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# Designing a climate change policy for the international maritime transport sector: Market-based measures and technological options for global and regional policy actions

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ABSTRACT

The international maritime transport sector has a significant abatement potential and some technical improvements that reduce GHG emissions would already be profitable without any policy in place. This paper analyses in-depth the limits and opportunities of policy options currently under consideration at the international level to stimulate the sector to reduce its GHG emissions. In particular, in order for the maritime transport sector to become more environmentally friendly, the flexible nature of international market-based measures and the European Union Emission Trading Scheme provide a definite window of opportunity without placing unnecessary high burden on the sector. However, the development of a regional policy, such as at European level, for the international maritime transport sector faces several obstacles: allocation of emissions, carbon leakage, permit allocation, treatment of the great variety in ship type, size and usage, and transaction cost. Global market-based policies could overcome most of these challenges.

This paper provides an in-depth analysis of the policy instruments currently under discussion to reduce the sector's burden on the environment, and focuses on economic theory, legal principles, technological options, and the political framework that together make up the basis of decision-making regarding the international maritime transport sector's climate change policies.



## 1. Introduction

How to reduce GHG emissions from the international maritime transport sector has been subject of international debate under the United Nations Framework Convention on Climate Change (UNFCCC) for over 15 years (Haites, 2009). The Maritime Environment Protection Committee (MEPC) of the International Maritime Organization (IMO), which is, since 1996, responsible for identification and further development of policy options to reduce GHG emissions from ships, has not managed to present any ambitious GHG policy so far. The World Shipping Council, representing about 60% of global seaborne trade, takes the stand that the adoption of specific maritime emission caps would be "inappropriate in the absence of a broader approach to regulation transportation emissions at the national and global level" (World Shipping Council, 2010). It emphasizes that although shipping is in absolute terms a substantial emitter of $CO_2$, it is the most carbon efficient means to transport goods.

A major bottleneck in the discussions has been the allocation of emissions to countries. In recent years, the IMO also considered proposals for sector-wide solutions that avoid the complexity of emissions allocation (Stochniol, 2007; Kågeson, 2008). The second IMO GHG study 2009 finds that market-based instruments have high environmental effectiveness and are cost-effective policy instruments as they allow both technical and operational measures as well as offsetting of emissions in other sectors. A mandatory limit on the Energy Efficiency Design Index (EEDI) is an alternative, rules-based, way towards greening of the sector. However, this measure will be introduced only for new ships, thus resulting in lower environmental effectiveness. In addition, it will not put an absolute cap on emissions and therefore will not take into account the expected increase in emissions of 150–200% by 2050 due to growth of the sector (IMO, 2009).

This paper provides an in-depth analysis of the policy instruments currently under discussion to reduce the sector's burden on the environment, and focuses on economic theory, legal principles, technological options, and the political framework that together make up the basis of decision-making regarding the international maritime transport sector's climate change policies.

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It analyzes the limits and opportunities of the market-based measures currently under discussion at the international level to reduce the sector's GHG emissions as well as inclusion of the sector in the European Union Emission Trading Scheme (EU ETS). Moreover, it reports on the main technological tools to abate air emissions and GHG from shipping estimating their cost-effectiveness. This paper provides an in-depth analysis of the international framework in which GHG emissions from international shipping could be regulated, with a special focus on the compatibility of inclusion of the sector in the EU ETS with the core body of international law related to this topic, namely: IMO conventions, the Kyoto Protocol, and the UNFCCC. The analysis identifies obstacles for the international shipping sector to realize implementation of a GHG reduction policy.

## 2. Air emissions from ships

Emissions from the maritime transport sector represent a significant and increasing air pollution source. The main air emissions resulting from burning this type of fuel include: sulfur dioxide ($SO_2$); nitrogen oxides ($NO_x$); volatile organic compounds (VOCs); particulate matter (PM); carbon dioxide ($CO_2$), and other GHGs. The amount of gases emitted from marine engines into the atmosphere is directly related to total fuel oil consumption, which depends on different factors such as the hull shape, the loading conditions, the roughness of the hull, the condition of the engine, etc. Auxiliary engines also contribute to the total exhaust gas emissions. This contribution to air emissions is particularly significant for cruise ships, which have a constant need for ancillary power to meet lighting and ventilation demands both at sea and in port. Emissions of $CO_2$ from international maritime shipping are estimated to account for 2.7% of total global emissions of in 2007 (IMO, 2009). $CO_2$ emissions from international shipping account for 4.1% of EU-15 emissions in 2007. This number includes emissions from international shipping by vessels of all flags and on lakes, waterways, and coastal waters but excluding fishery. EU-15 emissions have increased by 63% since 1990 (European Environmental Agency, 2009a, 2009b). Apart from being a heavy polluter, the shipping sector is expected to increase its GHG emissions significantly due to the increase in global goods traded (CE Delft et al., 2006), with mid-range estimates of a 150–200% increase by 2050 (IMO, 2009). For other air pollutants, in Lauer et al. (2009) it has been estimated that, in the event of no countermeasures being taken, sulfate emissions from ships will increase by 10–20% over the main routes in 2012, contributing up to 5.2% to the total tropospheric sulfate burden.

However, the sector has a significant abatement potential, meaning that environmental gains can be achieved. Nonetheless there are some challenges that need to be overcome in order to make such a policy successful. These challenges include deciding on a method to allocate ship emissions to countries, diminishing the risk of carbon leakage, and designing a policy that is administratively and politically feasible with respect to allowance distribution and treatment of the great variety in ship type, size, and usage. A global policy could overcome most of the above-mentioned challenges.

The following sections give an in-depth analysis on the current international debate on global market-based measures for this sector.

## 3. Market-based policy and climate change

Global climate change poses a challenge on policymakers as it involves decision-making about threats that are uncertain but that require high investments. Complicating matters, there are long time-lags between action and effect. Choosing an appropriate discount rate is fundamental for the results of the cost-benefit analysis that seems to underlie current climate change policy debates. For this reason the low discount rate in the famous Stern review on the economics of climate change (Stern et al., 2006) has been subject to substantive criticism (e.g., Nordhaus, 2007; Tol and Yohe, 2006). Inherently related is the time-inconsistency concept. Uncertainty about future benefits (of more biodiversity, less draughts, less threats from storms or floods, etc.) while facing certain costs creates incentives to postpone or weaken greenhouse gas (GHG) mitigation policies that are believed to be optimal in the long-run. Even when the optimal long-run policy in current debates is based on IPCC scenario's that are 'best estimates' with 'likely ranges' of temperature changes, leaving underexposed the unknowns and the inability to evaluate meaningfully possible catastrophic temperature increases (Weitzman, 2009).

As Underdal (2010) highlights, above circumstances ask for a transformation of long-term policy visions into a 'sustained program of activities', requiring above all perseverance in the policy field. As the system of environmental governance needs to be able to deal with a wide range of functions like sharing knowledge to reduce uncertainties and promoting rigorous mitigation action, it requires a hybrid system combining aspects of 'adaptive governance' with aspects of 'collective action'. The first model focuses more on diversity of actors, learning, and flexibility while the second involves energy, focus, and collective action. This political science viewpoint corresponds to a more general consensus among economists that market-based instruments outperform command-and-control measures in terms of cost-effectiveness for pollution control (e.g., Hahn and Stavins, 2010; Montgomery, 1972; Tietenberg, 2003), meaning that economic incentives rather than fixed rules should pave the way for a more sustainable climate. Based on the above, the complexity of climate change policy requires: (1) policymakers to set binding and ambitious long-term emission reduction goals, (2) economic incentives that encourage taking action in a flexible manner, (3) knowledge sharing of innovative mitigation practices, and (4) transparency, administrative ease, and solid compliance mechanisms.

In economic literature four market-based instruments are considered appropriate for climate change policies: emission taxes, emission trading, a hybrid policy (combing a tax with trading), and emission crediting that is voluntary (e.g., Baron et al., 2009; Bosi and Ellis, 2005; Goers et al., 2010; McKibbin and Wilcoxen, 2002; OECD, 2009) Of those measures emission taxes is not considered on a global scale as it has been considered politically difficult to implement this. The other three market-based policies have been discussed within IMO's Maritime Environment Protection Committee (MEPC) and will be discussed in Section 6 in detail.

The following section will give an overview of the current international debate for a global policy regulating GHG emissions from ships.

## 4. A global policy within the '*common but differentiated responsibilities and equal treatment of ships*' principles

As part of the Kyoto Protocol, the UNFCCC Conference of Parties (COP) agreed to pursue reduction of GHG emissions through IMO. In the 1990s the discussion focused primarily on how to allocate emissions to Parties, a topic that proved to be a major bottleneck for progress on the issue (Haites, 2009).

A central principle in international climate change negotiations is that of 'common but differentiated responsibilities', according to which legally binding emissions reduction commitments should apply only to Annex-I Parties (UN-DESA, 1992). The initial text comes from the Rio Summit in 1992: "In view of the different contributions to global environmental degradation, States have common but differentiated responsibilities. The developed countries acknowledge the responsibility that they bear in the international pursuit of sustainable development in view of the pressures their societies place on the global environment and of the technologies and financial resources they command" (UN-DESA, 1992). For maritime transport the basic principle is, on the contrary, equal treatment of ships.

In order to fully deliver its mandate as stipulated in Article 2.2 of the Kyoto Protocol to the UNFCCC,[3] the IMO Maritime Environment Protection Committee (MEPC) has analyzed the potential constraints of a new legally binding instrument addressing GHG emissions from international shipping.[4] In particular, the Committee voiced concerns about the compatibility between the Kyoto Protocol's "common but differentiated responsibilities" approach, and the Paris Memorandum of Understanding's "no more favorable treatment" concept, according to which relevant legal instruments (conventions) should apply also to ships, which fly the flag of a State, which is not a Party to that convention.[5] To ascertain whether there is a potential conflict between two different international treaties it has to be established whether or not they somehow regulate the same subject in a contradictory way.

The negotiation document for the Copenhagen climate change conference COP15 moves beyond allocation issues by considering only sectoral policy options (and the option 'no regulation') (Faber et al., 2009). With a sectoral approach shipping sector (practically: the IMO) will be included as a separate Party in the post-Kyoto protocol and has to live up to its sector-wide abatement targets. The IMO could apply its own market-based policy to realize emission reductions in a cost-effective manner. It would also be responsible for monitoring and enforcement. Enforcement takes place through Port State Control (PSC) where the ultimate penalty is the detention or ban of the ship that does not comply. With global coverage, the total of $CO_2$ emissions per ship can be calculated as a factor of the total fuel bought, without risking carbon leakage by ships bunkering in places that fall outside the regulation.

A second way of combining both principles is to differentiate commitments for Annex-I and non-Annex-I countries (UN-DESA, 1992) without relying on the nationality of ships.

A solution could be to differentiate responsibilities according to the route of the vessels or the ship size (Faber and Rensema, 2008). A justification for differentiated responsibilities in maritime policy is that the policy should not interfere with the growth potential of developing countries.

As some countries are dependent on maritime transport for their exports, and countries are thought to develop by periods of export-led economic growth, global coverage of the described policies could lead to lower economic growth (Faber and Rensema, 2008). Kågeson (2008) highlights that it may not be possible to achieve complete global coverage of an international maritime emission trading scheme, as support from developing countries might be limited. He therefore envisages three possible stages of implementation: firstly the set-up of a scheme by the IMO and the UNFCCC that is open for voluntary participation by States and ports, and secondly, a scheme that covers all traffic in the ports of Annex-I countries (UN-DESA, 1992), which can finally be extended to a scheme covering all maritime traffic on a global level.

The same could be applied on the basis of a tax or a levy system, although careful analysis of the effects is needed as a major threat to the environmental effectiveness of these systems is carbon leakage due to incomplete coverage. For the voluntary sectoral crediting option, this is not an issue.

At present, several market-based measures are under discussion within IMO's Maritime Environment Protection Committee (MEPC). At the MEPC61 ten proposals[6] for market-based measures have been discussed on the basis of an assessment carried out by an Expert Group (MEPC 60) that has evaluated the proposals on the basis of nine criteria such as environmental and cost-effectiveness, impacts on trade innovation and technological change, etc. (IMO, 2010a, 2010b). However, no decision was officially taken. The IMO GHG Working group will report on its conclusion on Market Base Measures during the IMO MEPC62 (11–15 July 2011).

Apart from market-based mechanisms, the MEPC has been able to introduce an Energy Efficiency Design Index (EEDI), that although still in a test phase is meant to become mandatory in the future (IMO, 2010a, 2010b). However, as is common practice for all IMO technical standards, the EEDI has a grandfather's clause saying that the legislation will affect only new buildings. As the economic life of a ship can be 25–30 years it may take decades for the policy to sort any effect on the sector's GHG emissions (Faber et al., 2009).

Years of discussion within the UNFCCC and IMO's Marine Environment Protection Committee (MEPC) on climate change have not yet resulted in any ambitious policy and the debate for a global policy is still open. However, the EU takes the stand that if neither the IMO nor the UNFCCC have succeeded in implementing policy directed at GHG reduction for the maritime transport sector by 2011 (European Commission, 2009). The following section will give a picture of the main constraints for the inclusion of the shipping sector within the EU ET.

## 5. Design choices for regional market-based policy: inclusion in the EU ETS

In the directive 2009/29/EC, in order to improve and extend the greenhouse gas emissions allowance trading system, where the GHG reduction goal is modified to at least 50% of 1990 levels by 2050, it is argued that all sectors of the economy should contribute to achieving the emission reductions. In order for the

[3] Art. 2.2 of the Kyoto Protocol to the UNFCCC: "The Parties included in Annex-I shall pursue limitation or reduction of emissions of greenhouse gases not controlled by the Montreal Protocol from aviation and marine bunker fuels, working through the International Civil Aviation Organization and the International Maritime Organization, respectively".

[4] This discussion has been pushed forward by the publication of the "Second IMO GHG Study 2009" (update of the 2000 IMO GHG Study) which has been prepared on behalf of the IMO by an international consortium led by MARTINEK. This study set out a comprehensive overview of policy options for the reduction of emissions, including a Maritime Emissions Trading Scheme, seen as "cost-effective policy instruments with high environmental effectiveness".

[5] http://www.parismou.org/upload/pdf/MOU,%20incl.%2031st%20%20Amendment%20editorial%20revised.pdf.

[6] (1) An International Fund for GHG from ships (GHG Fund) proposed by Cyprus, Denmark, the Marshall Islands, Nigeria and IPTA; (2) Leveraged Incentive Scheme (LIS) to improve the energy efficiency of ships based on the international GHG fund proposed by Japan; (3) Achieving reduction in GHG from ships through Port State arrangements utilizing the ship traffic, energy and environment model, STEEM proposal by Jamaica; (4) the United States proposal to reduce GHG emissions from shipping, the Ship Efficiency and Credit Trading (SECT); (5) the Vessel Efficiency System (VES) proposal by World Shipping Council; (6) the Global emission trading System (ETS) for international shipping proposal by Norway; (7) Global emission Trading System (ETS) for international shipping proposal by the United Kingdom; (8) further elements for the development of an Emission Trading System (ETS) for international Shipping proposal by France; (9) Market-Based Instruments: a penalty on trade and development proposal by Bahamas; (10) A rebate Mechanism for market-Based instruments for international shipping proposal by IUCN (IMO, 2010a, 2010b).

maritime transport sector to become more environmentally friendly, the flexible nature of the EU ETS and its proven success provides a definite window of opportunity without placing unnecessary high burden on the sector, but implementation requires policymakers to make politically difficult decisions.

When deciding which sectors to include in the scheme, it would be reasonable to include sectors that are among the heaviest polluters. Emissions from maritime shipping are estimated to account for 1.8–3.4% of total emissions in the EU (CE Delft et al., 2006), and approximately the same holds for global emissions. Apart from being a heavy polluter, the shipping sector is expected to increase its GHG emissions significantly due to the increase in global goods traded (CE Delft et al., 2006).The International Maritime Organization (IMO) has researched the maritime transport sector's maximum abatement potential and related marginal cost. In its analysis it included 25 different abatement measures, covering categories like propeller maintenance, hull coating, speed reduction, air lubrication, and main engine retrofit measures. A rough conclusion that can be drawn is that the estimated marginal abatement cost range from negative amounts to at maximum between $80, (low estimate) and $140, (high estimate) per ton of $CO_2$ avoided[7] (IMO, 2009). Average marginal abatement cost for all participating operators in the EU ETS were on beforehand estimated to be €20, and the average price of the permits has indeed varied around that value in the first trading period (Blok et al., 2001) and is currently balancing around €15. Due to its relatively high abatement cost the maritime transport sector as a whole is expected to become a net-buyer of allowances (Kågeson, 2007) However, with a fair amount of emission reductions that are cost-efficient at the current price of allowances, the sector has certainly the capability to realize GHG abatement itself. Another finding of IMO was that there is even a range of measures with negative cost efficiency, meaning that they are even profitable when there is no price on $CO_2$ emissions. The estimated maximum abatement potential lies between 210 and 440 Mt of $CO_2$, which is 15–30% of the total emissions of the vessels taken into account (IMO, 2009).

The following sections discuss some elements of an ET scheme applied to the shipping sectors.

First, as ships vary considerately in size, type and even usage agreeing with all stakeholders on the distribution of allowances will be a challenge. Second, small ships may incur significant transaction cost and it needs to be decided how to treat them. Third, as for inclusion of the sector in the EU ETS member states need to agree on how to allocate emissions to countries, which has proven to be a major bottleneck. Fourth, also a main issue for a non-global policy, choices on the geographical scope of the trading scheme needs to be made.

### 5.1. *Allocation of permits*

The great variety in ship size, type, and usage creates the necessity to choose carefully, which way to allocate the permits to the operators. The options are: (1) grandfathering based on a historic approach, (2) grandfathering based on a benchmark approach, and (3) auctioning. If allowances would be grandfathered based on historical emissions the ship activity in the base year is crucial. Ships traveling more in the base year than in a trading year would be advantaged over ships traveling more in a trading year compared to the base year. A specific problem is tramp shipping that is characterized by very irregular transport activity, making a historical approach rather unreliable. Grandfathering permits in this way can distort the competitive market for shipping due to high volatility in trading (CE Delft et al., 2006). Distributing allowances with a benchmark approach is shown to be difficult as it is difficult to design a benchmark that does not discriminate against the shipping categories. Auctioning permits places the responsibility for allocation with the sector itself, overcoming any discriminative problems. However, it needs to be assured that auctions take place frequently, corresponding to the high variability in some shipping industries. Another complication arises due to so-called "occasional sources"; ships that only occasionally enter the ports (Harrison et al., 2004).

An emission trading scheme with incomplete coverage in terms of countries, industries, or greenhouse gasses will to some extent be subject to carbon leakage. It can work in two ways: (1) through the fossil fuel price channel: the policy decreases the demand for fossil fuel, thereby lowering its price that triggers a higher fuel use and higher associated emissions in non-participating countries, and (2) through the competitiveness channel: carbon-intensive activities get re-allocated towards area's or sectors with less stringent policies, or the industry outside the region gains in market share.

### 5.2. *Transaction cost*

The cap-and-trade policy can confront participating operators as well as regulators with high transaction cost related to trading, monitoring, enforcement, and verification. The volume of allowances traded will decrease as a result of the cost associated with trading, resulting in sub-optimal trading. However, even with high transaction cost it is likely that a trading policy is more cost-effective than technical standards (Stavins, 1995). For small firms, transaction cost can add up to a large burden on their profitability. In an attempt to quantify the size of the burden, Jaraite et al. (2009) found that for Irish operators the average transaction cost per ton of $CO_2$ emitted are €0.08, which is a half percent of the price of $CO_2$-equivalent. Another finding is that transaction cost exhibit significant economies of scale. Total transaction cost per tonnage of $CO_2$ emitted appear to be more than 40 times as high for small firms (firms that are allocated less than 0.1% of total allocation) than for large firms (firms that are allocated more than 2% of total allocation).

### 5.3. *Allocation of emissions to member states*

In order to include maritime transport as a trading sector in the EU ETS, the participating countries need to decide on an allocation method of ship emissions to countries as the member states are responsible for the emissions of their national installations and ships change flag constantly. Already in 1996 the UNFCCC has selected eight allocation options that have became the topic of discussion on a global and European level. Progress on choosing the best allocation method has been slow due to the fact that whatever option is selected, some member state finds itself disadvantaged (Haites, 2009). Moreover, some allocation methods, like allocation of emissions to the country where the fuel is sold, are highly sensitive to evasion as tankers could easily get their fuel from outside the region. Alternatively, the maritime transport sector could be included separately in the EU ETS and the ship could be made the liable entity independent of the flag under which it sails. It would mean that the ship could only enter a port included in the EU emission trading scheme if it hands over documentation that shows it has covered its emissions with allowances (Kågeson, 2007). As the amount of emissions allocated to EU member states differs significantly with the allocation

[7] With a currency exchange rate of 1US$=0.70€ at 24 March 2011 this translates to about maximum marginal abatement cost of between €56 and €98, per ton of $CO_2$ avoided.

options, it is a very complex task to agree on the method with all stakeholders and still end up with ambitious targets.

### 5.4. Geographical scope

Ships are per definition easily movable, and can therefore reduce production cost simply by avoiding the European ports, seas, or gasoline sellers as much as possible, which leads to an ineffective environmental policy, as well as a loss of competitiveness of the European economy in general and European maritime transport companies in specific. Besides allocation of emissions, also the geographical scope of the scheme is important: it can be route-based, time-based, or geographical area-based. Unilateral action to include the maritime transport sector within the EU ETS is only considered by the EU due to the absence of a global policy, which is the desirable approach. Expansion of the second-best alternative over time to other (Annex-I) countries, linking of the EU ETS with other regional policies, or replacement of the policy by a global one are on the European agenda.

A route-based scheme could cover emissions from vessels arriving in European ports, departing from European ports, or both. It would trigger evasive behavior of ships preferring to go to non-EU ports and it also creates an incentive for non-participating ports to try to establish themselves as a hub for intercontinental ships. At the hub, the cargo could be transferred to boats that move between EU ports and the hub, and in that case the largest part of the intercontinental carbon emissions would not require allowances (Kågeson, 2007). Alternatively, the policy could only apply to inter-EU shipping but obviously this reduces the environmental effectiveness and lowers the GHG emissions in the cap (Faber et al., 2009). This option has been applied, for example, for the aviation emission trading scheme in Europe.

A time-based scheme covers all GHG emissions from fuel used during a certain period of time before calling at a European port, and is therefore similar to a route-based scheme. A distortion of competitiveness could arise since operators are stimulated not to call in European ports for a single journey, where he has to hand over allowances also for earlier travels – depending on the period of time the policy applies to Faber et al. (2009). This option likely faces legal feasibility problems and probably does not receive much support in the international debate considering that also emissions that have nothing to do with EU waters or ports could be included in the policy.

A geographical area-based scheme can cover emissions from vessels in the territorial waters (12 mile zone), in the exclusive economic zone (200 mile zone), on the continental shelf, or within the European Monitoring and Evaluation Program (EMEP, CE Delft et al., 2006). Depending on the costs associated with emissions ships can decide to avoid these waters, thereby undermining the effectiveness of the policy to a bigger or lesser extent. What is more important than ship behavior for this option is the coverage in itself. GHG emissions in territorial waters account only for a small percentage of total emissions from the ship's voyage, resulting in low environmental effectiveness of this option. It is estimated that, taking into account also intro-EU voyages, 12% of total emissions is emitted within the territorial sea zone (Faber et al., 2009). Basing the policy on the exclusive economic zone or continental shelf obviously reduces this problem.

## 6. Some mechanisms for a global policy on maritime $CO_2$ emissions

When analyzing the inclusion of the maritime transport sector in the EU ETS it became clear that the main challenges to make such a regional approach work are: (1) to decide on how to allocate shipping emissions to countries, and (2) to avoid the threat of carbon leakage and thereby evasion of the policy's effectiveness. Theoretically, the first two problems could be solved when the maritime transport sector is involved in a global mechanism to reduce the sector's $CO_2$ emissions: in a global system there would be no need for emission allocation to Parties (UNFCCC SBTA option 1: no allocation) and due to global coverage there is no room for ships to avoid regions that impose stricter regulations. Apart from that, there are administrative difficulties related to the great variety in ship type, size, and usage within the sector that can be addressed by using fuel consumption as the basis for emission calculations. Various options exist when designing a global regulation for maritime shipping. For all non-voluntary options it holds that the shipping sector (or practically: the IMO) could be included as a separate Party in the Kyoto protocol in order to be held accountable for the achievement of its abatement targets. This chapter will analyze several mechanisms for a global policy on maritime $CO_2$ emissions.

### 6.1. Global emissions trading

A Maritime Emission Trading Scheme (METS) is a global cap-and-trade system for the maritime transport sector only. The revenues from auctioning could be returned to the sector by means of subsidies on green technologies, or used for a technology fund to assist (companies in) developing countries in their mitigation efforts (Kågeson, 2008). In a closed system there is no interaction with other (regional) emission trading markets or sectors. In an open system, the METS would be linked to other markets, which allows for trade with other sectors that may face a lower marginal abatement cost than the shipping sector, favoring cost-effectiveness. The volume of allowances and the number of potential participants would also be much greater in an open system, which benefits market transparency and trade, but which could create more uncertainty (Kågeson, 2008). In a METS with global coverage there would be no carbon leakage caused by ships avoiding regions that have implemented a (regional) emission trading scheme. In summary, a global METS that is open to other sectors and that allocates permits by means of auctioning would generate the benefits of a cap-and-trade system without facing the problems related to inclusion of the sector in a regional emissions trading system.

### 6.2. Global cap and tax

A Maritime Emission Reduction Scheme (MERS) is a hybrid system combining a cap on total $CO_2$ emissions from international maritime transport with a tax on all its emissions. In the proposal that is under discussion in MEPC, the revenues of the taxes go to a fund that will be used for technical and operational industry improvements to increase the sectors abatement potential, the purchase of offset credits in the emission trading markets to make sure the sector stays below the predefined cap, and climate change adaptation in developing countries (Stochniol, 2007). The proposal suggests an emission charge of 40% of the market price of $CO_2$ allowances (set annually), and an emission cap that is until 2050 set at 2005 emission levels, and that decreases with 1% a year after 2050. It is calculated that with a charge of $10 and coverage of more than 2/3 of total maritime transport emissions, the fund would consist of $3 billion annually. This is translated into total environmental benefits in terms of lower abatement of 15 Gt $CO_2$ before 2050: 7 Gt $CO_2$ due to the technical and operational industry improvements and 8 Gt $CO_2$ due to emission offsets (Stochniol, 2007). A benefit of this system compared to an international maritime emission trading scheme is that it avoids set-up cost of a global trade system and transaction cost related to trading. A similar proposal combines a cap on total emissions with a flat bunker levy. However, as the levy is paid together with the fuel, the system could be subject to evasion as ships go bunkering in non-participating ports or offshore (Kågeson, 2008). It is suggested to link the levy to the cost related to offsetting to the levy, causing the levy to rise with non-compliance of ships – and vice-versa.

### 6.3. Global sectoral crediting

A Maritime Sector Crediting Mechanism (MSCM) is a voluntary mechanism where, again, baselines of emissions for the entire sector are set, but a reduction of emissions below that baseline generates tradable credits for the sector as a whole. It is fairly similar to a cap-and-trade approach, which can be thought of as ex-ante crediting. Making carbon marketable does create the incentives to reduce emissions but due to the voluntary nature there is no enforcement backing-up the system. For the same reason, the IMO needs to redirect incentives to individual sources to avoid non-cooperation and free-riding behavior. Generally, this mechanism is envisaged to encourage particularly developing countries to participate in GHG reduction. The system can only be implemented as complementary to an open cap-and-trade systems already in place as those systems are to guarantee the demand for the offsetting credits. As SCM is voluntary, the future supply of credits from this system is highly unpredictable. Given that demand is relatively stable and predictable, an unforeseen large credit supply reduces the carbon price and could therefore have far fetching effects on the incentives to mitigate GHG emissions also in other sectors (Baron et al., 2009).

As pointed out a global policy to regulate GHG emissions from shipping sector has to overcome several challenges to make such a policy successful. However, a policy framework combining technological options and marked based policies would be more efficient to achieve higher reduction targets for the abatement of GHG emissions from ships. The following section gives a brief picture of the current available technology options to reduce fuel consumption and to abate air emissions and GHG from ships fuel consumption. The section provides also a cost-effectiveness analysis of such technological options in order to give a magnitude of such costs within market-based policies framework. In fact, due to the high costs of some technological options, indeed, the maritime transport sector as a whole is expected to become a net-buyer of allowances in any emission trading scheme (Kågeson, 2007).

## 7. Technology to abate air emissions and GHG from ships

The maritime transport sector has a higher inertia to possible change compared to other transportation sectors. However, an increased awareness of the environmental impacts of the sector may represent the catalyst that leads shipping to move towards increased efficiency (Motorship, 2009). In addition, the global economic crisis and the high volatility of the fossil fuel prices are now attracting the interest of the entire maritime community, as they attempt to reconcile the environmental and economic objectives related to fuel consumption.

The detailed description of all the possible technological options is beyond the aim of the present paper,[8] which is focused on main elements for a cost-effectiveness assessment of the available technologies to abate $CO_2$ emissions from ships. The different technologies are grouped into four categories depending on the specific sector in which they are used. These categories are (Wartsila Corporation, 2009): (i) ship design, (ii) propulsion, (iii) machinery, and (iv) operation. Main available sources to derive the abatement potential of different technological options are the last two IMO reports (IMO, 2009, 2010a, 2010b) and a report by the Det Norske Veritas (DNV, 2009). Main available data sources for the measures cost-effectiveness are IMO (2009), DNV (2009), and Eide et al. (2009).

In Tables 1 and 2, information on the abatement potential of different technological options and their cost-effectiveness are reported. Different sources are taken into considerations to provide information also on their differences and the related uncertainties that have to be dealt with in this analysis.

The reported technologies are now available, ready to be employed immediately, and with proven results. These include air cavity systems, wind power, fuel additives, twin propellers, new propeller blades, recovering the waste gas heat, and so on (Miola et al., 2010). All of them together with the use of alternative "greener" fuels can contribute to reduce $NO_x$ emissions by up 80%, PM up to 90%, $SO_x$ up to 90%, and $CO_2$ emissions up to 70% (IMO, 2009).

Fig. 1 shows the average value of both cost-effectiveness and abatement potential, derived from the different sources comparing the effectiveness of the different measures. The IDs reported in the Fig. 1 have their correspondents in the Tables 1 and 2.

Fig. 1 identifies as the most effective measures: (i) the introduction of transverse thruster openings (ships design), (ii) the use of alternative (e.g. silicon based) hull coatings (operation), (iii) the use of towing kytes, (iv) the monitoring of the propeller's performance (propulsion), and (v) the reduction of the vessels' average speed (in order to reduce fuel consumption).

These measures could immediately lead to a 13% of fuel saving and the abatement of the related emissions, with an overall cost-effectiveness of 500$ saved per ton of $CO_2$ abated. This means that the sector has certainly the capability to start realizing GHG abatement itself (according to DNV (2009) the adoption of all the cost-effective measures may lead to a 20% of emissions and fuel savings) by cost-efficient manner.

## 8. Discussion and conclusions

Climate change policy needs to be able to promote collective actions while safeguarding flexibility and diversity. Due to uncertain future benefits and high present costs the issue faces the risk of time-inconsistency behavior, triggering policymakers to opt for unambitious environmental policies. Combining these considerations with the internal features of the international maritime transportation sector – being the most international sector with ships changing flag continuously and being highly diverse in type, size, and usage – explains partly the inability of the UNFCCC and the IMO to implement a clear-cut GHG reduction policy. The complexity of climate change policy for the international maritime transport sector requires: (1) policymakers to set binding and ambitious long-term emission reduction goals, (2) economic incentives that encourage taking action in a flexible manner, (3) knowledge and technology sharing of innovative mitigation practices, and (4) transparency, administrative feasibility, and easy-to-enforce monitoring and enforcement mechanisms. Moreover, if the sector is included as a separate Party in the post-Kyoto Protocol, a fund needs to be created to assist developing countries in addressing climate change. In this way, a global cap on bunker fuels regardless of flag or country would be in line with the "equal treatment" principle of the IMO while the financial support corresponds to the "common but differentiated responsibilities" concept of the international climate change negotiations.

[8] Please refer to the Annex B in Miola et al. (2010).

**Table 1**
$CO_2$ abatement potential for different technological measures to abate fuel consumption and emission from the maritime traffic.

| Category | ID | Measure | $CO_2$ reduction potential (Mt) | | $CO_2$ reduction potential (%) | |
|---|---|---|---|---|---|---|
| | | | DNV (2009) | IMO (2009) | DNV (2009)[a] | IMO (2009)[b] |
| **Design** | 1 | Air cavity lubrication | 50 | 16 | 3.27 | 1.28 |
| | 2 | Transverse thruster openings | – | 30 | – | 2.55 |
| **Operation** | 3 | Alternative hull coating | – | 45 | – | 3.60 |
| | 4 | Hull condition maintenance | 15 | 35 | 0.98 | 2.80 |
| | 5 | Propeller efficiency maintenance | 5 | 25 | 0.33 | 2.00 |
| | 6 | Speed reduction (fleet expansion) | 130 | 100 | 8.50 | 8.00 |
| | 7 | Speed reduction (Port turn around reduction) | 60 | – | 3.92 | – |
| | 8 | Trim/draft optimization | 10 | – | 0.65 | – |
| | 9 | Voyage execution (include optimum speed) | 30 | – | 1.96 | – |
| | 10 | Weather routing | 60 | 3 | 3.92 | 0.24 |
| **Machinery** | 11 | Cold ironing | 10 | – | 0.65 | – |
| | 12 | Common-rail upgrade | – | 3.2 | – | 0.26 |
| | 13 | Exhaust gas boiler on aux. engines | – | – | – | – |
| | 14 | Electronic engine control | 20 | – | 1.31 | – |
| | 15 | Engine monitoring & tuning | – | 5 | – | 0.40 |
| | 16 | Frequency convertor for electric motors | 40 | – | 2.61 | – |
| | 18 | Fuel consumption meter | – | 13.5 | – | 1.08 |
| | 17 | Fuel cell | 20 | – | 1.31 | – |
| | 19 | Gas fueled machinery | 90 | – | 5.88 | – |
| | 20 | Novell light system | – | 0.4 | – | 0.03 |
| | – | Reduced auxiliary power | – | – | – | – |
| | 21 | Shaft power meter | – | 13.5 | – | 1.08 |
| | 22 | Solar panel | – | – | – | – |
| | 23 | Steam plant optimization | 5 | – | 0.33 | – |
| | 24 | Waste heat recovery | 100 | – | 6.54 | – |
| | – | Wind generator | – | – | – | – |
| **Propulsion** | 25 | Contra-rotating propellers | 75 | – | 4.90 | – |
| | 26 | Fixed sails or wings | 20 | – | 1.31 | – |
| | 27 | Kite | 50 | 70 | 3.27 | 5.60 |
| | 28 | Propeller performance monitoring | – | 25 | – | 2.00 |
| | 29 | Propulsion efficiency devices | 25 | – | 1.63 | – |

[a] DNV (2009) refers to 2030 $CO_2$ emissions, estimated by DNV to be of 1530 Mt.
[b] IMO (2009) refers to 2020 $CO_2$ emissions, estimated to be of 1250 Mt.

Claims are being made within the international maritime transport sector that a sector-wide cap on its emissions is not inappropriate in the absence of global and regional regulation of the transport sector in general. This claim is partly justified by the fact that the sector is the most carbon extensive transport mode. However, absolute $CO_2$ emissions from international maritime shipping are estimated to account for 2.7% of total global emissions of in 2007 and are expected to increase with 150–300% by 2050 (IMO, 2009). Moreover, policy making to reduce GHG emissions in other transport sectors does indeed take place. For example, the EU has adopted legislation to regulate $CO_2$ emissions from road transport that enters into force in January 2010, and has agreed already as early as July 2008 upon including the Aviation sector within the EU ETS by 2012 (Europa, 2010). The IMO has researched that the sector's maximum abatement potential lies between 210 and 440 Mt of $CO_2$, which is 15–30% of the total emissions of the vessels taken into account. The IMO should set an ambitious emission cap and furthermore decide on a sectoral market-based instrument to give the appropriate incentives to operators to reduce their emissions at the lowest cost. The Energy Efficiency Design Index will only be environmentally effective if it sets an ambitious mandatory efficiency limit and does not include a grandfather clause saying that it only holds for new ships. Even then, the sector could profit from a market-based policy instead as it is expected to be more cost-effective than the EEDI.

A global maritime emission trading scheme that is open to other sectors and that allocates permits by means of auctioning is a valid option for the international maritime transport sector. A hybrid system that combines a cap with a tax has the benefit that it does not require the set-up of a global trade system and is thus easier to administer while still giving incentives to the sector to reduce its emissions. However, it does involve taxing of all $CO_2$ emissions and can therefore be less cost-effective for relatively green operators. A voluntary crediting system would gain more support from the operators itself while still giving incentives to reduce the opportunity cost of emitting $CO_2$. The downside of such a policy is that uncertain and possibly high supply of credits can distort the emissions trading market that the sector is linked to. Although the European Union prefers a global approach it will include the maritime sector in its environmental regulations if no agreement is reached for the sector by 2011. The aim of the EU is in this case to extend or to replace the policy such that all emissions are included in the cap.

It is not politically feasible that an agreement on how to allocate emissions to Member States will be reached, as each allocation option leaves some countries disadvantaged. Inclusion of the maritime transport sector within the EU ETS could be done by attributing emissions to the vessel – regardless of flag – and making the operator responsible for handing over the permits, or by including separately within the scheme. The main threat for unilateral regulation is carbon leakage and competitiveness concerns due to incomplete coverage, which the EU addresses by grandfathering (part) of the permits. Since recently also carbon dependent border-adjustment policies have been opted to address these concerns. Finally, a unilateral policy can be based on a geographical area (territorial waters, exclusive economical zone), a specific time before calling in a European port, or on

**Table 2**
Cost-effectiveness of different technological measures to abate fuel consumption and emission from the maritime traffic.

| Category | ID | Measure | Cost per ton of $CO_2$ averted ($/t) | | | | |
|---|---|---|---|---|---|---|---|
| | | | Eide et al. (2009)[a] | | DNV (2009)[b] | IMO (2009)[c] | |
| | | | Min | Max | Average | Min | Max |
| Design | 1 | Air cavity lubrication | – | – | −30 | −150 | −90 |
| | 2 | Transverse thruster openings | – | – | – | −160 | −140 |
| Operation | 3 | Alternative hull coating | −105 | −100 | – | −150 | −15 |
| | 4 | Hull condition maintenance | – | – | −20 | −155 | −35 |
| | 5 | Propeller efficiency maintenance | −100 | 30 | −45 | −160 | −65 |
| | 6 | Speed reduction (fleet expansion) | – | – | 90 | 80 | 135 |
| | 7 | Speed reduction (Port turn around reduction) | −100 | −50 | −70 | – | – |
| | 8 | Trim/draft optimization | −110 | −100 | −70 | – | – |
| | 9 | Voyage execution (include optimum speed) | – | – | −90 | – | – |
| | 10 | Weather routing | −110 | −100 | −30 | −165 | −100 |
| Machinery | 11 | Cold ironing | – | – | 205 | – | – |
| | 12 | Common-rail upgrade | – | – | – | −125 | 45 |
| | 13 | Exhaust gas boiler on aux. engines | – | | 190 | – | – |
| | 14 | Electronic engine control | −80 | 20 | 25 | – | – |
| | 15 | Engine monitoring & tuning | – | – | −75 | −90 | 470 |
| | 16 | Frequency convertor for electric motors | – | – | 50 | – | – |
| | 17 | Fuel cell | 220 | 250 | 55 | – | – |
| | 18 | Fuel consumption meter | – | – | – | −60 | 330 |
| | 19 | Gas fueled machinery | – | – | 20 | – | – |
| | 20 | Novell light system (LED based) | – | – | – | −95 | 440 |
| | 21 | Shaft power meter | – | – | – | −105 | 115 |
| | 22 | Solar panel | 300 | 450 | – | – | – |
| | 23 | Steam plant optimization | – | – | −90 | – | – |
| | 24 | Waste heat recovery | 0 | 180 | 150 | – | – |
| Propulsion | 25 | Contra-rotating propellers | – | – | −30 | – | – |
| | 26 | Fixed sails or wings | – | – | 105 | – | – |
| | 27 | Kite | −60 | −60 | 0 | −135 | −75 |
| | – | Pre-swirl stator | −100 | −80 | – | – | – |
| | 28 | Propeller performance monitoring | – | – | – | −160 | −130 |
| | 29 | Propulsion efficiency devices | – | – | −70 | – | – |

[a] Estimates from Eide et al. (2009) consider different scenarios of fuel price. Those reported here refer to the scenario, which consider a fuel price of 600$/t. In this study the cost-effectiveness is calculated for two ship categories, bulk carriers (Max estimate) and container ships (Min estimate).
[b] Estimates from DNV are derived from Eide et al. (2009), but consider the whole fleet.
[c] Estimates in IMO (2009) consider a 500$/ton fuel price, a 4% discount rate and 2020 as base year.

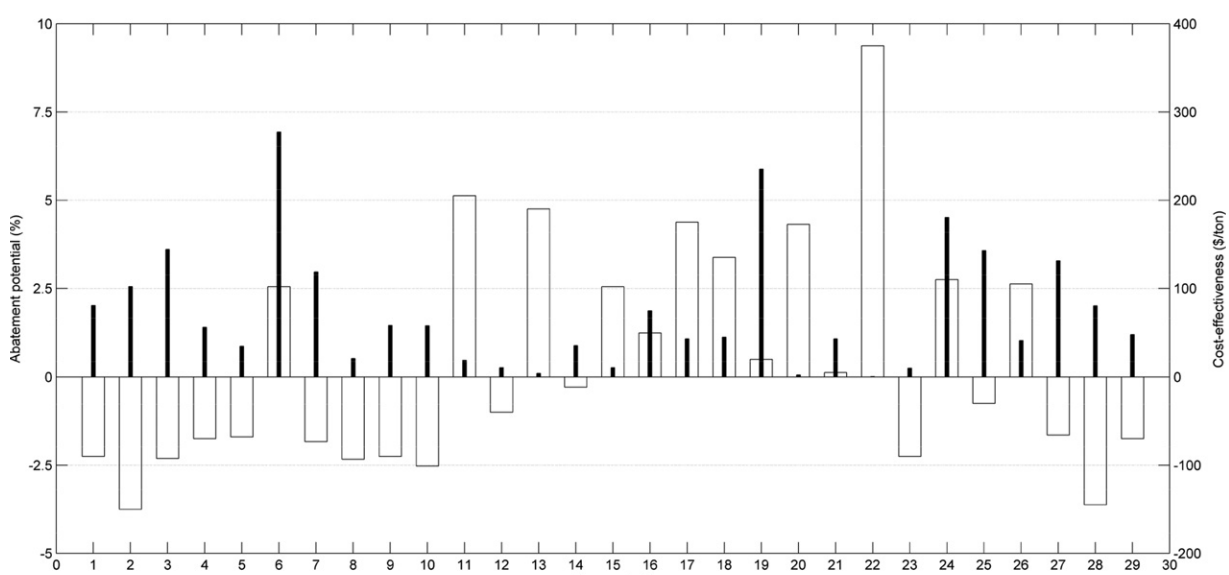


**Fig. 1.** Average environmental and economic effectiveness for different technological measures to abate fuel consumption and emission from the maritime traffic (technological measure IDs refer to those reported in Tables 1 and 2).

specific routes (arriving in EU ports, departing from there or only inter-EU ports). Obviously, this choice affects both environmental effectiveness as competitiveness and carbon leakage. For global or regional trading policies, transaction cost can be high. As they are found to exhibit significant economies of scale, this problem is more severe for vessels emitting low amounts of carbon.

Therefore it is advisable to exempt small installations from a part of their monitoring and reporting requirements by reducing for example the frequency of mandatory controlling visits or to exclude small installations from the trading system completely.

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