Implementing Energy Efficiency Design Index (EEDI)

IRCLASS
Indian Register of Shipping

What is EEDI?

Energy Efficiency Design Index (EEDI), formulated for new ships, is an index that estimates grams of CO_2 per transport work (g of CO_2 per tonne-mile).

It can be expressed as the ratio of **"environmental cost"** divided by **"Benefit for Society"**.

$$EEDI = \frac{\text{Impact to environment}}{\text{Benefit for society}}$$

In other words,

$$EEDI = \frac{CO_2 \text{ Emission}}{\text{Transport Work}}$$

It is a function of

- Installed power
- Speed of vessel
- Cargo carried

The philosophy behind EEDI is that its computation be simple and capable of broad application, and promote efforts by all stakeholders to reduce CO_2 emissions by reflecting a ship's energy efficiency in actual use.

It stimulates continued technical development of all the components influencing the fuel efficiency of a ship. It also separates the technical and design-based measures from the operational and commercial ones.

The document aims at updating the industry on matters related to EEDI and its application and impact.

EEDI Genesis

The GHG study conducted by IMO in 2000 resulted into an operational CO_2 index. It was accepted at IMO that such an index should reflect only the technical aspects such as the optimization of engines, hull and propeller or the use of non-fossil fuels, and **not the operational or commercial aspects.** This led to the refinement of the index. After much deliberation in its Marine Environmental Protection Committee's various sessions, the current empirical formulation was accepted. The formulations, which were recommended at different stages, are given below.

$$CO_2 Index = \frac{\sum_i FC_i * C_{carbon}}{\sum_i m_{cargo,i} * D_i}$$

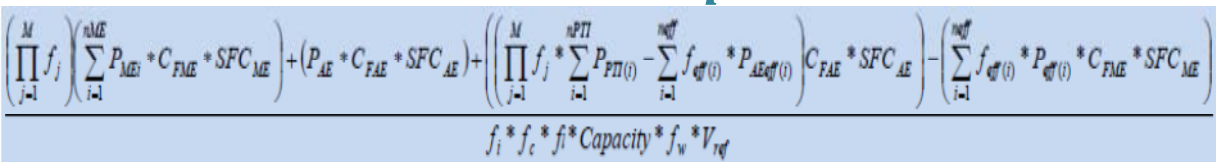
$$I = \frac{AFC * Power * (0.85 + 0.10) * 3.17}{DWT * Speed}$$

$$\frac{\left(\prod_{j=1}^{M} f_j\right)\left(\sum_{i=1}^{nME} C_{FMEi} SFC_{MEi} P_{MEi}\right) + P_{AE} C_{FAE} SFC_{AE} + \left(\sum_{i=1}^{nPTI} P_{PTIi} - \sum_{i=1}^{nWHR} P_{WHRi}\right) C_{FAE} SFC_{AE} - \left(\sum_{i=1}^{neff} f_{eff} P_{eff} C_{Feff} SFC_{MEi}\right)}{f_i Capacity \quad V_{ref} \quad f_W}$$

$$\frac{\left(\prod_{j=1}^{M} f_j\right)\left(\sum_{i=1}^{nME} P_{MEi} * C_{FME} * SFC_{ME}\right) + \left(P_{AE} * C_{FAE} * SFC_{AE}\right) + \left(\left(\prod_{j=1}^{M} f_j * \sum_{i=1}^{nPTI} P_{PTI(i)} - \sum_{i=1}^{neff} f_{eff(i)} * P_{AEeff(i)}\right) C_{FAE} * SFC_{AE}\right) - \left(\sum_{i=1}^{neff} f_{eff(i)} * P_{eff(i)} * C_{FME} * SFC_{ME}\right)}{f_i * f_c * fi * Capacity * f_w * V_{ref}}$$

EEDI is applicable to new ships. It is intended to ensure that new ships are designed to be energy efficient. It cannot be used as a performance indicator of the operational energy efficiency of the existing fleet of vessels.

EEDI Formula – Parameters explained



Parameter	Description	Source
C_F	Non-dimensional conversion factor between fuel consumption and CO_2 emission	MEPC 245(66) "2014 Guidelines on the calculation of the Attained EEDI for new ships"
V_{ref}	Ship speed in nautical miles per hour	At design Stage- Speed-power curves obtained from model testing At final Stage- Sea Trial Report
Capacity	Computed as a function of Deadweight as indicated in 2.3 and 2.4 of MEPC 245(66) "2014 Guidelines on the calculation of the Attained EEDI for new ships"	Stability Booklet
P_{ME}	75% of the main engine MCR in kW	NOx Technical File
P_{AE}	Auxiliary Engine Power	MEPC 245(66) "2014 Guidelines on the calculation of the Attained EEDI for new ships"
P_{PTI}	75% of rated power consumption of shaft motor	
P_{eff}	Output of innovative mechanical energy efficient technology for propulsion at 75% main engine power	
P_{AEeff}	Auxiliary power reduction due to innovative electrical energy efficient technology	
SFC	Certified Specific Fuel Consumption in g/kWh	NOx Technical file
f_j	Correction factor to account for ship specific design elements. (For e.g. ice classed ships, shuttle tankers)	MEPC 245(66) "2014 Guidelines on the calculation of the Attained EEDI for new ships"
f_w	Non dimensional coefficient indicating the decrease of speed in representative sea condition of wave height, wave frequency and wind speed	
f_i	Capacity factor for any technical / regulatory limitation on capacity	
f_c	Cubic capacity correction factor (for chemical tankers and gas carriers)	
f_l	Factor for general cargo ships equipped with cranes and other cargo-related gear to compensate in a loss of deadweight of the ship	
f_{eff}	Availability factor of innovative energy efficiency technology	MEPC.1/Circ.815

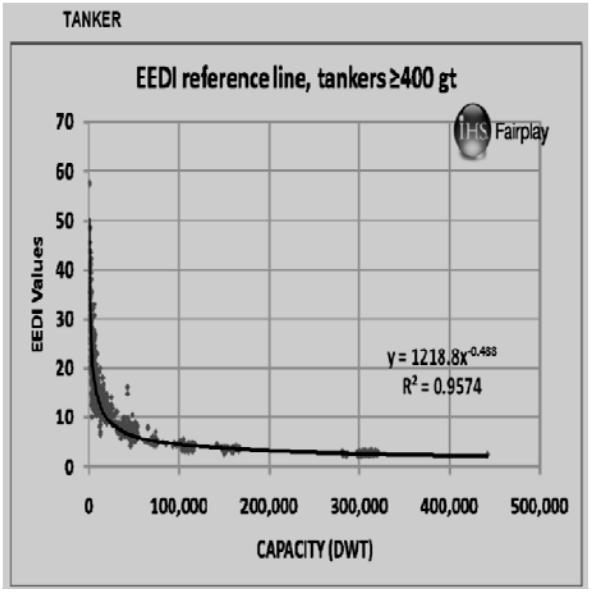
The EEDI expresses the impact to environment from shipping Vs the benefit to society from shipping. The EEDI formula takes into consideration special design features and needs, including the use of energy recovery, the use of low carbon fuels, performance of ships in waves and the need for ice strengthening of certain ships. The handling of certain design features such as electric propulsion is still subject to evaluation. The EEDI has a constant value that will only be changed if the design is altered. There are some ship types where the EEDI, in units per nautical-mile, may be considered less meaningful or relevant. This, and the possible need for a minimum size threshold, suggests that the units in which EEDI is measured may need modification to address some ship types and ship sizes, and that the EEDI may not be practically applicable to all ship types. However, large cargo ships can be covered and these ships account for a significant share of emissions.

$$EEDI = \frac{\text{Impact to environment}}{\text{Benefit to society}} = \frac{\text{Power*SFC* FC}}{\text{Deadweight *speed}}$$

EEDI Baseline

"A reference line (baseline) is defined as a curve representing an average index value fitted on a set of individual index values for a defined group of ships."

Reference line = a (Capacity) $^{-c}$
Where, *a* and *c* are constants determined from the regression curve fit.

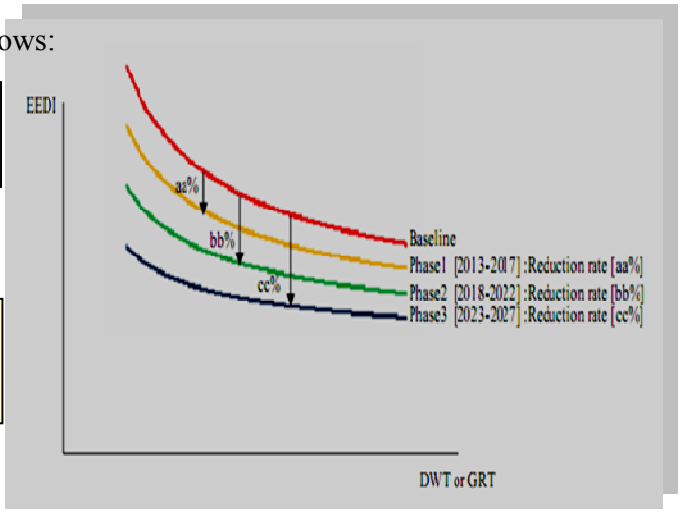


How EEDI is applied?

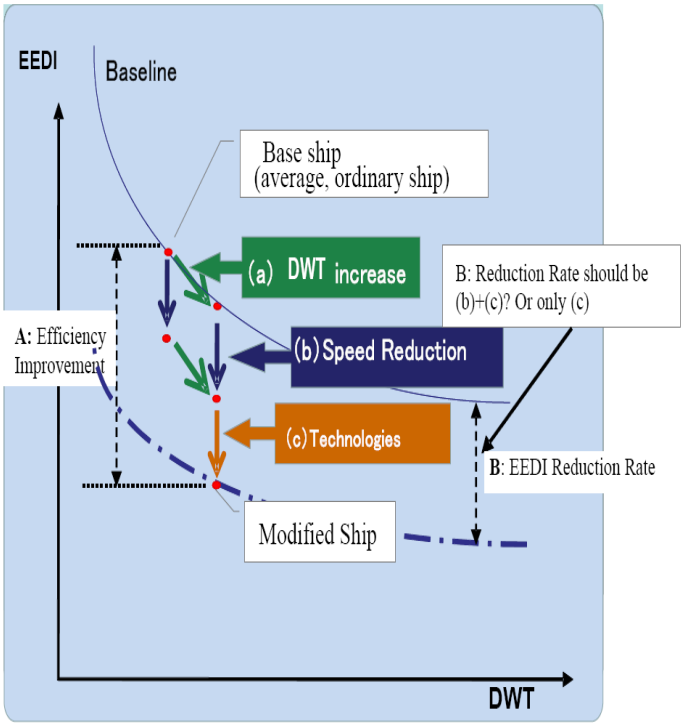
For each new ship the attained EEDI shall be as follows:

$$\text{Attained EEDI} \leq \text{Required EEDI} = \left(1 - \frac{X}{100}\right) * \textit{Baseline}$$

Reduction rate "X" would be determined according to year of built for new ships in phases



How to improve EEDI?



Technologies

- Hulls with less resistance and improved steering configurations.
- More efficient aft-ship, propeller and rudder arrangements.
- Lower energy consumption in main and auxiliary engines.
- Switch from oil to natural gas as main fuel.
- Miscellaneous technologies to reduce minor energy consumers (deck paint, pipe insulation, lighting, air conditioning, etc.)
- Zero or minimum ballast configurations (e.g., by alternative design or ship type)
- Marine fuel cells (longer term); and Hybrid ships (e.g., wind power, solar panels, and use of light materials, etc.) (longer term)

Applicable Ship Types and Reduction Factors (in %)

Ship Type	Size	Phase 0 1 Jan 2013 – 31 Dec 2014	Phase 1 1 Jan 2015 - 31 Dec 2019	Phase 2 1 Jan 2020 – 31 Dec 2024	Phase 3 1 Jan 2025 and onwards
Bulk Carrier	20,000 DWT and above	0	10	20	30
	10,000 – 20,000 DWT	n/a	0-10*	0-20*	0-30*
Gas Carrier	10,000 DWT and above	0	10	20	30
	2,000 – 10,000 DWT	n/a	0-10*	0-20*	0-30*
Tanker	20,000 DWT and above	0	10	20	30
	4,000 – 20,000 DWT	n/a	0-10*	0-20*	0-30*
Container Ship	15,000 DWT and above	0	10	20	30
	10,000 – 15,000 DWT	n/a	0-10*	0-20*	0-30*
General Cargo Ship	15,000 DWT and above	0	10	15	30
	3,000 – 15,000 DWT	n/a	0-10*	0-15*	0-30*
Refrigerated Cargo Carrier	5,000 DWT and above	0	10	15	30
	3,000 – 5,000 DWT	n/a	0-10*	0-15*	0-30*
Combination Carrier	20,000 DWT and above	0	10	20	30
	4,000 – 20,000 DWT	n/a	0-10*	0-20*	0-30*
LNG Carrier ***	10,000 DWT and above	n/a	10**	20	30
Ro-ro cargo ship (vehicle carrier)***	10,000 DWT and above	n/a	5**	15	30
Ro-ro cargo ship***	2,000 DWT and above	n/a	5**	20	30
	1,000 – 2,000 DWT	n/a	0-5* **	0-20*	0-30*
Ro-ro passenger ship***	4,000 GT and above	n/a	5**	20	30
	1,000 - 4,000 GT	n/a	0-5* **	0-20*	0-30*
Cruise passenger ship*** having non-conventional propulsion	85,000 GT and above	n/a	5 **	20	30
	25,000 – 85,000 GT	n/a	0-5* **	0-20*	0-30*

*** Reduction factor to be linearly interpolated between the two values depending upon vessel size. The lower value of the reduction factor is to be applied to the smaller size.**

**** Phase 1 commences for those ships on 1st September 2015**

***** Reduction rate applies those ships delivered on or after 1st September 2019.**
A ship *delivered on or after* 1 September 2019 means a ship:
.1 for which the building contract is placed on or after 1 September 2015; or
.2 in the absence of a building contract, the keel of which is laid, or which is at a similar stage of construction, on or after 1 March 2016; or
.3 the delivery of which is on or after 1 September 2019."

n/a means that no "required EEDI" applies.

Reduction rate "X" would be as given in the above table

$$\text{Attained EEDI} \leq \text{Required EEDI} = \left(1 - \frac{X}{100}\right) * Baseline$$

Reference line value (baseline) shall be calculated as follows:
Reference line value = $a \times b^{-c}$
where a, b and c are the parameters given below:

Ship type	a	b	c
Bulk carrier	961.79	DWT of the ship	0.477
Gas carrier	1120.00	DWT of the ship	0.456
Tanker	1218.80	DWT of the ship	0.488
Container ship	174.22	DWT of the ship	0.201
General cargo ship	107.48	DWT of the ship	0.216
Refrigerated cargo carrier	227.01	DWT of the ship	0.244
Combination carrier	1219.00	DWT of the ship	0.488
Ro-ro cargo ship (vehicle carrier)	$(DWT/GT)^{-0.7} * 780.36$ where DWT/GT<0.3 1812.63 where DWT/GT≥0.3	DWT of the ship	0.471
Ro-ro cargo ship	1405.15	DWT of the ship	0.498
Ro-ro passenger ship	752.16	DWT of the ship	0.381
LNG carrier	2253.7	DWT of the ship	0.474
Cruise passenger ship having non-conventional propulsion	170.84	GT of the ship	0.214

Certification of EEDI

Design Stage

For the preliminary verification at the design stage, a Ship Owner or a Shipbuilder is to submit to a verifier (Administration or its RO) an EEDI Technical File containing the necessary information for the verification and other relevant background documents. EEDI Technical File, which is to be developed by either a Ship Owner or a Shipbuilder, is to include at least but not limited to:

- Dead weight and shaft power of main and aux. Engines;
- Ship speed on deep water in the maximum design loaded conditions at the 75% of the maximum continuous rate (MCR) for the main engine;
- Specific fuel consumption (SFC) of the main engine at 75% MCR and auxiliary engines;
- Principal particulars, overview of propulsion system and electricity supply system on board;
- Estimation process and methodology of the power curves at design stage;
- Description of energy saving equipment; and
- Calculated value of the Attained EEDI.

The verifier is to issue the report on the preliminary verification of EEDI after verifying the attained EEDI at design stage.

Sea Trials Stage

Prior to the sea trial, a Ship Owner is to submit the final displacement table and the measured lightweight, or a copy of the survey report of deadweight, as well as a copy of NO_x Technical File as necessary.

The verifier is to attend the sea trial and confirm:

- Propulsion and power supply system;
- Particulars of the engines;
- Other relevant items described in the EEDI Technical File;
- Draft and trim, sea conditions; and
- Ship speed, shaft power of the main engine.

The verifier is to issue the report on the verification of EEDI after verifying the attained EEDI after the sea trial and it is proposed to issue an International Energy Efficiency (IEE) certificate. An illustration of the basic flow of certification process is shown in the adjacent figure.

DOCUMENTS TO BE SUBMITTED BY SHIPYARD

1. Design Stage

S.No.	Document	Description/Remarks
1.	EEDI Technical File	EEDI Technical File as defined in MEPC.254(67) "2014 Guidelines for survey and certification of EEDI"
2.	NOx Technical File	Copy of the NOx Technical File and documented summary of the SFC correction for each type of main and auxiliary engine with copy of EIAPP certificate. Note: if the NOx Technical File has not been approved at the time of the preliminary verification, the SFC value is to be provided by the engine manufacturer. In such cases, the NOx Technical File should be submitted at the final verification stage.
3.	Electric Power Table (Load Chart)	If P_{AE} is significantly different from the values computed using the formula in IMO Calculation Guidelines (Res. MEPC 245(66))
4.	Lines Plan of the ship and model particulars	- Report including the particulars of the ship model and propeller model
5.	Power curves	Power-speed curves predicted at full scale in sea trial condition (ballast condition) and EEDI condition (fully-loaded condition)
6.	a) Description of the tank test facility b) Tank test organization quality manual	If the verifier (flag administration or its RO) has no recent experience with the tank test facility and the tank test organization quality system is not ISO 9001 certified. - Quality management system of the tank test including process control, justifications concerning repeatability and quality management processes - Records of measuring equipment calibration - Standard model-ship extrapolation and correlation method (applied method and tests description)
7.	Gas fuel oil general arrangement plan	If gas fuel is used as the primary fuel of the ship fitted with dual fuel engines. Gas fuel storage tanks (with capacities) and bunkering facilities are to be described.
8.	Model Ship – Towing Tank test plan	Plan explaining the different steps of the tank tests and the scheduled inspections
9.	Model Ship – Towing Tank tests report	- Report of the results of the tank tests at sea trial and EEDI condition - Values of the experience-based parameters defined in the standard model-ship correlation method used by the tank test organization/shipyard - Reasons for exempting a tank test, only if applicable - Numerical calculations report and validation file of these calculations, only if calculations are used to derive power curves
10.	Ship Reference Speed (V_{ref})	Detailed calculation process of the ship speed, which should include the estimation basis of experience-based parameters such as roughness coefficient, wake scaling coefficient

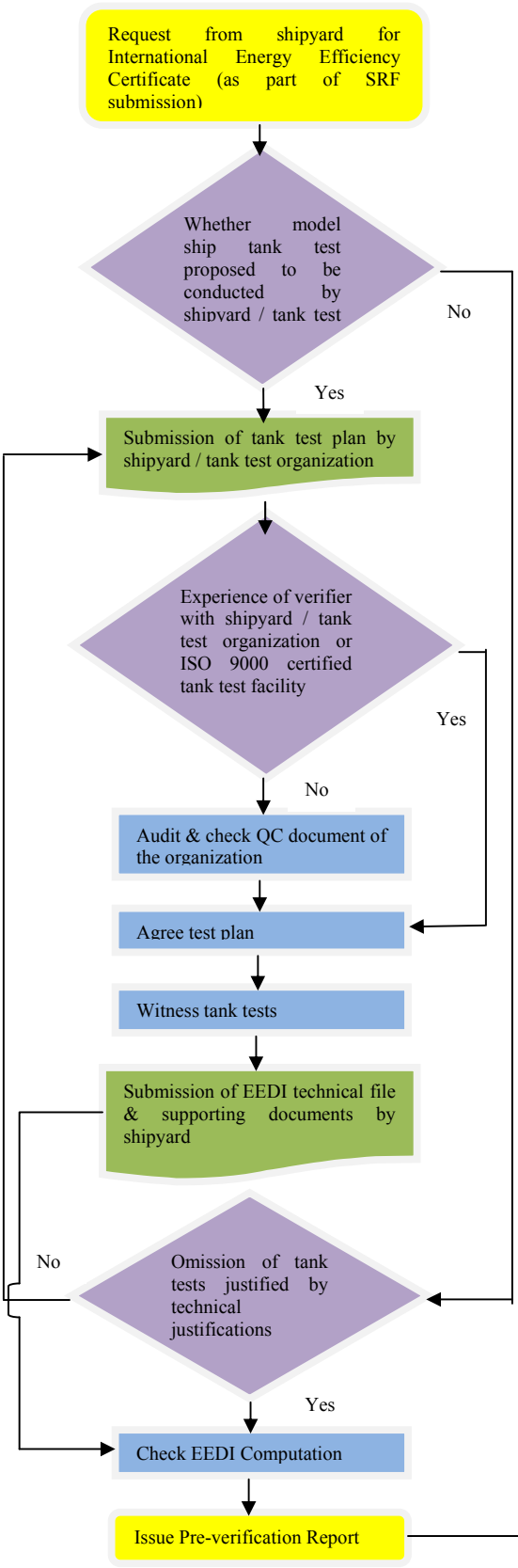
2. Sea trials stage

S.No.	Document	Description/Remarks
1.	Programme of sea trials	Description of the test procedure to be used for the speed trial, with number of speed points to be measured and indication of PTO/PTI to be in operation, if any.
2.	Sea trials report	Report of sea trials with detailed computation of the corrections allowing determination of the reference speed V_{ref}
3.	Final stability file	Final stability file including lightweight of the ship and displacement table based on the results of the inclining test or the lightweight check
4.	Final power curves	Final power curve in the EEDI condition showing the speed adjustment methodology
5.	Revised EEDI Technical File	Including identification of the parameters differing from the calculation performed at the initial verification stage
6.	Lines Plan of actual ship	

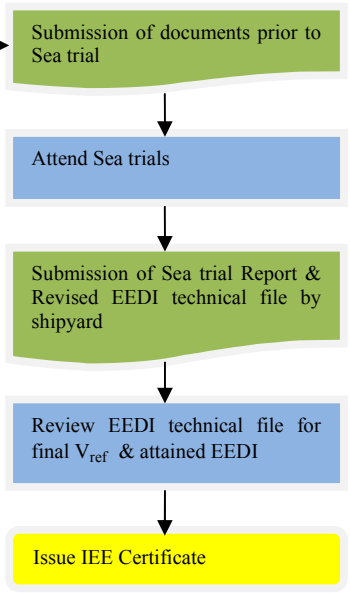
International Energy Efficiency Certificate

Certification Process – Flow Chart

Stage 1: Design Stage



Stage 2: Sea trials Stage



IRS's Role

- A service provider in certification of EEDI both at the design stage and sea trials stage in professional manner acting as an independent entity or as RO on behalf of flag administration.

- As an institution for management of ship data for the benefit of the ship owners in ascertaining the EEDI values of their current fleet for comparison with the IMO baseline and provide professional advice as and when required, to the Owners in choosing the best technical options available to improve the energy efficiency of their fleet.

- IRS can collaborate with the industry in carrying out research studies for
  - Improvements in hull, resistance of ship's hull and propulsion systems
  - Development of Energy efficient technologies and implementing them in a cost effective way and
  - Formulation of EEDI for unconventional ships.

For Further details, Contact
New Construction Division, Indian Register of Shippi

IRCLASS
Indian Register of Shipping

52-A, Adi Shankaracharya Marg, Opp. Powai Lake
Powai, Mumbai – 400 072.
Phone: 91-22-30519400, Fax: 91-22-2570 3611
Email: ho@irclass.org, Website: www.irclass.org