EEDI, Other Regulations to Come, and Their Implications for Ship Design

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ABSTRACT

This paper provides for review on how the international framework to control GHG emission has developed, and explains the principles behind the regulations adopted by the IMO. It argues that more importance will be attached to ship's performance at actual sea condition, and transparency on the fuel consumption during voyages will necessitates continued efforts by ship designers to pursue the energy efficiency.

KEY WORDS

GHG; EEDI; energy efficiency; IMO, MRV

INTRODUCTION

CO_2 emission from international maritime transport amounts to similar level as the total emission from Germany, and it is expected to increase by three times in the period of 2008 to 2050 (IMO, 2009), as the maritime transport volume continues to grow in proportion to world economic growth. The IMO (International Maritime Organization), legislative body in the field of safety and environment protection at sea, vitalized its activities in 2008 to curb the CO_2 emission from ships. After long and rigorous negotiations, IMO successfully adopted a set of new regulations, in the form of the amendments to the legally bounding instrument called Annex VI to MARPOL Convention[1], to require a ship that its EEDI (Energy Efficiency Design Index) be calculated, be verified by the third-party, and be less than the pre-set threshold value.

EEDI regulation can be said as great achievement to tackle the climate change in maritime transport, mainly in two aspects. Firstly, it broke the spell of CBDR (Common but Differentiated Responsibility) principle, which differentiate the countries according to binary classification of "developed" and "developing", which is ingrained in the overall framework of controlling the climate change but has hindered an agreement on a regulatory framework to cover all sectors. EEDI regulation, instead of CBDR, abided by the principle of uniform and flag-neutral application to any ocean-going ships, which strengthen the effectiveness of the regulation; such approach is the one that no other sector has ever achieved in the field of CO_2 emission control. Secondly, EEDI regulation has been developed by carefully taking into account the technical expertise of shipping and shipbuilding communities, unlike some of environmental regulations which were pushed and developed mainly with emotional enthusiasm, lacking thorough consideration of costs and benefits.

Now the new regulation has been implemented, and affects a vast number of players in maritime field, beyond those players who were directly involved in the process of developing the regulation. For vast majority of industrial players, it is difficult to see through what thoughts were behind the international negotiation process; this caused confusion in interpreting the regulation, induced proposals which may unnecessarily cause the instability of the regulatory system, and may bring burden to ship designers by frequent modification of rules.

It is important for industrial players (ship designers, shipyards, ship equipment manufacturers, ship owners, ship operators) , to understand in what principle the regulations have been developed, what rationale was used in detailed design of regulatory system, what kind of future regulations are being developed, so that they could properly consider future business strategy including the direction of ship design innovation.

This paper intends to serve the reference for those industrial players by using the form of "FAQ" which has been often heard at the discussion at the IMO and other industrial forum, in order to give insights on what will come next, and what maritime players should do proactively.

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[1] Ministry of Land, Infrastructure, Transport and Tourism (MLIT), Japan

[1] International Convention for the Prevention of Pollution from Ships, 1973, as Modified by the Protocol of 1978

WHY WE ARE DOING ALL THESE EXERCISES ON GHG

Is the international shipping "evil" in terms of climate change?

Almost all of Green House Gases (GHG) emission from ships is CO_2 emission generated from bunker oil. Therefore, in shipping, GHG can be regarded as CO_2, and combating the global warming is equal to reducing the energy consumed by the operation of ships.

International Maritime Organisation (IMO) is a specialized United Nations body in charge of developing and implementing international regulations in the field of maritime safety and marine environment protection. According to its study, the CO_2 emission from international shipping is 8.7 Mt in year 2007, accounting for about 2.7% of the total emission in the world. The seaborne transport volume has been increasing in rapid pace of about 4% annual growth, which is quite fast growth compared with other industry sectors in developed economies. This means that, although the international shipping is currently in the minor league of emission sources, it would become a major emission source in the near future.

Why is IMO, not UNFCCC, tackling the GHG issue?

The most comprehensive and basic international framework to address GHG emission is the United Nations Framework Convention on Climate Change (UNFCCC), signed at the Earth Summit in Rio de Janeiro in 1992 and having 195 Parties (Member States). UNFCCC itself, being a "framework" convention as its name stands for, does not include mandatory emission reduction targets which its Parties have to comply with. Like many other Conventions, UNFCCC is based on the concept of country-based obligations as the Convention is written in a way that "a country shall do this". One of the important characteristics of the UNFCCC is that it differentiates the rights and responsibilities of Parties based on whether they are developed countries ("Annex I countries" as Annex I of UNFCCC lists those developed countries) or developing countries ("non-Annex I countries). This principle is called "CBDR": Common but Differentiated Responsibilities. This means, under the umbrella of UNFCCC, more burdens shall be borne by the developed countries.

Kyoto Protocol was developed to supplement UNFCCC, and adopted in 1997 in Kyoto. Kyoto Protocol has set the binding numerical obligations of GHG emission reduction on Annex I countries; following the CBDR principle, such numerical targets are not applicable to Non-Annex I countries. International shipping, as well as aviation sector, was excluded in such GHG emission reduction obligation of the Parties under the Kyoto Protocol. Since then, IMO and International Civil Aviation Organisation (ICAO) have been tackling the CO_2 emissions from international shipping and aviation sector, respectively. The main reason of excluding the CO_2 emission from international shipping and aviation from Kyoto Protocol is that the emissions from a ship or an air craft cannot be attributed to a particular country.

Where do we stand in the entire picture? Are we in a stable regulatory regime?

The left-hand side of Figure 1 provided for an illustrative framework of three-step policy development and transfiguration (Akiyoshi, 2007) and the right-hand side of Figure 1 summarizes the corresponding GHG policy development at the IMO.

Kyoto Protocol delegated the related regulatory work to the IMO back in 1997 when it was adopted. IMO had not produced any tangible results since 1997 until 2007, except preliminary and purely technical discussion on the calculation formula for an index of efficiency of ships, assuming that such index is applied on voluntary basis. Naturally, this non-action was not regarded favorably by other policy forum such as UNFCCC. The agreement on "Bali Action Plan" by the COP13 (13th Conference of the Parties) of the UNFCCC at the end of 2007 brought a big change which showed the Parties' political willingness to agree on post-Kyoto Protocol framework to regulate the time after the Kyoto Protocol's commitment period of 2008–2012. The Bali Action Plan cleared the visibility for the post-Kyoto Protocol era, and increased the magnitude of political pressure in any fields of climate change, and IMO was no exception.

IMO had accelerated its discussion speed, and basic structure of regulatory framework started to emerge from early 2008. While some "outsiders" criticized IMO for its "slow" progress, from IMO insiders' view, the progress from 2008 to 2011 was conspicuous in light of almost non-action period of the preceding 10 years.

In the period when IMO was making progress in refining the policy ideas on energy efficiency indices and coming up with the ideas of Market-Based Measures (MBM), the negotiation to fix the post-Kyoto Protocol framework was at the edge of collapsing, as COP15 of UNFCCC at Copenhagen in December 2009 failed to agree on such legally binding framework. There had been no break-through since then. With the lack of progress and clear vision, political pressures have changed the momentum towards an easy-way-out, namely, securing the fund and revenue for climate change purposes. In parallel, the UNFCCC has been considering how to mobilize USD100 billion per year for climate finance purposes to developing countries from a wide variety of potential sources. There was no conclusion for the financial sources, but several reports considered that, inter-alia, aviation and maritime transport could be candidate sources. These reports suggest that international aviation and maritime transport could contribute at the largest USD40 billion (40%) to this financial purpose.

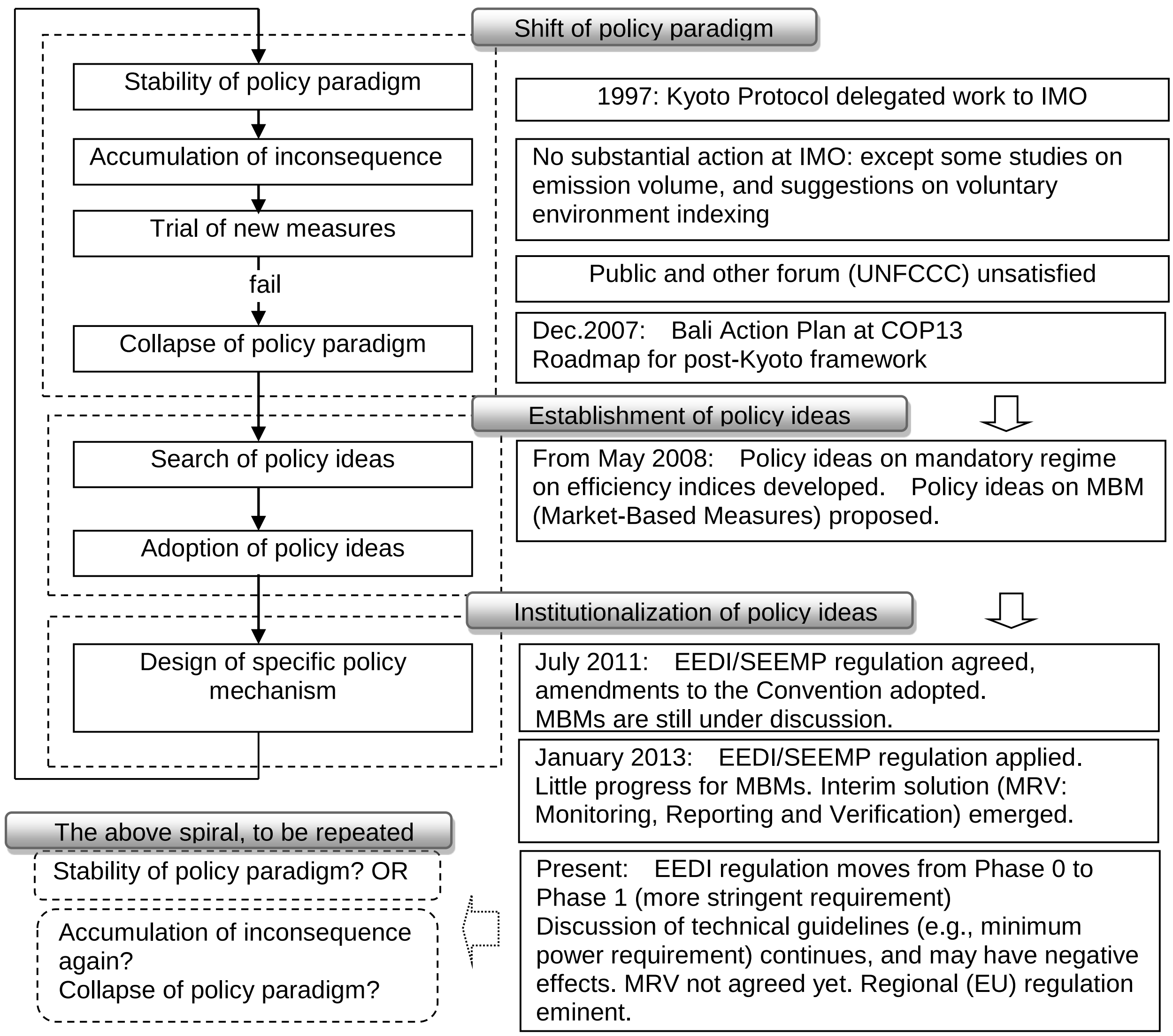

Figure 1: Policy development diagram and corresponding development in the IMO

The IMO was successful in institutionalize the policy ideas of energy efficiency regulations, namely EEDI (Energy Efficiency Design Index) and SEEMP (Ship Energy Efficiency Management Plan) by adopting the regulations as the amendments to MARPPL Convention in July 2011:

Despite five-year period of no conclusion, a post-Kyoto Protocol framework has been negotiated at the UNFCCC which aims at concluding such new legal instrument by 2015. At this moment, it is still uncertain on whether and how international aviation and maritime transport would be treated in the Post-Kyoto Protocol. Maritime industries and many countries with shipping interests have insisted that the work on controlling the emission from international shipping should be conducted under the auspice of IMO, not UNFCCC. UNFCCC principle of CBDR cannot be compatible with the long-standing IMO principles of non-discrimination and "no more favorable treatment"[2], under which the shipping and shipbuilding market has been functioning.

EEDI regulation started to be applied in 2013, and it is moving from Phase 0 (the requirement level is not so high, ships may be able to satisfy the standard without design modification) to Phase 1 (more stringent standards: new design would be

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[2] This means not to treat one ship more favorably than the others; regulations would apply to all ships equally.

necessary for many ships). However, there are some disturbance which may undermine the stability of policy paradigm. We still hear the questions on the fundamental structure of EEDI regulation: e.g., *"EEDI regulation is designed in a way that the engine downsizing and speed reduction is one of effective solution, and this will be disincentive for ship design innovation and be detrimental to securing the navigational safety"*. IMO's resources have been taken up for such discussion. Instability in regulatory framework may stagnate the willingness of industry players to pursue the innovation in ship design and operation.

The attempts to develop MBM through international framework has been unsuccessful, and as an interim solution, MRV (Monitoring, Reporting and Verification) is being discussed. Both MBM and MRV are tools to address the ships' performance during the actual operation, in addition to the ship performance verified at the design and construction stage (namely, EEDI). They are the essential elements to make the GHG regulatory mechanism at the IMO more complete and effective. Lack of those global instruments may mean that the reduction of CO_2 emission from ships be less that their potential. All of these movements, if combined, may lead to "inconsequence", and spurs the external criticism and pressure towards the maritime community and the IMO. Policy development in Figure 1 might go into another spiral of "inconsequence" and "collapse". In this scenario, possible outcome would be: the pressure may increase to identify the international transport as candidate financial sources, in the magnitude disproportionate to the GHG emissions from those sources (emissions from international transport accounts for less than 4% of the world total emissions). The post Kyoto-Protocol instrument, if agreed, might contain the top-down total reduction target in absolute terms (not in terms of energy efficiency), beyond the level that can be achieved by the industries' own efforts but which could only be met by the reducing the level transport activity or "offsetting" the emission by paying the "price", i.e., making financial contribution, which would cause excessive burden.

HOW THE IMO INSTRUMENTS CAN LEAD TO REDUCED EMISSION

A variety of regulatory tools: are they merely the product of fragmented ideas by bureaucrats?

The conceptual illustration in Figure 2 explains the entire picture of IMO's regulatory packages, some of which are already in force and others are under discussion, and the relations between the reduction measures and regulations.

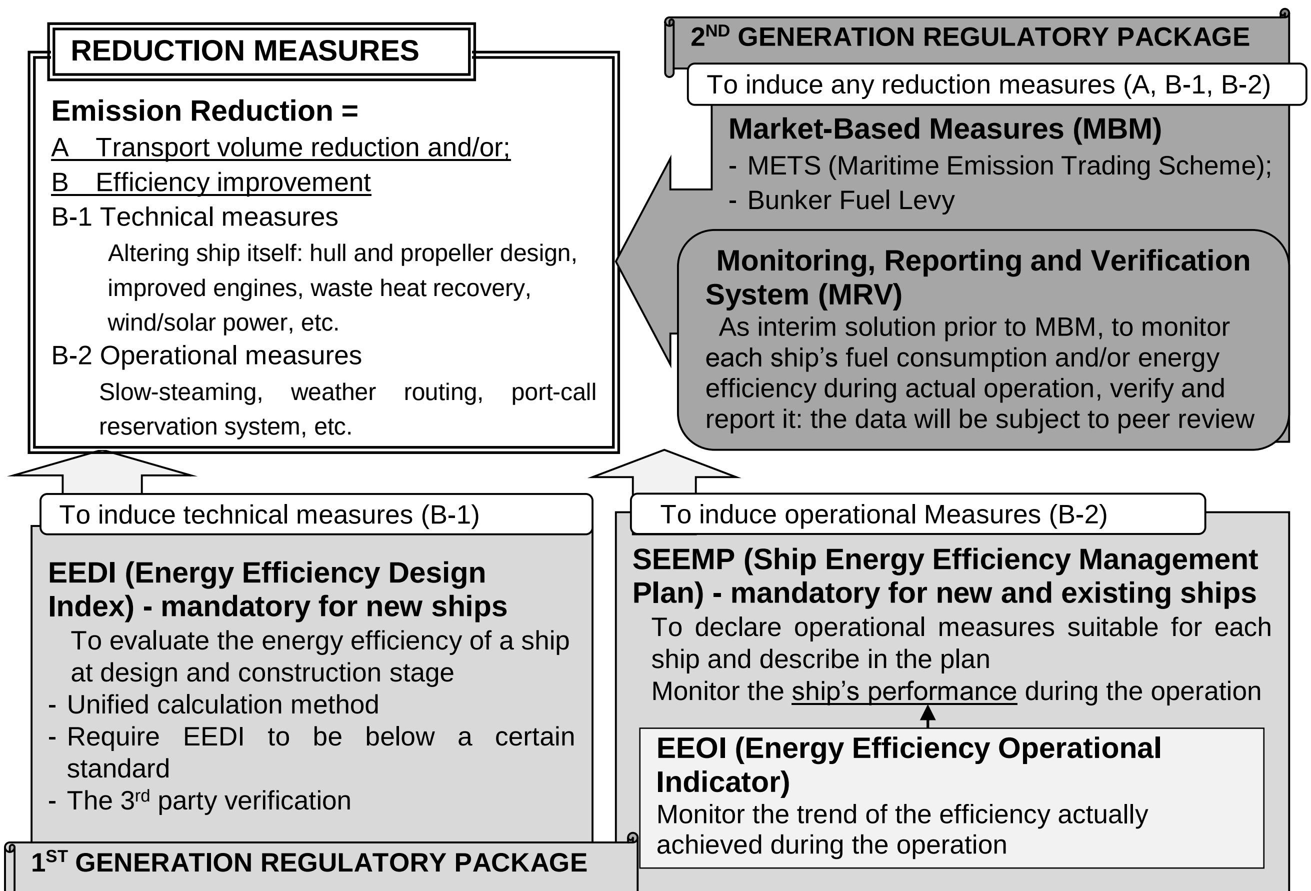

Figure 2 Conceptual illustration of policy ideas: relation between reduction measures and regulatory mechanisms

It would be useful for industry players to note how the regulatory packages, which are classified as the 1st generation (EEDI and SEEMP) and the 2nd generation (MBM, and MRV as interim tool), are designed to induce the reduction of CO_2 emissions; otherwise, the industry players would not be able to wipe out doubts on why they have to secure their compliance with new regulations, which cause them higher initial costs.

The amount of CO_2 emissions is determined by multiplying the level of activity with the efficiency[3]. In case of international shipping, the level of activity means the amount of transported cargo, which is expressed by "ton-mile" unit, and the efficiency means the amount of CO_2 emissions per unit transported cargo, which is expressed by "gramme/ton mile".

CO_2 emissions = (Activity) (Efficiency) [1]

Where: Activity = Transported cargo volume (ton mile);
Efficiency = CO_2 Emissions per unit transported cargo (gramme /ton mile).

For CO_2 emission reduction from international shipping, either of the followings, or both, is necessary:

- Reduction Option A: Reduction of the activity level (volume of transported cargoes) expressed in terms of ton mile
- Reduction Option B: Improvement of the efficiency, expressed in terms of gramme/ton mile

Under Reduction Option B, there are two ways of efficiency improvement:

- B-1: technical measures: to alter the configurations of ships: i.e., change the design and construction of ship at the time of newbuilding, or conduct the conversion of ships such as retrofitting some device while ships are in operation
- B-2: operational measures: to operate ships "wisely" at sea through speed optimization, higher load factor, and weather routing, etc. These measures would include those that can be taken for each individual ship at its captain's discretion with proper information tool and aids (slow steaming, optimum trim and weather routing), those that can be taken as the entire fleet management by a shipping company or an alliance of shipping companies (management to maximize the average load factor of the entire fleet), and those that can be achieved by good ship-to-port interface and support by proper infrastructure (port call reservation system, and port facility to minimize onloading/offloading time).

The regulatory system given in Figure 2 is designed to direct maritime industry towards:

- firstly, procure and use a good hardware (ship), to be reflected in EEDI; and
- secondly, operate such hardware (ship) "wisely", to be reflected in EEOI.

Details of the regulatory system design, so that such system could have the above effects, are given below.

Why do EEDI and EEOI use the same unit, gramme/ton mile? Are they helpful, after all?

The question comes down to which Reduction Option we should seek. Reduction Option A is simply to give up transporting goods according to the demand for seaborne transport. As the demand of seaborne transport is determined externally by the world economic growth and trade pattern, which is beyond control of maritime industry players. It is clear that the Reduction Option A does not provide for any help for the international shipping. Policy instruments should be the one to guide the industry to pursue the Reduction Option B-1 and B-2, and quantitative indicators for their achievements and goals should be furnished.

Reduction Option B-1 as well as B-2 is efficiency improvement, not being related to the absolute volume of the emission, thus it is natural that relevant indicators would be those expressed in terms of gramme/ton mile. The two indicators, EEDI and EEOI, represent, respectively, 1) efficiency potential, which can be calculated and verified at the time of design and construction, and 2) actually achieved efficiency which can only be obtained by the direct measurement during the operation. (Figure 3)

The 1st generation package consisting of EEDI and SEEMP (Ship Energy Efficiency Management Plan) and the 2nd generation package (MBM and MRV) are not "reduction measures" by themselves, but they are mechanism or tool to induce some of reduction measures to be taken by stakeholders. EEDI was designed to induce technical measures (B-1 in Figure 2). SEEMP, being intended to induce operational measures (B-2 in Figure 2) to be taken by ship operators, is a management tool to encourage a ship to take the optimum operational measures such as slow-steaming, weather routing and appropriately planned hull cleaning, while monitoring its own EEOI trend or other emission indicators.

[3] In this paper, the term "efficiency" means "emission efficiency" or "energy efficiency", being different from the term "efficiency" used in the context of economics, e.g., optimum resource allocation. Energy efficiency in transport sector is normally indicated by consumed fuel grams divided by transport activity (fuel grams per ton mile or per ton kilometer). Energy efficiency can also be expressed in terms of CO_2 grams / ton mile, because the conversion factor from fuel grams to CO_2 grams is constant, depending upon the type of fuel.

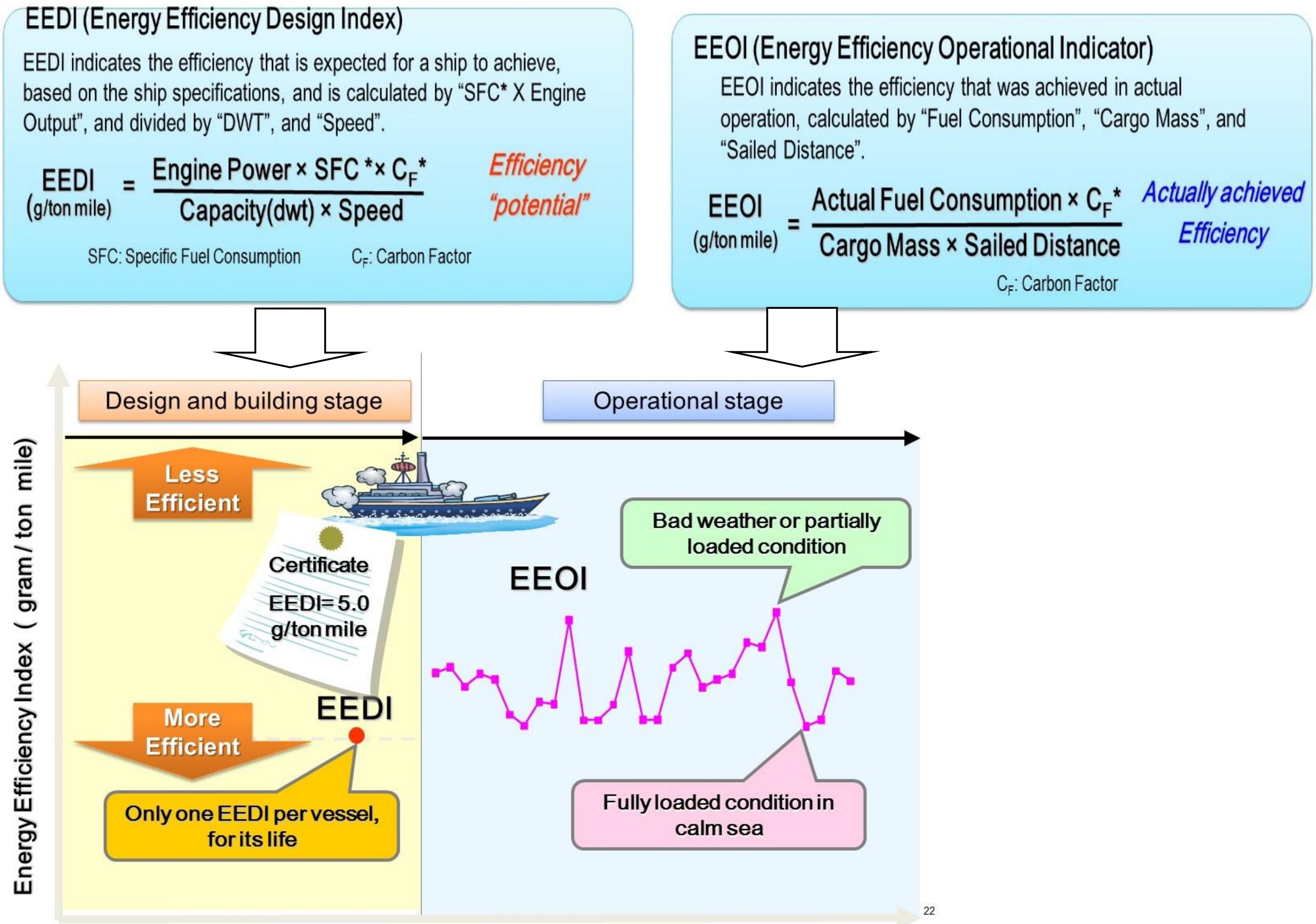

Figure 3 Concept of EEDI and EEOI, and their relation

In order to look into the illustration in Figure 3 in more detail, Figure 4 indicates the actual EEOI data recorded for Very Large Crude Oil Carrier (VLCC). EEOI values are normalized against the average EEOI of the first year.

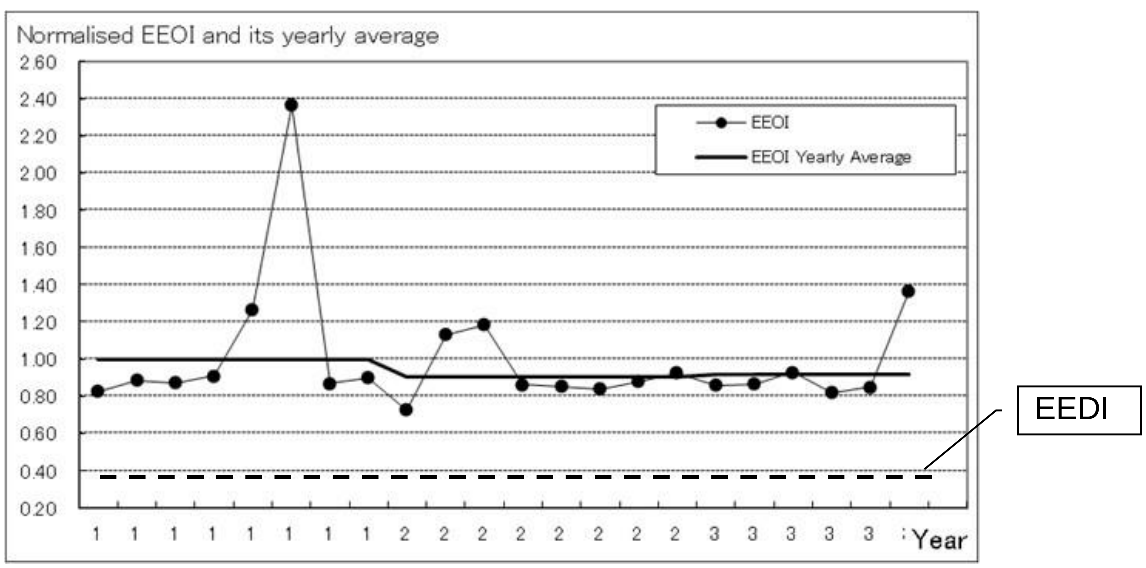

Figure 4 EEOI data series and their relative position to EEDI

SEEMP, being made mandatory for new ships and existing ships, is to be developed as a ship-specific plan by the shipowner, operator or any other party concerned, e.g., charterer. You may say that the SEEMP is just a piece of paper, something like the one that you write down a new year's resolution. No matter you accomplish your goal that you have specified or not, you would not be punished. SEEMP is based on the intuition and the rule-of-thumb that, if you think hard by yourself and write down what you will do in a piece of paper, and if such paper is made open to others, then it is more likely that you would follow your own pledge. Thus SEEMP is rather weak and open-ended as a regulatory tool, and is not a trump card in emission reduction. Yet it is important to try to address the operational measures.

Is the EEDI and SEEMP (the 1st generation package) a mighty tool to achieve the emission reduction?

As argued above, the SEEMP has relatively weak effects on ship operators to take B-2 operational measures. EEDI is to apply to only new ships, which means that it will take long time until the total emission reduction can be observed to a large degree. In addition, the EEDI has a single cut off point of judging compliance or non-compliance with the standard: a ship will be allowed to navigate on international voyage as far as its EEDI is not more than the preset "Required EEDI" which is a function of the ship's DWT. There is no incentive, as far as the regulation is concerned, to make EEDI significantly better (lower) than the minimum requirement level. Therefore, EEDI, in isolation, would not be effective for giving incentives to "top runners" in terms of energy efficiency. This is the limitation of the EEDI, and this is the point that the 2nd generation package, in particular, MBM, can demonstrate its importance.

"There are three ways of reduction, first, technical measures, second, operational measures, and third, Market-Based Measures", what is wrong with this narrative?

A Market-Based Measure (MBM) is a system to utilize economic incentives in inducing the CO_2 reduction. In essence, it is the system under which, if you burn more fuel and thus emit more CO_2, you have to pay more. If you want to save the money, you would think about any of Reduction Option, A, B-1, or B-2, or combination of them. The virtue of such economic incentive would be the freedom of your choice for Reduction Option: you would choose the best combination taking into account your specific situation. One of candidates for MBMs is Emission Trading Scheme (ETS), which is Europeans' favorite and has already been utilized for land-based emission sources. Under ETS for maritime transport, where each ship purchases the emission allowance, i.e., the ceiling of the CO_2 volume that a ship is allowed to emit; if the emission of the ship exceeds such ceiling, the ship would have to purchase extra allowance. Another candidate is the international solidarity levy[4] where levies are collected from each ship based on the volume of the emission (fuel consumed or purchased) and used for internationally agreed purposes, without being put into government treasuries of individual Parties.

MBM, which was also called as MBI (Market-Based Instrument) is not a "reduction measure" *per se*. It is an incorrect way to summarize the reduction measures as "first, technical measures, second, operational measures, and third, Market-Based Measures". The reduction measures are (A) Reduction of activity level (reduce the transported cargoes), and (B) Improvement of the efficiency by (B-1) technical measures, and (B-2) operational measures. There is no other way. MBM (MBI) is a regulatory mechanism or instrument which induce any of A, B-1 and B-2 reduction measures. Therefore, the term "MBI" is considered more appropriate to use, because the terminology of MBM might give a wrong impression that an MBM is a reduction measure. However, since the IMO continues officially using the term MBM, MBM is used throughout this paper.

Is MBM indispensable to induce the emission reduction? Is there any prospect that the MBM is agreed internationally?

In view of limited effects of EEDI and SEEMP, economic incentives should be utilized as an essential part of the regulatory system in order to strongly induce technical and operational measures to be taken by all the players. This is where MBM comes in. IMO has had no experience in MBM before, and the establishment of appropriate MBM would require extensive discussion and take much longer time than the development of the EEDI/SEEMP requirements. Therefore, the optimum way for the IMO to ensure the maximum effects in long term on the CO_2 reduction was to proceed without delay with the mandatory application of the 1st generation package and to deepen the discussion on the 2nd generation package concurrently.

The whole regulatory scheme was designed following the above strategy (two-step approach) at the time of the adoption of the 1st generation regulatory package as the amendments to MARPOL Convention, and such strategy itself was not wrong. However, things did not developed as expected, as far as the 2nd generation package (MBM) is concerned.

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[4] "Levy" is not familiar term for maritime community, but it basically means the same as "tax". Normally, the term "tax" is used when the money is collected and used within a single country. In this case, the money would be collected world-wide by international organization, and used according to the decision by the member states forming such international organization; in such a context, the term "levy" is used.

At the time of MEPC62 (July 2011), there were 10 different proposals on MBM on discussion table of the IMO. MEPC62, being too occupied to adopt the 1st generation package, postponed the discussion on MBM. MEPC 63 in 2012 continued its consideration of proposed MBM, and agreed on the need to undertake an impact assessment of the MBM proposals. IMO could not make good progress after that, and MEPC 65 in 2013 suspended discussions on MBMs.

MRV, which can be considered as a part of the 2nd generation regulatory package, emerged as an interim solution while the discussion on MBMs had been stuck. No matter what kind of MBMs are to be used, actual performance during voyages, e.g., the amount of fuel consumed or purchased, would have to be measured, recorded, verified and reported, anyway, as a basis of calculating the monetary amount that the ship would have to pay. MRV is, putting aside how the monetary burden should be imposed, to obtain the basic information of ship performance relating to CO_2 emission. In this sense, MRV would be a tool in preparatory stage pending the future introduction of the MBMs.

The institutionalization of the MBM would be quite complex. It would be necessary to establish an international body to collect the appropriate data which forms the basis of calculating monetary obligations, and collect the money (levy, or charge to purchase the emission allowance under the ETS), and use appropriately the collected money. A completely new international and legally binding instrument, possibly a new Convention, would have to be drafted, adopted and ratified by interested parties. While we cannot foresee such world-wide MBM instrument in the near future, the MRV would soon start, at the regional level (EU). MRV, while the monetary obligation would not be contained, is expected to have similar effects to MBM (to weaker degree, though), to induce the emission reduction, through higher transparency and peer review: if your ship gets a bad mark, your ship might be listed publicly.

WHAT THE THOUGHTS BEHIND THE SYSTEM DESIGN OF EEDI REGULATION WERE

Basic ideas on the EEDI mandatory requirements were initially offered and elaborated by Denmark. Such ideas have come to be shared, in the period of 2008 to 2009, by many IMO participants through the submissions to refine the EEDI concept mainly by Japan and Denmark, and are summarized as follows:

- Any new ship above certain tonnage is required to calculate its own EEDI ("Attained EEDI"), which is to be verified by the third party. The verification shall be carried out by the Administration or an organization recognized by it. Each ship shall be issued an international certificate that indicates its Attained EEDI (e.g., Attained EEDI = 5.0 g/ton mile)
- Attained EEDI of any new ship is required not to be more than the pre-set value ("Required EEDI"). Required EEDI is determined by the "reference line", which is average EEDI of existing ships expressed as a function of the capacity of ship (DWT for most of ship types), and by the EEDI reduction facter (X).
- Survey and certification system is to be established globally to ensure the compliance of the above requirements.

The above requirements can be expressed as follows.

$$\text{Attained EEDI} \leq \text{Required EEDI} \qquad [2]$$
$$\text{Required EEDI} = \left(1 - {}^{X}\!/_{100}\right)(\text{Reference line}) \qquad [3]$$
$$\text{Reference line} = a(\text{Capacity})^{-c} \qquad [4]$$

Where X: EEDI reduction factor; Capacity: DWT (for most ship types);
a and c: Constant coefficients fixed for each ship type.

Attained EEDI is to be calculated in accordance with the EEDI Calculation Guidelines adopted by the IMO. Its composition is illustrated in Fig. 5. The basic structure of the EEDI regulation as expressed in Equation [2], [3] and [4] can be illustrated as Fig. 6 (IMO, 2012)

Is the EEDI framework rational? Why is the reference line the function of DWT, not dependent on ship speed?

Reference line, as appears in Equation [4], is to be given as a mean regression line of the EEDI of existing ships (dependent variable) against the capacity (independent variable) of the same existing ships. Reference line is to be determined by IMO for each ship type category based on the empirical analysis using the data from the Lloyd's Register-Fairplay data service[5] to calculate the existing ships' EEDI as samples to represent an entire population belonging to a certain ship type category. The reference line is fixed by specifying the values of coefficients of a and c in Equation [4], and these coefficients are contained in the regulation text (Table 2 of Regulation 21, Annex VI, MARPOL73/78).

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[5] Lloyd's Register-Fairplay (LRFP) Data Service provides for the databases which include the principal particulars of all existing ships over 100 GT. Presently it is called IHS.

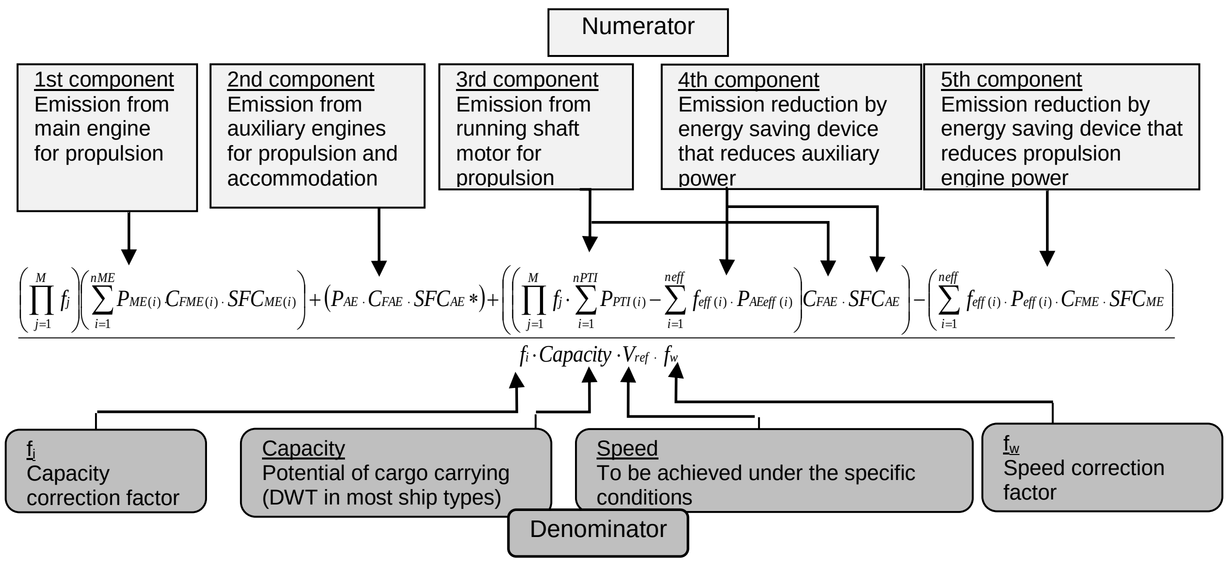


Figure 5 Components of the EEDI formula

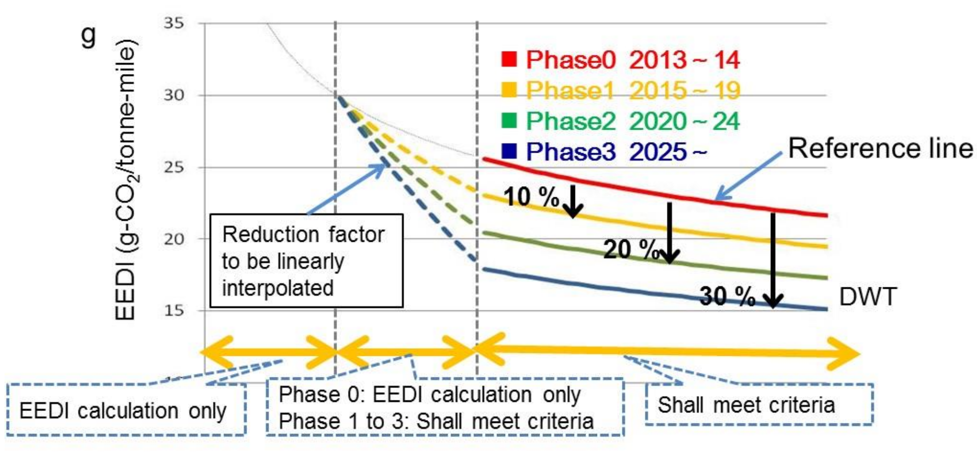


Figure 6 EEDI regulation at a glance

The set of Equation [2][3][4], as the basic structure of EEDI regulation, means that the value of Required EEDI is determined solely by the function of capacity (for most of ship types, DWT), not being affected by other ship design parameters such as ship speed. This means that ships of the same size, having different design speed, would have to satisfy the same requirement level. Is this fair? Shouldn't we loosen the requirement for those ships with higher design speed, as those ships can provide for transport service of higher quality?

A basic thinking, when a technical performance standard is to be imposed, would be to set a certain "standard value" for performance index, and to compare the performance index of each object (something that would be subject to regulation, a ship in this case) with the standard value for performance index. In setting such standard value, it is necessary, somehow, to find a way to express performance indices of a large population in the form of simple numerical function, without excessive scattering of the data points.

Meanwhile, one of the widely shared views at an early phase of discussion (around MEPC 57, March 2008) was the concept and simplified expression of the EEDI, as expressed in Equation [5].

$$EEDI\ (g/ton\ mile) = \frac{(C_F)(\mathrm{SFC(g/kWh)(Engine\ Output(kW) - Energy\ Saved(kW))})}{\mathrm{(DWT(tons))(speed\ (miles/h))}} \qquad [5]$$

Where: C_F is the conversion factor from the fuel volume to CO_2 volume; SFC: Specific Fuel Consumption

When looking into this formula, one may note "rule of thumb" of basic ship design, which is:

- Necessary engine output is, in general, in proportion to the cubic of the speed when other ship parameters such as the displacement are kept equal.
- Necessary engine output is, in general, in proportion to the displacement powered by two-third, when other parameters are kept equal.

Deadweight tons (DWT) is a proxy to the displacement, and one of basic parameters of ship specification. It is considered that ships of the same size (the same DWT) tend to have similar speed; if this is the case, EEDI would take a form of smoothly declining line by using DWT as independent variable (EEDI is in proportion to DWT powered by minus one-third). As DWT is the basic design parameter and one of the most important values to indicate ship's performance (it is cargo carrying capacity, i.e., profit potential), such curve of EEDI as a function of DWT would be convenient as the "standard value" of performance index, as far as the fitting of data points is reasonably good.

Figure 7 is an example of reference line for illustration purpose, (different from the one which was finally incorporated into the Regulation 21 of MARPOL Annex VI). As shown in Figure 7, the mean regression line on the existing ships' EEDI shows reasonably good fitting in most ship types. Figure 7 represents dry cargo carrier where R^2 coefficient is about 0.94[6]. The regression lines of EEDI with DWT as independent variable seemed to be capable of serving as standards for performance index. This is the main reason why the set of Equations [2], [3] and [4] were used as the bases of the EEDI regulation.

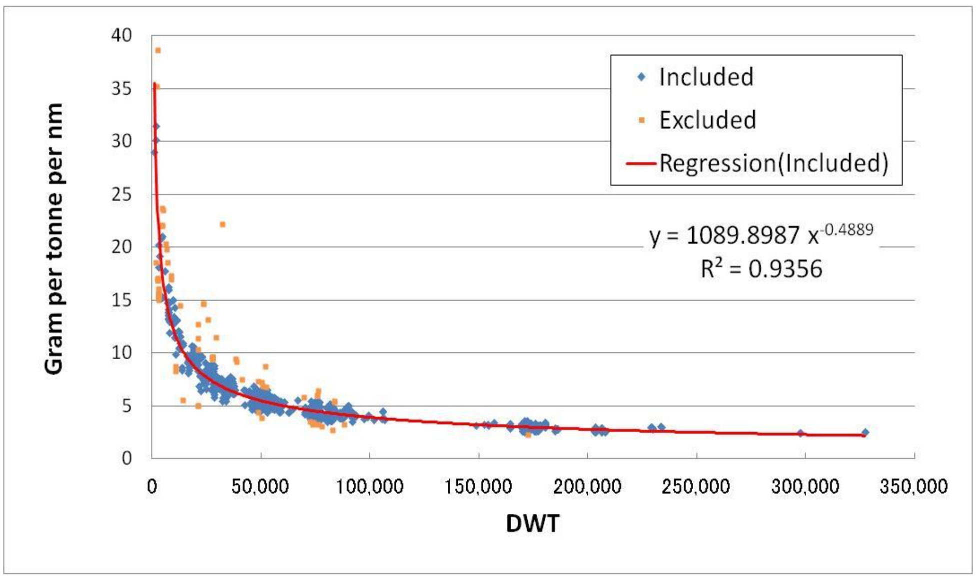


Figure 7 An example of reference line

Has the position of the Reference Line be set appropriately, or it is too "slack"?

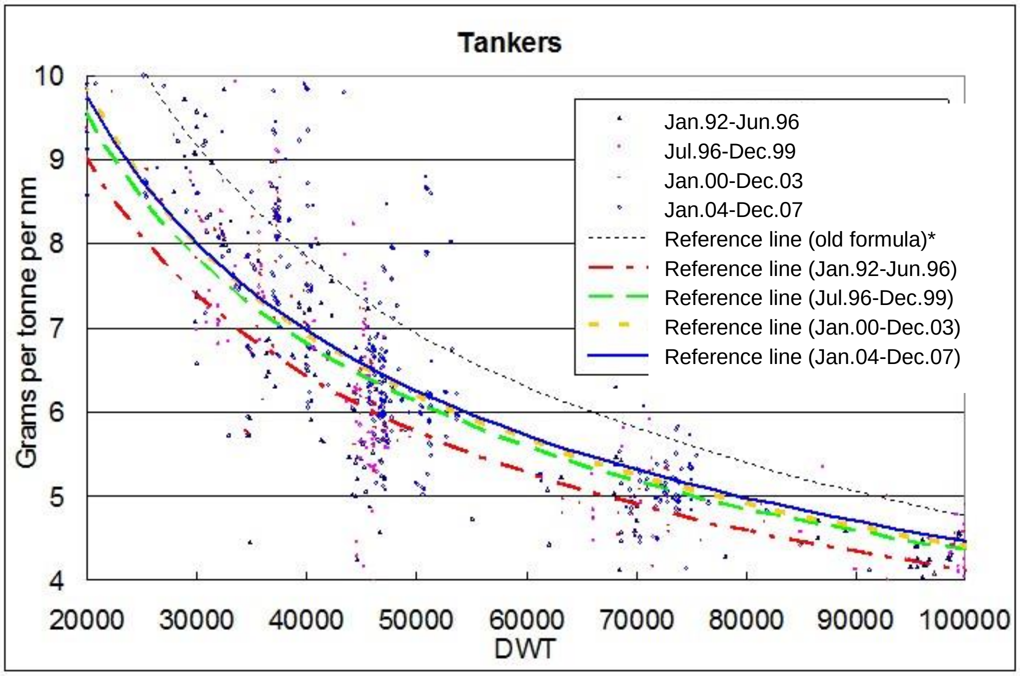
The position of the Reference Line influences the stringency level of the EEDI requirement: if the starting point (Reference Line) is positioned higher, it would be easier for ships to satisfy the present and future Required EEDI. In Figure 7, the data points were calculated based on the ship specification data in LRFP Data Service, and those ships of which delivery was between 1 January 1999 and 1 January 2009 were used as data points. In drawing a mean regression line of EEDI of existing ships, those points exceeding twice the standard deviation in the first run of regression are excluded, and then, the second run of regression is carried out, which becomes a reference line.

The factor which affects the position of Reference Line most is how to select the population of data points, the EEDI values calculated in simplified format of the existing ships. The question is: which existing ships should be chosen as the population. In particular, the time when those existing ships were designed and constructed significantly affects the EEDI values to be used as sample data point.

Figure 8 shows examples of different Reference Line, in case of tankers, when different populations of existing ships for regression samples are used, based on their dates of delivery. It should be noted that ship design and structure have been changed from year to year not only by owner's request but also by various safety and environment regulations and

[6] R^2 (r-squared) is a statistical measure of how well a regression line approximates real data points; R^2 of 1.0 (100%) means a perfect fit.

recommendations, such as double hull requirements for oil tankers, CSR (Common Structural Rules) for oil tankers and bulk carriers, and oil fuel tank protection for all ships. It is presumed that those regulations affect the Attained EEDIs of new ships.



*Old formula means the simplified EEDI formula for existing ships at an earlier phase of discussion, back at the time of MEPC58.

Figure 8 Difference of Reference Lines according to the period of construction of existing ships

It is clearly shown in Figure 8 that double hull requirements, which apply to oil tankers delivered on or after 6 July 1996, affect the EEDI significantly and the reference line drawn by the latest vessels, which were delivered from 1 January 2004 to 31 November 2007, is positioned the highest among all periods (the worst efficiency).

For the comparison purpose, the Figure 8 includes the Reference Line calculated by the simplified EEDI calculation formula used at time of MEPC58 (year 2009). Main difference between the old formula and the present formula is the calculation method of P_{AE}: the old formula used the fixed load point of auxiliary engines at 75% of the installed power (MCR), whereas the current formula calculates P_{AE} as a function of MCR of main engines. The refined calculation formula put the position of Reference Line more correctly, i.e., downwards, in the direction of making the requirement more stringent.

To compare the reference lines of different period of ships' delivery according to ship type, size and period, normalized EEDI values of each reference line (normalized against the "old-formula") are shown in Figure 9. It appears that for tankers as well as container ships, vessels built in recent years tend to have higher (worse) EEDI; this trend is the same for dry cargo carriers.

The above analysis could not identify the impacts of the CSR on the EEDI because of the lack of data of CSR-applied ships (contracted on or after 1 April 2006); however, it is expected that the application of CSR increased the weight of hull steal and thus led to an increase in the EEDI. In addition, new regulations, such as double side skin requirement for bulk carriers (constructed on or after 1 July 2006), damage stability requirements (constructed on or after 1 January 2009), oil fuel tank protection (delivered on or after 1 August 2010), and installment of ballast water management system (BWMS) under Ballast Water Management Convention, would lead to increase in the weight of hull because of constraint of tank arrangement and rearrangement of subdivisions, an increase of machinery room space, and/or an increase of required electric power. These arrangements could lead to decrease of DWT against the same displacement and/or an increase of required auxiliary engine power and thus result in the deterioration of energy efficiency. NOx regulations Tier II (constructed on or after 1 January 2011) and Tier III may also have a negative impact on energy efficiency.

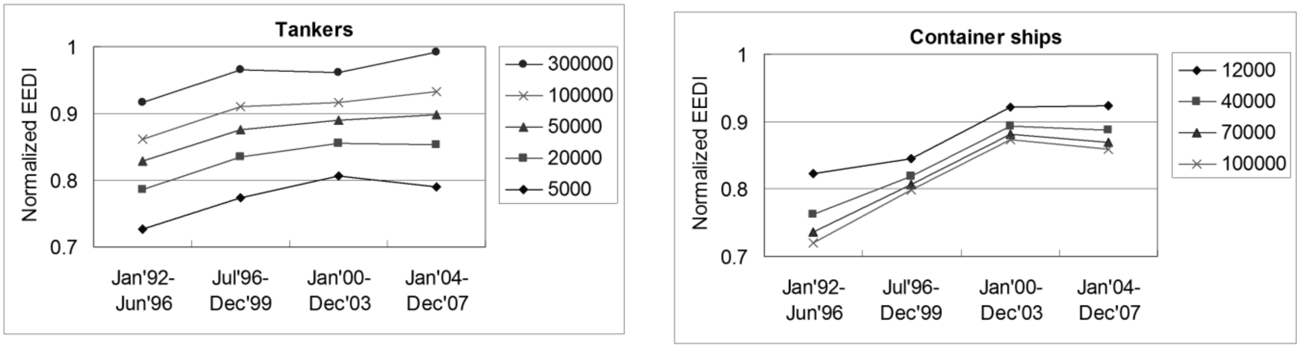


Figure 9 EEDI values corresponding to different reference lines, according to the period of delivery, normalized against the reference line value based on the old formula – Left: tankers, Right: container ships

In setting the position of the Reference Line, i.e., incorporating the values of coefficients a and c of Equation [4] into Regulation 21 of MARPOL Annex VI, it was decided that the sample population of "relatively young" existing ships that were constructed during the past 10 years. By looking into Figures 8 and 9, such selection of relatively young exiting ships pushed the position of Reference Line upwards, in the direction that it would be easier for new ships to comply with the regulation, i.e., having Attained EEDI lower than Required EEDI. This can be interpreted that the implementation aspects of the new regulation, rather than the "ambition" level of regulation, was more important: at the early stage of implementation of new regulation, the situation where many of new ships become non-compliant is clearly undesirable. One may say that some extent of "safety margin" was given to the industry. On the other hand, the effects of very recent regulations (NOx, BWMS, CSR) have not been taken into account. These are disadvantage for future new ships. Overall, the setting of the Reference Line is not too harsh, nor too slack, for the industry players.

Assuming that the Reference Line was set properly, then were the reduction factors reasonably fixed?

EEDI reduction factors in Equation [3] determine the ambition level of emission reduction and careful consideration was necessary. Simply put, there are three approaches to improve the value of EEDI: (1) DWT enlargement, (2) speed reduction (=installed power reduction) and (3) application of new technologies, as shown in Figure 10.

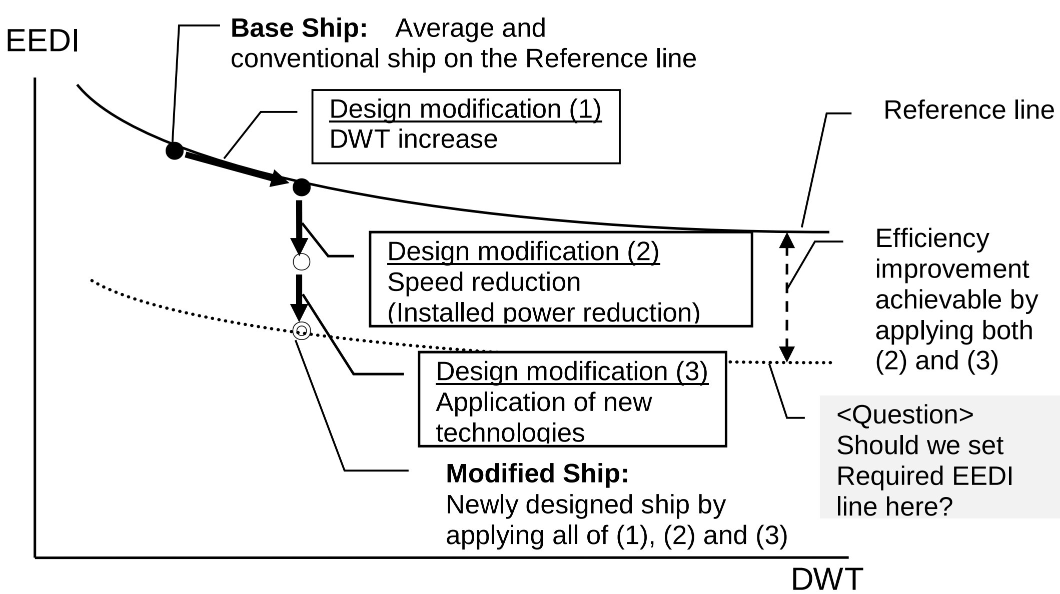


Figure 10 Three approaches to improve the EEDI

(1) DWT Enlargement

Although larger DWT requires larger engine power, DWT enlargement can improve the efficiency, i.e., reduce the value of EEDI. This is because, generally speaking, the necessary engine power increases in proportion to the DWT increase powered by two-thirds, and thus the increase of the denominator outweighs that of the numerator. It should be noted that, while DWT enlargement improves the efficiency and lowers the EEDI of a ship, the ship would be subject to lower (more stringent) Required EEDI due to the increase in DWT.

(2) Speed Reduction (=installed power reduction)

Lowering the speed would reduce the necessary engine power considerably as the engine power is in proportion to the speed powered by three. Thus, speed reduction is effective in improving the efficiency; this point caused some heated discussion at the IMO, and this issue will be revisited later.

(3) Application of New Technologies

New technology here means the one considered as technically achievable and applicable to a particular ship type from an engineering viewpoint. The advantage of application of new technology is that it can improve the EEDI without changing DWT and ship speed; the improvement of the efficiency would not cause any changes to, or constraints on, the operation patterns of the ship.

In Figure 10, the point of "Base Ship" represents the EEDI and DWT of the average and representative ship among existing ships which use the conventional machinery and propulsion system. The point of "Modified Ship" represents the EEDI and DWT where various efficiency improvement measures are assumed to be applied to "Base Ship".

The effect of (1) DWT increase is to move the original EEDI point of a Base Ship to the new point of a Modified Ship, in parallel with the reference line. This means that DWT increase, while it is effective in improving the energy efficiency of a ship, would not be an effective measure for the purpose of moving the EEDI point of the ship downward so that it can go below the Required EEDI line. The allegation that the size increase option is rather treated coldly in the EEDI regulation is correct.

The effect of (2) speed reduction (which means the reduction of installed engine power) does contribute to vertical downward shift of EEDI point. However, there are several points that need careful consideration. Firstly, the potential of improving the EEDI by speed reduction (engine downsizing) varies with ship size, ship type and specific situation under which ships operate. Even those ships with identical design and specification (the same hardware) would have varying potential of speed reduction (engine downsizing) according to the routes and trading pattern in which they are engaged in transport service. For example, ships engaged in shuttle service, with fixed schedule of going back and forth between ports in short time, would have little flexibility of lowering the service speed. Such route and service specific factors make it difficult to objectively estimate the EEDI improvement potential through the use of this option (speed reduction) as a basis of setting the EEDI reduction factors.

It should be recalled that Required EEDI for a new ship is the "minimum" requirement for every new ship; no matter in what special circumstances and routes ships are obliged to operate, they would have to satisfy this minimum requirement. If simply assumed "average" potential of EEDI improvement rate by speed reduction is taken into account in setting the EEDI reduction factors (this means the reduction rates become more ambitious), there will be problems of securing high degree of the compliance: certain group of ships will have limited flexibility of lowering the service speed, thus have difficulties to satisfy such minimum requirement. Therefore, this approach may end up with losing support, or at least acceptance, by the industry.

In view of the above points, it is considered appropriate that the speed reduction should be kept aside as a reserved option or some margin for ship owners to satisfy Required EEDI. Following this thought, it was suggested by Japan that the reduction factors be determined by considering the effects of (3) application of new technologies only. The energy-saving technologies could be applied to ships without affecting their basic parameters such as the capacity (DWT) and the speed, thus there would not be a situation where certain ships face particular difficulty for compliance, due to their operational patters. This approach is suitable for setting the minimum requirements that would equally apply to all ships in the same type and size segment.

In order to set the reduction factors, we had to consider appropriate combination of technologies to be applied for a particular ship type. It should be noted that there is "time factor" for such combination of technologies: maturity of each technology and future prospects on further development of such technology had to be considered. Extensive case studies were conducted to find out which technologies could be applied to a representative ship type to be built in certain year. Following such study (Otsubo, 2010), submitted by Japan to the IMO, the reduction factors were agreed and put into Reg. 21, MARPOL Annex IV.

In the process of setting the reduction factors, speed reduction (engine downsizing) was treated as a reserved option; however, once the regulation is in force, there is no rule on which of (2) speed reduction and (3) application of new technology would be used. EEDI is a goal-based standards, and it is up to industry players to choose the optimum combination of (2) and (3), through extensive discussion between a shipowner and a ship designer/builder.

HOW THE SHIP PERFORMANCE UNDER ACTUAL SEA SHOULD BE CONSIDERED

The EEDI Calculation Guidelines (Resolution MEPC.245(66)) contains the provision of "f_w" factor which would serve to reflect the ship performance under actual sea condition in the calculation of EEDI, as shown in Figure 5. The f_w coefficient was developed in attempt to express quantitatively the speed reduction in actual sea; the speed reduction means the increase of fuel consumption and CO_2 emission under the same voyage distance. Paragraph 2.9 of the EEDI Calculation Guidelines provides:

"9 f_w is a non-dimensional coefficient indicating the decrease of speed in representative sea conditions of wave height, wave frequency and wind speed (e.g., Beaufort Scale 6), and is determined as follows:

.1 for the attained EEDI calculated under regulation 20 and 21 of MARPOL Annex VI, f_w is 1.00;

.2 when f_w is calculated according to the subparagraph .2.1 or .2.2 below, the value for attained EEDI calculated by the formula in paragraph 2 using the obtained f_w should be referred to as "attained $EEDI_{weather}$";

.1 f_w can be determined by conducting the ship-specific simulation on its performance at representative sea conditions. The simulation methodology should be based on the Guidelines developed by the Organisation and the method and outcome for an individual ship should be verified by the Administration or an organization recognized by the Administration; and

.2 (omitted)

f_w and attained $EEDI_{weather}$, if calculated, with the representative sea conditions under which those values are determined, should be indicated in the EEDI Technical File to distinguish it from the attained EEDI calculated under regulation 20 and 21 of MARPOL Annex VI."

The ship performance estimated assuming calm sea condition: is that enough?

Since the start of the process of developing the EEDI formula, Japan has been pointing out the importance of reflecting the estimated ship performance under actual sea condition in the EEDI. The underlying fact is that the performance of ships in actual sea shows a wide variation even if the ships have the same principal particulars and similar specification, as shown in Figure 11. Figure 11 was developed using the data provided by a Japanese shipping company which operates Pure Car Carriers in North Pacific Ocean routes. The PCCs in Figure 11 had similar specification, and thus had the same design speed as predicted by tank test in calm sea condition. Despite that, they showed large deviation in the speed reduction in actual sea, thus resulting in considerable deviation in fuel consumption, which amounted to 10% difference in yearly fuel cost. The bottom line is to make a distinction between those ships showing superior performance (upper line in Figure 11) and inferior ships (lower line in Figure 11).

The f_w coefficient was designed to take care of this situation: it is defined as the ratio of speed reduction from calm sea condition to representative sea condition (Beaufort Scale 6). In Figure 11, Ship A (upper line) has the f_w value of about 0.98 (speed of 19.6kt in BF6 divided by speed of 20 kt in calm sea), while the Ship D (lower line) has the f_w value of about 0.91 (18.2 kt in BF6 divided by 20 kt in calm sea). The difference in f_w values can represent the difference in ship performance at actual sea.

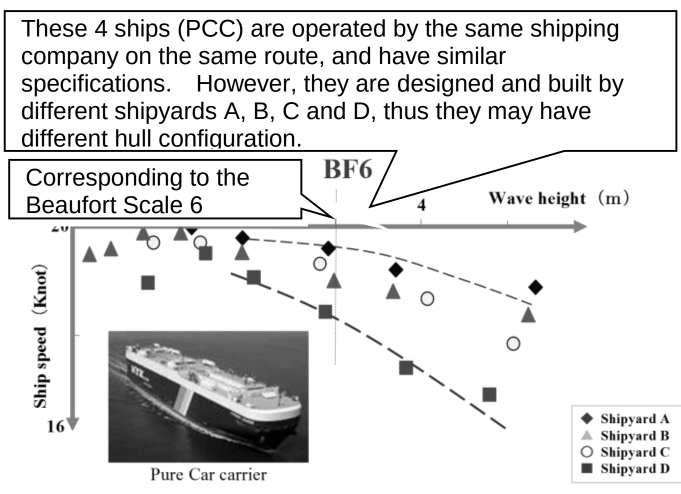


Figure 11 Observed speed reduction in actual operation in case of Pure Car Carrier

	Ship speed Calm Sea (knot)	75%MCR (kW)	Normalized EEDI against EEDI of Ship A (=100.0)	Ship Speed (knot) BF3	BF5	BF7
Ship A	15.03	9000	100.0	14.89	14.26	11.55
Ship B	14.62	8100	92.5	14.47	13.78	10.97
Ship C	13.88	6750	81.2	13.71	12.92	9.89
Ship D	12.18	4500	61.7	11.99	11.11	7.73
			Wave height(m)	0.6	2.0	4.0
			Wind speed(m/s)	4.4	9.8	15.7

BF6

11.7

f_W=0.84

Certificate for Ship C
EEDI=5.0g/ton mile
(for indication) f_W=0.84
$EEDI_{weather}$ =5.9 g/ton mile

Figure 12 Examples of ship speed reduction under actual sea conditions

In order to make sure that the ship be designed with due consideration of performance at actual sea condition, the ideal solution would be, in addition to the mandatory requirement of "Attained EEDI shall not be more than Required EEDI" with f_w being equal to 1.0 (which means the calm sea condition), to require the Attained EEDI with f_w (not equal to 1.0, calculated for each ship) not to be more than Required EEDI with the "standard f_w " (set as an average f_w as a function of ship size such as DWT). However, setting the "standard f_w " would be onerous task as it is difficult to collect a large number of sample data of f_w so that the "standard f_w " curve has sufficient statistical significance. It should be noted that, even in case of drawing the regression line for Reference Line, where it is relatively easy to collect the sample data of EEDI of exiting ships, there had been a lot of controversy as analyzed in the above section.

More practical approach was to use the EEDI values with calculated f_w value (not equal to 1.0) obtained in accordance with the simulation guidelines as an optional indication on the international certificate relating to the EEDI. This means that such certificate (IEE (International Energy Efficiency) Certificate) or its accompanying document (Technical File) would include:

- mandatory indication of the EEDI (with f_w being 1.0) which shall be compared to and satisfy the Required EEDI;
- optional indication of the "$EEDI_{weather}$" (with calculated f_w value, not equal to 1.0), not to be compared to the Required EEDI, but for reference to show the estimated ship performance under representative (not calm) sea conditions.

Another reason of the above treatment lies in the EEDI survey procedure. EEDI-related survey is based on the two-step approach including the verification at sea trial. However, the sea trial verification on f_w is quite difficult, as it needs to run a ship under specific sea condition and may take a few months. In sea trial, the ship speed is normally checked with several "runs" of the speed trial, and we cannot artificially create a particular sea condition at a certain point of time.

Can the requirement on minimum propulsion power solve the problem?

The above treatment of f_w in the EEDI regime would be relevant to the discussion about the need of regulating the minimum speed or minimum propulsion power. Background of such concern is that the speed reduction (engine downsizing) is one of solutions to satisfy the Required EEDI. At the IMO, there has been considerable discussion on the needs of avoiding safety risk at adverse weather conditions; if a ship has an excessively low design speed for the sake of complying with the Required EEDI and such ship has inferior seakeeping capability, this would pose a risk that the ship speed becomes too low under rough sea condition to be capable of evading, or getting out quickly of, dangerous sea areas and of keeping the maneuverability.

After a series of meetings, MEPC 65 adopted "the 2013 Interim Guidelines for determining minimum propulsion power to maintain the maneuverability of ships in adverse conditions" (MEPC.1/Circ.850) (hereafter, "the Interim Guidelines"); MEPC 67 agreed that the Interim Guidelines would be applied to ships required to comply with regulation 21 of MARPOL Annex VI during phase 0 and phase 1 (new ships of which contracts are made from 2013 to 2020). Then there was a Greek proposal to strengthen the requirement of the Interim Guidelines (MSC 93/21/5 and MSC 93/INF.13) and it will be discussed at MEPC 68. One of strengthened requirements in the Greek proposal is to significantly increase the minimum level of the total main engine output which is required to be more than the specified value calculated as a function of DWT for each ship type (the approach called "Level 1" in the Interim Guidelines). If the Greek proposal should be taken, considerable portion of existing ships, even without engine down-sizing, would fail to meet the requirements.

This initiative is an excessive overreaction to the concern that most of ships would be underpowered for the sake of complying with the EEDI regulation. Such proposal would seriously reduce the degree of freedom in ship design, and may nullify the efforts of designing more energy efficient ships.

Such risk of the proliferation of underpowered ships could be avoided by knowing in advance how much the ship speed would be reduced in rough sea, where f_w can give a simple and easy-to-understand indication. Such use of f_w as an indication to avoid safety risk is explained in Figure 12. Figure 12 shows that a ship A, which has calm sea speed of about 15kt, would face speed reduction down to about 12kt under Beaufort Scale 7 (BF7)[7]. In case of Ship D, the estimated speed under BF7 may pose a risk that the ship would lose rudder control in such a rough weather. Speed reduction (reduction of installed engine output) is an effective measure to improve the EEDI and thus to satisfy the Required EEDI. However, when shipowner and shipbuilder discuss the basic design of a new ship, they should avoid lowering the design speed as low as that of Ship D.

When the indication of coefficient f_w is included in the IEE certificate or in EEDI Technical File, this would give a useful idea for the ship owner to know, in advance, the ship's expected performance. Figure 12 shows an example of Ship C, of which EEDI (f_w =1.0) is 5.0 g/ton mile, and of which f_w value is 0.84. The IEE Certificate or EEDI Technical File for Ship C would indicate f_w value as well as the $EEDI_{weather}$. By this indication, the shipowner would have an idea that the Ship C, of which speed at calm sea is 13.88kt, would lose the speed under BF6 down to 11.7kt. With this information, the shipowner would be in a position to judge by itself whether the Ship C would have sufficient performance under the actual sea, in view of the operation pattern that the shipowner envisages.

FOR WHAT PURPOSE MRV, AS AN INTERIM MEASURE, CAN SERVE

EEDI & SEEMP regulation was a big step forward. However, as argued above, the 1st generation regulatory package is not enough and there is a room for all the existing ship to make further efforts. As it will take long time to institutionalize any

[7] Specification of example ships and their estimated speed reduction under sea conditions of BF3, 5 and 7 were provided by the SAJ (Shipbuilders' Association of Japan) for the purpose of MLIT's presentation at the IMO.

type of MBM, IMO has been discussing the establishment of a MRV (Monitoring, Reporting and Verification) and Data Collection system at the first phase. The Data Collection system should represent a ship' CO_2 emission performance, to be monitored, recorded, verified and reported as the ship is engaged in actual voyages. An appropriate indicator, or a metric, should show quantitatively to what extent the ship is designed and constructed in energy efficient way, and the ship is operated in energy efficient manner. Japan proposed an idea for a metric, *i.e.,* Annual Efficiency Ratio (AER), as shown in Figure 13.

$$\text{Annual Efficiency Ratio (AER)} = \frac{\sum_j FC_j \times C_{Fj}}{DWT \times D} \quad \text{[g-CO2 / ton-mile]}$$

j : the fuel type;
FC_j : the annual mass of consumed fuel j;
C_{Fj} : the fuel mass to CO2 mass conversion factor for fuel j;
DWT : the deadweight;
D : the annual distance sailed in nautical miles;

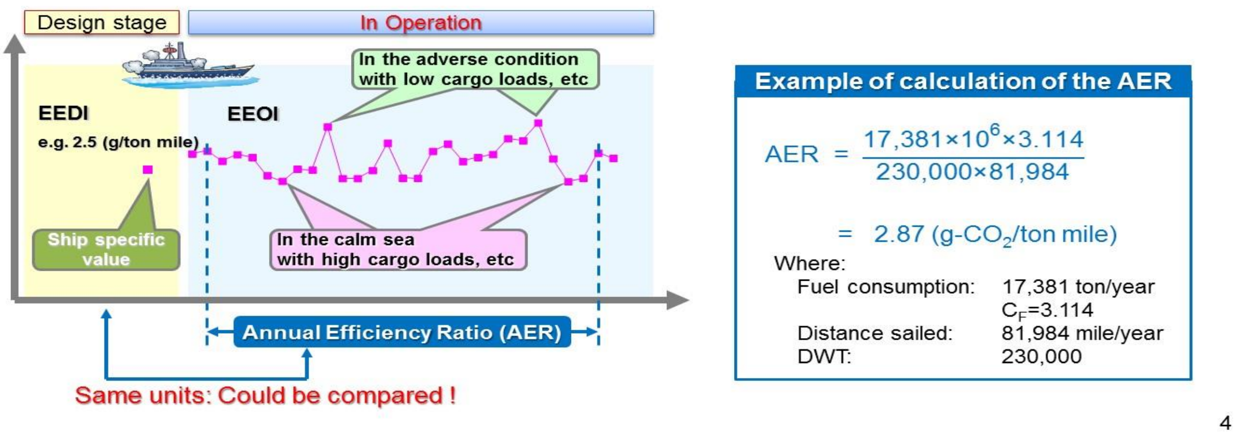


Figure 13 Concept of AER

What would be the best indicator for the MRV and Data Collection system?

AER has the following characteristics:

- Monitoring AER would be a good indicator of improvement (or deterioration) of energy efficiency of individual ships;
- The same unit as EEDI (gramme/ton mile) is employed, and by using the DWT, it is easy to compare the AER with the EEDI given to that particular ship;
- There is a good correlation between AER of individual ships and DWT; thus such "standard AER curves" can serve as a yardstick to know how the performance of a particular ship is positioned among other ships; and
- The calculation of AER would need only three sets of data (fuel consumption, distance sailed and DWT), which are already available according to other mandatory instruments.

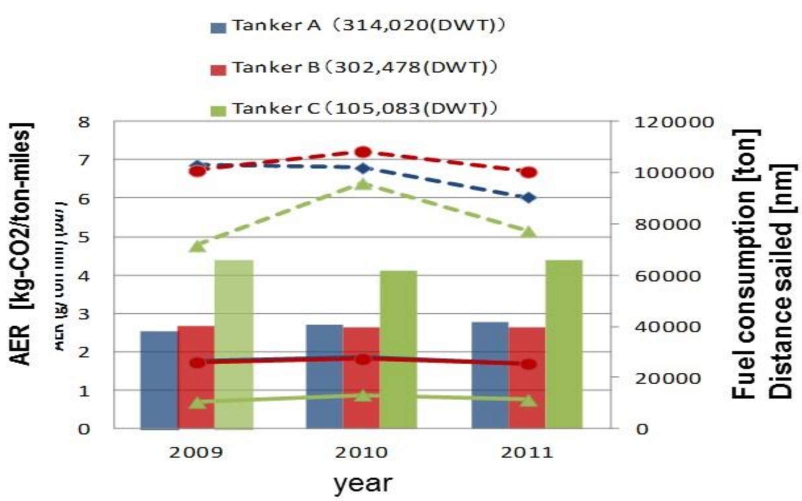


Figure 14 Examples of AER

AER could appropriate capture energy efficiencies of individual existing ships, taking well into account "transport work". Figure 14 indicates three sets of parameters, fuel consumption, distance sailed and AER, which were measured and recorded during voyage. Tanker B consumed larger fuels than Tanker C; however, Tanker B achieved a longer distance, carried larger cargoes than Tanker C. Calculated AER value of Tanker B shows a better efficiency ratio than that of Tanker C.
Figure 15 illustrates how the IMO would proceed in its efforts of introducing MRV.

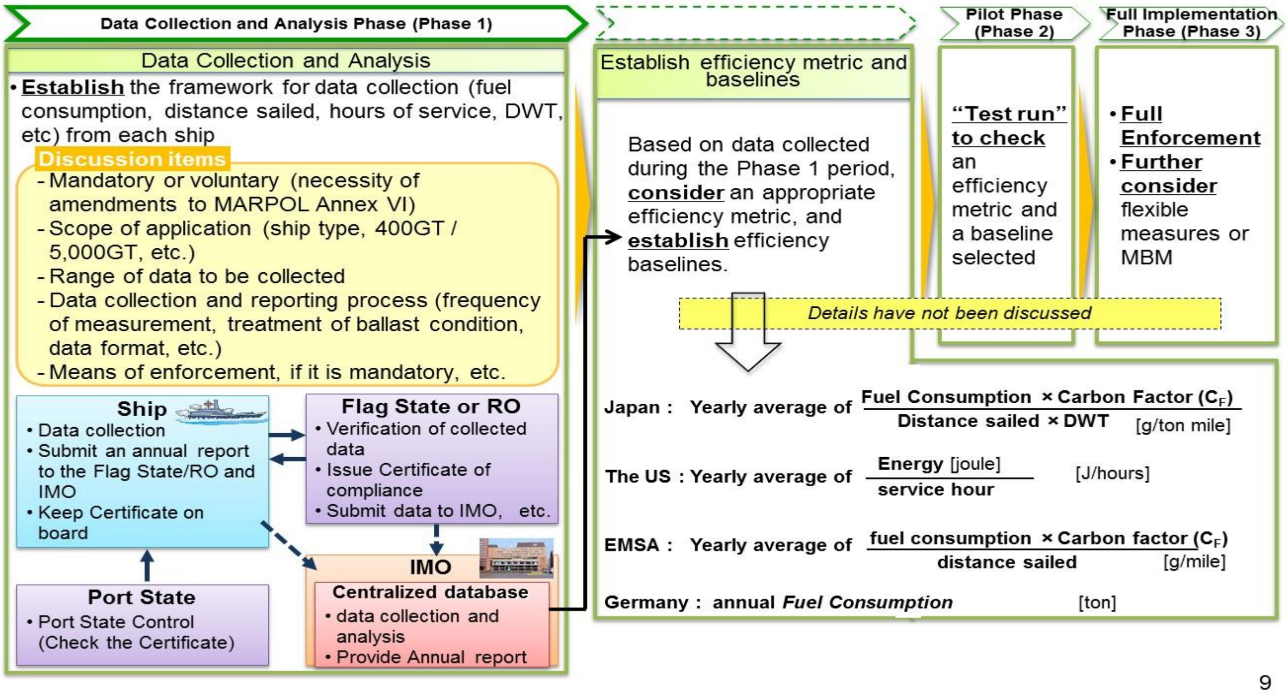


Figure 15 Roadmap for the MRV and Data Collection System

We are still in the phase 1 of Figure 15, and there a lot of issues to be discussed. On the other hand, the trend will not be turned over; there will be more emphasis on the ship's performance at actual sea. Further, there will be more transparency. The monitoring record of energy efficiency of individual ships remain, typically in the form of EEOI, the management tool of shipping company at this moment. However, such records and data may become more public. There may be a mandatory system of data collection, and to some extent, the collected data will be made open to the public and this will put peer pressure on those shipping companies which are supposed to improve energy efficiency of their fleet.

Will the EU regional regulation have negative effects?

In late 2011, the European Commission, giving its view that the 1st regulatory package agreed at the IMO was not sufficient, initiated the consideration to introduce a regional MBM for shipping (ETS or levy or any other tool). From January to April 2012, the EC initiative put this subject under public consultation process, calling views and comments worldwide.

In April 2012, MLIT (Ministry of Land, Infrastructure, Transport and Tourism), Japan, through diplomatic channel, sent out the Japanese Government's position paper to the EC: the message was that measures to address GHG emissions from shipping should be internationally developed, and that the IMO is the most competent body for this purpose. This message was followed by joint letter by an ally of the countries with shipping and shipbuilding interests. In October 2012, EC announced that, instead of introducing a regional MBM, the EC would start the consideration to introduce MRV based on the volume of fuel consumption. In November 2012, the EU sent their replies that, while the EC will intensify its efforts aimed at developing a global MRV framework, it will continue its work for the regional MRV.

Meanwhile, starting from 2012, developed countries (Japan, US, EU, etc) started informal discussion for introducing global MRV system at the IMO. Japan had advocated that MRV should have a linkage with EEDI, i.e. energy efficiency, and that MRV should cover not only fuel consumption but also cargo volumes and distance travelled, as the efficiency can be monitored. In February 2013, the EC adjusted its potential proposal to contain, in addition to the fuel consumption, the cargo volume and the distance travelled, taking into account Japan's view above.

In June 2013, EU-MRV draft regulation was submitted to EU Council and European Parliament, and in December 2014, the EU Council adopted the regulation. It is expected that in spring 2015, the European Parliament will adopt it, and then the development of detailed implementation guidance will start. The regulation will enter into force in July 2015 and the regulation will start to be applied from January 2018.

As a matter of principle, GHG-related regulation, as well as any other environmental regulation, should be implemented in a uniform way world-wide. Japan and other countries would continue to encourage the EU not to pursue the regional framework, but to intensify its efforts to engage actively in the IMO discussions to establish a global framework. Despite such demarche, we cannot clearly see how quickly the IMO can reach the agreement on the global framework, and the EU regional MRV will soon start applying to ships calling at EU ports, no matter they are EU-flagged or not. The EU regulation is mandatory and contains the penalty clause; ships not complying with the requirement of reporting to the EMSA (European Maritime Safety Agency) and respective Flag State may be prohibited from calling at EU ports.

Whether EU regulation will have positive or negative effects on the maritime industries, it will depend on whether such EU action will accelerate or deter the IMO negotiation process. Hopefully, the IMO global framework on MRV is established in the near future, so that the EU regional system could be integrated into the global system.

POLICY-MIX: ANY TOOLS, OTHER THAN EEDI, SEEMP AND MRV, THAT THE GOVERNMENT CAN USE FOR THE ENVIRONMENT AND FOR THE INDUSTRY

Policy-mix can be defined as an attempt to achieve the policy objective by combining different environmental policy instruments in a way that they are interrelated. Policy-mix is seen in the whole regulatory packages explained in the paper. It has been argued that the optimum way for the IMO to ensure the maximum effects in long term on the CO_2 reduction is to proceed without delay with the mandatory application of the 1st generation package and to deepen the discussion on the 2nd generation package concurrently. This means, in the future when the 2nd generation (MRV, and then MBM) is introduced, the mandatory EEDI and SEEMP regulatory system based on MARPOL Annex VI and the MRV/MBM based on new legal instrument would co-exist.

Environmental policy instruments relevant to CO_2 control in international shipping can be summarized and categorized as follows in Table 1[8]: those instruments that have been argued in this paper are underlined.

Table 1 Summary of policy instruments relevant to the CO_2 emission reduction from international shipping

	Activities by public organizations	Measures to induce or control polluters	Measures taken voluntarily or on contract
Direct instruments	Capital investment on port facility (efficient port operation) Measures on government-owned ships	Direct emission regulation <u>(Required EEDI)</u>	Application of EEDI to ships not covered by regulations (e.g., small ships, domestic ships)
Indirect instruments	R&D	ETS Levy Reduced port charges <u>Preferential loans</u> Subsidies to R&D	<u>SEEMP</u> <u>Monitoring of EEOI, AER</u>
Infrastructure for better functioning of instruments	Publicly accessible database of Attained EEDI <u>Reporting of EEOI (and/or AER), and publicly accessible database</u>		

What can the public organizations do?

Governments and other public organizations may conduct various activities to reduce emission from shipping. As direct measure, the capital investment at ports, such as enlarging births, dredging and installing larger cranes, would enable on-loading and off- loading of larger ships which have higher energy efficiency. In addition, the investment on port operation, such as the introduction of reservation system of port entry would reduce the waiting time for ships to call at ports, which would reduce

[8] Based on the categorization by Morotomi (2008), Table 1 is prepared by limiting the instruments relevant to the regulations in shipping. Possible policy instruments in the field of shipping have been added to Table 1.

the running of auxiliary engines while the ships are just afloat and waiting, and thus reduce CO_2 emission. Governments may also impose the emission regulations on the ships that are owned by the governments themselves.
As indirect instrument in this category, the governments or public organizations themselves could conduct the R&D for emission reduction and promulgate the results of such R&D.

Are there any other measures to induce or control the polluters?

In addition to those tools that have been argued (EEDI, SEEMP and MRV, etc.), there are possibilities of applying other measures. Reduced port charges could be introduced by each port authority or as a national policy, where the price of port charges to be collected from shipping companies is differentiated by certain indicators of CO_2 emission performance. As the EEDI has becomes the internationally unified indicator for energy efficiency, the value of Attained EEDI of each ship or its deviation from the Required EEDI could be a useful tool for the price differentiation of port charges.

Public financing organizations, such as Export-Import banks in each country that provide export credit facilities, could add, in their line-up, preferential loans for building of ships with better potential of reducing the emission. Attained EEDI given for each ship could be a workable yardstick in this case as well, and Japan has been pushing the proposal in this direction at the OECD which sets and administers the international rules on officially supported export credits, as argued in section below.
Theoretically, direct subsidies to emission reduction are considered inferior to taxes and permits (ETS). However, the subsidies to R&D have been widely utilized, especially in the field of environmental protection; this is because the assistance to R&D is considered to have small market distortion effects. MLIT has been providing for financial assistance for R&D to reduce CO_2 emission since 2009, and many of the R&D results have been utilized in ships that are already put into service.

Will the measures taken voluntarily or on contract useful?

While the calculation of the Attained EEDI has wide coverage as it is required for new ships of most ship type categories (excluding specialized ones such as fishing vessels, dredgers, drilling vessels, offshore supply vessels) of 400 GT and over, the requirements of satisfying the certain threshold (Attained EEDI shall not be more than Required EEDI) are limited in their coverage, as there are size cut-off points according to ship types (e.g., dry cargo carriers of less than 10,000 DWT are excluded).

However, it would be effective in emission reduction, if the players apply the EEDI scheme to those exempted ships on voluntary or contractual basis. Shipowners may wish to include such demonstration of the performance using the EEDI in their newbuilding contracts with shipbuilders, even for those ships exempted from the requirements.

In Table 1, SEEMP is put in the category of "measures taken voluntarily or on contract", despite the mandatory requirement on developing SEEMP and keeping it onboard. The reason of putting in this category is that the operational measures to be unilaterally declared and indicated in the SEEMP would not be checked or controlled. It is up to ship operator (land-based ship management company), ship master and crew whether they actually take the operational measures that have been declared as suitable to a particular ship.

What kind of the infrastructure is needed for better functioning of instruments?

Attained EEDI of each ship would have to be documented as IEE Certificate which shall be kept onboard for inspection. Therefore, the Flag State surveyors and Port State Control officers are in a position to know the value of Attained EEDI of a particular ship, but such information would not be made open to public in the present regulatory system. One step further would be to make such information open and publicly accessible, so that there will be much more transparency in the shipping companies' efforts in procuring and using energy-efficient ships. MRV is one of the attempts to increase the transparency.

However, the approach to have more transparency of individual ships' EEDI may face resistance from the industries because the EEDI values of new ships, in isolation, might be misleading in measuring the overall efforts of shipping companies. It is possible that a company happens to have a limited number of new ships, thus the public information on the EEDI for new ships may not represent the overall performance of the company. Theoretically, the EEDI can be calculated for existing ships as well, however, there are technical barriers to accurately calculate EEDI values for existing ships. Even though we assume that we could somehow calculate EEDI for existing ships with reasonable accuracy, the industries would still react unfavorably to the ideas of the open database of EEDI. For example, a company may still possess relatively old fleet (probably high EEDI values), but the company may have applied well-considered optimum operational measures and fully implemented them. Such efforts in operational aspects would not be reflected in the EEDI and its open database, thus the transparency in this particular case might penalize such company that has been making efforts.

Governments always come up with new regulations which are costly to the industry. Can't they invent financial incentives to reward the efforts to curb CO_2 emission?

Reducing CO_2 emissions from ship operation can be realized in two ways: construction of a more efficient ship, and more efficient operation of the ship. Although both are essential, building an energy efficient ship would have the priority because a ship with more energy efficiency operates more efficiently, assuming a similar level of operational efforts and skills. In other words, a ship's basic performance, which is determined at the time of construction, determines the limitation of operational efforts. Furthermore, once a ship is put into operation, the ship will operate for a long time. Small differences in environmental performance of ships will emerge as significant differences in their life time. Thus, construction of better ships is essential and should be promoted urgently. On the other hand, the EEDI regulation is like a "pass or fail" exam; satisfying the required EED is all that is needed and the scheme creates no economic incentives for excellence (i.e., superior ships having better EEDIs far beyond the minimum requirements).

The OECD's rule, SSU (Sector Understanding on Export Credits for Ships), sets common rules for officially supported export credits for ships, in particular, concerning interest rates and the duration of credits. There is no environmental perspective in the present SSU. In order to promote innovation in the maritime industry and to disseminate more efficient ships, it would be worthwhile to transform the SSU into an international mechanism supporting "reward for excellence" by incorporating environmental factors into its terms and conditions. (Figure 16)

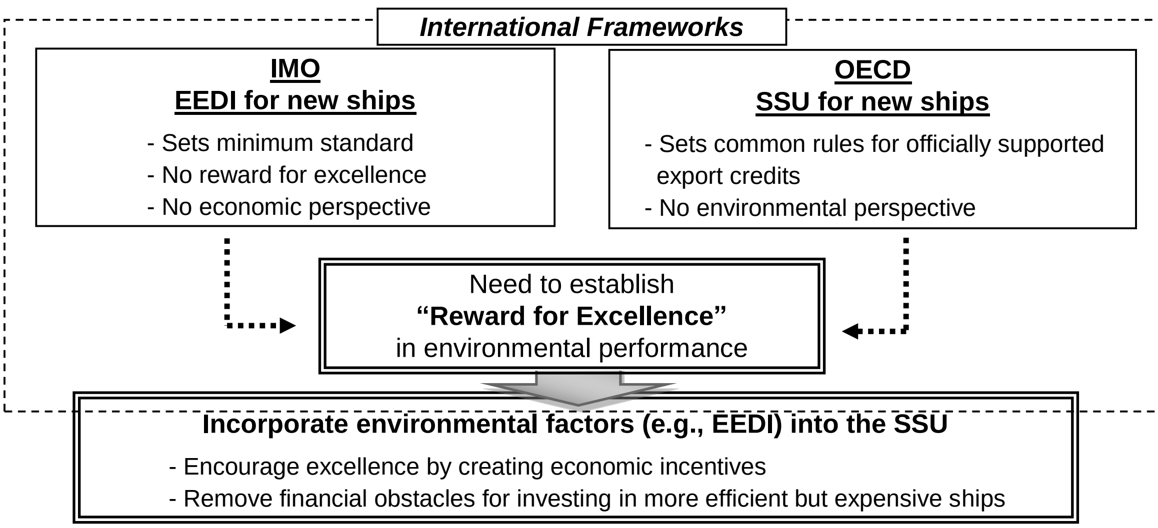


Figure 16 International frameworks relating to ship construction

The biggest obstacle for investing in more efficient ships is that those ships are normally expensive due to the utilization of advanced technologies. Taking into account such financial barriers for investing in low CO_2 emission ships, Japan proposed at the OECD that down payment and maximum repayment terms under export credit rule should be relaxed for low CO_2 emission ships as follows:

- Down payment: reduced to 15 %, as compared to 20% for ordinary ships
- Maximum repayment terms: extended to 18 years, as compared to 12 years for ordinary ships

Japan proposed that if the attained EEDI of some ship is lower than the ship's required EEDI by more than 20%, then the ship is considered to be a "low CO2 emission ship." In Japan's analysis of IHS data which was used by the IMO to determine EEDI requirements, about 5% of existing ships already satisfy this criterion. In other words, a ship whose EEDI is smaller than its required EEDI by more than 20% generally belongs to a group of top 5% of all existing ships. It is considered that the threshold at top 5% is ambitious enough, and improvement of EEDIs by more than 20% is desirable as a target.

Unfortunately, this proposal has not been agreed yet at the OECD. Unlike the IMO where two-third majority rule is used for the amendments to the Convention, the amendments to the SSU need the consensus of Member States, which makes the introduction of new initiative very difficult. On the other hand, in the longer term, it is considered that the environmental performance of a ship will become to influence the financial terms and conditions of newbuilding or other commercial transaction (such as the 2nd hand sales value of a ship).

CONCLUSIONS

Regulations on energy efficiency started rather generously for industry, but will continue to become more stringent.

The 1st generation regulatory package (EEDI and SEEMP) was developed and adopted, taking into account the acceptance level by the industry players, and under the time constraint to obtain wider support to agree on the international agreement. Therefore, the Required EEDI was set at a level that can be achieved by the application of new technologies only, keeping the speed reduction (engine down-sizing) as a reserved option. Reference Line as the starting point of the regulation was established by giving some "slacks", in order to alleviate the burden for industry, at least in the initial phase of the regulation.

While the regulation started rather mildly, the EEDI stringency level will be higher in the future. Although the review of the reduction factors, which determines the stringency level of the regulation, for Phase 2 and Phase 3, is under way, the general trend will not be reversed; the required level of energy efficiency of ships will continue to be higher. Under more stringent requirement level, an easy way out such as the speed reduction will not be a viable solution any more, and there should be even more rigorous efforts to improve energy efficiency.

As the consciousness for energy efficiency of ship owners will be higher, ship designers and builders that can have the credibility of delivering the ships with the expected performance will remain in the market. There will be more severe selection in the shipbuilding market.

More importance will be attached to the ship performance at actual sea conditions

There are mainly two trends: more importance will be attached to ship performance in energy efficiency at actual sea condition, and there will be higher demand and expectation for the transparency of environmental performance. These two trends are interrelated. In view of high oil prices that continued upward trend until very recent, ship operators are more and more conscious of ship performance at actual sea. The transparency will be required through the MRV, where EU regional scheme will be ahead of the global framework, and such new regime will put further pressure on ship owners and operators to use superior ships in terms of energy efficiency. Under the MRV, no matter it is regional or global, the ship performance during the operation such as fuel consumption and efficiency will be reported, and made open to public to certain extent.

Now, f_w and $EEDI_{weather}$ is an optional indication of the IEE Certificate. It is up to each ship whether its Certificate would indicate those values that has gone through the third party verification. It would be the interests of ship designers and builders, who are confident of the design superiority to utilizing f_w and $EEDI_{weather}$ as a marketing tools to differentiate them from other competitors. Such marketing efforts may be supported by the governments' policy-mix. In addition to the regulations already in force, there may be differentiated financial conditions in favor of more efficient ships.

"Safety first" is as a matter of course; excessive fear for the speed reduction should not be put on ship designers' shoulder.

Speed reduction (engine downsizing) is one of solutions for improving the Attained EEDI. It is a matter of course that ship designers and builders would care for the safety of the ship; if they sacrifice the safety such as the maneuverability under rough sea condition by simply choosing engines of smaller power, they would not be able to sell the ship. After all, it is owner to choose a ship and ship designer/builder. Strengthening the minimum propulsion power requirement would take away the degree of freedom for ship design, and have disincentive for ship designers/builders who have been making efforts to design and construct ships with higher efficiency while keeping the safety level.

Accumulation of inconsequence is dangerous for the sound development of the maritime industry.

GHG regulations should be a balanced one to effectively reduce the GHG emission without damaging the sound development of maritime transport activities. In order to achieve this, the IMO should continue to be the competent body of setting and implementing the regulations on the CO_2 emission from international shipping. However, there are, and will always be, external pressure on the IMO, its Member States and industry players in the maritime field, to bring tangible outcome. Otherwise, the political dynamics in the UNFCCC may lead to top-down approach, e.g., by setting the capping on the total volume of CO_2 emission which may restrict the activity level of seaborne transport, and by imposing the financial contribution that is disproportionate to the emission volume of international maritime transport sector among other sectors.

Now the 1st generation regulatory package is in force, and it is in the phase of "stability of policy paradigm". We do not know, at this stage, which direction the situation would develop. One scenario is the implementation of the 1st package continues smoothly, and the goal for higher efficiency is achieved: stability is kept. The other scenario would be that there will be lots of modification of the 1st package, such as unnecessary strengthening of the minimum propulsion power requirement or significant alleviation of the EEDI requirement levels in Phase 2 and Phase 3, and the discussion on the 2nd generation package would stagnate. In such a case, the outcome (efficiency improvement) will not be as much as expected. Such "accumulation of inconsequence" might lead to the "collapse of policy paradigm": there will be trial of new policy measures, which may not be deliberate and well thought, and industry players will be put in regulatory confusion.

Ship designers and builders would have to continue the efforts to improve the energy efficiency of ship, to be proactive by strengthening the dialogue with ship owner and operator so that they could fully understand the merits of such ships, and cope with EEDI requirement that will be become stringent step-by-step. In doing so, the total accumulated efforts will be visual in the form of the total emission volume vis-à-vis transport activity in international shipping. Such study of the total GHG emission and improvement in the efficiency should be conducted by the IMO, and this is the best defense to the policy instability and to the politically motivated intervention by international organization other than the IMO.

REFERENCES

IMO, "Update of the 2000 IMO GHG Study", MEPC59/INF.10 (2009).

AKIYOSHI, T. "Transfiguration of public policy and policy science: two regulatory reforms in the air transport industries in the United States and Japan" Tokyo: Yuhikaku, 2007. (in Japanese)

IMO, "2012 Guidelines on the Method of Calculation of the Attained Energy Efficiency Design Index (EEDI) for New Ships", Resolution MEPC.212(63) (2012).

OTSUBO, S. "Designing a Global and Effective Regulatory System to Reduce the CO2 Emission from International Shipping – Challenge for Maritime Industries –", *10th International Propulsion Symposium*, 2010.

MOROTOMI, T., ASANO, K., MORI, A. "Basic theory of environmental policy measures" and "Coping with the uncertainty and policy-mix", *Lecture on Environmental Economics*, Tokyo, Yuhikaku (2008) pp.43-82 (in Japanese)