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# REDUCTION OF GHG EMISSIONS FROM SHIPS

## Marginal abatement costs and cost-effectiveness of energy-efficiency measures

**Submitted by the Institute of Marine Engineering, Science and Technology (IMarEST)**

**SUMMARY**

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| *Executive summary:* | This document provides a summary of the report of a study on the economics and cost-effectiveness of technical and operational measures to reduce $CO_2$ emissions from ships |
| *Strategic direction:* | 7.3 |
| *High-level action:* | 7.3.2 |
| *Planned output:* | 7.3.2.1 |
| *Action to be taken:* | Paragraph 18 |
| *Related documents:* | MEPC 59/INF.10, EE-WG 1/INF.2 and MEPC 61/INF.18 |


## Introduction

1 The Marine Environment Protection Committee commissioned a study of greenhouse gas emissions from ships, first published in 2000, updated in 2009 as the Second IMO GHG Study 2009, and presented it at MEPC 59. The Second IMO GHG Study shows the social costs of some existing technical and operational measures.

2 The Society of Naval Architects and Marine Engineers (SNAME) Technical and Research (T&R) Committee, in cooperation with the Institute of Marine Engineering, Science and Technology (IMarEST), conducted an in-depth analysis of the cost-effectiveness and potential for reduction of $CO_2$ emissions by technical and operational measures for improving energy efficiency. This document is a summary of that report, which is provided in MEPC 61/INF.18.

3 In February 2010, SNAME and the Marine Board of the National Academies' Transportation Research Board (TRB) convened a symposium "*Climate Change and Ships: Increasing Energy Efficiency*". A major recommendation of the symposium was to "conduct an analysis of the marginal abatement costs for vessel owners and operators to employ technologies or operational measures to increase a vessel's energy efficiency and reduce its $CO_2$ emissions". Such a project should "address the direct costs of mitigation measures and opportunity costs of mitigation". A SNAME T&R *ad hoc* panel was established to conduct a study and report on its findings.

4 This study had two primary purposes. The first was to develop a standardized methodology for examining measures to improve energy efficiency on ships. The methodology was designed to estimate the cost-effectiveness and the potential of each measure to achieve reduction in $CO_2$ emissions. The second objective of this study was to apply the methodology to the 22 abatement measures for which data were available. This analysis provided estimates of the potential for reduction in $CO_2$ emissions and associated marginal abatement costs for 14 types of new and existing ships as defined by the IMO GHG Experts Group. For each vessel type, size, and age, these cost estimates were plotted against estimated potential reduction in $CO_2$ emissions, and the marginal abatement cost curves (MACC) for each ship type were presented. Sensitivity analyses were also performed to examine the impact of fuel prices and discount rates on the cost-effectiveness of the measures. To avoid complexity, all costs are in USD$ and emission reductions are in metric tonnes of $CO_2$. This study did not assume that ship owners and operators would make the investments or employ the specific operational measures, but just demonstrated what the estimated costs and benefits would be if the necessary investment(s) were made. The report strives to present these estimates in an accessible format. Key findings should be of interest to policy-makers, ship owners and operators, and other interested parties.

5 This report follows a six-step approach:

.1 Identification of $CO_2$ abatement technologies;
.2 Calculation of the cost-effectiveness of individual measures;
.3 Evaluation of the sensitivity to input parameters;
.4 Identification of constraints on and barriers to implementation;
.5 Rank-ordering technologies and operational measures; and
.6 Calculation of MACC as a function of ship type. MACC are plots of the cost-effectiveness of additional measures against the resulting cumulative reduction in $CO_2$ emissions.

6 First, the energy-saving technology and operational measures were identified and defined. The *ad hoc* panel developed the assumptions and key parameters for each measure, as well as for the maritime shipping sector. Next the *ad hoc* panel refined the basic equations and calculated the cost-effectiveness of each energy-efficiency improvement for each measure as a function of vessel type, size and age. The cost-effectiveness was expressed as the costs per unit of $CO_2$ emissions abated. Then the *ad hoc* panel examined the sensitivity and corresponding changes in estimated cost-effectiveness in response to the fluctuations of discount rates and fuel prices. Then market barriers and other constraints on a vessel owner or operator's willingness to implement a measure or group of measures were identified. Fifth, an approach to rank-order the measures or group of measures, based on their cost-effectiveness and the appropriateness of the measure, was developed, including impacts on percent (%) reduction, ease of implementation, and other factors. The individual cost-effectiveness was combined to develop MACC. The MACC show plotted abatement costs against $CO_2$ emissions reductions for the world fleet or a segment thereof. The MACC are presented with high and low estimates, with and without speed reductions (as speed reductions are often the measure with the highest abatement potential).

7 The approach required identifying the cost and benefit items related to the applications of measures for improvement in energy efficiency. The costs include: the capital costs, costs due to loss of service and time, and operational costs. Cost savings were measured in reduced consumption of carbon-based fuel. This approach required a substantial data input. Some data required making assumptions and other qualifying limitations. A prime example was future fuel price. The methodologies included several detailed analyses that derive, delineate and address all assumptions and their respective impacts on cost-effectiveness. These assumptions included the fuel price, the discount rate,

the suitable ship types and sizes for different fuel-saving measures, freight rates, opportunity costs, and the learning rate for the introduction of new measures as this relates to capital and service or operational costs. It should be noted that data for this study on the abatement measures were obtained from published sources, including both manufacturers and other studies. The study attempted to corroborate these data by direct interviews of operators and others with experience with the measures. However, further work needs to be done on the actual in-service cost, reliability, variability, and effectiveness of these measures. SNAME's T&R *ad hoc* panel will continue to evaluate these measures.

8 Two factors were singled out for sensitivity analyses because their changes may have a significant impact on the cost-effectiveness. These were: future fuel prices and the interest or discount rate. The write-down of the costs of a technology measure, and technological progress reducing the costs of a technology over time, are related to a ship's remaining life and are incorporated into the analysis of cost-effectiveness.

9 The report describes fifty (50) technical and operational measures for improvement in energy efficiency and presents a detailed analysis of twenty-two (22) of these measures for which the *ad hoc* panel could obtain data. Of the 50 measures identified, the *ad hoc* panel was only able to analyse 22, as insufficient data exist to assess other measures. Of the 22 measures analysed, several have limited potential application to certain ship types and sizes and others may not be appropriate for existing ships. The potential cost-effectiveness for some measures varies widely and may not be cost-effective in some circumstances. The cost-effectiveness analysis examined both new and existing ships:

.1 The analysis includes an assessment of the cost-effectiveness and abatement potential of each measure (often presented as a range). The *ad hoc* panel reviewed earlier studies and identified additional measures for improvement in energy efficiency, and incorporated incorrectly categorized measures as a supporting means rather than an improvement measure (e.g., hull monitoring supports hull cleaning and polishing);

.2 The applicability of each measure was determined for new and existing vessels and 14 ship types by size and age (a total of 318 combinations);

.3 Implementation barriers and strategies to address these barriers are described in the report;

.4 A basis for projecting and applying the learning rate for new technologies was developed and used in future cost estimates;

.5 The measures were grouped into 15 groups to ensure that similar measures were identified as being mutually exclusive so as not to overestimate the potential for improvements in energy efficiency of employing multiple measures;

.6 The *ad hoc* panel reviewed data on costs and abatement potential and the applicability of individual measures to both new and existing ships, and cross-checked the results with ship owners and operators, naval architects and marine engineers;

.7 Key assumptions were examined on, for example, current and future fuel prices and discount rates. The report explicitly described assumptions and methodology in order to present a transparent analysis;

.8 The *ad hoc* panel estimated the cost-effectiveness of measures for both new and existing ships as a function of ship size and, for existing ships, by age;

.9 MACC were developed as a function of ship type for new and existing ships. The Committee examined the role of measures, such as speed reductions, on MACC estimates; and

.10 MACC were analysed as a function of ship type, and a wide range in net marginal abatement costs and ship type was identified. An analysis of the cost-effectiveness of measures for improvement in energy efficiency suggests the existence of significant differences as a function of ship type, size and vessel age. Ongoing analysis will examine MACC as a function of ship size for each ship type.

10 For each measure and for each vessel type by size and by age, where the measure is appropriate, low and high estimates of the cost-effectiveness of employing the measure were estimated. The range of estimates reflects different operating patterns of vessels and uncertainty about the cost and abatement potential of individual measures. These estimates of cost-effectiveness are for a high and a low potential in emissions reduction. For each reduction potential, there is one high cost estimate and one low cost estimate. The low and high reduction potentials are associated with the ranges and uncertainty of both the cost-effectiveness and the potential for improvement in energy efficiency for each measure. The methods and assumptions to estimate the cost-effectiveness were described in detail. Key factors about each measure were analysed, as well as decision-making by the ship owner or operator on implementation, including but not limited to cost-effectiveness, capital and opportunity costs, pay-back periods, and discount and freight rates. The cost-effectiveness and the estimates of the potential for $CO_2$ emissions reduction for each measure vary widely as a function of ship type, size, and age. The *ad hoc* panel depicted this by providing low and high estimates. A range is given because of the uncertainty with respect to the costs and abatement potential. The aggregation of these costs, when estimating the net abatement potential using MACC similarly, shows that the costs and abatement potential vary widely among types of ships.

11 In turn, MACC resulting from the analysis are presented in this report for new construction for the fourteen ship types. These MACC were based on a rank-ordering of the measures or group of measures based on the cost-effectiveness and the appropriateness of the measure to a specific ship type and size, including impact on percent (%) emissions reduction, ease of implementation, and other factors. The cost-effectiveness of individual measures was summed to develop MACC. These MACC are graphically presented in this report with high, central and low estimates for the fourteen ship types. When aggregating cost-effectiveness estimates for measures to develop MACC, analysts should be attentive to the impact that certain measures have by ship types that affect the net costs and potential of energy-efficiency improvements. For example, speed reductions for containerships have a greater potential for emissions reduction relative to slower moving vessels and most other measures. The complete data and findings for each measure, including estimated cost effectiveness and potential reduction in $CO_2$ emissions that comprise these MACC, are available at: http://www.sname.org/SNAME/climatechange/MACreport and http://www.theicct.org/programs/Marine.

12 The cost-effectiveness analysis examined both new and existing ships. One of the most striking findings is that the MACC for 2020 and 2030 show a considerable abatement potential at negative costs. This means that many of these measures are profitable (i.e. show a positive net present value) on both new and existing ships. This finding is

consistent with other MACC studies for maritime transport, although this study also looked at existing ships and is also consistent with current industrial practice (i.e. implementation on existing ships). The interpretation of these findings requires careful consideration. First, considerable cost savings and reduction in $CO_2$ emissions can accrue now and to 2020 and beyond for existing ships. Second, the meaning of this finding is that by 2020 and 2030, the energy efficiency of the world fleet may be improved considerably while lowering transport costs, assuming that fuel prices will continue to rise in real terms and that demand for maritime transport will continue to grow.

13 Net abatement costs and the corresponding reduction in potential $CO_2$ emissions are highly dependent on speed reduction. For example, when speed reductions are eliminated as a design option for containerships in 2020, the central estimate for the potential reduction in $CO_2$ emissions is almost 52% less when it is included at the same net marginal abatement costs of zero or, more simply, at no net cost. This estimate excludes all non-speed-reduction operational measures and assumes that the speed-reduction operational measures identified in this report are a proxy for design speed reductions, all else being constant. Other operational measures account for about 2-3% of potential emissions reduction at net MAC of zero. Similar, though not as dramatic results (both in absolute and relative terms) are expected from most other ship types.

14 The *ad hoc* panel found that operational abatement measures had a significant potential to reduce emissions, as do technical measures. As noted, speed reduction accounts for most of the estimated reductions in operational $CO_2$ emissions. In total, operational measures accounted for 22% to 71% of total cost-effective emissions reduction, depending on ship type.

**Possible uses of these analyses and this report**

15 The outcome of this report does not favour a particular market-based approach, or specific energy-efficiency standards. The methodologies and analyses are structured to support the development and implementation of any regulatory and/or corporate policies that may be adopted. The *ad hoc* panel also expects that the results may be used by ship designers, builders, owners and operators as a tool in their decision-making on whether to employ one or more technologies or operational measures. The methodology and inputs are structured such that each can be varied should new information be incorporated or to posit and test different views on any of the assumptions.

16 The approach allows policy-makers and others to factor in new or different information about measures and/or basic assumptions easily. As the report provides and documents the assumptions and input data, as well as a replicate approach that is easy to follow, expanded or revised analysis can be accomplished quickly in a standardized manner. In turn, these can provide customized cost-effectiveness estimates for a suite of selected measures and specific ship type, size, and age, and in turn may be used to derive customized MACC.

17 The cost-effectiveness of measures and MACC presented in this report can be used for a number of purposes:

.1 *Improve the projections of future emissions*: Emission-reduction projections can be based on projections of increased demand and estimates of improvement in energy efficiency. In many studies, these latter estimates are based on historical data or on expert judgement. By using MACC to estimate improvements in energy efficiency, more accurate projections can be made, incorporating fuel price projections and other variables. In turn, the methodology can easily provide estimated reductions in gross $CO_2$ emissions by ship type, size, and age or any combination or aggregation thereof, for any policy assessment scenario under consideration;

.2 *Improve policy design choices*: Some policies may encourage one set of measures, while other policies may take another set into account. Some policies may affect some ship owners and operators more than others or some ship types more than others. The cost-effectiveness of measures and MACC presented in this report allows policy-makers to make an informed choice about which measures to include in the governmental and company policy options. They also allow them to identify which segments of the shipping industry or an owner's fleet are affected by the policies, as well as the extent;

.3 *Assist in the assessment of policies*: MACC and corresponding estimates of the potential reduction in $CO_2$ emissions may be used to analyse the costs, effects and cost effectiveness of policy instruments. They can be used to assess the costs imposed on the shipping sector by efficiency standards, the in-sector abatement encouraged by incentives such as fuel levies or cap-and-trade schemes, and the costs and effects of baseline- and credit-trading schemes. The MACC in particular can be used to:

.3.1 support cost-benefit analysis for future regulation of the international maritime industry;

.3.2 understand how the different parts of the industry will be affected by mandated and increasing requirements for energy efficiency and reduction in $CO_2$ emissions;

.3.3 understand how a vessel owner or operator decides which energy-efficiency measures to take first, and when to employ a measure (e.g., opportunity costs, barriers, importer/shipper expectations);

.3.4 contribute to cost-benefit analyses of climate policies for shipping. By clarifying the relation between costs and effects, MACC are a crucial element of any cost-benefit analysis of policies; and

.3.5 assist ship owners and operators in the selection of abatement measures. An overview of the cost-effectiveness of the different measures and combinations of abatement measures will help ship owners and operators select the measures that may be of interest to them, thus limiting the search costs and increasing the efficiency of shipping.

**Action requested of the Committee**

18 The Committee is invited to note the report of the SNAME Technical and Research *ad hoc* panel and take action as appropriate.

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