Environmental Research

of the German Federal Ministry for the Environment,

Nature Conservation and Nuclear Safety

Project No. (3711 45 104)

Further technical and operational measures for enhancing the energy efficiency of international shipping Environmental Aspects

DISCUSSION PAPER

by

Jasper Faber (faber@ce.nl)

Dagmar Nelissen (nelissen@ce.nl)

Stefan Seum on behalf of Öko-Institut (stefan.seum@seumconsulting.com)

Öko-Institut, Schicklerstr. 5-7, 10179 Berlin, Germany
CE Delft, Oude Delft 180, 2611 HH Delft, Netherlands
Tim Bäuerle, Weberstr. 2, 69120 Heidelberg, Germany

ON BEHALF OF THE

FEDERAL ENVIRONMENT AGENCY

7 July 2014

This paper was written for the German Federal Environment Agency (UBA) as part of the project titled “Analysis and further development of climate protection measures of sea shipping taking into account current developments at European and international level” (FKZ 3711 45 104). This project is being carried out by Öko-Institut (coordination), CE Delft and Tim Bäuerle LL. M.

Summary

In the International Maritime Organization (IMO) there are currently four measures under discussion that aim to enhance the energy efficiency and to reduce the fuel consumption of ships:

- the US proposal, which aims to reduce the energy used per hour in service;
- the Annual EEOI proposal, which aims to reduce CO_2 emissions per dwt-mile;
- the Individual Ship Performance Indicator (ISPI), which aims to reduce CO_2 emissions per mile; and
- the Fuel Oil Reduction Strategy (FORS), which aims to reduce CO_2 emissions by reducing fuel consumption.

This paper describes the four measures and analyses them, focusing on their expected environmental impact in terms of CO_2 emission reduction as well as their interaction with potential future market-based measures. To illustrate the differences between the four measures, quantitative examples for three virtual ships are presented.

The expected impact of the measures on the CO_2 emissions will greatly depend on their respective stringency. However, no targets have been determined yet, which is why the paper discusses design elements that have an impact on the environmental effect of the measures: the potential scope of the measures, their expected implementation time, the abatement measures they incentivise, whether they can be expected to remove barriers that prevent ship owners to take abatement measures as well as their expected environmental effectiveness, e.g. whether a measure limits total fleet emissions.

Analysing the elements, the following conclusions can be drawn:

- Both the US proposal and FORS can be applied in principle to all ship types and thus have the highest potential coverage of the fleet. The other measures are more suitable for cargo ships.
- The quicker a measure can be implemented, the sooner CO_2 can be reduced. Of the four measures, FORS can be expected to be implemented the quickest since it does not call for a data collection phase and works with a readily available baseline.
- All four measures do, in principle, incentivise the adoption of operational as well as technical emission abatement measures. However, only FORS incentivises slow steaming in a technology-neutral way. The other measures either reward it more than other options to reduce a similar amount of emissions (the US proposal) or less (the Annual EEOI and ISPI). Fuel switching is not rewarded in the US proposal, even when it reduces emissions.
- By rewarding lower capacity utilisation, the US proposal and the ISPI give an incentive that is not desirable from an environmental point of view.
- All four measures contribute to a removal of the barriers that prevent ship owners investing in CO_2 abatement reduction measures; all measures require ship owners to take CO_2 abatement measures. Thus, on the one hand, the measures help to overcome the split incentive problem between ship owners and charterers. On the other hand, the lack of transparency in the market can be reduced by prompting the ship owners that have invested in emission abatement to credibly show that the energy efficiency of their ships has improved to be able to earn back their investment via higher charter rates.

- None of the measures limits the total CO_2 emissions of the fleet since new ships may be added to the fleet and increase the total emissions. Regarding the emissions of the baseline fleet, i.e. the existing fleet at the time at which a measure is implemented, only FORS will ensure with certainty that these emissions will decline. This does not necessarily hold for the other measures as the activity (distance covered, hours in service or transport work in tonne miles) of the ships may increase.
- Progress indicated by each of the measures does not reflect reductions of CO_2 emissions of the fleet. All measures allow for an increase of emissions as a result of the addition of new ships to the fleet. Furthermore, the Annual EEOI, ISPI and the US proposal allow for a growth in emissions due to an increase of transport work, distance sailed or time in service, respectively. When slow steaming results in additional ships being added to the fleet, FORS and the US proposal do not take the emissions of additional ships into account, whereas the Annual EEOI and ISPI do.

Regarding the interaction of the measures with potential future market-based instruments, it can be concluded that there are two ways in which a measure to improve efficiency and reduce fuel use could co-exist with a Market-Based Measure (MBM) that also caps emissions. The first way would be to use the monitoring, reporting and verification requirements in the MBM. This could be combined with any of the proposed measures. The second way would be to introduce an MBM as a flexibility mechanism in FORS.

Zusammenfassung

In der International Maritime Organization (IMO) stehen derzeit vier Maßnahmen zur Verbesserung der Energieeffizienz beziehungsweise zur Verringerung des Kraftstoffverbrauchs von Schiffen zur Diskussion:

- der US Vorschlag zielt darauf ab, den Energieverbrauch je Nutzungsstunde zu verringern;
- der *Annual Energy Efficiency Operational Index (EEOI)* Vorschlag hat zum Ziel die CO_2 Emissionen je *DWT*-Meile zu verringern;
- der *Individual Ship Performance Indicator (ISPI)* soll eine Minderung der CO_2-Emissionen je zurückgelegter Meile bewirken;
- die *Fuel Oil Reduction Strategy* (*FORS*) möchte eine Reduktion der CO_2-Emissionen mittels Verringerung des Kraftstoffverbrauchs erwirken.

Im folgenden Diskussionspapier werden diese vier Maßnahmen beschrieben und analysiert, wobei der Schwerpunkt auf den jeweils zu erwartenden CO_2-Emissionsminderungen sowie auf einer Wechselwirkung mit potentiellen zukünftigen marktbasierten Maßnahmen liegt. Um die Unterschiede zwischen den vier Maßnahmen zu veranschaulichen, werden schließlich für drei fiktive Schiffe quantitative Beispiele präsentiert.

Der CO_2-Effekt der Maßnahmen wird weitgehend davon abhängen, wie streng die jeweilige Norm angesetzt werden wird. Da jedoch noch keine Reduktionsziele festgelegt worden sind, können die jeweiligen CO_2-Minderungspotentiale in dieser Studie nicht als solche quantifiziert werden, vielmehr werden die Ausgestaltungselemente der Maßnahmen analysiert, die einen Einfluss auf die CO_2-Emissionen haben werden. Die folgenden Elemente werden dabei berücksichtigt:

- der potentielle Deckungsgrad,
- die zu erwartende Dauer der Implementierung,
- die Anreizstruktur hinsichtlich der verschiedenen Emissionsminderungsmaßnahmen,
- der Beitrag zum Abbau von Barrieren hinsichtlich der Investition in die Minderungsmaßnahmen sowie
- die Umwelteffektivität der Maßnahme.

Folgende Schlussfolgerungen werden aus dieser Analyse gezogen:

- Grundsätzlich können sowohl der US-Vorschlag als auch *FORS* auf alle Schiffstypen angewendet werden und haben somit den größten potentiellen Deckungsgrad. Die anderen Maßnahmen sind vor allem zur Regulierung von Frachtschiffen geeignet.
- Je schneller eine Maßnahme implementiert werden kann, desto eher können CO_2-Emissionen gemindert werden. Es ist zu erwarten, dass *FORS* am schnellsten implementiert werden kann, da keine Datensammlung erforderlich ist und da diese Maßnahme eine bereits vorliegende Baseline nutzen würde.
- Prinzipiell setzen alle vier Maβnahmen den Anreiz sowohl operative als auch technische Emissionsminderungsmaßnahmen zu implementieren. Was *Slow Steaming* betrifft, setzt *FORS* jedoch den neutralsten Anreiz: Die anderen Maßnahmen belohnen *Slow Steaming* entweder mehr (US-Vorschlag) oder weniger (*Annual EEOI*, *ISPI*) als andere Minderungsmaßnahmen; darüber hinaus wird durch den US-Vorschlag ein

Kraftstoffwechsel nicht belohnt, selbst wenn dieser zu Emissionsminderungen führen würde.

- Sowohl der US-Vorschlag als auch der *ISPI* begünstigen eine geringere Kapazitätsauslastung und geben somit einen Anreiz, der aus Umweltperspektive nicht wünschenswert ist.
- Alle vier Maβnahmen tragen zu einem Abbau von Investitionshemmnissen für Emissionsminderungsmaßnahmen bei: Alle Maβnahmen erfordern, dass der Schiffseigner Minderungsmaßnahmen durchführt. Somit kann einerseits das *Split-Incentive*-Problem zwischen Schiffseigner und Charterer überwunden werden. Andererseits kann die Intransparenz im Markt abgebaut werden, da der Schiffseigner einen Anreiz hat, die Verbesserung der Energieeffizienz des Schiffes glaubwürdig nachzuweisen, um seine Investition mittels höherer Charterraten zurückzuverdienen.
- Keine der Maßnahmen begrenzt die CO_2-Emissionen der gesamten Flotte, da neue Schiffe zur Flotte hinzugefügt werden und die Gesamtemissionen dadurch steigen könnten. Was die Baselineflotte, d.h. die Flotte, die zum Zeitpunkt des Inkrafttretens einer Maßnahme besteht, betrifft, so kann nur unter *FORS* mit Sicherheit davon ausgegangen werden, dass deren Emissionen sinken werden. Bei den anderen Maßnahmen kann es sein, dass die jeweilige Aktivität (zurückgelegte Entfernung, Nutzungsstunden, Meilen und Tragfähigkeit) sich erhöht und die Effizienzverbesserung überkompensiert.
- Der Fortschritt, der durch die Maßnahmen aufgezeigt wird, reflektiert nicht die CO_2-Minderung der Gesamtflotte. Bei jeder der vier Maßnahmen kann es sein, dass die Gesamtemissionen durch ein Wachstum der Flotte steigen. Ferner können bei dem *Annual EEOI*, bei *ISPI* und dem US Vorschlag die Emissionen aufgrund erhöhter Transportleistung, längerer Transportabstände oder mehr Nutzungsstunden steigen. Wenn *Slow Steaming* zum Einsatz zusätzlicher Schiffe führen sollte, so reflektieren *FORS* und der US Vorschlag, im Gegensatz zu dem *Annual EEOI* und *ISPI,* die Emissionen der zusätzlichen Schiffe nicht.

Bezüglich der Wechselwirkung der vier Maßnahmen mit potentiellen zukünftigen marktbasierten Maßnahmen, gibt es grundsätzlich zwei Kombinationsmöglichkeiten. Zum einen könnten die Anforderungen hinsichtlich *Monitoring*, *Reporting* und *Verification* bei der Implementierung einer marktbasierten Maßnahme übernommen werden. Dies ist für alle vier Maßnahmen möglich. Zum anderen könnte *FORS*, durch einen Flexibilitätsmechanismus erweitert, als eine marktbasierte Maßnahme implementiert werden.

Table of Contents

1 Introduction

1.1 Background

MEPC 66 discussed further technical and operational measures for enhancing the energy efficiency of international shipping in a working group. The group discussed in detail four proposals made by various parties on this subject:

- A proposal by the US to enhance the energy efficiency of international shipping defined as energy used per hour in service (MEPC 65/4/19);
- A proposal to enhance the energy efficiency of shipping defined as CO_2 per deadweight mile, called 'Annual EEOI' (MEPC 66/4/6);
- A proposal to enhance the energy efficiency of shipping defined as CO_2 per mile, under which less efficient ships would need to do more, called Individual Ship Performance Indicator (ISPI) (MEPC 66/4/6);
- A proposal to enhance the energy efficiency by limiting the amount of fuel used per year, called FORS (MEPC 66/4/6).

The group concluded that further work was needed on all the metrics proposed so far and that no metric should be excluded at this point in time.

1.2 Aim of Report

The aim of the report is twofold:

The first aim of the report is to compare the expected environmental impact of the efficiency indicator as proposed by the US (65/4/19) with the expected environmental impact of the three alternative metrics as specified in the commenting paper (MEPC 65/4/30).

The second aim of the report is to develop ideas on how the standard proposed by the US as well as the three alternative standards could evolve into a market-based measure with an overall emissions cap.

1.3 Outline

In chapter 2 we first briefly describe the four proposed standards and subsequently analyse these standards in chapter 3. The phased implementation of the standard as proposed by the US is described in greater detail and the four proposals are compared with regards to their environmental impact based on a set of criteria. In chapter 4 the potential evolution of the four proposals is discussed. Chapter 5 concludes and provides an overview table of the outcomes of chapters 3 and 4. In the Annex the differences between the metrics underlying the four standards are illustrated with calculations carried out for three exemplary ship types.

2 Brief description of the proposed measures

2.1 US proposal

The US submission to MEPC 65 (MEPC 65/4/19) presents a phased approach to the implementation of an efficiency standard and proposes an efficiency metric; this is one of the four metrics currently under discussion at the IMO.

The phased implementation approach comprises three phases:

- Phase I: Data collection and analysis phase.
  In this first phase, relevant data will be collected centrally for two years and will subsequently be analysed by an expert group. Based on the analysis, baseline curves will be established per ship type. If possible energy efficiency standards, expressed as a function of dwt, will be derived from the baseline curves or, if the data does not support this, ship-specific standards could be developed.
- Phase II: Pilot phase.
  In this phase, ships will be evaluated against the standards but are not required to meet them. The purpose of the pilot phase is to gain experience with the system.
- Phase III: Full implementation.
  In this phase, ships will be required to comply with the applicable efficiency standards.

The different phases will be discussed in greater detail in section 3.1.

The phased approach in the US proposal can use different efficiency metrics. The efficiency metric that takes the most prominent role in the US proposal is 'Joules of fuel energy consumed/hours in service', with hours in service being defined as the hours a ship is underway. The US also recommends careful consideration of working with distance or other alternatives instead of working with hours in service. In this paper, however, we will focus on the indicator 'Joules of fuel energy consumed/hours in service' and will refer to it as the US proposal.

2.2 Alternative metrics

In the commenting paper (MEPC 65/4/30) on the US proposal (MEPC 65/4/19), three alternative metrics have been proposed, which have been elaborated in a submission by Japan and Germany (MEPC 66/4/6). These metrics will be described in more detail below.

2.2.1 Annual Energy Efficiency Operational Index (EEOI)

The Annual EEOI is an efficiency indicator that presents a ship's efficiency in terms of CO_2 emitted per unit of transport work. Two alternative definitions of transport work have thereby been proposed: one that relates the real cargo volume and the other that relates the nominal cargo volume (e.g. dwt or a share thereof) to the distance covered. Due to potential difficulties with the collection of reliable cargo volume data, MEPC 66/4/6 puts the nominal cargo option forward as an appropriate proxy to be considered by the Commission. Since the efficiency of a ship in terms of 'CO_2/tonne nautical mile' can be expected to fluctuate highly between voyages, it is proposed that annual averages are used. Regarding the baseline, three options are mentioned in the proposal: a ship-specific reference value, an average reference value per ship type/size category or a combination of both.

2.2.2 Individual Ship Performance Indicator (ISPI)

The Individual Ship Performance Indicator (ISPI) measures the efficiency of ships in terms of CO_2 emitted per nautical mile. It is proposed that the corresponding reference values are ship-specific and a data collection phase would be necessary for determining these reference values.

It is proposed that the emission reduction target is differentiated according to the initial technical efficiency of the ships. The initial technical efficiency of the ships would be measured by a ‘design efficiency factor' (DF) that relates the ships’ Estimated Index Value (EIV) to the baseline EIV of the relevant ship category and size. The Estimated Index Value is calculated by means of the simplified formula of the EEDI that has been used by the IMO to develop the EEDI reference lines (see Guidelines for calculation of reference lines for use with the EEDI, MEPC.215(63)). The design efficiency factors could be determined without a data collection phase.

The formula implies that a ship with a less fuel-efficient design will have to improve its efficiency more than a ship with a more efficient design.

2.2.3 Fuel oil reduction strategy (FORS)

FORS aims at reducing the fuel oil consumption of each individual ship by means of a fuel oil consumption standard. FORS thereby combines ship-specific reference values with a uniform percentage reduction target for all ships. No data collection phase is needed to determine the ship-specific reference values under FORS; instead, readily available data is used: The average 2007 operational profiles of a ship’s type/size category (i.e. average days at sea, average specific fuel oil consumption (SFOC), average engine load), as given in the Second IMO Greenhouse Gas Study, is combined with the ship’s actual engine power as given in the IHS Fairplay database to determine the ship’s reference fuel oil consumption.

3 Analysis of the proposed measures

3.1 The phased implementation as proposed by the US

The US has developed a phased implementation approach for their proposed efficiency measure (MEPC 65/4/19). In Table 1 a detailed overview of the different intended steps per phase and the intended responsibilities is provided.

Table 1: Overview of the phased implementation as proposed by the US (MEPC 65/4/19)

Phase I Data collection and analysis phase	Central database	Centralised database is set up.
	MRV	- Ships collect data (joules of fuel energy used, hours in service) - ‘Hours in service’ need to be attested by ship master for verification purpose. - Ships have to report (collected data, attained efficiency, basic ship data) to a centralised database on annual basis and compile data in annual report. - In statutory survey flag administration or recognized organisations (RO) verifies data in report and submits verification notice together with attained energy efficiency to centralized database.
	Baseline	After 2 years MEPC expert group establishes baseline curves for different ship

		types.
	Standard(s)	If possible MEPC sets standards on the basis of baseline curves. Alternatively, MEPC develops ship-specific standards.
Phase II **Pilot Phase**	MRV	- Ships collect data (joules of fuel energy used, hours in service) - 'Hours in service' are attested by ship master for verification purpose. - Ships have to report (collected data, attained efficiency, basic ship data) to a centralised database on annual basis and compile data in annual report. - In statutory survey flag administration or RO verifies data in report and submits verification notice together with attained energy efficiency to centralised database. - Compliance periods are no less than two and no more than five years. - Ships are evaluated against the standard by Flag States per compliance period but ships do not have to comply with standard in the pilot phase.
	Flexibility	Need for (initial) flexibility measures for non-compliant ships can be established.
	Adjustments	MEPC may consider recalculation of baseline curves and adjustment of standards.
	Labels	Option: MEPC could develop ship efficiency labels.
Phase III **Full implementation**	MRV	- Ships collect data (joules of fuel energy used, hours in service) - 'Hours in service' need to be attested by ship master for verification purpose. - Ships report data to a centralised database on annual basis and compile data in annual report. - Flag States/RO verify data in report during statutory surveys, submits verification notice together with attained energy efficiency to centralised database and notes the attained efficiency in the ship's International Energy Efficiency Certificate (IEEC). - Compliance periods are no less than two and no more than five years. - Ships are evaluated against the standard by Flag States per compliance period.
	Stringency	Stringency of standards is revised at no less than five-year intervals.

An implementation in the three proposed phases has the advantage that due to the data collection phase, current CO_2 emissions can be estimated more precisely. As a consequence, the environmental and economic impacts of alternative targets can be assessed more precisely ex ante, facilitating a goal-oriented choice of a target. However, working with a data collection phase as well as with a pilot phase has the major disadvantage that full implementation with mandatory efficiency improvements will only occur four to seven years after adoption of the proposal. Note, therefore, that the data collection phase is inherent to the US proposal as well as to the Annual EEOI and ISPI since data has to be collected for the establishment of a baseline.

3.2 Comparison of expected environmental impact of the different measures

The expected impact of the measures to enhance the energy efficiency and reduce fuel consumption on the CO_2 emissions of maritime shipping can only be analysed to a limited extent at this stage since their overall impact will strongly depend on their stringency of targets which have not been determined yet. At this stage we can only discuss the following elements that have an impact on the environmental effect of the measures:

1. Scope:

   Which part of the fleet will be covered by the proposed measure?

2. Implementation time:
   a. What is the scheduled time for the proposed measure to become effective?
   b. Which factors could turn out to be problematic and could delay implementation?

3. Incentivised abatement measures:
   a. Are both technical and operational CO_2 abatement measures in principle incentivised?
   b. Are there useful, specific abatement measures which are not incentivised?
   c. Are there specific, unwanted abatement measures incentivised?

4. Removal of barriers to taking CO_2 abatement measures:
   a. Can the measure contribute to a reduction of the split incentive between ship owners and charterers?
   b. Can the measure take away the lack of transparency and enable charterers to choose ships on the basis of their energy efficiency?

5. Environmental effectiveness of the measure:
   a. Are the CO_2 emissions of the baseline fleet[1] reduced if the fleet is compliant with the standard?
   b. Are the CO_2 emissions of the total fleet reduced if all ships are compliant?
   c. Are the ships more carbon-efficient if they comply with the standard?
   d. Are there any design elements of the measure that may lead to an overestimation of the expected environmental impact?

Note that in section 5 an overview table is given with a comparison of the different measures in which the findings of this section are also included.

3.2.1 US proposal

The US proposes to apply a standard on the efficiency of ships in terms of 'Joules of fuel energy consumed/hours in service', with the hours in service being defined as the hours a ship is underway.

[1] By "baseline fleet" we mean the existing fleet by the time the measure is implemented.

1. Scope

A maximum share of the fleet is covered by this standard since the standard is in principle applicable to all ship types.

2. Implementation time

The standard proposed by the US cannot become effective at short notice: a data collection phase is necessary to determine the baselines (2 years proposed); and after the baselines and standards have been determined, there is a pilot phase (with a proposed length of 2 to 5 years).

Before the data collection phase could start, a common definition of all the relevant parameters, including the as yet undefined 'hours in service', would need to be agreed upon. After the data collection phase, the establishment of the baselines and standards could turn out to be difficult and time consuming.

3. Incentivized abatement measures

Both technical and operational measures can, in principle, be used to comply with the standard, which has a positive effect on the maximum abatement potential of the standard.

However, higher capacity utilisation is not encouraged by the measure. In fact, ballast voyages contribute to a reduction of the average efficiency in terms of 'Joules of energy used/hours in service' because the energy use per hour in service is, all else being equal, lower for ballast voyages than for laden voyages (ships in ballast have a lower draft and consequently less friction).

Fuel switching is not incentivised by an efficiency measure that works with 'Joule of energy used' in the numerator since the energy consumption of vessels is not reduced by fuel switching. Switching to a fuel type that is associated with less CO_2 per unit of energy could, however, be desirable from an environmental point of view.[2]

4. Removal of barriers for taking CO_2 abatement measures

If a standard was implemented as proposed by the US, the split incentive problem between ship owners and charterers would be reduced since ship owners would be required to take CO_2 abatement measures regardless of whether they can subsequently profit from the charterer's reduced fuel bill or not.

[2] MDO/MGO (~75 gCO_2/MJ) and LNG (~57 gCO_2/MJ) are associated with less CO_2 emissions per energy unit than HFO (~78 gCO_2/MJ). The climate benefits of LNG depend crucially on methane slip because methane is a more powerful greenhouse gas than CO_2. Methane slip depends, amongst other things, on the engine technology. Some engine types do not have methane slip while in other engine types, methane slip may be 2%-4%. Methane is not only emitted as an exhaust gas, but also at different upstream points in the LNG supply chain. The climate benefits of switching to biofuels depend on emissions associated with the production of biofuel over the lifecycle (growing feedstock, transport and conversion into liquid fuel).

If this data/information became available for shippers as well, it would enable them to select a ship on the basis of the energy efficiency, which may trigger a competition between ship owners on environmental grounds.

5. **Environmental effectiveness of the measure**

If the ships of baseline fleet[3] are compliant with the standard, this would not necessarily mean that the CO_2 emissions of these ships would have been reduced; an increase of the fleet's 'hours in service' might counteract the reduction of the energy used per hour in service.

Regarding the CO_2 emissions of the total fleet, these may not only increase due to an increase of the 'hours in service' of the baseline fleet but also due to a growing fleet. The relative standard proposed by the US is not accompanied by an absolute emissions cap and thus allows for unlimited growth of the total emissions of the fleet.

Due to the standard, the efficiency of a ship in terms of 'Joules of fuel energy consumed/hours in service' has to be improved. Complying with the standard, however, does not necessarily mean that the transport efficiency actually has been improved: the ship may, for example, have had longer queuing times in front of ports, lower cargo load factors or have been transporting cargo with a lower density within the compliance period.

The efficiency metric proposed by the US favours slow steaming in the sense that if slow steaming is applied, the CO_2 emissions will have to be reduced to a lesser extent to comply with the standard than if another abatement measure was applied: slow steaming not only reduces fuel energy consumption (numerator of the indicator) but also leads to an increase in the hours in which a ship is in service (denominator of indicator), at least if the maximum amount of hours in service per year has not yet been reached. The standard may thus be less stringent than expected. From an environmental perspective, there is no benefit in favouring one particular emission reduction option over others.

'Hours in service' is a new concept for which no common definition currently exists. The verification of the reported 'hours in service' could thus be difficult, leading to an uncertainty regarding the actual target achievement.

3.2.2 Annual Energy Efficiency Operational Index

If the Annual Energy Efficiency Operational Index (EEOI) was used as a metric in a measure to improve the efficiency and reduce fuel use, a standard would be set on the ships' annual average CO_2 emissions per tonne nautical mile[4]. In the following, we discuss the different determinants of the environmental effect of this metric as listed above. Since working with nominal cargo volume of the ships (e.g. ships' dwt) is brought forward as an alternative for working

[3] By "baseline fleet" we mean the existing fleet by the time the measure is implemented.

[4] In the EEOI Guidelines (MEPC.1/Circ.684) the proposal is to use either mass of cargo or number of TEU's for cargo ships and to work with the number of passengers or the gross tonnage of the ship for passenger ships.

with the real cargo volume (actual mass of the cargo carried), we subsequently discuss the advantages and disadvantage of this alternative.

1. **Scope**

   In principle, the Annual EEOI can be applied to all ships whose primary purpose is to transport cargo and/or passengers. Ships that serve other purposes such as dredgers, fishing vessels, research vessels, etc. would thus not be covered. Non cargo/non-passenger ships accounted for 15% of emissions in 2007 (Buhaug et al., 2009).

2. **Implementation time**

   Just as for the implementation of the standard proposed by the US, a data collection phase is necessary to determine the baselines for the Annual EEOI. It can nevertheless be expected that the implementation of the Annual EEOI would be less time-consuming than the implementation of the US proposal since the EEOI has already been adopted as the primary monitoring tool for the Ship Energy Efficiency Management Plan and is thus an instrument adopted by the IMO and accepted by the international community of States. Some ship operators are also already monitoring the efficiency of their ships by means of the EEOI, a pilot phase will not be necessary.

   What could constitute a problem in the implementation phase is the fact that some ship owners/operators have reservations about reporting real cargo loads, considering these as business sensitive data. Reporting the EEOI on an annual basis, which would be the case for the Annual EEOI, or publishing the data with a time delay could help to overcome these reservations.

3. **Incentivised abatement measures**

   The Annual EEOI incentivises both the adoption of technical and operational CO_2 abatement measures, leading to a high maximum abatement potential. Regarding the operational measures, there is also an incentive to switch to alternative fuels[5] and to increase the capacity utilisation rate – in contrast to the measure proposed by the US. Since the real cargo load is often not under the control of the vessel operator and also influenced by global economic developments, the actual abatement potential of logistic measures may, however, turn out to be low.

   The Annual EEOI would disincentivise slow steaming in the sense that if slow steaming is applied, the EEOI is reduced to a lesser extent than CO_2 emissions. In contrast, if CO_2 is reduced through other measures, the EEOI and emissions are reduced by the same percentage. This difference occurs because slow steaming not only reduces the annual CO_2 emissions (numerator of indicator) but also results in a decrease in the distance covered in that year (part of the denominator of the indicator), if it is assumed that the time per port call remains constant. This does not mean, however, that slow steaming will consequently not be applied under the Annual EEOI; it only means that other abatement measure might be preferred.

[5] The Annual EEOI gives an incentive to switch to fuel types that are associated with less CO_2 emission per energy unit, which can be desirable from an environmental point of view. See footnote 2 for a discussion of the climate benefits of a fuel switch.

4. Removal of barriers to taking CO_2 abatement measures

The EEOI of a ship can greatly differ between voyages. These fluctuations can have different reasons such as different weather conditions, different routes, different types of cargo, the economic cycle, which has an impact on cargo load factors, etc. The explanatory power of the EEOI of a ship measured per voyage is thus very limited. This is the reason why the Annual EEOI works with an annual average in the first place. The question remains, however, whether an annual average provides relevant information for a potential charterer given that its utilisation profile could highly differ from that of the previous charterers of the ship. Nevertheless, the Annual EEOI will help to reduce the split incentive problem between ship owners and charterers. Just as the standard proposed by the US (see 3.2.1, point 4) the relative measure will require ship owners to invest into CO_2 abatement measures and therefore give ship owners the incentive to show credibly that the efficiency of their ship has improved. If this data/information becomes available for shippers as well, this would enable them to choose a ship on the basis of the energy efficiency, which in turn may trigger a competition between ship owners on energy efficiency grounds.

5. Environmental effectiveness of the measure

The emissions of the baseline fleet[6] are not necessarily reduced if the ships of the baseline fleet are compliant with the standard since the activity of the fleet in terms of tonne nautical miles may be increased. This is inherent to a relative standard.

The Annual EEOI does not set a cap on the fleet's CO_2 emissions. The total CO_2 emissions of the sector may thus increase not only due to a higher activity of the baseline fleet but also due to a growing fleet.

Discussion: nominal versus real cargo

Since some ship operators have reservations about reporting real cargo loads, considering these business sensitive data, it is proposed that nominal cargo data are used instead. Most probably this would mean that it is worked with (a certain share of) the deadweight tonnage of a ship.

Working with nominal instead of real load would have the advantages that:

- the standard would, due to less resistance from the sector, probably be implemented quicker and thus would become effective earlier,
- all ships could be covered by the Annual EEOI,
- the indicator is less volatile since it does not depend on economic circumstances.

On the other hand, working with nominal load would involve several disadvantages:

- An optimisation of the utilisation rate can no longer contribute to the compliance with the standard.
- The marine transport efficiency can no longer be compared with that of other transport modes.

---

[6] By "baseline fleet" we mean the existing fleet by the time the measure is implemented.

3.2.3 Individual Ship Performance Indicator (ISPI)

With ISPI a standard would be set on a ship's CO_2 emissions per unit of distance (nautical mile). The relative emission reduction target is thereby differentiated: Ships with a relative high initial technical efficiency have a lower reduction target than ships with a relative low initial technical efficiency.

1. Scope

   In principle, ISPI can be applied to all ship types. The application to certain ship types which typically consume fuel while covering little or no distance (e.g. dredging vessels) may, however, not be constructive.

   It is proposed that the relative emission reduction targets vary according to the ships' initial efficiencies: A design efficiency factor (DF) is applied to the default relative emission target (e.g. 20%), with the DF being the ratio of the ship's specific Estimated Index Value and the according industry average. The Estimated Index Value has been used by the IMO to determine the reference values for the Energy Efficiency Design Index but has not been calculated for all ship types by the IMO yet. Application to all ship types is thus not straight-forward.

2. Implementation time

   Like the US proposal and the Annual EEOI, ISPI necessitates a data collection phase for the determination of the baselines. In addition, for some ship types, the Estimated Index Values would have to be determined to be able to differentiate the emission reduction target of all ships.

   Relating the CO_2 emissions to the distance sailed is not an established concept under the IMO, but since distance data cannot be considered business-sensitive and can be measured precisely, distance as such will probably not be an obstacle in the implementation process.

   Rewarding early movers by differentiating the relative emission targets could enhance the acceptability and thus the time before ISPI is implemented.

3. Incentivised abatement measures

   ISPI would incentivise the same measures as the Annual EEOI with nominal cargo capacities. Ships can thus apply both technical and operational abatement measures to improve their efficiency; fuel switching is incentivised, whereas higher capacity utilisation is not. In fact, ballast voyages will contribute to a lower (better) annual average of the indicator because the fuel consumption on a ballast voyage is less than on a laden voyage, while the distance is the same. As with the Annual EEOI, slow steaming would reduce both the amount of fuel energy and the distance sailed per annum, at least if a ship is not able to operate enough extra days at sea and therefore could have a comparatively smaller impact on the indicator than other measures that reduce emissions or fuel energy by the same amount. This could make slow steaming less attractive.

4. Removal of barriers for taking CO_2 abatement measures

   Like the Annual EEOI, ISPI can be expected to fluctuate due to non-efficiency related factors like the density of the cargo. Although the ISPI can be expected to fluctuate less than the Annual EEOI, it is still questionable inasmuch the market will find it a useful measure for overcoming the split incentive problem and the lack of transparency on the side of the shippers.

However, as for all four standards under consideration here, ISPI will help to overcome the split incentive problem between ship owners and charterers by requiring ship owners to take CO_2 abatement measures. As a consequence the lack of transparency might also be solved because ship owners will have an incentive to credibly show that they have improved the energy efficiency of their ships and might want to make this data/information available for shippers, too.

5. Environmental effectiveness of the measure

ISPI works with a relative standard. This means that even if the baseline fleet[7] was compliant with the standard, its CO_2 emissions might increase due to longer distances covered in that year.

Since ISPI does not provide for a cap of the total fleet's CO_2 emissions, total CO_2 emissions of the sector can grow unlimited, not only due to longer distances covered but also due to a growing fleet.

If a ship is compliant with the relative standard, this does not necessarily mean that the ship's carbon efficiency is improved. ISPI may fluctuate less than the Annual EEOI but there are nevertheless non-efficiency related factors that have an impact on ISPI, e.g. cargo with varying density.

3.2.4 Fuel oil reduction strategy (FORS)

In contrast to the other proposed measures, the fuel oil reduction strategy works with an absolute and not with a relative standard: FORS obliges each ship to limit its annual fuel oil consumption. The ship-specific target is thereby determined on the basis of a ship-specific reference value and a relative target, which is the same for all ships. The ship-specific reference value reflects both the ship-type average operational profile of 2007 and the ship-specific engine power.

1. Scope

FORS sets an absolute standard on the ship's fuel consumption and can thus be applied to all ship types.

2. Implementation time

FORS can be implemented and become effective at short notice: Since the ship-specific reference values are determined on the basis of data that already is available, there is no need for a data collection phase. The calculation of the reference values is not expected to be time-consuming. FORS also does not envisage a pilot phase, which seems appropriate since ship owners can more easily anticipate the effort that is needed for the compliance with an absolute standard (FORS) than with a relative standard (the other proposals).

[7] By "baseline fleet" we mean the existing fleet by the time the measure is implemented.

The fact that under FORS ship operators will not have to report data that could be regarded as business-sensitive and that early movers are rewarded by working with a 2007 baseline could contribute to quick implementation.

3. **Incentivised abatement measures**

Ships can apply both technical and operational abatement measures to comply with FORS leading to a high maximum abatement potential.

Fuel switching, the optimisation of the capacity utilisation and slow steaming are specific operational measures. Regarding these measures, the following holds for FORS:

- FORS gives an incentive to switch to a fuel type with a higher calorific value – a fuel type that enables the same transport work to be carried out with a reduced amount of fuel. This fuel switch can be desirable from an environmental point of view.[8]
- FORS gives ships the incentive to use their 'fuel consumption budget' efficiently, so that an optimisation of the capacity utilisation is incentivised too.
- In contrast to the other proposed measures, FORS incentivises all measures to reduce emissions – be it slow steaming, technical or operational measures, to the same extent.

4. **Removal of barriers for taking CO_2 abatement measures**

If FORS was implemented, ship owners would be obliged to monitor and report the annual fuel oil consumption and the annual CO_2 emissions of their ships. These data however are not specific enough to take away the split incentive between ship owners and operators or to eliminate the lack of transparency regarding the energy efficiency of the ships on the part of shippers. This is because they cannot provide an indication of the fuel consumption/CO_2 emissions for a specific utilisation of the ship (e.g. fuel consumption for a specific cargo and route combination) that a charterer or shipper might be interested in. Nevertheless, in good economic times, FORS will prompt ship owners to improve the energy efficiency of their ships, which means that the split incentive problem is overcome. As a result ship owners have an incentive to credibly show that the energy efficiency of their ships has improved in order to earn back their investment expenditures via higher charter rates. If this information became available for shippers too, they would be able to select a ship on the basis on its energy efficiency and ship owners might compete based on the energy efficiency of their ships, too.

5. **Environmental effectiveness of the measure**

In contrast to the other three proposed measures, FORS works with an absolute and not with a relative standard. This means that if the baseline fleet[9] is compliant with the standard set under FORS, total CO_2 emissions of the baseline fleet are definitely reduced.

As with the other three measures, FORS does not limit total CO_2 emissions of the total fleet; it limits fuel consumption per ship whereas the growth of the fleet is not limited.

---

[8] See footnote 2 for a discussion of the climate benefits of a fuel switch.

[9] By "baseline fleet" we mean the existing fleet by the time the measure is implemented.

Whether FORS will lead to an improvement of transport efficiency will depend on the economic situation. In good economic times ships will have to improve their efficiency to be able to meet their fuel oil consumption limit, whereas in times of economic downturn ships can probably meet their limit without improving their efficiency.

4 Interaction with a potential future MBM

4.1 Why could there be a need for an MBM to complement a measure to improve efficiency and reduce fuel use?

All proposed measures to improve efficiency and reduce fuel use contain a reference to flexibility mechanisms that allow ships for which efficiency improvements are infeasible or very costly to comply at a lower cost. Market-Based Measures (MBM) may be helpful in creating flexibility. They may allow shipping companies for which meeting the standard would be very costly to contribute to efficiency improvements of others, for example, thus reducing the overall costs of meeting the target.

A measure to improve efficiency and reduce fuel use would improve the efficiency of the fleet and thereby reduce emissions relative to a situation without the measure. However, even with efficiency improvements in the order of 40% up to 2050, Buhaug et al. (2009) project shipping emissions to increase. For the medium term (2020), UNEP (2011) finds that emission reductions relative to 2005 are only possible with the most stringent efficiency standards, under which the sector would incur high costs. The reason why shipping emissions are projected to increase is that activity and transport work will increase.

Hence, it is unlikely that the proposed measures alone will help the shipping sector to contribute to the overall emission reductions that are necessary to fulfil the 2°C target. For a reduction of (net) emissions of shipping, an MBM would be required that sets a cap on the total amount of emissions and allows for the use of offsets.

4.2 Potential synergies between measures to improve efficiency and reduce fuel use and MBMs

In principle, all proposed measures to improve efficiency and reduce fuel use could be supplemented with an MBM.

MBMs could be introduced in order to accommodate non-compliance with the standard for ships for which this would be costly or otherwise infeasible. The US proposal proposes 'flexibility mechanisms' for ships that are not in compliance, such as allowing them extra time to comply or exemptions. One could also imagine other flexibility mechanisms, such as pooling the obligations of groups of ships, or, to go one step further, efficiency credit trading between ships, which is the MBM previously proposed by the US (see, for example, MEPC 59/4/48, 60/4/12, and 61/5/16). Efficiency credit trading would be a suitable flexibility mechanism for the US metric, the Annual EEOI and the ISPI. A suitable flexibility mechanism for FORS would be emissions trading or offsetting.

Efficiency credit trading could be effective in reducing the costs of meeting an efficiency target, as ships for which meeting the target would be costly or otherwise infeasible could finance the efficiency improvements of other ships. However, efficiency credit trading would not limit the aggregate emissions of the fleet. Emissions could still increase because of an increase in the number of ships or in their activity, whether this is defined as hours at sea, miles sailed or tonne-miles covered.

Offsetting would be an obvious flexibility mechanism for ships failing to meet their target under FORS. For each tonne of CO_2 that they emit over their target, they could surrender an offset for an equal amount. In order to be environmentally effective, the quality of the offsets would thereby need to be guaranteed so that they are really worth a tonne of CO_2. Emissions could still increase because of an increase of the fleet, but other increases in activity (e.g. increasing the speed and/or the amount of miles sailed) would not lead to higher aggregate emissions. A next step towards an MBM could then be to relate the emissions target for individual ships under FORS to the emissions of the entire shipping sector so that when the fleet size increases, the target for individual ships becomes more stringent. This, in combination with offsetting, would effectively limit the emissions of the shipping sector. By also allowing ships that stay below their FORS target to generate offsets, one would arrive at a system that resembles emissions trading.

Alternatively, MBMs could be introduced independent of the measure decided upon. The argument for their introduction would then be that other goals than efficiency need to be met, e.g. reducing CO_2 emissions. MBMs aimed at reducing or capping CO_2 emissions would be an ETS or a GHG Fund. These MBMs could use the monitoring, reporting and verification systems developed as part of the measure. Which measure is chosen is perhaps not so important since all require monitoring fuel consumption.

In summary, there are two ways in which a measure to improve efficiency and reduce fuel use could co-exist with an MBM that also caps emissions. The first way would be to use the monitoring, reporting and verification requirements in the MBM. This could be combined with any of the proposed measures. The second way would be to introduce an MBM as a flexibility mechanism in FORS.

5 Conclusions

In the IMO there are currently four measures under discussion that aim to enhance the energy efficiency and to reduce the fuel consumption of ships:

- the US proposal, aiming to reduce the energy used per hour in service;
- the Annual EEOI proposal, aiming to reduce CO_2 emissions per tonne-mile of transport work or dwt-mile;
- the Individual Ship Performance Indicator (ISPI), aiming to reduce CO_2 emissions per mile;
- the Fuel Oil Reduction Strategy (FORS), aiming to reduce CO_2 emissions.

Several elements that will have an impact on the environmental effect of these measures have been analysed in this study and the following can be concluded in this regard:

- Both the US proposal and FORS can, in principle, be applied to all ship types and thus have the highest potential coverage of the fleet.
- The quicker a measure can be implemented, the sooner CO_2 can be reduced. From the four measures, FORS can be expected to be implemented the quickest since it does not call for a data collection phase and works with a readily available baseline.
- All four measures do in principle incentivise the adoption of operational as well as technical emission abatement measures; however, only FORS does so in a technology-neutral way. The other measures either reward slow steaming more than other options to reduce a similar amount of emissions (the US proposal) or less (the EEOI and the efficiency indicator). Fuel switching is not rewarded in the US proposal, even when it reduces emissions.
- By rewarding lower capacity utilisation, the US proposal and the ISPI give an incentive that is not desirable from an environmental point of view.
- For all four measures it holds that they contribute to a removal of the barriers that prevent ship owners investing in CO_2 abatement reduction measures: All measures require ship owners to take CO_2 abatement measures. Thus, on the one hand, the measures help to overcome the split incentive problem between ship owners and charterers. On the other hand, the lack of transparency in the market can be reduced by prompting the ship owners that have invested in emission abatement to credibly show that the energy efficiency of their ships has improved in order to earn back their investment via higher charter rates.
- None of the measures limits the total CO_2 emissions of the fleet. Regarding the emissions of the baseline fleet, i.e. the existing fleet by the time a measure is implemented, only FORS will ensure with certainty that these emissions will decline. This does not necessarily hold for the other measures as activity (distance covered, hours in service or transport work in tonne miles) of the ships may increase.
- Two design elements of the US proposal make the achievement of an environmental target uncertain: Firstly, if slow steaming was applied, CO_2 would have to be reduced less than if another measure was applied since the metric rewards slow steaming more than the actual emission reduction, and secondly, since the verification of ‘hours in service’ could turn out to be difficult, the actual ‘hours in service’ may deviate from the reported ‘hours in service’.

There are two ways in which a measure to improve efficiency and reduce fuel use could co-exist with an MBM that also caps emissions. The first would be to use the monitoring, reporting and verification requirements in the MBM. This could be combined with any of the proposed measures. The second would be to introduce an MBM as a flexibility mechanism in FORS.

Table 2: Overview of the findings regarding the expected environmental impacts of the proposed measures and their potential evolution towards an MBM

		US proposal	Annual EEOI (real cargo load)	ISPI	FORS
Scope	Which part of fleet is covered?	Can be applied to all ships.	Can be applied to all ships whose primary purpose is to transport cargo and/or passengers.	Application to ship types that typically consume fuel whilst covering little/no distance (e.g. dredging vessels) may not be sensible. The Estimated Index Value is used for calculating a target correction factor but has not been calculated for all ship types by the IMO yet. Application to all ship types is thus not straight forward.	Can be applied to all ships.
Implementation time	Scheduled time	Data collection phase and pilot phase scheduled.	Data collection phase necessary.	Data collection phase necessary.	No data collection phase needed.
	Potential factors for delays/quick implementation	Commonly accepted definition of 'hours in service' and a baseline have to be established.	EEOI is an established metric within IMO. Baseline has to be established. Reservations about reporting real cargo loads.	Estimated Index Values have to be determined for some ship types. Baseline has to be established. Rewarding early movers enhances acceptability.	Rewarding early movers enhances acceptability. Baseline is readily available.

		US proposal	Annual EEOI (real cargo load)	ISPI	FORS
Incentivised measures	Are both types of measures (technical and operational) incentivised?	In principle, both technical and operational measures are incentivised.			
	Specific useful measures not/less incentivised	Fuel switching is not incentivised.[10]	Slow steaming could be less rewarded than other abatement measures if days at sea cannot be expanded sufficiently.	Slow steaming could be less rewarded than other abatement measures if days at sea cannot be expanded sufficiently.	
	Specific unwanted measures incentivised	Lower capacity utilisation is rewarded.		Lower capacity utilisation is rewarded.	
Removal of barriers	Split incentive	All proposed measures require ship owners to take CO_2 abatement measures and thus help to overcome the split incentive problem between ship owners and charterers.			
	Lack of transparency	Ship owners are required to take CO_2 abatement measures and thus have incentive to credibly show that energy efficiency has improved to earn back investment via higher charter rates.			

[10] See footnote 2 for a discussion of the climate benefits of a fuel switch.

		US proposal	Annual EEOI (real cargo load)	Efficiency Indicator	FORS
Environmental effectiveness	Is CO_2 of baseline fleet reduced if it complies with standard?	Not necessarily.	Not necessarily.	Not necessarily.	Yes.
	Is CO_2 of total fleet reduced?	None of the four proposed measures limits the total CO_2 emissions of the fleet. The annual EEOI and ISPI take into account that slow steaming may result in emissions of ships that are added to the fleet to make up for the lower transport work, whereas the US proposal and FORS do not.			
	Design elements that might give uncertainty whether environmental target is achieved.	If slow steaming is applied, CO_2 has to be reduced less than if another measure is applied. Environ. achievement ex ante thus unclear. Verification of 'hours in service' may be difficult; target achievement thus not clear.			
Interaction with a potential future Market-Based Measure (MBM)	Supplementary MBM	MBM without a cap on total fleet emissions: Efficiency credit trading.			MBM with cap: Emissions trading or offsetting.
	MBM independent of measure	MBM only makes use of the monitoring, reporting and verification requirements of the proposed measures.			

6 Illustrative Examples

In order to illustrate our findings on the environmental impacts of the four proposed measures under discussion (see section 3.2), we have calculated for three exemplary ships the indicators to which a standard would be applied per measure, as well as the impact that different CO_2 abatement measures would have on these indicators.

These calculations have been carried out for vessel types that reflect three different types of transport service, i.e. a large crude oil tanker, a medium size container vessel and a medium sized RoPax vessel.

The data used for the calculations stems from the Second IMO GHG Study. The data is therefore related to the year 2007 and do not represent the characteristics and activity of specific ships but of an average ship of a specific ship type/size category.

In the following table the characteristics and activities that have been used for the calculation are given.

Table 3: Characteristics and activities of exemplary ships

(rounded figures)	Crude oil tanker	Container vessel	Ferry
IMO size category	200,000+ dwt	5-7,999 TEU	RoPax, <25 kn
Average GT	155,700	70,300	4,700
Average cargo capacity (tonnes)	295,250	40,350	Not known.
Average capacity utilisation	48%	70%	Not known.
Average service speed (knots)	15.4	25.3	20
Distance covered per year (nm)	100,200	149,900	122,100
Transport work per year (million tonne-nm)	14,200	4,200	Not known.
Fuel type consumed	HFO	HFO	MDO
Fuel consumption per year (kt)	24.3	42.1	5.2
CO_2 emissions per year (kt)	77.0	133.7	16.3

Source: Second IMO GHG Study

Given these characteristics and activities of the three ship types, the following indicators can be derived for the different proposed measures:

Table 4: Indicator per proposed measure for exemplary ship types

(rounded figures)	Crude oil tanker	Container vessel	Ferry
US proposal (GJ/hour in service)	150	290	35
Annual EEOI (gCO2/tonne-nm)	5	32	28
ISPI (kgCO2/nm)	768	892	134

FORS (kt fuel)	24	42	5

According to the EEOI Guideline of the IMO, the transport work carried out by passenger ships, including RoRo passenger ships, should be calculated using the number of passengers or the GT. We have calculated the Annual EEOI.

If on the three ships a CO_2 abatement measure was applied that had no impact on the hours in which a ship is in service per year and also no impact on the cargo carried and the distance sailed by the ship per year, the application of such a measure would lead to the same relative change of the indicators per ship.

In the following, we will analyse the impact on the indicators of three CO_2 abatement measures where this is/could not be the case, i.e. where a CO_2 abatement measure does/could lead to a different relative change of the indicators for the very same ship and discuss the consequences.

Speed reduction

We assume the three ships reduce their average speed by 10% and the time per port call remains the same, with the result that each ship has a lower number of voyages per year, but each voyage takes longer, and the total time at sea per year increases. This has the following effects:

- Main engine fuel consumption is reduced by 19%;
- The hours at sea per annum increases because there are fewer port calls and less time is spent in port;
- The transport work and miles sailed decreases because there are fewer voyages per annum.

As a result, the US proposal will reward slow steaming more than FORS, and the other two indicators less. FORS is the only indicator that shows the same improvement in the indicator as the reduction in fuel consumption and CO_2 emissions:

Table 5: Relative impact of a 10% speed reduction on indicators

(rounded figures)	Crude oil tanker	Container vessel	Ferry
US proposal (GJ/hour in service)	-21%	-21%	-21%
Annual EEOI (gCO_2/tonne-nm)	-12%	-12%	-12%
ISPI ($kgCO_2$/nm)	-12%	-12%	-12%
FORS (kt fuel)	-19%	-19%	-19%

*Note that this is a rough calculation, for which the fuel consumption of the auxiliary engines and the boiler has been kept constant.

Lower capacity utilisation

A useful indicator should not reward a lower capacity utilisation of the ships.

Table 6: Relative impact on indicators if ships transport 10% less (assuming a 1% CO_2 emission reduction)

(rounded figures)	Crude oil tanker	Container vessel	Ferry
US proposal (GJ/hour in service)	-1%	-1%	-1%
Annual EEOI (gCO_2/tonne-nm)	+10%	+10%	-1%
ISPI ($kgCO_2$/nm)	-1%	-1%	-1%
FORS (kt fuel)	-1%	-1%	-1%

As Table 6 reveals, only the Annual EEOI penalises lower capacity utilisation, at least if the Annual EEOI is calculated by means of the real cargo carried. If the Annual EEOI of the ferry is calculated using the ship's nominal cargo (GT), the lower capacity utilisation is also not penalised by the Annual EEOI.

Fuel switching

A ship could decide to switch from, for example, Heavy Fuel Oil to Marine Diesel Oil in order to reduce its CO_2 emissions. Whereas the carbon content of MDO only differs slightly from the carbon content of HFO, the calorific value of MDO is higher for MDO, thus leading to a reduced amount of fuel that is needed to carry out the same transport work.

Table 7: Relative impact on indicators if ships switched from Heavy Fuel to Marine Diesel Oil

(rounded figures)	Crude oil tanker	Container vessel	Ferry
US proposal (GJ/hour in service)	0%	0%	0%
Annual EEOI (gCO_2/tonne-nm)	-4%	-4%	-4%
ISPI ($kgCO_2$/nm)	-4%	-4%	-4%
FORS (kt fuel)	-3%	-3%	-3%

As Table 7 reveals, a switch from HFO to MDO does not have an impact on the indicator of the US proposal; it does not incentivise fuel switching.

The impact on the indicator of the Annual EEOI and the ISPI is the same whereas the impact on the FORS indicator is lower. This can be explained by the fact that the FORS indicator is, in terms of fuel and not in terms of CO_2, the same as for the two other indicators.

7 References

Buhaug et al. (2009), Second IMO Greenhouse Gas Study.

UNEP (2011), Bridging the Emissions Gap. United Nations Environment Programme (UNEP).

MEPC 65/4/19, Proposal of the United States to enhance energy efficiency in international shipping, submitted by the USA.

MEPC 65/4/30, Comments on document MEPC 65/4/19 on enhancing energy efficiency in international shipping, submitted by Belgium, Canada, Denmark, Germany, Japan, Norway and the United Kingdom.

MEPC 61/5/16, Further details on the United States proposal to reduce greenhouse gas emissions from international shipping, submitted by the United States.

MEPC 60/4/12, Further details on the United States proposal to reduce greenhouse gas emissions from international shipping, submitted by the USA.

MEPC 59/4/48, Comments on MEPC 59/4/2 and MEPC 59/4/4 and an additional approach to addressing maritime GHG measures, submitted by the USA.