The Energy Efficiency Design Index (EEDI) for New Ships

During the 62nd session of the MEPC (11–15 July 2011), at IMO Headquarters in London, the represented Parties to MARPOL Annex VI adopted amendments to Annex VI Regulations for the prevention of air pollution from ships. Considered the first regulation to establish CO_2 standards across a global sector, the Energy Efficiency Design Index (EEDI) had been a central topic of discussion and development at the MEPC over the last 4 years. These amendments add a new Chapter 4 to Annex VI that focuses on the energy efficiency of large ships and mandates an increasingly stringent EEDI score for the majority of new vessels.

The regulation will require most new ships to be 10% more efficient beginning 2015, 20% more efficient by 2020 and 30% more efficient from 2025. If implemented according to this time schedule, the ICCT projects that up to 263 million tonnes (Mt) of CO_2 will be reduced annually by 2030. While the EEDI will add capital and implementation expense related to next-generation ship designs and technology, these costs are more than offset by projected savings up to 75 Mt and $52 billion of fuel annually.

The passage of EEDI regulation came with one important compromise that could affect the magnitude of benefits in the near term. As a concession to countries that were concerned about the capacity of their shipyards to develop and deploy necessary technologies, individual flag administrators will be allowed to defer mandatory EEDI requirements for up to 4 years beyond the planned implementation dates. It is likely that many flag authorities will request the delay, but more difficult to project how many ships would actually defer producing EEDI compliant ships, The EEDI comes at a time when many sectors are experiencing substantial growth and unilaterally developing more efficient ships to serve the demand, so the effect of any delay is likely to be diminished.

The regulation language allows for regular review and adjustment of the formula to improve its applicability and effect. Specific technical issues that were still under discussion as the regulation was passed were deferred to a special working group that will convene in late February 2012. Future revisions to the EEDI are expected to enhance its effectiveness and applicability by approving new efficiency technologies and including additional vessel classes.

ICCT Policy Updates summarize regulatory and other developments related to clean transportation worldwide.

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In addition to the EEDI, MEPC62 saw passage of the Ship Energy Efficiency Management Plan (SEEMP), a regulation to require all ships (or ship companies) to develop and maintain a plan to maximize the efficiency of ship operations. The second IMO GHG study (2009) concluded that a 10–15% reduction in fleet wide emissions was possible with operational strategies alone, indicating that the benefits of the SEEMP could be similar to those of the EEDI over the next several decades.

Even more substantial GHG mitigation measures are under discussion at the MEPC in the form of market based mechanisms (MBM) such as cap and trade, fuel levies, or mandatory technology standards. Progress on developing MBMs at the IMO is slow and contentious due to persistent disagreement about how to resolve the United Nations Framework Convention on Climate Change (UNFCCC) principle of "Common but Differentiated Responsibility" (CBDR) with IMO's principle of "Equal Treatment for All" (ETFA.)

Key components of the EEDI

The EEDI estimates ship CO_2 emissions per ton-mile of goods transported relative to a reference average of similar ships. The full equation (detailed in MEPC.1/Circ.681) includes several adjustment and tailoring factors to suit specific classes of vessels and alternate configurations and operating conditions. A detailed description of the EEDI equation is included as an appendix to this brief, but the fundamental formula can be simplified to:

$$EEDI = \frac{P \bullet SFC \bullet C_f}{DWT \bullet V_{ref}}$$

Where *P* is 75% of the rated installed shaft power, *SFC* is the specific fuel consumption of the engines, *Cf* is CO_2 emission rate based on fuel type, *DWT* is the ship deadweight tonnage,[1] and *Vref* is the vessel speed at design load. The calculated EEDI (Attained EEDI) based on design specifications and sea trials of new ships will have to be below a reference value (Required EEDI) that is based on a regression of EEDI values from existing ships built between 1999 and 2009 (Reference line).

The EEDI regulation applies to new cargo ships greater than 400 gross tons (GT) and varies with ship type, size, and function. The categories of ships covered include oil and gas tankers, bulk carriers, general cargo ships, refrigerated cargo carriers and container ships. Together, the included ship categories account for 72% of CO_2 emissions from the new-build fleet.[2]

The regulation currently does not apply to passenger, mixed-use vessels (ferries, roll-on roll-off [Ro-Ro] ships or vehicle carriers, and cruise ships), and other specialty vessels for which deadweight tonnage is not an adequate representation of transportation capacity. It also does not apply to vessels below 400 GT. The simplicity of the key variables in the EEDI equation also means that it cannot be applied to ships with alternative propulsion systems such as diesel-electric because the installed power variable ($P_{ME(I)}$) cannot be determined in the straightforward manner necessary for the equation. Future revisions of the regulation may seek to include additional ship and propulsion types by adjusting the formula or offering alternative formulations.

1 Deadweight Tonnage (DWT) is effectively a measure of a vessel's load-carrying capacity. For the EEDI equation, 100% of DWT is used for all vessels, with the exception of containerships where 70% is used.

2 Note by the International Maritime Organization to the thirty-third session of the Subsidiary Body for Scientific and Technical Advice (SBSTA 33), 4 November 2010.

As with other IMO regulations, a ship's flag state is ultimately responsible for ensuring that it is compliant with EEDI. Compliance is demonstrated by the issuance of an International Energy Efficiency Certificate (IEEC) by a verifier (Maritime Administration or Classification Society). Verification is conducted in two stages. A preliminary verification is done based on the ship design and a final verification test is done during a sea trial. The entire process involves the close involvement of the shipowner, shipbuilder, and verifier at each stage of the ship development.

Individual member states are also responsible for enforcement of IMO conventions and may structure various penalties for non-compliance among ships that carry their state's flag. Member states have limited authority over vessels from other flag countries but can reserve the right to deny entry to vessels that are not in compliance.

An "on-time" deployment of the EEDI will apply the design standards to ship orders placed on or after January 1, 2013 and to ships delivered after January 1, 2015 regardless of their order date. A three-step phase-in of the EEDI occurs in five-year increments: 10% greater efficiency for ships delivered between 2015 and 2019, 20% between 2020 and 2024, and 30% after 2025. Future ship efficiency improvements are determined relative to a baseline average efficiency of ships built between 1999 and 2009.

Any country can elect to delay the EEDI implementation by up to 4 years without penalty. This clause was added to provide flexibility to developing countries that were concerned about upgrading their shipbuilding industry in time to provide ships that could satisfy EEDI requirements. The first guaranteed year for deployment of EEDI compliant ships would be 2019.

In addition to the EEDI regulation, the new chapter 4 of Annex VI requires all ships or ship operating companies to develop and maintain a Ship Efficiency Management Plan (SEEMP) which provides a mechanism for monitoring efficiency performance over time and forces consideration of new technologies and procedures to optimize performance. A SEEMP will be a "live" document that details how the specific vessel will achieve optimize energy efficiency in operation, who is responsible, and how to track progress against targets. Many companies already use a SEEMP or similar plan. The regulation only requires that ships have a plan, but approval of the plan's contents and tracking of the ship's progress of SEEMP details by the flag administration is not required.

Benefits and considerations

Based on methodologies detailed in appendix A, and using IMO ranges for projected fleet growth, the ICCT estimates that if the EEDI is implemented according to the original schedule, with compliant ships deployed starting in 2015, the regulation would save 15–45 million metric tons (mmt) of CO_2 annually by 2020 and between 141 and 263 mmt of CO_2 annually by 2030. If implementation is delayed by 4 years for all ships, the potential CO_2 reductions drop to between 2 and 6 mmt for 2020 and 80 and 143 mmt for 2030. ICCT estimates for both the on-time and deferred case, based on the IMO mid-range growth estimate (Scenario A2), are illustrated in Figure 1, along with estimates of corresponding fuel cost savings.

As with other new-build vehicle standards, the benefits of EEDI will unfold gradually over time as new ships replace and augment the existing fleet. This effect is even more pronounced with the EEDI because ships have an operating life of approximately 25–35

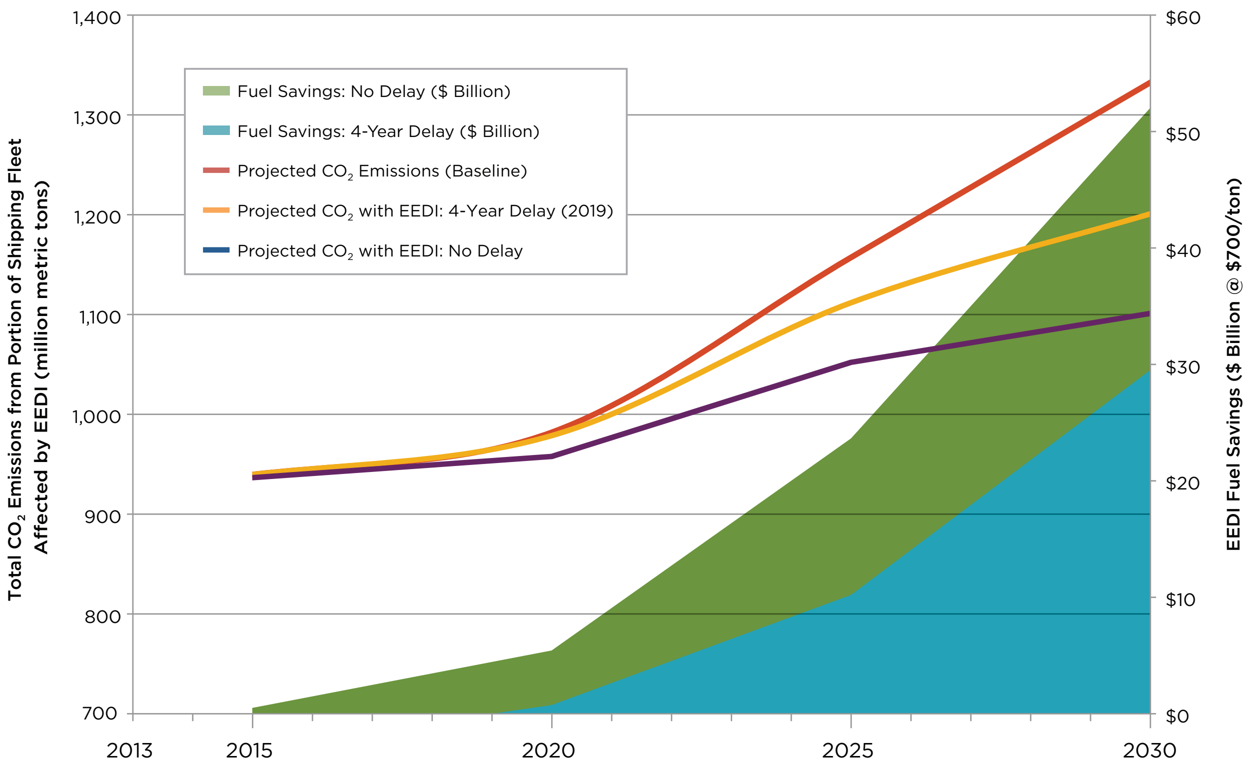

Figure 1. Projected CO_2 emissions and cost savings through 2030 from the shipping fleet affected by EEDI Regulation. IMO Scenario A2, with and without proposed 4-year delay.

years. This implies that it may not be until 2040–2050 before the entire world fleet is EEDI-compliant and the full benefits of the regulations are realized. The gradual nature of this regulation will be compounded (as shown previously) if a large majority of flag countries choose to allow the full four-year delays to implementation. There is no penalty for a country to elect to delay implementation requirements, so a flag administration might rationally choose the delay regardless of whether new flagged vessels are EEDI certified. A country may elect to delay the EEDI implementation to offer flexibility to companies operating ships under those flags to manage and build their fleet according to their own business needs.

For these reasons, the extent of actual delay in ships being rolled out to EEDI specifications will likely be more a function of market conditions and industry business models than of international politics. Most major container companies are already planning to build larger and more efficient ships that will increase capacity while reducing overall costs. Together with the common use of slow steaming to save money and fully utilize tonnage, this general shift in the container industry could create a container fleet nearly as efficient as an EEDI-compliant fleet, regardless of the regulation's implementation date. Other major ship classes, such as bulkers and tankers, whose fleets and landside reception facilities are optimized to current designs, may be more likely to favor delay. Figure 2 shows reductions from EEDI-covered ship classes according to IMO's high, middle and low estimates of fleet growth.[3] Because of the fleet size and the highest potential future demand, containerships account for both the majority of projected

3 IMO (2009). "Second IMO GHG study 2009; Prevention of air pollution from ships".

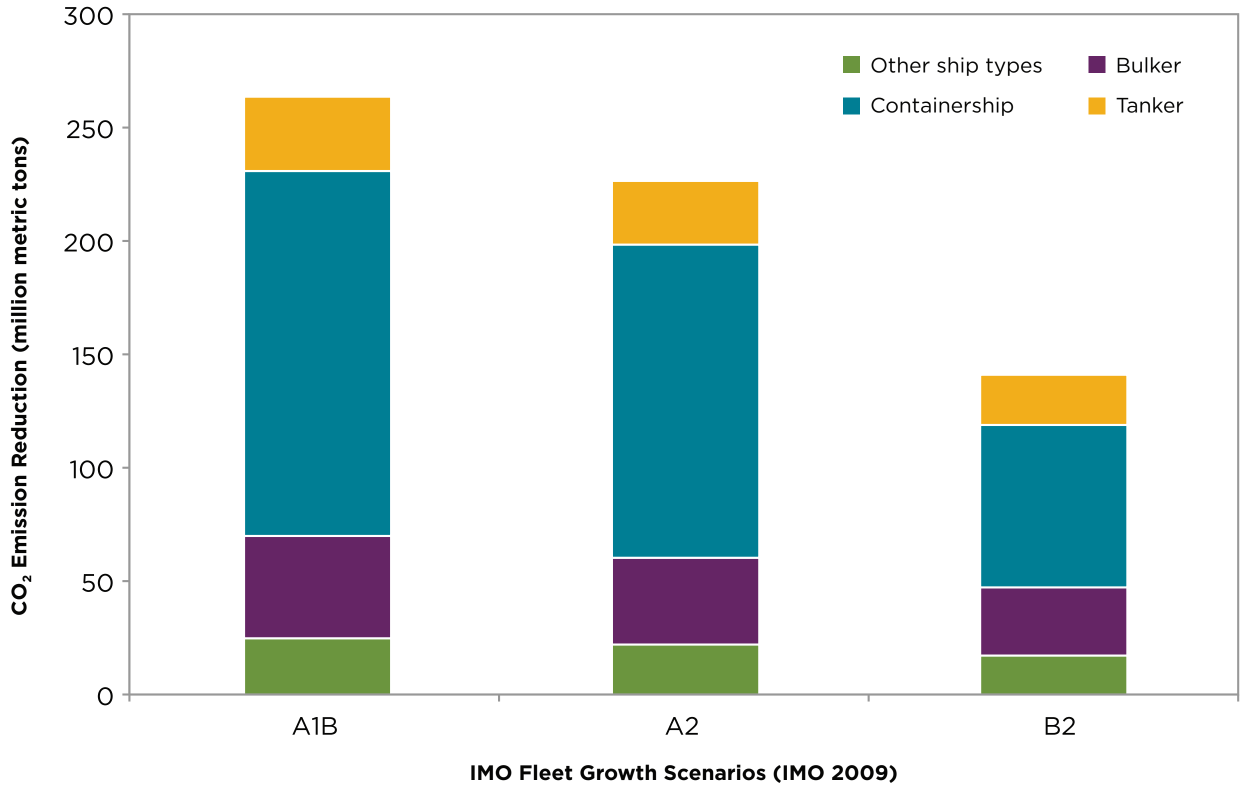

Figure 2. CO_2 emissions reductions in 2030 by ship type according to IMO's high-, mid-, and low-growth scenarios (assuming no delay in EEDI implementation).

savings and the most uncertain variable in the growth scenarios.

Other market drivers, such as the potential fuel savings with EEDI compliant ships, will also drive de facto implementation of EEDI-consistent ships. In the past, fuel price has not been a strong driver in decisions about how to build and equip new ships. Ship operators face two main annual costs that inform their decision: amortized capital costs of the ship and operating cost, which is dominated by the cost of fuel. Fuel price fluctuates substantially year-to-year and has been, on average, lower than the annual capital cost of the ship itself. This made minimalizing capital costs the dominant consideration in designing new ships.

The often-cited "split incentive" market failure, deriving from the separation of ship ownership and operation, compounds the tendency to emphasize minimizing capital costs. More recently, as noted by the Shipping Intelligence Network,[4] the annual capital costs associated with new ships relative to annual fuel costs has changed significantly such that annual fuel costs are much higher than capital costs. This effectively drives the economics of building new ships in the same direction as the EEDI regulation: diminishing the increased construction costs of EEDI compliant ships while emphasizing the fuel savings. Similarly, relatively high fuel costs will favor the development and marketability of the new efficiency technologies that enhance the EEDI rating of ships.

4 Martin Stopford, "Revolution in the Engine Room—Shocking Revelations", www.clarksons.net/sin2010/markets/Feature.aspx?news_id=31585 (accessed 22 September 2011).

Expected future developments

The Marine Environment Protection Committee (MEPC) agreed to a work plan to finalize details of the EEDI regulation. The work plan focuses on energy efficiency measures, including development of the EEDI framework for different ship types and sizes; propulsion systems, not covered by the current EEDI requirements; and development of the EEDI and SEEMP-related guidelines. The MEPC agreed to the terms of reference for the intercessional working group on energy efficiency measures for ships, scheduled to take place in February/ March 2012. A list of ongoing issues with the EEDI regulation, based on recent submissions to the MEPC, is contained in appendix C. Other issues that have been brought up in the past, such as revised methodology to facilitate inclusion of Ro-Ro ships, are likely to be re-introduced during the mandated periodic review of the regulation.

Despite the need for further refinement, passing the EEDI regulation is a substantial indication that the IMO is able to address GHG emissions from shipping despite challenging political disagreements among member countries. In addition to stimulating development and marketability of efficiency technologies, EEDI regulation clears the way for the IMO to focus on developing market-based mechanisms (MBM) for the shipping sector that would generate substantial near-term GHG reductions. MBM proposals being considered include measures that would generate money to fund GHG reductions outside of the sector (such as a fuel levy, or a cap and trade system, primarily) or measures that would further stimulate efficiency improvements solely within the sector. Progress of MBM discussions at the IMO has been hindered by opposing views on the applicability of the United Nations Framework Convention on Climate Change (UNFCCC) “common but differentiated responsibilities” principle to IMO’s policy of equal treatment for all (ETFA) countries.

Of the 169 IMO member countries, only the 59 countries that have (so far) ratified MARPOL Annex VI were eligible to vote on the EEDI regulation. While the forum sought consensus, detractors blocked that effort and called a vote. This resulted in passage of the measure by a 48-5 majority (with 2 abstentions and 4 absences). Notably, many developing nations and small island developing nations voted in favor of the EEDI, breaking with the conventional assumption that all developing countries oppose GHG regulations. Passing the EEDI indicates two important points: (1) that the IMO can take action on climate regulations; and (2) that, because the positive votes included many developing countries, in their view the principle of CBDR is not at odds with ETFA.

As further indication of the IMO’s clear intent to maintain equal treatment among its members as MBM discussions move forward, the final EEDI regulation language includes aspirational clauses about technology transfer and assistance that would help ensure that all countries have access to new technologies and processes that may be needed to meet EEDI standards. Inclusion of this language was originally intended to secure a specific commitment among countries but was left intentionally vague in the final draft to preserve IMO’s ETFA principle. The discussion of MBM is expected to resume at the next MEPC meeting in late February 2012.

Appendix A: Methodology and Assumptions

The estimates of CO_2 emissions from ships and the resulting graphs of relative emissions and fuel prices were based on an analysis of the existing fleet and rely on information drawn from the Second IMO Greenhouse Gas Study (2009)[5] and Lloyds Registry world shipping fleet data (2007).[6]

Specifically, the following data were used:

- Ship numbers and average fuel consumptions in 2007 by ship type and size (IMO)
- Ship numbers in 2020, and 2050 (IMO)
- Ship growth rates between 2020 and 2050 (IMO)
- Mandatory efficiency improvement in each phase (IMO)
- Ship age distribution in 2007 (Lloyds)

CO_2 emissions estimates were calculated using the following steps and assumptions:

- Divide ships into six age groups
- Assume ship age distribution in 2007 is the same as the distribution in 2010 by each ship category
- Assume ship retires in 30 years
- Extrapolate ship numbers in 2015, 2020, 2025, and 2030
- Ship numbers in a given year are equal to retired ships plus added ships
- Calculate the average age for each ship category weighted by fuel
- Assume 2010 is the reference year
- Assume a fixed annual energy efficiency improvement rate from the year an existing ship was built to 2010 (0.2% was used to be conservative)
- Calculate the accumulated energy efficiency improvement from the year an existing ship was built to 2010 to calculate the average fuel consumption in the phase zero
- Calculate fuel savings for each phase
- Calculate CO_2 savings from fuel savings based on relevant fuel types
- Remove the energy efficiency improvement rate built in to the IMO GHG report to avoid double counting.

5 IMO (2009). "Second IMO GHG study 2009; Prevention of air pollution from ships" International Maritime Organization (IMO) London, UK.

6 Lloyd's Register – Fairplay Database, 2007.

Appendix B: An Anatomy of the Energy Efficiency Design Index (EEDI) Equation for Ships

An Anatomy of the Energy Efficiency Design Index (EEDI) Equation for Ships

MAIN ENGINES EMISSIONS + AUXILIARY ENGINES EMISSIONS + SHAFT GENERATORS/MOTORS EMISSIONS − EFFICIENCY TECHNOLOGIES

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

TRANSPORT WORK

ENGINE POWER (P)

Individual engine power at 75% of Maximum Continuous Rating

- $P_{eff(i)}$ — Main engine power reduction due to individual technologies for mechanical energy efficiency
- $P_{AEff(i)}$ — Auxilliary engine power reduction due to individual technologies for electrical energy efficiency
- $P_{PTI(i)}$ — Power of individual shaft motors divided by the efficiency of shaft generators
- P_{AE} — Combined installed power of auxilliary engines
- $P_{ME(i)}$ — Individual power of main engines

CO_2 EMISSIONS (C)

CO_2 emission factor based on type of fuel used by given engine

- C_{FME} — Main engine composite fuel factor
- C_{FAE} — Auxilliary engine fuel factor
- $C_{FME(i)}$ — Main engine individual fuel factors

SPECIFIC FUEL CONSUMPTION (SFC)

Fuel use per unit of engine power, as certified by manufacturer

- SFC_{ME} — Main engine (composite)
- SFC_{AE} — Auxilliary engine
- $SFC_{AE}{}^{*}$ — Auxilliary engine (adjusted for shaft generators)
- $SFC_{ME(i)}$ — Main engine (individual)

CORRECTION AND ADJUSTMENT FACTORS (f)

Non-dimensional factors that were added to the EEDI equation to account for specific existing or anticipated conditions that would otherwise skew individual ships' rating

- $f_{eff(i)}$ — Availability factor of individual energy efficiency technologies (=1.0 if readily available)
- f_j — Correction factor for ship specific design elements. *E.g.* ice-classed ships which require extra weight for thicker hulls
- f_w — Coefficient indicating the decrease in ship speed due to weather and environmental conditions
- f_i — Capacity adjustment factor for any technical/regulatory limitation on capacity (=1.0 if none)

SHIP DESIGN PARAMETERS

- V_{ref} — Ship speed at maximum design load condition
- $Capacity$ — Deadweight Tonnage (DWT) rating for bulk ships and tankers; a percentage of DWT for Containerships DWT indicates how much can be loaded onto a ship

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Appendix C: IMO Ongoing EEDI Development, Active Initiatives as of 15 July 2011

ISSUE	RELATED DOCS	DELEGATIONS	SUMMARY OF ENGAGEMENT	EDITORIAL PROGNOSIS
Determination of coefficient "f_w" in the EEDI; "f_w" represents a non-dimensional coefficient indicating the decrease of speed in the representative sea conditions; Preliminarily agreed to be 0.65 of designed sea trial speed; other values from 0.7 to 0.85 are being suggested	MEPC 62/5/3	Japan	Japan's findings in investigating "f_w" and proposes methods for determining the coefficient through simulation	f_w will change annually based on market performance and fuel costs. A median value was proposed by the World Shipping Council during MEPC 62.
	MEPC 62/5/16	China	China's recommendation to remove "f_w" from EEDI	
	MEPC 62/5/23	Greece	Greece's agreement & support of Japan's findings	
	MEPC 62/5/24	Republic of Korea	Korea's recommendation to set "f_w" to 0.8	
	MEPC 62/5/31	Vanuatu	Vanuatu recommends more study and originally supported 0.85	
Verification of EEDI (ISO 15016:2002) comments based on a Norwegian analysis of speed trial data.	MEPC 62/5/5	Norway	Based on their analysis, Norwegians recommend changes to ISO 15016:2002 to ensure a more accurate and consistent verification results, condense the number of methods available within the standard, and makes clear recommendations on which methods to use where equivalent correction methods are available.	These issues are continuing into MEPC 63.
	MEPC 62/5/32	Japan & ITTC	ITTC's comments on 62/5/5 – recommending ITTC take a lead role as well to evaluate and comment on this issue.	
China, Saudi Arabia, and South Africa's proposal for amendments to mandatory energy efficiency regulations that would support developing countries.	MEPC 62/5/10	China, Saudi Arabia, & South Africa	Suggests delayed implementation by developing countries and free technology transfer. These issues were substantively agreed to at MEPC 62 in the form of a 4-year delay and language encouraging technology transfer among countries. Not all countries supported the final language because it did not make specific requirements for technology transfer.	Delegation supporting this approach other than authors: Brazil, Chile, & Kuwait. Others support parts of this approach come from the Cook Islands, Iran, Syria, Vanuatu, and others. This issue may be re-introduced at intercessional meetings and MEPC 63.
Consideration of the potential of EEDI leading to underpowered vessels being built	MEPC 62/5/19	BIMCO, CESA, IACS, INTERTANKO, INTERCARGO, & WSC	Presents draft interim guidelines to determine whether available propulsion power is sufficient to enable safe maneuvering in adverse conditions in the context of the EEDI framework. To facilitate an early implementation, a simplified assessment is suggested as the verification procedure in a first phase, which can be performed with the tools available today. The simplified assessment is a subset of the comprehensive assessment, which, due to its complexity, is only suggested for consideration in a later phase.	Updated Guidelines to be introduced at MEPC 63.
	MEPC 62/5/32	Japan & ITTC	Offers comments to submission MEPC 62/5/5 from Norway and recommends that the International Towing Tank Conference (ITTC), as NGO represented in IMO, is invited to review the methods for speed correction in winds and waves, etc., of ISO 15016:2002 and produce recommendations for improving them.	
Various issues associated with ice-classed ships & EEDI calculation of "f_i" in the EEDI equation	MEPC 62/5/26	Republic of Korea	Affects a relatively small portion of the world-wide fleet	
	MEPC 62/5/30	Finland & Sweden		
Incorporation of energy efficient measures & taking credit of those in EEDI	MEPC 62/5/25	Republic of Korea	Recommends criteria to be considered before benefits from any energy saving devices or technologies are deducted in the EEDI equation. These are: avoid double counting for devices already included in EEDI, devices/technologies should be considered as being to be used during normal seagoing conditions, and where combination of more than two devices/technologies are employed, the total effect of the combination should be deducted once. Lists the following energy saving devices/technologies that affect EEDI: CO2 capture, Future Propulsion Power (wind, fuel cell, photovoltaic cell, battery, etc.), improvement of propulsion efficiency (pre-swirl stator, Stem duct, CRP, duct propeller, propeller boss cap fins, thruster fin, etc.), technology for reducing friction (low friction coating, air lubrication system, above water aerodynamic design, etc.), and other systems (cold ironing, kite sail, hybrid auxiliary systems, etc.)	Given the significant number of efficiency technologies bbeing developed and broguth to market for ships, this will be a significant discussion at future MEPC meetings.