowance price assumptions. Ratios presented are calculated for a fuel price of USD 360 per metric tonne and an allowance price of USD 30 per metric tonne of CO_2.

The results presented in Table 13 depend on the fuel and carbon price. Most fuel price forecasts expect fuel prices to rise in the future. The International Energy Agency (IEA) forecasts a crude oil price of USD_{2007} 110 per barrel in 2020 and USD_{2007} 122 in 2030, much higher than the average price in 2007 of USD 69.33 (IEA, 2008). The Energy Information Administration (EIA) forecasts prices of USD_{2007} 112.05 per barrel in 2020 and USD_{2007} 124.60 in 2030 (EIA, 2009). Moreover, due to the revised MARPOL Annex VI, prices for maritime bunkers are expected to rise relative to crude oil prices (see below). Hence it is likely that in the coming decades fuel prices will be higher than the 2007 average.

Table 14 shows for a VLCC how the impact on the operational, maintenance and voyage costs varies with fuel price and carbon price. Higher fuel prices result in a lower impact, while higher carbon prices naturally result in a higher impact. Please note again that this is an assessment of a first order impact. The real impact is likely to be lower as ships will increase their efficiency due to higher fuel and carbon prices.

Table 14 **Operational cost price increase for a VLCC under different fuel and carbon price assumptions**

		Fuel price (USD/tonne of fuel)		
		USD 360	**USD 700**	**USD 1,040**
Carbon price (USD/tonne of CO_2)	USD 10	6%	4%	3%
	USD 30	18%	11%	8%
	USD 50	30%	18%	13%

Source: This report.

Comparison with economic impact of low sulphur fuel requirements

The revised MARPOL Annex VI requires ships to use fuels containing no more than 0.5% sulphur m/m from 2020 in all seas and 0.1% in SECAs. Many observers expect that such limits can only be met by using distillates. As distillate fuels are more expensive, this will raise costs for shipping. An IMO expert group has estimates that distillates may be 25 to 72% more expensive than heavy fuel oils (IMO, 2007). In the examples above, the CO_2 price of USD 30 per tonne and the fuel price is USD 360.5 per tonne. The resulting price increase is 25% of the price of fuel. Hence, this estimate of climate policy costs corresponds to the lowest estimates for the costs resulting from the revision of MARPOL Annex VI.

Conclusion

The costs structure of a ship varies greatly over different ship types and size categories. This section has assessed the quantitative impacts of an emissions trading scheme on six vessels which are common but are not supposed to be representative of the total world fleet. The analysis shows that at an allowance price of USD 30 per tonne of CO_2, the costs for these six ship types range from 7 to 16% of the total costs and from 14 to 22% of the operational costs. The share of costs is proportional with the price of the allowances, so higher allowance prices increase the share in total costs. Conversely, higher fuel prices lower the share in total costs.

4.5 First order impacts on prices of goods transported over sea

This section analyses the impacts on the costs of imports quantitatively. In case if the costs of climate policy would be transferred fully to the consumers, we have to investigate the possible impact on import values. How much of the increased costs of shipping would have to be borne by the final consumers of traded goods, and finally, what a percentage rise in prices of consumer goods could be expected depends on several factors, including:

- Elasticity of supply: the lower the elasticity of supply for maritime shipping, the higher the share of the additional costs related to climate policy that will have to be borne by the maritime shipping customers.
- Design of the policy – specifically, in ETS, if allowances will be allocated using auctioning or (partly) distributed for free.
- Share of maritime shipping costs in final consumer price of a given good.

In order to investigate the potential impact of climate policy in maritime shipping on import values, we will analyse a few typical examples of goods transported by maritime ships. We will adopt assumptions which allow assessing the worst-case scenario, i.e. the scenario inducing maximum possible estimates of impact (i.e. so that the risk of underestimating the impact of climate policy on consumer prices would be very low). Thus, we assume that (1) the elasticity of supply for maritime shipping of these goods is equal to zero, meaning that the increase in costs due to the emissions reduction policy will be fully transferred on to the consumers and (2) that in case of emissions trading all allowances will be allocated using auctioning, i.e. the ship operators will have to pay for every unit of CO_2 emitted and in case of a tax that full amount of tax per tonne of CO_2 will have to be paid by the responsible party. We also make a general assumption that the markets for the specific goods are perfectly competitive and that the changes in freight costs are reflected in price changes.

Table 15 below shows the expected increase of import values given the above assumptions. Value of costs of maritime transport per tonne of specific categories of goods as well as percentage ad valorem are based on Korinek and Sourdin (2009). On the basis of the assumed type of ship used for transport for a given commodity, we have applied the relevant percentage increase in operational transport costs based on data from the Table 13 (i.e. values for 2007 and a carbon price of USD 30 per tonne). Under the assumption that all increase in costs of transport is passed through to the consumer, increase in absolute value of the commodities has been calculated on the basis of the data on value/tonne (i.e. price per tonne). The last column shows an estimate of percentage increase in consumer prices resulting from increase in shipping costs due to the METS.

Table 15 **Estimated percentage increase in import values for different types of commodities**

Type of commodity	Ship type	Maritime transport costs (USD/ tonne)	Value of goods (USD/ tonne)	Transport costs as a share of value of imported goods (%)	Increase in shipping costs (USD 30 per tonne of CO_2)	Percentage increase in price of goods
Agriculture	Bulker	80.64	740.50	10.89	9-11%	1%
Raw materials: ores and coal	Bulker	32.59	134.89	24.16	9-11%	2-3%
Crude oil	Tanker	18.09	448.88	4.03	9-10%	0.4%
Manufactures	Container	173.94	3403.91	5.11	7-16%	0.4-0.8%

Source: Korinek and Sourdin (2009). Note: increase in shipping costs calculated for an allowance price of USD 30 per tonne of CO_2 and a fuel price of USD 360 per tonne of fuel.

From these numbers we can draw a conclusion that the expected increase in consumer prices due to CO_2 policy in maritime shipping ranges from 0.4 to 3%. The highest increase in prices (2-3%) is expected for raw materials, ores and coal (because a relatively high share of the value of these goods can be attributed to maritime transport costs), and the lowest, 0.4%, for crude oil. As raw materials are not consumed by the end user, the cost increase in consumer prices is probably towards the low values of the range presented here.

In principle, a much more detailed analysis of increase in import values can be done. We present an example here of imports from two South American countries into the EU: imports of cereals from Argentina and imports of coffee from Brazil. The former has high transport costs relative to the value of imports, whereas the second has low ad-valorem transport costs. Together, they present a range of possible outcomes. Table 16 shows that the increase in import value for these commodities ranges from 0.1% for coffee to 3% for cereals.

Table 16 **Increase in import value of two selected imports**

Commodity	Exporter	Year	Ad valorem maritime transport costs	Transport mode	Transport costs increase (allowance price USD 15-30)	Increase in import value
Coffee	Brazil	2006	0.02	Container	8-16%	0.1-0.3%
Cereals	Argentina	2005	0.30	Clean Bulk	4-11%	1-3%
		2006	0.23	Clean Bulk	4-11%	1-3%

Source: OECD Maritime Transport Costs Database, own calculations.

The increase in consumer prices may result in a reduced demand, or a substitution of imports by local production. The degree to which this is likely depends on the price elasticity of demand for products, the import substitution price elasticity and the geography of production. Analyzing these effects would require a general equilibrium trade model which is beyond the scope of this project.

4.6 Behavioural responses in the shipping sector

Inclusion of shipping in an emissions trading scheme results in CO_2 emissions getting a price. Ship owners and operators acting rationally will take measures to reduce emissions up to the point where the cost-effectiveness of these measures is equal to either the allowance price or the tax rate. These measures will reduce emissions from maritime transport and increase efficiency.

For analytical purposes, measures can be divided in technical measures and operational measures. Technical measures include new ship concepts, with different speed and capability, different hull and superstructure for new ships or retrofits to existing ships, more efficient power and propulsion systems and the use of renewable energy. Operational measures include increased maintenance, voyage optimisation and energy management (Buhaug et al., 2009).

A quantification of the costs and abatement potential of these measures in Buhaug et al. (2009) shows that in the next decade, most efficiency improvements can be obtained by operational measures applied to the existing fleet. This is supported by Det Norske Veritas (2009). In the longer term, an efficiency increase up to 75% is achievable from both operational and technical options (Buhaug et al., 2009).

In contrast to standards, emissions trading does not prescribe the way in which a sector should respond to an incentive to lower emissions. Hence, the shipping sector can use ship-based efficiency improvements, different logistics, a different geography of production, reduction of demand and offsets from other sectors as means to reduce emissions. If the actors are rational, their choice will depend on the cost-effectiveness of the different measures.

One aspect that merits special attention is the potential for a modal shift. Shipping is generally the most energy efficient mode of transport. However, small, fast ships can emit more CO_2 per tonne mile than trains or even some trucks (Buhaug et al., 2009). Still, in most cases a modal shift to e.g. road transport would lower maritime emissions but increase overall transport emissions. This could be counterproductive to the ultimate goal of reducing greenhouse gas emissions.

Shifting to alternative modes of transport is likely to be an issue primarily in short sea shipping. This assumption is supported by evidence on price elasticities and cross-price elasticities. While the price elasticity of demand for shipping is generally low (see above), it is much higher for short sea shipping and inland shipping. Beuthe et al. (2001) estimate the price elasticities for inland shipping in Belgium to be between -1.3 for longer distances and -2.6 for shorter distances. Oum et al. (1990) found that the price of inland shipping of coal is inelastic, while the price of inland shipping of wheat and oil is much more elastic. While these studies focused on inland shipping, the same may apply to short sea shipping. In Australia, the price elasticities of domestic shipping are estimated to be -0.8 on average, much higher than the price elasticity of international shipping (Bureau of Transport and Communications Economics, 1990). While there is scant evidence on cross-price-elasticities, it seems reasonable to assume that the much higher price elasticities in inland and short sea shipping are due to competition with other modes of transport, such as rail and road transport.

The analysis of the available evidence of own- and cross-price elasticities in short sea shipping indicates that, if the price of sea transport increases relative to road transport and rail, there would be a shift away from maritime mode of transport. Conversely, if road transport and rail become more expensive, e.g. because of fuel excise duties or because of the inclusion of power generation in an emissions trading scheme, there would be a modal shift towards short sea shipping. Hence, modal shift is most likely to occur in short sea shipping for the policies that increase the cost of shipping, insofar as costs of other transport modes are not increased simultaneously. In a climate policy setting where all sectors of the economy should contribute to reducing emissions, the costs of land-based transport modes are likely to increase as they need to reduce emissions as well.

4.7 Summary and conclusion

This chapter assesses the impacts of an emissions trading scheme on the shipping sector. It identifies the ship owner (in cases also the operator and the manager) as the actor directly impacted and the shipper (in cases also the charterer) and the consumer as actors being indirectly impacted. Other groups of actors may have a role to play in organizing the system. States will have to monitor compliance, both in their capacity of Flag State and Port State, ship crew will have to monitor emissions, classification societies may act as verifiers.

Regardless of whether the ship owner is designated with the responsibility to surrender allowances or not, we argue that in many cases he will assume this responsibility because in most cases the ship owner has the longest-term interest in the operation of a ship, and non-compliance may result in her detention. Note however that he may choose to pass this on contractually to the charterer or another party.

The actor assuming responsibility need not coincide with the actor bearing the costs of compliance. Who this actor is, depends on the market circumstances, which in a cyclical industry are very important. We argue that when demand for maritime transport is higher than supply, prices are not cost-related but are set by marginal demand. This means that the introduction of additional costs will not affect the price. In this case, the costs are borne entirely by the ship disponent owner and will reduce his profit margins. On the other hand, when demand is lower than supply, prices are set by marginal costs and costs are passed on to the shipper and ultimately to the consumer. Hence, in this situation the consumer will bear the costs.

As most tonnage is controlled in Annex I countries, and most cargo is transported to Annex I countries, these countries are likely to bear most of the costs regardless of the market situation.

The METS affects the cost structure of maritime transport. A new item is added to the voyage costs, viz. the costs of allowances. The size of the impact depends on the vessel type and size, the fuel price and the allowance price. We demonstrate that for 2007 cost figures and an allowance price of USD 30, the costs increase for six different ship types ranges from 7 to 16% of the total costs and from 14 to 22% of the operational costs. The share of costs is proportional with the price of the allowances, so higher allowance prices increase the share in total costs. Conversely, higher fuel prices lower the share in total costs.

As transport costs are a minor share of the prices of imported products, the impact on import prices is smaller than the impact on transport prices. We demonstrate that including maritime transport in an METS will have a small impact on import prices, ranging from less than 1% for petroleum products and manufactured goods to a few percent for raw materials like ores and coal.

It is likely that the shipping sector responds to the costs increases by increasing the efficiency of the fleet by technical and operational means. There appears to be a considerable potential to do so. This will reduce the actual cost increase.

5 Costs of the METS to economies

5.1 Analytical framework for estimating economic impacts

The impacts of the METS on economies are determined by its costs and benefits. The most important cost items are the net costs of abatement technologies and administrative costs. The most important benefits arise from the use of the revenues.

As discussed in chapter 4, it depends on the market circumstances that bears the costs. When demand for shipping is high, shipping companies bear the costs. When demand for shipping is low, the consumer bears the costs. This chapter focuses on the situation in which the consumer bears the costs. It assumes that the costs are borne by the importer of cargo or the user of maritime transport, and relates the cost increase for groups of countries to the Gross National product (GNP) of these countries in section 5.2. It does so quantitatively for 2006, the year for which the emissions have been calculated and for which GNP figures are available. The chapter goes on to qualitatively assess how the macro-economic impact may evolve over time in section 5.3.

This chapter estimates the maximum cost of the METS. It assumes that the net costs of abatement technologies are much larger than the administrative costs and that therefore the impacts stem from the fact that the costs of emitting CO_2 rise. As a result, the costs of maritime transport rise (see section 4.4).

In this first order approach, we assume that the cost increase will not reduce demand nor improve the fuel efficiency of maritime transport. We furthermore assume that imports are not substituted by domestic production. A change in any of these assumptions will reduce the costs of the policy. If the fuel efficiency of maritime transport is improved, the same amount of transport work can be delivered at lower CO_2 costs. Likewise, a substitution of imports by domestic production will have economic benefits to the country that partly offset the costs. In the first order approach, we assume that trade is balanced, i.e. that ships are equally laden regardless of their destination.

In this chapter, we ignore any impact of the use of revenues. Revenues can be used to offset some of the costs of the policy. This is the subject of chapter 7.

The first order approach is of course a crude estimation. In reality, it is likely that the increased costs of emissions will result in measures to improve the fuel-efficiency of maritime transport (e.g. by slow steaming, increasing ship sizes, improving logistic efficiency and by technical measures) and in lower transport demand. Moreover, the division of the costs over the importer and the exporter depends on the elasticity of demand and supply, respectively. This means that the division of costs would also depend on the type of cargo. For example, for crude oil transported to a region with no domestic production, the importer would probably pay the full costs, but for a manufactured product that is competing with domestically produced products, a larger share of the costs would fall on the exporter.

In order to fully assess the economic impacts, one would need to employ a general equilibrium model, which would take into account not only the changes in costs of transport as in the first order approach but also induced changes in transport demand and fuel efficiency improvements. While this is beyond the scope of this report, we will assess impacts on demand, fuel efficiency, and trade qualitatively.

5.2 First order impacts of the cost increase of maritime transport

The increase in maritime transport costs are, in first order approximation, determined by the emissions and the price of the allowances. The emissions are presented in chapter 3. Assuming allowance prices in the range between USD 10 and USD 50 with a central values of USD 15-30, we can calculate the increase in maritime transport costs. These costs can be related to GDP to assess the relevance of the economic impact. The costs should not be mistaken for the macro-economic impacts as they are transfers, not deadweight losses.

Table 17 Cost increase of maritime transport to regions

Region of destination	CO_2 emissions Mt CO_2	Cost increase of maritime transport USD bln. USD 15-30/tonne CO_2 (USD10-50)	Cost increase of maritime transport % of GDP USD 15-30/tonne CO_2 (USD10-50)
North America	120	1.8-3.6 (1.2-6.0)	0.01-0.02% (0.01-0.04%)
Central America and Caribbean	53	0.8-1.6 (0.5-2.7)	0.01-0.01% (0-0.02%)
South America	59	0.9-1.8 (0.6-2.9)	0.05-0.09% (0.03-0.15%)
Europe	277	4.2-8.3 (2.8-13.8)	0.02-0.05% (0.02-0.08%)
Africa	68	1.0-2.0 (0.7-3.4)	0.1-0.2% (0.07-0.33%)
Middle Eastern Gulf, Red Sea	62	0.9-1.9 (0.6-3.1)	0.08-0.15% (0.05-0.25%)
Indian Subcontinent	24	0.4-0.7 (0.2-1.2)	0.03-0.06% (0.02-0.1%)
North East Asia	194	2.9-5.8 (1.9-9.7)	0.03-0.06% (0.02-0.11%)
South East Asia	116	1.7-3.5 (1.2-5.8)	0.17-0.35% (0.12-0.58%)
Australasia	35	0.5-1.0 (0.3-1.7)	0.06-0.13% (0.04-0.21%)
World	1006	15.1-30.2 (10.1-50.3)	0.03-0.06% (0.02-0.1%)

Source: This report.

Table 17 shows that in a first order approach, the global maritime transport costs could rise by USD 15 billion to USD 30 billion if the allowances price was USD 15 – USD 30 per tonne of CO_2. This would be approximately 0.02-0.06% of the world GDP. For many regions, impacts are at or below this level. For some regions, impacts are higher, increasing to 0.0- 0.2% of GDP for Africa and 0.12- 0.35% of GDP for South East Asia.

Turning to country groups, Table 18 shows that in a first order approach the cost increase in maritime transport at an allowance price of USD 15-30 per tonne of CO_2 would vary from 0.02-0.04% of GDP for Annex I countries to 0.07-0.15% of GDP for most groups of developing countries. For small islands and developing states (SIDS), however, the impact would be considerably higher at 0.45-0.89% of GDP.

Table 18 **Cost increase of maritime transport to groups of countries**

Country group of destination	CO_2 emissions Mt CO_2	Cost increase of maritime transport USD bln. USD 30/tonne CO_2 (USD 10-50)	Cost increase of maritime transport % of GDP USD 15-30/tonne CO_2 (USD10-50)
Annex I countries	469	7.0-14.1 (4.7-23.4)	0.02-0.04% (0.01-0.06%)
Non-Annex I countries	582	8.7-17.5 (5.8-29.1)	0.08-0.15% (0.05-0.25%)
G77	465	7.0-13.9 (4.6-23.2)	0.07-0.14% (0.05-0.23%)
Least Developed Countries	13	0.2-0.4 (0.1-0.7)	0.06-0.12% (0.04-0.19%)
Small Islands and Developing States	99	1.5-3.0 (1.0-4.9)	0.45-0.89% (0.3-1.49%)

Source: This report.

5.3 Cost increases for economies: a closer look

5.3.1 Mitigation of emissions in the shipping sector

Various studies indicate that there is a considerable potential to reduce emissions in the shipping sector. A significant share of emissions can even be reduced at a net profit. For the global shipping market, we estimate that the total emissions could be reduced by 2-20% in a cost-effective way, with a central value of 10%. Measures that turn out to be among the most cost-effective are propeller maintenance, hull coating and maintenance, wind energy and retrofit hull measures such as transverse thruster openings (Buhaug et al., 2009). DNV (2009) estimates a cost-effective potential of up to 15% in 2008 with technologies such as boiler consumption reduction, engine monitoring and optimising trim.

In the future, the share of cost-effective emission reductions is expected to increase as measures on new ships become available and as fuel prices are forecast to rise because of rising crude oil prices (IEA, 2009) and because of requirements to reduce the SO_x emissions (Purvin and Gertz, 2009; IMO, 2007). Buhaug et al. (2009) estimate the cost-effective emission reduction potential for 2020 to be 11-30% with a central estimated value of about 20% (at a fuel price of USD 500 per tonne of fuel). CE et al. (2010) estimates the cost-effective reduction potential to be 23-45% with 33% as a central estimate (at a fuel price of USD 700 per tonne of fuel).

While not all the cost-effective measures may be implemented because of market failures, bounded rationality and split incentives, it is clear that even if only half of the cost-effective measures are taken up, the fuel efficiency of the fleet will improve by some 5% in 2010, by 10% in 2020 and by 16% in 2030. As a result, the economic impact will be reduced accordingly.

5.3.2 Future development of GDP and trade

All the figures on the economic impacts presented in section 5.2 relate to 2006. This section analyses qualitatively how the impacts are likely to develop in the coming decades. There are four important factors relating to future emissions of maritime transport (Buhaug et al., 2009):

- The volume of maritime trade (in tonnes) has historically been increasing at a somewhat lower rate than GDP (Eyring et al., 2005). We assume that this relationship holds in the next decades, and that trade patters remain constant. As a consequence, we expect that maritime transport (in tonne miles) will grow at a slightly lower pace than GDP. This is in line with the forecasts in Buhaug et al. (2009).
- The share of container ships with relatively high emissions will continue, thus increasing the average emissions per tonne mile.
- As trade volume grows, and as current bottlenecks such as the Panama Canal and ports are expanded, ships can continue to exploit economies of scale, thus lowering average emissions per tonne mile.
- Ships will respond to the introduction of CO_2 costs by increasing their technical and operational efficiency. Markets will drive average speed down; increased maintenance and hull coatings, wind power and other measures will all contribute to this. There appears to be a significant potential to do so (Buhaug et al., 2009; Det Norske Veritas, 2009). Thus average emissions per tonne mile will decrease.
- For a number of reasons, the share of ships using alternative fuels such as LNG may increase. As LNG has lower CO_2 emissions per unit of energy, this reduces the average emissions per tonne mile.

Thus there are three factors that lower the average emissions per tonne mile and one that will increase it. Buhaug et al. (2009) find in a quantitative scenario analysis that the three factors are probably larger than the one factor, so that emissions per tonne mile are expected to decrease in the coming decades.

Buhaug et al. (2009) have published forecasts of transport work and emissions for a number of scenarios. Table 19 presents these forecasts together with the scenarios' economic growth rates and derived efficiency improvement rates.

Table 19 **Forecasts of GDP, emissions and efficiency growth rates**

Scenario	GDP	Transport work	Fleet CO_2 efficiency	Emissions
	Average annual growth rates 2007-2050			
A1F1	3.9%	3.3%	0.6%	2.7%
A1B	4.0%	3.3%	0.6%	2.7%
A1T	3.6%	3.3%	0.6%	2.7%
A2	2.4%	2.6%	0.4%	2.2%
B1	3.3%	2.5%	0.4%	2.1%
B2	2.7%	2.1%	0.2%	1.9%

Source: Buhaug et al. (2009).

Note: The scenarios are SRES scenario families, a set of scenarios commonly used in evaluating the impact of climate change, mitigation and adaptation.

When emissions per tonne mile decrease and the transport work (number of tonne miles) grows at a slower pace than GDP, the relative costs of an METS depend on the average annual increase of prices of emission allowances. Table 19 shows that on average over all scenario's, the first order cost estimate of a METS relative to GDP will remain constant if allowance prices increase at an average of 0.9% per annum in real terms (or double every 75 years). However, this simple calculation ignores any increases in fuel efficiency of maritime transport, substitution of imports by domestic production and other means to reduce maritime emissions.

5.3.3 Distribution of costs

Up to this point, we have assumed that the costs will be borne by the country where a vessel sails to. This section discusses whether this assumption is likely to hold or not.

It should be noted that not all of the emissions to regions are associated with transporting cargo because global trade is not balanced. For example, crude oil tankers transport crude from the Middle Eastern Gulf to Europe and North America and sail back empty. So on their voyage to Europe and North America the emissions are associated with transporting crude, while the return voyage is not associated with transporting cargo, but is made to pick up crude again in the Gulf. In container shipping, the imbalance is probably less pronounced but still significant (Table 20).

Table 20 **More containers are shipped from Asia to Europe and the Americas than back (billion TEUs)**

	Asia-US	US-Asia	Asia-Europe	Europe-Asia
2007	15,248	4,986	17,237	10,085
2008	14,528	5,614	16,741	10,500

Source: UNCTAD, 2010.

The imbalance of world trade is reflected in shipping rates. It costs approximately twice as much to send a container from Asia to the USA or the EU than to send one back. However, the costs of operating the container ship are not very different. This means that while the costs are almost equal, they are allocated in such a way that the market with the highest demand (and the lowest price elasticity of demand) pays a larger share of the costs than other markets.

Table 21 **Average container freight rates 2006Q1-2008Q2**

Route	Average freight rate (USD per TEU)
USA to Asia	820
Asia to USA	1,736
Europe to Asia	841
Asia to Europe	1,703
USA to Europe	1,099
Europe to USA	1,746

Source: UNCTAD, 2008.

For non-containerised trade, similar patterns exist.

It is likely that costs of METS would be allocated in the same way as current costs. In other words, it is likely that developed countries would pay a higher share of the costs than developing countries. This would reduce the burden on developing countries and increase the burden on developed countries.

5.3.4 Import substitution

An increase in the price of imports, even a small increase as in Table 15, can result in less demand for the imported good. Three alternative reactions are possible:

1. Total demand is reduced.
2. The same goods are imported from other countries, e.g. countries that are nearer to the importing country and thus have lower transport costs.
3. The same goods are produced domestically.

The extent to which each of these will occur depends on price elasticities: the first on the own price elasticity of demand, the latter two on the so-called Armington elasticities (the third is sometimes called import substitution elasticities). All these elasticities vary between commodity and country, so without a general equilibrium trade model it is not possible to quantify the impact. However, it is likely that import substitution will occur in many cases, resulting in lower costs of the METS.

5.4 Impact on world trade

The cost increase of maritime transport will lower demand for it and this may impact world trade. To assess the impact, we look at the price elasticity of demand. The price elasticity of demand is defined as the measure of responsiveness in the quantity demanded for a commodity as a result of change in price of the same commodity. It is a measure of how consumers react to a change in price. In other words, it is percentage change in quantity demanded by the percentage change in price of the same commodity. A price elasticity of 0.5 means that if prices go up by 1%, demand decreases by 0.5%.

The only comprehensive overview of price elasticities of demand for maritime transport is almost 20 years old. Oum et al. (1990) report elasticities of 0.06–0.25 for dry bulk cargo, 0.2–0.3 for liquid bulk and 0.0–1.1 for general cargo. Meyrick and Associates et al. (2007) estimate the elasticity of non bulk maritime transport to be 0.23.

Elasticties for inland shipping and domestic maritime transport are much higher. The Australian Bureau of Transport and Communications Economics (BTCE) (1990) finds elasticity of demand for transport between Australian ports to be 0.83. Beuthe et al. (2001) estimate the price elasticities for inland shipping in Belgium to be between 1.3 for longer distances and 2.6 for shorter distances. Oum et al. (1990) found that the demand for inland shipping of coal is inelastic, while demand for inland shipping of wheat and oil is much more elastic. Van den Bossche et al. (2005) find that in the Netherlands, demand for domestic general cargo and container traffic is elastic (1.0 and 1.1 respectively) while demand for dry and wet bulk is inelastic (0.5 and 0.7). International inland shipping is less elastic for general cargo and containerized cargo (0.9 and 1.0) and more elastic for dry and wet bulk (0.7 and 0.8).

We attribute the higher elasticities for inland and domestic transport to the availability of alternative transport modes. This is supported by the available studies on cross-price elasticities. Oum et al (1990) find cross-price elasticities of 0.61–0.86 between inland shipping and rail, and BTCE (1990) finds cross-price elasticities between domestic maritime transport and rail of 1.41 to

2.29. We are not aware of studies on cross price elasticities of ocean transport.

The low price elasticities of maritime transport suggest that METS will have a limited impact on trade a price increase of about 10% will decrease trade by about 2-3%. In reality, improvements in fuel efficiency will result in lower price increases, and only in bad markets will prices be passed on. Moreover, the decrease in trade will be against a baseline scenario that projects continuing growth. In other words, the METS may slow growth of world trade.

5.5 Conclusion

The costs of a maritime ETS vary between regions and country groups. They also depend on the price of allowances. In a first order approach intended to estimate the maximum costs, all but three geographical regions were estimated to experience a cost increase of imports and other maritime services below 0.1% of GDP at an allowance price of USD 30 per tonne of CO_2. No region had a cost increase higher than 0.3% of GDP. The three regions that are worse affected are the Middle Eastern Gulf region, Africa and South East Asia.

In the same approach, the costs for groups of countries relevant to the climate debate were estimated to be around or below 0.1% of GDP for all groups with the exception of the SIDS, where the impact has been estimated at 0.66% of GDP.

In practice, the cost increase is likely to be lower overall as ship owners and operators improve the efficiency of maritime transport. Moreover, it will partly be offset by a substitution of imports by domestic production.

In practice, the cost increase for developing countries is likely to be smaller for two reasons. First of all, ship movements to developing countries are often in ballast. The most obvious example is crude tankers. The transport of crude is typically from developing countries to developed countries. The freight rates are set so that developed countries pay for both the transport and the return voyage. Hence, developed countries will also pay for the cost increase on both legs of the voyage. Second, when there is trade in two directions, trade is often unbalanced. Freight rates in the direction where demand is highest is typically higher than freight rates in the other direction. It is likely that developed countries will pay a larger share of the cost increases.

Whether the costs will increase or decrease depends primarily on the development of allowance prices. If they grow faster than about 0.9% per annum in real terms on average, the impact will increase. Otherwise the costs are likely to decrease.

6 Impacts on Competitive Markets

6.1 Introduction

While discussing issues of competition, we have to consider four maritime shipping markets:

a The new building market, where ships are ordered, but delivered with a time lag.
b The sale and purchase market, where existing vessels can be bought and sold immediately.
c The freight market, where ships are chartered.
d The demolition market, where vessels are sold for demolition.

For the purpose of this report, we will focus mostly on the freight market, as this market is most likely to be affected by the climate policy for maritime shipping. However in section 6.3 we will also analyse shortly the remaining markets.

6.2 The nature of the freight market

In order to analyse possible distortions at the market, first we will investigate if maritime shipping market is currently competitive and which features of the competitive market could be at risk due to introduction of METS.

It is traditionally said that maritime shipping markets follow a perfect competition model. Perfect competition is an economic model that describes a hypothetical market form in which no producer or consumer has power in the market to influence the price. When a perfectly competitive market is in balance, supply matches demand at an equilibrium price which is set at the level of long-term marginal costs of providing services. Perfectly competitive market is characterized with the following features: atomicity, homogeneity, perfect and complete information, equal access in response to customer needs, ease in entry/exit of new participants. In such a market, prices would normally move instantaneously to economic equilibrium. Below, we will try to assess if the maritime shipping market reveals all these characteristics of a competitive market (Fearnley, 2007).

1. *Atomicity* is a feature of a market in which there are a large number of small producers and consumers, each so small that their actions have no significant impact on others. In the context of maritime shipping, the producers are the ship owners or operators, the consumers are the charterers and shippers, and the commodity consists of various categories of transportation service. At the start of 2006, the world’s total merchant fleet comprised about 38,000 vessels of 300 Gt (gross tonnes), or more. About 26,000 of these vessels were controlled by almost 5,000 companies. Almost 90% of the companies control less than ten vessels; on average they each control less than three vessels. However it should be noted that in some trades, e.g. the iron ore trade, the natural resources are controlled by only a handful of companies, but the demand side is also concentrated. The global seaborne trade in iron ore was approximately 670 million tonnes in 2005. Out of this, three companies (CVRD, BHP, and RTZ) were

responsible for almost three quarters of the volumes annually shipped. However, these companies appear to have relatively little control over sea transport - they together controlled only about 17% of the chartering. The balance of their exports is controlled by their customers who, basically, comprise the global steel industry. Thus for this cargo market the supply side is concentrated and although the market as a whole should not be described as atomistic, the sea transport element appears is competitive. Thus, the level of atomicity of the maritime shipping market is very high.

2. *Homogeneity* means that goods and services are perfect substitutes; that is, there is no product differentiation. Hypothetically, this is correct in the sense that all ships of similar types can offer similar services. However, there will most likely be a differentiation in price for transporting the same type of cargo. For instance, oil exports from the Middle East Gulf to India are shipped in tankers between 10,000 DWT and 320,000 DWT. As freight per unit of cargo declines with increased ship size (economy of size), the ship owner's total costs increase with size. Furthermore, charterers will aim generally for the newest available vessel. The running costs of an older vessel, taking into account extra insurance (which the vessel's owner arranges) are higher. Time charter hire levels tend to reflect the lower (total) cost to the Charterers of chartering a more modern and efficient vessel. In particular, modern vessels normally have better fuel efficiency, are faster and carry more cargo for a given size. Hence, the shipping market is homogeneous to a large degree.
3. *Perfect and complete information*. For the shipping market this is very largely true. For the large bulk commodity markets (dry bulk and liquid bulk) price information is available from a variety of sources to owners and charterers on a continuous basis. Most shipbrokers provide daily and weekly assessments, as well as daily reports, covering individual fixtures concluded. Minute by minute information is available to clients. Furthermore, the Baltic Exchange publishes daily reports covering over 64 individual routes for tankers, bulk carriers, and gas carriers. In addition, they produce seven indices based on freight assessments. For more specialised types of vessels, information on prices (freight) may be less readily available. However, some shipbrokers operate in specialised shipping segments that monitor and regularly assess freight conditions. This information is not always published, but is often available upon request. It also requires those looking for such information to know whom to ask. Again, a key role of the shipbroker is to track vessels, cargoes, and freight rates paid/accepted using all available sources, and use the information to enhance business for their clients.
4. *Equal access in response to customer needs*. The maritime shipping industry has always been flexible enough to respond to the changing demands of its customer base. This can be seen in all markets and in the development of specialised vessels to service a particular trade. Most of the changes tend to be evolutionary rather than revolutionary. Within the same ship type there has been a general evolution towards larger ships. These larger vessels often have lower costs per unit of cargo. The logic is that larger vessels will reduce costs per unit of cargo and ease port operations as fewer calls are needed for importing a given volume of cargo. This is most evidently seen in the large cargo volume markets such as coal, iron ore, and crude oil.
5. *Ease in entry/exit of new participants*. There are a number of possible barriers to entry for a new player joining the tramp shipping market. The first is capital, the second is time, the third is management and the fourth is technological. Despite the fact that new and second hand vessels cost several million USD, finance is generally available in the shipping market. It is, therefore, right to assume that any new player interested in entering the market will, with collateral, be able to obtain the necessary finance to

purchase a vessel or vessels. The active financing market effectively mitigates the capital cost barrier to entry in the maritime shipping market. Time is a potential barrier, especially at the ship markets. An active second hand market for the desired ship type is necessary for a new player to enter immediately. Without an active second hand market, new vessels must be ordered, and market entry may thereby be delayed by several years. To become a major player in one of the more industrialised market segments (chemicals or car carriers) requires a lot more than having the equity to buy the required number of vessels. A player needs, amongst other features, organisation, (IT) systems, human resources, customer relations, preferably a track record, and sufficient cargo coverage. But these are not essential when buying one ship, or a handful of ships, as investors can operate as pure tonnage providers to the major shipping companies in the various segments. The production technologies in this context are the ships themselves. The theoretical basis for constructing ships is of course available to anybody. However, specific ship designs must be considered proprietary technology. This technology is owned either by the shipbuilders or by ship design companies. However, for a potential customer of a shipyard there are practically no restrictions or limitations to ordering any ship of any design. As long as the potential customer can prove his ability to carry out his contractual obligations (primarily that he is able to pay for the ship), shipyards is willing to offer any type of ship as long as it is within their capabilities to deliver. Thus, there is equal access to the production technology for anyone.

From the description above it seems that the maritime shipping market reveals characteristics of a competitive market. It is important to note that in reality, no market is perfectly competitive. Failure to fulfil every item described above does not indicate an uncompetitive market. In the section below we will investigate to what extent METS can be expected to have impact on any of the characteristics of the competitive market.

6.3 Potential of METS to induce distortions in the freight market

The purpose of this section is to investigate if introduction of METS is likely to have an impact on any of the features of the maritime shipping market which make it competitive. There are a few features which are certainly not going to be affected significantly, and these are: atomicity, perfect and complete information and ease of entry/exit. Regarding atomicity, even if climate policy would increase operating costs to such a level where the least competitive ship owners would go out of business, the impact would be expected to be marginal and the number of participants at the market would remain very high. In theory, if the administrative costs of METS were very high, the economies of scale in administration might induce collusion and forming larger companies, which could result in more market power of the largest companies. However this effect is not likely to happen, as administrative costs of METS are not expected to be very high (e.g. monitoring procedures for fuel consumption are already in place, and a large share of administrative costs could be covered from the revenues from auctioning allowances). Climate policy would also have no impact on freight information; increased costs would simply have to be reflected in prices. Similar situation would occur with ease of entry and exit. Assuming that the scheme would be global, no barriers for entry or exit of new participants would be created.

However the two remaining characteristics, i.e. homogeneity and equal access in response to customer needs may need a closer look.

With introduction of METS, owners of smaller and older ships may be put in a disadvantageous position because the emissions of CO_2 per kg of cargo are much higher for such ships than for modern and bigger vessels. Thus, climate policy for shipping is likely to affect owners of older ships relatively more than owners of modern ships. They will become less competitive because in order to recover the costs of operating the ships, they will have to charge higher prices for the same service. Hence the feature of product homogeneity may be affected in such a way that although the service (freight of a given cargo) in principle remains the same, an increased tendency to differentiate the price may occur because of the added component of costs related to METS. In consequence of this reduced homogeneity of the service, equal access to meet the consumers' needs may be impacted from the point of view of the owners of smaller and/or older ships, as they may not be able to be competitive as compared to the newer and larger ships.

The question arises if these observations really mean that competition at the market will be distorted. Such a conclusion would not be true because the equilibrium price in the long run settles at the level of marginal costs (in long-run minimum), and the ships that are not competitive will simply be driven out of business. While this might be seen as cruel or unjust by owners of older and smaller ships, these are simply the rules of a competitive market.

6.4 Impact on the market for new buildings and second hand ships

One could think of impact of METS on the market for building ships and second hand ships in terms of increasing demand for more efficient ships. Although prices at the market for buying ships tend to be very volatile, in the long run specification of the ship, including fuel economy, does play a role (Stopford, 2009). Fuel efficiency will be more important in presence of a climate policy scheme such as METS. Therefore, both new building market and second hand ships market can be affected in such a way that more fuel efficient ships will be valued higher.

Economy of scale is very much valid in shipping, larger vessels use on average less fuel per unit of cargo and consequently, fewer allowances would have to be bought per unit of cargo. Thus introduction of METS could increase the tendency to build larger ships. However there are certain important constraints that control the size of a vessel. These are most of all characteristics of harbours and trading lanes. Draught restriction is probably the key factor in designing a vessel. Trading flexibility, meaning that it could trade to and from as many ports as possible, is a very important factor for ship owners. Another limit to the tendency to exploit economies of scale is that with very large vessels, the value of cargo becomes too high or the volume becomes too large for the market to accommodate.

Therefore, there is a chance that METS would have some impact on ship sizes, however because of various limitations this impact is not expected to add much to the normal evolution of the shipping market. Besides, introduction of climate policy would imply the same requirements for all the participants of the market, so no distortions would be expected.

Regarding the ship demolition market, the only impact that could be expected is that demand for demolition might increase slightly because older and less efficient ships would become (even) less attractive. However estimating this effect quantitatively would at the moment not be possible because of too high uncertainties and lack of data.

6.5 Conclusion

In this chapter we analysed if introduction of METS would be likely to create distortions at the maritime shipping market. The only possible path leading to distortions was identified, namely that METS might put the owners of smaller and older ships in disadvantageous position and at more risk of going out of business. However, even if such a phenomena is likely to happen, this does not mean that the maritime shipping market would stop being competitive. On the contrary, this would only prove that the market works very well, by promoting more competitive and economically efficient market players. Thus we can conclude that while there may be a need to protect ship owners of particular types of ships (e.g. small ships) against this mechanism, the motives for such protection would be different than market distortion.

It is also worth to note that the climate policy instrument is in its essence aimed at eliminating (or at least alleviating) a market failure – that is, a failure to reflect social costs related to pollution in market prices. Thus, instead of creating distortions, successful introduction of METS would rather help to deal with an unwanted external effect at the maritime shipping market related to global warming.

7 Mitigating Undesired Effects

7.1 Introduction

The impacts of a global maritime emissions trading scheme on regions and country groups differ, as is shown in chapter 5 for economic impacts. There may also be other impacts that are unevenly distributed. For example, small and remote economies may experience an increase in the prices of imported foods (CE, 2008). If they have little possibility to enhance their domestic food production, they may be unevenly impacted. Another example could be remote economies that are heavily dependent on sea transport for their trade relations (Wang et al., 2009). If some of their competitors are less carbon-intensive in their sea transport, they would be unevenly impacted. Finally, there may be social impacts on islands whose connections to the mainland are dependent on ferries.

An uneven distribution of impacts is not undesirable in itself. On the contrary, international agreements often intentionally create differentiated impacts. The UNFCCC and the Kyoto Protocol are good examples of this, as they build on the principle of Common But Differentiated Responsibilities (CBDR) to put a higher impact on developed countries than on developing countries. However, in some instances an uneven distribution may be undesirable, for example when it would contravene with CBDR.

This chapter evaluates ways in which undesired impacts of a maritime emissions trading scheme can be avoided or mitigated. In doing so, it does not analyse in detail which impacts are undesirable and which are not. This is a political question that is outside the scope of this report. Rather, it considers the following impacts to be potentially undesirable:

1. The general economic impact on developing countries through increased costs of imports.
2. The impact on health and food security through higher prices for imported health and food items.
3. The impact on connections of islands with their mainland.
4. The impact on trade relations.

For each of these potentially undesirable impacts, ways to reduce them are analysed below.

7.2 Methods to reduce impacts

7.2.1 General economic impact through increased costs of transport

Chapter 5 concluded that the general economic impact through increased costs of transport can in first order be estimated at maximum 0.03 to 0.66% of GDP for different country groups. The total first order costs for Annex I countries would amount to USD 7.0–14.1 billion (at an allowance price of USD 15–30 per tonne of CO_2) and for non-Annex I countries to USD 8.7–17.5 billion, under the assumptions from Table 18. The same chapter argued that the real impact on developing countries is likely to be lower for a number of reasons.

7.2.2 Use of revenues

The total revenue of an auction could amount to USD 22.5 billion, while the total impact on non-Annex I countries would be USD 11.9 billion. The impact on LDCs and SIDS is even smaller at USD 2.6 billion (see Table 18). Consequently, there is a considerable scope to reduce the economic impact on non-Annex I countries by using these revenues, while leaving room to fund other causes. There are several ways to do so, each with advantages and disadvantages:

a Direct compensation – in this case, a country which faces an increase in import costs of a certain amount would get this amount from the auction revenues. This would enable these countries to reduce for example distortionary taxes and thus improve their economic performance, or countries could invest the money in mitigation and adaptation. This option would only yield additional climate benefits if countries decide to use the revenues for that purpose. In practice, it could be hard to measure the impact on costs of imports as one would need information on emissions on routes to countries, preferably on cargo routes rather than ship routes. Collecting such data from ship owners could impose a large administrative burden on them. Moreover, it may be hard to include land-locked countries in such a scheme.

b Compensation based on import shares – in this case, countries would get compensation in proportion to their share in global imports (assuming that the importer bears the cost). This has been proposed by Nigeria and Liberia to COP15[17]. Again, this would enable these countries to reduce for example distortionary taxes, or countries could invest the money in mitigation and adaptation. This option would not be a direct compensation for increased costs and some countries may receive more and others less than the additional costs they incur. For example, countries whose imports are transported in less efficient ships (smaller, older and/or faster ships) would receive relatively less while other countries would receive more. This option would not yield additional climate benefits, nor be related to the need for climate finance. In practice, it would be easier to implement than the previous option as trade-data are regularly collected. It could also be extended to land-locked countries.

In this case, Table 22 indicates that LDCs could receive 1.0% of the funds collected (USD 225 mln.) and SIDS 2.6% (USD 585 mln.). This is less than the first order economic impact on these countries, so a scaling factor could be contemplated.

Table 22 Value of imports as share of the global total, 2004-2008 average

Country group	Share of global imports
Annex I countries	66.9%
Non-Annex I countries	33.1%
G77	22.2%
Least Developed Countries	0.8%
Small Islands and Developing States	2.5%

Source: WTO.

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[17] Innovative Financing and International Maritime Emission Reduction Scheme. Proposal by Nigeria and Liberia | Draft COP 15 decision | 04 Nov 2009.

a Compensation based on need for climate finance – in this case, countries would get compensation in proportion to their need for climate finance, perhaps based on their nationally appropriate mitigation actions (NAMA) and National adaptation programmes of action (NAPAs) or other types of adaptation plans. The purpose of this compensation would not be to reduce distortionary taxes directly, but rather to prevent the need for a rise in taxes by providing non-tax income that can be spent on adaptation and mitigation. This option would not be a direct compensation for increased costs and some countries may receive more and others less than the additional costs they incur. In practice, it could be implemented if it could build on existing procedures for drafting and approving of plans and programmes.

In summary, directly compensating countries for their higher import prices would be administratively very complex. A compensation based on the quantity of imports would create net beneficiaries and net contributors, but it would probably be feasible from an administrative point of view. Compensation based on climate financing needs would also create net beneficiaries and net contributors, but it would be more in line with the general objective of the METS.

7.2.3 Exempt routes

The impact on developing countries could be reduced by exempting certain routes from the scope of the scheme. For example, voyages to and from SIDS or LDCs may be exempted.

How would this work? Ships would need to monitor their fuel use on voyages to and from ports in selected countries. When submitting their monitoring report, ship owners could deduct emissions on these voyages from their total emissions in the reporting period. This would mean that they would not have to surrender allowances for voyages to and from ports in these countries. Hence, provided that these routes are sufficiently competitive, the costs on these routes would not increase.

Note that the costs of imports to these countries may still increase when their imports are transhipped in a country that is not exempt. For example, if a container is shipped from A to C with a transhipment in B, and C is exempt but A and B are not, the voyage from A to B would face the cost increase, but the voyage from B to C wouldn’t. As a result, the costs of transporting the container from A to C would still increase, but not to the same extent as when C would not be exempted.

In some cases, route-based exemptions could lead to avoidance of the scheme by adding additional port calls to countries which are exempted. This can probably be made unprofitable for most bulk shipments by defining a route as starting in the port of laden and ending in the port of unloading. However, such a definition would make little sense in break bulk cargo. Hence, avoidance would be possible in this segment. The extent to which avoidance will occur depends on the availability of port capacity along major trading routes. It is not likely that ships will make large detours just to avoid the METS unless the price of allowances becomes very high. Avoidance could be especially severe if countries with major ports were exempted from the emissions trading scheme. Several SIDS have important ports.

Avoidance of the scheme would lead to less emissions under the cap, hence less reduction of emissions. Thus, it would reduce the environmental effectiveness of the scheme.

Ignoring avoidance, if emissions on routes to SIDS and LDCs would be exempted from the scheme, this would reduce the amount of emissions under the scheme by maximally 12% (see Table 6).[18] The auctioning revenues would be reduced by the same amount.

In summary, it would be possible to exempt certain routes from the scheme, but for ships sailing on these routes, the administrative burden would increase as they would have to monitor emissions on the exempted routes. In addition, such an exemption would reduce the environmental effectiveness of the scheme. The effectiveness would be seriously undermined if avoidance would become large, e.g. if routes to and from major ports would be exempted.

7.2.4 Exempt ships

An exemption of ships could take several forms, including:

- An exemption of certain ship types.
- An exemption of ships below a certain size.
- An exemption of ships emitting less than a certain amount.
- An exemption of specific ships.

The first, an exemption of certain ship types such as ferries or general cargo ships, would only reduce undesired impacts on developing countries if these countries are predominantly served by ships of certain types. This does not seem likely, as developing countries differ widely in the commodities they import.

For countries that depend on passenger ships for their connections to other countries, an exemption of passenger ships would reduce the impact.

The exemption of ships below a certain size would reduce undesired impacts if developing countries were predominantly served by ships below a certain size. There is anecdotal evidence that this is the case for some of the smallest and most remote economies (CE, 2008). However, many of the least developed countries have ports where large ships regularly call and the same is true for SIDS. Hence, it would not be feasible to mitigate the impacts on these country groups by exempting ships below a certain threshold.

Figure 6 shows that smaller ships tend to be engaged in coastal shipping. Hence, the exemption of ships below, say, 500 Gt would reduce the impact on regions with a large share of coastal shipping, i.e. Europe and the Caribbean. A threshold of 5,000 Gt would do little for most developing countries, but would significantly reduce the impact on Europe. As most European countries have developed economies, such a threshold would do little to reduce the impact on developing countries.

The emissions of ships are a function of their engine power, the number of days in operation and operational parameters such as speed. Engine power is correlated with ship size, and larger ships tend to spend more days in operation than smaller ships (Buhaug et al., 2009). Hence, exempting ships emitting less than a certain threshold would have a similar effect as exempting ships below a certain size. We argued above that the latter would not reduce the impacts on developing countries. Nevertheless, an exemption of ships that emit less than a certain amount of greenhouse gases could be a way to reduce the administrative burden of the scheme.

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[18] In reality the emissions would be reduced by less than 12% as there is an overlap between LDCs and SIDS.

Some of the smallest and most remote economies are served by one or two ships that provide liner services between these economies and larger countries near by. This is the case, for example, for many Pacific islands states (CE, 2008). It would be feasible to exempt these ships from the scheme as long as they would engage solely in providing liner services between these islands and other countries.

In conclusion, the exclusion of ships based on type, size or amount of emissions would not reduce undesired effects, except for an exemption of passenger ships. In some cases, the exclusion of specific ships would reduce impacts on some of the smaller and more remote economies. However, it would not reduce all undesired impacts.

7.2.5 Exempt cargo types

The impact on food security and health could be reduced by exempting emissions associated with the transport of food and health items. This would require that emissions of ships carrying several cargoes would be allocated to each cargo type, and ship owners would not be required to surrender allowances for emissions associated with food and health items. Such a procedure would be administratively complex for the ship owner and for the regulator.

7.3 Conclusion

There are several ways to mitigate undesired impacts on developing countries. The most promising seems to be compensation using the revenues from the auction. After compensation, there would still be sufficient funds to finance other causes. Compensation can take many forms. The most direct compensation would require ship operators to monitor and report emissions per voyage, and this could be administratively complex. Indirect forms of compensation would overcompensate some, while leaving others undercompensated. Still, they would be easier to implement from an administrative point of view.

In addition, it would be feasible to exempt ships that sail exclusively to and from certain isolated regions.

Other options seem to have important drawbacks. Excluding routes could lead to avoidance of the scheme which would reduce its environmental effectiveness. Excluding certain cargoes would be administratively very complex as ship owners would have to allocate emissions to different cargoes.

8 Conclusions

This report presents a Maritime Emissions Trading Scheme that has the following design features:

- It covers CO_2 emissions of all ships above a certain size threshold. A global scheme would be more environmentally effective since it would cover all shipping emissions. Moreover, it would not suffer from avoidance and avoid thus distortion in competition.
- The METS would be an open system and allow responsible entities to surrender allowances or credits from other emissions trading schemes or from the wider carbon market as long as they are of sufficient quality. By opening the METS to allow the use of allowances from other sectors, the price volatility would be significantly reduced as more sectors with different business cycles would be included. Insofar as other sectors have lower marginal abatement costs, the average allowance price would decrease. The volume of allowances and the number of potential participants would also be much larger in an open system, which should be beneficial for market transparency and liquidity.
- The responsible entity would either be the ship owner or there would be an obligation on each ship to carry documents that demonstrate compliance with the system. The owner has directly or indirectly (through contracts with operators, crew, et cetera) control over the emissions of a ship. The owner is clearly identifiable and linked to the ship. In either case, the accounting entity would be the ship. This means that the owner is responsible for surrendering sufficient allowances for each of his ships. This also ensures that the ship can be held liable if it is not compliant.
- Monitoring, reporting and verification is essential for the effectiveness of the METS. Given the diversity in equipment on board ships, we propose to have each ship owner file a monitoring and verification plan for each ship to the competent authority before the start of the scheme. This plan should outline in detail the method by which it will monitor fuel use and which data will be used to verify the emissions. The competent authority will need to approve of the plan before a ship is allowed to enter the scheme.
- There are several ways to initially allocate the allowances. While auctioning is clearly economically the most efficient way to allocate allowances, introducing full auctioning at once may give a shock to the sector that it may not be able to absorb. By combining auctioning with free allocation for a limited time period, a balance can be struck between economic efficiency, administrative burden and impact on the sector.

Impacts on the shipping sector

Three types of actors are directly affected by the increase in maritime costs. These are the ship owner (in cases also the operator and the manager), the shipper (in cases also the charterer) and the consumer. All will be affected by the increase in transport costs. Other groups of actors may be impacted indirectly. States will have to monitor compliance, both in their capacity of Flag State and Port State, ship crew will have to monitor emissions, classification societies may act as verifiers.

The METS affects the cost structure of maritime transport. A new item is added to the voyage costs, viz. the costs of allowances. The size of the impact depends on the vessel type and size, the fuel price and the allowance price. We demonstrate that for 2007 cost figures and an allowance price of

USD 15-30, the costs increase for six different ship types ranges from 4 to 16% of the total costs. The share of costs is proportional with the price of the allowances, so higher allowance prices increase the share in total costs. Conversely, when fuel prices are higher, the cost increase resulting from the METS is relatively lower.

The responsible entity need not coincide with the actor bearing the costs of compliance. Who this actor is, depends on the market circumstances, which in a cyclical industry are very important. We argue that when demand for maritime transport is higher than supply, prices are not cost-related but are set by marginal demand. This means that the introduction of additional costs will not affect the price. In this case, the costs are borne entirely by the ship owner or disponent owner and will reduce his profit margins. On the other hand, when demand is lower than supply, prices are set by marginal costs and costs are passed on to the shipper and ultimately to the consumer. Hence, in this situation the consumer will bear the costs.

As transport costs are a minor share of the prices of imported products, the impact on import prices is smaller than the impact on transport prices. We demonstrate that including maritime transport in an METS will have a small impact on import prices, ranging from less than 1% for petroleum products and manufactured goods to a few percent for agricultural products and raw materials.

It is likely that the shipping sector responds to the costs increases by increasing the efficiency of the fleet by technical and operational means. There appears to be a considerable potential to do so. This will reduce the actual cost increase.

Impacts on regions and country groups

The economic impacts of a maritime ETS vary between regions and country groups. They also depend on the price of allowances. In a first order approach intended to estimate the maximum economic impact, all but three geographical regions were estimated to experience impacts below 0.05-0.1% of GDP at an allowance price of USD 15-30 per tonne of CO_2. No region had an impact higher than 0.17-0.35% of GDP. The three regions that are worse affected, are the Middle Eastern Gulf region, Africa and South East Asia.

In the same approach, the impacts on groups of countries relevant to the climate debate were estimated to be around or below 0.08–0.15% of GDP for all groups with the exception of the SIDS, where the impact has been estimated at 0.45-0.89% of GDP.

In practice, the impact is likely to be lower overall as ship owners and operators improve the efficiency of maritime transport.

Moreover, the impact on developing countries is likely to be smaller for two reasons. First of all, ship movements to developing countries are often in ballast. The most obvious example is crude tankers. The transport of crude is typically from developing countries to developed countries. The freight rates are set so that developed countries pay for both the transport and the return voyage. Hence, developed countries will also pay for the cost increase on both legs of the voyage. Second, when there is trade in two directions, trade is often unbalanced. Freight rates in the direction where demand is highest is typically higher than freight rates in the other direction. This can be explained by Ramsey pricing. It is likely that because of Ramsey pricing, developed countries will pay a larger share of the cost increases.

Whether the economic impact will increase or decrease depends primarily on the development of allowance prices. If they grow faster than about 0.9% per annum in real terms on average, the impact will increase. Otherwise the impact is likely to decrease.

Impacts on competitive markets

The METS will not distort competitive markets. The only possible path leading to distortions is that METS might put the owners of smaller and older ships in disadvantageous position and at more risk of going out of business. However, even if such a phenomena is likely to happen, this does not mean that the maritime shipping market would stop being competitive. On the contrary, this would only prove that the market works very well, by promoting more competitive and economically efficient market players. Thus we can conclude that while there may be a need to protect ship owners of particular types of ships (e.g. small ships) against this mechanism, the motives for such protection would be different than market distortion.

It is also worth to note that the climate policy instrument is in its essence aimed at eliminating (or at least alleviating) a market failure – that is, a failure to reflect social costs related to pollution in market prices. Thus, instead of creating distortions, successful introduction of METS would rather help to deal with an unwanted external effect at the maritime shipping market related to global warming.

Mitigating undesired impacts

There are several ways to mitigate undesired impacts on developing countries. The most promising seems to be compensation using the revenues from the auction. After compensation, there would still be sufficient funds to finance other causes. Compensation can take many forms. The most direct compensation would require ship operators to monitor and report emissions per voyage, and this could be administratively complex. Indirect forms of compensation would overcompensate some, while leaving others undercompensated. Still, they would be easier to implement from an administrative point of view.

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Annex A Country groups and regions

A.1 Regions

Note that some countries may appear in more than one region if they have ports in different sea areas.

North America	
Bermuda	St. Pierre & Miquelon
Canada	USA

Central America and Caribbean		
American Virgin Islands	El Salvador	Puerto Rico
Anguilla	Grenada	St. Kitts-Nevis
Antigua & Barbuda	Guadeloupe	St. Lucia
Bahamas	Guatemala	St. Vincent & Grenadines
Barbados	Haiti	Trinidad & Tobago
Belize	Honduras	Turks & Caicos Islands
British Virgin Islands	Jamaica	
Cayman Islands	Martinique	
Colombia	Mexico	
Costa Rica	Montserrat	
Cuba	Netherlands Antilles	
Dominica	Nicaragua	
Dominican Republic	Panama	

South America	
Argentina	French Guiana
Aruba	Guyana
Bolivia	Netherlands Antilles
Brazil	Paraguay
Chile	Peru
Colombia	Suriname
Ecuador	Uruguay
Falkland Islands	Venezuela

Europe		
Aland Islands	Isle of Man	Republic of Latvia
Albania	Israel	Republic of Lithuania
Austria	Italy	Republic of Moldova
Azores	Lebanon	Republic of Slovenia
Belgium	Luxembourg	Republic of Turkmenistan
Bulgaria	Madeira	Romania
Canary Islands	Malta	Russian Federation
Cyprus	Monaco	Serbia
Czech Republic	Montenegro	Slovakia
Denmark	Netherlands	Spain
Faroe Islands	Norway	Svalbard & Jan Mayen Islands
Finland	Poland	Sweden
France	Portugal	Switzerland
Germany	Republic of Azerbaijan	Syria

Europe		
Gibraltar	Republic of Croatia	Turkey
Greece	Republic of Estonia	Ukraine
Greenland	Republic of Georgia	United Kingdom
Hungary	Republic of Ireland	
Iceland	Republic of Kazakhstan	

Africa		
Algeria	Kenya	Sao Tome & Principe
Angola	Liberia	Senegal
Arab Republic of Egypt	Madagascar	Seychelles
British Indian Ocean Territory	Malawi	Sierra Leone
Cameroon	Mauritania	Socialist People's Libyan Arab Jamahiriya
Comoros	Mauritius	Somali Democratic Republic
Democratic Republic of Congo	Mayotte	South Africa
Equatorial Guinea	Morocco	St. Helena
French Southern Territories	Mozambique	Tanzania
Gabon	Nigeria	The Congo
Ghana	Republic of Benin	The Gambia
Guinea	Republic of Cape Verde	Togo
Guinea-Bissau	Republic of Djibouti	Tunisia
Heard & McDonald Islands	Republic of Namibia	Uganda
Ivory Coast	Reunion	Western Sahara

Middle Eastern Gulf, Red Sea	
Arab Republic of Egypt	Saudi Arabia
Eritrea	Saudi Arabia
Ethiopia	State of Bahrain
Iran	State of Qatar
Iraq	Sultanate of Oman
Jordan	United Arab Emirates
Kuwait	Yemeni Republic

Indian Subcontinent	
Bangladesh	Republic of Maldives
British Indian Ocean Territory	Sri Lanka
India	Union of Myanmar
Pakistan	

North East Asia	
Cambodia	People’s Republic of China
Democratic People's Republic of Korea	Republic of Korea
Japan	Russian Federation
Laos	Taiwan
Mongolia	Vietnam

South East Asia	
Christmas Island	Philippines
Cocos (Keeling) Islands	Republic of Singapore
East Timor	Sultanate of Brunei
Indonesia	Thailand
Malaysia	

Australasia		
American Pacific Territories	Guam	Papua New Guinea
American Samoa	Independent State of Samoa	Pitcairn Islands
Antarctica	Kiribati	Republic of Palau
Australia	Marshall Islands	Solomon Islands
Bouvet Island	Nauru	Tahiti
Chile	New Caledonia	Tokelau Islands
Cook Islands	New Zealand	Tonga
Federated States of Micronesia	Niue Island	Tuvalu
Fiji	Norfolk Island	Vanuatu
French Polynesia	Northern Marianas	Wallis & Futuna

A.2 Country groups

Annex I countries		
Australia	Hungary	Romania
Austria	Iceland	Russian Federation
Belarus	Ireland	Slovakia
Belgium	Italy	Slovenia
Bulgaria	Japan	Spain
Canada	Latvia	Sweden
Croatia	Liechtenstein	Switzerland
Czech Republic	Lithuania	Turkey
Denmark	Luxembourg	Ukraine
European Economic Community	Monaco	United Kingdom of Great Britain and Northern Ireland
Estonia	Netherlands	United States of America
Finland	New Zealand	
France	Norway	
Germany	Poland	
Greece	Portugal	

Non-Annex I countries
All other countries that are not listed under Annex I.

G77		
Afghanistan	Gabon	Panama
Algeria	Gambia	Papua New Guinea
Angola	Ghana	Paraguay
Antigua and Barbuda	Grenada	Peru
Argentina	Guatemala	Philippines
Bahamas	Guinea	Qatar
Bahrain	Guinea-Bissau	Rwanda
Bangladesh	Guyana	Saint Kitts and Nevis
Barbados	Haiti	Saint Lucia
Belize	Honduras	Saint Vincent and the Grenadines
Benin	India	Samoa
Bhutan	Indonesia	Sao Tome and Principe
Bolivia	Iran (Islamic Republic of)	Saudi Arabia
Bosnia and Herzegovina	Iraq	Senegal
Botswana	Jamaica	Seychelles
Brazil	Jordan	Sierra Leone

G77		
Brunei Darussalam	Kenya	Singapore
Burkina Faso	Kuwait	Solomon Islands
Burundi	Lao People's Democratic Republic	Somalia
Cambodia	Lebanon	South Africa
Cameroon	Lesotho	Sri Lanka
Cape Verde	Liberia	Sudan
Central African Republic	Libyan Arab Jamahiriya	Suriname
Chad	Madagascar	Swaziland
Chile	Malawi	Syrian Arab Republic
China	Malaysia	Thailand
Colombia	Maldives	Timor-Leste
Comoros	Mali	Togo
Congo	Marshall Islands	Tonga
Costa Rica	Mauritania	Trinidad and Tobago
Côte d'Ivoire	Mauritius	Tunisia
Cuba	Micronesia (Federated States of)	Turkmenistan
Democratic People's Republic of Korea	Mongolia	Uganda
Democratic Republic of the Congo	Morocco	United Arab Emirates
Djibouti	Mozambique	United Republic of Tanzania
Dominica	Myanmar	Uruguay
Dominican Republic	Namibia	Vanuatu
Ecuador	Nepal	Venezuela (Bolivarian Republic of)
Egypt	Nicaragua	Viet Nam
El Salvador	Niger	Yemen
Equatorial Guinea	Nigeria	Zambia
Eritrea	Oman	Zimbabwe
Ethiopia	Pakistan	
Fiji	Palestine	

Least Developed Countries		
Afghanistan	Gambia	Rwanda
Angola	Guinea	Samoa
Bangladesh	Guinea-Bissau	São Tomé and Principe
Benin	Haiti	Senegal
Bhutan	Kiribati	Sierra Leone
Burkina Faso	Lao People’s Democratic Republic	Solomon Islands
Burundi	Lesotho	Somalia
Cambodia	Liberia	Sudan
Cape Verde	Madagascar	Tanzania
Central African Republic	Malawi	Timor-Leste
Chad	Maldives	Togo
Comoros	Mali	Tuvalu
Congo, Democratic Republic	Mauritania	Uganda
Djibouti	Mozambique	Vanuatu
Equatorial Guinea	Myanmar	Yemen
Eritrea	Nepal	Zambia
Ethiopia	Niger	

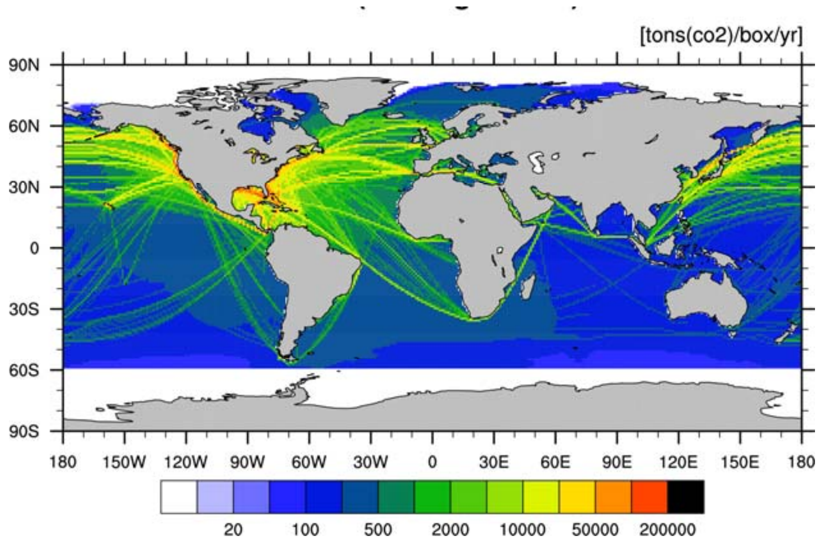
Small Islands and Developing States		
Antigua and Barbuda	Marshall Islands	Tuvalu
Bahamas	Federated States of Micronesia	Vanuatu
Bahrain	Mauritius	American Samoa
Barbados	Nauru	Anguilla
Belize	Palau	Aruba
Cape Verde	Papua New Guinea	British Virgin Islands
Comoros	Samoa	Commonwealth of Northern Marianas
Cuba	São Tomé and Príncipe	Cook Islands
Dominica	Singapore	French Polynesia
Dominican Republic	St. Kitts and Nevis	Guam
Fiji	St. Lucia	Montserrat
Grenada	St. Vincent and the Grenadines	Netherlands Antilles
Guinea-Bissau	Seychelles	New Caledonia
Guyana	Solomon Islands	Niue
Haiti	Suriname	Puerto Rico
Jamaica	Timor-Leste	U.S. Virgin Islands
Kiribati	Tonga	
Maldives	Trinidad and Tobago	

European Union	
Austria	Latvia
Belgium	Lithuania
Bulgaria	Luxembourg
Cyprus	Malta
Czech Republic	Netherlands
Denmark	Poland
Estonia	Portugal
Finland	Romania
France	Slovakia
Germany	Slovenia
Greece	Spain
Hungary	Sweden
Ireland	United Kingdom of Great Britain and Northern Ireland
Italy	

Annex B Emission plots

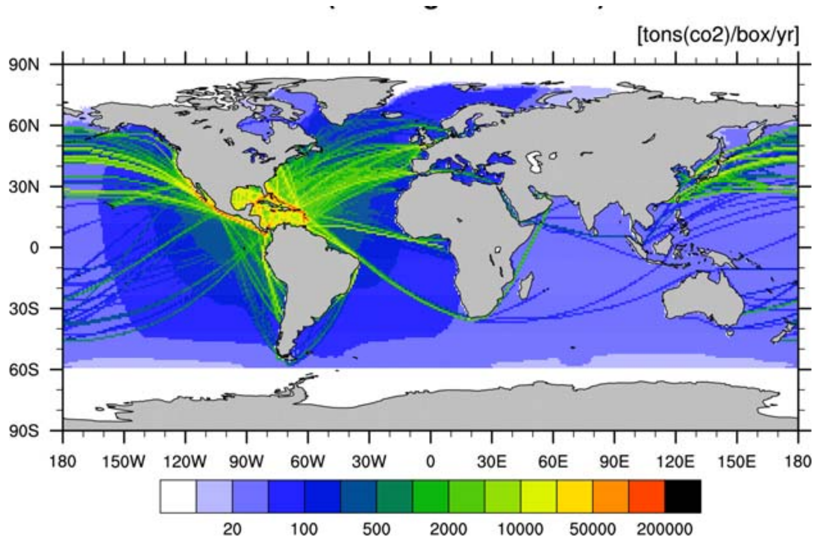
The SeaKLIM algorithm was run to calculate the emission totals for geographical regions. These calculations are done (a) for all ships leaving a certain region and (b) for all ships arriving in a certain region. Overall, the fuel consumption and CO_2 emissions for ships arriving and leaving a certain region are very similar. This annex shows the CO_2 emission densities of maritime transport as calculated by the SeaKLIM model. The main sea routes are clearly visible.

Figure 13 Emission densities of ships arriving in North America



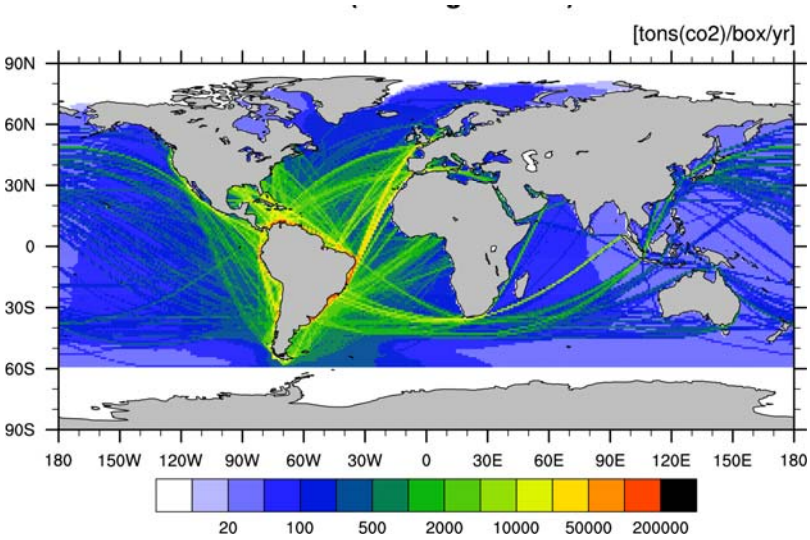
Source: This report.

Figure 14 Emission densities of ships arriving in Central America and the Caribbean



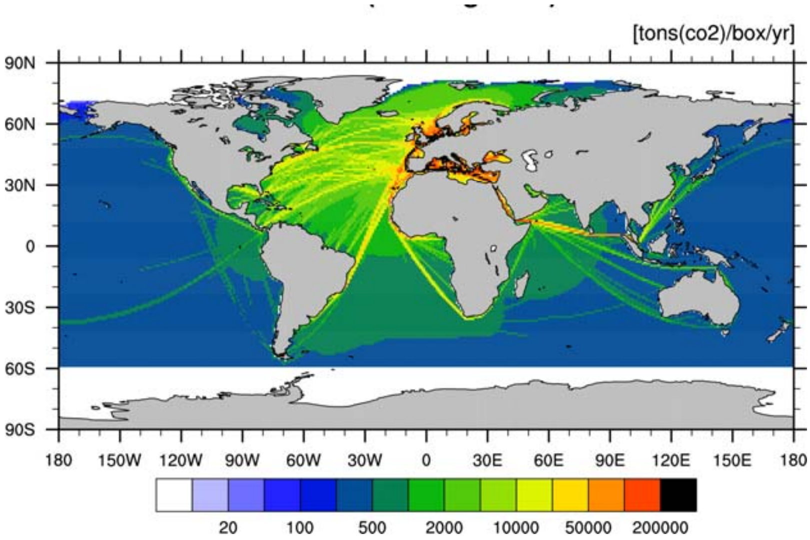
Source: This report.

Figure 15 Emission densities of ships arriving in South America



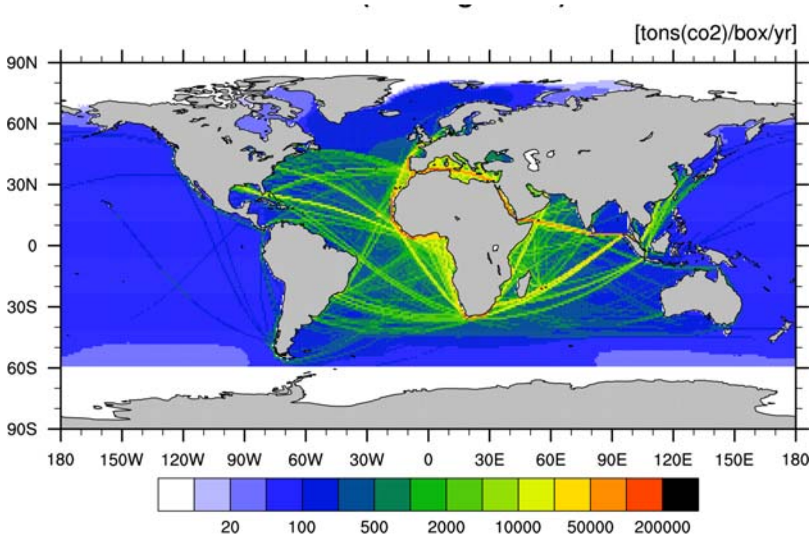
Source: This report.

Figure 16 Emission densities of ships arriving in Europe



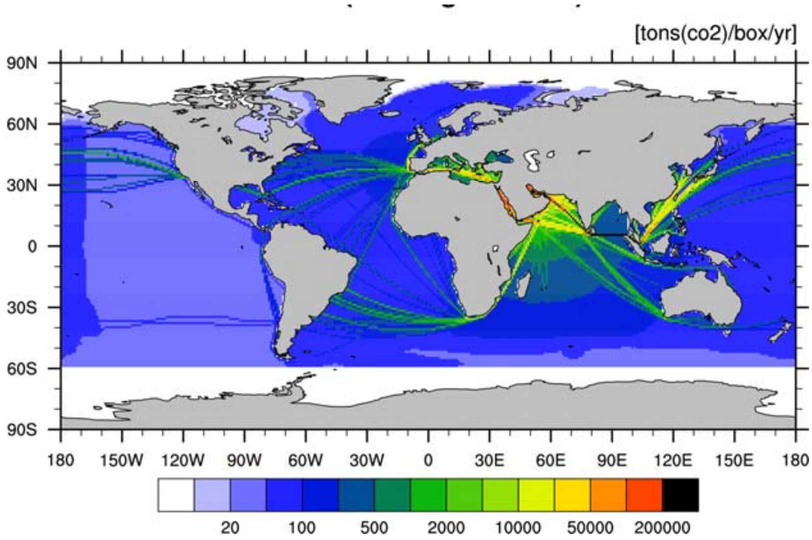
Source: This report.

Figure 17 Emission densities of ships arriving in Africa



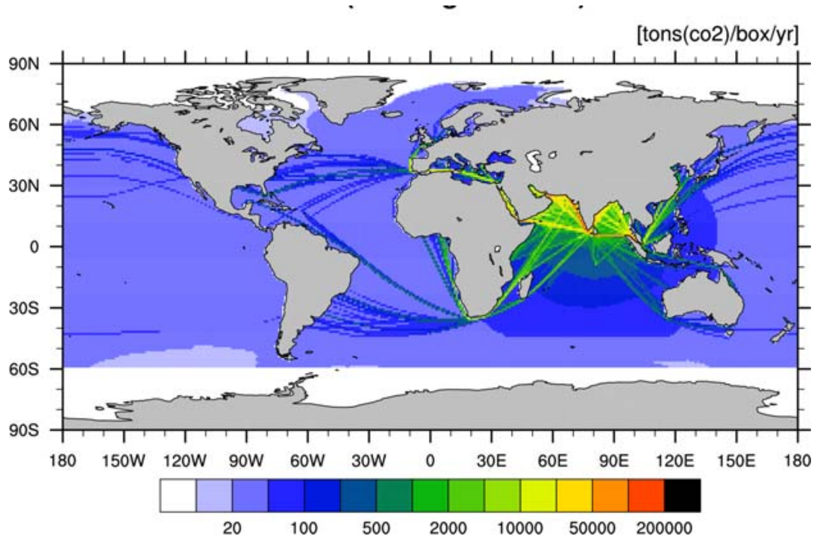
Source: This report.

Figure 18 Emission densities of ships arriving in the Red Sea and the Middle Eastern Gulf



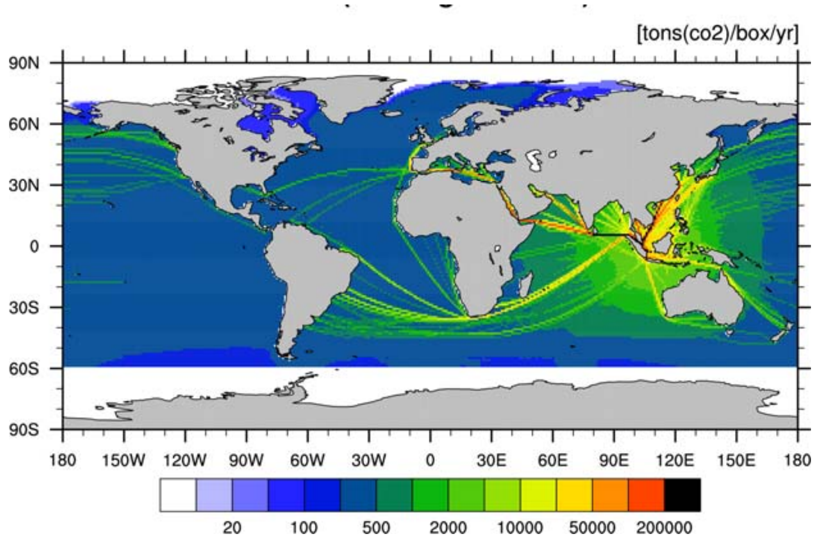
Source: This report.

Figure 19 Emission densities of ships arriving in the Indian Subcontinent



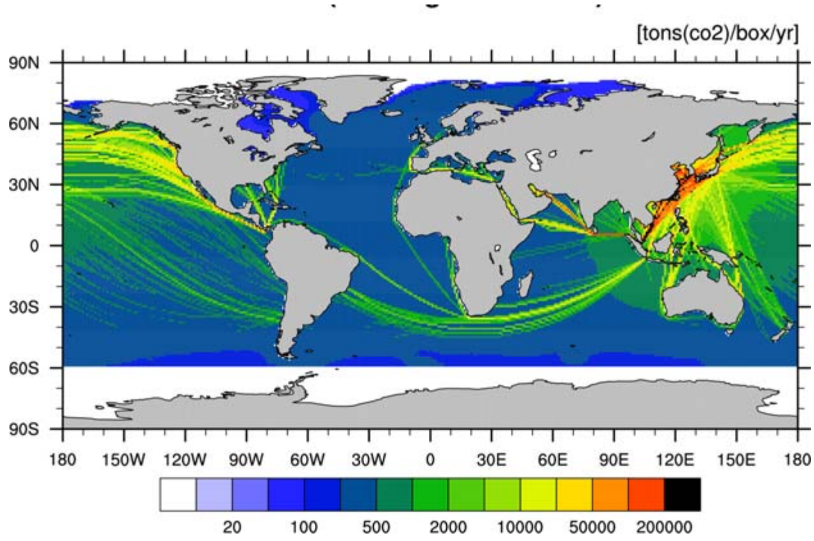
Source: This report.

Figure 20 Emission densities of ships arriving in South East Asia



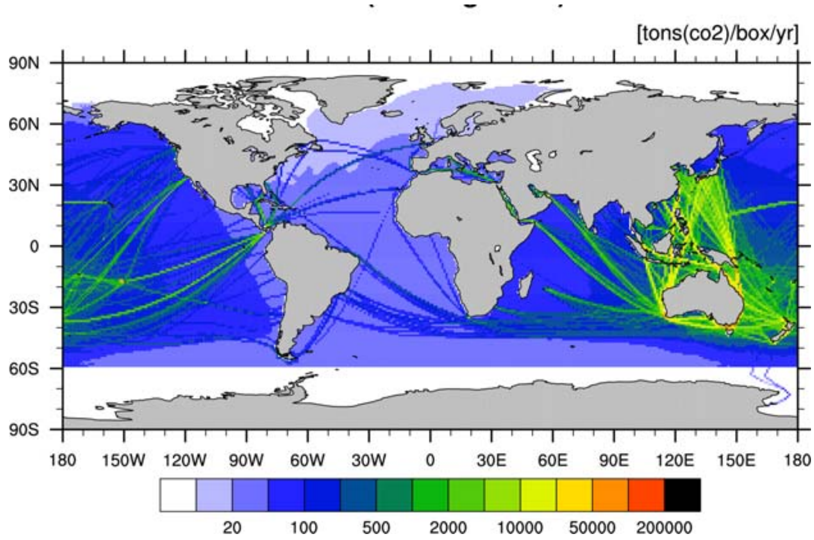
Source: This report.

Figure 21 Emission densities of ships arriving in North East Asia



Source: This report.

Figure 22 Emission densities of ships arriving in Oceania



Source: This report.

Annex C Cost structure

C.1 Capesize bulker

Table 23 **Operating costs of a capesize bulker, 2007**

Capesize Bulker		
	DWT:	**80,000+**
	Word Fleet:	**998 (151,690,215 dwt)**
	Average Size:	**151,994 dwt**
	Sample size:	**56**
	Sample average size:	**157,478 dwt**
	Sample average age:	**Jul-1993**
OpCost Report		
All figures are for the year *31 December 2007*		
Item	**USD (per year)**	**USD (per day)**
Crew Wages	814,850	2,232
Provisions	62,014	170
Crew Other	97,336	267
Crew Costs Total	974,200	2,669
Lubricants	248,734	681
Stores Other	164,693	451
Stores Total	413,427	1,132
Spares	186,710	512
Repairs & Maintenance	171,247	469
Dry docking[19]	323,316	886
Repairs & Maintenance Total	681,273	1,867
P&I Insurance	122,929	337
Insurance	159,603	437
Insurance Total	282,532	774
Registration Costs	23,146	63
Management Fees	240,785	660
Sundries	65,533	180
Administration Total	329,464	903
Total Operating Costs 2007	**2,680,896**	**7,345**

Source: Moore Stephens LPP, 2008.

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[19] Dry docking costs are based on Moore Stephens' Average dry dock costs for year ended 31 December 2007 and divided by 5.

Average bunker price was in 2007 USD 360.5 per tonne. A capesize bulk vessel burns about 60 tonnes of bunkers per day of normal operation. From the 'Second IMO GHG study 2009' a bulk vessel between 100,000-199,999 DWT operates on average 279 days at sea per year. This gives us the following bunker cost of USD 6,034,770 per year or USD 16,534 per day.

Emission-wise the CO_2 coefficient is 3.09 tonnes of CO_2 per tonne of bunkers, which gives us that a capesize will estimate emit approximately 185 tonne CO_2 per day or approximately 51,727 tonne CO_2 per year in operation.

If we assume a USD 30 per tonne price for the CO_2, this would mean a yearly cost of USD 1,551,810 or USD 42,608 per day.

The average capesize new built price from 1992 through 2007 was 50 million USD (Fearnley Consultants), hence our estimate of the annual capital costs were 5.06 million USD. Note that actual capital costs may be higher or lower, depending on factors described above.

C.2 Cost structure of a handysize product tanker

Table 24 Operational costs of a handysize product tanker

Handysize Product Tanker		
	DWT:	**30,000-50,000**
	World Fleet:	**1,620 (69,217,941 dwt)**
	Average Size:	**42,727 dwt**
	Average Age:	**August 1998**
	Sample size:	**193**
	Sample average size:	**42,713 dwt**
	Sample average age:	**April 1997**
OpCost Report		
All figures are for the year 31 December 2007		
Item	**USD (per year)**	**USD (per day)**
Crew Wages	924,043	2,531
Provisions	74,842	205
Crew Other	185,333	508
Crew Costs Total	1,184,218	3,244
Lubricants	141,422	388
Stores Other	173,028	474
Stores Total	314,450	862
Spares	204,926	561
Repairs & Maintenance	230,929	633
Dry docking[20]	263,862	723
Repairs & Maintenance Total	699,717	1,917
P&I Insurance	90,857	249
Insurance	103,556	284
Insurance Total	194,413	533
Registration Costs	12,432	34
Management Fees	276,563	758
Sundries	80,323	220
Administration Total	369,318	1,012
Total Operating Costs 2007	**2,762,116**	**7,567**

Source: Moore Stephens LPP, 2008.

Average bunker price was in 2007 USD 360.5 per tonne. A handysize product tanker vessel burns about 32 tonnes of bunkers per day of normal operation. From the ‘Second IMO GHG study 2009’ a tanker vessels between 20,000-59,999 DWT operates on average 171 days at sea per year, however we believe this is a wrong number and estimates the days at sea is 275 days. This gives us the following bunker cost of USD 3,172,400 per year or USD 8,692 per day.

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[20] Dry docking costs are based on Moore Stephens’ Average dry dock costs for year ended 31 December 2007 and divided by 5.

Emission-wise the CO_2 coefficient is 3.09 tonnes of CO_2 per tonne of bunkers, which gives us that a handysize product tanker will estimate emit approximately 99 tonne CO_2 per day or approximately 27,192 tonne CO_2 per year in operation.

If we assume a USD 30 per tonne price for the CO_2, this would mean a yearly cost of USD 815,760 or USD 2,235 per day.
The average handysize new built price from 1992 through 2007 was 34 million USD (Fearnley Consultants), hence our estimate of the annual capital costs were 3.47 million USD. Note that actual capital costs may be higher or lower, depending on factors described above.

C.3 Cost structure of a VLCC

Table 25 Operational costs of a VLCC tanker

VLCC		
	DWT:	**250,000-320,000**
	World Fleet:	**491 (145,146,042 dwt)**
	Average Size:	**295,613 dwt**
	Average Age:	**April 1999**
	Sample size:	**73**
	Sample average size:	**300,440 dwt**
	Sample average age:	**June 1999**
OpCost Report		
All figures are for the year *31 December 2007*		
Item	**USD (per year)**	**USD (per day)**
Crew Wages	1,158,697	3,175
Provisions	76,213	209
Crew Other	197,228	540
Crew Costs Total	1,432,138	3,924
Lubricants	318,638	873
Stores Other	184,339	505
Stores Total	502,977	1,378
Spares	339,586	930
Repairs & Maintenance	299,098	820
Dry docking[21]	320,298	878
Repairs & Maintenance Total	958,982	2,627
P&I Insurance	231,556	634
Insurance	244,862	671
Insurance Total	476,418	1,305
Registration Costs	27,885	76
Management Fees	239,905	657
Sundries	174,749	479
Administration Total	442,539	1,212
Total Operating Costs 2007	**3,813,054**	**10,447**

Source: Moore Stephens LPP, 2008.

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[21] Dry docking costs are based on Moore Stephens' Average dry dock costs for year ended 31 December 2007 and divided by 5.

Average bunker price was in 2007 USD 360.5 per tonne. A VLCC tanker burns about 90 tonnes of bunkers per day of normal operation. From the 'Second IMO GHG study 2009' a tanker vessel on 200,000+ DWT operates on average 274 days at sea per year. This gives us the following bunker cost of USD 8,889,930 per year or USD 24,356 per day.
Emission-wise the CO_2 coefficient is 3.09 tonnes of CO_2 per tonne of bunkers, which gives us that a VLCC will estimate emit approximately 278 tonne CO_2 per day or approximately 76,199 tonne CO_2 per year in operation.

If we assume a USD 30 per tonne price for the CO_2, this would mean a yearly cost of USD 2,285,970 or USD 6,263 per day.

The average VLCC tanker new built price from 1992 through 2007 was 92 million USD (Fearnley Consultants), hence assuming a 25 year economic life and a private interest rate of 9%, the annual capital costs were 9.37 million USD. Note that actual capital costs may be higher or lower, depending on factors described above.

C.4 Cost structure of a container main liner

Table 26 Operational costs of a container main liner

Container Main Liner		
	TEU:	**2,000-6,000**
	World Fleet:	**1,773 (6,405,918 TEU)**
	Average Size:	**3,613 TEU**
	Average Age:	**March 1999**
	Sample size:	**97**
	Sample average size:	**3,923 TEU**
	Sample average age:	**July 1999**
OpCost Report		
All figures are for the year 31 December 2007		
Item	**USD (per year)**	**USD (per day)**
Crew Wages	940,038	2,575
Provisions	71,186	195
Crew Other	131,658	361
Crew Costs Total	1,142,882	3,131
Lubricants	346,537	949
Stores Other	135,338	371
Stores Total	481,875	1,320
Spares	248,872	682
Repairs & Maintenance	229,786	630
Dry docking[22]	196,497	538
Repairs & Maintenance Total	675,155	1,850
P&I Insurance	91,867	252
Insurance	192,862	528
Insurance Total	284,729	780
Registration Costs	19,811	54
Management Fees	236,193	647
Sundries	86,893	238
Administration Total	342,897	939
Total Operating Costs 2007	**2,129,237**	**5,834**

Source: Moore Stephens LPP, 2008.

Average bunker price was in 2007 USD 360.5 per tonne. A Container Main Liner vessel burns about 135 tonnes of bunkers per day of normal operation. From the 'Second IMO GHG study 2009' a container vessel between 3,000-4,999 TEU operates on average 250 days at sea per year. This gives us the following bunker cost of USD 12,166,875 per year or USD 33,334 per day. Emission-wise the CO_2 coefficient is 3.09 tonnes of CO_2 per tonne of bunkers, which gives us that a container main liner will estimate emit approximately 417 tonne CO_2 per day or approximately 104,288 tonne CO_2 per year in operation.

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[22] Dry docking costs are based on Moore Stephens' Average dry dock costs for year ended 31 December 2007 and divided by 5.

If we assume a USD 30 per tonne price for the CO_2, this would mean a yearly cost of USD 3,128,640 or USD 8,572 per day.

The average container main liner new built price from 1992 through 2007 was 47.2 million USD (Fearnley Consultants). Assuming a 25 year economic life and a private interest rate of 9%, we estimate the annual capital costs at 4.81 million USD.

C.5 Cost structure of a RoRo vessel

Table 27 Operating costs of a RoRo vessel

RoRo		
	DWT:	**5,000-30,000**
	World Fleet:	**1,232 (16,852,348 dwt)**
	Average Size:	**13,679 dwt**
	Average Age:	**May 1992**
	Sample size:	**34**
	Sample average size:	**14,491 dwt**
	Sample average age:	**April 1991**
OpCost Report		
All figures are for the year *31 December 2007*		
Item	**USD (per year)**	**USD (per day)**
Crew Wages	766,464	2,100
Provisions	68,142	187
Crew Other	89,406	245
Crew Costs Total	924,012	2,532
Lubricants	143,424	393
Stores Other	113,578	311
Stores Total	257,002	704
Spares	188,463	516
Repairs & Maintenance	157,410	431
Dry docking[23]	199,747	547
Repairs & Maintenance Total	545,620	1,495
P&I Insurance	75,577	207
Insurance	106,305	291
Insurance Total	181,882	498
Registration Costs	8,176	23
Management Fees	112,881	309
Sundries	102,914	282
Administration Total	223,971	614
Total Operating Costs 2007	**2,132,487**	**5,842**

Source: Moore Stephens LPP, 2008.

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[23] Dry docking costs are based on Moore Stephens' Average dry dock costs for year ended 31 December 2007 and divided by 5.

Average bunker price was in 2007 USD 360.5 per tonne. A RoRo vessel burns about 39 tonnes of bunkers per day of normal operation. From the ‘Second IMO GHG study 2009’ a RoRo vessel on 2,000+ lane meters operates on average 219 days at sea per year. This gives us the following bunker cost of USD 3,079,031 per year or USD 8,436 per day.
Emission-wise the CO_2 coefficient is 3.09 tonnes of CO_2 per tonne of bunkers, which gives us that a RoRo vessel will estimate emit approximately 121 tonne CO_2 per day or approximately 26,392 tonne CO_2 per year in operation.

If we assume a USD 30 per tonne price for the CO_2, this would mean a yearly cost of USD 791,760 or USD 2,169 per day.

The average RoRo new built price from 1992 through 2007 was 54.5 million USD (Fearnley Consultants). Hence, assuming a 25 year economic life and a private interest rate of 9%, the annual capital costs are 5.55 million USD.