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MariEMS Learning Material

This is the 27th compilation by Professor Dr Reza Ziarati on the work of the EU funded Erasmus + MariEMS' partners and material extracted from the IMO TTT Course. The material is composed from Chapter 27 of the learning material. Readers are also advised to refer to the papers on IdeaPort and IdealShip projects led by C4FF and published by MariFuture.

27. Energy Efficiency Operational Indicator (EEOI)

27.1 Introduction

EEOI is one element of the IMO regulatory framework that is intended to act as an "energy efficiency performance indicator" during the operational phase of the ship and be used to monitor overall ship energy efficiency performance. IMO Guidelines "MEPC.1/Circ.684" provide the methodology and basis for EEOI development and calculations. In this section, extracts of these Guidelines are provided in order to further understand the EEOI purpose and method of calculation. Additionally, information will be provided on the experience so far in the use of EEOI.

The purpose of EEOI, according to IMO guidelines, is to establish a consistent approach for measuring a ship's energy efficiency for each voyage or over a certain period of time. The EEOI is expected to assist ship-owners and ship operators in the evaluation of the operational performance of their fleet. It is hoped that it will enable the monitoring of individual ships in operation and thereby the results of any changes made to the ship or its operation. In fact The EEOI is advocated to be used as a monitoring tool in the SEEMP.

EEOI, similar to EEDI, represents the amount of CO_2 emissions from a ship per unit of cargo-mile transport service (with a unit of gCO_2/tonne.mile). However as against the EEDI that is defined for one operating point of a ship, EEOI represents the actual CO_2 emission from combustion of all types of fuels on board a ship during each voyage, which is calculated by multiplying total fuel consumption for each type of fuel (distillate fuel, refined fuel or LNG, etc.) with the respective carbon factor of each fuel. The performed transport work is calculated by multiplying the actual mass of cargo (tonnes, number of TEU/cars, or number of passengers) and the corresponding actual distance in nautical mile travelled by the vessel.

At this stage, IMO has developed the EEOI to encourage ship-owners and ship operators to use it on a voluntary basis and to collect information on the outcome and experiences in applying it. So far, the feedback received on effectiveness of EEOI as a monitoring tool has been mixed.

The rest of this section is taken mostly from IMO Guidelines [MEPC.1/Circ.684] with some textual adjustments. The main aim of the section is to become familiar with the IMO guidelines and how EEOI is calculated.

27.2 Background and objectives

The EEOI guidelines can be used to establish a consistent approach for the voluntary use of an EEOI, which will assist ship-owners, ship operators and parties concerned in the evaluation of the performance of their fleet with regard to CO_2 emissions. As the amount of CO_2 emitted from a ship is directly related to its actual fuel consumption, the EEOI can also provide useful information on a ship's performance with regard to its operational fuel efficiency. The objective of the IMO guidelines is to

provide the users with assistance in the process of establishing a mechanism to achieve the limitation or reduction of GHG emissions from ships in operation. The EEOI guidelines are intended to provide an example of a calculation method which could be used as an objective, performance-based approach to monitor the efficiency of a ship's operation. The EEOI Guidelines are recommendatory in nature and present a possible use of an operational indicator. However, ship-owners, ship operators and parties concerned may implement either the IMO guidelines or an equivalent method in their environmental management systems and consider adoption of the principles therein when developing plans for performance monitoring.

27.3 Basic definitions

To help with consistent estimation of EEOI, the following definitions are provided in the EEOI guidelines:

Fuel consumption: Fuel consumption is defined as all fuels consumed at sea and in port or for a voyage or period in question (e.g., a day), by main, auxiliary engines, boilers and incinerators.

Distance sailed: Distance sailed means the actual distance sailed in nautical miles (deck log-book data) for the voyage or period in question.

Ship and cargo types: The EEOI guidelines are applicable for all ships performing transport work. The types of cargo are generic and include but not limited to: all gas, liquid and solid bulk cargo, general cargo, containerized cargo, heavy lifts, frozen and chilled goods, timber and forest products, cargo carried on freight vehicles, cars and freight vehicles on Ro-Ro ferries and passengers (for passenger and Ro-Ro passenger ships).

Cargo mass carried or work done: In general, cargo mass carried or work done is expressed as follows:

- For dry cargo carriers, liquid tankers, gas tankers, ro-ro cargo ships and general cargo ships, metric tonnes (t) of the cargo carried should be used;
- For containerships carrying solely containers, number of containers (TEU) or metric tons (t) of the total mass of cargo and containers should be used;
- For ships carrying a combination of containers and other cargoes, a TEU mass of 10 t could be applied for loaded TEUs and 2 t for empty TEUs; and
- For passenger ships, including ro-ro passenger ships, number of passengers or gross tonnes of the ship should be used;

In some particular cases, work done can be expressed as follows:

- For car ferries and car carriers, number of car units or occupied lane metres;
- For containerships, number of TEUs (empty or full); etc.

It should be generally noted that for specific cases, the choice of cargo definition should fit the purpose of energy management and may vary from one company to the other.

Voyage: Voyage generally means the period between a departure from a port to the departure from the next port. Alternative definitions of a voyage could also be acceptable.

Consistent implementation of the above definitions in a company is essential for subsequent benchmarking of energy performance indicators such as EEOI across the fleet.

27.4 Establishing the EEOI

Calculation formula

The basic expression for EEOI for a voyage is defined as:

$$EEOI = \frac{\sum_j FC_j \leftrightarrow C_{Fj}}{m_{cargo} \leftrightarrow D} \qquad (1)$$

The guidelines allow averaging of EEOI over a number of voyages. Where the average of the indicator for a period or for a number of voyages is obtained, the EEOI is calculated as:

$$AverageEEOI = \frac{\sum_i \sum_j (FC_{ij} \leftrightarrow C_{Fj})}{\sum_i (m_{cargo,i} \leftrightarrow D)} \qquad (2)$$

Where:

- j is the fuel type;
- i is the voyage number;
- FC_{ij} is the mass of consumed fuel j at voyage i;
- C_{Fj} is the fuel mass to CO2 mass conversion factor for fuel j;
- m_{cargo} is cargo carried (tonnes) or work done (number of TEU or passengers) or gross tonnes for passenger ships; and
- D is the distance in nautical miles corresponding to the cargo carried or work done.

The unit of EEOI depends on the measurement of cargo carried or work done, e.g., tonnes CO_2/ (tonnes .nautical miles), tonnes CO_2/ (TEU·nautical miles), tonnes CO_2/ (person·nautical miles), etc. It should be noted that Equation (2) does not give a simple average of EEOI among the number of voyages; thus simple averaging of the voyages' EEOI must be avoided. Instead, for using the average value as a performance indicator, calculation of rolling average is used.

Rolling average

Rolling average, when used, can be calculated in a suitable time period, for example one year or a number of voyages, for example six or ten voyages, which are agreed as statistically relevant to the initial averaging period. The rolling average EEOI is then calculated for this period or number of voyages by Equation (2) above using the following technique. For a series of voyages (e.g. for 20 voyages), the first element of the rolling average (e.g. for a subset of 4 voyages) is obtained by taking the average of the initial number of voyages (e.g. initial 4). Then the subset is modified by "shifting forward"; that is, excluding the first voyage in the previous subset (e.g. voyage 1) and including the next voyage (e.g. voyage 5). This new subset number two will give the second rolling average element. This process continues until all voyages are covered.

Data sources

Primary data sources selected could be the ship's log-book (bridge log-book, engine log-book, deck log-book and other official records). It is important that sufficient information is collected on the ship with regard to fuel type and quantity, distance travelled and cargo type so that a realistic assessment can be generated.

Amount and type of fuel used (bunker delivery notes or other sources) and distance travelled (according to the ship's log-book or other sources) need to be documented by the ship on a consistent basis. The whole process may be automated if possible.

Fuel mass to CO_2 mass conversion factors (C_F)

C_F is a non-dimensional conversion factor between fuel consumption and CO_2 emissions produced. It is used in EEOI formula; see Equations (1) and (2). The value of C_F according to IMO guidelines is given in Table 6.1.

Type of fuel	Reference	Carbon content	C_F (t-CO_2/t-Fuel)
Diesel/Gas Oil	ISO 8217 Grades DMX through DMC	0.875	3.206000
Light Fuel Oil (LFO)	ISO 8217 Grades RMA through RMD	0.86	3.151040
Heavy Fuel Oil (HFO)	ISO 8217 Grades RME through RMK	0.85	3.114400
Liquefied Petroleum Gas (LPG)	Propane Butane	0.819 0.827	3.000000 3.030000
Liquefied Natural Gas (LNG)		0.75	2.750000

Table 27.4.1: Carbon factor of marine fuels

Data collection template

For a voyage or period (e.g., a day), data on fuel consumption/cargo carried and distance sailed in a continuous sailing pattern could be collected as shown in the reporting sheet below, Table 27.4.2.

Name and type of ship						
Voyage or day (i)	Fuel consumption at sea and in port in tonnes				Voyage or time period data	
	Fuel type ( )	Fuel type ( )	Fuel type ( )	...	Cargo (m) (tonnes or units)	Distance (D) (NM)
1						
2						
3						
4						

Note: For voyages with m_{cagro}=0, it is still necessary to include the fuel used during this voyage in the summation above the line.

Table 6.2:- EEOI data reporting sheet (template) [MEPC.1/Circ.684]

The above template is from IMO guidelines; however alternative templates may be used for the purpose if required.

27.5 Further aspects

Main calculation steps

The EEOI should be a representative value of the energy efficiency of the ship operation over a consistent period which represents the overall trading pattern of the vessel. In order to establish the EEOI, the following main steps will generally be needed:

- Define the period for which the EEOI is calculated
- Define data sources for data collection
- Collect data
- Convert data to appropriate format; and finally
- Calculate EEOI.

Data recording and documentation procedures

Ideally, the data recording method used should be uniform so that information can be easily collated and analysed to facilitate the extraction of the required information. The collection of data from ships should include the distance travelled, the quantity and type of fuel used, and all fuel information that may affect the amount of carbon dioxide emitted.

Monitoring and verification

Documented procedures to monitor and measure, on a regular basis, should be developed and maintained. It is important that the source of figures established are properly recorded, the basis on which figures have been calculated and any decisions on difficult or grey areas of data. This will provide assistance on areas for improvement and be helpful for any later analysis.

Ship and shore responsibility

Based on IMO guidelines and in order to avoid unnecessary administrative burdens on ships' staff, it is recommended that monitoring of an EEOI should be carried out by shore staff, utilizing data obtained from existing required records such as the official and engineering log-books and oil record books, etc. The necessary data could be obtained during internal audits under the ISM Code, routine visits by superintendents, etc.

27.6 References and further reading

1. MEPC.1/Circ.684, "Guidelines for voluntary use of the ship EEOI", MEPC.1/Circ.684, 17 August 2009.
2. Resolution MEPC.203(62) "Amendments to the Annex of the Protocol of 1997 to amend the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978" relating thereto (Inclusion of regulations on energy efficiency for ships in MARPOL Annex VI), IMO MEPC, adopted 15 July 2011.
3. Resolution MEPC.212 (63): "2012 Guidelines on the Method of Calculation of the Attained EEDI for new ships", Adopted by IMO MEPC on 2 March 2012.
4. Resolution MEPC.213 (63), "2012 Guidelines for the development of a ship energy efficiency management plan (SEEMP)" IMO MEPC, Adopted on 2 March 2012.
5. Resolution MEPC.214 (63): "2012 Guidelines on Survey and Certification of the EEDI", IMO MEPC, adopted on 2 March 2012.
6. Resolution MEPC.231 (65): 2013 Guidelines for calculation of reference lines for use with the energy efficiency design index (EEDI), adopted in 2013.
7. Resolution MEPC.232 (65): 2013 Interim Guidelines for determining minimum propulsion power to maintain the manoeuvrability.
8. Resolution MEPC.233 (65): 2013 Guidelines for calculation of reference lines for use with the Energy Efficiency Design Index (EEDI) for cruise passenger ships having non-conventional propulsion.
9. ABS "Ship Energy Efficiency Measures, Status and Guidance", http://ww2.eagle.org/content/dam/eagle/publications/2013/Energy%20Efficiency.pdf, cited September 2015.
10. IMO MARPOL Annex VI, 2013, "MARPOL Annex VI and NTC 2008 with Guidelines for Implementation, 2013 Edition, IMO.
11. Resolution MEPC.229 (65), "Promotion of Technical Co-Operation and Transfer of Technology Relating to the Improvement of Energy Efficiency of Ships", Adopted on 17 May 2013.
12. MEPC.1/Circ.795.rev1 Unified Interpretations to MARPOL Annex VI (2014).

13. MEPC.1/Circ.815: 2013 Guidance on treatment of innovative energy efficiency technologies for calculation and verification of the attained EEDI for ships in adverse conditions.
14. Resolution MEPC.254 (67): 2014 Guidelines on Survey and Certification of EEDI (one amendments made in MEPC 68).
15. Resolution MEPC.245 (66): 2014 Guidelines on the method of calculation of the Attained Energy Efficiency Design Index (EEDI) for new ships, adopted 4 April 2014.
16. Resolution MEPC.251 (66): Amendments to MARPOL Annex VI and the NOX Technical Code 2008 (Changes to Regs. 2, 13, 19, 20 and 21 and …. and certification of dual-fuel engines under the NOX Technical Code 2008), Adopted on 4 April 2014.
17. Resolution MEPC.245 (66): 2014 Guidelines on the Method of Calculation of the Attained EEDI for new ships, Adopted on 2 March 2012.
18. Industry Guidelines (2015): 2015 Industry guidelines on calculation and verification of Energy Efficiency Design Index, MEPC 68 / INF.30.
19. OCIMF "Example of a Ship Energy Efficiency Management Plan", Submission to IMO, MEPC 62/INF.10, 8 April 2011.
20. Resolution MEPC.260(68) , Amendments to the 2011 Guidelines Addressing Additional Aspects to the NO_x Technical Code 2008 with Regard to Particular Requirements Related to Marine Diesel Engines Fitted with Selective Catalytic Reduction (SCR) Systems (Resolution MEPC.198(62)), adopted on 15 May 2015.
21. Resolution MEPC.259 (68), 2015 Guidelines for Exhaust Gas Cleaning Systems, adopted on 15 May 2015.
22. Resolution MEPC.261 (68), "Amendments to the 2014 Guidelines on Survey and Certification of the Energy Efficiency Design Index (EEDI)", (Resolution MEPC.254 (67)), adopted on 15 May 2015.
23. Resolution MEPC.262(68), "Amendments to the 2013 Interim Guidelines for
24. Determining Minimum Propulsion Power to Maintain the Manoeuvrability of Ships in Adverse Conditions", (Resolution MEPC.232 (65), as amended by Resolution MEPC.255 (67)), adopted on 15 May 2015.
25. Resolution MEPC.263 (68), "Amendments to the 2014 Guidelines on the Method of Calculation of the Attained Energy Efficiency Design Index (EEDI) for New Ships, (Resolution MEPC.245 (66)), adopted on 15 May 2015.