Further reading on EEDI:

The following explanations are important:-

- **Capacity:** (a) For bulk carriers, tankers, gas carriers, ro-ro cargo ships, general cargo ships, refrigerated cargo carriers and combination carriers, the deadweight should be used as “Capacity”; (b) For passenger ships and ro-ro passenger ships, gross tonnage (measured as per the Tonnage Convention, 1969), need be used as “Capacity”.(c)For container ships: 70% of the deadweight should be used as “Capacity”. Analysis of container ship operations show that, contemporary container ships only sail in the maximum operation (i.e. full-load) for about 10% of the time. Besides, when a ship is loaded to a lesser draft (which is true 90% of the time of container ship operations), part of the bulbous bow will be nearer to the surface or even waterline. This state of sailing will cause decreasing energy efficiency and increasing CO_2 emissions vis-a-vis the emissions of a vessel optimized to more realistic load levels.

- **Deadweight:** the difference in tonnes between, the “displacement” of a ship in water of relative density of 1.025 at the load-waterline corresponding to the assigned summer freeboard, and, the lightweight of the ship. (This is defined in MARPOL Annex I, Regulation 1.23)

- **Lightweight:** the displacement of a ship in metric tons without cargo, fuel, lubricating oil, ballast water, fresh water and feedwater in tanks, consumable stores, and passengers and crew and their effects. (This is defined in MARPOL Annex I, Regulation 1.24)

- **Gross tonnage:** Tonnage as measured in accordance with the International Convention on Tonnage Measurement of ships, 1969, Annex I, Regulation 3. This is used as “capacity” for both passenger ships and ro-ro passenger ships, since it is a measure of the volume and reflects the size of the accommodation, including the portion used for passengers.

- **Deadweight and tank capacitie**s, which are supposed to be key data at the design stage, are contained in the preliminary stability information. Gross tonnage is not a part of the key data at the design stage for some ships. Therefore, a preliminary calculation of the "tonnage measurement" ought to be done, by the shipbuilder at the design stage. Such computation of the tonnage should contain, volume of each space such as under main deck, superstructure, deck house etc.

- **Summer load line draft:** Merchant ships need an approved stability booklet on board which shows a number of loading conditions. One of these conditions is the fully loaded departure condition, i.e. the deepest draught to which a ship is allowed to be loaded, taking all applicable requirements into consideration. As is well known, the "deepest operational draft", will be equivalent to the summer load line.

- **V_{ref}:** the ship's speed measured in nautical miles per hour(knots), on deep water in the condition corresponding to the "Capacity" as explained above. This figure can be provided by the shipbuilder, early in the design stage, based either on model testing or calculations. The figure is included in the new building contract between the ship owner and the shipyard and ought to be provided by the shipbuilder / designer at the design stage.

The generic EEDI formula as shown above, very broadly, may be represented by the configuration: {(∑A + ∑B - ∑C), wholly divided by the product of {Capacity .V_{ref}}

[The denominator, "Capacity .V_{ref}" g has already been detailed earlier]. Now let us see the numerator.

The numerator is (∑A + ∑B - ∑C)

∑: Basically indicates "individual" aggregation of:

(A) stands for contributions to the CO_2 emission from each main engine, considering that a ship may have more than one main engine;

(B) stands for contributions to the CO_2 emission from each auxiliary engine, considering that a ship will usually have more than one auxiliary engine; and,

(C) stands for the Innovative energy efficiency technologies, leading to reduction of CO_2 emission.

Computation of "Attained EEDI"

The computation of **Attained EEDI** is fundamentally based on the EEDI formula explained earlier, i.e. **$\{(\Sigma A + \Sigma B - \Sigma C) / (\text{Capacity} . V_{ref})\}$,**with some **"correction-factors"** incorporated in the formula for fine-tuning the **Attained EEDI**-value as computed. For example, in the denominator, the correction factors denoting the "capacity" of the specialized type of the ship being dealt with, i.e. say, ice-class ships or, bulk-carriers / tankers under the Common Structural Rules of the IACS or, chemical tankers/ LNG Carriers or, Weather-factor, have been multiplied with the product of "**Capacity and V_{ref}**".

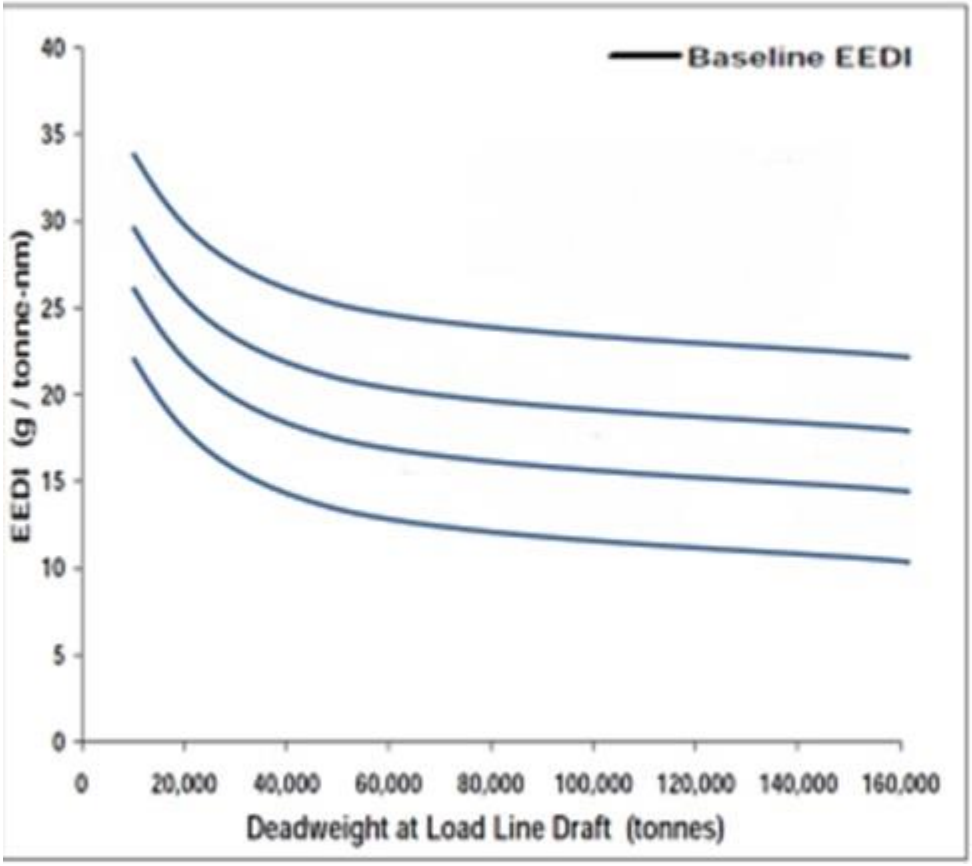
If you are further interested for studying in-depth the detailed formula for calculating the **Attained EEDI**, which is the concern of the ship-designer / ship-builder and not the ship's operating engineer, you may refer to the "2012 Guidelines on the Method of Calculation of the Attained Energy Efficiency Design Index (EEDI) for New Ships" vide the IMO Resolution MEPC. 212(63).

ENERGY EFFICIENCY DESIGN INDEX BASELINE

- EEDI baseline is a graph that act as a benchmark for a ship depending on type and size.
- EEDI baseline is done by analyzing a number of ship which is of the same type.
- Data obtained is plotted in a graph.
- A new ship will be compared to the baseline for compliance.

ENERGY EFFICIENCY DESIGN INDEX PHASE

- Phase 0 - Starting 01.01.2013 until 31.12.2014(0% CO_2)
- Phase 1 - Starting 01.01.2015 until 31.12.2019(10% CO_2)
- Phase 2 - Starting 01.01.2020 until 31.12.2024(20% CO_2)
- Phase 3 – Starting 01.01.2025 and onward(30% CO_2)



REDUCING EEDI VALUE

- Reduce ship speed.
- Uses to innovative efficiency technology such as WHR, Kite, Hull Bubble technology etc.
- Optimize the Hull form to reduce resistance.
- Use smooth hull coating to reduce resistance.
- Use Dual Fuel Diesel Electric Propulsion System.

Factors which affect the EEDI values of a new ship and energy saving technologies

From the formula of EEDI mentioned earlier, it is evident that if the DWT is increased, the value of EEDI reduces. However, if the DWT increases, the engine power required would also rise. However, it may be noted that the engine power increase in proportion to the DWT increase is powered by two-third.

Therefore, the increase of the denominator (i.e. DWT), outweighs the increase of the numerator. Therefore, enlargement of the DWT, improves the efficiency and lowers the EEDI of the ship,

Lowering the speed in the denominator would lower the engine power considerably, since Power α V^3. Therefore, the lowering of speed is very effective in improving efficiency. The scale of possible emission reduction is considerable. In a certain study it was observed that there could be an emission reduction, across a range of container ships, up to about 70%, if the speed was halved. Informatively, even though container ships represent only 4% of all vessels, they are responsible for 20% of all CO_2 emissions from ships.

As already explained above, the introduction of new technologies are also expected to increase the efficiency and reduce the value of the EEDI. The advantage of application of innovative technology is that it can improve the EEDI value without affecting the DWT or ship's speed. In other words, the improvement in efficiency would not result in any changes to, or lays constraints on, the pattern of operation of the ship.

Energy saving technologies with respect to the hull and propeller of a ship, which significantly improve energy efficiency. These are merely being mentioned here, without going into their details, as follows: -

- Optimizing the length and hull fullness ratio is important to reduce ship resistance. When the length is increased too much, it increases the wetted surface area and the frictional resistance. When the hull fullness ratio is too small, the hull lines are too blunt, and the resistance is also increased
- Lightweight construction, i.e. steel can be substituted by lighter alternatives such as Aluminium, carbon fibre or glass fibre sandwich constructions, high tensile steels.
- Reduction of hull friction results in bunker consumption reduction. Thus, improving the hull smoothness through surface preparation and maintaining it free of fouling / barnacles during the vessel's operation by using hull advanced-coatings contributes largely to energy efficiency. Low-surface-energy coatings makes the hull-surface, non-stick. This reduces fuel consumption and consequently the ship's emissions.
- Air bubbles are injected along the hull and recesses under the hull are filled with air, through automated compressors and valves. This layer

of air in the ship's hull reduces the friction and the fuel consumption thereby.

- Optimizing of propeller-hull interface, flow devices and improvement of propulsion efficiency:

1. Ducted Propeller. These are also called "shrouded" propellers and have the energy saving potential for enlarge tankers. 2 to 4% energy conservation is expected, at laden draughts. At ballast draughts, the saving would be substantially less, since the savings are attractive at high thrust-loading, i.e. a large mass moving at low speed.
2. Integrated ducted propellers with the duct ahead of the propeller, the interaction between the hull and propeller will be improved, giving a definitive benefit.
3. Pre and post-swirl devices. A large number of vessels lose a good bit of energy by way of rotation of the propeller, imparting rotational instead of axial momentum on the water. A variety of devices are on offer to recover some of this energy. These can either be upstream of the propeller (i.e. pre-swirl) or downstream of the propeller (post swirl). These devices are simple, do not rotate, and, can reduce the rotational losses generated by the propeller. Since the rotational losses are about 5 to 7%, the potential saving is substantial.
4. Podded propellers. These propellers operate in faster, less disturbed water outside the boundary layer. In addition, there is a saving on account of being able to reshape the aft end of the hull and reduce the overall resistance of the ship. However, the overall hydrodynamic efficiency of the hull/podded propeller combination is less than that of a conventional, well designed, single screw propulsion system because of the propeller / hull interaction effects.
5. Co-axial contra-rotating propellers. In this configuration, two propellers face each other, operating in the opposite direction, with the propeller in the aft recovering the rotational energy in the water-stream from the forward propeller. Theoretically, about 10 to 12 % improvement in propulsive efficiency can be achieved by the use of these propellers. In effect, the power of the main propulsion engine as required to be installed would be less. However, there are certain problems with respect to high cost, gear-box and, bearings, arising out of one shaft rotating inside the other, in opposite directions.
6. Propeller design. A number of high-efficiency propeller designs are available. Even though their efficiency gains over the full range of ship sizes are yet to be proven, savings up to 4% over a well-designed conventional propeller should be achieved by all these designs. The saving will however be dependent on the specific ship design and the propeller loading.

7. Propeller boss fins i.e., using a propeller with fins, the vortex in the hub is eliminated and energy can be recovered from the rotation flow around the boss.

As an alternative fuel, LNG is an attractive solution, not only because of lesser emissions, which gives 22% lower CO_2 emissions, 16 to 20 % lower greenhouse gas emissions, no sulfur emissions, but also because of lower equivalent fuel price. Other fuels like bio-fuel, hydrogen and carbon capture have very promising lower carbon future, but not likely to be put to use, at least in the next decade.

Improvement of the efficiency of the main propulsion engine, by practicing better engine control, by way of de-rating, long stroke, electronic injection, common rail injection, two-stage turbo charging to increase engine efficiency in the whole range of operation.

Reduction of power demand on board, by, say, (a) the use of more electricity and heat–efficient lighting; (b) the use of energy efficient heating, ventilation and air-conditioning; and, (c) the usage of pumps and fans at variable speed as per necessity. The use of variable-speed electrical motors for providing measured control of rotating flow machinery, leads to significant reduction in their energy use. Frequency controlled pumps, instead of fixed rpm pumps, for say cooling water and other systems, with high utilization rate, can decrease energy consumption for the pumps substantially.

Around 25% of the energy generated in the main engines is lost to the exhaust as heat. With an exhaust gas boiler and fresh water generator, this waste heat can be partly recovered and thereafter the balance heat can be used to say, drive turbines for electricity production, leading to less fuel consumption by the auxiliary engines. The amount that could be recovered would depend on the type of engines used, the exhaust gas temperature and the sulfur content in the fuel, since dew point of the acid restricts allowable outlet temperature of exhaust gas heat exchangers.

Alternative sources of energy include:

- Wind power (Attractive for ship’s speeds below 15 knots. Sails kites etc. are considered as emerging technologies)

- Wind engines (Rotors positioned on the main deck of a ship, can get thrust generated, taking advantage of the Magnus effect)
- Towing Kite (the kite is attached to the bow of a ship and wind energy can be used to supplement the power of the ship's engines)
- Solar Power. Using photo voltaic cells for producing and delivering electricity for catering to the on-board power requirements.

Procedures for survey and Certification

The **Attained EEDI** ought to be calculated as per Regulation 20 of Annex VI, and the EEDI-calculation-guidelines, i.e. MEPC. 245(66).

Survey and Certification of the EEDI should be conducted in two stages:(i) Preliminary Verification of the design stage and, (ii) final verification at the sea trial.

For Preliminary verification at the design stage, an application for an initial survey and an EEDI Technical File containing the necessary information for the verification and other relevant background documents should be submitted to a verifier.

The EEDI Technical File must include: (i) DWT OR GT for passenger and ro-ro passenger ships, (ii) the maximum continuous rating (MCR) of the main and auxiliary Engines, (iii) the ship's speed (Vref) as referred to in the EEDI calculations, (iv) Type of fuel, (v) the specific fuel consumption of the main engine at 75% of MCR power , (vi) the SFC of the auxiliary engines at the 50% of MCR power, and the electric power table for certain types of ships, as necessary, as defined in the EEDI calculations, (vii) power curves(kW – knot) estimated at the design stage under the condition as specified in the EEDI calculation guidelines, (vii) Principal particulars , ship type, Class notations, and an overview of the propulsion system and the electrical power system on board, (viii) description of the energy saving equipment, (ix) estimation process and methodology of plotting the power curves at the design stage, (ix) calculated value of the attained EEDI, showing the summary of the calculations, (x) calculated values of the attained EEDI weather and, fw value not equal to 1.0 which is used for estimating attained EEDI under regulations 20 and 21 of Annex VI, if those values are calculated as based on the EEDI calculation guidelines, indicating representative sea-conditions. Separate requirements are specified for LNG carriers, ships equipped with dual fuel engines using LNG and fuel oil etc.

Guidelines are specified for: (i) Final verification of the attained EEDI at sea trial, (ii) Verification of the attained EEDI in case of major conversion, etc.; which are not detailed here since these do not come within the purview of the sea-going marine engineer’s Certificate of Competency.