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Agenda item 9(a) - Emissions from fuel used for international aviation and maritime transport

Technical and operational measures to improve the energy efficiency of international shipping and assessment of their effect on future emissions

November 2011

SUMMARY

July 2011 was marked by a breakthrough at IMO with the adoption of the first ever global and legally binding climate deal for an industry sector. IMO adopted a new chapter to Annex VI of the International Convention for the Prevention of Pollution from Ships (MARPOL) that includes a package of mandatory technical and operational measures to reduce GHG emissions from international shipping, with the aim of improving the energy efficiency for ships through improved design and propulsion techniques, as well as through improved operational practices. These measures are expected to enter into force on 1 January 2013.

This document by the IMO Secretariat provides detailed information on the specific technical and operational energy efficiency measures adopted, the Energy Efficiency Design Index (EEDI) and Ship Energy Efficiency Management Plan (SEEMP). Background information by the IMO Secretariat on the development of regulatory measures and associated technical policy and legal considerations related to control of greenhouse gas emissions from international shipping can be found in a separate complementary document.

In October 2011 IMO completed a study to estimate the CO_2 emission reductions resulting from the adoption of mandatory technical and operational energy efficiency measures for international shipping. A summary of the results from the study is also provided.

INTRODUCTION

1 International shipping is the most environmentally-friendly and energy efficient mode of mass transport and only a modest contributor to the total volume of atmospheric emissions while moving a considerable part of world trade (90%). Nevertheless, a global approach for further improvements in energy efficiency and emission reduction is needed as sea transport is predicted to continue growing significantly in line with world trade.

2 The International Maritime Organization (IMO), as the UN's Specialized Agency responsible for the global regulation of all facets pertaining to international shipping, has a key role in ensuring that the environment is not polluted by ships – as summed up in IMO's mission statement: **Safe, Secure and Efficient Shipping on Clean Oceans**.

TECHNICAL AND OPERATIONAL ENERGY EFFICIENCY MEASURES FOR SHIPS

3 In recent years, discussions at IMO have resulted in the development of technical and operational measures for ships, the Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP), respectively, that have the broad and emphatic support of Governments, industry associations and organizations representing civil society interests. All are united in the same purpose: to ensure that the EEDI and SEEMP deliver environmental effectiveness by generating, through enhanced energy efficiency measures, significant reductions in GHG emissions from international shipping.

4 Numerous stakeholders – policy-makers, shipowners, naval architects, class societies, etc. – are contributing to this endeavour, providing technical and other input to the debate, leading to the development of an instrument that is eminently suited for its intended purpose.

5 In October 2011 IMO completed a study to estimate the CO_2 emission reductions resulting from the adoption of mandatory technical and operational energy efficiency measures. The Executive Summary for the study is given at annex. The study indicates that by 2020, about 150 million tonnes of annual CO_2 reductions are estimated from the introduction of the EEDI for new ships and the SEEMP for all ships in operation, a figure that, by 2030, will increase to 330 million tonnes of CO_2 annually. In other words, the average reduction will, in 2020, be approximately 14% and, by 2030, approximately 23%, when compared with business as usual. The reduction measures will also result in a significant saving in fuel costs to the shipping industry, although these savings require deeper investments in more efficient ships and more sophisticated technologies than the business as usual scenario. The annual fuel cost saving estimate gives a staggering average figure of US$50 billion by 2020, and an even more astonishing US$200 billion by 2030.

MANDATORY REGULATIONS ON ENERGY EFFICIENCY FOR SHIPS

6 Amendments to MARPOL Annex VI were adopted during MEPC 62 in July 2011 (resolution MEPC. 203(62)), adding a new chapter 4 to Annex VI on *Regulations on energy efficiency for ships* to make mandatory the EEDI for new ships, and the SEEMP for all ships. The regulations apply to all ships of 400 gross tonnage and above and are expected to enter into force on 1 January 2013. However, under regulation 19, an Administration may waive the requirement for new ships of 400 gross tonnage and above from complying with the EEDI requirements. This waiver may not be applied to ships above 400 gross tonnage for which the building contract is placed four years after the entry into force date of chapter 4. The amendments to MARPOL Annex VI represent the first ever mandatory global GHG regime for an international industry sector or transport mode.

IMO'S ENERGY EFFICIENCY DESIGN INDEX

7 Shipping is permanently engaged in efforts to optimize fuel consumption, e.g., through the development of more efficient engines and propulsion systems, optimized hull designs and larger ships, and thereby achieve a noteworthy reduction in fuel consumption and resulting CO_2 emissions on a capacity basis (tonne-mile). Although ships are the most fuel efficient mode of mass transport, the Second IMO GHG Study 2009 identified a significant potential for further improvements in energy efficiency mainly by the use of already existing technologies. Additional improvements in hull, engine and propeller designs, together with reduction in operational speed, may lead to considerable reductions as illustrated in Table 1.

Table 1: Potential reductions of CO_2 emissions by using existing technology and practices (Source: Second IMO GHG Study 2009)

<table>
<tr><th>DESIGN (New ships)</th><th>Saving of CO_2/tonne-mile</th><th>Combined</th><th>Combined</th></tr>
<tr><td>Concept, speed and capability</td><td>2% to 50%[+]</td><td rowspan="6">10% to 50%[+]</td><td rowspan="10">25% to 75%[+]</td></tr>
<tr><td>Hull and superstructure</td><td>2% to 20%</td></tr>
<tr><td>Power and propulsion systems</td><td>5% to 15%</td></tr>
<tr><td>Low-carbon fuels</td><td>5% to 15%[*]</td></tr>
<tr><td>Renewable energy</td><td>1% to 10%</td></tr>
<tr><td>Exhaust gas CO_2 reduction</td><td>0%</td></tr>
<tr><td>OPERATION (All ships)</td><td colspan="2"></td></tr>
<tr><td>Fleet management, logistics and incentives</td><td>5% to 50%[+]</td><td rowspan="3">10% to 50%[+]</td></tr>
<tr><td>Voyage optimization</td><td>1% to 10%</td></tr>
<tr><td>Energy management</td><td>1% to 10%</td></tr>
</table>

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

8 The EEDI addresses improvements in energy efficiency by requiring a minimum energy efficiency level for new ships; by stimulating continued technical development of all the components influencing the fuel efficiency of a ship; and by separating the technical and design-based measures from the operational and commercial ones. It is already being used to enable a comparison to be made of the energy efficiency of individual ships with similar ships of the same size that could have undertaken the same transport work (i.e. moved the same cargo).

Applicability

9 The EEDI formula – as presently drafted – is not supposed to be applicable to all ships. Indeed, it is explicitly recognized that it is not suitable for all ship types (particularly those not designed to transport cargo) or for all types of propulsion systems (e.g., ships with diesel-electric, turbine or hybrid propulsion systems will need additional correction factors).

10 Indeed, the first iteration of the EEDI has been purposefully developed for the largest and most energy intensive segments of the world merchant fleet, thus embracing 70% of emissions from new ships and covering the following ship types: oil and gas tankers, bulk carriers, general cargo ships, refrigerated cargo carriers and container ships. For ship types not covered by the current formula, suitable formulae will be developed in due course to address the largest emitters first. IMO's MEPC (Marine Environment Protection Committee) is poised to consider the matter in detail at future sessions, with a view to adopting further iterations of the EEDI.

Purpose of the EEDI

11 The Energy Efficiency Design Index for new ships creates a strong incentive for further improvements in ships' fuel consumption. The purpose of IMO's EEDI is:

.1 to require a minimum energy efficiency level for new ships;

.2 to stimulate continued technical development of all the components influencing the fuel efficiency of a ship;

.3 to separate the technical and design based measures from the operational and commercial measures (they will/may be addressed in other instruments); and

.4 to enable a comparison of the energy efficiency of individual ships to similar ships of the same size which could have undertaken the same transport work (move the same cargo).

12 The EEDI establishes a minimum energy efficiency requirement for new ships depending on ship type and size and is a robust mechanism to increase the energy efficiency of ships step-wise for many decades to come. The EEDI is a non-prescriptive, performance-based mechanism that leaves the choice of technologies to use in a specific ship design to the industry. As long as the required energy efficiency level is attained, ship designers and builders would be free to use the most cost-efficient solutions for the ship to comply with the regulations. The reduction level in the first phase is set to 10% and will be tightened every five years to keep pace with technological developments of new efficiency and reduction measures. IMO has set reduction rates up to 2025 from when a 30% reduction is mandated for most ship types calculated from a reference line representing the average efficiency for ships built between 1999 and 2009 (Table 2).

Table 2: Reduction factors (in percentage) for the EEDI relative to the EEDI Reference line

Ship Type	Size	Phase 0 1 Jan 2013 – 31 Dec 2014	Phase 1 1 Jan 2015 – 31 Dec 2019	Phase 2 1 Jan 2020 – 31 Dec 2024	Phase 3 1 Jan 2025 and onwards
Bulk Carrier	20,000 DWT and above	0	10	20	30
	10,000 – 20,000 DWT	n/a	0-10*	0-20*	0-30*
Gas carrier	10,000 DWT and above	0	10	20	30
	2,000 – 10,000 DWT	n/a	0-10*	0-20*	0-30*
Tanker	20,000 DWT and above	0	10	20	30
	4,000 – 20,000 DWT	n/a	0-10*	0-20*	0-30*
Container ship	15,000 DWT and above	0	10	20	30
	10,000 – 15,000 DWT	n/a	0-10*	0-20*	0-30*
General Cargo ships	15,000 DWT and above	0	10	15	30
	3,000 – 15,000 DWT	n/a	0-10*	0-15*	0-30*

Ship Type	Size	Phase 0 1 Jan 2013 – 31 Dec 2014	Phase 1 1 Jan 2015 – 31 Dec 2019	Phase 2 1 Jan 2020 – 31 Dec 2024	Phase 3 1 Jan 2025 and onwards
Refrigerated cargo carrier	5,000 DWT and above	0	10	15	30
	3,000 – 5,000 DWT	n/a	0-10*	0-15*	0-30*
Combination carrier	20,000 DWT and above	0	10	20	30
	4,000 – 20,000 DWT	n/a	0-10*	0-20*	0-30*

*	Reduction factor to be linearly interpolated between the two values dependent upon vessel size. The lower value of the reduction factor is to be applied to the smaller ship size.

n/a	means that no required EEDI applies.

Implementation

13	The following circulars were issued (17 August 2009) following MEPC 59 and may be found on the IMO website: www.imo.org:

.1	the EEDI formula was circulated as MEPC.1/Circ.681, Interim Guidelines on the method of calculation of the Energy Efficiency Design Index for new ships (annex 17 to MEPC 59/24);

.2	the EEDI verification procedure was circulated as MEPC.1/Circ.682, Interim guidelines for voluntary verification of the EEDI (annex 18 to MEPC 59/24);

.3	the SEEMP was circulated as MEPC.1/Circ.683, Guidance for the development of a SEEMP (annex 19 to MEPC 59/24); and

.4	the Energy Efficiency Operational Indicator (EEOI) was circulated as MEPC.1/Circ.684, Guidelines for voluntary use of the ship EEOI (annex 20 to MEPC 59/24).

EEDI coverage

14	The EEDI is developed for the largest and most energy intensive segments of the world merchant fleet and will embrace 70% of emissions from the applicable new ships.

The EEDI formula

15	The EEDI provides a specific figure for an individual ship design, expressed in grams of CO_2 per ship's capacity-mile (a smaller EEDI value means a more energy efficient ship design) and calculated by the following formula based on the technical design parameters for a given ship:

$$\frac{\left(\prod_{j=1}^{M} f_j\right)\left(\sum_{i=1}^{nME} P_{ME(i)} \cdot C_{FME(i)} \cdot SFC_{ME(i)}\right) + \left(P_{AE} \cdot C_{FAE} \cdot SFC_{AE}*\right) + \left(\left(\prod_{j=1}^{M} f_j \cdot \sum_{i=1}^{nPTI} P_{PTI(i)} - \sum_{i=1}^{neff} f_{eff(i)} \cdot P_{AEeff(i)}\right) C_{FAE} \cdot SFC_{AE}\right) - \left(\sum_{i=1}^{neff} f_{eff(i)} \cdot P_{eff(i)} \cdot C_{FME} \cdot SFC_{ME}\right)}{f_i \cdot Capacity \cdot V_{ref} \cdot f_w}$$

That can be illustrated by the following simplified formula:

$$EEDI = \frac{CO_2\ emission}{transport\ work}$$

16 The CO_2 emission represents total CO_2 emission from combustion of fuel, including propulsion and auxiliary engines and boilers, taking into account the carbon content of the fuels in question. If shaft generators or innovative mechanical or electrical energy efficient technologies are incorporated on board a ship, these effects are deducted from the total CO_2 emission. The energy saved by the use of wind or solar energy will also is deducted from the total CO_2 emissions, based on actual efficiency of the systems. For technologies for EEDI reduction please refer to Table 3.

Table 3: Technologies for EEDI reduction

No.	EEDI reduction measure	Remark
1	Optimised hull dimensions and form	Ship design for efficiency via choice of main dimensions (port and canal restrictions) and hull forms.
2	Lightweight construction	New lightweight ship construction material.
3	Hull coating	Use of advanced hull coatings/paints.
4	Hull air lubrication system	Air cavity via injection of air under/around the hull to reduce wet surface and thereby ship resistance.
5	Optimisation of propeller-hull interface and flow devices	Propeller-hull-rudder design optimisation plus relevant changes to ship's aft body.
6	Contra-rotating propeller	Two propellers in series; rotating at different direction.
7	Engine efficiency improvement	De-rating, long-stroke, electronic injection, variable geometry turbocharging, etc.
8	Waste heat recovery	Main and auxiliary engines' exhaust gas waste heat recovery and conversion to electric power.
9	Gas fuelled (LNG)	Natural gas fuel and dual fuel engines.
10	Hybrid electric power and propulsion concepts	For some ships, the use of electric or hybrid would be more efficient.
11	Reducing on-board power demand (auxiliary system and hotel loads).	Maximum heat recovery and minimising required electrical loads flexible power solutions and power management.
12	Variable speed drive for pumps, fans, etc.	Use of variable speed electric motors for control of rotating flow machinery leads to significant reduction in their energy use.
13	Wind power (sail, wind engine, etc.)	Sails, fletner rotor, kites, etc. These are considered as emerging technologies.
14	Solar power	Solar photovoltaic cells.
15	Design speed reduction (new builds)	Reducing design speed via choice of lower power or de-rated engines.

17 The transport work is calculated by multiplying the ship's capacity as designed with the ship's design speed measured at the maximum design load condition and at 75% of the rated installed shaft power. Speed is the most essential factor in the formula and may be reduced to achieve the required index.

Safe Speed

18 The need for a minimum speed to be incorporated into the EEDI formula has been duly acknowledged by the MEPC and, to that end, regulation 21.5 states that "For each ship to which this regulation applies, the installed propulsion power shall not be less than the propulsion power needed to maintain the manoeuvrability of the ship under adverse conditions, as defined in the guidelines to be developed by the Organization."

19 It should, therefore, be clear that IMO fully supports the view that a minimum installed power to maintain safe navigation in adverse weather conditions is of critical importance to ensure both the safety and efficiency of international shipping. While the EEDI instrument therefore contains the standard to be achieved on this matter, implementation of that standard will be enabled through guidelines that are also to be adopted. With technical input from all concerned parties, these guidelines will be further developed. A draft set of such guidelines will be considered for adoption by the MEPC in March 2012.

Installed Power

20 Although the easiest way to improve a ship's fuel efficiency is, indeed, to reduce speed – hence the move to slow steaming by a significant number of ships – there is a practical minimum at which fuel efficiency will decrease as a ship is slowed down further. There are other ways to improve fuel efficiency, such as waste heat generators, which do not impact on speed (they impact on auxiliary engines). Indeed, improvements in road transport efficiency have been made through advances in technology that have, however, not led to a sacrifice in speed; rather, quite the opposite.

21 It has been (wrongly) argued that the EEDI limits installed power and so induces owners to use small-bore high-rpm engines, thereby increasing fuel consumption. However, a reduction of installed power does not require a reduction in engine bore and increasing rpm. The easiest way to reduce power would be to "de-rate" the exact same engine by limiting the "maximum" rpm (remember, horsepower = torque multiplied by rpm). This would have the impact of increasing propeller efficiency (if the exact same propeller is installed), as propeller efficiency will generally improve as rpm decreases. Another practical way to reduce installed horsepower is to install an engine with one cylinder fewer. This would have no impact on specific fuel consumption or rpm. Such engines can be identified by reference to the catalogues of major engine manufacturers.

22 Of course, there are "economies of scale" in ships' fuel efficiency. The larger the ship is (at a given speed), the lower the fuel consumption per unit of cargo. However, such economies of scale are limited by trade considerations, physical port limitations (generally, draft) or cargo logistics issues. Therefore, ships tend to be designed to be as large as practical for a given trade.

Status of the EEDI

23 As stated in paragraph 13 (Implementation), the EEDI was circulated in August 2009 for trial purposes to ensure its feasibility and for further improvement of the calculation method. The regulatory text introducing the EEDI as a mandatory measure for all new ships under MARPOL Annex VI was adopted by Parties to MARPOL Annex VI in July 2011. The amendments to MARPOL Annex VI are expected to enter into force on 1 January 2013.

Future developments

24 The EEDI formula is not applicable to all ship types e.g., Ro-Ro ships, or all types of propulsion systems, e.g., ships with diesel-electric, turbine or hybrid propulsion systems will need additional correction factors, and MEPC will consider the matter in detail at future sessions.

Conclusions EEDI

25 The EEDI establishes a minimum energy efficiency requirement for new ships depending on ship type and size and is a robust mechanism that may be used to increase the energy efficiency of ships stepwise to keep pace with technical developments for many decades to come. The EEDI is a non-prescriptive mechanism that leaves the choice of what technologies to use in a ship design to the stakeholders as long as the required energy efficiency level is attained enabling the most cost-efficient solutions to be used.

26 Introduction of the EEDI as a mandatory measure for all ships will mean, provided it enters into force as expected on 1 January 2013; that between 31 and 42 million tonnes of CO_2 will be removed from the atmosphere annually by 2020 compared with business as

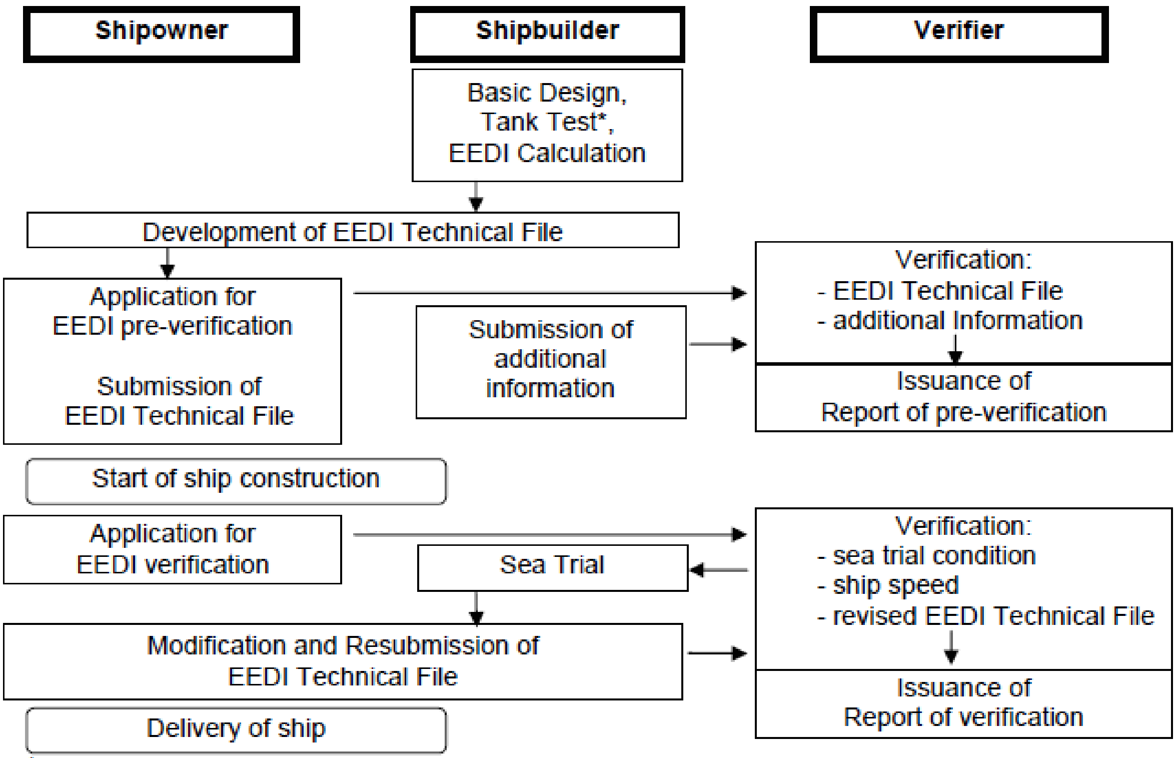
usual depending on the growth in world trade. For 2030, the reduction will be between 155 and 224 million tonnes annually from the introduction of the EEDI. By 2050, the estimated annual reductions are 603 and 995 million tonnes of CO2 respectively.

Verification of the EEDI

27 Regulation 20 of the regulatory text requires the attained EEDI for a new ship to be verified. Guidelines on verification of the EEDI are to be considered for adoption at MEPC in March 2012 to assist verifiers (ship surveyors) of the EEDI in conducting the verification in a uniform manner. The guidelines will also assist shipowners, shipbuilders as well as engine and equipment manufacturers, and other interested parties, in understanding the procedures of EEDI verification.

Verification in two stages

28 The attained EEDI should be calculated in accordance with the EEDI calculation Guidelines. EEDI verification should be conducted on two stages: preliminary verification at the design stage, and final verification at the sea trial, before issuance of the final report on the verification of the attained EEDI. The basic flow of the verification process is presented in Figure 1.



* To be conducted by a test organization or a shipbuilder itself.

Figure 1: Basic flow of verification process

Preliminary verification at the design stage

29 For the preliminary verification at the design stage, a shipowner should submit to a verifier (e.g., a Maritime Administration or a Classification Society) an application for the verification and an EEDI Technical File containing the necessary information for the verification and other relevant background documents as required by the guidelines.

Final verification of the Attained EEDI at sea trial

30 Prior to the sea trial, a shipowner should submit the application for the verification of the EEDI together with the final displacement table and the measured lightweight, as well as other technical information as necessary. The verifier should attend the sea trial and confirm compliance in accordance with the guidelines and the EEDI guidelines.

Issuance of the EEDI verification report

31 The verifier should issue the Report on the Preliminary Verification of EEDI after it has verified the Attained EEDI at design stage in accordance with the guidelines. Following the sea trial, the verifier should issue the final report on the verification of the attained EEDI after it has verified the Attained EEDI at the sea trial in accordance with the guidelines.

Status of the verification guidelines

32 The guidelines are to be applied to new ships for which an application for EEDI verification has been submitted to a verifier, and form part of the regulatory framework governing the scheme.

IMO'S SHIP ENERGY EFFICIENCY MANAGEMENT PLAN

33 The amendments to MARPOL Annex VI require that all international ships over 400 gross tonnage retain on-board a Ship Energy Efficiency Management Plan (SEEMP). Guidance for the development of a SEEMP is contained in IMO circular MEPC.1/Circ.683.

34 The purpose of the SEEMP is to establish a mechanism for a company and/or a ship to improve the energy efficiency of ship operations. Preferably, the ship-specific SEEMP is linked to a broader corporate energy management policy for the company that owns, operates or controls the ship. It should be recognized that the international fleet of merchant vessels comprises a wide range of ship types and sizes that differ significantly in their design and purpose, and that ships operate under a broad variety of different conditions.

35 Sea transport has a justifiable image of conducting its operations in an energy efficient way, and in a manner that creates little impact on the global environment. It is nevertheless the case that enhancement in efficiencies can reduce fuel consumption, save money, and decrease the environmental impacts from ships. While the yield of individual measures may be small, the collective effect across the entire fleet will be significant. In global terms it should be recognized that operational efficiencies delivered by a large number of ships will make a valuable contribution to reducing global carbon emissions.

Practical approach

36 Mandatory management plans are used to regulate a range of ship operations where traditional command and control regulations would not work, and is also the chosen option for reduction of GHG emissions from the operation of ships engaged in international trade. To regulate ship operations by traditional prescriptive regulations (as is the customary practice for technical regulations) is not feasible, e.g., to determine the most energy efficient speed, optimum ship handling practices or the preferred ballast conditions for all ships in a set of regulations could hardly be done and keeping it updated would not be possible. A management plan is a familiar tool for the shipping industry and provides a flexible mechanism where shipowners and operations can choose the most cost-effective solutions for their ships and their operations.

37 The SEEMP provides an approach for monitoring ship and fleet efficiency performance over time and forces the responsible persons and entities to consider new technologies and practices when seeking to optimize the performance of the ship (see Table 4 for SEEMP related measures). The Second IMO GHG Study 2009 indicates that a 20% reduction on a tonne-mile basis by mainly operational measures is possible and would be cost-effective even with the current fuel prices, and the SEEMP will assist the shipping industry in achieving this potential.

Table 4: SEEMP related measures

No.	Energy Efficiency Measure	Remark
1	Engine tuning and monitoring	Engine operational performance and condition optimisation.
2	Hull condition	Hull operational fouling and damage avoidance.
3	Propeller condition	Propeller operational fouling and damage avoidance.
4	Reduced auxiliary power	Reducing the electrical load via machinery operation and power management.
5	Speed reduction (operation)	Operational slow steaming.
6	Trim/draft	Trim and draft monitoring and optimisation.
7	Voyage execution	Reducing port times, waiting times, etc. and increasing the passage time, just in time arrival.
8	Weather routing	Use of weather routing services to avoid rough seas and head currents, to optimize voyage efficiency.
9	Advanced hull coating	Re-paint using advanced paints.
10	Propeller upgrade and aft body flow devices	Propeller and after-body retrofit for optimisation. Also, addition of flow improving devices (e.g. duct and fins).

38 The IMO circular MEPC.1/Circ.683 provides guidance for the development of a SEEMP that should be adjusted to the characteristics and needs of individual companies and ships. The SEEMP is a management tool to assist a company in managing the ongoing environmental performance of its vessels and, as such, it is recommended that the plan be implemented in a manner which limits any onboard administrative burden to the minimum necessary.

Ship-specific plan

39 The SEEMP should be developed as a ship-specific plan by the shipowner, operator or any other party concerned, e.g., the charterer. The SEEMP seeks to improve a ship's energy efficiency through four steps: planning, implementation, monitoring, and self-evaluation and improvement. These components play a critical role in the continuous cycle to improve ship energy management.

Status of the SEEMP

40 The regulatory text introducing the SEEMP as a mandatory measure for all ships under MARPOL Annex VI was adopted by Parties to MARPOL Annex VI in July 2011. The amendments to MARPOL Annex VI are expected to enter into force on 1 January 2013.

Guidance on best practices for fuel-efficient operation of ships

41 The above mentioned IMO circular also contains guidance on best practices related to voyage performance, optimized ship handling, hull and propulsion system maintenance, the use of waste heat recovery systems, improved fleet management, improved cargo handling and energy management. It also covers areas such as fuel types, compatibility of measures, age and operational service life of a ship as well as trade and sailing area.

42 Industry has also begun to develop model plans based on experience. The Oil Companies International Marine Forum (OCIMF) have produced a model SEEMP and submitted it to IMO for information in document MEPC 62/INF.10.

THE ENERGY EFFICIENCY OPERATIONAL INDICATOR

43 Improvements in energy efficiency are possible by operational measures, such as fleet management, voyage optimization and energy management, with 10 to 50% reductions of CO_2 emissions (on a capacity mile basis) estimated through the combined use of these measures. Saving energy at the operational stage is presently addressed by the SEEMP and the EEOI can be used as a monitoring tool and to establish benchmarks for different ship segments of the world fleet categorized by ship type and size.

Purpose of the EEOI

44 Guidelines for voluntary use of the ship EEOI have been developed to establish a consistent approach for measuring ships' energy efficiency at each voyage or over a certain period of time, which will assist shipowners and ship operators in the evaluation of the operational performance of their fleet. As the amount of CO_2 emitted from ships is directly related to the consumption of bunker fuel oil, the EEOI can also provide useful information on a ship's performance with regard to fuel efficiency.

45 The EEOI enables continued monitoring of individual ships in operation and thereby the results of any changes made to the ship or its operation. The effect of retrofitting a new and more efficient propeller would be reflected in the EEOI value and the emissions reduction could be quantified. The effect on emissions by changes in operations, such as introduction of just in time planning or a sophisticated weather routing system, will also be shown in the EEOI value.

EEOI coverage

46 The EEOI can be applied to almost all ships (new and existing) including passenger ships, however it cannot be applied to ships that are not engaged in transport work, such as service and research vessels, tug boats or FPSOs, as it is the transport work that is the input value together with emissions (fuel consumed x CO_2 factors for different fuel types).

The EEOI formula

47 The EEOI provides a specific figure for each voyage. The unit of EEOI depends on the measurement of cargo carried or the transport work done, e.g., tonnes CO_2/(tonnes·nautical miles), tonnes CO_2/(TEU·nautical miles) or tonnes CO_2/(person·nautical miles), etc. The EEOI is calculated by the following formula, in which a smaller EEOI value means a more energy efficient ship:

$$EEOI = \frac{actual\ CO_2\ emission}{performed\ transport\ work}$$

48 The actual CO_2 emission represents total CO_2 emission from combustion of fuel on board a ship during each voyage, which is calculated by multiplying total fuel consumption for each type of fuel (distillate fuel, refined fuel or LNG, etc.) with the carbon to CO_2 conversion factor for the fuel(s) in question (fixed value for each type of fuel).

49 The performed transport work is calculated by multiplying mass of cargo (tonnes, number of TEU/cars, or number of passengers) with the distance in nautical miles corresponding to the transport work done.

Status of the EEOI

50 The EEOI is circulated to encourage shipowners and ship operators to use it on a voluntary basis and to collect information on the outcome and experiences in applying it. The EEOI will be used as a monitoring tool in the SEEMP and to establish benchmarks.

51 A sample form of a SEEMP is presented below for illustrative purposes.

Name of Vessel:		GT:	
Vessel Type:		Capacity:	
Date of Development:		Developed by:	
Implementation Period:	From: Until:	Implemented by:	
Planned Date of Next Evaluation:			

1 Measures

Energy Efficiency Measures	**Implementation** (including the starting date)	**Responsible Personnel**
Weather Routeing	<Example> Contracted with [Service providers] to use their weather routeing system and start using on trial basis as of 1 July 2012.	<Example> The master is responsible for selecting the optimum route based on the information provided by [Service providers].
Speed Optimization	While the design speed (85% MCR) is 19.0 kt, the maximum speed is set at 17.0 kt as of 1 July 2012.	The master is responsible for keeping the ship speed. The log-book entry should be checked every day.

2 Monitoring

- Description of monitoring tools (e.g. the EEOI, or another suitable indicator or MRV tool)

3 Goal

- Measurable goals

4 Evaluation

- Procedures of evaluation

MODEL COURSE FOR ENERGY EFFICIENT OPERATION SHIPS

52 At MEPC 60 the Committee noted that, to assist in achieving the visions and goals set out in resolution A.947(23) on the "Human Element Vision, Principles and Goals for the Organization", and the principles and aims of resolution A.998(25) on the "Need for capacity-building for development and implementation of new and amendments to existing,

instruments", the IMO Secretariat had engaged the World Maritime University (WMU) to develop a draft model course on energy efficient operation of ships.

53 A draft Model Course was submitted to MEPC 62 as document MEPC 62/INF.39. It was developed on the elements comprising the SEEMP as agreed at MEPC 59 (MEPC 59/24, annex 19) as well as on the Guidance for the development of a SEEMP as agreed and contained in MEPC.1/Circ.683. This draft model course provides general background on the climate change issue and IMO's related work and aims at building the different operational and technical tools into a manageable course programme, which will promulgate best practice throughout all sectors of the industry. The Course will help create benchmarks against which operators can assess their own performance.

54 The Committee agreed that the draft model course was an excellent start to providing a structured training course but that it required additional work to identify the relevant parts and information, such as key practical operational efficiency measures, which are pertinent to the ship's deck and engineering officers. The Committee also considered important that consideration be given to integration of the SEEMP into the on board safety management system. In light of the improvements necessary to the Model Course, the Committee invited interested delegations to provide practical information and examples on the efficient operation of ships to the Secretariat by 31 August 2011 for inclusion in the IMO Model Course. The draft Model Course will be published in November 2011.

55 The purpose of the IMO model courses is to assist training providers and their teaching staff in organizing and introducing new training courses, or in enhancing, updating or supplementing existing training material, so that the quality and effectiveness of the training courses may thereby be improved.

ASSESSMENT OF CO_2 EMISSION REDUCTIONS RESULTING FROM THE INTRODUCTION OF TECHNICAL AND OPERATIONAL ENERGY EFFICIENCY MEASURES FOR SHIPS

56 Following the adoption of mandatory energy efficiency measures for ships, IMO commissioned a study (completed in October 2011) by Lloyd's Register and DNV on estimated CO_2 emission reductions associated with the mandatory technical and operational measures The full study can be found in IMO document MEPC 63/INF.2.

57 The study indicates that the adoption by IMO of mandatory reduction measures for all ships from 2013 and onwards will lead to significant emission reductions and also a striking cost saving for the shipping industry. By 2020, about 150 million tonnes of annual CO_2 reductions are estimated from the introduction of the EEDI for new ships and the SEEMP for all ships in operation, a figure that, by 2030, will increase to 330 million tonnes of CO_2 annually. In other words, the average reduction will in 2020 be approximately 14%, and by 2030 approximately 23%, when compared with business as usual. The reduction measures will also result in a significant saving in fuel costs to the shipping industry, although these savings require deeper investments in more efficient ships and more sophisticated technologies than the business as usual scenario. The annual fuel cost saving estimate gives a staggering average figure of US$50 billion by 2020, and even more astonishing US$200 billion by 2030.

FUTURE ACTIVITY

58 The new chapter 4 to MARPOL Annex VI also includes a regulation on Promotion of technical co-operation and transfer of technology relating to the improvement of energy efficiency of ships, which requires Administrations, in co-operation with IMO and other international bodies, to promote and provide, as appropriate, support directly or through IMO to States, especially developing States, that request technical assistance. It also requires

the Administration of a Party to co-operate actively with other Parties, subject to its national laws, regulations and policies, to promote the development and transfer of technology and exchange of information to States, which request technical assistance, particularly developing States, in respect of the implementation of measures to fulfil the requirements of Chapter 4.

59 In advance of entry into force of the foregoing regulatory provisions, IMO is already providing technical assistance to developing countries for the transition to energy effient shipping. A programme funded by the Republic of Korea is providing such support in Asia while further interventions, funded by IMO itself and other donours, will follow in other regions.

60 MEPC 62 also agreed on a work plan and schedule for further development of the remaining EEDI and SEEMP related guidelines, EEDI framework for ship types and sizes and propulsion systems not covered by the current EEDI requirements. For this purpose, MEPC 62 agreed to terms of reference for an intersessional working group meeting on energy efficiency measures for ships that will take place in January 2012. The intersessional working group meeting should report to MEPC 63 in February/March 2012 and is tasked with:

.1 further improving, with a view to finalization at MEPC 63,

.1 draft Guidelines on the method of calculation of the EEDI for new ships;

.2 draft Guidelines for the development of a SEEMP;

.3 draft Guidelines on Survey and Certification of the EEDI; and

.4 draft interim Guidelines for determining minimum propulsion power and speed to enable safe manoeuvring in adverse weather conditions.

.2 considering the development of EEDI frameworks for other ship types and propulsion systems not covered by the draft Guidelines on the method of calculation of the EEDI for new ships;

.3 identifying the necessity of other guidelines or supporting documents for technical and operational measures;

.4 considering the EEDI reduction rates for larger tankers and bulk carriers; and

.5 considering the improvement of the guidelines on the Ship Energy Efficiency Operational Indicator (EEOI) (MEPC.1/Circ.684).

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ANNEX 1

ASSESSMENT OF IMO MANDATED ENERGY EFFICIENCY MEASURES FOR INTERNATIONAL SHIPPING

ESTIMATED CO_2 EMISSIONS REDUCTION FROM INTRODUCTION OF MANDATORY TECHNICAL AND OPERATIONAL ENERGY EFFICIENCY MEASURES FOR SHIPS

EXECUTIVE SUMMARY OF THE PROJECT FINAL REPORT

Report Authors:

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Tore Longva, DNV, Oslo, Norway

Date of report:

31 October 2011

Executive Summary

1 This study was commissioned by the International Maritime Organization (IMO) to analyse the potential reduction resulting from the mandated energy efficiency regulations on EEDI and SEEMP as finalised at MEPC 62 in July 2011 and also to estimate the projected reduction in CO_2 emissions from international shipping for every year up to year 2050 resulting from these agreed measures, using a number of scenarios.

2 This Study was undertaken by Lloyd's Register (LR) in partnership with Det Norske Veritas (DNV). Dr. Zabi Bazari (LR) and Mr. Tore Longva (DNV) were the main contributors to the report. They additionally received assistance from colleagues within their organizations.

3 Mandatory measures to reduce greenhouse gas (GHG) emissions from international shipping were adopted by Parties to MARPOL Annex VI represented in the Marine Environment Protection Committee (MEPC) of the International Maritime Organization (IMO), when it met for its 62nd session from 11 to 15 July 2011 in London, representing the first ever mandatory global GHG reduction regime for an international industry sector.

4 The amendments to MARPOL Annex VI - *Regulations for the prevention of air pollution from ships,* add a new chapter 4 to Annex VI *on Regulations on energy efficiency for ships* to make mandatory the Energy Efficiency Design Index (EEDI) for new ships, and the Ship Energy Efficiency Management Plan (SEEMP) for all ships. Other amendments to Annex VI add new definitions and the requirements for survey and certification, including the format for the International Energy Efficiency Certificate. The regulations apply to all ships of 400 gross tonnage and above, and are expected to enter into force internationally through the tacit acceptance procedure on 1 January 2013.

Reduction factors (in percentage) for the EEDI relative to the reference line for each ship type.

	Size	Phase 0 1 Jan 2013 – 31 Dec 2014	Phase 1 1 Jan 2015 – 31 Dec 2019	Phase 2 1 Jan 2020 – 31 Dec 2024	Phase 3 1 Jan 2025 onwards
Bulk Carriers	>20,000 Dwt	0%	10%	20%	30%
	10-20,000 Dwt	n/a	0-10%*	0-20%*	0-30%*
Gas tankers	>10,000 Dwt	0%	10%	20%	30%
	2-10,000 Dwt	n/a	0-10%*	0-20%*	0-30%*
Tanker and combination carriers	>20,000 Dwt	0%	10%	20%	30%
	4-20,000 Dwt	n/a	0-10%*	0-20%*	0-30%*
Container ships	>15,000 Dwt	0%	10%	20%	30%
	10-15,000 Dwt	n/a	0-10%*	0-20%*	0-30%*
General Cargo ships	>15,000 Dwt	0%	10%	15%	30%
	3-15,000 Dwt	n/a	0-10%*	0-15%*	0-30%*
Refrigerated cargo carriers	>5,000 Dwt	0%	10%	15%	30%
	3-5,000 Dwt	n/a	0-10%*	0-15%*	0-30%*

* The reduction factor is to be linearly interpolated between the two values depending on the vessel size. The lower value of the reduction factor is to be applied to the smaller ship size.

Table i – EEDI reduction factors, cut off limits and implementation phases

5 The EEDI requires a minimum energy efficiency level (CO_2 emissions) per capacity mile (e.g. tonne mile) for different ship type and size segments (Table i). With the level being tightened over time, the EEDI will stimulate continued technical development of all the components influencing the energy efficiency of a ship. Reduction factors are set until 2025 when a 30% reduction is mandated over the average efficiency for ships built between 1999 and 2009. The EEDI has been developed for the largest and most energy intensive segments of the world merchant fleet and will embrace about 70% of emissions from new oil and gas tankers, bulk carriers, general cargo, refrigerated cargo and container ships as well as combination carriers (wet/dry bulk). For ship types not covered by the current EEDI

formula, suitable formulas are likely to be developed in the future according to work plan agreed at MEPC 62.

6 The SEEMP establishes a mechanism for a shipping company and/or a ship to improve the energy efficiency of ship operations. The SEEMP provides an approach for monitoring ship and fleet efficiency performance over time using, for example, the Energy Efficiency Operational Indicator (EEOI) as a monitoring and/or benchmark tool. The SEEMP urges the ship owner and operator at each stage of the operation of the ship to review and consider operational practices and technology upgrades to optimize the energy efficiency performance of a ship.

7 In this study, scenario modelling was used to forecast possible world's fleet CO_2 emission growth trajectories to 2050. The scenarios included options for fleet growth, EEDI and SEEMP uptake, fuel price and EEDI waiver. Table ii shows the combined scenarios modelled in this Study.

8 A model, designed specifically to account for the uptake of emission reduction technologies and measures and the implementation of regulations to control emissions, has been used to predict likely CO_2 emission levels to 2050. The model keeps track of the year of build for all ships, and scraps the oldest and least energy efficient ships first. By including the scrapping rate, the renewal rate of the fleet is taken into account. A methodology was used to determine the impact of future EEDI regulatory limits on various ships based on the level of spread (expressed by the standard deviation) of EEDI values for the current fleet reference lines.

Scenario	IPCC growth scenario	EEDI Uptake scenario	SEEMP uptake	Fuel price scenarios	Waiver scenario
A1B-1	A1B	Regulation	Low*	Reference	5%
A1B-2	A1B	Regulation	Low	High	5%
A1B-3	A1B	Regulation	High**	Reference	5%
A1B-4	A1B	Regulation	High	High	5%
B2-1	B2	Regulation	Low	Reference	5%
B2-2	B2	Regulation	Low	High	5%
B2-3	B2	Regulation	High	Reference	5%
B2-4	B2	Regulation	High	High	5%
A1B-3W	A1B	Regulation	High	Reference	30%

* 30% ** 60%

Table ii – Combined scenarios

9 Based on scenarios modelled in this Study, results shows that the adoption by IMO of mandatory reduction measures from 2013 and onwards will lead to significant emission reductions by the shipping industry (see Figure i).

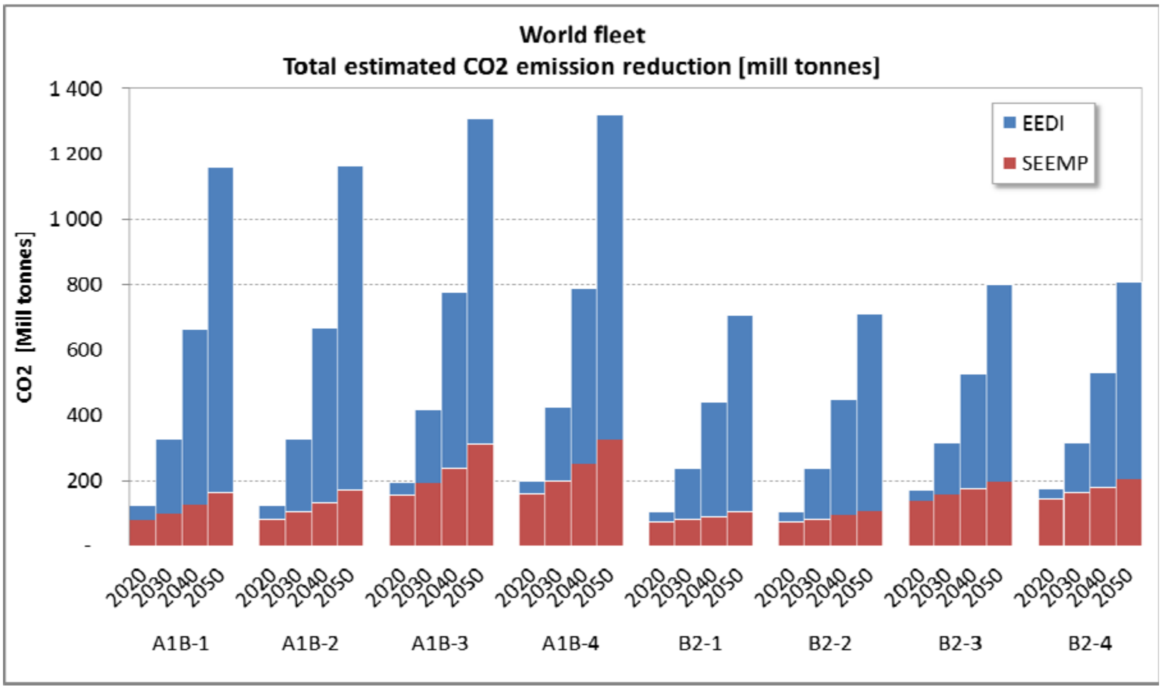

Figure i – Overall annual CO_2 reduction potential for SEEMP and EEDI (waiver 5%)

Findings

10 According to Figure i:

.1 By 2020, an average of 151.5 million tonnes of annual CO_2 reductions are estimated from the introduction of the EEDI for new ships and the SEEMP for all ships in operation, a figure that by 2030, will increase to an average of 330 million tonnes annually (Table iii, showing the average for scenarios A1B-4 and B-2);

Year	**BAU** Mill tonnes	**Reduction** Mill tonnes	**New level** Mill tonnes
2020	1103	152	951
2030	1435	330	1105
2040	1913	615	1299
2050	2615	1013	1602

Table iii - Estimated average CO_2 emission reductions (million tonnes) for world fleet compared with estimated BAU CO_2 emissions (million tonnes)

.2 Compared with Business as Usual (BAU), the average annual reductions in CO_2 emissions and fuel consumed are estimated between 13% and 23% by 2020 and 2030 respectively (Tables iii);

.3 CO_2 reduction measures will also result in a significant reduction in fuel consumption (Table iv) leading to a significant saving in fuel costs to the shipping industry, although these savings require deeper investments in more efficient ships and more sophisticated technologies, as well as new practices, than the BAU scenario.

Year	2020		2030	
Scenarios	Low (B2-1) Mill tonnes	High (A1B-4) Mill tonnes	Low (B2-1) Mill tonnes	High (A1B-4) Mill tonnes
BAU fuel consumption	340	390	420	530
Reduction in fuel consumption	30	70	80	140
New fuel consumption level	310	320	340	390

Table iv - Annual fuel consumption reduction (in million metric tonnes) for world fleet

.4 The average annual fuel cost saving is estimated between US$20 and US$80 billion (average US$50 billion) by 2020, and between US$90 and US$310 billion (average US$200 billion) by 2030 (Table v).

	High (A1B-4)		Low (B2-1)	
Year	2020 $billion	2030 $billion	2020 $billion	2030 $billion
BAU fuel cost	490	1170	240	510
Reduction in fuel cost	80	310	20	90
New fuel cost level	410	860	220	420

Table v - Annual fuel cost reduction (in billion US$) for world fleet

11 The results of the study indicate that SEEMP measures (mainly operational) have an effect mostly in the medium term (e.g. 2020) whilst EEDI measures (technical) should have significant impact on the long term (e.g., 2030) as fleet renewal takes place and new technologies are adopted; however, none of the scenarios modelled will achieve a reduction in total CO_2 level relative to year 2010 (Figure ii).

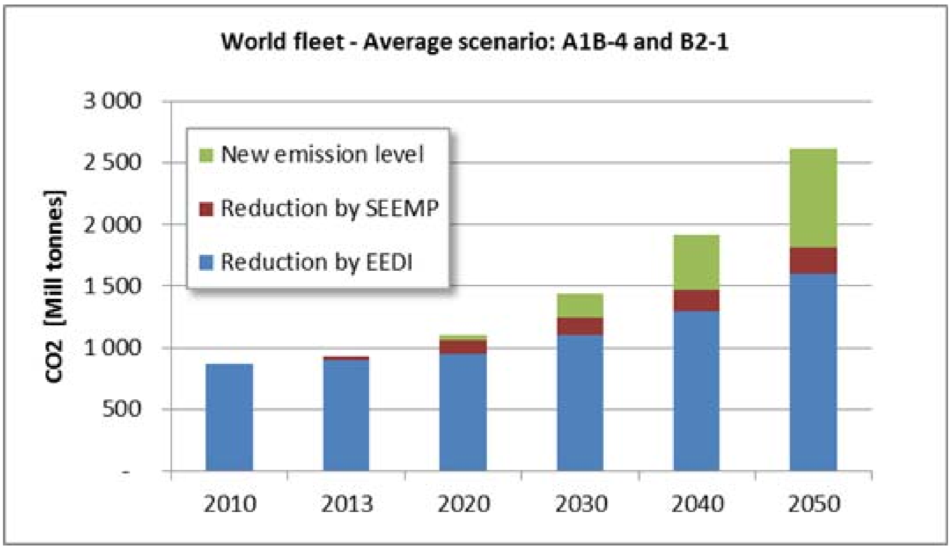

Figure ii - Annual emission reduction by 2050 and new emissions levels (average of A1B-4 and B2-1 scenarios)

Concluding remarks

12 Based on the results of this Study, the following conclusions may be made:

.1 Significant potential for reduction of CO_2 emissions from ships due to EEDI and SEEMP regulations is foreseen to 2050 with emission reduction due to SEEMP (primarily operational measures) likely to be realised more rapidly than that for EEDI (primarily technical measures), as the effect of EEDI will occur only as and when older, less efficient, tonnage is replaced by new, more efficient tonnage.

.2 The existing mandatory application of EEDI will drive more energy efficient ship design and realise the CO_2 emission reduction potential associated with technical innovation and the use of lower or no carbon fuels. Calculations made within this Study suggest that the existing limits to the EEDI can be achieved via technological developments and some design speed reduction as highlighted in this report.

.3 Forecasts with different scenarios indicate total annual CO_2 emissions in 2050 of 3215 million tonnes for BAU and new emissions level of 1895 million tonnes (1320 million tonnes reduced) for scenario A1B-4 (high growth combined with high SEEMP uptake and high fuel price) and a total annual CO_2 emissions in 2050 of around 2014 million tonnes for BAU and new emissions level of 1344 million tonnes (706 million tonnes reduced) for scenario B2-1 (low growth combined with low SEEMP uptake and reference fuel price).

.4 For EEDI, an annual reduction of about 1000 million tonnes of CO_2 for A1B scenario and 600 million tonnes of CO_2 for B2 scenario is foreseen in 2050. For SEEMP, an annual reduction of about 325 million tonnes of CO_2 for A1B-4 scenario and 103 million tonnes of CO_2 for B2-1 scenario is foreseen by 2050.

.5 The transport efficiency will improve with the same rate as the emission reduction taking into account the growth rate of the fleet. Table vi provides the transport efficiency development for different ship types under the modelled scenarios. As indicated, various vessels' transport energy efficiency nearly doubles and the emissions per cargo unit nearly halves from 2005 to 2050.

Year	Bulk carrier	Gas tanker	Tanker	Container ship	General cargo ship	Refrigerated cargo carrier
2005	9	13	13	30	40	40
2010	9	12	12	28	37	37
2020	8	10	10	23	30	30
2030	7	9	9	20	27	27
2050	5	7	7	16	21	20

Table vi - Transport efficiency (g CO_2/tonne-mile) improvement associated with the different ship types using scenario B2-4/A1B-4

.6 The impact of the waiver clause in Regulation 19.5 is estimated to be low on total emissions reduction potential due to EEDI. A change of waiver level from 5% to 30% will result in a decrease in CO_2 reduction levels by 7 million tonnes per year in 2030 (overall reduction is 416 million tonnes for this scenario).

.7 Based on the analysis provided in this appendix, it is concluded that the likelihood of Flag States or shipowners to opt for an EEDI waiver is low due to low compliance costs and commercial disadvantage of non-compliance. Accordingly, the level waiver uptake level taken in this Study as 5% (low) and 30% (high) is regarded as reasonable. It is most likely that waiver will be at the level of 5% as current indications imply.

.8 Implementation of SEEMP-related energy efficiency measures are generally cost effective; however, it is likely that adoption of these measures will need to be stimulated. Follow-on monitoring and audits, and high carbon and fuel prices are expected to play a role in driving uptake of SEEMP efficiency measures. Although it is not anticipated to have a target-based regulatory framework for SEEMP in the foreseeable future; putting in place an effective audit/monitoring system, building awareness and resolving split incentive issues on operational energy efficiency measures will facilitate enhanced uptake of SEEMP measures in the world fleet.

	EEDI reduction measure	Energy Efficiency Measure
1	Optimised hull dimensions and form	Engine tuning and monitoring
2	Lightweight construction	Hull condition
3	Hull coating	Propeller condition
4	Hull air lubrication system	Reduced auxiliary power
5	Optimisation of propeller-hull interface and flow devices	Speed reduction (operation)
6	Contra-rotating propeller	Trim/draft
7	Engine efficiency improvement	Voyage execution
8	Waste heat recovery	Weather routing
9	Gas fuelled (LNG)	Advanced hull coating
10	Hybrid electric power and propulsion concepts	Propeller upgrade and aft body flow devices
11	Reducing on-board power demand (auxiliary system and hotel loads).	
12	Variable speed drive for pumps, fans, etc.	
13	Wind power (sail, wind engine, etc.)	
14	Solar power	
15	Design speed reduction (new builds)	

Table vii Technologies for EEDI reductions and SEEMP related measures

.9 The mandatory use of SEEMP based on current IMO Regulations will provide a procedural framework for shipping companies to recognise the importance of the operational energy saving activities. It will significantly boost the level of awareness and, if implemented properly, will lead to a positive cultural change. However, and in view of lack of regulatory requirements for target setting and monitoring, SEEMP effectiveness will need to be stimulated / incentivised via other initiatives.

.10 To make the application of SEEMP more effective and to prepare the shipping industry for likely future carbon pricing via MBMs, it seems that use of the EEOI (Energy Efficiency Operational Indicator) or a similar performance indicator should be encouraged or mandated. This will involve more accurate and verifiable measurement of fuel consumption that could pave the way for CO_2 foot printing and data verification in the future.

.11 The estimated reductions in CO_2 emissions, for combined EEDI and SEEMP, from the world fleet translate into a significant average annual fuel cost saving of about US$50 billion in 2020 and about US$200 billion by 2030; using fuel price increase scenarios that take into account the switch to low sulphur fuel in 2020.

.12 Investigations show that ship hydrodynamic and main engine optimisation will bring about energy saving opportunities of up to about 10% with no significant additional cost of shipbuilding. In addition, the main and auxiliary engines are already available with reduced specific fuel consumption of about 10% below the values used in the reference line calculations. The above two combined effects is indicative that cost of compliance, for an "average ship", to phases 0 and 1 will not be significant. As a consequence of current developments in ship design and new technologies coming onto market, the cost of EEDI compliance in phase 1 seems to be marginal as the 10% reduction requirement may be achieved by low-cost hull form design and main engine optimisations. Cost of compliance for phase 2 and phase 3 may be higher and will involve some design-speed reduction for an average ship. However, the overall life-cycle fuel economy of the new ships will be positive as indicated by the high savings in fuel costs.

.13 Despite the significant CO_2 emission reduction potential resulting from EEDI and SEEMP regulations, an absolute reduction in total CO_2 emissions for shipping from the 2010 level appears not to be feasible using these two measures alone. For all scenarios, the projected growth in world trade outweighs the achieved emission reduction using EEDI and SEEMP, giving an upward trend, albeit at a very much reduced rate compared to BAU.

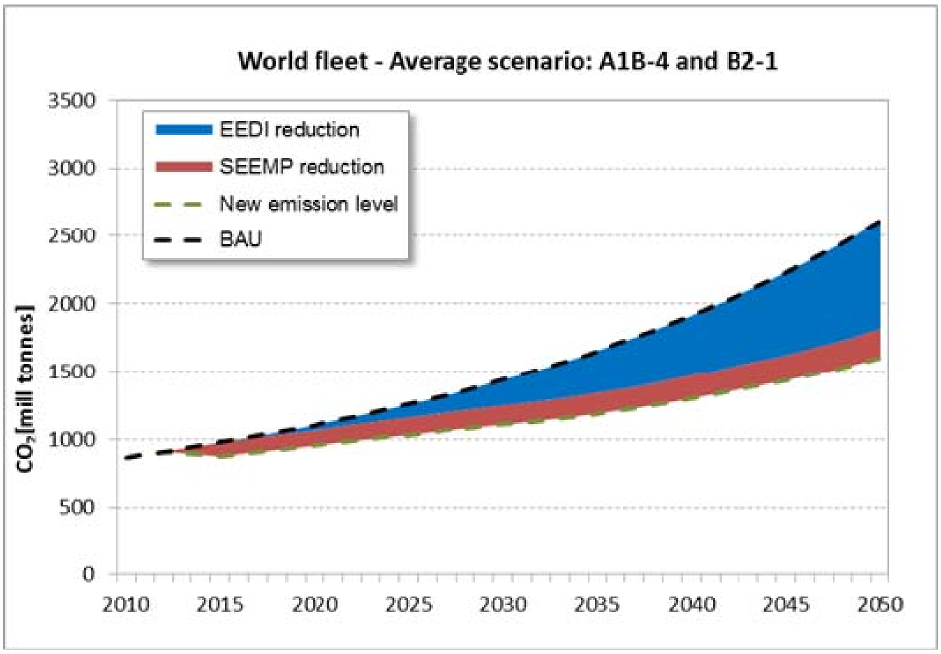

Figure iii – World fleet CO_2 level projections (average of A1B-4 and B2-1 scenarios)

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