Economic impacts of MRV of fuel and emissions in maritime transport

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Summary

In June 2013, the European Commission issued a strategy to address GHG emissions from maritime transport. The strategy consists of three consecutive steps:

1. Monitoring, reporting and verification of CO_2 emissions from large ships using EU ports.
2. Greenhouse gas reduction targets for the maritime transport sector.
3. Further measures, including MBMs.

For the first step, the Commission issued a legislative proposal to establish an EU system for monitoring, reporting and verifying (MRV) of CO_2 emissions from large ships using EU ports. Ships would thereby be obliged to monitor four parameters on a voyage basis, namely fuel consumption, distance travelled, time spent at sea, and cargo carried. The monitored parameters would need to be verified and different indicators based on these parameters would have to be reported on an annual basis.

We find that all of the parameters that have to be monitored according to the MRV proposal are in principle already being monitored on board ships, although some ship owners might have to adjust the frequency and/or the timing of the monitoring. The main additional obligations for ship owners will be that the monitored data will have to be verified and reported.

According to the proposed MRV regulation the monitoring methodology for CO_2 emissions/fuel consumption would have to be laid down in the monitoring plan with the ships having the choice among the following four alternative methodologies:

1. Bunker Delivery Notes and periodic stocktakes of fuel tanks.
2. Bunker fuel tank monitoring on board.
3. Flow meters for applicable combustion processes.
4. Direct emissions measurements.

where the accuracy and the investment costs of these four monitoring methods increase in the above order.

The European Commission has estimated that the proposed MRV regulation will lead to additional annual administrative costs for the ship owners/operators of about € 76.4 million in total and € 6,700 per entity. We find that if ship owners invested in more accurate fuel consumption monitoring methods they would indeed have to incur higher investment costs but on the other hand their operational MRV costs would decline: the lowest operational MRV costs are associated with direct (continuous) emissions monitoring, followed by the use of fuel flow meters, tank monitoring, and Bunker Delivery Notes combined with stocktakes. This can be explained by the degree to which monitoring and reporting can be carried out electronically and by the accuracy and verifiability of the monitoring which has an impact on the verification costs. We estimate that ship owners and operators could lower operational MRV costs by € 5 – € 9 million annually by using automated fuel monitoring or continuous emissions monitoring. In addition, investing in more accurate fuel consumption monitoring will also, due to synergies regarding the EU and IMO air pollution regulations, lead to cost savings for both ship owners and regulators. This holds all the more so from 2015 onwards, when ships in Emission Control Areas will be subject to more stringent sulphur regulations and more inspections will have to be carried out to ensure compliance.

The European Commission expects that the implementation of the MRV regulation will lead to a reduction of the CO_2 emissions of European maritime transport of up to 2% in the year 2030. This claim is not substantiated.

Several shipping companies have, on a voluntary basis, started programmes to improve the efficiency of their fleet over the past years. These companies have not only invested in MRV, but also taken various other actions:

- invested in data analysis systems;
- monitored other data;
- taken operational or technical measures to improve fuel efficiency.

It appears that all these actions have to be taken in combination with MRV to be able to achieve efficiency improvements.

In most cases, the companies have relied on fuel flow monitoring because it yields more accurate results than periodic stock takings.

We therefore conclude that only if the MRV regulation prompted ship owners, either on a voluntary or on a mandatory basis, to invest in accurate and comprehensive monitoring and data analysis systems, a significant CO_2 emission reduction could be expected from the regulation. This would most likely be a CO_2 emission reduction higher than the 2% expected by the European Commission from the currently proposed regulation.

1 Introduction

1.1 Political background

In June 2013, the European Commission issued a strategy to address GHG emissions from maritime transport. The strategy consists of three consecutive steps:

1. Monitoring, reporting and verification of CO_2 emissions from large ships using EU ports.
2. Greenhouse gas reduction targets for the maritime transport sector.
3. Further measures, including MBMs.

For the first step, the Commission issued a legislative proposal to establish an EU system for monitoring, reporting and verifying (MRV) CO_2 emissions from large ships using EU ports. Ships would thereby be obliged to monitor four parameters on a voyage basis, namely CO_2 emissions/fuel consumption, distance travelled, time spent at sea and cargo carried.

Regarding the CO_2 emissions/fuel consumption, the monitoring methodology that would be applied on a certain ship would have to be laid down in the monitoring plan with the ships having the choice among the following four alternative methodologies:

- Bunker Delivery Notes and periodic stocktakes of fuel tanks;
- bunker fuel tank monitoring on board;
- flow meters for applicable combustion processes;
- direct emissions measurements.

1.2 Objective of study

The objective of this study is to analyse some of the impacts of the proposed MRV regulation on the shipping industry and on the wider economy and to compare the advantages and drawbacks of each of the different monitoring methods. The following impacts of the regulation are thereby considered:

1. The additional requirements for ship owners/operators induced by the MRV proposal.
2. The additional costs that will have to be incurred by the different stakeholders.
3. The potential environmental benefit in terms of CO_2 reduction.

1.3 Approach

The additional requirements for ship owners/operators that arise from the proposed MRV regulation are determined by comparing these obligations with those from current regulations and with common practice on board.

Starting point for the estimation of the costs induced by the proposed MRV regulation is the cost estimation as presented by the European Commission in the Impact Assessment (EC, 2013b). We will analyse this cost estimation by discussing whether all relevant cost items have been taken into account and by comparing the cost estimation with the EU ETS MRV costs identified for airline operators and for operators of industrial/power generating installations. The cost estimation of the European Commission does not take possible

investments into monitoring technologies into account. We analyse how the induced costs may change depending on the fuel monitoring methodology applied and analyse whether synergies with the MRV related to air pollution regulations could occur.

The European Commission expects the proposed MRV regulation to reduce CO_2 emissions by at least 2% in the year 2030. To asses this estimation we look at the fuel monitoring practice and the CO_2 emission reduction of ship owners that already, on a voluntary basis, are actively working on the improvement of the energy efficiency of their fleet. In addition, we discuss how the CO_2 reductions are likely to vary depending on the fuel monitoring method used.

1.4 The four alternative fuel monitoring methods

If the level of the fuel that is left in the tanks on board a ship is determined at the beginning and at the end of a voyage and if this information is combined with information on the amount of fuel that has been bunkered on the voyage, it will be possible to calculate the amount of fuel that the ship has consumed on that voyage. This actually is the first monitoring method that the European Commission allows for: a combination of periodic stocktakes and Bunker Delivery Notes. Periodic stocktakes can thereby be expected to be carried out manually on board, otherwise the second monitoring method would probably be applied. A Bunker Delivery Note (BDN) is a document that is issued by the bunker fuel supplier to the ship operator that specifies, amongst others, the quantity and the quality of the fuel supplied.

The second monitoring method allowed for by the European Commission is fuel tank monitoring on board. Here again a ship's fuel consumption is calculated on the basis of tank level data. In contrast to the first method, tank levels are not manually determined but by tank sounding systems. Since the tank level can be read-out before and after bunkering the BDNs that are required for the first method are redundant here.

The third and the fourth monitoring methods do not rely on tank level data, but rather work by continuously monitoring either the in- and outflow of the fuel from the tanks on board (third method) or the stack emissions on board (fourth method).

These four CO_2 emissions/fuel consumption monitoring methods have different characteristics. In a previous report, we have shown that the first two options have low investment costs but higher manpower costs than the latter two options (CE Delft, 2013). BDNs do not require any and periodic manual stocktakes very little equipment/investment costs; automated bunker fuel tank monitoring equipment is relatively cheap and already installed on many ships. Fewer ships have flow meters, although many ships with modern fuel systems do have them. Flow meters are considerably more expensive than tank sounding systems, but less expensive than direct emissions monitoring systems, which very few ships have.

In terms of accuracy, it is also clear that fuel flow meters and direct emissions measurement yield more accurate estimates of fuel consumption (IMarEST (MEPC 65/INF. 3/Rev.1), CE Delft, 2013) than the first two methods. These findings have been confirmed empirically by Aldous et al. (2013) who found that the standard error in tank monitoring is considerably larger than in continuous monitoring. Direct emission measurement systems have been shown to be more accurate than fuel flow meters (IMarEST (MEPC 65/INF. 3/Rev.1), CE Delft (2013)).

2 Induced obligations

The MRV proposal of the European Commission imposes certain monitoring and reporting obligations on ship owners. In this section we describe these obligations and subsequently analyse to what extent they constitute additional requirements. The certificates and documents that have to be carried on board ships due to international regulations as well as the common monitoring and documentation practices are analysed to determine the extra obligations for ship owners.

2.1 Obligations for ship owners under proposed MRV system

The MRV regulation as proposed by the European Commission imposes on companies[1] the obligation to monitor per ship (≥ 5,000 GT) certain parameters on a voyage basis as well as to calculate and report certain aggregates and indicators per calendar year.

The parameters/information that have to be monitored per voyage (see Article 9 of the proposal) are as follows:

- port of departure and port of arrival including the date and hour of departure and arrival;
- the amount and emission factor for each type of fuel consumed in total and differentiated between fuel used inside and outside emission control areas;
- distance travelled;
- time spent at sea;
- amount of cargo carried in metric tonnes and cubic metres;
- number of passengers (for passenger ships);
- CO_2 emitted;
- transport work.

The actual fuel consumption for each voyage can thereby be determined using one of the following monitoring methods:

- Bunker Fuel Delivery Note (BDN) and periodic stocktakes of fuel tanks;
- bunker fuel tank monitoring on board;
- flow meters for applicable combustion processes;
- direct emissions measurements.

The fuel consumption of main engines, auxiliary engines, boilers and inert gas generators has to be taken into account and the fuel consumption at berth within ports has to be calculated separately.

The CO_2 emissions can be calculated using default values of emission factors.

Regarding the distance travelled, either the real distance travelled or the distance of the most direct route between the port of departure and the port of arrival corrected by a certain factor can be reported.

[1] According to the proposal, companies are responsible for the monitoring, reporting and verification. Companies are thereby defined as 'the owner of a ship or any other person who has assumed the responsibility from the ship-owner for its operations.

Transport work has to be determined by multiplying the distance travelled with the amount of cargo carried.

Per calendar year the companies have to report the following (see Article 10 of the proposal):
- amount and emission factor for each type of fuel consumed in total and differentiated between fuel used inside and outside emission control areas;
- total CO_2 emitted;
- aggregated CO_2 emissions from all voyages between ports under a Member State's jurisdiction;
- aggregated CO_2 emissions from all voyages which departed from ports under a Member State's jurisdiction;
- aggregated CO_2 emissions from all voyages to ports under a Member State's jurisdiction;
- CO_2 emissions which occurred within ports under a Member State's jurisdiction at berth;
- total distance travelled;
- total time spent at sea;
- total transport work;
- average energy efficiency.

The average energy efficiency has thereby to be determined by at least the following four indicators:
1. Fuel consumption related to distance travelled.
2. Fuel consumption related to transport work.
3. CO_2 emissions related to distance travelled.
4. CO_2 emissions related to transport work.

The fourth indicator is thus in fact comparable to the Energy Efficiency Operational Indicator (EEOI), however not applied to all voyages but to voyages from and to EU ports only. The EEOI is an energy efficiency index that has been developed for certain ship types within the IMO for voluntary use.[2]

2.2 Obligations under IMO instruments

SEEMP

According to MARPOL Annex VI, Regulation 22, each ship ≥ 400 GT has to keep a Ship Energy Efficiency Management Plan (SEEMP) on board. The SEEMP has to be ship specific and has to be set up in accordance with the IMO guidelines.

These SEEMP guidelines (MEPC 63/23 Annex 9) differentiate the following four steps of the management plan:
1. Planning.
2. Implementation.
3. Monitoring.
4. Self-evaluation and improvement.

In the planning phase, the current energy usage should be determined and a list of measures that could be used to improve the energy efficiency of the ship has to be compiled. The SEEMP should also describe how each measure should be implemented and who the responsible person is. Ships can, on a

[2] For detailed information on the EEOI see 'Guidelines for voluntary use of the ship energy efficiency operational indicator (EEOI)' (MEPC.1/Circ.684).

voluntary basis, set an energy efficiency goal as the last part of the planning phase.

The energy saving measures should be implemented according to the plan and the energy efficiency of the ships should be monitored quantitatively.

Monitoring should therefore be done by an established method, preferably by an international standard. The EEOI is considered the primary monitoring tool, although other quantitative measures are also considered to be appropriate. It is recognized that the trade a ship is engaged in may determine the feasibility of the efficiency measures under consideration.

In the last phase, the effectiveness of the measures and their implementation is evaluated by the company itself.

Other obligations under IMO instruments

Regulation 18 of MARPOL Annex VI obliges vessels of 400 GT and above as well as platforms and drilling rigs to keep a record of the fuel oil that they bunker by means of a **Bunker Delivery Note** (BDN).The BDN is issued by the bunker fuel supplier and has to contain at least the following information (MEPC.1/Circ.508):

- name and IMO number of receiving ship;
- port;
- date of commencement of delivery;
- name, address and telephone number of marine fuel oil supplier;
- product name(s);
- quantity (metric tons);
- density at 15˚C (kg/m^3);
- sulphur content (% m/m); and
- a declaration signed and certified by the fuel oil supplier's representative that the fuel oil supplied is in conformity with regulation 14(1) or (4)(a)and Regulation 18(1) of MARPOL Annex VI.

According to Regulation 18 of MARPOL Annex VI, the bunker delivery notes have to be kept on board for a period of not less than three years following the delivery.

Regulations 17.1 and 36.1 of MARPOL Annex I, oblige every oil tanker of 150 GT and above and every other ship type of 400 GT and above to keep an **Oil Record Book**, Part I. Whenever certain machinery space operations take place such as the bunkering of fuel, an entry has to made in the Oil Record Book.

Regulation 14.6 of MARPOL Annex VI obliges ships that are using separate fuel oils to comply with the IMO sulphur emissions regulation to follow a fuel oil changeover procedure and to keep a **fuel changeover log book**: the ships have to carry a written procedure showing how the fuel oil changeover is done and the following information has to be recorded in a log book when any fuel oil changeover operation is completed prior to the entry into an emission control area or commenced after exit from such an area:

- the volume of low sulphur fuel oils in each tank;
- date and time of the changeover;
- position of the ship at the changeover.

There also several regulations of the SOLAS Convention in place that require ships to document certain information that is relevant for the MRV system.

SOLAS for example specifies the type and frequency of entries into a vessel's deck log book. Such entries involve most operations taking place on board the vessel, amongst which the entering and leaving of a port. If not credibly proved otherwise, this information would allow the distance sailed to be determined by means of default distances between ports.

Also the mass of certain goods has to be documented before loading due to SOLAS. This holds especially for potentially dangerous goods. Regarding the mass of containers, the Sub-Committee on Dangerous Goods, Solid cargoes and Containers of the IMO agreed in September of this year to the draft amendments of SOLAS chapter VI which will require mandatory verification of the gross mass of containers.

2.2.1 Obligations from EU regulation

For all cargo imported into or exported from the EU, carriers have to submit entry/exit summary declarations, which contain information on the gross mass, amongst others (EC, 2006). Most of the intra-EU sea trade is actually covered by this regulation too, since ships that leave the Member States' territorial waters (12 nautical mile zone) are considered to pass the EU's external border.

2.2.2 Common practice

Common practice on board ship also provides information relevant for the MRV system. For example, in the engine room log book the running hours of different machinery will be recorded, and the destination of the cargo is documented in the bill of lading.

The fuel consumption as such is even monitored under certain charter agreements. Here the ship owner pays for the fuel expenditure in the first place and subsequently charges the charterer for the fuel that has been consumed. The fuel consumption is thereby not necessarily monitored per voyage but will in many cases be related to the period that the ship has been chartered.

2.3 Additional obligations for ship owners/operators

From the above we can conclude that all of the parameters that have to be monitored according to the MRV proposal are in principal already being monitored on board: tank levels are documented on a regular basis, the amount of fuel bunkered as well as the relevant information on the voyage and cargo are being documented. Only the frequency and/or the timing of the monitoring will have to be adjusted by some ship owners since under the MRV regulation the parameters will have to be monitored per voyage and fuel consumption will have to be monitored not only per voyage but also differentiated by ECA/non-ECA area. This means for example that a ship owner who decides to monitor the fuel consumption of a ship by means of Bunker Delivery Notes in combination with periodic stock takes will have to carry out stock takes every time the ship calls at an EU port and that ships that do not switch fuels when entering an ECA but make use of end-of-pipe technologies will, although IMO regulation does not require so, still have to monitor their fuel consumption within the ECA separately thus making two extra 'virtual port calls'.

One of the indicators that is proposed for reporting is similar to the EEOI. Ships that, due to the SEEMP, already work with the EEOI will thus have relatively low additional monitoring obligations since they already monitor transport work on a voyage basis. This holds all the more so if these ships also already monitor their fuel consumption according to the EEOI guidelines (MEPC.1/Circ.684), i.e. if they already monitor their fuel consumption on a voyage basis.[3]

For ships that, for SEEMP purposes, work with an energy efficiency indicator other than the EEOI, the MRV system will naturally have higher additional monitoring and reporting costs.

The verification of the annual emissions report clearly is a new requirement for each ship owner since the SEEMP regulation does not require any kind of verification.

[3] Although the guidelines for the Energy Efficiency Operational Index (EEOI) do prescribe that fuel consumption is monitored on a voyage basis, it is sufficient for the correct calculation of the EEOI to monitor the aggregated fuel consumption of all voyages within the monitoring period, since the numerator of the EEOI is the sum of the fuel consumption of the different voyages.

3 Induced costs

3.1 Which costs can be expected?

If the proposed MRV regulation was implemented, ship owners/operators, the national competent authorities, and the EU competent authority would have to incur certain costs. In Table 1 an overview is given of the different cost items associated with the MRV regulation together with the stakeholder that most probably will have to bear the respective costs.

Table 1 Overview on cost items associated with MRV regulation

Cost item	Stakeholder to bear costs
Familiarization with obligation	National authorities, EU authority, Ship owner/operator
Designing information material	National authorities, EU authority
Informing subjected entities	National authorities, EU authority
Developing reporting tool	EU authority
Registry costs	Ship owner
Purchase of additional monitoring and reporting equipment	Ship owner
Additional maintenance of monitoring and reporting equipment	Ship owner/operator
Setting up monitoring plan	Ship owner
Additional monitoring	Ship owner/operator
Reporting (setting up emissions report)	Ship owner/operator
Verification of information submitted	National authorities, EU authority
Processing of verified reports	EU authority
Enforcement (if ship is inspected compliance has to be checked (by ensuring that document is on board), application of penalties, execution of expulsion order)	National authorities

3.2 Cost estimation of the European Commission

In the impact assessment of the proposed MRV regulation (EC, 2013a and 2013b) the annual additional administrative costs[4] have been determined for ship owners/operators, for the national competent authorities, as well as for the EU competent authority. In Table 2 these administrative costs are given per stakeholder group, both for the group as a whole (in million Euro) and per entity (in Euro).

[4] The *additional* costs are referred to as 'burden' in the impact assessment.

Table 2 **Additional annual administrative costs (scope: ships of 5,000 GT and above)**

Stakeholder	Total (million €)	# of entities	Per entity (€)
Ship owner/operator	76.4	11,400	6,700
National competent authority	2.6	27	95,500
EU competent authority	2.2	1	2,200,000
Total	81.2		

Source: Based on EC 2013a and EC 2013b; non-recurring costs have been spread over 10 years.

The additional administrative costs consist mainly of personnel expenditures but also include the costs for private sector verification and 'equipment costs' for national authorities and EU competent authority regarding the design of information material.

The additional annual administrative costs for the ship owners/operators are estimated to amount to some € 76.4 million in total and to € 6,700 per entity.[5]

In the impact assessment these costs are set off against the expected fuel expenditure savings: the discounted administrative costs amount to € 0.6 billion and the discounted fuel expenditure savings to € 9.4 billion, leading to a net benefit of € 8.8 billion in the period until 2030. The expected fuel expenditure savings are thereby based on the 2% fuel saving that is expected from the MRV regulation.

3.3 Analysis of cost estimation of European Commission

In the following we will analyse the cost estimation of the European Commission. We thereby discuss whether all relevant cost items have been taken into account and compare the cost estimation with the EU ETS MRV costs identified for airline operators and for operators of industrial/power generating installations.

3.3.1 Completeness

A few cost items have not been taken into account in the impact assessment of the European Commission:

1. It can be expected that ship owners will have to register their ships with the EU authority and have to maintain this register. The European Commission seems to have neglected this cost item. The costs of registering ships can be significant if they can be compared with the costs of setting up a registry in the EU ETS, which is reported to amount to € 2,500 in a recent study on small aviation emitters in the EU ETS (PwC et al., 2013).The costs for *maintaining* a registry account in the EU's Union registry have been reported to amount to around € 500 per annum.
2. In the MRV proposal the investment costs for developing a reporting tool that will have to be incurred by the EU are specified to be € 0.5 million. These costs do not seem to have been taken into account in the impact assessment.
3. The European Commission comes to the conclusion that in the period until 2030 the MRV regulation will generate a net benefit of € 8.8 billion. The fuel expenditure savings from a 2% fuel consumption reduction have been taken into account here. What is not clear from the impact

[5] Note that in the main document of the impact assessment (EC, 2013a) these costs are specified as € 26.1 million in total and € 2,300 per ship owner/operator. This difference can be explained by the fact that the costs specified in the main document of the impact assessment are exclusive of the costs for private sector verification.

assessment is whether the investment and maintenance costs associated with the abatement measures that enable the 2% reduction of the fuel consumption have thereby been accounted for.
These costs are not necessarily associated with the MRV regulation, since the regulation does not oblige ships to reduce their fuel consumption, however, they have to be taken into account when determining the cost effectiveness of the MRV regulation for ship owners/operators. Even if the abatement measures are cost effective, the net benefit of the MRV regulation will be lower.

3.3.2 Comparison with MRV costs for EU ETS

Most of the administrative costs estimated by the European Commission are personnel expenditures and are estimated by specifying for the different tasks the number of necessary man-days and by applying a specific hourly wage rate.

The hourly wage rates are assumed to be:

- € 41.5/hour for the tasks related to national competent authorities and ship owners/operators; and
- € 67/hour for the tasks carried out by the EU competent authority.

In a recent report to the Commission however, PwC et al. (2013) have worked with an hourly rate of € 75 for aircraft operators which is significantly higher than the € 41.5 that have been assumed for ship owners/operators here.

The amount of man-days assumed per task and per entity is specified in Table 3.

Table 3 Man-days assumed per task and per entity in impact assessment

Stakeholder	Task	Assumed man-days	Non-recurring costs*
Ship owner/operator	Familiarization with obligation	20	X
	Preparation of monitoring plan	5	X
	Retrieving relevant information from existing data (net of BAU)	0.4	
	Adjusting existing data	2	
	Filling in forms and tables, incl. recordkeeping	1	
	Verification	2	
	Submitting the information	1	
National competent authority – informing & controlling compliance***	Familiarization with obligation	50	X
	Designing information material	7.4**	X
	Informing the subjected entities	420	X
	Verification of information submitted	210	
National competent authority – enforcement***	Familiarization with obligation	5	X
	Verification	11	
EU competent authority	Familiarization with obligation	50	X
	Designing information material	200	X
	Informing the subjected entities	8,550	X
	Verification of information submitted	2,850	

Source: EC (2013b); scope: ships of 5,000 GT and above; * non-recurring costs are spread over the first 10 years;**The 200 man-hours specified in the impact assessment are related to the 27 EU countries; ***Controlling compliance refers to the verification of the information submitted to the EU whereas enforcement refers to the actual enforcement by e.g. Port State Control.

The *aggregated* annual man-days assumed per entity are specified in Table 4.

Table 4 Total annual man-days assumed per entity for all tasks in impact assessment

Stakeholder	Average annual man-days in the first 10 years per entity	Annual man-days in the subsequent years per entity
Ship owner/operator	9	6
National competent authority – informing and controlling compliance	258	210
National competent authority – enforcement	8	7
EU competent authority	2,927	2,850

Source: Based on EC (2013b).

The man-days scheduled for ship owners/operators are lower in comparison to aircraft operators. PwC et al. (2013) report that they spent on average 83 hours to set up a monitoring plan for emissions and tonne-kilometre data, 85 hours to implement the monitoring plan and 72 hours annually to monitor and report emissions. If the monitoring plan would be valid for 10 years, this would translate to an average 89 hours per year or approximately 11 days. In view of the strict MRV requirements that aircraft operators already had to comply with for safety reasons, we think it is unlikely that the effort for shipping companies will be less.

The third party verification of the data monitored is expected to be outsourced against € 3,750 per annum per ship owner/operator. For small aviation emitters, verification costs are only available for verification of RTK data. These amount to about € 1,200 (PwC et al., 2013). The costs expected for the shipping sector thus seem to be relatively high.

The overall annual MRV costs for ship owners and operators are estimated to be € 6,700. These costs are comparable to the € 7,300 annual compliance costs of small aviation emitters reported by PwC et al. (2013) but are lower than the MRV costs for ETS installations that have been identified for a sample of German ETS firms: Heindl (2012) finds MRV costs of around € 8,500 on average, albeit with a large variation.

3.4 Cost differences per monitoring method

The proposed MRV regulation allows ship owners to choose among four different fuel consumption monitoring methods. Depending on the monitoring method applied, the additional MRV costs of ship owners/operators will differ.

While the more automated, accurate monitoring methods are associated with higher investment costs, the opposite holds for the operational MRV costs:

If fuel consumption is monitored by Bunker Delivery Notes together with periodic stocktakes, the frequency of the stocktakes may have to be increased due to the MRV regulation, leading to some extra monitoring costs. These extra monitoring costs would be relatively high if stocktakes are carried out manually. Reporting of the fuel consumption data will lead to additional costs too. Only if the stocktake data is already being entered into electronic systems would the additional reporting costs be minimal. But even if this is the case, the fuel consumption data would still have to be linked to the relevant

emission factors. Third party verification could turn out to be relatively high since a cross check with other parameters might be needed.

Tank monitoring on board, the second possible methodology choice, is in principal very similar to the first method: only BDNs do not have to be produced and stocktakes are not carried out manually. Just as under the first method, the MRV regulation would lead to a change in the frequency of the stocktakes. If the stocktake data can be read-out electronically, fuel consumption per voyage can easily be determined by tank monitoring and MRV costs can be significantly lower compared to the first method.
Fuel consumption data however would still need to be linked to the relevant emission factors and third party verification would probably also call for a number of cross checks.

Monitoring fuel consumption using fuel flow meters has the advantage over working with stocktakes (manually or automated) in that fuel consumption is directly measured and does not need to be determined on the basis of tank stock data. Since automated, monitoring and reporting will be associated with relatively little extra costs and since the fuel consumption data retrieved can be expected to be more reliable than the data determined by the first two methods, verification costs can be expected to be lower too. However, just as for the other two monitoring methods, fuel consumption data will need to be linked to the relevant emission factors.

For direct emission measurement, the costs for monitoring, reporting and verification can be expected to be the lowest since monitoring is fully automated and the most accurate. Even though the monitored CO_2 emission data will have to be converted into fuel consumption data, this will not be associated with extra monitoring costs, at least if the monitoring device also captures the CO_2 concentration of the exhaust gases.

Assuming that the automated fuel flow meters and direct emissions monitoring would eliminate the need for retrieving relevant information from existing data and for filling in forms and tables, including recordkeeping, it would save an estimated 1.4 man days annually according to Table 3. With 11,400 ships over 5,000 GT and 18,400 ships in total, this would reduce reporting costs by € 5–€ 9million per annum.

3.5 Possible synergies with other regulations

The investment costs associated with tank monitoring devices, fuel flow meters, and direct emission measurement devices may not only lead to reduced reporting and verification costs with respect to the proposed MRV regulation but could also lead to a reduction of the administrative costs for ship owners/operators and/or national authorities related to other regulations, in particular air pollution regulations.

Many ships choose to comply with the IMO and the EU sulphur regulation by using a fuel with a low(er) sulphur content. Ships then have to keep Bunker Delivery Notes on board and have to keep a sample of the fuel bunkered. If ships switch to a fuel with a lower sulphur content when entering and leaving a Sulphur Emission Control Area (SECA) ships also have to follow a certain fuel changeover procedure, where they have to monitor and report the level of the tank that contains the fuel suitable for compliance with the regulation. (MARPOL Annex VI, Regulation 14.6) Verification by the national authorities

can comprise the inspection of the BDNs, of the documentation of the fuel changeover procedure and testing the bunker samples.

The use of tank monitoring devices or fuel flow meters could lower the monitoring and reporting costs of ship owners/operators by reducing the costs for determining the low sulphur fuel tank stocks in the course of the fuel changeover procedure and hence also the verification of these data by the national authorities. The costs for the verification of the fuel quality used in- and outside the SECAs, i.e. testing of fuel samples, however cannot be reduced by ships using fuel flow meters.

If ship owners would make use of direct (continuous) emissions monitoring, monitoring and reporting costs for compliance with the sulphur regulations could be reduced even more, since the fuel changeover procedure and the related documentation could become superfluous. Since the inspection of the documentation of the fuel changeover procedure would then also no longer be necessary, as well as the testing of the fuel samples, verification costs of national authorities would be reduced as well.

Direct continuous emissions monitoring systems can also lead to a reduction of the compliance costs for those ship owners that make use of emission reducing devices to comply with NO_x and sulphur regulations, at least if the direct emissions monitoring system can also measure NO_x and SO_x emissions. Exhaust gas cleaning systems ('scrubbers') can for example be used to remove SO_x from the exhaust gas of a ship or selective catalytic reduction systems can be applied to reduce the a ship's NO_x emissions by chemical reduction. These devices need IMO approval to ensure that the emission standards can be met with these devices. Direct continuous emission monitoring systems can be used to this end (MEPC.184(59)). And if ships make use of scrubbers they also have to demonstrate that the systems work properly after the approval. Daily spot checks of the exhaust gas quality are recommended to this end and a continuous emission monitoring system would produce this data without extra effort. An IMO Submission by the United States and Ireland suggested that continuous emissions monitoring systems was the most suitable to demonstrate compliance with the IMO NO_x standards, but the IMO Sub-Committee on Bulk Liquids and Gases concluded (BLG, 2013) that a mandatory requirement is not appropriate at this stage.

Quantification of the MRV costs that could be saved related to compliance with air pollution regulations is difficult because there is little data available. We estimate the current costs for the national authorities to be less than € 1.5 million per year in the EU, although this depends on the number of MARPOL Annex VI inspections of Port State Control and the costs per inspection.

Our estimates are based on the following facts:

- EU Member States carried out approximately 17,000 ship inspections in 2012.(Paris MoU,2013).
- The Dutch Port State Control had planned to carry out 230 MARPOL Annex VI inspections in 1,510 ship inspections (the number of actual MARPOL Annex VI inspections was 86) (InspectieLeefomgeving en Transport, 2013).
- Five MARPOL Annex VI inspection cost € 2,800 (RIVM, 2012).
- An analysis of a fuel oil sample costs € 150 (Bloor et al., 2013).

Assuming that the costs of MARPOL Annex VI inspections and their share in the number of ship inspections are constant in EU Member States, EU states have carried out almost 2,600 inspections for a total cost of € 0.4 - € 1.5 million in 2012.[6]

From 2015 onwards, ships in Emission Control Areas will be subject to more stringent sulphur regulations which will increase the costs of compliance (and consequently the benefits of non-compliance). As a result, it is likely that more inspections will need to be carried out to keep the share of non-compliant ships at its current level. Thus, the benefits of continuous emissions monitoring would increase.

3.6 Potential benefits for ship equipment manufacturers

The proposed MRV regulation allows ship owners to choose one out of four fuel monitoring methods. If this choice was narrowed to the more automated, more accurate methods for all or for some ship types/sizes, the MRV regulation would lead to higher investment costs for some ship owners[7] which would constitute a demand impulse for the marine equipment industry.
More specifically, the regulation could lead to an increased demand for:

- sensors and meters to be installed on board;
- electronic systems including interfaces and software that gather, store and/or process the data;
- data analysis services.

According to the European Commission (EC, 2013b), about 11,400 ships of 5,000 GT and above will have to comply with the MRV regulation. For the global fleet it is roughly estimated that owners of about 10% of the ships of 5,000 GT and above are currently, on a voluntary basis, actively working on the improvement of the fuel efficiency of their ships. If the same share was to hold for the fleet that would fall under the MRV regulation, it can be expected that extra ship equipment for about 10,000 ships would be in demand due to the stricter MRV regulation.

There is large number of small and medium sized enterprises in the marine equipment industry and it is therefore very difficult to tell which country, in terms of employment, would profit the most from this demand impulse.
A thorough market analysis was beyond the scope of this study but from desktop research we found headquarters of relevant marine equipment companies to be located in Northwestern Europe, the US, Canada, and Japan. But since many companies are global enterprises and since production facilities may be located not in the same country as the headquarters it is still difficult to determine where the employment impact would be the highest.

In general it holds that the suppliers of sensors and meters are often not only active in the shipping sector but rather serve different sectors; the applications for the shipping sector are often well established for other sectors and are then being transferred to the shipping sector.

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6 The main uncertainty in this calculation results from the cost per inspection. The lower figure assumes that the costs are just related to the analysis of the fuel. RIVM (2012) reports the costs of inspection by PSC ships coming alongside of inspected ships. This is probably more expensive than inspections in port. However, it is not clear from the text whether this figure includes the costs of the chemical analysis and potential other enforcement costs.

7 Due to economies of scales these investment costs can be expected to decrease in the long run.

Electronic monitoring systems including interfaces and software can naturally be produced everywhere. Some companies however do offer integrated solutions in the sense that they collaborate with the suppliers of the sensors and meters.

There is a multitude of suppliers of vessel performance monitoring services active on the market. Traditionally these services have been offered for fuel expenditure saving purposes but environmental regulation now plays an increasing role; there is for example a rising number of companies that do offer assistance in the implementation of the IMO Ship Energy Efficiency Management Plan which is mandatory since the beginning of 2013.
The companies offering vessel performance monitoring services typically are stand alone service companies, a branch of a shipping or marine equipment company or a classification society. Some of these companies are, due to technology cluster reasons, located in the same countries as the suppliers of fuel/emission monitoring equipment, however the spread over countries is much higher due to the heterogeneity of the suppliers.

3.7 Conclusions

The European Commission has estimated that the proposed MRV regulation will lead to additional annual administrative costs for the ship owners/operators of about € 76.4 million in total and € 6,700 per entity. These additional costs comprise the administrative costs for monitoring and reporting as well as the costs for third party verification. We come to the conclusion that the cost estimate for monitoring and reporting is rather low but that the cost estimate for third party monitoring is rather high if compared to the EU ETS MRV costs of aircraft operators. The total MRV cost estimate is comparable to those identified for aircraft operators but lower than the EU ETS MRV costs identified for operators of industrial/power generating installations.

The proposed MRV regulation allows ship owners/operators to choose among four different fuel consumption monitoring methods. Depending on the monitoring method applied, the additional MRV costs of ship owners/operators will differ. While the more automated, accurate monitoring measures are associated with higher investment costs, the opposite holds for the operational MRV costs: the lowest operational MRV costs are associated with direct (continuous) emission monitoring, followed by the use of fuel flow meters, tank monitoring, and Bunker Delivery Notes combined with stocktakes.
This can be explained by the degree to which monitoring and reporting can be carried out electronically and the accuracy and the verifiability of the monitoring which has an impact on the verification costs.
We estimate that ship owners and operators could lower MRV costs by € 5 – € 9 million annually by using automated fuel monitoring or continuous emissions monitoring.

Due to synergies with air pollution regulations, regulators could at the current level of inspections annually save € 0.4 - € 1.5 million if ships made extensive use of continuous emissions monitoring systems. From 2015 onwards, ships in Emission Control Areas will be subject to more stringent sulphur regulations which will increase the costs of compliance (and consequently the benefits of non-compliance). As a result, it is likely that more inspections will need to be carried out to keep the share of non-compliant ships at its current level. Thus, the benefits of continuous emissions monitoring would increase.

The proposed MRV regulation allows ship owners to choose one out of four fuel monitoring methods. If this choice was narrowed to the more automated, more accurate methods for all or for some ship types/sizes, the MRV regulation would lead to higher investment costs for some ship owners and to a demand impulse for the marine equipment industry. There is large number of small and medium sized enterprises in the marine equipment industry and it is therefore very difficult to tell which country, in terms of employment, would profit the most from this demand impulse.

4 Impact on CO_2 emissions

4.1 Impact on CO_2 emissions expected by European Commission

The European Commission expects that the implementation of the MRV regulation will lead to a reduction of the CO_2 emissions of European maritime transport of up to 2% in the year 2030 compared to the baseline. This is, in absolute terms, an emission reduction of 4.46 Mt of CO_2 in the year 2030. The cumulative CO_2 emission reduction until 2030 is estimated to amount to 55.9 Mt which is equivalent to an annual 2% emission reduction in the period 2018-2030 compared to the baseline.

The European Commission points out that the 2% emission reduction estimate has been confirmed during bilateral discussion with stakeholders and that some leading stakeholders expect the emission reduction to be even higher (EC, 2013a).

The European Commission bases the expected CO_2 emission reduction from an MRV regulation on the Maddox (2012) report. Since no MRV regulation as such is analysed in the Maddox report it is not clear how the study supports the expected 2% emission reduction for 2030. In the study different measures to remove the market barriers that prevent the implementation of cost effective CO_2 abatement measures in the shipping sector are analysed. The two measures that may have an impact comparable to an MRV regulation are the 'Vessel fuel consumption certification' and the 'Enhanced SEEMP implementation' measures.

The CO_2 reduction that the European Commission expects to be realised through the MRV regulation is ascribed to the additional information that would become available on the fuel consumption/efficiency of the ships. This would trigger an improvement of the fuel efficiency of the ships.

The measure 'Vessel fuel consumption certification' means that a consistent approach to measuring vessels' fuel consumption would be established and that the monitored data would be verified by a third party, such as a classification society. Reliable information on the fuel consumption of ships would then make relative energy efficient vessels more attractive for charterers and buyers and enable ship owners to earn back investment costs for energy efficiency measures by charging charterers higher rates for more efficient ships.

The 'Enhanced SEEMP implementation' would, in contrast to the current SEEMP, require companies to implement specific verifiable procedures within an environmental management system that would be subject to auditing. Regarding the environmental impact of the enhanced SEEMP implementation, it is acknowledged that it is difficult to quantify the impact but stated that there is some indication that it may result in an improved environmental performance.

The approach that has been used in Maddox (2012) to quantify the emission reduction associated with the different measures to remove the market barriers for investment into CO_2 abatement measures is as follows: The *maximum* abatement potential of twelve CO_2 abatement measures is quantified at 169 Mt CO_2 in 2020. Implementing all the political measures

presented in the study would remove the market barriers to such an extent that the total maximum abatement potential of the twelve abatement measures would be realized. For each political measure, an estimation is then made of the extent to which it contributes to removing the market barriers and this share then determines the share of the maximum abatement potential that can be ascribed to the specific political measure. The CO_2 emission reduction of the specific political measure is then, based on the 'professional judgement' of the authors distributed over the different individual CO_2 abatement measures.

According to this approach, the global 2020 emission reduction of 'Vessel fuel consumption certification' measure amounts to 52 Mt CO_2 and to 21 Mt CO_2 for the 'Enhanced implementation of the SEEMP' measure. This is equivalent to an emission reduction of 4% and 1.6% in 2020 respectively.

4.2 Review of the CO_2 emission reduction expected by the Commission

If implemented, the MRV regulation would not lead to a price on carbon, so for the MRV regulation to have an effect on CO_2 emissions, abatement measures that currently already are cost efficient have to be available and the regulation has to prompt ship owners to, at least partially, take up these measures.

For many ship types cost efficient CO_2 abatement measures are indeed available. If the MRV regulation is successful in removing (some of) the market barriers that prevent the adoption of these measures, then a CO_2 reduction effect can be expected from the MRV regulation.

In Maddox (2012) this approach has been chosen but the MRV regulation is not explicitly analysed. The crucial question thus arises whether the MRV regulation is able to help remove these market barriers.

The market barriers that the MRV regulation could remove in principle are:
1. The split incentive between charterers and ship owners. And
2. The lack of information of ship owners and operators.

The split incentive arises because the owner of a ship who does not use the ship himself is only willing to invest in CO_2 abatement measures if he can consequently raise the charter rates to earn back his investment costs. However, a charterer is only willing to pay higher charter rates if he actually is able to compensate the additional expenses by a reduced bunker bill. For that, the charterer needs credible and reliable information on the fuel consumption of a ship

Due to the proposed MRV regulation, charterers will indeed get verified information on the fuel consumption and efficiency of a vessel. However this information will probably not be more meaningful for a charterer than the maximum amount of fuel consumption per day that is currently specified in the charter contracts. The energy use of the vessel in absolute terms per year is probably not meaningful enough since it does not say anything about the underlying use of the ship and the EEOI that would have to be reported according to the MRV proposal might also be of limited value for a charterer since factors that are not related to the energy efficiency of the ship can have an impact on the indicator too.

What would constitute useful information for a charterer are ship specific speed-consumption curves set up for different drafts and standardized sea/weather conditions. Speed-consumption curves specify a ship's expected fuel consumption depending on the speed of a ship. These curves would have to be determined on a regular basis, since maintenance of e.g. the ship hull, would have an impact on the speed dependent fuel consumption. Aldous et al. (2013) show that the calculation of speed-consumption curves is only reliable for the more accurate fuel monitoring methods, i.e. continuous fuel flow meters and emissions monitoring.

It can thus be concluded that the proposed regulation will by itself not be sufficient to remove the split incentive market barrier. Depending on the monitoring method, it may allow the ship owner to convey more reliable information about the fuel-efficiency/consumption of the ship, but only when the monitoring method is sufficiently accurate.

The proposed MRV regulation can thus be expected to have an effect mainly on the CO_2 emissions of vessels that are operated by the ship owners themselves. Some of these ship owners are already, on a voluntary basis, actively working on the improvement of the CO_2 emissions of their fleet. From this subset of ship owners, that still is the minority, no extra emission reductions can be expected due to the proposed MRV regulation.

In order to get an indication of the effect that the MRV regulation could have on the vessels of other ship owners, it is useful to look at the monitoring practice of the active ship owners. If the monitoring practice of these ship owners was comparable to the requirements set by the MRV proposal, then a CO_2 emission reduction can be expected to be realised.

4.2.1 Monitoring practice of active stakeholders

Some ship owners are, on a voluntary basis, actively working on the improvement of the CO_2 emissions of their fleet. Through an internet search and by contacting firms in our network, we have identified a number of companies that do so. An overview of the monitoring practice of these shipping companies is given in Table 5.

Table 5 Overview monitoring practice of some active stakeholders

Shipping company	Fuel monitoring method	Additional parameters monitored	Data analysis system
NORDEN	Flow meters are installed on the newest vessels	NORDEN applies the CASPER analysis system which requires additional information on: – Wind and sea conditions (cross-checked with Metocean data) – Speed through water calculated – Speed over ground – Draft/trim – Engine related data (e.g. RPM of ME, flow meter, indication, etc.)	YES
Møller-Maersk	Maersk Line recommends to invest in separate fuel supply and return meters for ME, AE, boilers and incinerators	The vessel performance management system of Maersk Technology uses a matrix of key performance indicators derived from engineering plant parameters and navigational information	YES

Shipping company	Fuel monitoring method	Additional parameters monitored	Data analysis system
NYK	Flow meter	A voyage summary report includes information on: – Distance and voyage hours – Displacement and draft – Speed and propulsion – M/E output – Wind – Roll and Pitch – Slip	YES
Wilh. Wilhelmsen ASA	Not known	Performance Monitoring and Analysis works with: – Navigational data – Engine data – Weather and sea conditions – Loading conditions (draft/trim)	YES
Various shipping companies using CASPER (Propulsion Dynamics)	Tank soundings, but preferably fuel flow meters	– Wind and sea conditions (cross-checked with Metocean data) – Speed through water calculated – Speed over ground – Draft/trim – Engine related data (e.g. RPM of ME, flow meter, indication, etc.)	YES

Sources: NYK Line (2013a), Van Hook (2012), Wallenius Marine (2013), NORDEN (2013) and Propulsion Dynamics (2013).

Three conclusions can be drawn from this overview:

1. Ship owners who seek to improve the energy efficiency of their fleet have, at least on the newer ships of their fleet, installed flow metres to monitor the fuel consumption. This is in line with the findings in the empirical work of Aldous et al. (2013) who found that the error in noon report data[8] is much higher than in continuous monitoring data. It follows from this work that it is much harder to measure the effect of technical or operational measures using noon report data. It is also in line with several experts who have told us that the installation of flow meters is the first thing you do if you are serious about improving the fuel efficiency of a ship.
2. In order to improve the fuel efficiency of vessels, many other parameters (and these are not only cargo load and distance as proposed in the MRV regulation) have to be monitored next to fuel consumption. This is the case because the energy consumption of a ship depends on several factors: external factors (e.g. weather and sea conditions), the technical efficiency of a ship, the state of maintenance of a ship (e.g. hull resistance due to algae fouling) and the way it is operated (e.g. load and trim conditions). So in order to find out how energy efficiency can be improved on a specific ship you have to be able to correct the fuel consumption for certain factors and be able to monitor the performance of certain parts of the ship (e.g. propeller performance).
3. The raw monitoring data that is gathered by the ship owners needs to be analysed to be able to improve the fuel efficiency of a ship.

Thus, since the MRV regulation would not oblige ship owners to make use of fuel consumption monitoring methods as accurate as flow meters and would

[8] It is common practice on board that certain data like e.g. position, speed, weather- and sea conditions are gathered on a daily basis and recorded in a so-called noon report. In contrast to continuous monitoring, noon data constitute a snap-shot.

also not oblige them to monitor the ship in a comprehensive way, the MRV regulation will very likely have only a very limited effect on CO_2 emissions. Only if the MRV regulation stimulated ship owners, on a voluntary basis, to invest in advanced monitoring systems that go beyond the monitoring requirements specified in the proposed MRV regulation, can CO_2 emission reductions be expected. To get an indication of the CO_2 emission reduction that ship owners then could achieve, we present in the following section the reductions that have been realized by some of the active ship owners.

4.2.2 CO_2 emission reduction of active ship owners

Some of the ship owners actively working on the improvement of the CO_2 emissions of their vessels do publish the emission abatement measures they have taken as well as the CO_2 emissions of their fleet. The emissions are thereby reported in absolute terms as well as in terms of an emission index like for example the EEOI.

In many cases the information published does not allow one to determine the CO_2 emission reduction that has taken place as a result of the adoption of an abatement measure: Absolute emissions are often reported on a fleet level and not compared to a specific baseline and emission indicators, like the EEOI, are business cycle dependent thus not allowing one to determine whether the change of the indicator is actually due to an improvement of the energy efficiency. In Table 6 the CO_2 abatement measures applied by four ship owners are given in the first column. The CO_2 emission reduction associated with these measures are given in the second column. Note that these are only available for two ship owners. In the third column finally the development of the CO_2 index applied by the ship owner is listed.

Table 6 CO_2 abatement measures taken by active ship owners and their effects

	Applied abatement measures	CO_2 reduction associated with measures	Development CO_2 index
NORDEN	– Trim optimization – Optimization hull/propeller cleaning – Increased frequency of overhaul of vessel's turbo chargers, vessel's scavenger air coolers, and fuel oil pumps and injectors – Optimization of calibration of the engine by shaft torque measuring – Improvement of energy efficiency of electric heaters – Use of electric steam generators – Use of advanced hull coating – Use of latest design of slide valves – Scrape down analysis – M/E perform check/service – Speed optimisation by means of right steaming and virtual arrival voyages	Estimation of the CO_2 reduction associated with measures taken: – 2007: 2.4% – 2008: 3.3% – 2009: 4.7% – 2010: 6.2% – 2011: 7.7%	2012 EEOI for (owned vessels) compared to 2007: – Dry cargo: -0.7% – Tankers: +19%
Møller-Maersk	Maersk Line has applied the following measures: – Super slow steaming – Auxiliary waste heat recovery – Antifouling hull coatings – Optimisation hull cleaning and	2012 CO_2 improvement compared to 2010 baseline: -Maersk Line & Tankers: 7%.	2012: 25% reduction of CO_2/ container compared to 2007.

	Applied abatement measures	CO_2 reduction associated with measures	Development CO_2 index
	periodicities – Ballasting for trim – Drag reduction – Automated prime mover tuning – Variable speed of pumps and ventilation system – Adjustment of design of new ships: • use of bigger ships • improvement hull and propeller design • modification of bulbous bow • adaptation of propulsion system for a range of operating conditions	Benchmarking: in 2012 customers of Maersk have saved 6.3% CO_2 compared to choosing a shipping line with industry average performance	
NYK	NYK has: – certified all its operating vessels with ISO 1400.1 – has launched an in-house 'Save Bunker Campaign' – installed different technical measures on some vessels such as • electronically controlled engines, • MT-FAST, a device improving propulsion efficiency • air lubrication system • solar cells	Only absolute CO_2 emissions of total fleet available	The average 2012 EEOI of the entire NYK fleet has improved by 15.78% compared to 2006 and by 6.85% compared to 2010
Wilh. Wilhelmsen ASA	– Slide valves – Ducktails – Waste heat recovery – Improvement of design of new builds, like change of length – Ballast optimization – Use of silicon-based antifouling – Implementation of Environmental Management System – Establishment of Energy Efficiency Working Group – Implementation of PMA on the entire fleet – In-house energy efficiency competitions (winning entries are implemented)	Only absolute CO_2 emissions of total fleet available	Fleet EEOI on lowest level in 2012 since 2005; has improved in 2012 by 0.6% although shipping volumes have increased
Various shipping companies using CASPER (Propulsion Dynamics)	Optimised hull and propeller maintenance Other measures	Across a fleet, 3%-8%, more for individual ships	

Sources: NORDEN (2012, 2011, 2010, 2009), Van Hook (2012), Møller-Maersk Group (2012), NYK Line (2013b), NYK Group (2013), Wallenius (2013) ,Wilh. Wilhelmsen (2012) and Propulsion Dynamics (2013).

From the two ship owners that have determined the CO_2 emission reduction that can be associated with the applied abatement measures we can conclude that due to comprehensive monitoring of the fleet and due to the abatement measures taken, an emission reduction of up to 8% has been achieved.

Propulsion Dynamics (2013) offers a data analysis system that allows ship owners to optimize the frequency and the quality of hull and propeller maintenance. They find that the CO_2 abatement potential differs highly between the ships of a fleet but typically lies in the range of 3-8%.

4.3 Differences between monitoring technologies

As explained above, ships have to be monitored in a comprehensive way in order to be able to detect ship specific abatement potentials. The method with which the fuel consumption is monitored can play a crucial role here as well. On the one hand, the four options for fuel monitoring given in the MRV proposal differ with respect to the accuracy with which the fuel consumption is measured and on the other hand they allow to a different extent to draw conclusions on where on board the fuel is actually consumed: Monitoring fuel consumption by direct emission measurement or by fuel flow meters will result in more accurate fuel consumption data than monitoring fuel consumption by means of tank monitoring or by Bunker Delivery Notes combined with periodic stocktakes; measuring fuel consumption by means of flow fuel meters or by monitoring the tanks will give a better insight into the structure of the fuel consumption on board.

4.4 Conclusions

The proposed MRV regulation in its current form can be expected to have only a very limited effect on CO_2 emissions. It will not reduce the split incentive problem between ship owners and charterers and the monitoring requirements are not far reaching enough to offer ship owners useful new insights: it is not required to work with accurate measures of fuel consumption and only very limited extra parameters have to be monitored. However, for a ship owner to improve the fuel efficiency of his ship, accurate fuel monitoring, monitoring of several other parameters (such as e.g. draft, sea conditions, etc.) and the analysis of the data monitored is necessary. Also the reporting requirements, i.e. the data that has to be reported, are not specific enough. What would e.g. constitute more useful information for a charterer are ship specific speed-fuel consumption curves set up for different conditions and updated on regular basis. We can thus conclude that only if the MRV regulation prompted ship owners, either on a voluntary or on a mandatory basis, to invest in accurate and comprehensive monitoring and data analysis systems, a significant CO_2 emission reduction could be expected from the regulation. This would most likely be a CO_2 emission reduction higher than the 2% expected by the European Commission from the currently proposed regulation.

5 Conclusions

This study has analysed the impacts of the proposed MRV regulation on the shipping industry and on the wider economy and compared the advantages and drawbacks of each of the different methods to monitor fuels. The following impacts of the regulation have been considered:

1. The additional requirements for ship owners/operators induced by the MRV proposal.
2. The additional costs that will have to be incurred by the different stakeholders.
3. The potential environmental benefit in terms of CO_2 reduction.

5.1 New obligations following from the MRV proposal

The study concludes that all of the parameters that have to be monitored according to the MRV proposal are in principle already being monitored on board ships. This is done either as an element in the Ship Energy Efficiency Management Plan (SEEMP), which is obligatory from the beginning of 2013 for all ships over 400 GT, or because it is common practice.

The MRV proposal introduced three new obligations regarding the way in which the data are presented and used:

- ship owners have to make a distinction between routes to and from EEA ports and other routes;
- ship owners have to verify their fuel consumption, emissions and transport work;
- ship owners have to report to public authorities.

The main additional costs are in verifying and reporting. A prerequisite for verification will also be the establishment of a monitoring plan.

5.2 Costs associated with these obligations

The European Commission has estimated that the proposed MRV regulation will lead to additional annual administrative costs for the ship owners/operators of about € 76.4 million in total and € 6,700 per entity. These additional costs comprise the administrative costs for monitoring and reporting as well as the costs for third party verification. We come to the conclusion that the cost estimate for monitoring and reporting is rather low but that the cost estimate for third party monitoring is rather high if compared to the EU ETS MRV costs of aircraft operators. The total MRV cost estimate is comparable to those identified for aircraft operators but lower than the EU ETS MRV costs identified for operators of industrial/power generating installations.

The proposed MRV regulation allows ship owners/operators to choose among four different fuel consumption monitoring methods. Depending on the monitoring method applied, the additional MRV costs of ship owners/ operators will differ. While the more automated, accurate monitoring measures are associated with higher investment costs, the opposite holds for the operational MRV costs: the lowest operational MRV costs are associated with direct (continuous) emissions monitoring, followed by the use of fuel flow meters, tank monitoring, and Bunker Delivery Notes combined with stocktakes.

This can be explained by the degree to which monitoring and reporting can be carried out electronically and by the accuracy and verifiability of the monitoring which has an impact on the verification costs. We estimate that ship owners and operators could lower operational MRV costs by € 5 – € 9 million annually by using automated fuel monitoring or continuous emissions monitoring.

Due to synergies with air pollution regulations, regulators could at the current level of inspections save € 0.4 - € 1.5million if ships made extensive use of continuous emissions monitoring systems. From 2015 onwards, ships in Emission Control Areas will be subject to more stringent sulphur regulations which will increase the costs of compliance (and consequently the benefits of non-compliance). As a result, it is likely that more inspections will need to be carried out to keep the share of non-compliant ships at its current level. Thus, the benefits of continuous emissions monitoring would increase.

If the choice of monitoring methods would be narrowed to the more automated, more accurate methods for all or for some ship types/sizes, the MRV regulation would lead to higher investment costs for some ship owners which would constitute a demand impulse for the marine equipment industry. There is large number of small and medium sized enterprises in the marine equipment industry and it is therefore very difficult to tell which country, in terms of employment, would profit the most from this demand impulse.

5.3 Potential emission reductions resulting from MRV

MRV is in itself unlikely to result in emission reductions or efficiency improvements. Only insofar as it induces operational or technical measures to be taken, can it result in fuel efficiency improvements. The proposed MRV regulation will most likely not do so since it will neither reduce the split incentive between ship owners and charterers, nor provide ship owners with sufficient additional insight into their fuel consumption pattern to take any further action. This is the case because the proposed regulation does not require the accurate measurement of fuel consumption or the reporting of indicators that are specific enough for charterers to use in their evaluation of ships. What would e.g. constitute more useful information for charterers are ship specific speed-fuel consumption curves set up for different conditions and updated on regular basis.

Several shipping companies have, on a voluntary basis, started programmes to improve the efficiency of their fleet over the past years. These companies have not only invested in monitoring of fuel consumption, but also taken various other actions:

- invested in data analysis systems;
- monitored other data;
- taken operational or technical measures to improve fuel efficiency.

In most cases, they have relied on fuel flow monitoring because it yields more accurate results than periodic stock takings.

We therefore conclude that only if the MRV regulation prompted ship owners, either on a voluntary or on a mandatory basis, to invest in accurate and comprehensive monitoring and data analysis systems, a significant CO_2 emission reduction could be expected from the regulation. This would most likely be a CO_2 emission reduction higher than the 2% expected by the European Commission from the currently proposed regulation.

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