Environmental Research

of the German Federal Ministry for the Environment,

Nature Conservation and Nuclear Safety

Project No. (3711 45 104)

Monitoring, Reporting and Verification of CO_2 emissions from ships
Design options, their feasibility and implications

DISCUSSION PAPER

by

Jasper Faber (faber@ce.nl)

Dagmar Nelissen (nelissen@ce.nl)

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

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

ON BEHALF OF THE

GERMAN FEDERAL ENVIRONMENT AGENCY

25 September 2013

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 Oeko-Institut (coordination), CE Delft and Tim Bäuerle LL. M.

Summary

The European Commission is currently working on a regional Monitoring, Reporting and Verification (MRV) system as an intermediary step towards a regional or a global regulation of the GHG emissions of maritime shipping. In this paper we discuss the implications and the feasibility of different design options of such a regional MRV system.

The European Commission has short-listed several regional market-based measures aimed at reducing the greenhouse gas emissions from maritime shipping for a stakeholder consultation and an impact assessment. These market-based measures differ with respect to the data that are needed for their implementation and the data that are needed post implementation. These data needs should be taken into account when choosing the parameters that would need to be monitored under an MRV regulation.

Assuming that ships have an incentive to improve the monitored elements over time, the direct effect of a stand-alone MRV system for CO_2 emissions would depend on the parameters to be monitored and on the options that are available to the ships to improve the monitored elements. If, for example, the operational efficiency of ships was monitored, a ship could apply technical as well as operational reduction measures to improve its operational efficiency, whereas if the technical efficiency of ships was monitored, a ship could only apply technical measures to improve its technical efficiency. The direct effect of an MRV system on CO_2 emissions would thus potentially be lower if the technical and not the operational efficiency of ships was monitored. However, independent of the parameters that are monitored, a direct effect of a stand-alone MRV system on CO_2 emissions can only be expected if the MRV system will provide additional insight to the actor that is actually paying for the fuel consumption of the ship.

There are certain mandatory documentation and reporting requirements in place that may offer useful data for an MRV system and thus could limit the additional costs of an MRV system.

Vessels of 400 GT and above have to record their fuel uptakes and have to keep Bunker Fuel Delivery Notes on board for a period of not less than 3 years according to Regulation 18 of MARPOL Annex VI. However, there are no legal requirements to measure and report fuel consumption of vessels. Nonetheless, fuel consumption is monitored on board of vessels for several purposes and will not require additional data collection. However, for some ships (mainly smaller and older ones), the accuracy of the data may be limited and only sufficient if measured over a longer period of time.

Monitoring the vessels' operational efficiencies requires the monitoring of distance sailed and cargo loads, too. Distance sailed data is readily available. Cargo load is also known to the ship operators, but the shipping industry prefers the cargo load to be derived through a formula based on the nominal load instead of working with the actual load per voyage.

If Europe required vessel operators to use technical installations on board ships for monitoring and reporting purposes or if new installations were required, it would likely create a conflict with the IMO and would need to be adopted by the IMO. However, if the monitoring and reporting mandates did not mandate particular technical installations on ships and are built around existing ones, no juridical conflicts would result and the system could benefit from the use of the existing technical monitoring and communication options.

Monitoring, reporting and verification of marine vessels for environmental purposes would not require additional institutions besides those already in existence for safety purposes. However, their legal mandate as well as their personnel and technical capacity may need to be expanded.

Since data monitored under the Ship Energy Efficiency Management Plan (SEEMP) do not have to be reported and verified, verification could be the value added of an MRV system, at least if it leads to an enhancement of the accuracy of the data monitored and thus to more transparency for the ship owner/charterer and shipper. At the same time, verification is associated with extra administration and thus extra administrative costs for both the reporting entity and public (national) administrations.

Regarding the format in which to monitor and report, the EEDI politically does not provide a suitable format, since the IMO has stated that it is not acceptable that the EEDI is applied to the existing fleet.

The EEOI is linked to the SEEMP and may be further developed. Both EEOI and EEDI offer valuable templates for designing an index to be used in an MRV system. In order to avoid political stalemate, an MRV system may identify its own index, for which both IMO indices offer good templates. The *Existing Vessel Design Index* is another example of an index system.

Zusammenfassung

Die Europäische Kommission arbeitet derzeit an einem regionalen MRV (*Monitoring, Reporting and Verification*) System zur Überwachung von, Berichterstattung über und Prüfung von Kohlendioxidemissionen aus dem Seeverkehr als einem Zwischenschritt hin zu einer regionaler oder globalen Regulierung von Treibhausgasemissionen der Seeschifffahrt. Im vorliegenden Papier diskutieren wir die Implikationen und die Durchführbarkeit verschiedener Ausgestaltungsoptionen eines solchen regionalen MRV Systems.

Die Europäische Kommission hat verschiedene regionale marktbasierte Maßnahmen zur Verringerung der Treibhausgasemissionen der Seeschifffahrt zum Zwecke der Befragung von Stakeholdern und der Folgenabschätzung in eine engere Auswahl genommen. Diese marktbasierten Instrumente unterscheiden sich darin, dass sie unterschiedliche Daten sowohl für ihre Implementierung als auch nach ihrer Implementierung benötigen. Diese unterschiedlichen Datenanforderungen sollten bei der Entscheidung der in einem MRV System zu überwachenden Parameter berücksichtigt werden.

Davon ausgehend, dass Schiffe einen Anreiz haben, die überwachten Parameter mit der Zeit zu verbessern, hängt der Effekt, den ein reines MRV System auf die Kohlendioxidemissionen der Schifffahrt haben würde, davon ab, welche Parameter überwacht werden und welche Möglichkeiten dem Schiff überhaupt zur Verfügung stehen, um die überwachten Parameter zu verbessern. Wenn beispielsweise die betriebliche Effizienz eines Schiffes überwacht würde, könnte ein Schiff sowohl technische als auch betriebliche Reduktionsmaßnahmen treffen, wenn hingegen die technische Effizienz eines Schiffes überwacht würde, könnte es nur technische Reduktionsmaßnahmen treffen, um seine durch das System erfasste Effizienz zu verbessern. Der potentielle CO_2-Reduktioneseffekt eines reinen MRV Systems ist dann erwartungsgemäß auch geringer falls die technische und nicht die betriebliche Effizienz der Schiffe überwacht würde. Unabhängig davon, welche Parameter überwacht werden, kann aber nur dann überhaupt ein direkter Effekt eines reinen MRV Systems erwartet werden, wenn das System demjenigen, der für den Kraftstoffverbrauch des Schiffes aufkommt, auch neue Einsichten liefert.

Es gibt derzeit schon bestimmte Überwachungs- und Berichterstattungsverpflichtungen, die nützliche Daten für ein MRV System liefern und somit die zusätzlichen Kosten eines MRV Systems beschränken könnten.

Was den Kraftstoffaufnahme betrifft, so müssen Schiffe mit 400 GT und größer gemäß Verordnung 18 von MARPOL Annex VI Bunker Fuel Delivery Notes für mindestens 3 Jahre an Bord bewahren, jedoch bestehen derzeit keine rechtlichen Verpflichtungen den Kraftstoffverbrauch zu messen und zu rapportieren. Nichtsdestotrotz wird der Kraftstoffverbrauch der Schiffe zu verschiedenen Zwecken an Bord erfasst und es wäre somit keine zusätzliche Datenerfassung erforderlich. Allerdings könnte die Genauigkeit der Daten, insbesondere bei kleinen und alten Schiffen, beschränkt und nur bei langfristigen Messungen ausreichend sein.

Das Überwachen der betrieblichen Effizienz der Schiffe erfordert die Erfassung der zurückgelegten Strecken und der jeweiligen Ladungen. Entfernungsdaten liegen hier vor. Zwar kennen die Reeder die Beladungen, doch würden sie es bevorzugen, wenn nicht mit der tatsächlichen Beladung, sondern mit einer Abschätzung mittels der nominalen Beladung gearbeitet würde.

Wenn Europa die Reeder verpflichten würde, technische Installationen zu Überwachungs- und Berichterstattungszwecken an Bord zu verwenden, so könnte dies zu einem Konflikt mit der IMO führen und müsste die Verpflichtung von der IMO angenommen werden. Falls eine MRV Verordnung aber keine spezifischen technischen Installationen vorschriebe sondern vielmehr bei den bestehenden Verpflichtungen anschlösse, sind keine juristischen Konflikte zu erwarten und könnte sich das System trotzdem der vorhandenen technischen Überwachungs- und Kommunikationsmöglichkeiten bedienen

Um zu Umweltzwecken ein MRV System für die Seeschifffahrt einzurichten, müssten neben den bestehenden Institutionen, die Sicherheitszwecken dienen, keine zusätzlichen Institutionen geschaffen werden. Allerdings müssten deren rechtliches Mandat, deren technische Kapazität und Personalbestand wohl aufgestockt werden.

Da die Daten, die im Zuge des *Ship Energy Efficiency Management Plan* (SEEMP) erfasst werden, nicht rapportiert und überprüft werden müssen, könnte die Überprüfung der Daten einen Mehrwehrt des MRV Systems darstellen, zumindest wenn die Überprüfung die Genauigkeit der Daten verbesserte und somit den Schiffseignern, Charterern und Verladern mehr Transparenz verschaffte. Andererseits ist eine Verifizierung der Daten mit einem zusätzlichen administrativen Aufwand und somit auch mit zusätzlichen Kosten für die rapportierende Instanz und die öffentliche Hand verbunden.

Was das Maß betrifft, in der es zu rapportieren gelte, so scheint der *Energy Efficiency Design Index* (EEDI) politisch gesehen nicht geeignet zu sein, da die IMO eine Verwendung des EEDI für bestehende Schiffe als nicht akzeptabel eingestuft hat. Der *Energy Efficiency Operational Index* (EEOI) steht im Zusammenhang mit dem SEEMP und könnte noch weiterentwickelt werden. EEOI und EEDI stellen wertvolle Ausgangspunkte für einen Index dar, der bei einem MRV System verwendet werden könnte. Um einen politischen Stillstand zu vermeiden, könnte ein MRV System mit einem eigenen Index arbeiten. Ein weiteres Beispiel für einen Index ist der *Existing Vessel Design Index*.

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1. Introduction

At the beginning of October 2012, the Vice-President of the European Commission and the EU Commissioner for Climate Action stated that it is their joint intention to pursue a monitoring, reporting and verification (MRV) system based on fuel consumption at EU level in early 2013. This MRV system would be a necessary starting point for intermediary steps towards further global measures next to the EEDI. Market-based mechanisms at EU level could thereby be an intermediary step.

This paper analyses the possible designs of MRV regulation, and specifically discusses how MRV regulation can be used as a first step towards an MBM and how MRV could be designed to have an effect on emissions itself. It starts with an analysis of the relation between MRV and MBMs in Section 2. Section 3 describes the availability of data and the additional monitoring requirements. Reporting is discussed in Section 4 in connection with existing reporting requirements. Section 5 discusses verification and Section 6 the potential metric of an MRV system.

The paper focuses on monitoring, reporting and verification of ship emissions. It does not discuss in detail *who* should be reporting and which entity would be the best recipient of the data.

Note that the different design elements as specified by the European Commission in its proposal for a regulation on the monitoring, reporting and verification of CO_2 emissions from maritime transport as published at the end of June 2013 are not discussed in this paper.

2. MRV and MBMs

The choice of the data that would need to be monitored and reported by the maritime shipping sector under a mandatory MRV system is crucial for two reasons: Firstly, it can have an impact on the feasibility of the future implementation of specific market-based instruments and, secondly, it will have an impact on whether and to what extent the MRV system as such can prompt the sector to take measures to reduce GHG emissions.

In this chapter we will therefore first analyse the data needs of the different market-based measures that had been short listed by the European Commission.

The data that could be gathered with an MRV system will depend on the geographic scope to which it will be applied. In the second section of this chapter we therefore relate the data needs of the different market-based measures and the data that could be gathered under an MRV system, depending on the scope of implementation.

In the third section of this chapter we analyse how an MRV system should be set up to be most effective in terms of CO_2 emission reductions.

2.1. Data needs stemming from different MBM options

The following nine types of market-based measures had been shortlisted by the European Commission for an impact assessment and stakeholder consultation (EC, 2012):

- Compensation fund:

    - contribution-based,
    - target-based:
        - overall target based on historical transport performance,
        - overall target based on historical emissions,
- Emissions trading scheme (ETS),
- Bunker fuel tax,
- Emissions tax (ET),
- Mandatory emission reduction per ship:
    - with a target related a historical emission baseline,
    - with a target related to:
        - an operational efficiency index,
        - a technical efficiency index.

These market-based measures differ with respect to the data that is needed for their implementation and with respect to the data needed after the measures have been implemented. Seven main categories of data can thereby be differentiated:

Depending on the choice of market-based measure, the following data may be needed prior to the implementation of measures:

1) CO_2 emissions of the fleet.
2) CO_2 emissions per ship.
3) Activity of the fleet.
4) Activity per ship.

Again, depending on the choice of instrument, the following data may be needed after implementation of measures:

5) CO_2 emissions per ship.
6) Activity per ship.
7) Fuel purchased in the EU.

The activity of a ship or the fleet could thereby mean different things, e.g. nautical miles sailed or nautical tonne/TEU miles or nautical dwt/GT miles.

In Table 1 an overview is given on the different market-based measures under consideration at EU level and their data needs concerning the seven data categories.

Table 1: Data needs of market-based measures under consideration at EU level

		Contribution based comp. Fund	Target-based comp. fund; overall target based on historical transport performance	Target-based comp. fund; overall target based on historical emissions	ETS	Bunker fuel tax	Emissions Tax	Mandatory emission reduction per ship (target related to historical baseline)	Mandatory emission reduction per ship (target related to operat. eff. index)	Mandatory emission reduction per ship (target related to techn. eff. index)
Data needs for implementation	CO_2 emissions of fleet			For determining overall target.	To determine baseline/cap.					
	CO_2 emissions per ship		For dividing target between funds.	For dividing target between funds.	If allowances allocated on basis of historical emissions.			To determine baseline/cap.	To determine baseline index.	Under standard conditions.
	Activity of fleet		For determining overall target.							
	Activity per ship				If allowances allocated on basis of output benchmark.				To determine baseline index.	
Data needs after implementation	CO_2 emissions per ship	To control contribution payments	To control whether target is met.	To control whether target is met.	To determine amount of allowances to be submitted.		To determine tax debt.	To control whether target is met.	To control whether target is met.	To control whether target is met (under standard conditions).
	Activity per ship								To control whether target is met.	
	Fuel purchased in EU					To determine tax debt.				

From Table 1 it becomes clear that for three policy options, neither emissions nor activity data are a necessary condition for implementation:

- A contribution-based compensation fund,
- A bunker fuel tax,
- An emissions tax,

since the minimum fee that the EU will prescribe the contribution fund(s) and the tax rate of a bunker fuel/emissions tax can be decided on politically.

For two instruments both emissions and activity data are a necessary condition for implementation:

- An ETS with the allowances allocated on the grounds of an output benchmark, and
- a mandatory emission reduction per ship with a target related to an operational efficiency index.

For four instruments only emissions data are a necessary condition for implementation:

- A target-based compensation fund with an overall target based on emissions,
- An ETS with the allowances not allocated on the grounds of an output benchmark,
- A mandatory emission reduction per ship with a target related to a historical baseline,
- Mandatory emission reduction per ship with a target related to a technical efficiency index (where the emissions are measured under standard conditions).

And finally, for one instrument only activity data are a necessary condition for implementation, i.e. for a target-based compensation fund with an overall target based on historical transport performance.

Note that the aggregation level of the data that is needed for implementation differs between instruments. For an Emissions Trading Scheme with allowances that are auctioned, emissions data on *flee*t level are sufficient for implementation and for a target-based compensation fund for which the overall target is based on historical transport performance activity data on *fleet* level are sufficient for implementation.

Also the meaning of activity of a ship/fleet differs between the policy measures. In the IMO proposal of the US for an operational efficiency standard (MEPC 64-5-6) distance sailed, cargo mass carried or work done per tonne mile are specified. When the EEOI would be used under a SEEMP, the distance sailed and the cargo mass carried per tonne mile would have to be monitored on a route basis.

After implementation of the measures, for all measures, except a bunker fuel tax, CO_2 emissions data per ship are needed. Under a technical emission standard, these data stem from a test per “rating cycle”.

2.2. MRV system and data needs of MBMs

An MRV system could be implemented at EU level in four different ways. An obligation to monitor and report data could be imposed

- on all ships in EU ports

  a. on routes to/from EU ports,
  b. on all routes;

- on EU-flagged ships:

  a. on routes to/from EU ports,
  b. on all routes.

It can be expected that a market-based measure will be implemented flag-neutrally and on routes to/from EU ports. Therefore, only when using the first option (1.a.) the data necessary for the implementation of measures with an overall emission target, i.e. an emissions trading scheme and a target based compensation fund, could be gathered.

Data relevant for a ship specific emissions cap would be gathered under options 1.a. and 2.a., whereby under the second option (2.a.) a smaller share of the ships that would fall under the market-based measures would be covered. But also for the first option (1.a.) it holds that ships that start to sail on routes to/from Europe at a later point in time would not be covered in the MRV system phase; this is inherent to this market-based measure.

Since the monitoring of data of EU-flagged ships is probably easier to implement, it is a conceivable option, too. Data gathered from EU-flagged ships only could, independent of whether the third or the fourth option is applied, be used to determine the average operational efficiency of ship types, which could be used to determine a baseline for an operational efficiency standard.

2.3. How to get maximum effect from MRV system?

In Figure 1 a stylised representation of the factors that determine total maritime CO_2 emissions is given. It also allows the factors to be identified that determine CO_2 emissions on ship level.

The CO_2 emissions of a ship are, in the first instance, determined by the ship's operational CO_2 efficiency (CO_2 emissions per unit of transport work) and the transport work that is carried out by the ship (e.g. in terms of tonne miles).

A ship's operational CO_2 efficiency depends on three main factors: the technical energy efficiency of the ship, the carbon content of the fuel used, and on different operational factors, such as the speed at which the ship is sailed, how well the ship is maintained or the route that is chosen.

Total transport demand, ship size, the ship's relative transport price (compared to other ships and other transport modes) together with logistic factors (determining, for example, the ship's load factor) and the speed determine its transport work. The ship's operational CO_2 efficiency thereby has, via fuel costs, an impact on the ship's relative transport price.

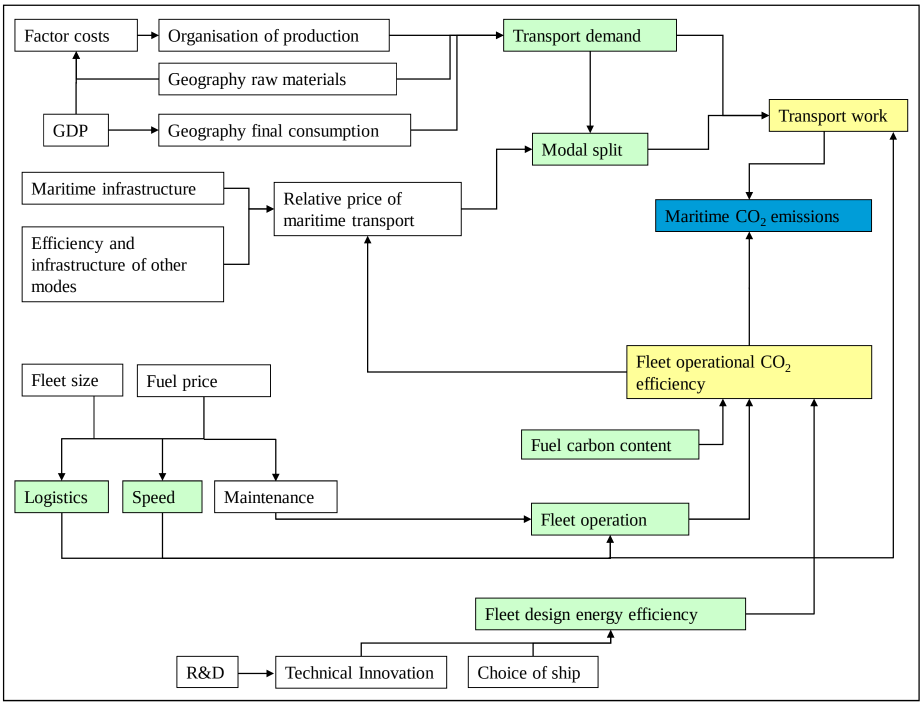

Figure 1: Stylised representation of factors that determine total maritime CO_2 emissions.

From Figure 1 it becomes clear that the effect of the MRV system on CO_2 emissions will differ depending on the data that is monitored, simply because the number of options to bring about an improvement of the data monitored differs:

If CO_2 emissions are monitored (e.g. from fuel consumption in combination with carbon content), then the maximal number of options can be used to effect an improvement of the data monitored, whereas monitoring of the technical efficiency of a ship will only incentivise the adoption of technical measures.

However, if operational CO_2 emissions are the only value monitored, this would probably not give enough transparency, since a reduction of CO_2 emissions does not necessarily mean that the operational CO_2 efficiency of a ship has been improved. It could simply be brought about by less transport work having been carried out.

Monitoring operational CO_2 efficiency, i.e. monitoring both operational CO_2 emissions and the transport work carried out thus seems to be the better option. This still gives the opportunity to effect an improvement of CO_2 emissions in all possible ways but at the same time gives transparency too.

If both CO_2 emissions and transport work are to be monitored, the question remains on what level of aggregation and using what values this would be carried out. Ideally one would like to know the emissions, the cargo mass transported and the distance sailed per voyage, just as under the EEOI. However, the sector may be reluctant to report data like the cargo mass transported per route, since this may be business-sensitive information (for detailed information on the EEOI and its appraisal by stakeholders see 6.2). The use of an alternative approach may therefore be necessary:

- CO_2 emissions and transport work could be monitored per voyage as described above, but only total CO_2 emissions and the efficiency index (total CO_2/total tonne nautical miles) could be reported.
- When determining the transport work an average load factor (including empty voyages) could be applied to the cargo capacity of a ship. In this case total CO_2, total relevant nautical miles and maximum cargo capacity would have to be reported.
- Instead of working with the transport work, the tonnage of a ship could be used so that total CO_2, total relevant nautical miles and dwt/GT would have to be reported.

The first alternative approach is still the most accurate; it has, however, the disadvantage that verification of the data is restricted.

The advantage of the second and the third alternative is that no data needs to be monitored and verified that may be business-sensitive and that less data needs to be monitored and verified. This however comes at the cost of less transparency. An MRV system making use of the second and third alternative approach still incentivizes the use of all possible CO_2 reduction measures (numerator of index will decline) but this may be rewarded less than optimally. When increasing the load factor, the denominator of the index (transport work done) will not adjust accordingly.

The impact of an MRV system on the CO_2 emissions of ships will not only depend on the data that will be monitored. For an MRV system to have an impact on a ship's CO_2 emissions, it also has to give additional insight to the party that is paying for the fuel consumption of the ship and this party should be able to take measures to bring about an improvement of the data monitored.

If the data to be monitored under an MRV system are already being monitored for internal purposes or will be monitored after implementation of the Ship Energy Efficiency Plan (see 6.1.1 for more information), it is very likely that the additional effect on CO_2 emissions will be rather small. An additional effect could stem from the verification of the reported data under an MRV system which is not being carried out under the SEEMP, assuming that verification leads to a higher accuracy of the data monitored and thus to a higher transparency. Only if the sector is provided with feedback e.g. by giving information on averages to provide the sector with a kind of benchmark and/or if the reported data would be published, to give the shippers the opportunity to choose a relative clean ship, can a significant additional emission reduction be expected from an MRV system. The latter, i.e. the publication of the data, may however lessen the acceptance of an MRV system.

Independent of whether an MRV system will have an additional CO_2 emission reduction effect, it will provide data that is necessary for the implementation of market-based measures. Three market-based measures have been identified, for the implementation of which activity data is necessary and for which the choice of the data to be monitored is thus crucial:

- A target-based compensation fund with an overall target based on historical transport performance,
- An emissions trading scheme where the allocation of the allowances is based on an output benchmark,

- Mandatory emission reduction per ship with a target related to an operational efficiency index.

For the target-based compensation fund and for the emissions trading scheme this could mean that an alternative design could be preferred, i.e. a target-based compensation fund with an overall target based on emissions and an ETS where the allocation of allowances is not based on an output benchmark (e.g. auctioning) or that the definition of activity is selected according to the definition chosen under the MRV system. The latter would probably be the case for the mandatory emission reduction per ship with a target related to an operational efficiency index.

2.4. Conclusion

The market-based measures (MBMs) that had been shortlisted by the European Commission for a stakeholder consultation and an impact assessment differ with respect to the data that are needed for their implementation and the data that are needed after their implementation.

A Monitoring, Reporting and Verification (MRV) system can be implemented on different levels. If all ships sailing to/from EU ports have to use an MRV system, the data collected with the MRV system are most suitable for a later implementation of a MBM. The monitoring of data of EU-flagged ships might, however, be easier to implement. Data gathered from EU-flagged ships could be used to determine the average operational efficiency of ship types, which could be used to determine a baseline for an operational efficiency standard.

The effect of the MRV system on CO_2 emissions will differ depending on the data that is monitored, because the number of options to effect an improvement of the data monitored differs respectively. From this point of view the monitoring of operational CO_2 emissions would be the best option, however, limiting monitoring to this would probably not give enough transparency, since a reduction of CO_2 emissions does not necessarily mean that the operational CO_2 efficiency of a ship has been improved. Monitoring both operational CO_2 emissions and the transport work carried out thus seems to be the best option. Working therefore with an index that is comparable to the EEOI, seems only to be an option when, due to business sensitivity, not all data that is needed for the calculation of the index would have to be reported. Alternatively, the transport work incorporated in the index could be determined by applying an average load factor to the cargo capacity of a ship or, instead of working with the transport work, the tonnage of a ship could be utilized.

The effect of the MRV system on CO_2 emissions will also depend on whether it will give additional insight to the party that is paying for the fuel consumption of the ship and this party should be able to take measures to bring about an improvement of the data monitored.

If the data to be monitored under an MRV system are already being monitored for internal purposes or will be monitored after implementation of the Ship Energy Efficiency Plan (SEEMP), it is very likely that the additional effect on CO_2 emissions will be rather small. An additional effect could stem from the verification of the reported data which is not being done under the SEEMP, assuming that verification leads to a higher accuracy of the data monitored and thus to a higher transparency. Only if the sector is provided with feedback, e.g. by giving information on averages to provide the sector with a kind of benchmark and/or if the reported data would be published, to give the shippers the opportunity to choose a relative clean ship, can a significant additional emissions reduction be expected from an MRV system. The latter, i.e. the publication of the data, may however lessen the acceptance of an MRV system.

Independent of whether an MRV system will have an additional CO_2 emission reduction effect, it will provide data that is necessary for the implementation of market-based measures. The choice of the data that needs to be monitored and reported under an MRV system can thereby have an impact on the market-based measure that could be implemented at a later stage, since for the implementation of some MBMs activity data are a necessary condition. For the target-based compensation fund and for the emissions trading scheme this could mean that an alternative design could be preferred, i.e. a target-based compensation fund with an overall target based on emissions and an ETS where the allocation of allowances is not based on an output benchmark or that the definition of activity is selected according to the definition chosen under the MRV system. The latter would probably be the case for the mandatory emission reduction per ship with a target related to an operational efficiency index.

3. Monitoring

3.1. Discussion of availability of data on board ships / in shipping companies

There are certain mandatory documentation and reporting requirements that may offer useful information for MRV:

- Bunker Fuel Delivery Notes (MARPOL Annex VI Reg. 14 & 18)
- Devices that measure and indicate operational parameters, such as speed (vessels >300 GT), heading, propeller revolution, force and direction of trust etc. (vessels >500 GT). (SOLAS Chapter V Regulation 19)
- Automated signals that provide information including position, course and speed. (SOLAS Chapter V Regulation 19)
- Pre-port-arrival notification requirement and list of ten last port calls. (Directive 2010/65/EU)
- Vessel registration, IHS Fairplay, formerly Lloyds Register Fairplay.

MARPOL Annex VI Regulations 14 and 18 require vessel operators to document certain information with regard to fuels and make them available to the responsible authorities. Regulation 14 covers aspects with regard to fuel sulphur levels and regulation 18 with regard to fuel quality. One part of the documentation and reporting are the Bunker Fuel Delivery Notes (BDN). The BDN provide details on the amount, quality, date, time and location of fuel uptakes. Details have to be recorded in a logbook – either a separate logbook, the official logbook or other specific logbooks.

SOLAS V, Regulation 19 sets high standards for internationally travelling vessels of 300 GT and upwards and all passenger ships. The purpose of SOLAS V Reg. 19 is to enhance safety at sea. It establishes the construction, design, equipment, and manning standard on board vessels that must be implemented. Furthermore, it establishes the Automated Information System (AIS), which offers the ability to track the position and heading of ships.

With Directive 2010/65/EU, the European Parliament and Council establishes the reporting requirements for safety and security purposes for vessels bound to a European port. Vessels have to report certain information, including a list of the past ten ports, 24 hours ahead of arrival or at least upon departure of a port if less than 24 hours away.

The mandatory vessel identification and technical vessel information, such as installed power, is stored in the IHS Fairplay database. This data can provide a sound basis for verifying fuel consumption through modelling.[1]

However, besides BDN information, there are no legal requirements to measure and report fuel consumption of vessels. Nonetheless, fuel consumption is monitored on board of vessels for several purposes.

International marine shipping has become an advanced competitive industry and plays a vital role in the global economy. As such, modern vessels that are engaged in international trade[2] are high tech products. Marine engineers seek solutions to accommodate today's needs of marine vessel operators and charterers, for example to accurately determine fuel consumption for chartered vessels (CE Delft 2009). Technical innovation has influenced the management on board ships and determines the data available on board as well as the capabilities of data transfers.

There are two parameters of significant importance for monitoring the environmental performance of ocean going vessels, i.e. the emissions of greenhouse gases and airborne toxics: the amount of fuel burned and the amount of energy generated. The first directly correlates with the greenhouse gases released. It also indicates the emissions of sulphur oxides and particulate matters in relationship to the fuel quantity and quality. The second, in combination with technical engine data, in particular indicates the emissions of nitrogen oxides and hydro carbons. Thus the monitoring of fuel and energy are the two prime parameters to be measured for environmental management purposes.[3]

The cost of fuel plays a significant role with regard to the overall cost for the operators. It influences the freight rates and the profitability of ocean shipping. However, the impact of fuel cost differs with the marine service types, in particular between liner services and bulk services

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1 IMO has agreed to use IHS Fairplay database for calculating the EEDI of new ships. It should be noted that the privatization of the vessel registration data, including data on the technical setting of the ship and its cargo capacity, makes vessel analysis for scientific purposes difficult and at least very expensive. In the past, many inventory analysis where based on the former version, the Lloyds Register Fairplay, which was publicly available in libraries up to 2009/2010 edition. Today, this officially collected data can only be obtained electronically and for very high fees. The monopole of IHS on the vessel data may create barriers for using it for verification purposes in the future.

2 Internationally travelling cargo vessels account for approximately 45 % of the number of ships, while they represent about 90 % of the marine gross tonnage (IMO 2009).

3 The measurement of airborne emissions in the stacks of ocean ships is not a proven technology. Besides technical difficulties (e.g. large air flow volume, heterogeneous exhaust flows), exhaust gas monitoring would need to prove viable in the extreme conditions at sea.

(UNCTAD 2010). Nonetheless, optimizing fuel consumed per transport work is one mechanism to improve profitability and is thus in the interest of vessel operators (or charterer if they are obliged to pay the fuel bills[4]).

However, monitoring fuel consumption and other parameters also serve other needs, such as scheduling of hull maintenance. The amount of fuel used per transport work is determined by several key performance indicators:

- Fuel used per shaft energy output; indicates for example engine maintenance needs.
- Energy per log of the ship (speed relative to the water); indicates for example level of hull and propeller fouling.
- Speed over ground, distance sailed and ahead; can be optimized according to planned arrivals.
- Wind and ocean currents; necessary information to evaluate engine and ship performance data.

Modern ship management focuses on those key performance indicators to improve overall vessel efficiency. Several marine service firms offer vessel management solutions that include technical components (i.e. fuel flow meters), hard and software components as well as onshore management components. The (voluntary) Ship Energy Efficiency Management Plan as adopted by the IMO creates additional incentive to implement advanced and real time monitoring on board of vessels. Chartered vessels report in so-called noon reports the fuel levels ones per day.

The fuel storage and flow system on large ocean going vessels, provide the setting that offers several methods of fuel monitoring on ships. In order to assess the technical options for fuel monitoring, it is important to understand the technical principles of vessel's fuelling systems.

The vast majority of ocean vessels operate on heavy fuel oil (HFO). HFO need to be heated to become pumpable and purified to avoid damage of the injection system and the engine. The fuel is stored at around 40 °C in the main tanks (usually multiple), from which they are pumped to settling tanks. Here they are heated to about 70 °C and some water and solids are separated. From the settling tanks the fuel is processed in separators, which are heated centrifuges. The impurities are collected and withdrawn as sludge and the fuel is pumped in day tanks. From here the fuel is processed in boilers and brought to 7 to 10 bar pressure and 130 °C. The fuel is then filtered and pumped to the injection pumps that take up the fuel needed. The rest fuel is circulated back to the day tank or settling tank, after being cooled down. In addition, marine vessels may contain tanks for different fuel types, for example Marine Diesel Oils that may be blended with HFO or used in certain locations.

At the minimum a vessel master tracks its fuel consumed over a period of time in order to plan fuel uptakes. This may be done by measuring the main tank fuel levels (tank sounding), or by

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[4] It is common practice that charterers pay for the fuel consumed. Therefore, charter contracts include provisions to determine the fuel on board at the beginning and at the end of charter contracts as well as for measuring and reporting fuel per voyage. Hereby, speed data are used to check the plausibility of fuel consumption data, taking weather conditions into account. Fuel consumption data are usually verified at the end of the charter by third party verifiers.

measuring the fuel inflow in the day tanks via flow through meters or calibration tanks (see CE Delft 2009, Oeko-Institut et al. 2011). The vessel master may then determine the times and amount of fuel uptakes that are necessary. However, those simple fuel measurements are not sufficient to manage a vessel by using the above key performance indicators.

The vessel management with key performance indicators requires a more detailed monitoring of fuel flow, energy output and speed. For this purpose fuel flow meters are placed at the inflow and outflow of the fuel injectors. The delta then provides the amount of fuel burned at any given time[5]. This fuel consumption provides valid information for the vessel operator, when analysing it against energy output and speed data.

This advanced vessel monitoring is often paired with knowledge, monitoring and forecast information of the weather and the ocean currents on the route. Today, many vessels are being managed from shore based stations that bundle and process a large amount of vessel monitoring, weather and ocean current data.[6]

Thus it can be concluded that fuel consumption data exists on board of all vessels. The vast majority of large vessels likely have technical installations that provide highly accurate real-time fuel consumption figures, while smaller and older vessels may only have capabilities to measure fuel consumption in longer time periods. The fuel consumption information may be stored and processed electronically or manually in log-book entries.

3.2. Monitoring vessel efficiency

One stated goal of a European MRV system is to improve the vessel's efficiency. Thus, vessel efficiency itself may be monitored. A similar effort is made through the SEEMP, which is a voluntary management plan to improve the vessel's fuel efficiency.

Determining the vessels' efficiencies is based on

fuel consumed divided by distance sailed and cargo loaded

It is apparent that efficiency factors are most sound if they are based on primary measured data. Thus the above on fuel measurement also applies.

The additionally challenging aspects are distance monitoring and cargo load monitoring. Here too, it would be most accurate to base it on real data.

For a detailed discussion on distance monitoring see Oeko-Institut (2011). In short, automated distance monitoring would need to rely on existing equipment on ships, which would be technically sufficient to do so. However, currently the AIS signals are not captured sufficiently by satellites in order to provide a near global coverage. Furthermore, it is questionable whether AIS data captured by private satellite organisations can legally be used for regulatory purposes. LRIT signals are dedicated signals sent by ships to authorized States that requested it. Thus, to

5 Normalized to the fuel's density and carbon content.

6 Companies that offer vessel management solutions including technical fuel and engine monitoring include Kongsberg Maritime, ABB Marine, KRAL and Krill Systems. Integrated vessel and fleet management is offered by many service firms and the marine classification societies.

date, LRIT signals may be used for communications, but do not provide the basis for continuous distance monitoring.

However, the distances sailed are known to the Master of the vessel and information is kept in the official logbook. Furthermore, some data, i.e. the last ten ports, already have to be reported to European Port State authorities. Thus distance sailed data is easily available and could be requested for any time in the past in order to be used to calculate the vessel's efficiencies. The question is who is demanding it, how is the information being communicated (transmitted), and who is processing the data. In Oeko-Institut (2011) it is concluded that Port States would have the authority to demand it; that it would be best left up to the vessel master whether to use LRIT, fax or online forms to submit the data; and that a European centralized processing would reduce double data acquisition and burdens for the vessel operators.

The other challenging aspect is the real cargo load. Cargo load on vessels is a competitive aspect and it is unlikely that vessel operators are willing to disclose this information easily. From experience gathered managing the Clean Cargo Working Group, it is a fact that information on vessel utilization, empty voyages etc. is used to negotiate freight rates. Vessel operators happily overbook vessel spaces and then find solutions through freight sharing in alliances and additional charter. However, they do not want to be known to have “empty” spaces on vessels because it immediately would be used by customers to negotiate for lower rates. Thus, it is unlikely that cargo load information would be provided to national authorities.

At the same time, cargo information may be obtained through the bill of ladings. Theoretically, Port States could withdraw the information of the cargo unloaded and loaded in their ports. However, to determine cargo load on voyages is tedious and probably unfeasible for vessels in liner services that often also unload and load cargo in ports of States not part of the same regulation.

A third option to the cargo load determination may be the use of the nominal capacity and pre-defined cargo utilization factors. This approach is used in modelling vessel emissions for geographic inventories (IMO GHG Study, US port studies). The nominal vessel capacity is part of the vessel information in the IHS Fairplay database or could be demanded as a data point by a MRV scheme. Average utilization factors could be derived through trade and cargo analysis for different type of vessels. The resulting cargo load figures would be less accurate than those based on prime data, but would offer a fair manner for vessel operators to assess their vessels' efficiencies. Moreover, using real cargo load data might be even unfair, because it would make the vessel's efficiencies dependent on aspects of cargo flows, for which the vessel operators have no control. For example, if an economic downturn reduces the capacity utilization, the vessel efficiency would decrease as well.

Monitoring the vessel efficiencies is principally possible by using fuel consumption data and records about the distances sailed. Cargo load should be derived through a formula based on the nominal load. A vessel efficiency monitoring would be close to the approach of the EEOI, but should be named and designed specifically for the MRV purpose. Using the EEOI term may create friction with the stakeholders at the IMO that do not want the EEOI to be used for regulatory purposes (for detailed information on the EEOI and its appraisal by stakeholders see 6.2.2).

3.3. Discussion of relationship between monitoring needs and "scope", i.e. geographical scope

One variable of the proposed European MBM and MRV for marine shipping is the geographical scope. While stakeholders in Europe have emphasized that a global system, implemented through the IMO, would be preferred, Europe may go ahead with a regional system. With regard to the geographical scope of a regional system, three concepts have been elaborated so far:

- Covering all ships within the territorial waters or EEZ.
- Covering all distances of ships voyages with destination at a European port and leaving a European port.
- Covering all vessel activities within a given time frame, e.g. one year.

As we have discussed previously vessels may, as a minimum, collect information of fuel consumed in a period of time in order to plan fuel uptakes and at maximum conduct real time key performance parameter monitoring, potentially combined with shore-based vessel and fleet management. Those two levels of sophistication have ample influence on the feasibility of monitoring requests and result in different additional burden depending on the mandated monitoring information.

Example: vessel that measures fuel in time intervals through tank soundings:

- The vessel could relatively easy report on the fuel consumed over a period of time (e.g. one year). BFDN and voyage data could serve as verification data.
- Fuel consumed for particular voyages could also be monitored with a degree of accuracy, by measuring the tank levels at the beginning and at the end of the voyage.
- The determination of fuel consumed on parts of particular voyages (e.g. EEZ) is rather difficult because tank soundings at sea are challenging and inaccurate. Options would include determining the overall vessel efficiency (based on past period's reporting) and using those factors for the distances sailed.

Example: vessel that continuously measures and monitors key performance parameters including fuel consumption:

- The vessel could easily report on the fuel consumed over a period of time (e.g. one year). BFDN and voyage data could serve as verification data.
- The vessel could relatively easily supply parallel data on fuel consumption and distance sailed. Therefore, it also could start reporting its fuel consumption at any given point during a voyage up to an ending point. The reporting would create little additional burden for the vessel's crew.

For verification purposes the vessel's log-books, the BFDN and other information (such as port of calls, distance information, AIS observations, etc.) could be used by the adequate authorities (CE Delft 2009, Oeko-Institut 2011). While the IMO stated that the EEOI should not be used for regulatory purposes, it is nevertheless technically and legally feasible for authorities in the EU to apply similar modelling of vessel performances in order to check the plausibility of reported data[7].

4. Reporting

4.1. Comparison of communication / surveillance options ship to shore.

The question of using existing installations for communication and surveillance is rather a question of communication than of monitoring. If Europe required vessel operators to use technical installations on board of ships for monitoring purposes, it could create a conflict with other States that could only be avoided by adopting IMO regulations on monitoring equipment. However, if the monitoring requirements can be met using existing installations on ships, they could still benefit from the technical capabilities of communication options. For example, a MRV could mandate the fuel to be monitored and reported but leave the monitoring techniques to the ship operators. Technical data and distance data could be used to check occasionally for plausibility, similar to the reporting between vessel operator and charterer. The data could be requested by the Port State, conditionally upon calling at a port, but the means of transmission could be left open. Vessel operators could then choose those means that create the least additional burden, which might, for example, be LRIT signals. Therefore, the following only lists vessel-to-shore communications and surveillance options without suggesting using those directly for monitoring purposes.

System	Type	Prime Purpose	Receptor	Data Processor
AIS	VHF signal sender - receiver	Safety	Ship to ship; onshore antenna	Ships; Marine safety organisations
AIS	VHF signal satellite receiver[8]	Private vessel tracking	Ship to shore by satellite	Corporate
LRIT	Satellite communication; Inmarsat	Safety, national security	Data Center Port State	Maritime Administration
Text messaging	Satellite communication; Inmarsat	Communication, fleet management	Ship to Corporate and other recipients	Corporate, Maritime Administration
Email	Like text messaging	Communication	Crew to recipients	NA
Fax	Like text messaging	Communication	Like text messaging	Like text messaging

[7] The monitoring of vessels' fuel consumption would not require information on the transport work of the vessel, which is part of the EEOI. Since transport work information, such as cargo utilization, is sensitive corporate data, modelling without this information may increase the acceptance by vessel operators.

[8] As mentioned above, most vessels in commercial transport are equipped with AIS. The World's Radio Communication Conference allows the two AIS frequencies AIS-1 and AIS-2 to be picked up by satellites. Thus AIS signals received by satellites expand the geographic reach of AIS coverage. However, its legal use for regulatory purposes is not yet determined.

Marine communications can be differentiated into short range and long range communications. Short range communications use very high frequency (vhf) signals similar to radar signals. The Automatic Identification System (AIS) uses vhf signals. Its range is similar to the range of sight and dependent on the height of the antenna.

Long range communications rely on satellite receptors, i.e. the Inmarsat system, a private organisation under the host of the International Mobile Satellite Organisation (IMSO). Inmarsat was launched in 1979 by the IMO to enhance vessel safety at sea. Satellites today can receive Long Range Identification and Tracking (LRIT) signals, as well as regular text, email and fax messages. The Inmarsat system has a near global coverage, except pole ward of 70° North and South.

4.2. Institutional requirements for European port States and non-Port States

Maritime administrations for communicating with vessels and for observing territorial waters already exist in all Port States. Furthermore, a dense network of AIS shore receivers is installed along the European coast. The data of the AIS network is processed by the maritime administrations.

LRIT data has to be submitted to Port States, once the ship has indicated a port arrival or if it is within 1000 nautical miles off shore and not within the jurisdiction of another State. The receptors are also the maritime administrations.

The European Council of Ministers adopted in October 2007 a Council Resolution that established the European LRIT Data Centre. The LRIT data centre is housed at the European Marine Safety Agency (EMSA). EMSA is also the centralized data centre for AIS data of EU Member States. The network of AIS data and its exchange is called SafeSeaNet (SSN), operated for EU Member States as well as Norway and Iceland (EMSA 2010). (For further discussion on AIS, LRIT and SSN see Oeko-Institut 2011).

The monitoring of marine vessels for environmental purposes would not require additional institutions besides those already in existence for safety purposes. However, their legal mandate as well as their personnel and technical capacity may need to be expanded. It seems beneficial to further strengthen European Institutions and centralize the data processing, considering that many vessels call at European ports of different Nation States. (For further discussion of options see CE Delft 2009 and Oeko-Institut 2011)

The enforcement of a mandatory monitoring system may be more challenging to European institutions than the processing of monitoring information itself. Any European system would be bound to international law and therefore any enforcement measure would need to be based on the principle of proportionality. Non-compliance with mandatory reporting could be punished with fines, for which the US ballast water reporting provides a template, which has established criminal charges in cases on non-compliance. Another option would be to categorize vessels that participate and those that do not participate in the monitoring of fuel consumed. Those that participate may be rewarded by conducting fewer Port State inspections.

The US Maritime Information Services of North America (MISNA) offers an example of a cooperative approach to vessel monitoring, although it tracks and monitors AIS signals and does not monitor the vessels' fuel consumption. However, run as a non-profit organisation, it shares particular information from participating vessels with the US Coast Guard and the port authorities, while it disseminates particular information to the vessel operating companies that can use this information for better vessel and fleet management. While the participation in the MISNA reporting is voluntary, participating vessels are being regarded as “low risk vessels” aiding their port clearance and inspection decision processes (Page, E. 2011). “Several in the marine industry (...) finding ways to accelerate an industry developed vessel tracking solution that meets the needs of governments while also aiding commercial interests”.

One open question is the use of the potentially raised funds through an MBM. Options are to circle the funds fully or partially back to the industry or to provide financing for other greenhouse gas reducing initiatives. A question also remains as to what extent non-Port States, which some of the seaborne cargo is headed to or originates from, may participate in a monitoring system and may benefit from funds available through an MBM system.

5. Verification

As discussed in section 2, verification could play a crucial role regarding the impact of an MRV system on CO_2 emissions. Since data monitored under the SEEMP do not have to be reported and verified, verification could be the value added by an MRV system, at least if it leads to an enhancement of the accuracy of the data monitored and thus to more transparency for the ship owner/charterer and shipper.

At the same time, verification is associated with extra administration and thus extra administrative costs for both the reporting entity and public administrations.

What could nevertheless be a good reason for verification under an MRV system is the fact that most market-based measures, with the exception of a bunker fuel tax collected from the bunker fuel supplier, will need verification of vessel-related data. It could therefore be very useful to gain experience on verification under an MRV system. In addition, if the data that is monitored under an MRV system is used for the implementation of a market-based measure, acceptance could be higher due to a better quality of verified monitored data.

Regarding verification there should be a distinction between verification of the data that is monitored before it is reported and a verification of the reported data.

Verification of the data that is monitored before it is reported would have to be carried out by a recognized third party. Verification on this level could involve the certification of monitoring equipment, control of on-board documentations (e.g. deck-log books) and cross-checking of data with other business data. Verification guidelines would have to be established to this end.

For enforcement purposes, verification of the reported data would have to be carried out by a public entity. This could be done by carrying out plausibility tests on the data reported. Since data can better be tested on plausibility if you have a larger data sample, public verification could probably be more easily carried out by one central European entity to which the data then would have to be reported too.

On-site controls that would have to be carried out by State Port Control could then be confined to ships for which implausible data have been reported and to ships that are being controlled for other reasons and/or to random extra controls. Hereby bunker delivery notes, deck-log book, and bill of lading are relevant documents.

6. Potential metric of an MRV system

6.1. Institutional aspects

6.1.1. IMO conclusions on use of EEDI and EEOI

In July 2011 during MEPC 62, amendments to MARPOL Annex VI were adopted, adding 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). The regulations apply to all ships of 400 GT and above and are expected to enter into force 1 January 2013.

EEDI

The EEDI requires new ships to comply with a minimum design energy efficiency that varies over ship type and size. The reference energy efficiency equates to the average efficiency for ships built between 1999 and 2009 (for further details see IMO(2012b)).The reduction level in the first phase is set to 10% and will be tightened every five years with reduction rates being, at least for the bigger ship sizes, 30% in 2025.

Administrations may waive the requirements, though the waiver cannot be applied to ships for which the building contract is placed four years after the EEDI regulation enters into force.

Under the EEDI the attained energy efficiency of a new ship is determined by the EEDI formula that relates the ships' CO_2 emissions to its transport work. CO_2 emissions are determined on the grounds of technical design parameters of the ship, taking into account the carbon content of the fuel used and specific technical CO_2 reduction measures applied. Transport work is calculated by multiplying the ship's capacity as designed with the ship's design speed. (For further details see IMO (2012c)).

The IMO recognizes that the EEDI formula is not suitable for all ship types, particularly not for ships that are *not* designed to transport cargo, and also not suitable for all types of propulsion systems, e.g. not for hybrid propulsion systems. Ship types covered by the EEDI formula are: oil and gas tankers, bulk carriers, general cargo ships, refrigerated cargo carriers and container ships. For the other ship types formulas will be developed.

The design "[s]peed is the most essential factor in the formula and may be reduced to achieve the required index" (IMO, 2011). Concerns have been raised that when ships reduce their installed propulsion power to reduce the design speed that the manoeuvrability under adverse conditions may not be sufficient enough. MEPC therefore has acknowledged the need for a minimum speed to be incorporated into the EEDI formula (IMO, 2011).

A ship's attained EEDI needs verification. The IMO has set up a guideline regarding the verification procedure (IMO, 2012d).

As to a possible use of the EEDI to the existing fleet, the outcome of MEPC 63 is unambiguous: "The Committee having considered the above views, agreed that the EEDI had been developed as a regulatory tool for new ships only and, as a design index, it was inappropriate to extending its application to the existing fleet. Proponents of MBM proposals which rely on design benchmarks/parameters were invited to clarify in their proposals the relation between such design benchmarks/parameters and the EEDI set out in the new chapter 4 to MARPOL Annex VI" (IMO, 2012a).

EEOI

The voluntary Energy Efficiency Operational Indicator (EEOI) was introduced by the IMO as one element to manage the vessels' greenhouse gas emissions (MEPC 1/Circ.684) in addition to the mandatory Energy Efficiency Design Index (EEDI for new ships) and Ship Energy Efficiency Management Plan (SEEMP). The introduction of the EEOI was motivated by findings of the second IMO GHG study (IMO 2009) that identified multiple operational options to reduce a vessel's greenhouse gas emissions. Operational improvement measures are documented in the ship's SEEMP and it was envisioned that the EEOI would be used to monitor the success of SEEMP measures and to provide benchmarks for the industry.

The principle formula of the EEOI is the amount of fuel used - at a specific voyage or during a time period - divided by the performed transport work. Transport work might be transported tonnes of cargo, numbers of containers or passengers, etc. Several studies and submission to the IMO have analysed the results of applying the EEOI to existing vessels. While the discussions in the IMO focus on the EEDI, the general perception of the EEOI is that it is not suitable to provide comparable benchmarks or to monitor a vessel's performance over time (VDR [BMVBS 2012], Hapag Lloyd [Guntermann 2012] and several submissions to the MEPC by, for example. Germany, Denmark and Japan). The critique of the EEOI focuses on technical aspects of the index-value calculation. However, it must be assumed that there are economic reasons for rejecting the EEOI as an appropriate tool.

6.1.2. Monitoring Mechanism Decision

The "Monitoring Mechanism Decision" (Decision No 280/2004/EC) that covers the reporting from the EU and its Member States required under the UNFCCC and the Kyoto Protocol is currently under revision. According to the European Commission (EC, 2011), the aim of the revision is, among other things, to

- facilitate development of new *Union* climate change mitigation and adaptation instruments, and
- provide legal basis for the implementation of future reporting requirements and guidelines pursuant to Union legislation or international agreements decisions.

In the Proposal for a Regulation from November 2011[9] the maritime transport sector was identified as a sector of great significance in reducing GHG emissions and taking action at EU level, where currently no or insufficient data was collected to underpin effective policy design and implementation.

It was stressed that since policy discussions within the Union and internationally are ongoing the proposal would take a prudent approach to reporting on emissions from international

[9] Proposal for a Regulation of the European Parliament and of the Council on a mechanism for monitoring and reporting greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change, 2011/0372 (COD) from 23.11.2011.

maritime transport. Therefore the proposal would ensure that the monitoring mechanism provides an adequate framework for setting detailed reporting requirements at a larger stage when a concrete policy outcome would be reached, be it at international or EU level. This would ensure coherence with a future policy framework, avoid duplicating efforts and ensure that the Union is able to implement detailed requirements most efficiently.

According to the proposal, requirements for the monitoring and reporting of emissions from maritime transport by Member States should be adopted in a manner which is complementary and consistent with any requirements agreed at the UNFCCC or, to the extent possible, with requirements applied to vessels as determined in the extent of the IMO or through an EU measure addressing GHG emissions from maritime transport.

In Article 10 of the proposal it was constituted that the Commission would be empowered to adopt a delegated act to specify the requirements for monitoring and reporting of CO_2 emissions from maritime transport relating to marine vessels calling at Member States' seaports and that emissions should be reported on a yearly basis whereas the emissions reported in a specific year are the emissions of the year before the previous year.

Regarding the Proposal for Regulation from November 2011 opinions were, however, divided.

The proposed amendment of the European Parliament regarding Article 10 aimed at monitoring and reporting of all climate-relevant data, at the extension of the European Emissions Trading Scheme to also cover the maritime transport sector, to let the Member States report the data gathered to EMSA which would analyse these data to determine the overall impact of the sector on global climate, including non-CO_2 impacts. The ship types that, taking a size and traffic threshold into account, in any case should be covered by the mechanism are also specified (see the Annex for the EP's exact proposal).

The European Council of Ministers however had removed the entire article.

The arguments tabled against the mandatory monitoring/reporting of the maritime transport sector were the expected high administrative costs for the Member States and that the regulation would get ahead of European and international legislation.

As a result of a compromise reached between the European Parliament and the Council, the European Parliament adopted a legislative resolution on the proposal for a Regulation of the European Parliament and of the Council in March 2013. This proposal does not contain provisions for maritime transport anymore: "[S]ince the Commission has announced that it intends to propose new monitoring and reporting requirements for emissions from maritime transport, a recital underlines that such provisions should not be included in this Regulation at this time" (EP, 2013).

6.2. EEOI as potential metric

The Energy Efficiency Operational Index (EEOI) is a potential index to be used in an MRV system. In this section the critique of the EEOI and counter-arguments as well as the Existing Vessel Design Index and other viable alternatives are presented.

6.2.1. Critique of EEOI

The critique of technical aspects is based mainly on findings of large spreads and fluctuations in test runs of the EEOI. Reasons for large variations in different test runs are for example the consideration of real load (which differs largely from zero in ballast voyages to near full capacity on some routes of bulk carriers), differences in the voyage definitions and variations in ship and service types. Some causes for the spreading results are summarized below:

- Definition of voyage: The voyages used in test runs include single-loaded trips from port A to port B up to the recognition of entire return voyages. Mathematically, the IMO guidelines for the EEOI include a potential error by defining the denominator as cargo times distance. If cargo is zero, the denominator becomes zero.
- Fuel consumption and greenhouse gas emissions occur during loaded, partially loaded and empty (ballast) voyages and during the times in port. A voyage might be defined as a loaded trip from port A to port B, a voyage A to B including the port time in port B or as a round trip starting in port A and ending when the vessel returns to port A. The EEOI under each definition differs greatly.
- Seasonal variabilities: some services, in particular liner services, show seasonal variabilities in their cargo utilization. A RoRo vessel for example might show a wide spread of EEOI values in different times of the year due to a fluctuating pattern of cargo and passenger space utilization.
- Effects of cargo density: low density cargo, for example liquified natural gas, result in larger EEOI values compared to high density cargo, for example crude oil.
- Variations within sister ships: technically similar sister ships may show a spread of EEOI values depending on the variability of the services they are operating in.

All aspects above were reasons for the high variability of EEOI values within vessel categories, which in turn has been used by governments and industry to argue against the EEOI as an instrument to assess the operational efficiency of vessels. However, as we argue below, these technical arguments are not sufficient to explain the denial of the EEOI as an instrument for GHG monitoring.

One argument that may be more important for the rejection is economic in nature. Vessel operators and shipping companies are reluctant to disclose information on the cargo load of their ships, because cargo utilization information may be used by their customers to negotiate lower freight rates. Freight rates are freely negotiable between shipping companies and customers. Once the customers know of free capacities on particular routes, they would aim to lower the price of transport. This is of particular importance for all vessels in liner services, where the customer only pays for the carriage of their cargo from A to B. Lowering freight rates on routes with empty cargo capacity (e.g. westbound trade from the US to Asia) is a common practice in order to increase the capacity utilization and thus the profitability of the necessary return run. However, concrete knowledge on empty spaces will be used by customers in price negotiations. Thus the shipping industry is reluctant to discuss any aspect that would point to under utilized service routes and thus reluctant to disclose information on their vessel`s EEOI.

Bookers of cargo operations with bulk cargo are, on the other side, aware that the freight rate also includes the ballast voyage back to the next loading port. Therefore, bulk shipping would be less affected by those dynamics.

6.2.2. Countering the critique of the EEOI

The critique of the technical aspects of the EEOI can be countered with technical solutions or better definitions of terms and references. However, the motivation of the shipping industry to keep secret real cargo loads on particular routes is a valid concern on economic ramifications. Therefore, any wide dissemination of the EEOI or any other operational indicator must seriously take those concerns into account.

Some counter-arguments to the technical critique are given below:

- Definition of voyage: the EEOI itself offers the option to build rolling averages, which would level the variabilities, or to use a period of time instead of a voyage for calculating EEOI values. However, both “voyage” and “period” would need a clear definition in order to lead to sound results. The draft European Norm “Methodology for calculation and declaration of energy consumption and GHG emissions of transport services (freight and passengers)” (prEN 16258) provides some guidance. According to the norm:
    - All empty voyages and fuel consumed in ports must be included, for example the idle time and ballast voyages returning to the original departure port A.
    - The transport performance of liner services equals the average utilization over the entire trip returning to the departure port A, regardless of the port to port segment in between.
    - A representative period therefore needs to include entire operational cycles of ships, representing their common economic dedication.

Solid EEOI values without emission gaps can be expected to be achieved if EEOI calculations adhere to sound definitions of “voyage” and “period” as outlined above.

- Seasonal variabilities: The choice of a representative period of time would also level seasonal variabilities. Thus for services with significant seasonal variabilities a representative period of time would result in sound values.
- Cargo density: the effects of different cargo density may be overcome by defining normalization units other than tonnage of cargo. Those may be, for example, cubic meter (of gas), number of container units (TEU), lane meter (potentially weighted according to bearing capacity) and numbers of passengers. Since vessels may be benchmarked only within their respective categories, the effects of different cargo densities matter mostly for container carriers, RoRo vessels, ferries and passenger ships that may carry different cargo within the same category.
- Variations between sister ships: variations of EEOI values between sister ships are not sufficient to argue against the validity of EEOI values because the EEOI particularly aims to identify operational parameters that have an influence on GHG emissions. However, EEOI values should always be interpreted with care, recognizing that reasons outside the responsibility of the vessel operator (e.g. weather, routes) will influence the vessels' performance.

6.3. Existing Vessel Design Index and other viable alternatives

One option to overcome the economic concerns of the maritime industry might be to use the DWT of a ship (or TEU capacity, lane meter, volume, etc.) together with average cargo utilization factors. This would avoid the need to disclose business-sensitive information and it would withdraw the cargo aspect, over which the vessel operator has only limited control, from the EEOI equation.

There are ample examples of the application of average utilization factors and knowledge on average utilization is relatively firm. Recent inventories of marine emissions have usually used a bottom-up modelling approach. This bottom-up methodology also uses average utilization factors in order to estimate the transport activity to accomplish certain transport needs. For example, the following utilization rates were used in the 2009 IMO GHG study: crude oil tanker 48%, chemical tanker 64%, general cargo vessels 60% and container vessels 70%.

Determining the average cargo load is most challenging for vessels in liner service, i.e. container vessels, RoRo vessels and full car carriers. In contrast to bulk carriers, which in simple terms run an empty return trip for each loaded trip and thus have utilizations of below 50%, liner services operate in circular patterns with multiple loading and discharging ports. The overall capacity utilization thus depends on the loading and unloading patterns as well as on aspects such as international trade imbalances. However, the methodology in EcoTransIT World showed the possibility of calculating more detailed, trade-route dependent, utilization factors using assumptions and trade data [IFEU et al. 2011, Appendix 6.3 page 90). Industry representatives have verbally confirmed the relative accuracy of these utilization figures.

One methodology that also uses average utilization rates is the Existing Vessel Design Index (EVDI) by the Rightship organisation (www.shippingefficiency.org). This organisation aims to benchmark existing vessels' CO_2 performance by using a derivation of the EEDI. It is supported by large players of the maritime industry, including Maersk Line, TK Shipping, Star Bulk, ABB and others. The Clean Cargo Working Group (www.bsr.org) urges to treat each vessel equally and applies the vessels' nominal capacity or in other words a 100% cargo utilization. An homogeneously applied lower utilization rate (e.g. 70%) may satisfy the desire for equal treatment as well. Therefore, it can be concluded that the maritime industry would be open to a system that uses realistic average utilization rates instead of disclosing real cargo loads.

7. Conclusions

This paper has analysed how MRV regulation can be used as a first step towards an MBM. All MBMs require MRV, but the requirements of what needs to be monitored and how differs. Moreover, there are often different requirements prior to the implementation of an MBM, when MRV is used to establish essential MBM design parameters, and after the first implementation, when MRV is meant to ensure compliance with the MBM.

For example, an ETS or a target-based compensation fund requires establishing a cap or a target. As current emission estimates have a considerable uncertainty range, a period in which emissions in the relevant scope are monitored and reported can inform the policy choice of setting the cap or target. Once such an MBM is implemented, these systems require ships to monitor and report verified emissions when surrendering allowances or paying a contribution to the fund.

While monitoring emissions prior to implementation can help with setting design parameters in many MBMs, the level of aggregation differs. For an ETS and many variants of the fund, total emissions of the fleet are sufficient. Other MBMs require ship emissions. Some MBMs also require transport data, such as the efficiency-based MBMs.

Almost all MBMs require monitoring and reporting ship emissions once implemented. The only exception is the bunker fuel tax. In addition, the efficiency-based MBMs require monitoring and reporting ship activity data.

MRV may have a small effect on emissions if some type of efficiency metric is monitored and if the results are published. In that case, this information may help charterers, shippers and other stakeholders select the most efficient ship available. It is unlikely that monitoring emissions or fuel-efficiency without publishing the data will have an impact on emissions, as such monitoring is already a legal requirement under MARPOL Annex VI and hence shipping companies will already collect such data.

Monitoring fuel and/or emissions does not require additional data collection, as it is common practice to monitor the fuel consumption of ships. However, for some ships the accuracy of the data may not be very high.

There are several ways in which ships and shipping companies currently communicate with port states that can be used to facilitate the reporting of emissions.

Shipping companies have several sources of information that can be used to verify monitored emissions. For example, fuel consumption data recorded on board ships can be compared with bunker fuel delivery notes, financial data on fuel sales, fuel bills (if a ship is chartered), etc.

While shipping companies would probably not incur significant costs for monitoring and reporting, verification may be more costly. Hence, it should be contemplated at which stage of the policy cycle verification becomes a necessity.

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9. Annex

Proposal of the European Parliament for amendment of a Regulation of the European Parliament and of the Council on a mechanism for monitoring and reporting greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change, 2011/0372 (COD) from 23.11.2011(EP, 2012):

Article 10

Reporting ***climate-relevant information relating to*** *maritime transport*

1. The Commission shall *[…]* adopt a delegated act in accordance with Article 29 of this Regulation ***by the date mentioned in Recital 3 of Directive 2009/29/EC of the European Parliament and the Council of 23 April 2009 amending Directive 2003/87/EC so as to improve and extend the greenhouse gas emission allowance trading scheme of the Community***[10] to specify requirements for the monitoring and reporting of ***climate-relevant information relating*** **to** maritime transport relating to marine vessels calling at Member States' seaports. The monitoring and reporting requirements adopted shall be consistent with ***methodologies*** agreed at the UNFCCC and with ***methodologies*** applied to vessels in the context of the IMO or ***requirements*** through Union legislation addressing GHG emissions from maritime transport. To the extent possible, monitoring and reporting requirements shall minimise Member States' workload including through the use of centralised data collection**,** maintenance ***and publication.***

The requirements shall cover ships responsible for significant emissions, including at least tankers, bulker, general cargo and container ships, subject to appropriate de minimis size and traffic thresholds.

2. ***Following the adoption of a delegated act pursuant to paragraph 1,*** Member States shall determine and ***gather*** to the Commission ***and the European Maritime Safety Agency (EMSA)*** by 15 January each year ('year X') for the year X-2, ***the climate-relevant information relating to maritime transport, and shall make that information available to the public. That information shall be made available in a manner that is useful to the charterers or users of such ships.***

(2a)The EMSA shall provide analysis inter alia of maritime transport's overall impact on the global climate, based on the information provided pursuant to paragraph 2, including on non- CO_2 ***impacts such as from black carbon, and effects of aerosols, and establish forecasts including through modelling and traffic data where relevant. The EMSA shall regularly review the modelling by reference to scientific advances.***

The EMSA shall also present options for establishing performance labelling.

[10] *OJ L140, 5.6.2009, p. 63.*