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Economic and operational impact of the MRV implementation on maritime transport processes

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Abstract

The European Union (EU) and International Maritime Organisation (IMO) strongly feel the need for initiating measures to reduce greenhouse gas (GHG) emissions from international shipping lines regionally and globally using a package of tools called Green Shipping Practices (GSP). The GSP includes the use of global market-based mechanisms (MBMs), adoption of the energy efficiency design index (EEDI), establishing compulsory energy efficiency standards for all new ships, and the ship energy efficiency management plan (SEEMP) recommended as a new management tool for ship owners. Furthermore, the European Commission (EC) has proposed that owners of large ships using EU ports should report their verified emissions (Monitoring, Reporting and Verification of Carbon dioxide (CO_2) emissions (MRV)) from 2018. In addition, IMO has introduced collection and reporting of ship fuel consumption data (SFCD) under the IMO SFCD scheme based on similar conditions, but related to global shipping. By providing a holistic analysis of the above-mentioned tools with a special focus on MRV and SFCD, this paper presents their economical and operational implications on the maritime transport processes. The working hypothesis that there is a correlation between the introduction of MRV and SFCD tools and reduction of maritime transport anthropopresure has been proved.

Keywords: maritime transport, green shipping, verification of GHG emission

1. Introduction: shipping emissions

Public concerns over environmentally friendly operations and resource conservation in the shipping sector have been on the rise. Given the global importance of seaborne trade, this study considers shipping only within the cargo movement by ships with intermodal connections and specifically investigates green shipping practices (GSP) in sea transportation. Special attention is focused on monitoring, reporting and verification of carbon dioxide (CO_2) emissions (MRV) and reporting of ship fuel consumption data (IMO SFCD scheme; Lai, Lun, Wong, Cheng, 2013) as tools effective from 2018. Although shipping facilitates global trade (e.g. 90% of the intercontinental transportation), it generates a great amount of environmental pollution (e.g., CO_2 emission, oil spill and other anthropopresure effects). While most shipping research studies focus on shipping productivity (Vanroye, van Mol, 2009; Zatouroff, Luke, 2013; Pac B., Miler, 2015), environmental management and its impact on shipping operations and processes remain still largely unexplored in the literature. Due to heightened environmental awareness in business (e.g., introduction of corporate social responsibility (CSR), internalisation of maritime transport costs as represented by total social cost/total social benefit analysis, or external electricity costs scheme

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(ExternE)),[2] the shipping industry is also expected to focus on environmental awareness (Lun, Lai, Wong, 2011) to the extent that shipping operations and processes become more environmentally friendly in serving and facilitating world trade. In response, IMO and European Union (EU) are deeply motivated to introduce GSP so that shipping companies and transport operators pursue measures to mitigate environmental damages caused by their activities (Lai, Lun, Wong, Cheng, 2011). This study defines GSP broadly as the package of tools that includes the energy efficiency design index (EEDI), introducing compulsory energy efficiency standards for all newly built ships, and the global market-based measures (MBMs) as well as MRV as an efficient tool for monitoring, reporting and verification of carbon dioxide (CO_2) emissions (Brzozowska, Miler, 2017) in addition to generating SFCD.

During the last decade, it was widely recognised that shipping GHG emissions have a direct impact on human health and living conditions, which is proving to be challenging for environmental policy-makers. Additionally, emissions from vessels and shipping sector contribute to local and regional acidification and eutrophication (part of anthropopresure activities) and also influence the so-called radiative forcing (RF) of climate (Corbett, Winebrake, Green, Kasibhatla, Eyring, Lauer, 2007). The overall impact of shipping emissions on climate change (as a process) according to Corbett and Köhler (2003) is shown in Fig. 1.

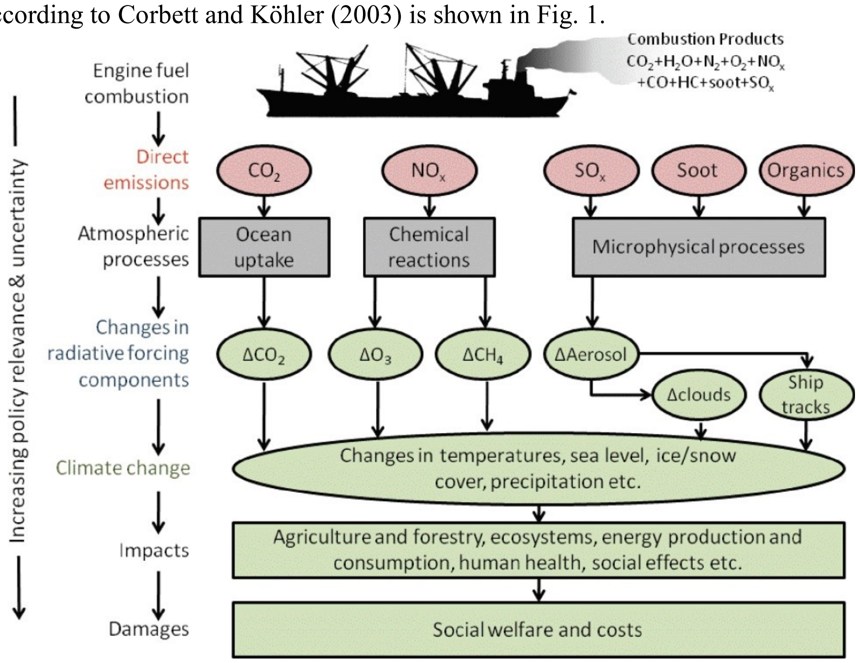

Figure 1. Schematic diagram of the overall impacts of emissions from the shipping sector on climate change (Second IMO GHG Study, 2009)

Although international shipping is said to be the most energy-efficient mode of mass transportation and only moderately contributing to the overall GHG (mainly CO_2 emissions), a global approach in further improvement of its energy efficiency and effective emission control is needed. Especially sea transportation facilitating seaborne trade (90% of worldwide intercontinental trade is facilitated by maritime transportation) will continue to grow (Brzozowska, Miler, 2017). To reduce GHG emissions in sea transport, there is a need for implementation of the CO_2 emission monitoring system as a first step for CO_2 emission management.

2. The need for monitoring carbon dioxide emissions

Carbon dioxide is the most important GHG emitted by shipping industry in both in terms of total amount (quantity) and potential impact on global warming processes. Emissions of CO_2 from shipping in comparison with total (global) emissions are depicted in Fig. 2.

[2]Damages caused to the environment resulting from air pollution lead to economic losses, which are not included in energy production cost and is termed external cost (so-called ExternE (external electricity costs)). The composition of external expenses consists of a variety of types of health costs, the costs of environmental damage, loss due to greenhouse gas emissions and the cost of possible failure. Health insurance and the so-called greenhouse effect health impacts 98% of the external costs from SO_2 and 100% of those from particulates.

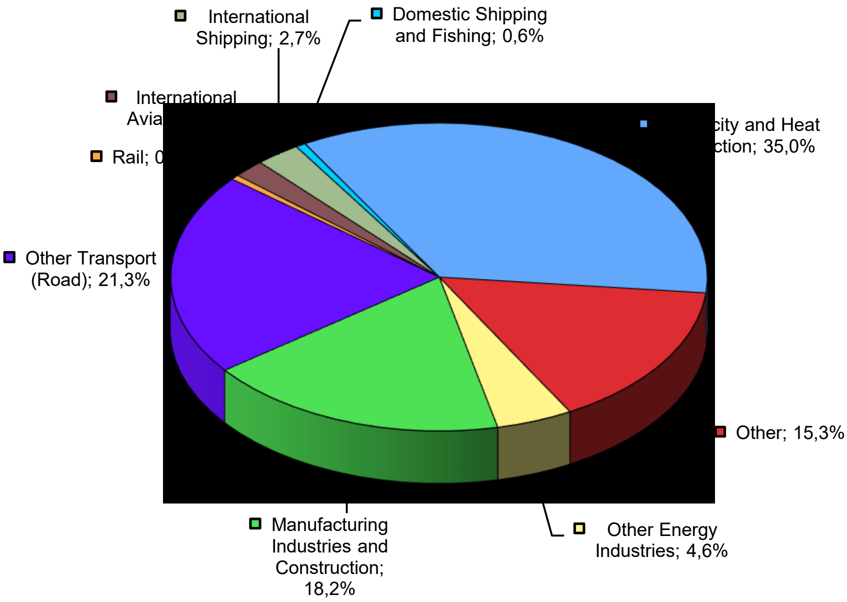

Figure 2. CO_2 emissions from shipping in comparison with global total emissions (Second IMO GHG Study, 2009) also (Buhaug, Ø. et al., 2012)

The level of CO_2 emissions is related to shapes of the vessels, dimensions of the hull, efficiency of the engine and the overall (including navigation, weather conditions, load, etc.) performance of the ships. The potential emission of CO_2 from various types of ships is depicted in Fig. 3.

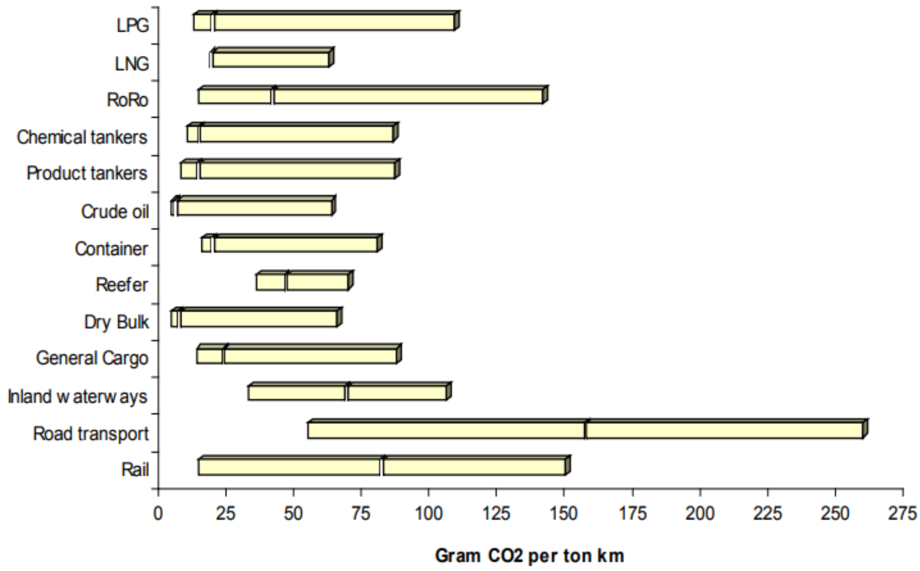

Figure 3. Emission competitive against vessels 10–15 000 dwt (gram of CO_2 per tonkm range per vessel type) (Jurdziński, 2012)

The entire GHG emissions from shipping industry is estimated to be 1 billion tonnes a year, which accounts for approximately 3% of the world's total emissions and 4% of the EU's emissions. Left untouched, these emissions are expected to be doubled by 2050. This remains in contradiction with internationally agreed decision of keeping global warming below +2°C, which requires a focus on lowering emissions worldwide (50% from the 1990 levels by 2050). Fig. 4 shows above mentioned estimations.

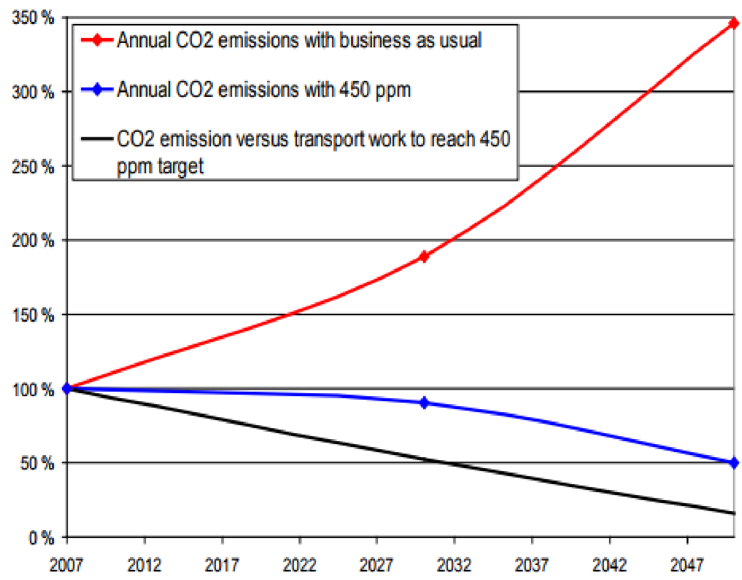

Figure 4. International shipping CO_2 emission scenarios until 2050 (www.imo.org, 2018))

The results of these analyses stress the need for reducing negative estimates. Increases in carbon dioxide emissions derive not only from the growing number of operated vessels, but also which technology is deployed by the vessels. It is true that changes in the last decade steadily increased the fuel supply cost of ships. So, there is a need for reduction in emission, but it is possible only through implementation of monitoring and verification of the CO_2 emission (including its radiative forcing (RF) impact).

The RF of CO_2 is dependent upon its own concentration because of spectral saturation, such that, in calculating the impacts of CO_2 from shipping, it is necessary to know the "background" RF (equation 1):

$$\Delta RF_{\text{Shipping}} = \Delta RF(C_{\text{Background}}) - \Delta RF(C_{\text{Background}} - C_{\text{Shipping}}) \tag{1}$$

The contribution of CO_2 emissions from shipping to ambient concentrations of CO_2 is assumed to be the difference between that from total "background" emissions and the calculated contribution from shipping as follows. The response of CO_2 concentrations, $C(t)$, to the rate of emission of CO_2, $E(t)$, was also modeled (Meier-Reimer, Hasselmann, 1987; Endresen, Bakke, Sørgård, Berglen, Holmvang, 2005) and approximated to the results from the carbon-cycle model (Hasselmann, Hasselmann, Giering, Ocana, von Storch, 2007), so that

$$\Delta C(t) = \int_{t_0}^{t} Gc(t - t')E(t')\,dt' \tag{2}$$

and:

$$G_C(t) = \sum_{j=0}^{5} \alpha_j e^{-t/\tau_j} \tag{3}$$

where τ_j is the *e*-folding time of mode *j* and the equilibrium response of mode *j* to a unit forcing is $\alpha_j \tau_j$, using separately calculated mode parameters.

The data necessary for the calculation of emissions from ships while in transit and in ports may come from many different sources (Brzozowska, Miler, 2017) also (Miler, Szczepaniak, 2014) such as the following:

- The data from the port authority and pilot station-data used in the calculation of the time of the individual ship
- The data from automatic identification system (AIS) used for automatic exchange of data useful to avoid possible collisions between vessels and identifying the ship for different edge systems, which monitor the movement of ships (VTS)
- The data from ships register with a detailed description of the vessel, to demonstrate the power of ships main engine and auxiliary engines

- Daily ship reports should be considered the most reliable source of information, particularly on main engines and auxiliary engines fuel consumption and loading condition.

All these vital prerequisites of environmentally friendly shipping demand integration and global acceptance, and therefore the EU and IMO have introduced unified regulations on shipping.

3. EU (MRV) and IMO (SFCD) regulations on the monitoring of CO_2 emissions

Maritime safety policy is considered to play a vital role in protection of European marine environment. Thus legislation, preventive measures and tools for control have been designed and implemented after severe ecosystem disasters (single-hull tankers *Erika* and *Prestige* in 1999 and 2002) (www.imo.org, 2018).

European Commission (EC) brought in extraordinary measures to reduce the number of the old tankers that were in operation to transport crude oil and has forced ship owners to escalate the scraping process of single-hull oil tankers. A strict enforcement of the existing legislation has been introduced by increasing the number of port state inspections inside territorial waters of the EU and the partial harmonisation to criminal sanctions for pollution of the environment or by establishing the European Maritime Safety Agency (EMSA). There are only examples of the vast efforts that have been made to improve safety on the high seas within the EU (Green Paper, 'Towards a Future EU Maritime Policy', 2006). Consequently, a number of policies, options and tools to reduce GHG emissions from shipping sector have been conceived, including technical tools for which investments are needed. But they are challenged by the shipping sector for economic reasons.[3] Among options we can identify the following that are most effective (already introduced or planned to be introduced in the nearest future). These options introduce tools, which can be divided into three categories (Brzozowska, Miler, 2017):

- Technical tools such as
  - Mandatory limit on the energy efficiency design index (EEDI) for new ships
  - Mandatory (discussed voluntary) reporting of the EEDI for all new ships
- Operational tools focused on
  - Mandatory (discussed voluntary) reporting of the energy efficiency operational indicator (EEOI)
  - Mandatory (discussed voluntary) use of a ship efficiency management plan (SEMP)
  - Mandatory limit on the EEOI value, combined with a penalty for noncompliance
- Market-based mechanisms (MBM) include
  - Maritime Emissions Trading Scheme (METS)
  - International GHG Compensation Fund (ICF), to be financed by the levy on marine bunkers.

The EEDI, the most important and promising among the abovementioned technical tools, is designed to express the emission of GHG (CO_2) from any type of ship under specific conditions (e.g. sea state: wind, waves; engine load, draught etc.) The EEDI unit is calculated in grams of CO_2 per capacity-mile.[4] When considering the EEDI formula, it is easy to observe that all aspects of modern shipping have been predicted and implemented (e.g. energy recovery, use of low-carbon fuels (LNG), performance in waves or on ice fields causing certain haul strengthening etc.) Finally, it is clearly stated that "[…] the handling of certain design features, such as electric propulsion, is still subject to evaluation. The EEDI has a constant value that will only be changed if the design is altered" (Second IMO GHG Study, 2009).

Similarly, for the EEOI, the fundamental principles are the same as agreed for EEDI. However, in this case, emissions index indicates the ratio between the cost (also calculated in the total social cost scheme including internalization of maritime transport costs) and benefits generated by the new settings (also calculated in total social benefit scheme). The EEOI expresses actual CO_2 efficiency in terms of emissions of CO_2 per unit of transport work, using the following formula (MEPC/Circ.471, 2009):

$$\mathrm{EEOI} = \frac{\sum_i \mathrm{FC}_i \times \mathrm{C}_{\mathrm{carbon}}}{\sum_i \mathrm{m}_{\mathrm{cargo},i} \times \mathrm{D}_i} \tag{4}$$

[3] The lack of investment in new technologies (usually costly) is widely observed. This obviously contributes to raising the level of CO_2 emissions from marine vessels. The cost of retrofitting ships and equipping them with the technologies that will allow reducing carbon dioxide emissions are often too expensive for ship owners. Therefore, they are not interested in their implementation. This also may explain the resistance on the part of numerous companies and associations of carriers in maritime transport who do not want marine transportation to be covered by a strict regulation for carbon dioxide emission control.

[4] "Capacity" is an expression of the cargo-carrying capacity relevant to the cargo that the ship is designed to carry. For most ships, capacity will be expressed as deadweight tonnage (DWT).

where
FC_i indicates fuel consumption on voyage i,
C_{carbon} denotes the total amount of carbon content in the fuel used on voyage i,
$m_{cargo,i}$ is the mass of cargo transported on voyage i,
D_i is the distance of voyage i.

As fuel efficiency has become an important factor for the promotion of energy-efficient fleet management, a ship efficiency management plan (SEMP) has been introduced. The shipping industry (mostly ship operators, charterers, and fleet owners) is highly interested in the development of technical tools that can improve vessels' fuel and energy efficiency in a cost-effective manner. In the conceptual stage, the SEMP presents a framework for vessel's energy-saving operations by monitoring and maintaining performance and considering options for improvement in a very complex and structured way (Second IMO GHG Study, 2009).

The SEMP should not be considered in isolation, as there is a clear possibility of using it alongside EEOI for monitoring performance and evaluation. This mechanism provides an opportunity to monitor not only a single ship but also the efficiency of the entire fleet in terms of performance and establishes some options for optimization and improvement based on EEOI (Miler, Szczepaniak, 2014).

The new package of measures, implemented from 2013, represents the adoption of technical and operational measures for new ships, thus becoming the first ever mandatory global GHG reduction regulation regime for the international shipping industry.[5]

However, only the technical and operational measures alone will not be sufficient to reduce GHG emissions in a satisfactory way, especially if the future growth of maritime transportation based on demand is considered. Therefore, market-based mechanisms (MBMs) also act as a complementary tool and should serve two main purposes (Baltic Maritime Outlook, 2006):

- Providing a fiscal (economical) incentive to the marine industry (with a focus on shipping) to invest for increasing the efficiency of the operations
- Offsetting of growing ship emissions.

In addition, in June 2013, the European Commission (EC) put forward a legislative proposal to establish a system of monitoring, reporting and verification of CO_2 emissions from large ships (MRV) operating within EU seas and those entering EU ports. For the first time, a tool, in particular MRV, has been designed to build a global shipping emissions monitoring system and, if widely accepted, would create an EU-wide legal framework for collecting, verification and publication of CO_2 emission data on an annual basis "[…] from all ships over 5 000 gross tons that use EU ports, irrespective of where the ships are registered" (www.imo.org, 2018). The EC proposed that the MRV system would apply to shipping activities carried out from January 1, 2018. Therefore, the new data regulation is in force.

3.1. New MRV Rules

Due to the absence of an international agreement within the IMO regarding restrictions on CO_2 emissions from international maritime transportation at the beginning of the legislation process, the EC included shipping to community obligations for GHG reduction. The strategy plan was the first step in a three-step approach defined as Monitoring, Reporting and Verification of CO_2 emissions from shipping (MRV). The second phase includes specifying reduction target for GHG emissions from ships (450 ppm) and finally, in the third phase, the introduction of market-based instruments in environmental policy is planned.[6] The timeline with the sequence of steps necessary to introduce the entire MRV regulations is depicted in Fig. 5 (Reg. EU sig/757, 2015).

[5] The adopted measures add to MARPOL Annex VI a new Chapter 4 entitled "Regulations on energy efficiency for ships," making mandatory the Energy Efficiency Design Index (EEDI) for new ships and the Ship Energy Efficiency Plan (SEEMP) for all ships. The regulations apply to all ships over 400 gross tonnage and above and entered into force through the tacit acceptance procedure on 1 January 2013.

[6] The implementation of the first of these activities is a regulation of the European Parliament Council (EU) 2015 sig/757 of 29 April 2015 year in terms of Monitoring, Reporting and Verification of carbon dioxide CO_2 emissions from maritime transport and amending the provisions of Directive 2009/16/EC sig (MRV) – *Official Journal of the European Union* L 123/57.

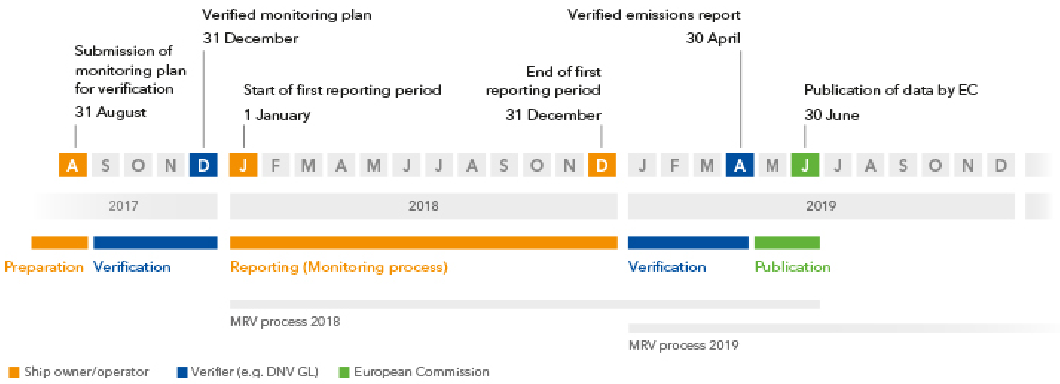

Figure 5. The MRV TimeLine

This regulation introduces shipowner's obligation of continuous monitoring of CO_2 in each cruise ship from 1 August 2018. Based on the monitoring plan, shipping companies should monitor CO_2 emissions for each ship on a pre-voyage and an annual basis by applying the appropriate methods. By 30 April of each year, companies shall submit to the EC and to the authorities of the Flag States concerned a report on CO_2 emissions and other relevant information for the entire reporting period for each ship in their fleet for verification by the contracted verifier[7] who shall assess the conformity with requirements.[8] An annual report based on the approved monitoring plan assessed by the verifier should include but is not limited to following information (Reg. EU 757, 2015)[9]:

- Amount and emission factor for each type of fuel consumed in total
- Total aggregated CO_2 emitted in comparison with:
  - 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 that occurred within ports under a Member State's jurisdiction at berth
- Total distance travelled
- Total time spent at sea
- Total transport work (in tonne-mile)
- Average energy efficiency.

3.2. IMO collection and reporting of ship fuel consumption data (IMO SFCD)

IMO has also adopted a three-stage approach to consider further measures to improve ships' energy efficiency. The first step is data collection, followed by data analysis in the second step. The third step is the final decision-making on further measures to be taken by IMO to implement appropriate amendment to the MARPOL convention. The new IMO regulations was adopted during 70th session of MEPC in October 2016 as an amendment to MARPOL Annex VI. A new Regulation (22A) has been added to the collection and reporting of ship fuel consumption data (SFCD).[10]

Similar to the MRV, the SFCD collection system is compulsory for all ships of 5,000 gross tonnage and above; ships are required to submit consumption data for each fuel type used on board, with all additional, specified data including proxies for transport work. The methodology shall be included in the approved flag administration SEEMP plan.

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[7] Verifiers should be independent and competent legal entities and should be accredited by national accreditation bodies established under Regulation (EC) No 765/2008 of the European Parliament and the Council, see more at http://www.imo.org/MediaCentre/HotTopics/GHG/Pages/default.aspx.

[8] Requirements are laid down in Articles 8 to 12 and Annexes I and II from the regulation EU 2015/757 of the European Parliament and the Council. Once the assessment concludes that the emissions report is free from material misstatements, the verifier shall issue a verification report stating that the emissions report has been verified as satisfactory. The verifier shall issue, on the basis of the verification report, a document of compliance for the ship concerned valid for 18 months after the end of the reporting period.

[9] This Regulation does not apply to warships, naval auxiliaries, fish-catching or fish-processing ships, wooden ships of a primitive build, ships not propelled by mechanical means, or government ships used for non-commercial purposes.

[10] The data collection system is enshrined in the amendments to the International Convention for the Prevention of Pollution from Ships (MARPOL) Fuel oil Consumption Database' (Appendix IX), Fuel Oil Consumption Reporting' (Appendix X). These amendments entered into force on 1 March 2018 and the first reporting period will be in the calendar year 2019.

The aggregated data should be reported by ships' operator to the Flag State Administration (FSA) after the end of each calendar year. The Flag State thereafter would submit the collected data to the IMO data centre and, as per the requirements, will issue a Statement of Compliance to the ship. Then, based on summarised and anonymised data , the IMO will produce an annual report to the MEPC (MEPC.292/71, 2017). A summation of the differences between both the adopted systems (MRV implemented by EU Commision and IMO ship fuel oil consumption data collection (SFCD)) is presented in Table 1 (MEPC.292/71, 2017).

Table 1. Differences between MRV implemented by EU Commision and IMO ship fuel oil consumption data collection (SFCD)

Description of the main features	EU MRV	IMO SFCD
Compulsory	Ships 5000 GT > Voyages to/from EU port of calls EU Monitoring Plan Starting 1st January 2018	Ships 5000 GT > All voyages Updated SEEMP Starting 1st January 2019
First monitoring period	2018	2019
Exemptions	Warships, naval auxiliaries, fish-catching/processing ships, ships not propelled by mechanical means and government ships used for non-commercial purposes	Not defined yet
Parameters to report	Fuel consumption and CO_2 Total cargo on-board Distance travelled Time at sea and in port	Fuel consumption and CO_2 Ships deadweight Distance travelled over ground (O/G) Time spent underway
Verification	Independent approved Verifier	Flag adminstration
Reporting to	European Commision	Flag State Admisntration
Ceritification	Document of Compliance CoC Issued by Verfier valid for 18 month	Statement of Compliance issued by Flag state valid for 12 month
Publication	Public database	Anonymous public database

4. Implications of the GSP (MRV/ SFCD) tools on maritime transportation

Fuel consumption as a significant element of operating costs represents area of special attention for all ship operators and ship owners. In recent years, through technical and design-based improvements, shipping has achieved noteworthy reduction in fuel consumption, resulting in lower CO_2 emissions on a capacity basis (tonne-mile) (Miler, Szczepaniak, 2014). Additional reductions could be realized through operational measures such as lower speed and voyage optimization (www.euractiv.com, 2018). Fig. 6 (Baltic Maritime Outlook, 2006) indicates all possible factors that have a potential influence on maritime CO_2 emissions.

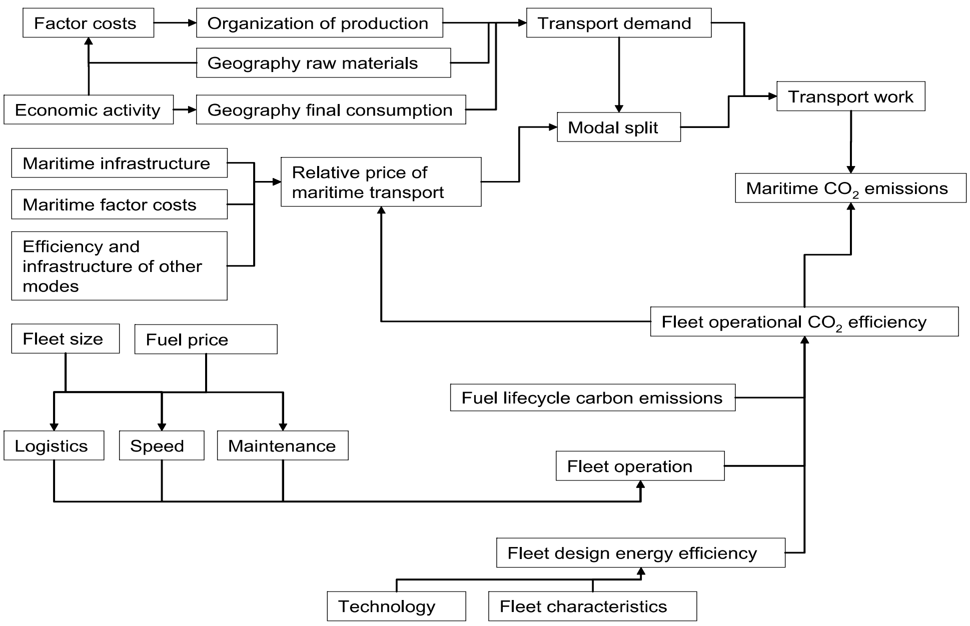

Figure 6. Factors determining maritime emissions of CO_2

After only a few years of being in force, the first iteration of the EEDI has been developed. However, the evaluation covered only the largest and the most energy-intensive segments of world's merchant fleet (covering approximately 70% of total emission from new ships) including tankers, gas and bulk carriers, general and refrigerated cargo ships as well as container ships. The EEDI has been confirmed as a promising and efficient tool (Miler, Szczepaniak, 2014).

Keeping fuel costs, which usually makes up 50% of the operational costs, in check is a major factor in shipping industry economics. The SEEMP offers to ship operators of all existing ships the opportunity to reduce operating cost immediately by cutting the fuel costs (by saving fuel). As the regulation "[…] does not set any energy efficiency requirements it will be up to the industry to proactively utilize SEEMP to ensure they optimize the fuel saving benefits. Such an approach will be important to achieving both sustainable development and economic goals for the industry going forward" (Baltic Maritime Outlook, 2006) and (Miler, Szczepaniak, 2014).

Certainly, the "economy of scale" in vessels' fuel efficiency indicates that the larger the ship (at a given speed), the lower is the fuel consumption (calculated per unit of cargo: tonne, TEU). However, such tendency is limited by the trade considerations (terms of trade), limitations in port facilities (e.g. depth, cranes efficiency) and cargo logistics issues (warehousing conditions such as temperature and humidity). Therefore, ships tend to be designed to be as large as practical for a given trade and a given service (http://ec.europa.eu/clima/policies/transport/shipping/docs/com_2013).

The effective implementation of the SEEMP by any merchant vessel ensures reduction in fuel consumption. In order to enable optimisation of the ship's energy efficient performance, the implemented measures (SEEMP) should assure robust monitoring and appropriate benchmarking for all efficiency indicators (sensors) employed either at sea or in the port.[11] A proper use of all available measures and tools should benefit the shipping sector directly by cost improvements and indirectly by reduction of GHG emissions (Miler, Szczepaniak, 2014).

What is of the highest importance, according to the UE Commission's assessment, is that MRV, after introduction in January 2018, is expected to help in cutting shipping-related CO_2 emissions by up to 2% in comparison with "standard" business shipping activities. The MRV would also be responsible for reduction in the net costs to ship owners potentially by up to €1.2 billion per year by 2030 (IMO MEPC 61/Inf.2, 2010). "In addition, it will provide useful insights into the performance of individual ships, their associated operational costs and potential resale value, which should benefit ship owners, who will be better equipped to take decisions on major investments and to obtain the corresponding finance" (www.euractiv.com, 2012).

For the development of future energy efficiency scenarios, some assumptions have been evaluated. In Table 2, the presented figures correspond to the most optimistic scenario with the highest possible improvement in energy consumption, in which net improvements, excluding the use of low-carbon fuels (e.g. LNG), depending on the ship type and size, range from 58% to 75% in 2050.[12]

Table 2. Assessment of potential reduction of CO_2 emissions from shipping by using known technology and practices

DESIGN (New ships)	**Saving (%) of CO_2 / tonne-mile**	**Combined design and operation**
Concept, speed and capability	2–50†	
Hull and superstructure	2–20	
Power and propulsion systems	5–15	10–15%†
Low-carbon fuels	5–15*	
Renewable energy	1–10	
Exhaust gas CO_2 reduction	0	25–75%†
OPERATION (All ships)		
Fleet management, logistics and incentives	5 50†	
Voyage optimization	1–10	10–50%†
Energy management	1–10	

* CO_2 equivalent based on the use of LNG

† Reductions at this level would require reductions of speed

Despite all the efforts already introduced, GSP tools can also have a direct impact on shipping transportation behaviours, for example changes in transport patterns, fleet modernisation by scrapping old ships, changes in structure of cargo flows in transhipment markets, lowering competition level for seas announced as a particularly

[11] However this is more complicated as energy efficiency of different ships can be affected by many variables factors during voyage, not least, the weather and sea conditions they each experience – the Authors' note.

[12] Entire calculation is based on Reduction of GHG Emissions From Ships – Full Report of the Work Undertaken by the Expert Group on Feasibility Study and Impact Assessment of Possible Market-Based Measures, IMO MEPC 61/Inf. 2 2010 and Second IMO GHG Study 2009 – the Authors' note.

sensitive sea area (PSSA) and sulphur emission control area (S-ECA) with further economic consequences (Brzozowska, Miler, 2017).

5. Summary

When selecting a particular ship to be deployed on a particular trade route, ship operators take into account the cost, time, and capacity. Their objective is to find the optimal mix of the key economic drivers such as the least costly route, the shortest distance and the maximum amount of goods that can be transported at any given time.[13]

Fuel consumption represents a significant element of the cost of operating a ship today. In recent years, shipping sector could achieve noteworthy reductions in fuel consumption through technical- and design-based measures, resulting in a significant drop in CO_2 emissions on a capacity basis (tonne-mile).

Although international shipping is said to be the most energy efficient mode of mass transport and only a modest contributor to overall CO_2 emissions, a global approach to further improve its energy efficiency and effective emission control is needed.

A prominent way for further reduction of GHG through technical and operational measures has been identified (GSP tools). This paper finds that GSP (including MRV and SFCD) tools are cost-effective policy instruments with a high environmental effectiveness. These instruments capture the largest amount of emissions under their scope, allow both technical and operational measures in the shipping sector to be used and can offset emissions in other sectors.

The future for the shipping industry will undoubtedly involve implementation of GSP tools to operating and business practices, particularly in the management of the volume and shape of capacity and the requirement for more sophisticated planning and decision making (involving emission control). Such changes are unlikely to be achieved in the short to medium term, as the earnings performance for most operators is dire and is likely to continue for many years ahead until the current position of oversupply is rectified. The investment or exit (modal split and changing shipping pattern) (Zatouroff, Luke, 2013) strategies for maritime transport operators are limited in these circumstances.

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[13] The type of good being transported also matters. Raw commodities, which operate with very thin margins, generally go the least costly route; high-value, time-sensitive or perishable goods will take the shortest route – the Authors' note.

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