INTERNATIONAL MARITIME ORGANIZATION

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MARINE ENVIRONMENT PROTECTION COMMITTEE
60th session
Agenda item 4

MEPC 60/INF.19
15 January 2010
ENGLISH ONLY

PREVENTION OF AIR POLLUTION FROM SHIPS

Updated Marginal Abatement Cost Curves for shipping

Submitted by Norway

SUMMARY

Executive summary:	This document presents work undertaken by DNV on CO_2 Marginal Abatement Cost Curves (MACC) for shipping towards 2030 based on an assessment on the cost and potential of 25 greenhouse gas abatement measures across 59 ship segments
Strategic direction:	7.3
High-level action:	7.3.1
Planned output:	7.3.1.3
Action to be taken:	Paragraph 2
Related documents:	MEPC 59/4/24, MEPC 59/INF.10 and MEPC 60/4/23

Introduction

1 This document summarizes the analysis using the A1B and B2 Intergovernmental Panel on Climate Change (IPCC) growth scenarios and baselines from the 2nd IMO GHG study as basis for the fleet growth estimates. The results show that shipping could cut just above 30% of emission relative to a business-as-usual baseline in 2030 in a cost-effective manner. This would reduce the emission level by between 510 and 670 MT depending on the growth scenario chosen. By implementing all the measures included in DNV's study, over 50% reduction can be achieved. Reducing emissions below the present level will be expensive with the measures known today only. Structural measures (e.g., new shipping business models and contracts), however, may have a significant potential to reduce emission beyond what is described in this study.

Action requested of the Committee

2 The Committee is invited to note and make use of the information in this document, as appropriate, in the further work on reduction of greenhouse gas emissions from international shipping.

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ANNEX

COST-EFFECTIVE REDUCTION OF CO_2 TOWARDS 2030

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Executive summary

DNV has developed CO_2 Marginal Abatement Cost Curves (MACC) for shipping towards 2030 based on an assessment on the cost and potential of 25 greenhouse gas abatement measures across 59 ship segments. This document summarizes the analysis using the A1B and B2 Intergovernmental Panel on Climate Change (IPCC) growth scenarios and baselines from the 2nd IMO GHG study as basis for the fleet growth estimates. The results show that shipping could cut just above 30% of emission relative to a business-as-usual baseline in 2030 in a cost-effective manner. This would reduce the emission level by between 510 and 670 MT depending on the growth scenario chosen. By implementing all the measures included in DNV's study, over 50% reduction can be achieved. Reducing emissions below the present level will be expensive with the measures known today only. Structural measures (e.g., new shipping business models and contracts), however, may have a significant potential to reduce emission beyond what is described in this study.

Introduction

In shipping, as in society at large, an intense debate is underway regarding the technical and economic feasibility of different CO_2 reduction target levels, which emission reduction measures should be pursued, and the costs of different options for meeting the reduction target levels. Shipping is already facing expectations from various stakeholders on emission levels and emission reduction targets for specific years, independent of the choice of specific instruments to achieve the targets (e.g., emission trading scheme and global fuel levy).

To provide a quantitative basis for these discussions, DNV has compiled a database comprised of an assessment on the cost and potential of 25 CO_2 emission reducing measures across 59 ship segments, with the purpose gaining insight in various reduction measures and creating Marginal Abatement Cost Curves (MACC) for shipping towards 2030. The first results were presented in two recently published papers: *Pathways to Low Carbon Shipping*[i,ii]. The purpose of this document is to adapt the study and results to the baselines and growth scenarios (IPCC A1B and B2) most commonly used within the IMO, to demonstrate the potential CO_2 emission reduction and the associated costs.

Methodology

The research done in DNV aims to identify the CO_2 abatement potential and cost on measures for the world fleet in 2020 and 2030, and to produce marginal abatement cost curves for shipping. The current world fleet consists of approximately 100,000 ships above 100 GT which can be divided into 68 different segments (e.g., crude oil tankers >200,000 dwt and container ships < 1,000 TEU). This study has been limited to cover 59 of the segments representing about 60,000 ships in 2007 and increasing to between 80,000 to 100,000 ships by 2030 depending on the growth scenario used. Service and fishing vessels were not included in this assessment, as the technical and operational characteristics of these vessels are very different from cargo transporting ships.

DNV uses an activity based model[iii,iv] calculating fuel consumption and exhaust gas emission from all relevant compounds, including CO_2, which is the focus of this study. The emission calculations are based on installed power, time at sea and fuel consumption and the different fleet segments are modelled separately. The model is different from previous models for future fleet emissions in that it allows for modelling of the introduction of measures in the fleet through explicitly keeping track of new builds coming into the fleet and the scrapping of obsolete ships. The future world fleet is constructed using growth and scrapping rates to find the number of ships in operation for a given year in a given ship segment. The baseline values and segmentation used in the research to simulate the future world fleet is based on the 2nd IMO GHG study[v].

In each segment an average ship has been used to represent all ships in that segment. Ships within a segment will share a number of common characteristics, such as: general trading areas, major hull lines, speed and cargo capacities. Due to these similarities one can use average values for speed, engine size, ship size, operating profile, etc., per segment to assess the CO_2 reduction effect and cost of a given reduction measure. The values are based on the average or typical ship within a segment and will produce a reasonable estimate for all the ships in this segment. By assessing the cost and potential on the average ship in each segment, the total fleet can be analysed efficiently.

Each of the segments and measures has been modelled separately with regard to:

- operational assumptions (e.g., speed, days at sea, average fuel consumption)
- emission reduction potential of each measure in 2010, 2020 and 2030
- investment and operational costs of each measure in 2010, 2020 and 2030
- year of phase-in of available measures
- operational lifetime of measures

For each ship segment, and for every applicable emission reduction measures, a cost per tonne CO_2 avoided and a total reduction potential is calculated[vi]. The cost of implementing a measure includes both initial costs (e.g., design and installation) and operational costs (e.g., maintenance, training and lost revenue).

Cost issues that have not been covered are external cost savings due to reduced local emissions such as NO_x, SO_x and particles, and reduced maintenance costs due to lower number of engine running hours.

Baselines and assumptions

The consensus emission estimate for the world fleet in 2007 was 1,046 MT CO_2, of which 870 MT were emitted by international shipping[v]. The growth scenarios used in this document are the A1B and B2 scenarios of the IPCC, which have been adapted to shipping[v]. A1B assumes rapid and successful economic development, economic and cultural convergence globally, pursuit of personal wealth and use of a balanced mix of energy sources. In contrast B2 emphasizes on local solutions to economic, social and environmental sustainability, with continuously increasing population and intermediate economic development.

The growth rates have been applied on the total shipping emission level, which will be used throughout this document. Table 1 shows the emission level in 2007 and the business-as-usual (BAU) baselines for 2020 and 2030 under the A1B and B2 growth scenarios.

Mt CO_2/year	**Baseline**	**Scenario A1B**		**Scenario B2**	
	2007	**2020**	**2030**	**2020**	**2030**
Total shipping	1,046	1,443	1,962	1,283	1,574

Table 1: Shipping emission level baselines including both domestic and international shipping

By including a scrapping rate, the renewal rate of the fleet is taken into account. A high-scrapping rate will ensure a faster uptake of new technologies. For simplicity, a common scrapping rate has been used for all ship types of 3% p.a. from 2012. Because of the recent high growth and subsequent slow-down a 4% rate p.a. from 2007 to 2012 has been used.

The fuel price is an important input to the model as all benefits are directly linked to the fuel savings resulting from many of the measures. The fuel prices used in the model are set to 500 $/T for MDO, 350 $/T for HFO and 450 $/T for LNG[1] in 2007. The MDO and HFO prices are held constant, while the LNG prices are gradually reduced to 350 $/T in 2030. The results are sensitive to changes in the fuel prices.

The costs and benefits are calculated annually during the expected remaining operational lifetime of the vessel or the expected lifetime of the measure (whichever is shortest), and depreciated to a present value using an annual risk-free rate of 5% (real)[vii].

Assessed measures

The measures included in the study are presented in Table 2, including an indication whether the measure has been modelled implemented on new ships, existing ships or all ships. It can be assumed that there will be incremental improvements on hull and machinery which is considered a no-cost measure – meaning it is part of business-as-usual. These improvements have been taken into account through the measure "General improvements".

Alternative energy sources			
Measure	**Applies to**	**Measure**	**Applies to**
Gas-fuelled engines	New ships	Wind power: Kite	All ships
Wind generator	All ships	Wind power: Fixed sails or wings	All ships
Solar panels	All ships		
Operational improvements to reduce fuel consumption			
Measure	**Applies to**	**Measure**	**Applies to**
Trim/draft	All ships	Engine monitoring	Existing ships
Weather routing	All ships	Speed reduction (port efficiency)	All ships
Voyage execution	All ships	Propeller efficiency	All ships
Steam plant operation improvements	All ships		
Technical measures to reduce main engine fuel consumption			
Measure	**Applies to**	**Measure**	**Applies to**
Electronically controlled engines	New ships	Air cavity/lubrication	New ships
Waste heat recovery	New ships	Contra-rotating propeller	New ships
Speed reduction (fleet increase)	All ships	Propulsion efficiency devices	All ships
Hull condition	All ships	General improvements	New ships
Technical measures to reduce auxiliary engine fuel consumption			
Measure	**Applies to**	**Measure**	**Applies to**
Cold ironing	All ships	Reduced auxiliary power use	Existing ships
Fuel cells as auxiliary engines (including fuel switching)	New ships	Exhaust gas boilers on auxiliary engines	New ships
Frequency converters	New ships	Energy efficient light system	New ships

Table 2: Measures assessed in this study

1 Based on prices delivered in Japan and a surcharge for delivery.

Results and conclusions

Table 3, Figure 1 and Table 4 illustrate how much emissions can be reduced for the world fleet in 2020 and 2030, with different marginal costs levels. Figure 2 shows the continuous marginal cost curves and respective emission level achieved, when reduction potential is subtracted from the emission baseline in the given year. The total emission level achieved at a certain marginal cost can be read directly from the chart.

Shipping could cut just above 30% of emission relative to the BAU baseline in 2030 in a cost-effective manner. This would reduce the annual emission level by between 510 and 670 MT depending on the scenario chosen. By implementing all measures included in the DNV study, over 50% reduction can be achieved. Reducing emissions below the present level will be costly with the measures known today only and modelled growth.

Marginal cost level	Scenario A1B		Scenario B2	
	2020 [MT CO_2]	2030 [MT CO_2]	2020 [MT CO_2]	2030 [MT CO_2]
<0 $/tonne	360	669	306	511
<50 $/tonne	443	842	379	643
<100 $/tonne	501	942	429	722
All measures	576	1,054	491	813

Table 3: Reduction potential on world fleet for different marginal cost levels

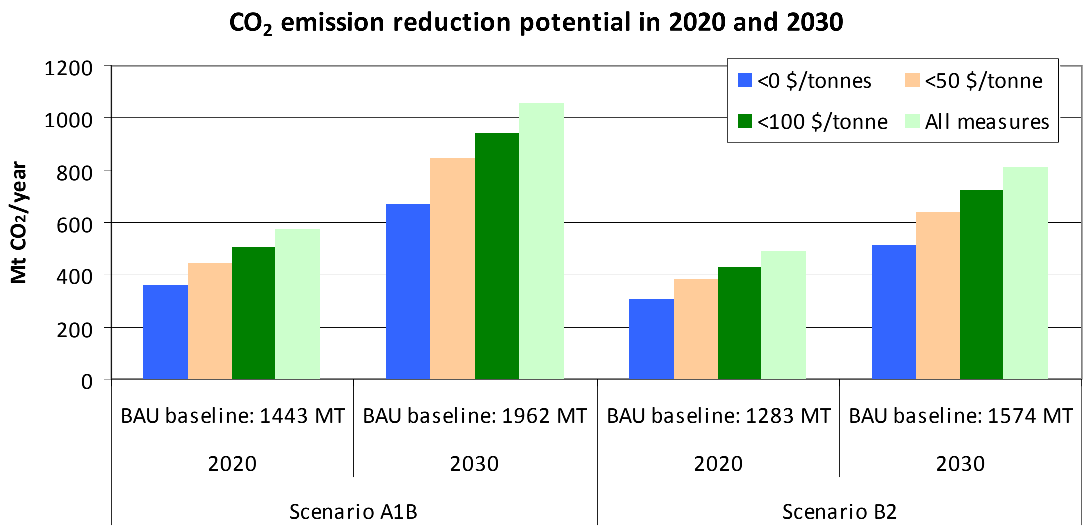

Figure 1: Reduction potential on world fleet for different marginal cost levels. The bars show the emission reduction when applying all measures with a marginal cost lower than that given in the label

Marginal cost level	Scenario A1B		Scenario B2	
	2020	2030	2020	2030
<0 $/tonne	25%	34%	24%	32%
<50 $/tonne	31%	43%	30%	41%
<100 $/tonne	35%	48%	33%	46%
All measures	40%	54%	38%	52%

Table 4: Reduction potential relative to BAU baselines (total shipping) for different marginal cost levels

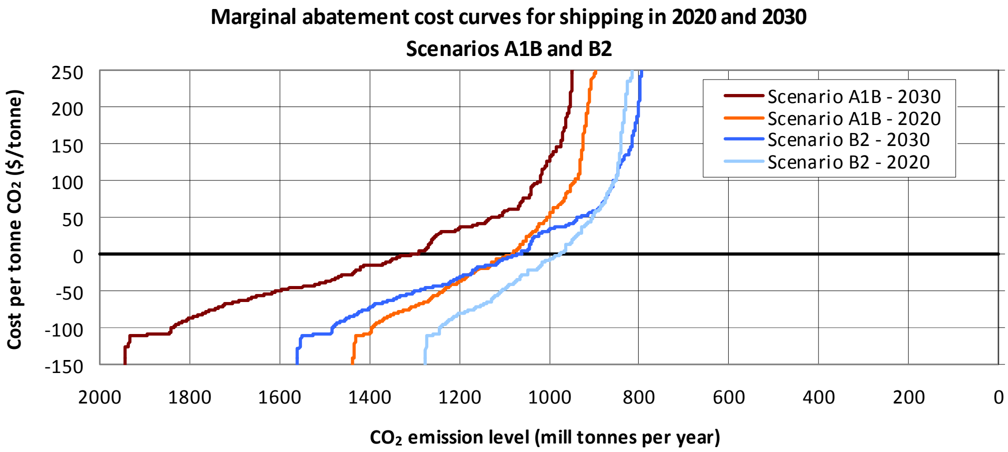

Figure 2: Marginal abatement cost curves for 2020 and 2030 under the A1B and B2 growth scenarios. The curves show the marginal cost (y-axis) for reaching a certain emission level (x-axis). The lines will move to the right with higher reduction potentials. The left ends of the curves indicate the baseline emissions (total shipping) for the different years and growth scenarios

By choosing a wide scope and applying the assessment on the total world fleet, the depth to which individual emission reduction measures can be explored is limited, as well as their applicability to individual ships or ship segments. It is likely that when analysed in detail, a given abatement measure will have different effect and cost for two ships within the same segment. This level of detail cannot realistically be included in a fleet-wide model, and must be covered by more detailed models, and the results presented here should not be used for individual ships. Making assumptions on a wide range of parameters, e.g., fuel cost, discount rates, cost, reduction potential and fleet development, create a large uncertainty range. There is however significant value to be taken from the work as it takes a global and fleet-wide view using a single consistent methodology, building on the in-depth work of others. The aim is to allow an effective comparison of the cost and reduction of different opportunities.

The most important technical and operational measures have been included, but other measures can be added to the study to further extend the results. Further, DNV foresee that many new measures will emerge in the next two decades, and some of them may have significant effect also before 2030. The measures included in this study only to a small extent include structural measures, where all players in shipping work together to reduce emission. Examples on such measures are improved contracts between charterers and shippers or fewer ballast journeys. Structural measures may have a significant potential to reduce emission beyond what is described in this study.

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i Pathways to Low Carbon Shipping – abatement potential towards 2030, DNV, 15 December 2009.

ii Pathways to Low Carbon Shipping, DNV, 9 June 2009.

iii Eide, M.S., Endresen, Ø. and Longva, T. (2009): Future CO_2 Emissions: Outlook and Challenges for the Shipping Industry, paper presented at IMDC 2009.

iv CO_2 emissions form shipping – technical and operational options for emission reduction, DNV and LR, Submission from Norway, MEPC 58/INF.14, October 2008.

v Buhaug, Ø., Corbett, J.J., Endresen, Ø., Eyring, V., Faber, J., Hanayama, S., Lee, D.S., Lee, D., Lindstad, H., Markowska, A.Z., Mjelde, A., Nelissen, D., Nilsen, J., Pålsson, C., Winebrake, J.J., Wu, W.–Q.,Yoshida, K., 2009. Second IMO GHG study 2009, International Maritime Organization (IMO), London, UK, April 2009.

vi Eide, M., Endresen, Ø., Skjong, R., Longva, T., Alvik, S. (2009): Cost-effectiveness assessment of CO_2 reducing measures in shipping, Maritime Policy and Management, 36:4, 367-384.

vii Longva, T., Eide, M. S., Skjong, R. (2010): Determining a Required Energy Efficiency Design Index Level for New Ships Based on a Cost-Effectiveness Criterion, Maritime Policy and Management, in press.