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Climate regulation of ships

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Sammendrag:.
Denne rapporten gjev ein oversikt over fem mogelege reguleringssystem for karbondioksidutslepp frå internasjonal skipsfart. Sterke og svake sider ved desse systema blir samanlikna ut frå ni kriterium. Dei to huvudtypane er standardbasert og marknadsbasert regulering. Standardbaserte reguleringssystem kan vere lettare å få aksept for, men kostnaden er svakare insentiv for å redusere utsleppa enn ved marknadsbaserte reguleringssystem.

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Abstract:
This report gives an overview of five possible regulation schemes for carbon dioxide emissions from international shipping. The strengths and weaknesses of the schemes are compared with regard to nine criteria. The two main categories are standard-based and market-based regulation. Standard-based regulation may have a higher acceptability than market-based regulation, but at a cost of a weaker incentive effect to reduce emissions than in the case of market-based regulation.

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Preface

This report is financed by Norwegian Shipowners' Association (Norges Rederiforbund). The study has been carried out in the period August-December 2007. The objective of the study has been to examine possible regulation systems for CO_2 emissions from international ship traffic, and compare strengths and weaknesses of these. The report will be forwarded to the Norwegian Ministry of Environment, as a background for a possible Norwegian submission to the next meeting of the Marine Environment Protection Committee (MEPC) of the International Maritime Organization (IMO) in March/April 2008 (MEPC 57), where mechanisms for controlling CO_2-emissions from international shipping will be considered. The assessment and development of mechanisms for regulating CO_2 emissions is part of a process which is to be concluded in 2009.

1 Introduction

In this report we explore possible regulation systems for greenhouse gas emissions from international ship traffic, and compare their strengths and weaknesses.

There are two motivations for studying regulation of greenhouse gas emissions from ships in international trade. The first motivation is the stronger pressure felt to regulate emissions from international shipping, given that these emissions presently are not subject to any regulation, that ships are responsible for some 2 - 3% of global CO_2 emissions, and that emissions are expected to increase with increased demand for sea transportation. Emissions from international shipping were exempted from the Climate Convention (UNFCCC) and the Kyoto Protocol. However, article 2.2 of the protocol states that industrialized countries "shall pursue limitation or reduction of emissions of GHGs not controlled by the Montreal Protocol from aviation and marine bunker fuels, working through the ICAO and the IMO, respectively". If the International Maritime Organization (IMO) does not live up to this challenge, greenhouse gas emissions from international shipping might be regulated at regional level, for instance within the EU, where inclusion of marine transport in EU's Emission Trading Scheme (EU ETS) is considered. Unilateral action by EU is possible in legal terms as long as the principle of "right of innocent passage" is not compromised.

The second motivation for ship owners and countries with a sizeable ship sector to engage in climate regulation of ship traffic is the opportunity to influence the design and implementation of a regulation system. This could also contribute to a practical and knowledge-based regulation system.

For the design and implementation of regulation systems we are concerned with three major types of efficiency. The first type is that a regulation system should lead to environmental efficiency; it should contribute to significant reductions of global greenhouse gas emissions. By itself a policy tool or regulation system does not necessarily lead to significant mitigation of emissions; this depends on the strictness of targets and implementation of a regulation system. The second type is cost-effectiveness, which is to mean that the regulation system as far as possible should minimize the cost to society of reaching the environmental target envisaged. The third type is administrative efficiency, which means that implementation and operation of the regulation system should be as little resource-demanding as possible.

Emissions from shipping consist of various gases and particles that have warming or cooling (or both) effects on climate. Carbon dioxide (CO_2), nitrogen oxides (NO_x) and sulfur dioxide (SO_2) are the key compounds emitted. These emissions influence atmospheric concentrations of greenhouse gases and aerosols. The effects occur on different timescales ranging from days to centuries, and the spatial distributions of the climate effects are different, which make evaluation and comparisons complicated. In this report, however, we limit the scope to regulation of CO_2 emissions, and refer those interested in details on emissions and climate effects from shipping to Annex 1 and references therein.

The scope of this report is to select a small number of possible regulation schemes for CO_2 emissions from international shipping and assess how well each perform with regard to a set of criteria that are spelled out. We present a qualitative evaluation, where strengths and weaknesses of the schemes are compared. The focus is on stimulating ship owners to reduce emissions trough reduced fuel consumption, or in the longer term to use alternative fuels.

In the next chapter we briefly discuss main policy tools for regulating CO_2 emissions from ships, followed by an overview of existing and planned regulations of CO_2 emissions from ships. The fourth chapter examines important criteria a regulation system for ships should satisfy. In the fifth chapter we present five selected regulation schemes for ships, which are followed by an assessment of how well these alternatives fare on the criteria. Finally, in the seventh chapter, the study is summarized.

2 Main policy tools for regulating emissions from ships

Basically there are two types of environmental regulations: ‘command and control’ and market-based instruments. They differ foremost with regard to firms’ ability to make decisions on emission reductions. With command and control, the regulator gives a firm permission to emit a certain amount of pollution, thus making many of the pollution control decisions for the firm, and thereby also limiting the firm’s choice. Market-based instruments give more freedom to the firm, simply providing an incentive for the firm to find the best way to reduce pollution. As a firm generally is better informed about emission reduction costs, it is usually able to find a more cost-effective solution than the regulator using ‘command and control’. Furthermore, marked-based instruments are more flexible than ‘command and control’ as they more easily allow firms to introduce better solutions later as technologies evolve. In the following discussion we focus on market-based instruments since these are likely to provide for more cost-effective solutions.

2.1 A charge on emissions

Introducing a charge on each ton of CO_2 makes emitters face the social cost of their emissions. This is one way of obtaining cost-effectiveness. To maximize profits, firms will reduce emissions until the cost of cutting back one more unit of CO_2 is equal to the charge they have to pay to emit one more unit. A charge controls the price of CO_2, but the exact quantitative effect, that is effect on emissions, cannot be determined beforehand. However, the quantitative effect can be observed after a while, although other factors also might have affected the emission level. The quantitative effect will be larger in the long term than short term since long-term flexibility is larger due to replacement of equipment that has a long life-length. In the ship sector this translates to scrapping of old ships and contracting new ships.

2.2 Emissions trading

A system for emissions trading is established by setting a total cap on emissions, dividing the cap into allowances (also named quotas or permits), usually equivalent to 1 ton of CO_2 each, and allocate these allowances to emitters. Firms are not allowed to emit more CO_2 than the amount of CO_2 allowances they possess. When firms buy or sell allowances the market determines a price to emit one ton of CO_2. Firms with a relatively low cost of emission reduction will reduce more and sell freed allowances, whereas high-cost firms will reduce less and buy allowances. Emissions trading leads to a cost-effective solution since all firms face the same price for emitting one more ton of CO_2. Trading with CO_2 emission allowances was introduced in the EU ETS and in the Norwegian emissions trading system from 2005. The Norwegian system will be a part of the European system from January 2008. Emissions trading will also be initiated under the Kyoto Protocol from 2008. As opposed to a charge on emissions, an emissions trading system fixes the quantity of emissions but allows the price to vary. In theory both the CO_2 price and effect on emissions will be the same for a charge and an emissions trading system.

The efficiency of this type of scheme depends on how allowances are distributed. Before the first trading period of a new emission trading system allowances can be auctioned or given out for free, or by combining these methods. Also for allowances for later trading periods either of these allocation methods can be used. Provided the regulator has set aside an allowance reserve in a trading period, for instance as a provision for new firms, spare allowances can be sold on the market.

2.2.1 Free allocation

Free allocation of allowances is often the most politically feasible solution but has several disadvantages. The regulator would need to gather sufficient information to be able to distribute the allowances. The allocation method is in contradiction with the polluters pay principle. The incentive effect to reduce emissions remains in the case of free allowances, however, since the cost of CO_2 emissions is visible to the firm. There is an alternative cost to emitting CO_2 since less emissions means allowances that can be sold on the market. The most common principle of free allocation is grandfathering, whereby allowances are given out in proportion to emissions in an earlier period. This type of reward for the largest emitters may be seen as unfair to other firms that have already reduced their emissions significantly.

Free allowances lead to distortions if allocation is based on emissions that a firm can influence, for instance if next period allocation depends on present period emissions. Then there will be an incentive for the firm to reduce its emissions less than it would otherwise do. In a more dynamic perspective free allocation of allowances can lead to the establishment of new firms that do not employ the most effective technology and thus emits too much CO_2. Furthermore such an allocation method easily leads to unproductive lobbyism.

In the case of shipping, and if free allowances are given to existing ships, new ships might be given new allowances to avoid distortion of competition. If these allowances are given in proportion to expected emissions, ships that emit more might be rewarded in relative terms, which is not desirable. If ships are kept in operation for the benefit of receiving free allowances this introduces a distortion since these ships should have been scrapped and replaced by more efficient ships. This problem is an argument for letting ship owners keep the allowances even if ships cease to operate.

The problems related to free allowances is more pronounced for shipping than for other sectors. The activity level varies a lot, and therefore allocating allowances based on one or a few base years will be more difficult than for land-based activities. Basing allocation on expected emissions is also difficult, as the emissions vary a lot from ship to ship.[1] It would require a lot of administrative work for a regulator to gather sufficient information. A further difficulty is represented by ship owners having private information on costs to reduce emissions and may have strategic reasons to hold back this information since if may affect the allocation of free allowances.

2.2.2 Auctioning allowances

Auctioning of allowance can avoid the incentive problems associated with free allowances discussed above. Being faced with the ‘full’ cost of emitting CO_2, instead of just the alternative cost that free allocation represents, firms might be more keen to invest in more efficient technologies, as the gains becomes more visible. Even though auctions have to be arranged, this way of allocating allowances requires less administration than free allowances.

2.3 Standards

A standard represents a ‘command and control’ instrument. A regulator can specify the technical construction or operational practices for a ship to meet the standard. Both the technical construction and the operational practices influence CO_2 emissions from a ship. Potential emission reductions from various measures are shown in Table 1. Note that the reduction potential from operational measures can be larger than the potential from technical measures.

[1] There are even large variations between sister ships, i.e. ships that have equal design. For more information, see the Marintek et al (2000) report on the IMO index and CE Delft et al. (2006), Part B.

Table 1-3 – CO_2 reduction potential by technical measures

Measures, new ships	Fuel/CO_2 saving potential	Combined[1]	Total[1]
Optimised hull shape	5 - 20 %	5 – 30 %	5 – 30%
Choice of propeller	5 - 10 %		
Efficiency optimised	10 – 12 %[2] 2 - 5 %[3]	14 – 17 %[2] 6 - 10 %[3]	
Fuel (HFO to MDO)	4 – 5 %		
Plant concepts	4 - 6 %	8 – 11 %	
Fuel (HFO to MDO)	4 – 5 %		
Machinery monitoring	0.5 –1 %		
Measure, existing ships	**Fuel/CO2 saving potential**	**Combined[1]**	**Total[1]**
Optimal hull maintenance	3 – 5 %	4 - 8 %	4 – 20 %
Propeller maintenance	1 – 3 %		
Fuel injection	1 – 2 %	5 - 7 %	
Fuel (HFO to MDO)	4 – 5 %		
Efficiency rating	3 – 5 %	7 - 10 %	
Fuel (HFO to MDO)	4 – 5 %		
Eff. rating + TC upgrade	5 – 7 %	9 - 12 %	
(HFO to MDO)	4 – 5 %		

[1] Where potential for reduction from individual measures are well documented by different sources, potential for combination of measures is based on estimates only
[2] State of art technique in new medium speed engines running on HFO.
[3] Slow speed engines when trade-of with NOx is accepted.

Table 1-4 – CO_2 reduction potential by operational measures.

Option	Fuel/CO_2 saving potential	Combined[1]	Total[1]
Operational planning / Speed selection		1 - 40 %	1 - 40 %
Fleet planning	5 - 40 %		
"Just in time" routing	1 - 5 %		
Weather routing	2 - 4 %		
Miscellaneous measures		0 – 5 %	
Constant RPM	0 - 2 %		
Optimal trim	0 - 1 %		
Minimum ballast	0 - 1 %		
Optimal propeller pitch	0 - 2 %		
Optimal rudder	0 - 0.3 %		
Reduced time in port		1 – 7 %	
Optimal cargo handling	1 - 5 %		
Optimal berthing, mooring and anchoring	1 - 2 %		

[1] Where potential for reduction from individual measures are documented by different sources, potential for combination of measures is based on estimates only

Table 1. CO_2 reduction potential by measures.[2] Source: Marintek et al. (2000).

Three standard types exist:

A technical standard gives specific instructions on how a ship should be built, i.e. the choice of propeller or measures for the machine.

[2] These tables give an overview of various technical and operational measures. For more details please confer Marintek et al. (2000), page 14-15.

A design emission standard specifies the expected CO_2 emission level required of a new ship when operated in a certain way under normal conditions. The ship builder is free to choose among technical solutions that will provide this level.

Note that both a technical standard and a design emission standard only put restrictions on the construction of the ship, and do not limit the actual emissions, which depend on both how the ship is constructed and on how it is operated. This is the major disadvantage with these types of standards.

An operational emission standard or performance standard requires a ship to meet certain levels of CO_2 emissions per unit of work during operation. In the case of shipping, this can be CO_2 emissions per ton of cargo or passenger transported per nautical mile. The ship owner is free to choose how this level should be met. He can either order a new, efficient ship, or upgrade an existing ship, and be less concerned about the operation of the ship. Alternatively, he can order a less efficient ship, or use an existing ship, and be careful to operate it in a way that leads to lower emissions, for example by reducing speed.

Technical standards represent a less flexible option than both a design emission standard and an operational emission standard since it requires the usage of one certain technology in the construction of a ship. As there are numerous ways for a ship to limit its emissions, requiring one specific technology will limit the ship owner's choice. It will also require a lot of work for the regulator to find the most suitable design. The best technology for one ship may not be the best for another ship. Furthermore, technological development will almost certainly provide even better technologies in the future. The ship owners and the market will find the best technology if a proper price on emissions is established. If the best technology, i.e. the one that gives the cheapest emission reductions for each ship, is not applied, the total costs of emission reduction in the sector will turn out to be higher than necessary.

Because of the large variety of ship types and sizes, many different standards are required. This is further discussed in section 5.2.

A standard can be combined with an emissions charge, and also with a credit. If a ship does not meet these requirements, it will have to pay for exceeding emissions, and if emissions are lower than the standard they receive a credit. A standard with charge and credit therefore in some ways resembles a market-based regulation. An example of such as regulation scheme is further discussed in 5.2.2, where an operational emission standard is combined with emission fee, and possibly a credit.

2.4 Other instruments

There are other policy tools to reduce emissions. Implementing a subsidy or reward for pollution control will have the same effect as a charge in the short run, but leads to excess pollution in the long run. In such as regulation system polluters are paid for each ton reduced emission compared to a reference level, for instance emissions last year. Public funds to finance a subsidy must be raised from distorting taxes that lead to efficiency losses. Hence, this is not the most viable option.

A hybrid emission trading scheme adds a "trigger price" to a standard emission trading scheme. Such a scheme sets an upper bound on the marginal cost of abatement through capping the allowance price, but otherwise operates like an emissions trading program. The regulator can implement the price cap through selling allowances from a reserve if the market price hits the cap, or can simply allow firms to pay the fee (which is equal to the price cap) for the number of allowances being short to emissions. Such a hybrid system fails to guarantee a particular emission level, but does guarantee a price cap per ton of CO_2 for its users. Pizer (1997) argues that some hybrid system designs may be more efficient than both a traditional emission trading system and a charge system.

3 Existing and planned regulations for ships

To date, there are no regulations on the emissions of greenhouse gases from ships in international trade. There exist regulations on other environmental problems related to international ship traffic. Here we briefly present ongoing processes in the IMO, the EU, and Norway with respect to regulating CO_2-emissions from international and domestic shipping.

3.1 International Maritime Organization (IMO)

The IMO was established in 1948 for the purpose of developing and maintaining a comprehensive regulatory framework for international ship traffic. Safety, security, competency of seafarers and protection of the environment are main areas. Prevention of air pollution from ships, and hereunder emissions of greenhouse gases, is dealt with by the Marine Environment Protection Committee (MEPC), one of the specialized committees under the IMO.

The most important regulation on marine pollution is the MARPOL 73/78 Convention. In 1997, air pollution was included in Annex VI. Up to present, greenhouse gas emissions are not included. While a new instrument addressing greenhouse gas (GHG) emissions may not be included in MARPOL Convention, it provides useful provisions in relation to an instrument regulating GHG emissions from international shipping.

> ” **Enforcement**
> Any violation of the MARPOL 73/78 Convention within the jurisdiction of any Party to the Convention is punishable either under the law of that Party or under the law of the flag State. In this respect, the term "jurisdiction" in the Convention should be construed in the light of international law in force at the time the Convention is applied or interpreted.
>
> With the exception of very small vessels, ships engaged on international voyages must carry on board valid international certificates which may be accepted at foreign ports as prima facie evidence that the ship complies with the requirements of the Convention.
>
> If, however, there are clear grounds for believing that the condition of the ship or its equipment does not correspond substantially with the particulars of the certificate, or if the ship does not carry a valid certificate, the authority carrying out the inspection may detain the ship until it is satisfied that the ship can proceed to sea without presenting unreasonable threat of harm to the marine environment.”
>
> **“Amendment Procedure**
> Amendments to the technical Annexes of MARPOL 73/78 can be adopted using the "tacit acceptance" procedure, whereby the amendments enter into force on a specified date unless an agreed number of States Parties object by an agreed date.
>
> In practice, amendments are usually adopted either by IMO's Marine Environment Protection Committee (MEPC) or by a Conference of Parties to MARPOL.”[3]

[3] Confer www.imo.org; section about MARPOL.

> "Inspection and monitoring of compliance are the responsibility of member States, but the adoption of a Voluntary IMO Member State Audit Scheme is expected to play a key role in enhancing implementation of IMO standards."[4]

In 2000, the IMO published a report that considered the contribution to climate change from ship emissions, and evaluated ways to regulate these emissions.[5] This concluded that the following strategies could be feasible at that time:

1. Explore the interests for entering into voluntary agreements on GHG emission limitations between the IMO and the ship owners, or to use environmental indexing.
2. Start working on how to design emission standards for new and possibly also for existing vessels.
3. Pursue the possibilities of credit trading from additional abatement measures implemented on new and possibly also on existing vessels.

This is based on the assumption that it is too difficult to implement strict regulations on international shipping, due to its evasive nature. More recent reports, however, claim that the informational barriers that inhibit a proper regulation of this sector are possible to overcome.

In recent years, IMO has developed a CO_2 index, which we discuss further in section 5.2. It was adopted in 2005, and implemented on a voluntary basis until 2008 as a trial period. "Industry, organizations and interested Administrations are invited to promote the use of the attached Interim Guidelines in trials and report their experiences back to MEPC 58 (October 2008)." (IMO 2005) This can be considered as an important step towards establishing an international regulation regime for CO_2 emissions, but will only lead to small emission reductions if it is not used as a base for a more stringent policy.

At MEPC 56 (July 2007) it was agreed to establish a Correspondence Group to discuss possible approaches on technical, operational and market-based measures to address GHG emissions from ships and report to MEPC 57 (March/April 2008), in order to speed up the process with the aim to conclude in 2009.

3.2 The European Union (EU)

Within the EU, more progress on regulation on emissions from ships has been made. A strategy to reduce atmospheric emissions was presented in November 2002. This included emissions leading to both air pollution and climate change.[6] However, only the work on air pollution has resulted in concrete action, as for example a directive as regards the sulfur content of marine fuel that came into force in August 2005.[7]

In December 2006, a report written for the European Commission was finalized. Due to the lack of progress in the IMO, the European Commission wanted to explore the possibility of a regional regulation system.[8] Three policy options were considered to be the most promising ones:

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[4] Confer www.imo.org; section "About IMO".

[5] MARINTEK, et al. (2000). Study of Greenhouse Gas Emissions from Ships. International Maritime Organisation.

[6] http://ec.europa.eu/environment/air/transport.htm#3

[7] EU (2005). Directive 2005/33/EC of the European Parliament and of the Council.

[8] CE Delft et al. (2006). Greenhouse Gas Emissions for Shipping and Implementation Guidance for the Marine Fuel Sulfur Directive. CE Delft.

1. A requirement to meet a unitary CO2 index limit value
2. Mandatory differentiation of harbor dues (possibly based on the CO2 index)
3. Inclusion of maritime transport in EU ETS

EU has stated that they prefer a global solution for international shipping under the auspices of IMO. If, however, IMO has not been able to agree on an acceptable solution by 2009, EU intends to include shipping in the EU ETS. [9]

3.3 Norway

In Norway, domestic shipping is required to pay a CO_2 charge on the use of mineral oil (Norwegian Ministry of the Environment 2007). This corresponds to approximately 25 EUR/ton of CO_2.[10]

Norway has signaled that emissions from international transport must be subject to CO_2 emission regulations in the future. The Norwegian Prime Minister said at the UN Secretary-General's High Level Event on Climate Change in September 2007 that "In our view international air transport and maritime transport need to be included in the carbon market."[11]

Traditionally, Norway has been working through the IMO to reach an agreement on how to regulate greenhouse gas emissions from international shipping. Norway supported the voluntary implementation of the CO_2 index (confer section 5.2; Norwegian Ministry of the Environment 2007). In July 2007, Norway submitted a proposal at Marine Environment Protection Committee's (MEPC) 56th Session. This proposal is described in section 5.4 and evaluated in section 6.

4 Criteria a regulation system for ships must satisfy

Both the establishment and operation of a system for regulating CO_2 emissions from ships must satisfy a number of requirements or criteria. In this section we discuss the following criteria which are deemed important for carbon dioxide regulation systems for ships: Level playing field; Robust; Simple administration; Cost-effective; Flexible; Internationally acceptable; Money generated channeled back into sector; Legally feasible; Can be implemented soon.

It is likely that all criteria cannot be satisfied at the same time, meaning that there are trade-offs between them. Consequently an assessment of regulation systems based on these criteria will be forced to prioritize among them. To this issue we return in section 6.

4.1 To what extent does a regulation scheme ensure a level playing field for all ships?

A regulation system for ships should be neutral across all nations and ship categories for the purpose of eliminating the possibility of evasion and leakage of emissions, and to avoid reduced competitiveness of ship owners that comply with regulations. Thus the instruments implemented to put a price on CO_2 emissions should not lead to any unwanted market distortions in terms of other environmental or commercial effects. Ship owners should not be subject to less stringent regulations by changing flag.

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[9] http://www.reuters.com/article/environmentNews/idUSL1639411220070416.

[10] Approximately 200 NOK/ton CO_2.

[11] http://www.regjeringen.no/en/dep/smk/primeminister/Prime-Minister-Jens-Stoltenberg/Speeches-and-Articles/2007/Speech-at-The-Secretary-Generals-High-Le.html?id=481637.

Another dimension of level playing field is related to marine transport as compared to other modes of transportation. For some freight categories and routes there is competition between ship transport and rail or truck transport, and even air transport in some cases. The ideal solution is that all modes of transportation pay the same price per ton of CO_2 emitted (and for other negative environmental effects, such as air pollution from aerosols). This is, however, generally not the case, but at least in some European countries environmental or climate regulations on land transport through taxes exist. The exception is aviation, where there up till now is close to no environmental regulation, but where EU is planning to include aviation in EU ETS from 2011-2012.

Under the United Nations Framework Convention on Climate Change (UNFCCC), countries have “common but differentiated responsibilities” (United Nations Framework Convention on Climate Change 1992). If one should introduce differentiated responsibilities for ships dependent on the flag state, e.g. less stringent regulation for ships from developing countries, this would distort competition and make the scheme less robust as the ships can evade it by flagging out to other countries. Besides, only including industrialized countries would not provide the necessary effect since only 15% of the world fleet is registered in these countries.

There are, however, other ways to differentiate between ships that might induce fewer distortions. CE Delft et al. (2006) and Faber et al. (2007) have considered differentiation based on the route of the vessel. Another is to base it on the origin or destination of the cargo. A recent workshop concluded that, in general, no technical issues related to monitoring and reporting remains that can not be solved.[12] This also holds for differentiation, and is in line with other conclusions on this topic. Both systems of differentiation, however, will require large amount of data, especially the one based on cargo.

Even though a system ensures a level playing field, it can still differentiate between countries by for example spending parts of the funds collected from the scheme on adaptation projects in developing countries. There might also be other ways to compensate these countries to make them willing to adopt a scheme that avoids distortions.

For this study, however, we require that the regulation system for CO_2 emissions from ships is so designed that the price on emissions is independent of the flag state of the ships, thus achieving a genuine level playing field.

4.2 To what extent can evasion of a regulation scheme be prevented?

In the context of a regulation system for ship robustness means that it is difficult for ship owners to shirk their obligations according to the system. A ship owner will have incentives to follow the regulations if the probability of being caught and the cost of non-compliance are sufficiently large. This requires a well-functioning reporting, monitoring, and verification, and not the least an enforcement system. An obvious possibility is for ships to be able to provide proper documentation to any port state control officer that show that they follow the regulations. However, there is always a possibility to falsify documents to avoid paying for the emissions. This requires regular monitoring and verification of ship activities, and the possibility to impose fines on ships that are not in compliance to increase the robustness of any regulation scheme. It might be too costly to verify the activities of all ships, so an alternative is to select a random sample of ships for thorough investigation.

[12] For more information, see Norwegian Ministry of the Environment et al. (2007), Technical Workshop on Bunker Fuel Emissions Bulletin, International Institute for Sustainable Development.

4.3 Is administration of a regulation scheme simple for flag states?

For a given emission reduction target for the maritime sector, and cost-effectiveness achieved, the regulation scheme with the lowest administrative costs has the preference. Introduction of a charge appears to be easier than an emissions trading system, since an emission trading market requires more procedures and institutions for allocation of allowances, trading, reporting and verification, and a registry of emissions and allowances.

A standard for emissions relative to transport (confer section 5.2) requires even more information to provide sufficient data to create a standard. Different ship categories and ship sizes show great variation in emissions per ton-kilometer transport, and there will be a tradeoff between making the scheme as effective and fair as possible and avoiding too complex administration due to differentiation between various ship categories.

4.4 Can a regulation scheme achieve the emission reduction target at low overall cost?

For a given emission reduction target for the ship sector, emissions should be reduced at lowest possible cost. If the ship sector is included in a wider regulation system the cost saving and thereby level of cost-effectiveness attained, can be even larger since more low-cost mitigation options should be available. Cost-effectiveness requires that the marginal cost of emissions, i.e. the cost for emitting one extra ton of CO_2, is equal for all ships. In the case of emissions trading the price on emissions reflects the target in terms of total allowable CO_2 emissions set by the regulator. All ships will reduce emissions until the cost of reducing one more unit of CO_2, is equal to the CO_2 price, this being a charge or an allowance price. If ships do not face the same price on CO_2 emissions, ship owners will adjust their reduction efforts to the different price levels, making the marginal emission reduction costs different across ships. This implies that total emission reduction cost could be lowered by reducing relatively more emissions from ships with low marginal costs.

A cost-effective solution across sectors requires that the marginal cost of reductions in the maritime sector is equal to the marginal cost in other sectors. Thus the same charge on emissions or a wide emissions trading scheme would ensure a cost-effective way of reducing emissions across all sectors of the economy.

4.5 Can a regulation scheme be easily modified?

The regulation system should be flexible to allow adjustments of the system as a response to new information, changed circumstances, or general policy changes. There are uncertainties about future targets; the costs of emission reductions, how they may change over time, and what gases, particles and sectors that might be included in the regulation system in the future. This implies that regulations imposed today might be subject to change in the future, and thus one should be able to revise the regulation system in a transparent manner whenever new information and circumstances make this warranted. Although regulation should be robust, an excessively rigid system could actually be perceived as less credible and inhibit ship owners from undertaking necessary investments to meet future commitments.

4.6 Can a regulation scheme be established and operated at low cost to make it acceptable to all states?

The best solution is a global regulation system for CO_2 emissions from ships. The alternative is regional regulation schemes. Regional schemes are much more exposed to evasion, and this clearly represents a second-best option. As countries have different characteristics and interests, it is difficult to tell what kind of regulation scheme that is most likely to be adopted. However, it is reasonable to believe that a scheme that is less strict, and hence less costly for ships, is more likely to be adopted and might therefore be a preferred first step.

The other option is to find ways of partly compensating the most skeptical countries. Developing countries could be opposed to a regulation system satisfying the level playing field criterion. They might find such a regulation system unfair and costly for them. However, they might be more willing to accept such a system if part of the money generated will be channeled back to the ship sector, and even more so to developing countries. This could be done by spending a portion of the funds generated on adaptation projects in developing countries to handle climate change, for instance the adaptation fund under the UNFCCC, or possibly through buying credits through the CDM mechanism.

4.7 Are possible revenues from a regulation scheme recycled to the marine sector?

When developing a regulation system for greenhouse gases for a sector there is usually no explicit constraint on the use of income from sale of allowances or charges paid to the regulator. In the case of a system of charges income goes to the regulator and commonly the regulator sees the spending of the income generated as a separate issue. This is also supported by most economic models, where the sought after effect is the incentive to reduce emissions due to the charge. The income can then be seen as any other tax income, and spent on any important task where public funding is required. In addition, if the income from charges is channeled back into the regulated sector, there is a significant risk that the incentive effect of the charge is reduced and therefore also the cost-effectiveness. Only if the money is channeled back in a way that the firms cannot influence, and in this context, particularly not influence by emitting more or less greenhouse gases, will distortions be avoided. Assuming that the charge is set at the correct level, the point is that recycling of income in effect lowers the effective charge level. In practice it is difficult to avoid all distortions of this type.

If some or all allowances are auctioned in a cap-and-trade scheme, or some allowances later sold by the operator, and the revenue generated recycled to the marine sector, this could easily infringe on the cost-effectiveness of the trading system for the same reasons mentioned in the case of a charge.

On this background a criterion on cost neutrality for the regulated sector may seem out of place. In this report, however, we assume that channeling money back to the ship sector increases the feasibility of an international regulation system for ships. If there is a non-marginal net cost of the regulation system the possibility of having the most reluctant countries agree to the system seems slim. Therefore the challenge is to have the income somehow channeled back into the ship sector without this leading to distortions, at least not significant distortions. The ship owners should not be able to influence the probability of receiving parts of this revenue by taking actions that is not compatible with the intention of the scheme. Possible ways to reimburse ships are in proportion to their sailing distance, or as a fixed annual remuneration based on their IMO CO_2-index.[13] It is not evident that these types of recycling do not create unwanted incentives – e.g. sailing an extra mile means extra costs in terms of CO_2, but a part of this cost will be offset by the extra revenue from the reimbursement. This means that the incentive effect of the CO_2 cost will be weaker, so this reimbursement alternative could contain an important weakness.

Another possibility is to create a Research and Development (R&D) fund for investments that can reduce future emissions, for example through increased fuel efficiency of ship engines. Implementing new, promising technologies is often long-term and associated with substantial risk. Experiences from early implementation could prove useful for further development of the technology. The marginal costs of reducing emissions by using a new technology is often declining in the total amount invested due to learning. Furthermore the value to society of developing such technologies is often larger than value for private firms,

[13] This is mentioned in Kågeson (2007).

leading to insufficient investments from a social perspective. Therefore using money generated by the regulation system for a R&D fund can provide an additional benefit for society, which also could balance some of the potential distortions from reimbursement.

4.8 Is a regulation scheme legally feasible within IMO?

Any regulation scheme for the marine sector must comply with the United Nations Convention on the Law of the Sea (UNCLOS). For a regulation system to be effective, enforcement must be possible. According to CE Delft et al. (2006) port states have wide discretion under general international law, and are able to require all ships, irrespective of flags, to meet certain conditions for entry into port. If these conditions are not met, the port State is able to expel or detain the ship. Even though port States may not have the right to force foreign ships to meet the conditions, or make them pay a fee if they do not, expelling them might be a strong enough enforcement instrument. Some policy options might be in conflict with international trade law. This holds especially for non-global (regional) systems. Regional systems are not discussed in this report, for one reason since they can lead to strategic behavior by ship owners to evade the regulation scheme.

4.9 Can a regulation scheme be implemented soon?

Due to the long lifetime of ships and investment decisions made continuously it is important that the cost of CO_2 is taken into account as soon as possible. The first requirement for this is speedy adoption by IMO. The time needed by IMO and the implementation time is, however, difficult to predict.

5 The selected regulation alternatives

We have selected a small set of five regulation schemes for CO_2 emissions from ships based on the policy literature, economic theory, and recent proposals to IMO. Other alternatives have been proposed, but these five alternatives are a good representation of the main alternatives.

The examination of the alternatives is based on the assumption that they will be globally implemented. It is further assumed that IMO will adopt the scheme including the necessary control mechanisms and sanctions in case of non-compliance. This enforcement has to be tailor-made to each type of regulation scheme, primarily based on flag state control supplemented by secondary port state control. Other control authorities may be required, depending on the characteristics of each regulation alternative.

The design and strictness of a scheme determines to what degree it leads to real emission cuts. In the case of a charge or an emissions trading system, both these approaches would end up with the same price level and the same emission reductions. The provision for such an outcome is the absence of market imperfections and uncertainty, and an appropriate specification of a charge system or an emission allowance system.

We now examine the five regulation schemes in the following sequence:

A. A cap-and-trade scheme.
B. A design emission standard.
C. An operational emission standard with fee.
D. A charge on emissions from ships.
E. A combined cap and charge scheme.

5.1 Alternative A: A cap-and-trade scheme

In this scheme a cap on total emissions from the marine sector is agreed upon under the auspices of IMO. The scheme covers ship transport globally. We assume that this system is open through linking to a much wider emission trading system that covers many sectors. Examples of wider systems are trading under the Kyoto Protocol in the period 2008-2012, which is limited to industrialized countries, and trading under EU ETS in the period 2008-2012 and beyond, which presently is limited to EU countries plus Norway.

Taking the Kyoto Protocol and thus the period 2008-2012 as the case at hand, we find it unlikely that a cap-and-trade system for shipping can be an integral part of the Kyoto Protocol. However, we assume that ship owners are allowed to buy emission allowances from other sectors to comply with their cap on emissions. Ship owners could also be allowed to buy project-based credits from developing countries through the Clean Development Mechanism (CDM), and Joint Implementation (JI) credits from industrialized countries. But the marine sector is likely not allowed to sell allowances to other sectors since marine emissions (defined by the marine cap) would be additional to the emission cap defined by the Kyoto Protocol. Selling marine allowances to sectors included in the Kyoto Protocol would therefore increase supply of allowances under the protocol and reduce the equilibrium price. A global climate policy treaty beyond 2012 may, however, fully include marine transportation, and may also allow trading for a wider group of countries than the present Kyoto Protocol. In this case there would be no restrictions on trading between the marine sector and other sectors.

One benefit of linking the marine sector scheme to the wider trading system is that this leads to a more cost-effective solution since more sectors face the same price on emissions. But since the marine sector is likely not allowed to sell allowances to other sectors a soft cap would reduce the allowance price within the sector. This not only implies smaller emission reductions from ships, but also reduces cost-effectiveness since an implication would be a lower allowance price in the marine sector than in the wider emission trading system. Therefore the cap for the marine sector should be set low enough to make sure that the regulation results in real emission cuts and leads to a cost-effective outcome.

The following steps are required to establish a cap-and-trade emission trading system for shipping:

1. IMO decides on a global cap and target period for CO2 emissions in the marine sector.
2. The design of the trading scheme and its operation is coordinated with the regulating body of the wider trading scheme for the purpose of certifying compatibility with regard to features such as units, trading periods, registry, accounting, etc. Some co-ordination is also required for monitoring the two systems, and with regard to verification and enforcement. The most relevant wider trading scheme is found under the Kyoto Protocol and its three flexible mechanisms: emissions trading (for industrialized countries), JI (in industrialized countries) and CDM (in developing countries).
3. Rules and procedures for trading with the wider emission trading system are negotiated and established.
4. Allowances are distributed to ships (ship owners) based on auctions or on some type of grandfathering. Auctions could take place in each state or in a wider group of states. In case of grandfathering allowances are allocated for free based on emissions in an earlier period. An alternative method is to allocate free allowances based on bench-marking (for instance building on a CO_2-index, valid both for existing ships and new buildings in all flag states), whereby free

allowances are given out at a level equivalent to the most efficient ships in a ship category (e.g. at level that corresponds to the 10% lowest-emitting ships per ton and mile). Another possibility is for some allowances to be given out for free based on the ship categories and index values illustrated in Table 2.

5. Trading within the marine sector can commence, and eventually purchase of allowances or credits from the wider emission trading scheme. The market determines an allowance price. The price will vary over time according to supply and demand.
6. A registry keeps track of emissions, stock of allowances and trading to certify that the allowance obligation for each ship is fulfilled for the specified accounting period(s). Emission calculations can be based on fuel consumption, possibly fuel bunkered e.g. six months back to reduce the possibilities for evading the system if the trading scheme is not global (confer Kågeson 2007).
7. Each ship owner must take care to comply with his emission cap and allowance obligation in the trading period. Bunkered fuel must be reported so that CO_2 emissions can be calculated. During each accounting period (usually lasting one year) a ship owner must keep account of emissions, the stock of allowances (and CDM and JI credits), and take steps to purchase if there is a deficit or sell if there is a surplus. In case of surplus, allowances can alternatively be saved and used for compliance in the next accounting period. After the accounting period is ended a ship owner must surrender allowances equivalent to emissions, under the surveillance of the operator of the trading system. If there is a deficit in number of allowances, the operator can claim a fee per ton of CO_2 to be paid by the ship owner, and the ship owner has to buy missing allowances and surrender these.

With regard to step 4, free allocation of allowances easily leads to efficiency distortions (a disincentive to invest in new measures to reduce emissions) as noted in section 2.2.1, but this problem can be resolved if allowances are auctioned (or sold by the regulator after trading has started). A common feature of trading systems is that the income generated from auctioning goes to each state government. However, in case the auctioning income is kept by the marine sector (e.g. IMO), it must be handled and redistributed in a way that minimizes disincentives in the next round. In regulation alternative E (confer section 5.4) such disincentives are reduced by generating a fund, and spending part of the fund on adaptation measures in developing countries, and on improving ship technologies and infrastructure in the marine sector. If the cap-and-trade scheme for the marine sector later is fully integrated in a wide emission trading system, it is unlikely that recycling of money back to sector will be accepted as this deviates from the conditions of other sectors included in the trading system.

5.2 Design and operational emission standards

Various forms of standards to regulate emissions exist. In terms of ship transport the main relevant types are a design emission standard and an operational emission standard. A design emission standard sets forth requirements for the construction of new ships, with a view to expected emissions. An operational emission standard is performance based and thus relates to allowable emissions per unit of transport conducted, for example emissions per ton and nautical mile. For all standards the regulator must decide on a manageable number of ship categories, for which a separate standard is developed and implemented. Given the large number of different ship constructions and sizes this means that each category will contain ship types of some heterogeneity. This limitation implies a certain efficiency loss when standards are employed in such a heterogeneous sector as shipping. We discuss these two main standard alternatives in turn.

5.2.1 Alternative B: Design emission standard

In this regulation scheme the regulator decides on a suitable number of categories for new ships, and thereafter decides a required level of *expected* CO_2 emissions for each category.[14] This expected level can be based on a certain operation of the ship under average conditions. The ship builder is free to choose among technical solutions that will provide this level.

This requires substantial collection and processing of data. After establishing the standard scheme, implementation is relatively straightforward. Each ship should be inspected before delivery, and given a certificate if it is verified that the ship meets the standard. The task of verifying that new ships satisfy the standard should be left to an independent organization (such as Classification Societies acting as Recognized Organizations on behalf of flag states). If better designs are developed or more ambitious climate targets require a more stringent scheme, the standards can be tightened in the future.

A major disadvantage of a design emission standard is that the effect on greenhouse gas emissions could be quite limited, since emissions to a large extent depends on how the ship is operated, where a design emission standard has no influence.

A design emission standard on new ships will make sure that all new ships are built efficiently. This is important due to the long lifetime of ships. Other policy instruments such as a charge set at a high enough level could have a similar effect on new investments. The future cost savings justifying the investment in a more efficient ship today might be uncertain to ship owners. It will depend on both the fuel price and on the price on CO_2, which might be highly volatile.[15]

In addition, as IMO has a long experience with standards, this regulation alternative might be easier accepted than a marked based instrument, and thus be implemented sooner. This will not exclude the possibility of implementing a marked based instrument in addition to give ship owners incentives to reduce emissions also when operating the ship.

For new ships a design emission standard could be combined with an operational emission standard with fee, see next section.

5.2.2 Alternative C: Operational emission standard with fee

This regulation scheme implements a standard on *actual* emissions per ton and nautical mile from both new and existing ships. The ship owners are free to choose how to reduce emissions; either by improving the technical construction or operational practices of the ships.

Imposing an operational emission standard with fee resembles an emission charge, except that the fee is only paid for emissions exceeding a certain limit, which is the standard. A stricter overall standard means lower emissions from the ship sector. This alternative will generate less revenue than the (pure) charge regulation alternative. The port state control officers could be given the responsibility to verify that fees are paid for the emissions exceeding the CO_2 standard. In case of non-compliance, the ship could be detained until the fees plus a penalty are paid.

A variant of this regulation scheme is to include a credit for ships that perform better than the standard, that is if emissions per ton and nautical mile is below the level specified by the standard. In such a case ship owners will have an incentive to do better than the standard imposed.

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[14] In theory, a design emission standard could be implemented for existing ships as well. This is discussed in Marintek 2000. According to this study, a design emission standard for existing ship could lead to accelerated scrapping, which in turn would could reduce emissions, but is unlikely to be cost-effective; it would be difficult to monitor and implement.

[15] The CO_2 allowance price in the EU ETS has varied from 7-32 €/ton CO_2 before the collapse of the price in autumn 2006.

Because of the large variety of ship types and sizes, many different standards are required. There are several ways to categorize ships. In general there is a tradeoff between the desire to differentiate and the need to limit the number of categories due to administrative simplicity. IMO has a CO_2 index under development that reflects the fuel consumption per unit of transport work in ton-km. This index could be the basis for a standard, but there are some problems associated with it. Smaller ships will always be at a disadvantage compared with larger ships. In times of lower market demand, either globally or on specific routes or return voyages, the CO_2 index will increase. Ship owners will only have limited possibilities to influence these developments. The index must therefore be so defined that it reflects different ship types, sizes and trade variations in a fair manner.[16]

Table 2 shows the variations in average IMO CO_2 index between the 19 ship categories used in Lloyd's Register, and illustrated hereby the need for differentiating between ship categories. This categorization is well established and statistical data is available for these categories. Since CO_2 indexing is applicable only to ships performing transport work, ship categories that are not primarily designed to performing transport work are disregarded.

Ship type	Total number of ships	Index unit	Average index	Average gross tonnage	Ships in study
LNG Tanker	175	g CO2 / ton n. mile	66,5	79652	3
LPG Tanker	1020				0
Chemical Tanker	2970	g CO2 / ton n. mile	23,5	20311	49
Crude Oil Tanker	1850	g CO2 / ton n. mile	8,0	57703	46
Product Tanker	5047				0
Other Liquids	365				0
Bulk Dry	5267	g CO2 / ton n. mile	7,6	81519	4
Bulk Dry/Oil	152				0
Self Discharging Bulk Dry	166				0
Other Bulk Dry	1105				0
General Cargo	15859				0
Passenger/General Cargo	339				0
Container	3283	g CO2 / ton n. mile	96,5	40021	23
Refrigerated Cargo	1242	g CO2 / ton n. mile	124,3	9850	11
RoRo Cargo	1959	g CO2 / ton n. mile	94,9	49294	29
Passenger/RoRo Cargo	2743	g CO2 / car unit n. mile	9379,0	2894	199
Passenger Ship	2873				0
Other Dry Cargo	240				0
Total	**46654**				**364**

Table 2. Lloyd's Registers ship categories. Source: CE Delft et al. (2006).

[16] One possibility is to define an index based on a ships design parameters such as deadweight or gross tonnage and speed as a specified percentage of the engines' max continuous rating. Such an index will also be a function of ship type and size.

In case emissions are below the standard, an option is for credits to be sold to other sectors with similar commitments to reduce their emissions. The administration of such a regulation system with trading of credits would be more complicated than with a charge on emissions (regulation alternative D).

5.3 Alternative D: A charge on emissions from ships

Emissions associated with fuel sold can be calculated from fuel sales. Availability and accessibility of marine fuel sales data is fairly good. On the other hand some off-shore bunkering and bunkering in states that are not a member of IMO may not be registered, confer the discussion in Annex 1 and the lower CO_2 emissions estimated from on marine fuel in Figure A1. Thus incomplete sales data may give some ship owners an opportunity to evade a charge. The charge could be paid to IMO, and not to countries. The charge income could be used to establish a fund administered by IMO, and the money used to support implementation of new, promising technologies, and to other important measures to mitigate greenhouse gas emissions globally.

When a charge is imposed, emitters have an incentive to reduce emissions as long as the marginal cost of reducing emissions is lower than the charge they would otherwise pay. The impact on emissions is equivalent if there are no market distortions, both in the case ship owners pay the charge, or in the case fuel suppliers do it. In both cases ships will bear the burden of the charge by facing an increased fuel price. In any case, the ships must prove that they have paid a charge on their emissions to be allowed to enter ports. This can be verified by port state control authorities.

5.4 Alternative E: A combined cap and charge scheme

This scheme has been proposed by Norway to IMO and is based on three elements. Firstly, it contains a cap on total CO_2-emissions from international shipping, which is agreed by IMO. Secondly, a charge on CO_2-emissions from all international shipping is introduced. Thirdly, a fund is established under the IMO, to which the emission charge is paid to. The fund should be controlled by a board established under IMO. The purpose of the fund is threefold, and the charge income would fund:

- Maritime industry GHG improvements;
- CO_2-credits purchased on emission trading markets; and
- Climate change adaptation in developing countries.

The first two components should jointly deliver the required emission reductions to meet the cap through improvement programs and emission offsets.

The first portion of the fund would thus go to ship owners applying for financial aid for implementation of low-emission technology and practices, and to stimulate infrastructure improvements. The GHG reductions obtained would be additional to the ongoing technical and operational improvements in the ship sector.

The second portion would be used for emission allowances and credits purchased at emission trading markets if the reductions from GHG projects within the shipping sector are not sufficient to meet the total emission cap. The emission allowances would be purchased through existing carbon markets, *inter alia* project-based credits such as CDM. Effectively, this portion of the fund would offset the emissions above the total cap of the entire international maritime transport sector with emission reductions elsewhere, and at lower cost.

The third portion of the fund would be spent on projects in developing countries to help these countries to adapt to the impacts of climate change. The most straight-forward alternative is to support adaptation funds under the UNFCCC.

6 Assessment of regulation schemes with respect to criteria

In this section we assess the five alternative regulation schemes for CO_2 emissions from ships A, B, C, D and E with respect to the nine criteria described in chapter 4. Obviously such an assessment is subjective, both in terms of how well a regulation alternative fare on one criterion, and in terms of the importance of one criterion compared to other criteria. We carry out a qualitative assessment of relative strengths and weaknesses of the five regulation schemes with regard to the nine criteria. A summary of the discussion is presented in Table 3.

6.1 Ensuring a level playing field

The additional costs related to CO_2 emissions are neutral across all nations and ship categories for all regulation alternatives if they are adopted globally. However, the standard alternatives B and particularly C are more complex due to large number of ship types and transportation activities, which makes a perfectly neutral effect difficult to obtain in practice, confer the discussion in section 5.2. For alternative A, a global cap and trade system, free allocation of allowances may compromise the level playing field criterion since it is difficult to design free allocation schemes that work perfectly neutral.

6.2 Prevent evasion of the regulation scheme

All schemes are more or less robust if they are implemented globally, making it difficult for a ship owner to shirk his commitments to reduce emissions. Due to the relative simplicity to implement scheme B, a design emission standard, this may be the most robust alternative. On the other hand, at a different note, scheme B is less robust than the other schemes since ship owners can operate ships in a way such that the effect on emissions is negligible. To some extent this is also the case for regulation scheme C, since it is impossible to design an operational emission standard that is sufficiently comprehensive to cover all ship types and trades well.

6.3 Simple administration for flag states

The pure charge and design emission standard alternatives seem to be the easiest to administer. A cap-and-trade regime seems more complicated to establish and administer. Operational emission standards combined with fee will be more costly to implement than the pure charge alternative. The cap and charge proposal (E) is combining a charge and purchase of allowances from other sectors. On this background we have chosen to give highest score for D, medium score for A and B, and lowest score for C and E.

6.4 Achieving the emission reduction target at low overall cost

The broad picture is that the four schemes A, C, D and E will provide emission reductions in a more or less cost-effective way. The cost of emitting CO_2 will be equal for all entities. In this way the incentives to reduce emissions are also taken care of. However, a design emission standard (B) will fail to give effective incentives to reduce CO_2 emissions since a ship owner that operates a ship in a manner that causes relatively high emissions will not pay anything extra for the additional emissions. In scheme C only emissions exceeding the standard are prone to pay the fee, unless combined with a credit for emissions lower than the standard. Also in the case of scheme E the level of cost-effectiveness can be somewhat reduced since the charge will likely be lower than the allowance price in a wide emission trading system. Accordingly we have given scheme B a low score and scheme A and D a high score on cost-effectiveness.

6.5 Easy to modify regulation scheme

The emission standard alternatives B and C are probably less flexible than the others. Even if standards can be revised over time, this is more demanding given the complexity of different standards for different ship categories. Future knowledge, technology and policy changes will be possible to incorporate through regulating an emission fee in a more straight-forward manner. The cap in a cap-and-trade scheme can also be revised, but flexibility will be reduced within each trading period given a fixed total cap. Therefore we have given highest score for scheme D and lowest score for scheme B and C, whereas the other two receive a medium score.

Regulation scheme	Strengths	Weaknesses
A. Cap and trade	• Cost-effective • Can be implemented soon	• Difficult allocation in case of free allowances
B. Design emission standard	• Relative simple to establish • High acceptability • Can be implemented soon	• Not cost-effective • Weak incentives • Low flexibility
C. Operational emission standard with fee	• Stronger incentives to reduce emissions than design emission standard • High acceptability	• Complexity • Less cost-effective than cap-and-trade and charge
D. Charge on emissions	• Cost-effective • High flexibility • Simple administration	• Low acceptability
E. Cap and charge	• Higher acceptability than charge • Technology development	• Less cost-effective than cap-and-trade and charge • Complexity

Table 3. Comparison of strengths and weaknesses of regulation schemes.

6.6 Establish and operate the regulation scheme at low cost to make it acceptable to all states

The score on this criterion depends on the implicit net cost for ship owners generated by a scheme, and how this compares across nations, ship categories and transport niches. Scheme B will likely have relative high acceptability since an additional cost will only be put on new ships, and since the additional cost will be small. Alternative C will be less costly for the sector than the other alternatives, since it implies that only emissions exceeding the standard must be paid charges for, and since there furthermore is a possibility for credits for lower-than-standard emissions. This means that the acceptability of this scheme for many countries will be higher than for most other schemes. On this background scheme D gets the lowest score, followed by A, which do somewhat better due to the possibility of free allowances.

6.7 Recycling of possible revenues from regulation scheme to the marine sector

All alternatives or schemes can be designed so that the charge or allowance income generated stays within the sector. The exception is B, where no revenues are generated. In the case that ship owners are allowed to sell allowances to other sectors if emissions are below the relevant standard, additional revenue for the ship sector could be generated. We have, however, chosen to give all schemes a fair score on this criterion.

6.8 Legal feasibility within IMO

There are few differences between the alternatives when it comes to the possibility of being legally adopted and implemented by all nations. Legal feasibility is more dependent on how a regulation scheme is designed. Schemes B and C, however, fits better with the functioning of IMO than the other schemes, and may therefore have higher legal feasibility.

6.9 The regulation scheme should be implemented soon

An emission trading system, as in alternative A, takes some time to establish, but there is experience from e.g. EU ETS. Establishing an emission charge system (D) will take some time, since putting a charge on international ship transport is a new experience. A design emission standard (B) could possibly be established in a shorter period. Alternatives C and E contain some complexity that requires a somewhat longer period. Taken together this perspective means that schemes B and A receive a higher score than the three other schemes.

7 Summary

This study of possible regulation systems for CO_2 emissions from international shipping has shown that two main regulation types exist, either based on standards or on market-based instruments. The standard-based regulation schemes likely have a higher acceptability than a charge or a cap-and-trade system, but perform less well with regard to providing good incentives to reduce emissions and therefore lead to cost-effectiveness. The cap with charge is a type of compromise scheme between a standard-based and market-based scheme that has medium performance on account of both acceptability and incentives. In summary the choice of regulation scheme for CO_2 emissions from international shipping is a trade-off between what is feasible in the short term and what is more desirable in the long term.

Annex 1. The climate effect of ship traffic

The climate effect

Shipping emits gases and particles that affect the chemical composition of the atmosphere and in consequence contribute to climate change. The key compounds emitted are carbon dioxide (CO_2), nitrogen oxides (NOx) and sulfur dioxide (SO_2). The emissions perturb atmospheric concentrations of greenhouse gases (CO_2, CH_4 and O_3) and aerosols (sulphate, SO_4), causing both warming and cooling effects. In addition, sulphate causes a significant indirect cooling, via changes in cloud microphysics.

Carbon dioxide (CO_2)
Shipping emits CO_2 due to fossil fuel combustion. CO_2 is the dominating man-made greenhouse gas. CO_2 has a long adjustment time in the atmosphere (>100 year), much longer than the atmospheric mixing timescale, so the climate effect of CO_2 is the same for shipping as for other sources of CO_2 emissions. Since the adjustment time of CO_2 in the atmosphere is long, the concentration of CO_2 in the atmosphere depends on the emission history of CO_2. Figur A1 shows historical CO_2 ship emissions based on estimated sales of marine fuel in the period 1925 to 2002 *(Endresen, et al.* 2007) as well as estimated ship CO_2 emissions based on a bottom up approach by *Eyring, et al.* (2005). The emission of CO_2 has grown due to higher activity, but the emissions per tonne transported by sea have been significantly reduced as a result of larger and more energy efficient ships. The emission estimates differ between these two studies because of different assumptions and methods, see Figur A1. There is an ongoing scientific discussion on the present day fuel consumption in shipping, regarding whether bunker sale statistics are representative when estimating emissions or if the bunker sale statistics are too low *(Corbett and Koehler* 2003; *Endresen, et al.* 2004; *Endresen, et al.* 2007; *Eyring, et al.* 2005). The emission estimates of CO_2 from shipping in year 2000 vary from 600 to 800 Tg CO_2 (including fishing), corresponding to 2.3-3.0% of the total man made CO_2 emissions.

Nitrogen oxides (NO_x)
Nitrogen oxides (NO_x)[17] are emitted from shipping activity due to high temperature and pressure in the engine leading to a reaction between N_2 and O_2 from the ambient air. The estimate for NO_x emission from shipping varies (10-21 Tg NO_2 per year) corresponding to 11-23% of the total anthropogenic NO_x emission. The shipping sector has high NO_x emissions in terms of g NOx/g fuel due to the high combustion temperatures necessary to increase engine efficiency. The ratio between shipping NO_x emission and road transport NO_x emission is 78% while the corresponding ratio for CO_2 emissions is 19% *(Eyring, et al.* 2005). Emissions of NO_x have both a warming and a cooling effect on the climate, warming due to production of ozone (O_3) and cooling due to reduction in the lifetime of methane (CH_4) through complex chemical reactions in the atmosphere (Berntsen et al. 2005; Fuglestvedt et al. 2007).

Ozone (O_3) is produced in the atmosphere in chemical reactions where NO_x acts as a catalyst. Shipping emits NO_x in clean regions of the marine atmosphere. The production of ozone from NOx emissions is more effective when emissions take place in clean regions than in already polluted areas. The lifetime of NO_x emissions from shipping is short (~days), and the lifetime

[17] Nitrogen oxides (NOx): nitrogen monoxides (NO) and nitrogen dioxide(NO_2)

of ozone is in order of weeks. The perturbation of the ozone from shipping is mainly restricted to the Northern Hemisphere, since the majority of the ship emissions occur there.

NO_x also reduces the atmospheric lifetime of CH_4. NO_x emissions increase the hydroxyl radical (OH) concentrations in the atmosphere. OH is the main oxidizing agent in the troposphere and controls the degradation of methane. Higher levels of OH lead to reduced lifetime of methane. Methane has a lifetime of approximately 10 years, and therefore the perturbation on the methane concentration due to NO_x emissions occurs on a global scale.

Sulfur dioxide (SO_2)

The fuel used in shipping has high sulfur content. Shipping contributes 6-11% of total anthropogenic SO_2 emissions. The emission of SO_2 is higher from the shipping sector than the road sector *(Eyring, et al.* 2005). When the fuel is combusted, SO_2 is emitted and through chemical/microphysical processes sulphate (SO_4) is formed. The sulphate aerosols can affect the climate directly or indirectly through changing the clouds properties, both having a cooling effect on climate.

The *direct effect* of SO_4 is by reflecting incoming solar light, and the solar radiation reaching the earth is reduced.

The SO_4 particles can also act as a cloud condensation nuclei. Ship emissions increases the particle numbers in the relative clean atmosphere over the ocean, and the droplet numbers increases and the size of the droplets decreases. Clouds with equal water content but with smaller droplets reflect more sunlight than clouds with larger droplets, and thus the reflectivity of the clouds increases due to ship emissions. This is called the *first indirect effect* of sulphate. The cloud cover area and the lifetime of the clouds can also change when additional particles are added in the atmosphere causing additional cooling (*second indirect effect*).

The lifetime of sulphate is in order of days, and the effect is located over the ocean in both hemispheres. The ocean absorbs more solar light than land, so the effect of sulphate aerosols over the ocean is higher than over land.

Other gases and particles

Among the Kyoto gases, it is only CO_2 emissions that are of significant magnitude. The emissions of N_2O and CH_4 from shipping are less than 0.1% of the total anthropogenic CO_2 equivalent emissions, and the effect of direct CH_4 emission and N_2O can be neglected.

Carbon monoxide (CO) and non methane volatile organic compounds (NMVOC) are precursors of ozone in the troposphere. The ozone production in clean environments like over ocean, is dominated by NO_x emissions (Eyring, et al., 2007) and the emission of CO and NMVOC from shipping (from propulsion) is small.

Shipping emissions also enhance other particles than sulphate that have a direct and indirect effect on climate. But sulphate particles are the dominant particle for these two effects. Lauer, et al. (2007) estimated that 75% of the direct and indirect effect of aerosols from shipping are due to sulphate.

Recently a study has indicated that annually approximately 60 000 cardiopulmonary and lung cancer deaths are due to particulate matter emissions from shipping, with most deaths occurring near coastlines in Europe, East Asia, and South Asia (Corbett, et al. 2007).

Quantifying the climate effect

Emissions from shipping consist of various gases and particles that have warming or cooling (or both) effects on climate. The effects occur on different timescales ranging from days to centuries, and the spatial distributions of the climate effects are different. These differences in fundamental characteristics make illustrations and comparisons complicated.

A common way to illustrate the climate effect is to use the concept radiative forcing (RF). It is defined as the change in the energy balance of the earth/atmosphere given in Watt per square meter (W/m^2). It is often used as a proxy for changes in global mean temperature since many studies indicate that RF is proportional to global temperature change. (Some recent studies indicate, however, that there are deviations from this relationship for some mechanisms).

Several studies have calculated RF due to shipping for different components, given as current RF vs pre-industrial time. The results are summarized in Figur A2 taken from Lauer et al. (2007).

The RF from CO_2 for shipping is approximately 2% of total RF for CO_2 given by IPCC 2007 (Forster et al. 2007). The main uncertainty in RF calculation for CO_2 from shipping is the uncertainty in the emission estimates. The level of scientific understanding of the CO_2 effect given in IPCC 2007 is high.

The NO_x emissions cause both warming and cooling effects due to the effects on O_3 and CH_4. There are uncertainties in the emission estimate for NO_x, as well as large uncertainties in the chemistry modeling. Since the magnitude of the warming and cooling effects of NO_x emissions are of about equal size the net effect is small but the uncertainty range includes both positive and negative values (net warming and net cooling). Eyring, et al. (2007) estimated 20% uncertainty in the RF calculation of O_3 from shipping due to use of different models. In addition is the large uncertainty in the emission estimate. The level of scientific understanding of the O_3 effect is labeled medium in IPCC 2006, and the RF estimate from O_3 shipping is 1.6-6% of the total man made best estimate given in IPCC Third Assessment Report (TAR).

The scientific understanding of the direct effect of aerosols is medium to low. The best estimate of the total anthropogenic direct aerosols effect given in IPCC 2007 is -0.5 W/m^2 with uncertainty range -0.9 to -0.1 W/m^2. Various estimates of RF for the direct effect of ship emission correspond to 2.8 to 7.6% of the best estimate of total man made aerosol direct effect. There are large uncertainty in these estimates due to uncertainty in the emissions and uncertainty in the calculations of chemical and radiative effects.

For the indirect effect of aerosols, the scientific understanding is lower. It is labelled low in IPCC 2007. The best estimate given in IPCC 2007 for the total indirect aerosol effect is -0.7 W/m^2 with uncertainty range -1.8 to -0.3 W/m^2. There is a large spread in the calculation of the indirect aerosols RF from shipping. Lauer, et al., (2007) used three different emission inventories, and calculated RF indirect from shipping to be 27-86% of the best estimate given in IPCC 2007. In addition to the uncertainty in the emissions, the uncertainty in the model calculation is large for the indirect aerosol effect.

Despite the wide range of RF values calculated, there is high confidence that the present-day net RF due to shipping is negative. In comparison, the net radiative forcing from aviation and road transport sector are positive (Sausen, et al. 2005, Fuglestvedt et al. 2007). Fuglestvedt et al. (2007) also find a negative net RF from shipping. In a forward looking perspective this negative effect occur on short time scales but disappears on longer time scales.

The negative net RF from shipping does not imply a direct cancellation of the warming effect. The components with negative RF can affect other parameters than the global mean temperature; e.g. the hydrological cycle and wind patterns (Matthews and Caldeira 2007). Emissions of SO_2 and NOx have several other indirect effects; e.g. acidification or fertilization of the ocean which will further affect the exchange of CO_2 between the atmosphere and the ocean (Doney et al., 2007) or production on ozone which may affect the uptake of CO_2 in the biosphere (Sitch et al. 2007)

It is important to note that this historical perspective is not particularly useful for policymakers for comparison between the climate effect from different species for the shipping sector. The RF calculation for CO_2 is based on the whole emission history due to the long lifetime of CO_2 in the atmosphere. An emission based comparison of how current and future emissions affect future climate is then needed. (See Fuglestvedt et al. 2007 for a discussion of these perspectives).

The RF from shipping CO_2 will probably increase in the future. The other RF components are highly dependent on the technology in the fleet and sulphur content of the fuel, and are assumed to be reduced in the future. In addition to impacts on the climate, local (in coastal areas and harbors with heavy traffic) and regional (long-range transport) air quality problems are of concern because of their impact on human health.

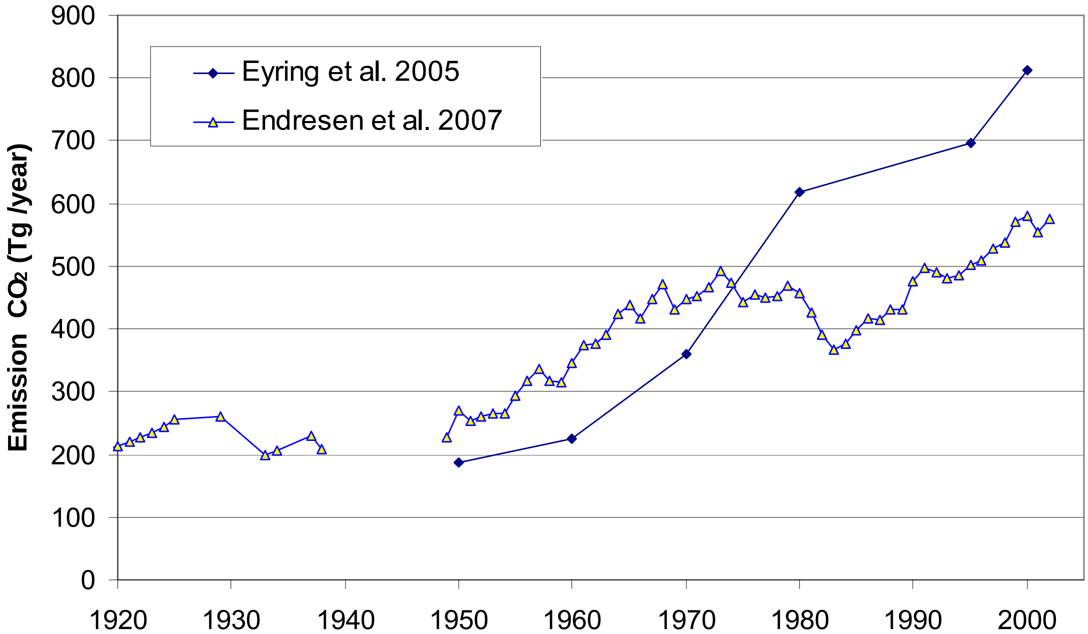

Figure A1. Two estimates of historic CO2 emissions from shipping. Endresen, et al. (2007): Development of CO2 ship emissions, based on estimated sales of marine fuel, 1920–2002 (including the fishing and military fleet). Note that no data are available for World War II. Eyring, et al. (2005): CO2 emissions development from civilian and military shipping calculated based on ship number statistics and average engine statistics. The emission estimate in year 2000 is based on detailed fleet-modeling.

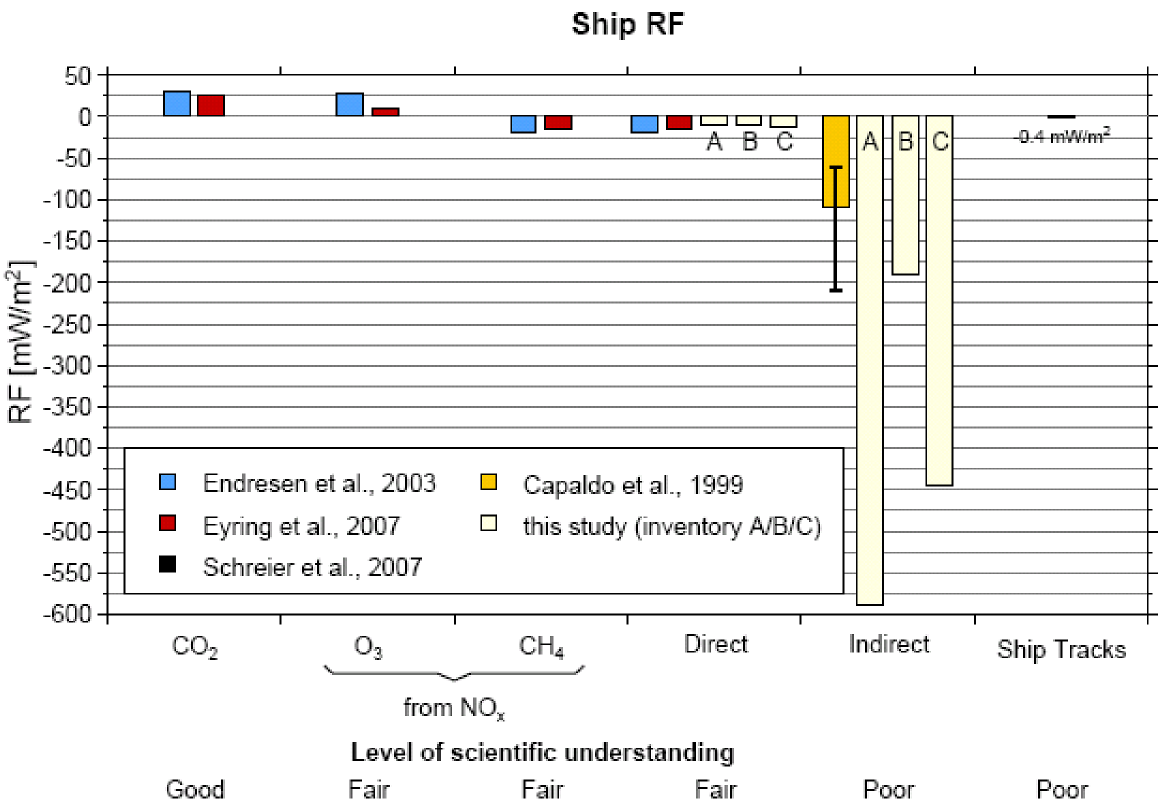

Figure A2. Annual mean radiative forcing due to emissions from international shipping in mWm−2. Values for CO2, O3, CH4 (reduced lifetime), and SO4 (direct aerosol effect) are taken from Endresen et al. (2003) and Eyring et al. (2007). The indirect aerosol effect calculated by Capaldo et al. (1999) includes the first indirect effect of sulfate plus organic material aerosols only, the error bar depicts the range spanned by their additional sensitivity studies. The estimated direct and the indirect aerosol effect calculated in this study also includes changes due to BC, POM, NH4, NO3, and H2O from shipping in addition to SO4 and refers to the changes in all-sky shortwave radiation fluxes and net cloud forcing (sum of shortwave and long-wave cloud forcing) at the top of the atmosphere, respectively. The net cloud forcing is calculated from the differences in the simulated all-sky fluxes and the corresponding clear-sky fluxes at top of the atmosphere. The global annual mean RF due to ship tracks is taken from the satellite data analysis by Schreier et al. (2007). [Figure taken from (Lauer, et al. 2007).]

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