INTERSESSIONAL MEETING OF THE WORKING GROUP ON REDUCTION OF GHG EMISSIONS FROM SHIPS
6th session
Agenda item 2

ISWG-GHG 6/2/10
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FURTHER CONSIDERATION OF CONCRETE PROPOSALS TO IMPROVE THE OPERATIONAL ENERGY EFFICIENCY OF EXISTING SHIPS, WITH A VIEW TO DEVELOPING DRAFT AMENDMENTS TO CHAPTER 4 OF MARPOL ANNEX VI AND ASSOCIATED GUIDELINES, AS APPROPRIATE

Main elements of the mandatory operational energy efficiency performance rating mechanism and the potential technical solutions

Submitted by China

SUMMARY

Executive summary:	This document provides further explanation of the main elements of the proposed mandatory rating mechanism for the operational energy efficiency performance of ships and recommends some potential technical solutions to help with the decision-making process
Strategic direction, if applicable:	3
Output:	3.2
Action to be taken:	Paragraph 18
Related document:	ISWG-GHG 6/2/9

Introduction

1 In document ISWG-GHG 6/2/9, China proposed a mandatory rating mechanism for the operational energy efficiency performance of ships, as a candidate category A short-term measure to reduce the carbon intensity of international shipping. This document provides a further explanation of the main elements of the proposed mechanism and recommends some potential technical solutions to help with the decision-making process.

2 The empirical analyses provided in this document were carried out based on the annual statistical data obtained from several reputable Chinese shipping companies, between 2012 and 2017. Since a small number of observations are missing for some time periods or for some entities, this data sample is featured as an unbalanced panel data set. The number of ships under observation and the records obtained are shown in table 1.

Table 1: Details of the data sample

Ship type	Ships under observation	Records obtained
Bulker	480	1,566
Tanker	149	549
Container ship	531	1,550

Main elements of the rating mechanism

3 As specified in document ISWG-GHG 6/2/9, the proposed mandatory rating mechanism for operational energy efficiency of ships is quite similar to the "reference line – reduction rate" system of Energy Efficiency Design Index (EEDI) requirements, and it allows a certain range of deviations. The main elements of the mechanism include one or more recognized operational performance or carbon intensity indicators (generally referred to as Carbon Intensity Indicator (CII) to facilitate discussion), a series of predetermined reference lines for different ship types, the carbon intensity reduction rates over time, as well as the acceptable fluctuation rates of the attained CIIs.

Carbon Intensity Indicators

4 Appropriate indicators for operational energy efficiency or carbon intensity of ships have been discussed for years. A general agreement is that different ship types may need different indicators. For the main-stream cargo ships, the most commonly discussed indicators are the Energy Efficiency Operational Indicator (EEOI) and the Annual Efficiency Ratio (AER). Since the statistics on cargo carried on board a ship have been excluded from the IMO fuel oil Data Collection System (IMO DCS) due to commercial sensitivity, the calculation of EEOI cannot be supported by the existing regulatory framework. AER, in comparison, can be supported by IMO DCS, but its distorted results are frequently questioned. This is because a ship carrying more cargo and travelling a longer distance in laden (meaning a better operational condition) would yield a worse metric value in AER.

5 Having considered the operational profiles of different ship types, China proposes an alternative operational indicator for the tramp segments, named the Energy Efficiency Performance Indicator (EEPI). The formulation of EEPI is similar to AER, but the total distance travelled in the denominator of AER has been replaced by the distance travelled whilst laden, as presented by Eq.(1):

$$EEPI = \frac{\sum_i \sum_j F_{ij} \times C_{F_j}}{DWT \times \sum_i d_{laden_i}} \qquad (1)$$

where i is the sequence number of the voyage, j is the fuel type, F_{ij} is the consumption of fuel type j on voyage i ; C_{F_j} is the conversion factor (unitless) of fuel type j when converted from fuel consumption to CO_2 emission; DWT is the ship capacity (deadweight tonnage); and d_{laden_i} is the distance travelled whilst laden on voyage i .

6 EEPI can be applicable to any ship type where the distinction of different loading conditions (in ballast or laden) is possible and can yield metric values quite consistent with EEOI. For ship types which do not conduct a typical ballast voyage, EEPI can still be applied, but the laden distance would be equal to the total distance travelled, thus yielding the same results as AER. A thorough exploration of the performance of EEPI, when compared with AER, can be found in the journal paper *An alternative benchmarking tool for operational energy efficiency of ships and its policy implications* (https://doi.org/10.1016/j.jclepro.2019.118223).

7 If EEPI can be accepted as a better indicator for certain segments, IMO DCS is suggested to be finetuned to additionally include the data of annual total distance travelled whilst laden, where applicable.

Fluctuation in the attained CIIs

8 Unlike the stable design efficiency, the operational energy efficiency performance of a ship is highly volatile and varies with all factors that influence the fuel oil consumption and transport work, including: capacity utilization, sailing speed, displacement, trim, fouling, wind force and sea state. These factors and their interactions make the operational performance of ship rather complex. Therefore, an insight into the fluctuation pattern is an essential prerequisite for operational performance appraisal.

9 To quantify the fluctuation pattern of the operational performance of a ship, the fluctuation rate of attained CII (denoted $F_{\mathrm{CII},t}$) is defined as the difference of its natural log values between adjacent periods t and t-1, calculated as $F_{\mathrm{CII},t} = \ln(\mathrm{CII}_t) - \ln(\mathrm{CII}_{t-1})$. This is because the factual percentage change depends on whether the beginning or ending value is used as the reference, which would yield wide discrepant absolute values when the variation is large. In contrast, using the logarithmic approximation is similar in spirit to taking the average of the beginning and ending values as the denominator in computation. When the exact percentage change is concerned, it can be calculated through an exponential transformation $\exp(F_{\mathrm{CII},t}) - 1$.

10 Based on the data sample described in paragraph 2, the annual fluctuation rates of CIIs of individual ships are calculated, taking EEOI, AER and EEPI as the indicators. The probability density as well as the cumulative probability distribution of the absolute values of $F_{\mathrm{CII},t}$ for each ship type can be found in figure 1. The dashed curves in the graphs are generated by the fitted normal distribution functions using the mean and standard error of the corresponding group of observations.

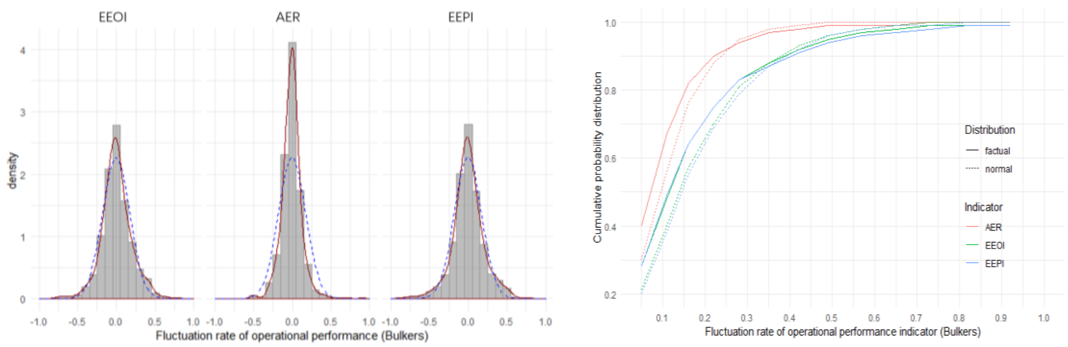

Figure 1(a): Probability density and cumulative probability distribution of $F_{\mathrm{CII},t}$ for bulkers

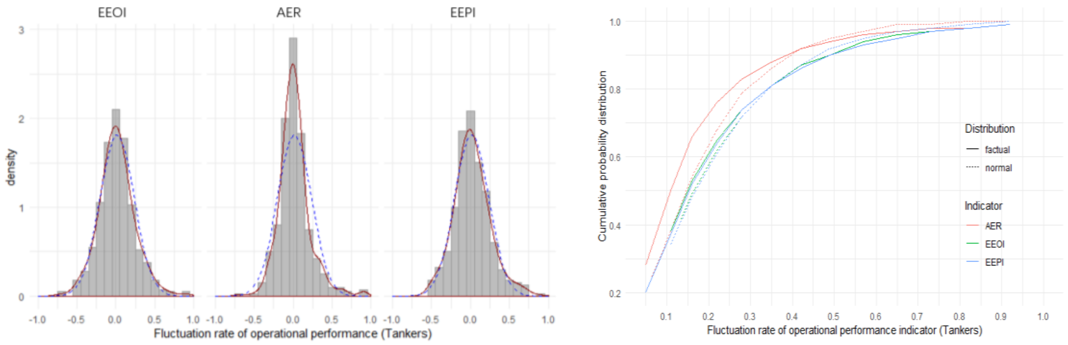

Figure 1(b): Probability density and cumulative probability distribution of $F_{\mathrm{CII},t}$ for tankers

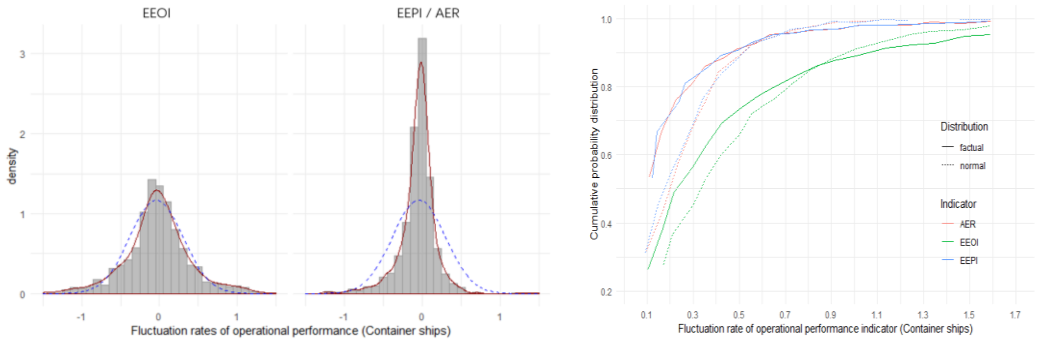

Figure 1(c): Probability density and cumulative probability distribution of $F_{\mathrm{CII},t}$ for containerships

11 Based on the estimated cumulative probability distribution functions, the absolute values of $F_{\mathrm{CII},t}$ on typical quantiles for different ship types can be derived, as presented in table 2. All data shown have been rounded on 0.05.

Table 2: Absolute values of $F_{\mathrm{CII},t}$ on typical quantiles of the cumulative probability distribution

Ship type	CII	Absolute fluctuation rates of CIIs ($F_{\mathrm{CII},t}$)			
		1st quartile	Median	3rd quartile	0.95 quantile
Bulker	EEOI	<0.05	0.10	0.20	0.50
	EEPI	<0.05	0.10	0.20	0.50
	AER	<0.05	0.10	0.15	0.30
Tanker	EEOI	<0.10	0.15	0.30	0.60
	EEPI	<0.10	0.15	0.30	0.65
	AER	<0.05	0.10	0.20	0.50
Containership	EEOI	0.10	0.25	0.50	1.50
	EEPI/AER	<0.05	<0.10	0.20	0.65

12 As shown in figure 1 and table 2, the absolute fluctuation rates of CIIs are quite high. For the bulk carriers, more than 5% of the absolute annual fluctuation rates of EEOI and EEPI can reach above 0.50 (meaning that in more than 5% of cases, for instance, the attained EEOIs or EEPIs may increase from 20 gCO_2/t.nm to 30 gCO_2/t.nm), and half are above 0.10 (meaning that in more than 50% of cases, for instance, the attained EEOIs or EEPIs may increase from 20 gCO_2/t.nm to 22 gCO_2/t.nm). For the oil tankers, more than 5% of the absolute annual fluctuation rates of EEOI and EEPI can reach above 0.60, and half are

above 0.15. The operational performance of the containerships is the most volatile. More than 5% of the absolute annual fluctuation rates of EEOI can reach above 1.50, and half are above 0.25. The probability distribution patterns of the CIIs for all ship types under observation are leptokurtic and fat tailed, rather than normally distributed. This means that although more data points concentrate around the mean when compared with a normal distribution, there are also unneglectable amounts of observations lay far away.

The acceptable fluctuation rates of CIIs

13 The extremely high volatility in operational performance of ships implies that the rigorous "reference value – reduction rate" mechanism for EEDI cannot be applicable to CIIs. Otherwise, ships may risk failing to meet the requirements even if they had made all efforts within their capacity, or unfairly rewarded due to a superficially excellent performance by luck. To gauge the operational performance, a relatively broad approach is more suitable. The key is to identify an appropriate scale, which should be sensitive enough to reflect substantial changes, while is tolerant to factors partly under control and robust to random influences. A possible strategy is to assign an A to C rating to a ship based on achieved annual CIIs, indicating a superior, moderate or inferior performance respectively. For a given maximum acceptable fluctuation rate k and a reference operational performance level CII_{ref}, the moderate performance range (Level B) can be defined as within the band $(1 \pm k)\mathrm{CII}_{ref}$. Thus, an achieved CII higher than $(1+k)\mathrm{CII}_{ref}$ is rated as Level C, and an achieved CII lower than $(1-k)\mathrm{CII}_{ref}$ is rated as Level A.

14 Since some influencing factors are completely beyond control, the scale of the fluctuation induced by these factors should be taken as the lower limit of the acceptable fluctuation rate. The upper limit of acceptable fluctuation rate can be defined as the scale below which at least 95% of the annual fluctuation rates observed can be covered. Within this range, the choice of an acceptable fluctuation rate k mainly depends on the extent to which the volatility in operational performance is believed controllable.

15 For demonstration purposes, table 3 shows a series of selected acceptable fluctuation rates (k), while the graphs in figure 3 present the detailed rating results. Using these selected acceptable fluctuation rates (k), the proportion of ships rated as level B is about 60%-70%, while the ships rated as Level A and Level C are about 10%-20% of the total respectively. A smaller value of k would result in a smaller proportion of Level B ships, and a larger proportion of Level A and Level C ships. Given the roughly balanced distribution of the ships holding different ratings, the overall operational performance of the fleet segment can be represented by the reference lines (or in combination with a reduction rate) across the median values of CIIs of individual ships.

Table 3: Selected acceptable fluctuation rates of CIIs for different ship types

Ship types	**selected acceptable fluctuation rates (k) of CIIs**		
	EEOI	EEPI	AER
Bulker	0.20	0.20	0.15
Tanker	0.35	0.30	0.30
Containership	0.45	0.30	0.30

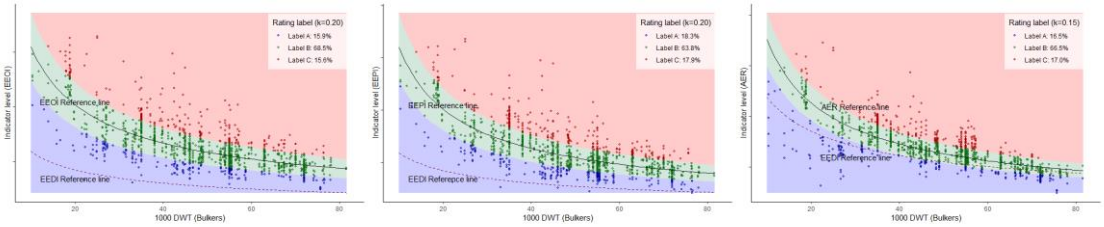

Figure 3(a): Rating results of bulkers based on the given k values

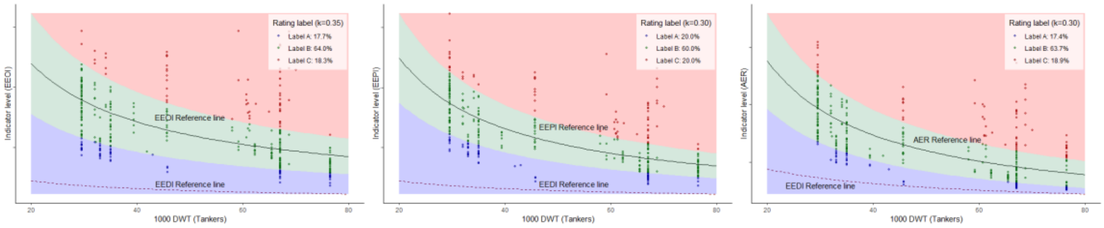

Figure 3(b): Rating results of tankers based on the given k values

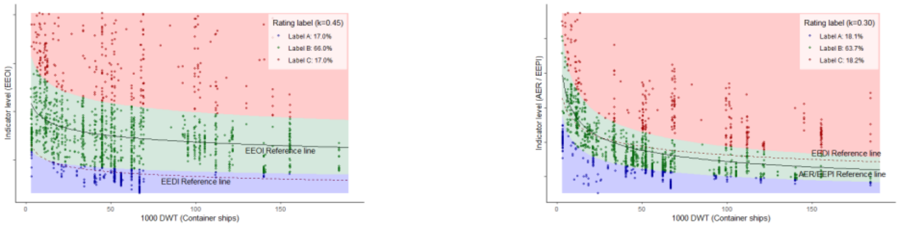

Figure 3(c): Rating results of containerships based on the given k values

The reference lines and reduction rates of CIIs for different ship types

16 In demonstrating the acceptable fluctuation rates of CIIs, the reference lines of CIIs for different ship types were estimated through quantile regressions, using the historical operational performance of ships between 2012 and 2017 as samples. To develop a series of reference lines in line with the Initial IMO GHG Strategy, the operational performance of different ship segments for the year 2008 is needed. These estimations are expected to be provided by the Fourth IMO GHG Study, which will be finalized by MEPC 76 in autumn 2020. The reduction rates of CIIs over time are mostly a policy decision, which should be made taking into account the 2008 base year level, the operational performance trends since after, and the levels of ambition claimed in the Initial Strategy. It is recommended that the reference lines and reduction rates of CIIs for different ship types should be different, given the different operational features and the various improvement potential.

Conclusions and proposal

17 Decisions on all the key elements of the proposed rating mechanism rely on data. The technical solutions proposed by this document are mainly for demonstration purposes. A comprehensive empirical analysis is needed and should be treated as an urgent task. Such an analysis should at least cover the following key issues: the suitable carbon intensity indicators, the 2008 operational energy efficiency performance (the reference lines) as well as the carbon intensity trends since after, the fluctuation patterns of CIIs and the contribution of major influencing factors, and the acceptable fluctuation rates of CIIs. Based on the research findings, the associated guidelines or guidance can be revised or developed as necessary.

Action requested of the Working Group

18 The Group is invited to consider the proposal set out in this document and take action as appropriate.

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