Environmental Engineering and Management Journal October 2011, Vol.10, No. 10, 1589-1596
http://omicron.ch.tuiasi.ro/EEMJ/

"Gheorghe Asachi" Technical University of Iasi, Romania

CLIMATE CHANGE POLICY IN SHIPPING FOCUSING ON EMISSION STANDARDS AND TECHNOLOGY MEASURES

Christos A. Kontovas·, Harilaos N. Psaraftis

Laboratory for Maritime Transport, School of Naval Architecture and Marine Engineering
National Technical University of Athens, 9 Iroon Polytechneiou, Zografou, Greece

Abstract

There is a growing concern that the Earth's atmospheric composition is being altered by human activities which can lead to climate change. Policy measures to reduce carbon dioxide emissions are on the agenda of the International Maritime Organization (IMO) and the European Union (EU). Climate Change is an environmental problem and answers have to be sought among robust environmental policies that are often classified in market-based, command-and-control and voluntary instruments. Although there is evidence that many uncertainties surround the climate change phenomenon and the contribution of shipping, shipping is under severe political pressure. The paper presents an overview of the related uncertainties and environmental policies and focuses on emission standards and technology solutions. From a political point of view, it is easier to pass legislation that calls for technological and operational measures and may indeed have a high potential in reducing emissions.

Key words: climate change policy, emission standards, environmental policy, market based instruments, shipping policy

Received: April, 2011; Revised final: September, 2011; Accepted: October, 2011

1. Introduction

Air pollution from ships and especially carbon dioxide emissions are currently at the center stage of discussion by the world shipping community. The Kyoto Protocol (UNFCCC, 1997) gave the International Maritime Organization (IMO) the task of tackling bunker emissions, but until now not a single binding measure has been agreed. Although some regulation exists for non-Greenhouse Gases (GHGs), such as SO_2, NO_x and others, shipping has thus far escaped being included in the Kyoto global emissions reduction target for CO_2 (Quesada et al., 2010).

It is well known that fossil fuels such as marine bunkers contain high percentage of carbon and hydrocarbons and the burning of these fuels produces carbon dioxide which is one the GHGs (Gaba, 2010). According to the United Nations Framework Convention on Climate Change (UNFCCC), carbon dioxide enhances radiative forcing and contributes to global warming which is the increase in the average temperature of the Earth's near-surface air and oceans (IPCC, 2007).

As noted in the second IMO GHG Study 2009 (Buhaug et al., 2009) that was submitted to the Marine Protection Environment Committee (MEPC) of the IMO, transportation produces roughly 27.7% of the world's CO_2 emissions of which roughly 21.3% of those are from road transportation, 2.6% from aviation, 0.5% from rail, and 3.3% from all marine transportation. Carrying over 90% of world trade, international shipping contributes just 2.7% to global anthropogenic CO_2 which is a sign of a remarkably efficient industry and a very environmentally friendly mode of transportation. In more detail, total CO_2 emissions from shipping (both domestic and international) are estimated to 1,046 million tons (in 2007), or 3.3% of global CO_2 emissions (Buhaug et al., 2009). However, CO_2 emission estimates vary among different studies, see for example Psaraftis and Kontovas (2009a), Buhaug et al. (2009), (Appendix

· Author to whom all correspondence should be addressed: E-mail: kontovas@mail.ntua.gr; Phone: +30 210 772 1410

1) and Miola and Ciuffo (2011) for a comparison of activities based inventories.

A fortiori, it is much more difficult to estimate future emissions. Many scenarios for future GHG emissions, including those presented in Buhaug et al. (2009) are based on assumptions on global development in the IPCC (Intergovernmental Panel on Climate Change) Special Report on Emissions Scenario (SRES) storylines. However, extreme uncertainties exist in these trajectories. For instance, the difference between the most optimistic and most pessimistic scenario for maritime transport emissions projected to 2050 is by a factor of 10 (Buhaug et al., 2009), and even these two extremes are not known with absolute certainty. According to most studies, containerships are the top carbon dioxide emitters (Buhaug et al., 2009; Psaraftis and Kontovas, 2009a). Furthermore, a dramatic economic recession has been witnessed during the last two years. As a result, ships including these top polluters had to sail at lower speeds and a high percentage of the container fleet was idle. Although the models predicted some increase of the emissions, even in the short term this did not happen. And these models do not examine what will happen if the trans-siberian railway or the Arctic sea route between East Asia and Europe becomes commercially attractive. Therefore it is very difficult to estimate the exact amount of emissions that shipping currently emits and will emit in the future.

A major issue at yet another level regards the contribution of shipping to climate change. There is no doubt that international shipping has been a fast growing sector of the global economy and its share on total anthropogenic emissions has increased lately. However, the nature of the contribution to climate change is complex. In addition to warming by CO_2 emissions, ship emissions of sulfur dioxide (SO_2) cause cooling through effects on atmospheric particles and clouds, while nitrogen oxides (NO_x) increase the levels of the greenhouse gas ozone (O_3) and reduce the GHG methane (CH_4), causing warming and cooling, respectively and the result is a net global mean radiative forcing (RF) from the shipping sector that is currently strongly negative (Eyring et al., 2009; Gavrilescu, 2008). One could go into more deep details on every one of the uncertainties described above or even into more generic ones. For example, Schelling (2007) poses some questions that expose the relevant uncertainties. How much carbon dioxide may join the atmosphere in a business as usual scenario? How much average warming is to be expected from a specific increase in the concentration of GHGs? How will this average warming translate into climate change and what the effects will be in 50 or 150 years from now?

The scope of this paper is to alarm the reader and not focus too much on the uncertainties. Furthermore, the uncertainties described above should not be a reason for inaction which is inline with the so-called "Precautionary Principle".

From the environmental economics' point of view, climate change is *"the greatest and widest-ranging market failure ever seen"*, presenting a unique challenge for economics (Stern, 2006). In environmental policy-making, policies are often classified in market-based, command-and-control and voluntary instruments. Economists are usually in favor of market based instruments (MBI) and most of them are in favor of taxes because of their simplicity. However shipping is a complex industry. Based on the principle of equal treatment for all ships, developed countries are also urging all Member-States to quickly adopt emission reduction regulation, noting that most of the world tonnage is registered in non-Annex I countries though. On the other hand, many countries including China, Brazil, India and other developing countries are totally against MBIs. Developing countries argue that IMO should apply the "Common But Differentiated Responsibilities" (CBDR) principle also used in the Kyoto Protocol. Clearly, a balance should be achieved between the Kyoto protocol's principle of CBDR and IMO's principle of "no more favorable treatment" which means that any MBI should not for instance penalize vessels based upon their flag. In shipping, a ship can easily shift its flag to a non-Annex I country in order not to be affected by the relative regulation (IMO, 2010e). It is indeed apparent that these two principles are not compatible. For more on this issue see Wang (2010) who investigates the economic costs of CO_2 reduction with and without considering the CBDR under different regulatory scenarios and discusses the policy concerns of developing countries. What is, therefore, important is to study all feasible solutions and especially those that are simple, cost effective and those that could easily pass politically. This is in line with Stiglitz (2006) who states that the biggest problem with Kyoto is *"to bring the developing countries within the fold"*.

To that extent, the next Section discusses the possible ways to internalize the cost of externalities according to standard economic theory including also some proposals that have been submitted to the Marine Environment Protection Committee (MEPC) of the IMO and form the basis of the international shipping regulations. Section 3 presents the case of emission standards and Section 4 the case of technological measures. Finally, Section 5 concludes the paper.

2. Environmental policy in theory

2.1. Incentive-based Strategies

Incentive-based environmental policies require that public authorities set the targets of emission reductions and the rules; and leave the firms to adopt cost-effective emission control measures. There are basically two categories of incentive policies: (1) charges and subsides and (2) transferable emission permits. Most of the discussion within the IMO currently focuses in emission charges and transferable permits.

More precisely, charges are emission taxes or fees levied on the discharges. Most economists favor emissions taxes following the idea of Pigou (1920) that by charging for every unit of emissions released firms tend to reduce their emissions. Note that obtaining all necessary information to impose the ideal tax is quite costly and, in practice, regulators determine the charge by using the trial-and-error process. The biggest problem of such a system is the effective monitoring. On the other hand, tradable emission permits allow the voluntary transfer of the right to emit from one firm to another. In this system firms are allocated a number of emission permits and are entitled to emit one unit per permit but these permits are transferable. A market for these permits will eventually develop and firms that can reduce emissions at a low cost may prefer to sell its permit to a firm that can reduce pollution only at a high cost (Field and Field, 2009).

One may notice that these two systems lead to equivalent results in the long term but with different uncertainty in the outcome. A tax provides for cost certainty; the cost is fixed because of the Pigovian tax. Trading permits, on the other hand, provides for environmental certainty. What's fixed is the cap itself and it is based on an assessment of the level of emissions you need to get to in order to protect the climate. In that sense, if the cap is set too high, as in the early stages of the EU Emission Trading Scheme (ETS), permit prices will be low and the incentive effect will be weak. If the cap is set too low, permit prices will be very high and that can lead to the disruption of economy and trade.

Regarding the application of these measures in shipping, a document submitted to the IMO by Cyprus, Denmark, the Marshall Islands and Nigeria describes a "tax" for GHGs (IMO, 2010a), originally proposed by Denmark. Even though the most recently adopted name is 'international GHG fund scheme', the scheme is essentially a levy on bunker fuel paid for by the party buying the fuel. According to the relevant submission, all ships of gross tonnage (GT) above 400 GT engaged in international trade would be subject to GHG contributions established at a given cost level per tonne of fuel bunkered. Fuel suppliers will then transfer the contributions to the Fund and these will be allocated for purposes consistent with the objectives of the Kyoto Protocol. The proposal sounds simple, is indeed a tax and as a market based policy it can guarantee the emissions reduction that IMO seeks. The implementation of the system also looks simple as there is already a regulation for bunker fuel supplier to maintain records of bunkers sold. However, there are some key points that deserve extra attention. First of all, a more detailed regulation has to be developed in order to be able to identify ships that are engaged in international trade– although it would be good for the environment to impose a tax in every ship. Secondly, a key element for the success of this proposal is that ships must buy fuel at registered fuel suppliers only and therefore Member-States should require that all fuel suppliers within their territory become register suppliers. Ship operators should also be required to purchase fuel only from these suppliers. Finally, the GHG contribution per tonne has to change over time in order to ensure that the agreed GHG emission reduction targets are achieved.

On the other hand, regarding an allowance trading system in shipping, things are more complicated. A submission from Norway presented some basic aspects of such a system (IMO, 2008a; 2010b). Submissions of Germany, France and Norway (IMO, 2009) and of United Kingdom also support this scheme (IMO, 2010c). Emission reductions can be achieved by setting a cap on emissions from international shipping, and then allowing through trading of emission allowances the target could be met. Ships will then need to surrender allowances for the emissions they create by acquiring allowances and credits from within the sector or buy them from other sectors. The allowances could be distributed by free allocation or auctioning. The establishment of a cap and target periods are very crucial (IMO, 2009). The cap is also responsible for the price volatility which is another serious drawback of an emissions trading scheme. While carbon taxes directly control the price of emissions, cap-and-trade controls the quantity of emissions but with much more volatility in energy-related prices. This increased volatility that is evident in both US acid rain program and EU ETS can seriously affect business investments. Investors (companies and governments) cannot make investment decision when future carbon prices are so uncertain (Kontovas and Psaraftis, 2010b).

In December 2009, a report (CE Delft, 2009) written for the European Commission was finalized. Due to the lack of progress in the IMO, the European Commission launched that study to provide the Commission's services with technical input to support the development of a policy to reduce greenhouse gas emissions from maritime transport. The IMO is under political pressure to be included in Kyoto and the stated intent of EU to propose measures for shipping in the event the IMO fails to reach a decision by the end of 2011 would (at least in theory) provide a push to regulate emissions through market based instruments. Indeed, and even though China, Brazil, India and other developing countries are against MBMs, an Expert Group was established to undertake a feasibility study and impact assessment of the various proposals submitted for a market-based measures for international shipping (IMO, 2010e). In any case, the authors feel that this political pressure to adopt a market-based instrument without much analysis of both pros and cons is not logical.

2.2. Emission Standards in Theory

Historically, emission standards have been the most popular approach to control environmental pollution. Emission standards do create incentives for R&D in emissions control and can have a positive effect in the problem that we are discussing although we do admit that are weaker than those of economic incentive types that we described in the previous Section. However, we believe that they have to be the first approach to deal with the problem of carbon dioxide emissions as it will be easier to be applied by most IMO-member states.

In public policy, a Command and Control (CAC) approach is one where the regulator mandates the behavior in law to what is thought to be socially desirable (Field and Field, 2009). As the name implies, this approach consists of a "command", which sets a standard and a "control", which monitors and enforces the standard (Asafu-Adjaye, 2005).

There are three main types of standards: ambient, technology and emission. In brief, ambient standards are environmental quality levels in the ambient environment, such as a city or a port, and are usually expressed as average concentration level over some period of time. On the other hand, technology standards specify the technologies or techniques that should be adopted and do not specify some end result, such as a threshold level (Field and Field, 2009). For example, the requirement that all ships should be equipped with scrubbers in order to lower sulfur dioxide emissions is a technology standard. Furthermore, the regulator may specify operational measures, such as a mandatory speed reduction measure. The third types of standards are the so-called emission standards (or performance standards) and regulate the level of emissions allowed. Standards may impose a ceiling on total emissions in a period or a maximum allowable emissions rate, something that IMO has set in the case of NOx emissions.

The advantages of standards is that they are the most widely understood form of environmental policy and the most pragmatic approach in the case of environmental protection under uncertainty. Furthermore, this is the most favorite form of environmental policy for politicians since it has the lowest political cost, way lower compared to market based instruments (Hanley et al., 2006). On the other hand, the biggest disadvantages of standards are that the threshold is difficult to be determined and that under a CAC approach firms have no incentive to reduce emissions beyond the standards. Note also that this approach is effective only when the penalties are high and the enforcement methods are strong enough (Asafu-Adjaye, 2005; Field and Field, 2009).

3. Emission standards in practice

3.1. Standards in practice: Examples from various other sectors

In most cases emissions standards are firstly tested in voluntary agreements and when it seems that they work then become mandatory. For example, the so called ACEA agreement was an agreement between the European Commission and the European Automobile Manufacturers Association (ACEA) that was signed in 1998 and sought to achieve an average of 140 g/km of CO_2 by 2008 for new passenger vehicles sold in the EU. The ultimate target is to reach an average of 130 g/km by 2015. Being a voluntary agreement this system was a failure although some reduction was achieved. In April 2009, the European Commission (EC) published Regulation No 443/2009 which sets the average CO_2 emissions for new passenger cars at 130 g CO_2/km, by means of improvement in vehicle motor technology (European Parliament, 2009). This is in line with the NOx standards already being used in shipping.

Similarly, on September 15, 2009, the US Environmental Protection Agency (EPA) and the Department of Transportation's National Highway Safety Administration (NHTSA) proposed a National Program (U.S. EPA, 2010) that could reduce emissions and improve fuel economy for new cars and trucks sold in the United States according to which they propose a limit of an average CO_2 emissions at approximately 155 g CO_2/km (250 g CO_2/mile).

The International Civil Aviation Organization (ICAO) is also developing a global carbon dioxide standard for new aircraft types, among other recommendations from the organization's committee on aviation environmental protection (CAEP). CAEP met at ICAO headquarters from 1-12 February 2010, in Montreal, Canada, and announced the ICAO's commitment to the development of a carbon dioxide standard for commercial aircraft by 2013.

3.2. Emission standards in shipping

As discussed above, emissions standards are the most popular approach to control environmental pollution and are currently being used by the IMO to control NOx and SOx emissions. IMO pollution rules are contained in the "International Convention on the Prevention of Pollution from Ships", known as MARPOL 73/78. In 1997, the MARPOL Convention has been amended to include Annex VI titled "Regulations for the Prevention of Air Pollution from Ships" which sets limits on NOx and SOx emissions from ship exhausts (IMO, 2008c).

Effective in July of 2005, MARPOL Annex VI (Regulation 13) set limits (in g/kWh) on emissions of nitrogen oxides (NOx) from diesel engines that are over 130 kW. The NOx emission limits depend on the engine maximum operating speed. Under this rule, the shipowner and, ultimately, the engine manufacturer are required to provide certification that the engine meets the IMO NOx Technical Code when delivered to the vessel (IMO, 2008c).

The MARPOL Annex VI (Regulation 14) controls apply to SOx emissions and include a global cap of 4.5% on the sulphur content of fuel oil. All fuel oils for use onboard a vessel covered by this annex will need to be ordered, and verified from the bunker receipt on delivery, as having a maximum sulphur content of 4.5% m/m. Furthermore, SOx Emission

Control Areas (SECAs) were established in the Baltic and Northern Sea with more stringent controls on sulphur emissions. A new emissions control area in North America will become effective in August 2012. In these areas, the sulphur content of fuel oil used onboard ships should not exceed 1.5%. The alternative is that ships must fit an exhaust gas cleaning system or use any other technological method to limit SOx emissions to less or equal to 6 g/kWh (IMO, 2008c).

Performance standards regarding carbon dioxide emissions are also currently under discussion at the IMO and will be briefly analyzed in the following paragraphs. The IMO's Energy Efficiency Design Index (EEDI), in conjunction with the Energy Efficiency Operational Indicator (EEOI) was designed so as to help shipping achieve fuel efficiency and consequently a reduction in GHG emissions. However, the extent to which this will be truly achieved is subject to considerable debate.

Energy Efficiency Design Index (EEDI)

MEPC 58 discussed the use of the draft Interim Guidelines on the Energy Efficiency Design Index for new ships (IMO, 2008b) for calculation and trial purposes with a view to further refinement and improvement. The original objective was to establish a mandatory Energy Efficiency Design Index of the environmental performance of new ships within 2010 or 2011. Note that EEDI was finally adopted in July 2011.

The attained new ship Energy Efficiency Design Index is a measure of ships CO_2 efficiency and is defined as (Eq. 1):

$$\frac{\left(\prod_{j=1}^{M} f_j\right)\left(\sum_{i=1}^{nME} C_{FMEi}\, SFC_{MEi}\, P_{MEi}\right) + P_{AE} C_{FAE} SFC^*_{AE} + \left(\sum_{i=1}^{nPTI} P_{PTIi} - \sum_{i=1}^{nWHR} P_{WHRi}\right) C_{FAE} SFC_{AE} - \left(\sum_{i=1}^{neff} f_{eff} P_{eff} C_{FMEi} SFC_{MEi}\right)}{fi\ Capacity\ \ V_{ref}\ \ f_W} \quad (1)$$

The index seems complicated, but basic idea is that the numerator indicates CO_2 emission from main and auxiliary engines with a deduction from energy recovery systems that improve fuel efficiency and the denominator is based on the maximum design load condition (Capacity) and the design speed (V_{ref}).

In the case of a mandatory EEDI a baseline will be used as a limit for new designs. Given that the most obvious way to affect EEDI values is to reduce installed main engine power and thus reduce design speed, EEDI probably means a power limit for new ships.

Furthermore, deficiencies in the formula for the EEDI baseline were also identified in a submission to the IMO by Greece (IMO, 2010d) and ways on how to alleviate these deficiencies were proposed. An important caveat concerns the speed data that is used in the regressions. To the extent that ship speeds are drawn from databases, caution is necessary on how they are obtained, how they are used and how the results of the regression curves are interpreted. Furthermore, whatever the regression formula is, half of the sample ships, have an EEDI above the baseline, which in and of itself, is a problem. The authors believe that there is a serious physical inconsistency between (a) the EEDI formula and (b) the formula for the EEDI baseline (the so-called EEDI 'reference line'). In (a), and assuming that ship engine MCR grows like the cube of speed, EEDI grows like speed squared. In (b), speed does not enter the formula at all. This combination is tantamount to a speed limit, and that this speed limit can often be below the current operating speeds of several classes of ships.

Finally, Devanney (2010) states that EEDI induces owners to use smaller bore, higher RPM engines which will consume more fuel when the market is not in a boom and ships have to sail at slower speeds. In any case, EEDI is to be applied only on new designs and its potential to reduce current emissions is limited.

Energy Efficiency Operational Indicator (EEOI)

The EEOI (IMO, 2008b) is defined as the CO_2 efficiency of ships in terms of CO_2 emissions per unit transport work and may be expressed as (Eq. 2):

$$EEOI = \frac{\sum_{i} FC_i \times C_{Fi}}{m_{cargo} \times D} \quad (2)$$

where: FC is the fuel consumption, C the emission factor that converts fuel consumption to mass of CO_2 emissions, m the cargo transported and D the distance. The indicator is therefore defined as the ratio of mass CO_2 emitted per unit of transportation work, and this implies energy efficiency of a ship in operation.

The EEOI is currently voluntary and can measure the CO_2 efficiency based on its operational profile. On the other hand, EEDI is under development with the objective to arrive to a mandatory index for new designs. In practice this could also be applied to current ships but it would then be somehow similar to the EEOI. Actually, EEDI and EEOI follow the same principle, that is both indices express the ratio between the cost (i.e emissions) and the benefits that is generated (Buhaug et al., 2009).

EEOI as a performance indicator is intended as tool for evaluating the environmental efficiency of a ship or a fleet and it would allow a company to work out trends relative to the efficiency of its fleet and thus not only to achieve emission reduction but also reductions in fuel costs – that is the double dividend for a shipping company when reducing fuel consumption. Note that a mandatory EEOI has been discussed in 2008 but there is still not enough support from Member-States. In the case of a mandatory EEOI, the most effective ways to reduce the index is to steam at a lower speed or limit the cargo that the vessels are carrying. These are the easy solutions but this does not mean that these are the correct ones.

To sum up, a command-and-control policy could promote efficiency by demanding the use of a certain control technology or measure that is so effective and widely available and that requiring the installation of that technology or the mandatory use of that measure makes much more sense than regulating emissions by other means. Catalytic converters for cars and double hull tankers are both good examples. In the case of carbon dioxide there are currently no widely available and cost effective technology alternatives, however, operational measures that could become mandatory may exist. For example, speed reduction measures are proven to be cost-effective and may conceivably have a large potential to reduce emissions. It should be noted that operational measures and technology are somewhat under-investigated within the IMO. This is indeed wrong since new technologies can be proven cost effective and very radical in emissions reduction such as the example of catalytic converters that was discussed previously. The next Section focuses on technical innovation and operational measures that could be proven to be cost effective. There is no doubt that some of them may pass easily and can also provide drastic reduction of carbon dioxide emissions.

4. Technical innovation, operational measures and emissions reduction

As noted in the Second IMO GHG study (Buhaug, 2009) there are several technology measures and practices that have a great potential to reduce carbon dioxide emissions, see Table 1. For instance, using renewable energy sources, such as the wind and the sun, or alternative fuels such as biofuels and natural gas should be considered in R&D Projects.

However, first and foremost ship operators and regulator should work closely with engine manufacturers in order to improve the energy efficiency of the engines that they produce. Energy recovery from exhausts, controlling Common Rail fuel injection; turbocharging and variable valve timing are available techniques that can be used in order to achieve more efficient engines. Note for example, the reduction in the Specific Fuel Oil Consumption (SFOC) of marine engines which is a measure of fuel consumption in relation to work done. For large engines built before 1983 the average specific fuel oil consumption was 205 g/kW-h, between 1984 and 2000 it dropped to 185 and after then it came as low as 175 which are the average values used in the Second IMO GHG study (Buhaug et al., 2009).Thus, historically it has been proven that engines can become more and more energy efficient although the constant SFOC for the newest engines implies that raising the already high efficiency level of modern engines is nowadays limited.

As discussed in the previous Section, emissions standards in g/kWh have been set in MARPOL Annex VI (Regulations 13 and 14) for SOx and NOx emissions (IMO, 2008c). The authors therefore believe that a similar CO_2 limit should be considered. In line with this rationale, an emissions standard in gr CO2 per tonne nm will be placed for new ship when the mandatory EEDI will be adopted.

Furthermore, the shippers or the ship owners should not be penalized by imposing market based instruments. In the same sense it would be rather naïve to blame a car driver for emitting too much of CO_2 per Km –the car manufacturer can only be blamed. The car driver might be conceivably blamed for emitting too much carbon dioxide by using the car too much, even when this is not necessary. On top of that, it would be much more efficient to set emission standards regarding the engine or the ship itself and let the engine maker and the shipbuilder come back with innovative technical ideas regarding more efficient engines, hulls, propellers, and so on.

Still, it should be noted that as most of the above apply only to new ships, any emissions reduction will be realized only in the medium to long term. In the short term, operational measures have also a great potential to reduce emissions and have to be seriously considered. Thus, in the short term operational measures will curb emissions, while at the same time R&D can produce more efficient engines and other technologies will become mature.

Table 1. Potential reduction of CO_2 emissions from shipping by using known technology and practices (Buhaug et al., 2009)

DESIGN (New Ships)	***Saving (%) of CO_2/(Tonne*Mile)***	***Combined***	***Combined***
Concept, speed & capability	2-50*	10-50%+	25-75%+
Hull and superstructure	2-20		
Power and propulsion systems	5-15		
Low-carbon fuels	5-15*		
Renewable energy	1-10		
Exhaust gas CO_2 reduction	0		
OPERATION (All ships)			
Fleet management, logistics & incentives	5-50+	10-50%+	
Voyage Optimization	1-10		
Energy Managament	1-10		

+ *Reductions at this level would require reductions of speed*
* *CO_2 equivalent based on the use of Liquefied Natural Gas (LNG)*

Then the implementation of these measures will have a long term reduction which can be greater than the one achieved by market based instruments.

As presented in Table 1, operational measures such as speed reduction may have a high emissions reduction potential. However, speed reduction is a complex issue: reducing speed will indeed reduce fuel consumption, which means lower fuel cost for the operator and less emissions for the environment. Thus, at a first, speed reduction seems a good solution. But reduced speed comes at a cost and that is increased time at see which will distort the market as more ships will be needed to carry the same throughput per year. More ships do not necessarily mean more total emissions (Psaraftis and Kontovas, 2009b). Last year when freight rates were low and fuel prices were high, it was indeed profitable to reduce speed and slow steaming was a notable phenomenon in the container market. Note also that two US Ports, the Port of Long Beach and the Port of Los Angeles, offer a 15% discount on dockage fees to vessels that voluntary comply with a so-called Vessel Speed Reduction Program and reduce their speed to 12 knots within 40nm of Point Fermin while entering or leaving the ports (Kontovas and Psaraftis, 2010a). Clearly, in most cases slow steaming is a “win-win” scenario: it reduces fuel consumption which means bunker cost savings and reduced emissions.

To sum up, there is evidence that operational measures have not been carefully investigated. These measures can be easily implemented by operators since they play a major role in fuel reduction. Bunker cost is a cost that every shipowner wants to minimize. Fuel economy also means reduced emissions. Therefore it is suggested that policy makers should also try to focus on operational measures.

5. Discussion and conclusions

Air pollution from ships is currently at the center stage of discussion by the world shipping community. The role of the IMO is very important as it is the United Nations agency responsible for shipping. Article 2.2 of the Kyoto Protocol gave IMO the task of tackling bunker emissions, but until now not a single binding measure has been agreed for Greenhouse Gases (GHGs). Although some regulation exists for non-GHGs, such as SO_2, NOx and others, shipping has thus far escaped being included in the Kyoto global emissions reduction target for GHGs. Given the potential catastrophic effect of Climate Change there is a need for immediate action. Environmental policies that should be used include incentive-based strategies, for example emission charges or tradable permits and emission standards. There is no doubt that market based instruments have the highest potential in reducing emissions. That is the reason for being at the center stage of the discussion within IMO. However, the “Common But Differentiated Responsibilities” (CBDR) principle used in the Kyoto Protocol is clearly incompatible with the IMO's principle of "no more favorable treatment".

In any case, it is out of the scope of this work to comment into detail on these issues. The purpose of this paper is to address measures that can be easily implemented, could be supported by most IMO member-states and stakeholders, including shippers, and will result in substantial emissions reductions. IMO is discussing some of these measures however they are not given high priority. A regulator, for example IMO, can specify the technical construction or operational practices for a ship to meet the standard. For example, an operational emission standard or performance standard requires a ship to meet certain levels of CO_2 emissions per unit of work during operation - that is a mandatory Energy Efficiency Operational Index (EEOI).

As discussed above the International Civil Aviation Organization is moving towards defining standards for new airplanes and that is also the case for cars (both in the European Union and the United States). It is interesting to note that the European Union which threatens to include shipping in its Emissions Trading System (ETS) has chosen to establish absolute emission standards in road transportation. The authors believe that a good way to reduce emissions from shipping is to set similar standards for the marine engines. Engine manufactures can use technological measures to improve the fuel consumption of their engines and thus to reduce emissions. This should be considered very carefully since at the moment it looks like that the shipper is the only responsible for reducing emissions. For the operator, operational measures such as speed reduction look therefore more attractive but a realistic solution has to take into account those that produce the engines and not those that run the ships.

Finally, we repeat that shipping carrying over 90% of world trade, and emitting just 2.7% of global anthropogenic CO_2 -this is a sign of a remarkably efficient industry. Shipping as the most environmentally friendly mode of transportation, serves the world trade and development and should contribute to its share of responsibility of Climate Change.

Acknowledgment

We would like to thank the Editor and two anonymous referees for comments that substantially improved the manuscript.

References

Asafu-Adjaye J., (2005), *Environmental economics for non-economists: techniques and policies for sustainable development*, 2nd Edition, World Scientific Publishing, Hackensack, NJ.

Buhaug Ø., Corbett J.J., Endresen Ø., Eyring V., Faber J., Hanayama S., Lee D.S., Lee D., Lindstad H., Markowska A.Z., Mjelde A., Nelissen D., Nilsen J., Pålsson C., Winebrake J.J., Wu W.Q., Yoshida K.,

(2010), *Second IMO GHG study 2009* , International Maritime Organization (IMO) London, UK.
CE Delft, (2009), *Technical support for European action to reducing Greenhouse Gas Emissions*, Report to the European Commission, Tender DG ENV.C3/ATA/2008/0016, On line at: http://ec.europa.eu/environment/air/transport/pdf/ghg_ships_%20report.pdf
Devanney J., (2010), EEDI: A Case Study in Indirect Regulation of CO2 Pollution, Center for Tankship Excellence, On line at: http://www.c4tx.org/ctx/pub/
EPA, (2010), EPA and NHTSA to Propose Greenhouse Gas and Fuel Efficiency Standards for Heavy-Duty Trucks; Begin Process for Further Light-Duty Standards: Regulatory Announcement, On line at: http://www.epa.gov/otaq/climate/regulations/420f10038.htm
European Parliament, (2009), Reduction of CO_2 emissions from light-duty vehicles: emission performance standards for new passenger cars (1753/2000/EC), Final legislative act, European Parliament, On line at: http://www.europarl.europa.eu/oeil/file.jsp?id=5582632
Eyring V., Isaksen I., Berntsen T., Collins W., Corbett J., Endresen O., Grainger R., Moldanova J., Schlager H., Stevenson D., (2010), Transport impacts on atmosphere and climate: Shipping, *Atmospheric Environment*, **44**, 4735-4771.
Field B., Field M., (2009), *Environmental Economics*, 5th Edition, McGraw-Hill, San Francisco, CA.
Gaba A., (2010), Air pollution reduction by using of low NOx burners for furnaces and boilers, *Environmental Engineering and Management Journal*, **9**, 165-170.
Gavrilescu D., (2008), Carbon dioxide generation – implications for Romanian pulp and paper industry, *Environmental Engineering and Management Journal*, **7**, 111-117.
Hanley N., Shogren J., White B., (2006), *Environmental Economics: In Theory and Practice*, 2nd Edition, Palgrave Macmillan, London.
IMO, (2008a), Document GHG-WG 1/5/5 - Consideration of elements needed in market mechanism to reduce GHG emissions from international shipping, Submitted by Norway, International Maritime Organization.
IMO, (2008b), Document MEPC 58/23 - Report of the Marine Environment Protection Committee on its Fifty-Eight Session, Submitted by the Secretariat, International Maritime Organization.
IMO, (2008c), Document MEPC 58/23 –Annex VI, Submitted by the Secretariat, International Maritime Organization.
IMO, (2009), Document MEPC 59/4/25- Positive Aspects of a Global Emission Trading Scheme for International Shipping, Submitted by France, Germany and Norway, International Maritime Organization.
IMO, (2010a), Document MEPC 60/4/8 - An International Fund for Greenhouse Gas emissions from ships, Submitted by Cyprus, Denmark, the Marshall Islands, Nigeria and IPTA, International Maritime Organization.
IMO, (2010b), Document MEPC 60/4/22 - A further outline of a Global Emission Trading System (ETS) for International Shipping, Submitted by Norway, International Maritime Organization.
IMO, (2010c), Document MEPC 60/4/26 - A global emissions trading system for greenhouse gas emissions from international shipping, Submitted by United Kingdom, International Maritime Organization.
IMO (2010d), Document MEPC 60/4/26 - Comments on the EEDI Baseline Formula, Submitted by Greece, International Maritime Organization.
IMO, (2010e), Document MEPC 61/INF.2 - Full report of the work undertaken by the Expert Group on Feasibility Study and Impact Assessment of possible Market-based Measures, 13 August 2010, International Maritime Organization.
IPCC, (2007), *Climate Change 2007: The Physical Science Basis - Contribution of Working Group I to the Fourth Assessment, Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
Kontovas C.A., Psaraftis H.N., (2010a), *Reduction of Emissions Along the Intermodal Container Chain*, Proc. 2010 Annual Conference of the International Association of Maritime Economists (IAME), July 2010, Lisbon, Portugal.
Kontovas C.A., Psaraftis H.N., (2010b), *Carbon Dioxide Emissions Valuation and its Uses*, Proc. 3rd International Symposium on Ship Operations, Management & Economics of the Society of Naval Architects an Marine Engineers (SNAME), 7-8 October, Athens, Greece.
Miola A., Ciuffo B., (2011), Estimating air emissions from ships: Meta-analysis of modelling approaches and available data sources, *Atmospheric Environment*, **45**(13), 2242-2251.
Pigou, (1920), *The economics of welfare*, 4th edition, Macmillan, London.
Psaraftis H.N., Kontovas C.A., (2009a), CO_2 emissions statistics for the world commercial fleet, *WMU Journal of Maritime Affairs*, **8**, 1-25.
Psaraftis H.N., Kontovas C.A., (2009b), *Ship Emissions: Logistics and Other Tradeoffs*, Proc. 10th Int. Marine Design Conference (IMDC), 26-29 May, Trondheim, Norway.
Quesada J.M., Villar E., Madrid-Salvador V., Molina V., (2010), The gap between CO_2 emissions and allocation rights in the Spanish industry, *Environmental Engineering and Management Journal*, **9**, 1161-1164.
Schelling T., (2007), Climate Change: The Uncertainties, the Certainties and What They Imply About Action, *The Economists' Voice*, **4**(3), Article 3.
Stern N., (2006), *Stern Review on The Economics of Climate Change. Executive Summary*, HM Treasury, London.
Stiglitz J., (2006), A New Agenda for Global Warming, *The Economists' Voice*, **3**(7), Article 3.
UNFCC, (1997), Kyoto Protocol to the United Nations Framework Convention on Climate Change, On line at: http://unfccc.int/resource/docs/convkp/kpeng.htm
Wang H., (2010), Economic costs of CO_2 emissions reduction for non-Annex I countries in international shipping, *Energy for Sustainable Development*, **14**(4), 280-286.