Module 2:

Ship Energy Efficiency Regulations and Related Guidelines

IMO Train the Trainer Course

Name of the Presenter
Affiliation of the presenter,
City, Country

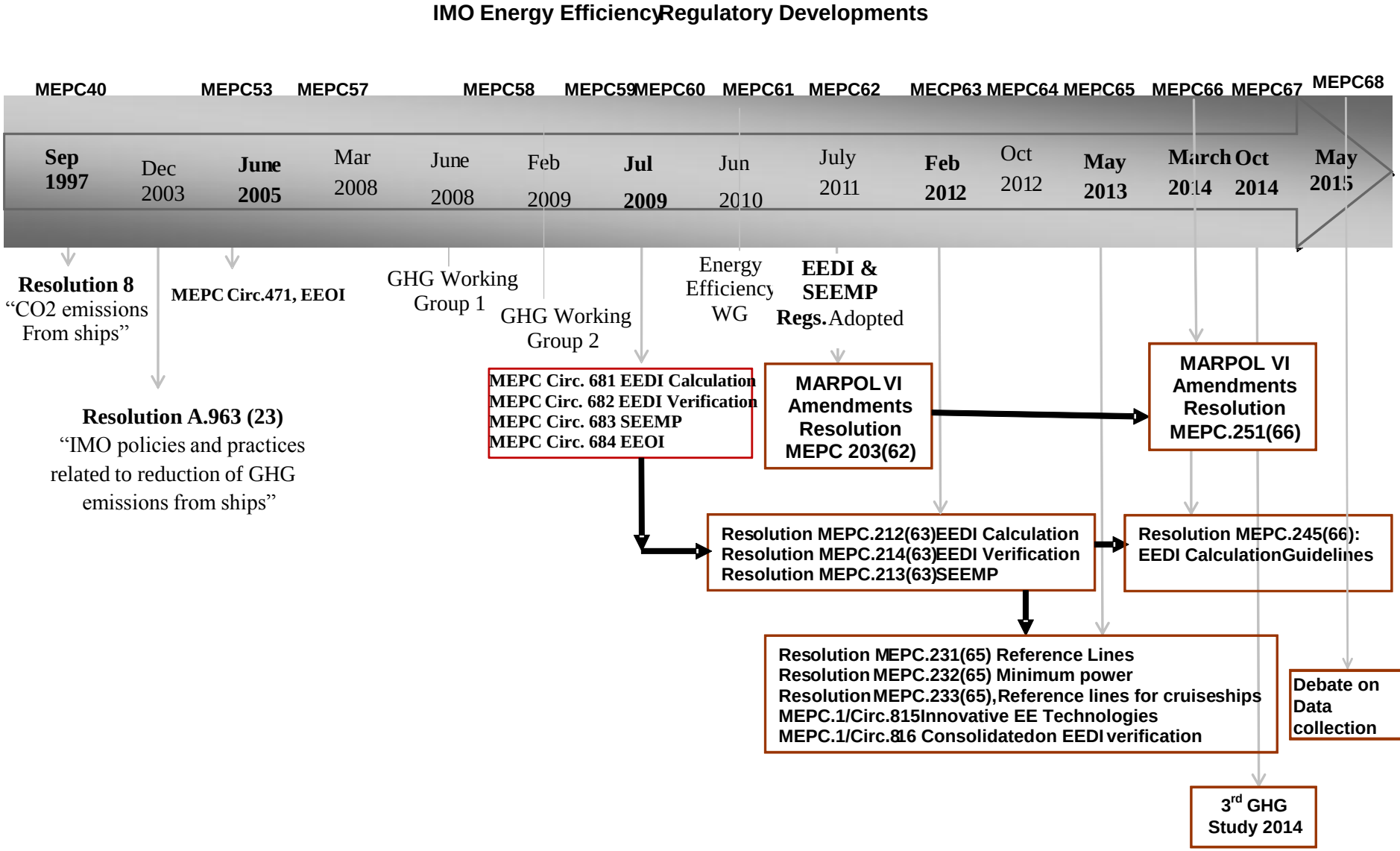
Energy Efficient Ship Operation

Venue, City, Country
Day xx to Day yy, Month, Year

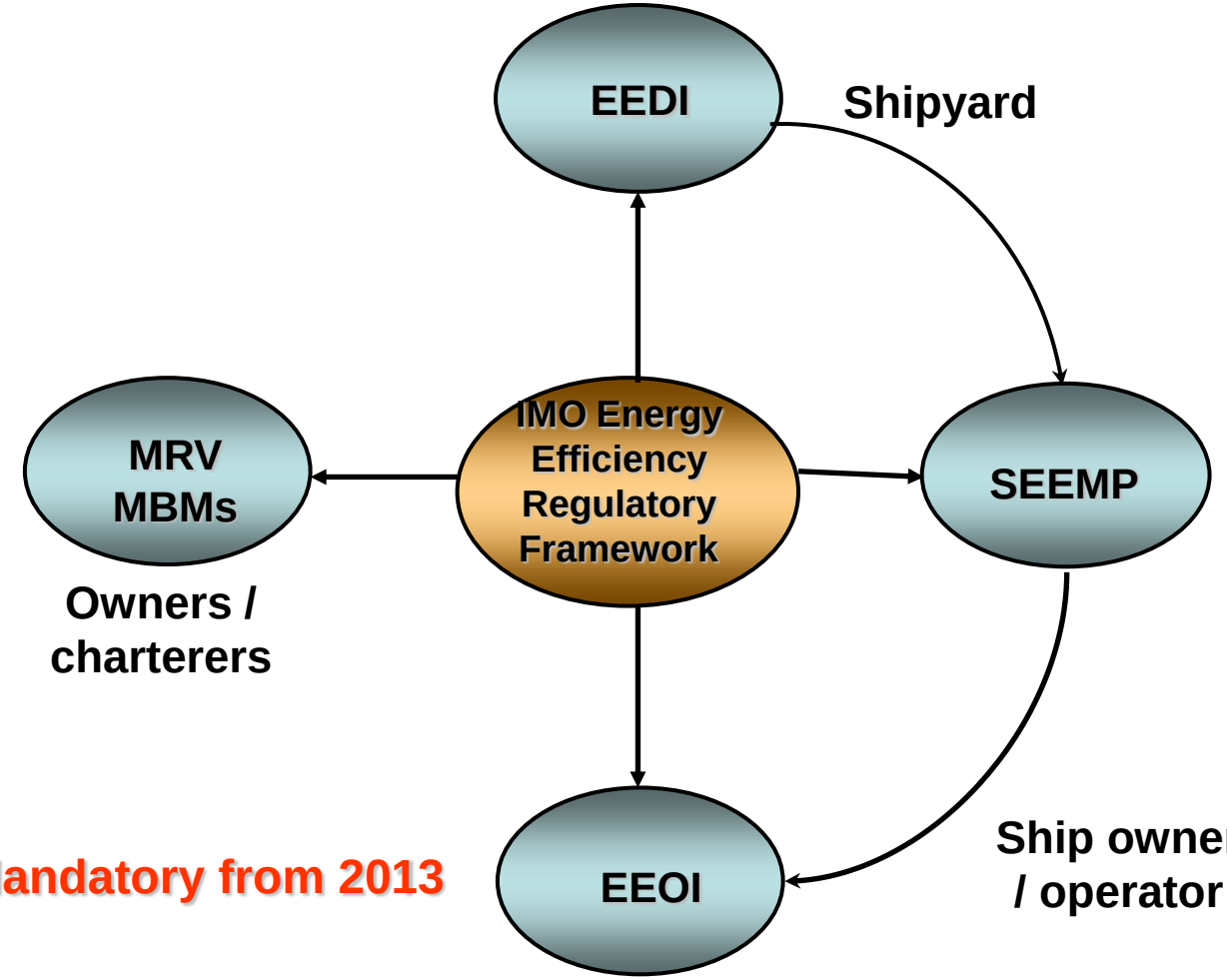
Content

- IMO regulatory framework for ship energy efficiency.
- Chapter 4 of MARPOL Annex VI regulations
- Guidelines for calculation of Attained EEDI
- Guidelines for verification of Attained EEDI
- Guidelines for development of SEEMP
- Guidelines for calculation of EEOI

IMO energy efficiency regulatory activities



IMO framework for GHG emissions control from ships



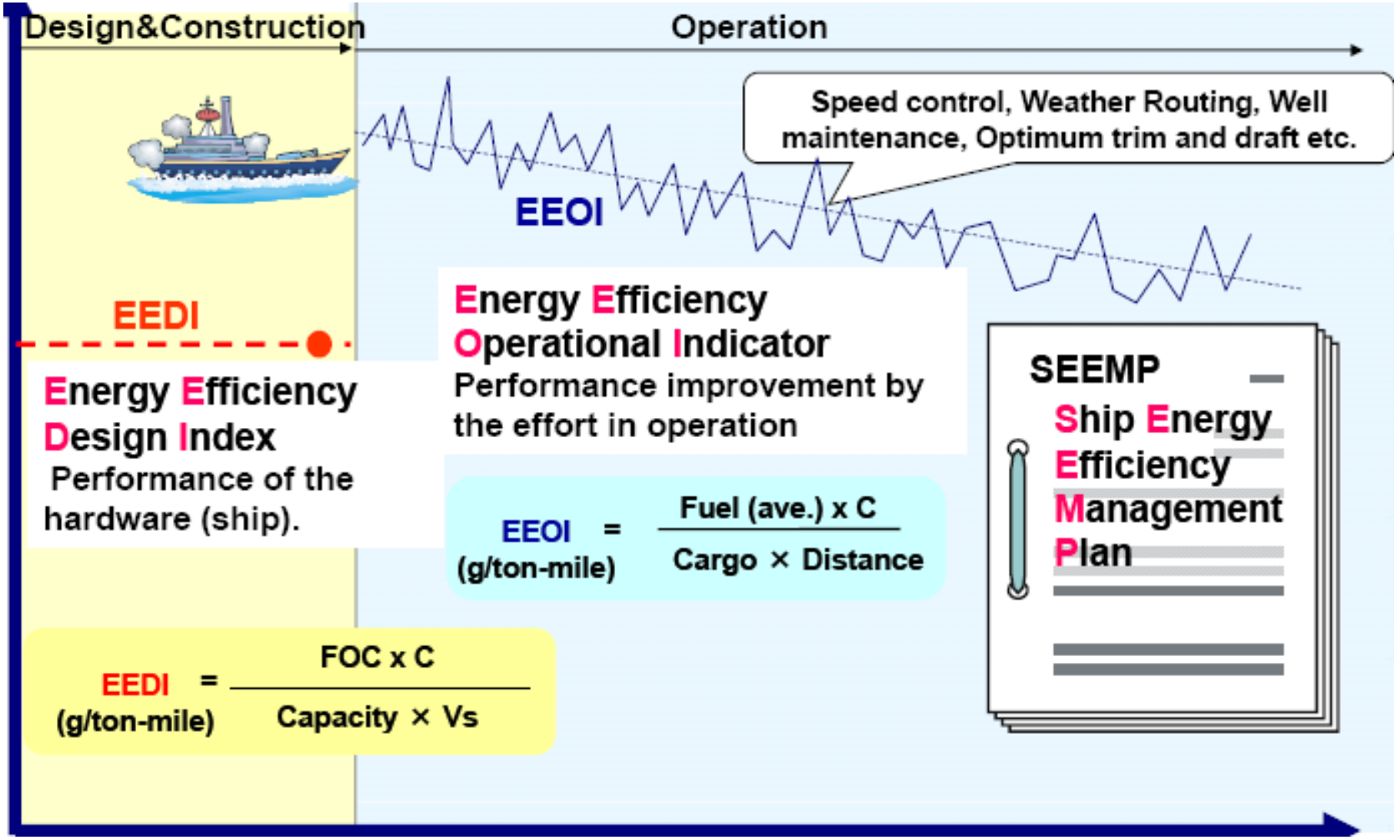
EEDI and SEEMP: Mandatory from 2013

EEOI: Voluntary

Data collection: Under discussion

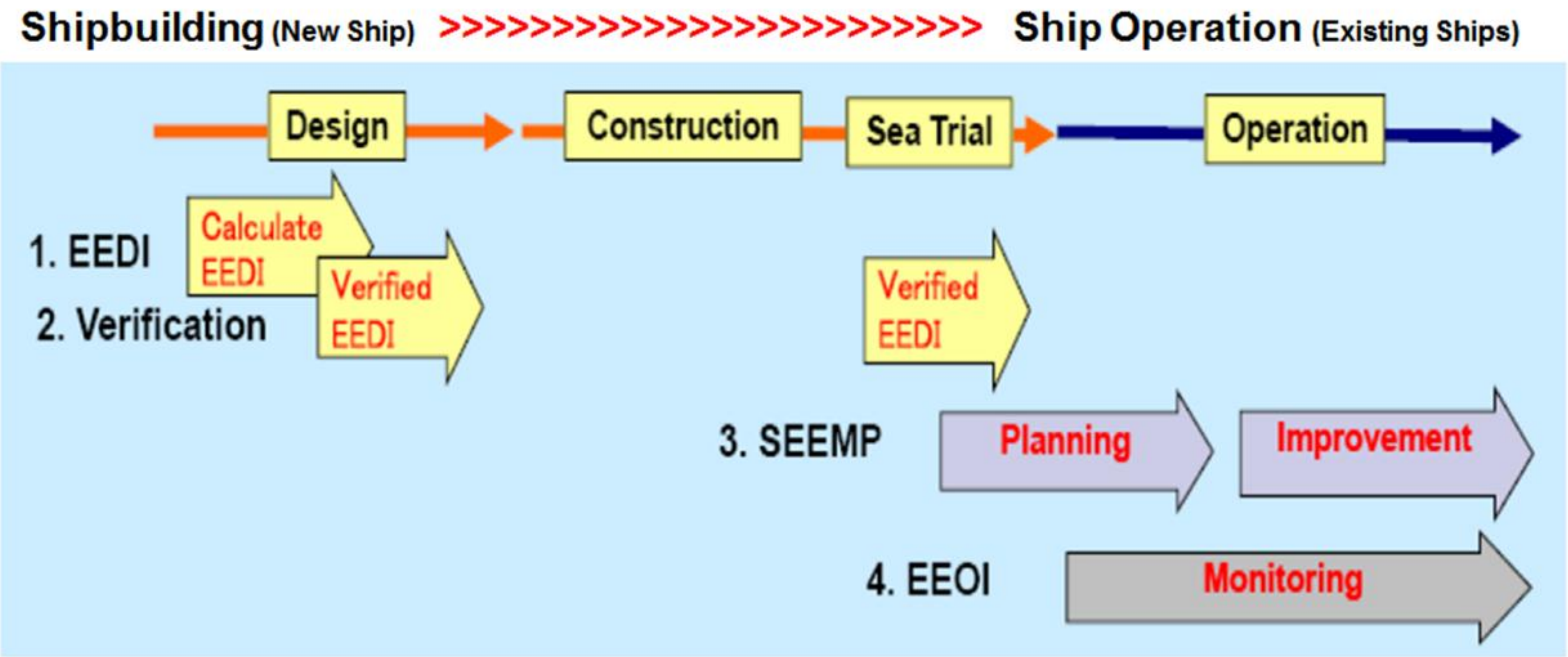
MBMs: Discussion currently suspended

EEDI, EEOI and SEEMP links



Source: IMO presentation on Technical measures

EEDI, EEOI and SEEMP processes



PART 1 – MARPOL Annex VI Regulations on Energy Efficiency for Ships

- Amendments to existing Annex VI regulations
- Chapter 4 regulation

Amendments to Existing Annex VI Regulations

Res.MEPC.203(62) vs Res.MEPC.176(58)

- Regs with RED has changed as a result of Chapter 4

Resolution MEPC.176(58)	**Resolutions MEPC.203(62) & MEPC251 (66), …..**
Chapter I Reg. 1 Application Reg. 2 Definitions Reg. 3 Exceptions and Exemptions Reg. 4 Equivalents	Chapter I Reg. 1 Application Reg. 2 Definitions Reg. 3 Exceptions and Exemptions Reg. 4 Equivalents
Chapter II Reg. 5 Surveys Reg. 6 Issue or endorsement of a Certificate Reg. 7 Issue of a Certificate by another Party Reg. 8 Form of Certificate Reg. 9 Duration and Validity of Certificate Reg. 10 Port State Control on Operational Requirements Reg. 11 Detection of Violations and Enforcements	Chapter II Reg. 5 Surveys Reg. 6 Issue or endorsement of a Certificate Reg. 7 Issue of a Certificate by another Party Reg. 8 Form of Certificate Reg. 9 Duration and Validity of Certificate Reg. 10 Port State Control on Operational Requirements Reg. 11 Detection of Violations and Enforcements

New ship (Reg. 2.23)

- "New ship" means a ship:

  1. for which the building contract is placed on or after 1 January 2013; 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 July 2013; or
  3. the delivery of which is on or after 1 July 2015.

In the UI (Unified Interpretation), MEPC.1/Circ.795.rev2 , the above is further clarified for other phases of EEDI implementation.

Major conversion (Reg. 2.24)

- "Major Conversion" means in relation to chapter 4 a conversion of a ship:
  - which substantially alters the dimensions, carrying capacity or engine power of the ship; or
  - which changes the type of the ship; or
  - the intent of which in the opinion of the Administration is substantially to prolong the life of the ship; or
  - which otherwise so alters the ship that, if it were a new ship, it would become subject to relevant provisions …Convention not applicable to it as an existing ship; or
  - which substantially alters the energy efficiency of the ship and includes any modifications that could cause the ship to exceed the applicable Required EEDI as set out in Regulation 21.

In the UI (Unified Interpretation), MEPC.1/Circ.795.rev2 , the term "major conversion" is further clarified.

Ship types definitions (part of Regulation 2)

- For Chapter 4**, ship types** are defined under these Regulations:
  - 2.25 Bulk carrier
  - 2.26 Gas carrier (none LNG carriers)
  - 2.27 Tanker
  - 2.28 Container ship
  - 2.29 General cargo ship
  - 2.30 Refrigerated cargo ship
  - 2.31 Combination carrier
  - 2.32 Passenger ship
  - 2.33 Ro-Ro cargo ships (vehicle carrier)
  - 2.34 Ro-Ro cargo ships
  - 2.35 Ro-Ro Passenger ship
  - 2.38 LNG carrier
  - 2.39 Cruise passenger ships

- A number of other clarifications are made under Regulations 2 (ice breaking cargo ship, conventional and non-conventional propulsions ..)

Surveys and certification (Reg. 5.4)

- Ships of chapter 4 shall also be subject to the surveys as below:
  - An initial survey before a new ship is put in service …
  - A general or partial survey, after a major conversion of a ship ... to ensure that the attained EEDI is recalculated as necessary……
  - For major conversions regarded as a newly constructed ship, the Administration shall decide the necessity of an initial survey …
  - For existing ships, the verification of having a SEEMP on board … shall take place at the first intermediate or renewal survey whichever is the first, on or after 1 January 2013."
- Survey and verification for EEDI shall be according to IMO's "EEDI survey and verification Guidelines".

IEE (International Energy Efficiency) Certificate (Reg. 6)

- An IEE Certificate … issued to any ship of 400 gross tonnage and above before that ship may engage in voyages to ports or offshore terminals under the jurisdiction of other Parties.
- The certificate shall be issued or endorsed either by the Administration or any organization duly authorized by it.

International Energy Efficiency Certificate

- No IAPP (International Air Pollution Prevention) Certificate or IEE Certificate shall be issued to a ship which is entitled to fly the flag of a State which is not a Party (Reg. 7).
- The IEE Certificate shall be drawn up in a form corresponding to the model given in appendix VIII to this Annex (Reg. 8)

Duration of validity of IEEC (Reg. 9)

- The IEEC shall be valid throughout the life of the ship subject to the provisions of paragraph 11 below.
- 11 An IEEC issued under this Annex shall cease to be valid in any of the following cases:
  - If the ship is withdrawn from service or
  - If a new certificate is issued following major conversion of the ship; or
  - Upon transfer of the ship to the flag of another State …..

Port State Control on operational requirements (Reg. 10)

- In relation to chapter 4, any Port State inspection shall be limited to verifying, when appropriate, that there is a valid IEEC on board, in accordance with article 5 of the Convention.

Article 5 - Certificates and special rules on inspection of ships

1. Subject to …. a certificate issued under the authority of a Party to the Convention … shall be accepted by the other Parties …

2. . … Any such inspection shall be limited to verifying that there is on board a valid certificate, unless there are clear grounds for believing that …
3. . ……..

4. With respect to the ship of non-Parties to the Convention, Parties shall apply the requirements of the present Convention as may be necessary to ensure that no more favourable treatment is given to such ships.

New Chapter 4 of MARPOL Annex VI Regulations

Res.MEPC.203(62) vs Res.MEPC.176(58)

Resolution MEPC.176(58)	Resolution MEPC.203(62)
Chapter Ⅲ Reg. 12 Ozone Depleting Substances Reg. 13 Nitrogen Oxides(NOx) Reg. 14 Sulphur Oxides(SOx) and Particular Matter Reg. 15 Volatile Organic Compounds (VOCs) Reg. 16 Shipboard Incineration Reg. 17 Reception Facilities Reg. 18 Fuel Oil Availability and Quality	Chapter Ⅲ Reg. 12 Ozone Depleting Substances Reg. 13 Nitrogen Oxides(NOx) Reg. 14 Sulphur Oxides(SOx) and Particular Matter Reg. 15 Volatile Organic Compounds(VOCs) Reg. 16 Shipboard Incineration Reg. 17 Reception Facilities Reg. 18 Fuel Oil Availability and Quality
	Chapter Ⅳ **Reg. 19 Application** **Reg. 20 Attained EEDI** **Reg. 21 Required EEDI** **Reg. 22 SEEMP** **Reg. 23 Promotion of technical co-operation and transfer of technology relating to the improvement of energy efficiency of ships**
Appendix Ⅰ~Ⅵ	Appendix Ⅰ~Ⅵ **Appendix Ⅷ Form of International Energy Efficiency(IEE) Certificate**

Regulation 19 - Application

Regulation 19 - Applications

- This chapter shall apply to all ships of 400 gross tonnage and above.
- The provisions of this chapter **shall not apply** to:
  - Ships solely engaged in voyages within waters of Flag State.
  - However, each Party should ensure …that such ships are constructed and act in a manner consistent with chapter 4, so far as is reasonable and practicable.
- Regulations 20 and 21 shall not apply to ships which have **non-conventional propulsion**, except cruise passenger ships and LNG carriers having conventional or non-conventional propulsion, delivered on or after 1 September 2019.

Regulation 19 – Application (Waiver)

- …….. the Administration may waive the requirement for a ship … from complying with regulation 20 and regulation 21.
- The provision of the above shall not apply to ships with:
  - Contract date 1 January 2017.
  - Keel laying 1 July 2017
  - Delivery date of 1 July 2019.
- The above implies that waiver is only for 4 years.
- The Administration of a Party … which allows application of waiver … to a ship …. shall communicate this to the Organization for circulation to the Parties …….

Regulation 20 – Attained EEDI

Regulation 20 – Attained EEDI

- The attained EEDI shall be calculated for:
  - each new ship;
  - each new ship which has undergone a major conversion; and
  - each new or existing ship which has undergone so extensive major conversion, that is regarded by the Administration as a newly constructed ship
- The above are applicable to ships defined in Regulations 2.25 to 2.35, 2.38 and 2.39.
- The attained EEDI shall be specific to each ship …… and be accompanied by the EEDI Technical File ….
- The attained EEDI shall be calculated taking into account guidelines developed by the Organization (Resolution MEPC.245(66))
- The attained EEDI shall be verified either by the Administration or by any organization duly authorized by it.

Regulation 21 – Required EEDI

Regulation 21.1 – Required EEDI

- 1 For each:
  - new ship;
  - new ship which has undergone a major conversion; and
  - each new or existing ship which has undergone so extensive major conversion, that is regarded by the Administration as a newly constructed ship
- For ships defined in Regulation 2.25 to 2.31, 2.33 to 2.35 and 2.39:
  - Attained EEDI ≤ Required EEDI ; and
  - Required EEDI = (1-**X**/100) x **reference line value**
- Where
  - **X** is the reduction factor
  - **Reference line value** is estimated from EEDI Reference line.

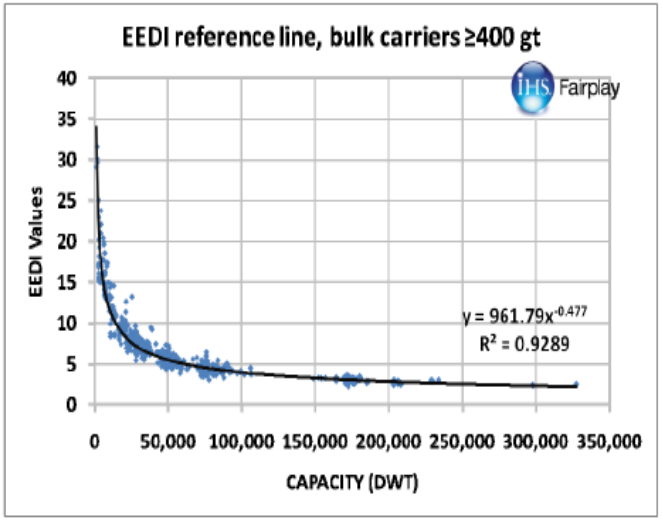
Regulation 21 – Required EEDI details
Cut-off levels, phases and reduction rates

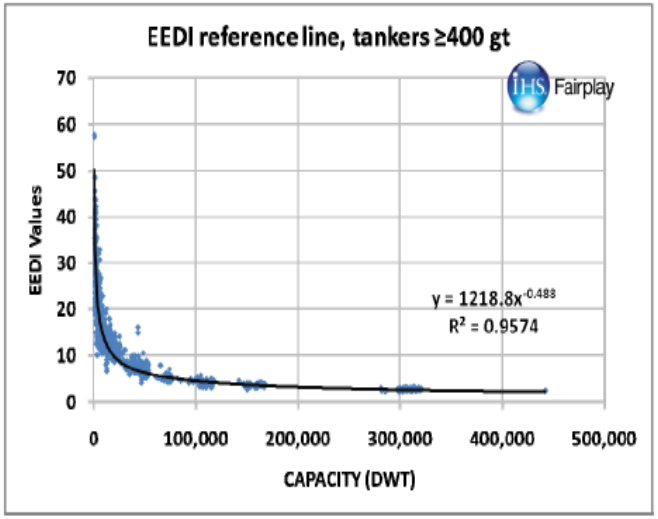
Ship Type	Size	Phase 0 1 Jan 2013 – 31 Dec 2014	Phase 1 1 Jan 2015 – 31 Dec 2019	Phase 2 1 Jan 2020 – 31 Dec 2024	Phase 3 1 Jan 2025 and onwards
Bulk carrier	20,000 DWT and above	0	10	20	30
	10,000 – 20,000 DWT	n/a	0-10*	0-20*	0-30*
Gas carrier	10,000 DWT and above	0	10	20	30
	2,000 – 10,000 DWT	n/a	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 ships	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***	1000 DWT and above	n/a	5**	20	30
	250 – 1,000 DWT	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*

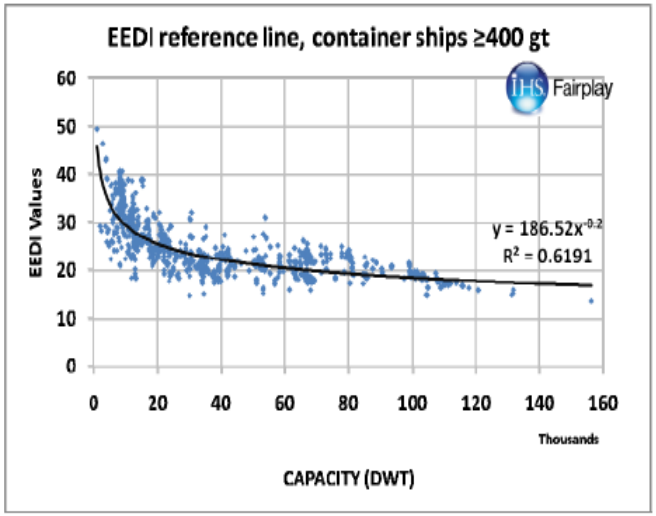
Reference lines

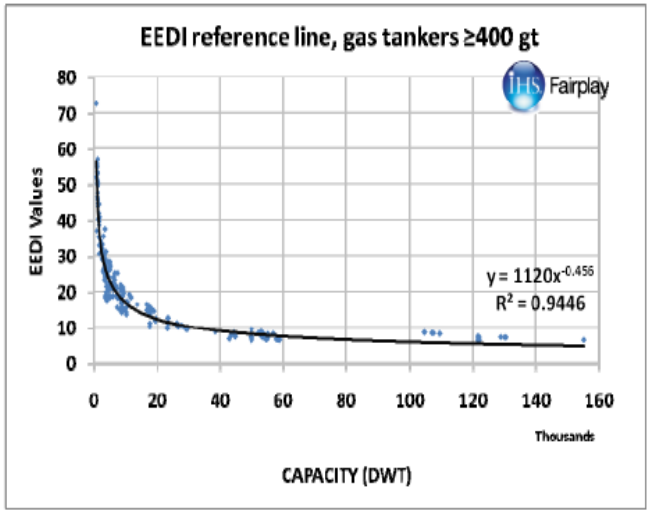
- Reference lines are ship specific.
- Dependent on ship type and size.
- Calculated ship data from HIS Fairplay database:

$$Estimated\ Index\ Value = 3.1144 \cdot \frac{190 \cdot \sum_{i=1}^{NME} P_{ME\,i} + 215 \cdot P_{AE}}{Capacity \cdot V_{ref}}$$









For details of how reference lines are developed, see **Resolution MEPC.231(65):** 2013 Guidelines for calculation of reference lines ……

Regulation 21.3 – Reference line

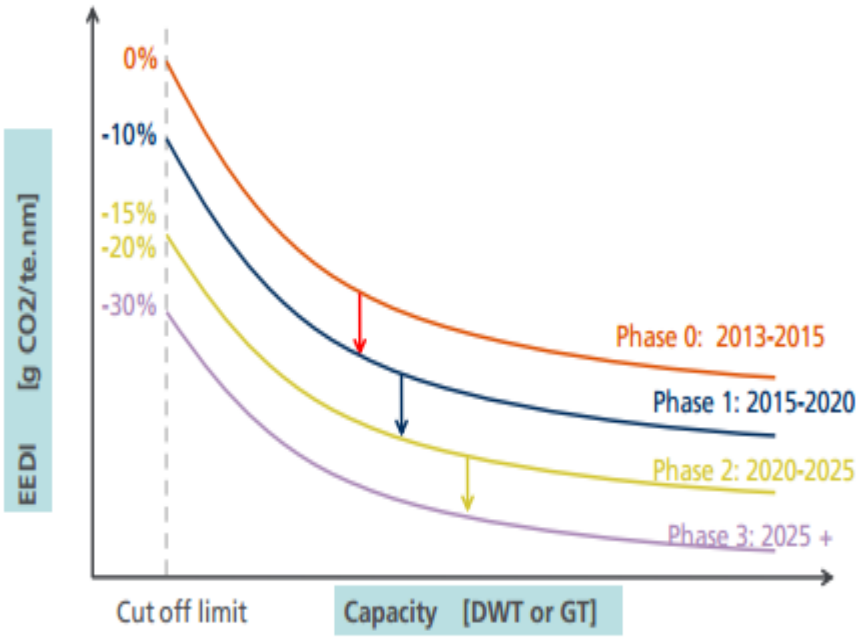
- Reference line = $a*b^{-c}$

Ship type defined in regulation 2		a	b	c
2.25	Bulk carrier	961.79	DWT of the ship	0.477
2.26	Gas carrier	1120.00	DWT of the ship	0.456
2.27	Tanker	1218.80	DWT of the ship	0.488
2.28	Container ship	174.22	DWT of the ship	0.201
2.29	General cargo ship	107.48	DWT of the ship	0.216
2.30	Refrigerated cargo carrier	227.01	DWT of the ship	0.244
2.31	Combination carrier	1219.00	DWT of the ship	0.488
2.33	Ro-ro cargo ship (vehicle carrier)	$(DWT/GT)^{-0.7}$ · 780.36 where DWT/GT<0.3	DWT of the ship	0.471
		1812.63 where DWT/GT≥0.3		
2.34	Ro-ro cargo ship	1405.15	DWT of the ship	0.498
2.35	Ro-ro passenger ship	752.16	DWT of the ship	0.381
2.38	LNG carrier	2253.7	DWT of the ship	0.474
2.39	Cruise passenger ship having non-conventional propulsion	170.84	GT of the ship	0.214

Reg. 21 - Reduction factor and cut-off limits

- Reduction factor is the % reduction in Required EEDI relative to Reference Line.

- Cut off levels:
  - Bulk Carriers: 10,000 DWT
  - Gas carriers: 2,000 DWT
  - Tankers: 4,000 DWT
  - Container ship: 10,000 DWT
  - Gen./ref. Cargo: 3,000 DWT



Review of phases and reduction factors (Reg. 21.6)

At the beginning of Phase 1 and at the midpoint of Phase 2, the Organization shall review the status of technological developments and, if proven necessary, amend the time periods, the EEDI reference line parameters for relevant ship types and reduction rates set out in this regulation.

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 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 Tanker	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 Ship	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*

Technology review for EEDI Phase 2

- Corresponding Group was established at MEPC 67.
- Purpose: To review the status of technological developments relevant to implementing Phase 2 of EEDI regulation via:
  - Data collection and analysis
  - Use of information in IMO EEDI database (established at MEPC 66)
  - Publicly available and verifiable information from all stakeholders.
- Report on the following:
  - The range of technologies that may be used to comply with the EEDI Phase 2.
  - The current use of these technologies and the progress needed for EEDI Phase 2.
- Progress report to MEPC 68, interim report to MEPC 69.

Regulation 22 - SEEMP

Regulation 22 - SEEMP

Regulation 22

Ship Energy Efficiency Management Plan (SEEMP)

1 Each ship shall keep on board a ship specific Ship Energy Efficiency Management Plan (SEEMP). This may form part of the ship's Safety Management System (SMS).

2 The SEEMP shall be developed taking into account guidelines adopted by the Organization.

SEEMP and IEE Certificate

- For existing ships, a Record of Construction needs to be filled and an IEE Certificate issued when the existence of SEEMP on-board is verified.

Supplement to the International Energy Efficiency Certificate
(IEE Certificate)

RECORD OF CONSTRUCTION RELATING TO ENERGY EFFICIENCY

Notes:

1 This Record shall be permanently attached to the IEE Certificate. The IEE Certificate shall be available on board the ship at all times.

5 Ship Energy Efficiency Management Plan

5.1 The ship is provided with a Ship Energy Efficiency Management Plan (SEEMP) in compliance with regulation 22 ..... ☐

Verification that a SEEMP is on-board

- The verification will be done as part of first intermediate or renewal survey, whichever is the first, after 1 January 2013.

.4 For existing ships, the verification of the requirement to have a SEEMP on board according to regulation 22 shall take place at the first intermediate or renewal survey identified in paragraph 1 of this regulation, whichever is the first, on or after 1 January 2013."

Regulation 23 - Promotion of technical cooperation and technology transfer

Regulation 23 - Promotion of technical co-operation and transfer of technology

- Administrations shall, in co-operation with the Organization and other international bodies, promote and provide, as appropriate, support directly or through the Organization to States, especially developing States, that request technical assistance.
- The Administration of a Party shall co-operate actively with other Parties, …, to promote the development and transfer of technology and exchange of information to States which request technical assistance, particularly developing States, for implementation of … the requirements of chapter 4 of this annex, in particular regulations 19.4 to 19.6."

Supplement to IEEC – Record of construction

Supplement to the International Energy Efficiency Certificate
(IEE Certificate)

RECORD OF CONSTRUCTION RELATING TO ENERGY EFFICIENCY

Notes:

1 This Record shall be permanently attached to the IEE Certificate. The IEE Certificate shall be available on board the ship at all times.

2 The Record shall be at least in English, French or Spanish. If an official language of the issuing Party is also used, this shall prevail in case of a dispute or discrepancy.

3 Entries in boxes shall be made by inserting either: a cross (x) for the answers "yes" and "applicable"; or a dash (-) for the answers "no" and "not applicable", as appropriate.

4 Unless otherwise stated, regulations mentioned in this Record refer to regulations in Annex VI of the Convention, and resolutions or circulars refer to those adopted by the International Maritime Organization.

- The records of construction contains the following information:
  - Particular of ship
  - Propulsion system
  - Attained EEDI
  - Required EEDI
  - SEEMP
  - EEDI Technical File
  - Endorsement that provided data are correct.

PART 2 – Guidelines on EEDI Calculation and Verification

- Guidelines for Attained EEDI calculation
- Guidelines for Attained EEDI verification

Guidelines on the Calculation of the Attained EEDI

- Resolution MEPC.245(66): 2014 Guidelines on the Method of Calculation of the Attained EEDI for new ships, Adopted on 4 April 2014

Attained EEDI: Formula

- EEDI (gCO2/tonne.mile) =

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

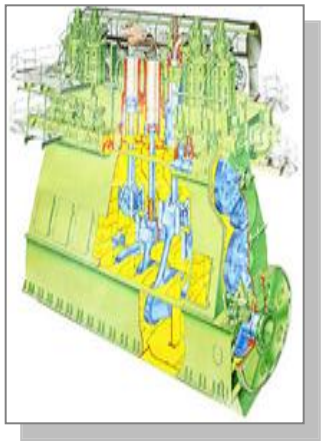
- Not applicable to a ship having diesel-electric propulsion, turbine propulsion and hybrid propulsion except for:
  - Cruise passenger ships and
  - LNG carriers

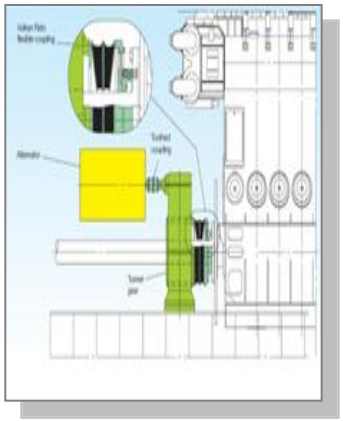
Attained EEDI: Calculation formula

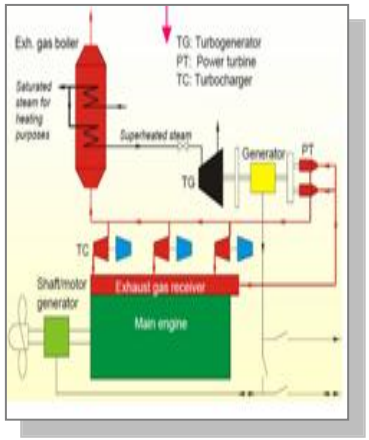
Main Engine(s)	Aux Engine(s)	Innovative Energy Eff. Power Gen. Technologies	Innovative Energy Eff. Propulsion

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

[gCO2/(tonne.nm)]





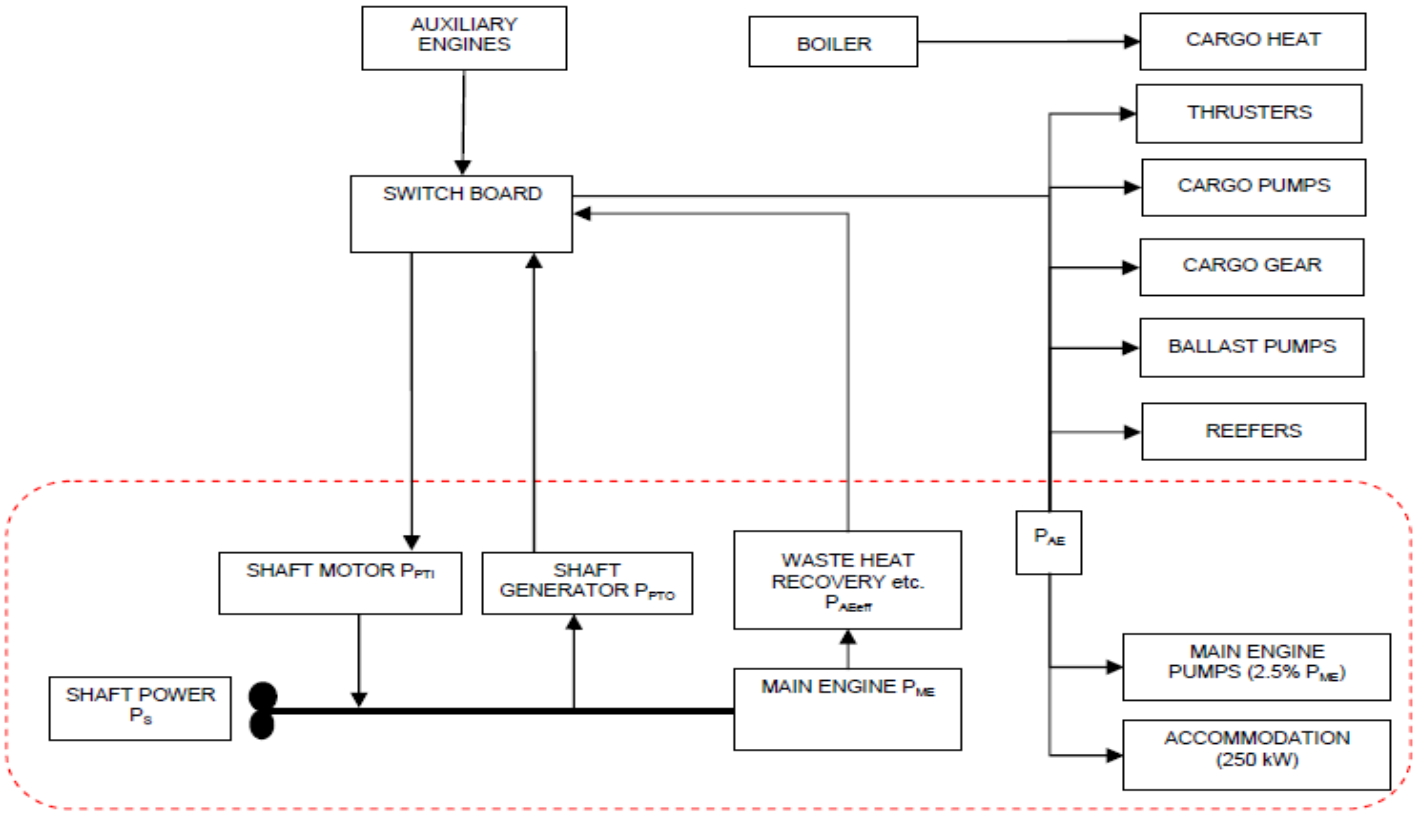


Boilers are excluded from EEDI

Scope of Attained EEDI (dashed red line)

APPENDIX 1

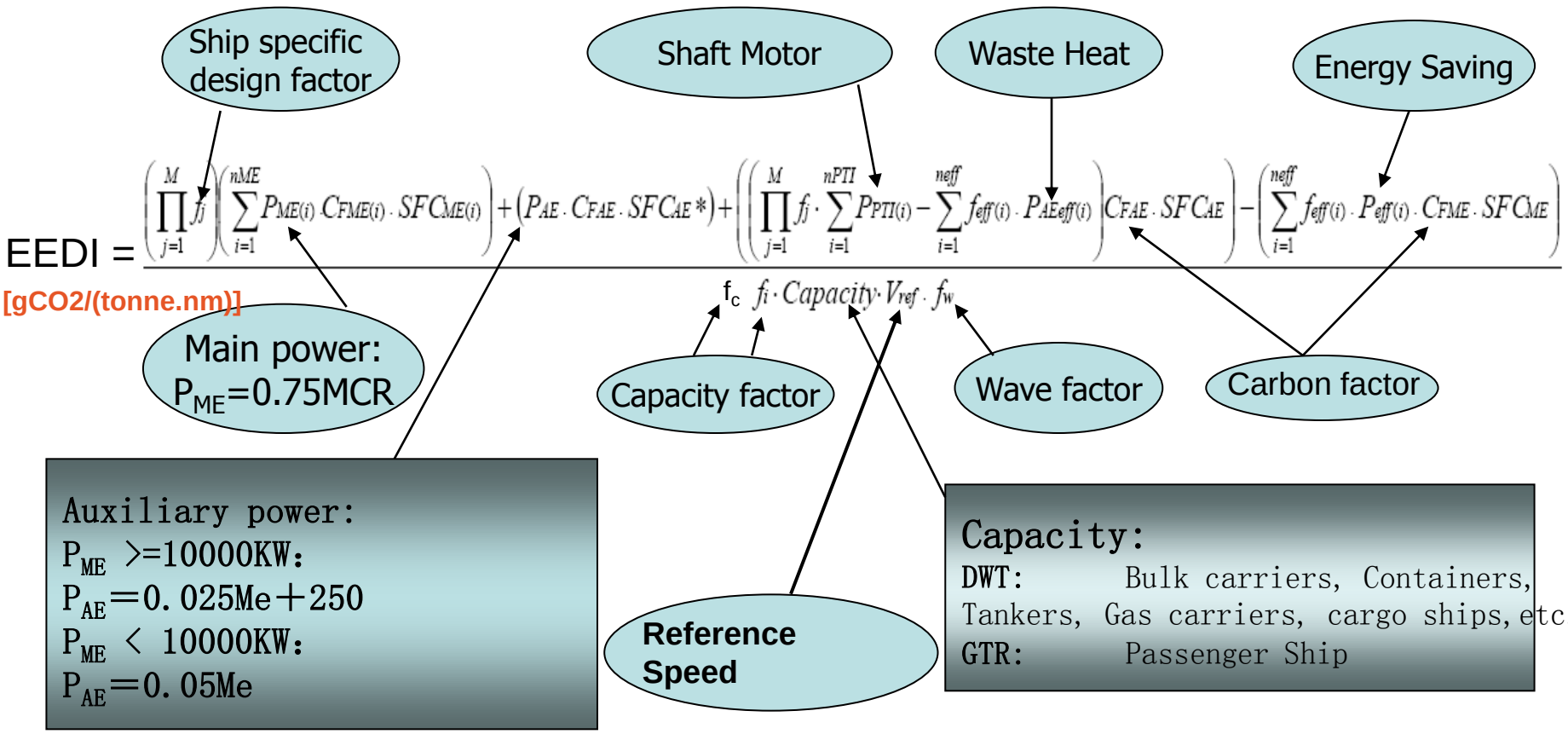
A GENERIC AND SIMPLIFIED MARINE POWER PLANT



Note 1: Mechanical recovered waste energy directly coupled to shafts need not be measured, since the effect of the technology is directly reflected in the V_{ref} .

Note 2: In case of combined PTI/PTO, the normal operational mode at sea will determine which of these to be used in the calculation.

Attained EEDI: Parameters



EEDI condition

- EEDI is calculated for a single operating condition of the ship. This will be referred to as EEDI Condition.

- The EEDI Condition is as follows:
  - **Draft:** Summer load line draft.
  - **Capacity:** Deadweight (or gross tonnage for passenger ships) for the above draft (container ship will be 70% value).
  - **Weather condition:** Calm with no wind and no waves.
  - **Propulsion shaft power:** 75% of main engine MCR (conventional ships) with some amendments for shaft motor or shaft generator or shaft-limited power cases.
  - **Reference speed (Vref):** is the ship speed under the above conditions.

Main Parameters

Capacity

- Deadweight for cargo ships:

- 70% of deadweight for
  - Containerships.

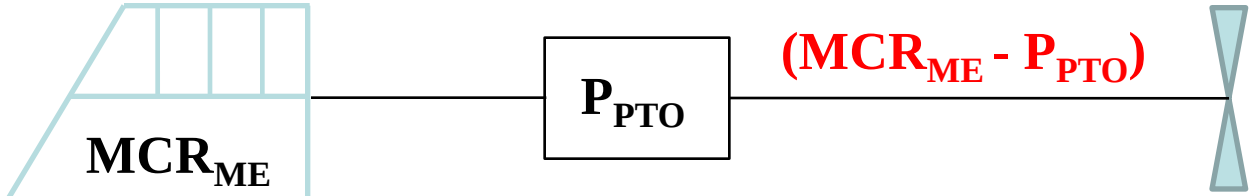
- Gross tonnage for passenger ships

Main (engine) power – PM_E (options)

- **Power for propulsion**
  - (P_{ME}) main engine

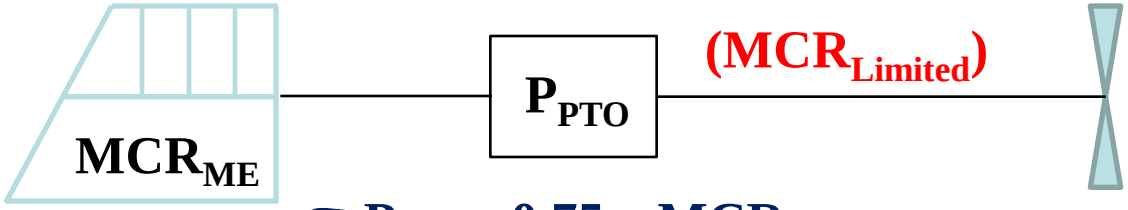
☞ $P_{ME} = 0.75 \times MCR_{ME}$

  - (P_{PTO}) Shaft generator
    - ✓ P_{PTO}(small)



☞ $P_{ME} = 0.75 \times (MCR_{ME} - P_{PTO})$

    - ✓ Main engine (big)
    - ✓ $\underline{P_{PTO}(big)}$

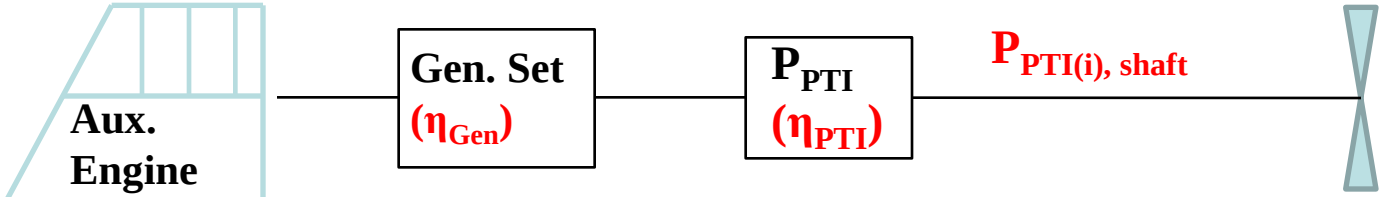


☞ $P_{ME} = 0.75 \times MCR_{Limited}$

Main engine power (options)

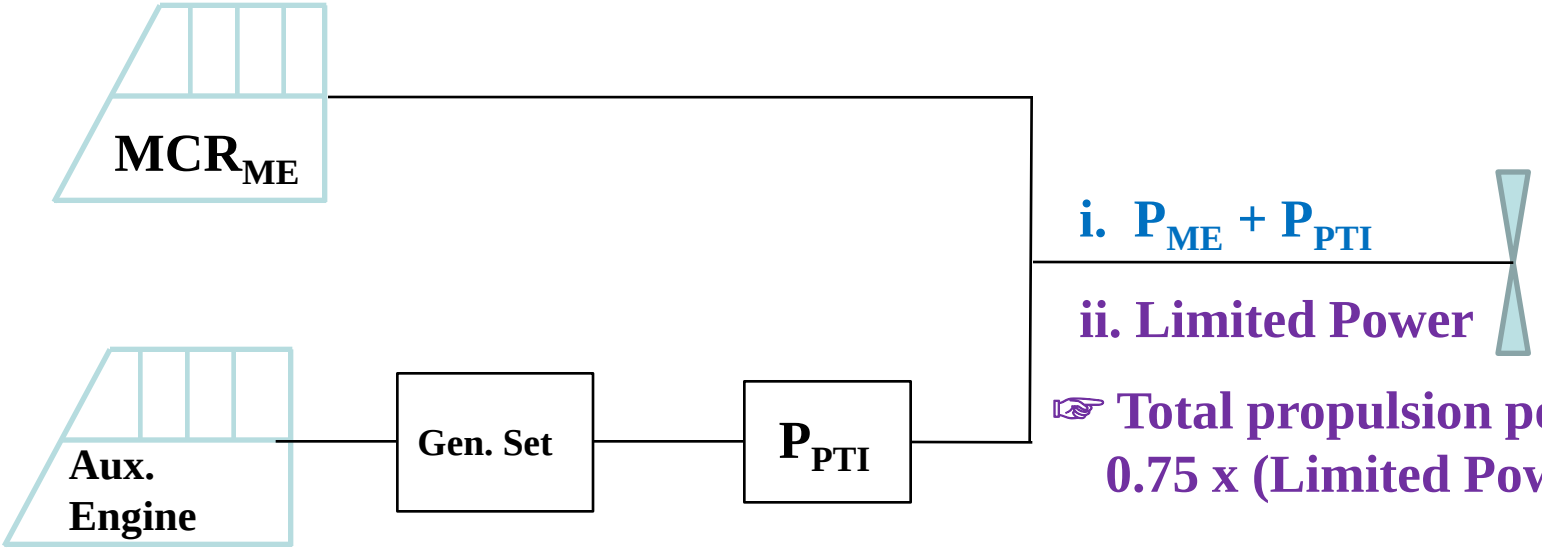
- **Power for propulsion – Electric ship type**
  - **(P_{PTI}) shaft motor**

$$\sum P_{PTI\,(i),shaft} = \sum (P_{PTI\,(i)} \cdot \eta_{PTI\,(i)}) \cdot \eta_{Gen}$$



☞ $P_{PTI} = 0.75 \times P_{PTI}$

- **Measurement of V_{ref} (main engine + shaft motor)**



☞ Total propulsion power = 0.75 x (Limited Power)

Reference speed - Vref

- Measured under EEDI Condition using the P_{ME} as propulsion shaft power.

Auxiliary (engine) power - P_{AE}

- P_{AE} is the required auxiliary engine power to supply normal maximum sea load ship's (excluding cargo) requirements.
- P_{AE} is calculated as follows:

.1 For ships with a main engine power of 10,000 kW or above, P_{AE} is defined as:

$$P_{AE(MCRME\geq 10000KW)} = \left(0.025 \times \left(\sum_{i=1}^{nME} MCR_{MEi} + \frac{\sum_{i=1}^{nPTI} P_{PTI(i)}}{0.75} \right) \right) + 250$$

.2 For ships with a main engine power below 10,000 kW, P_{AE} is defined as:

$$P_{AE(MCRME<10000KW)} = \left(0.05 \times \left(\sum_{i=1}^{nME} MCR_{MEi} + \frac{\sum_{i=1}^{nPTI} P_{PTI(i)}}{0.75} \right) \right)$$

- P_{AE} calculations has specific rules for LNG carriers where re-liquefaction plant involved.
- For cases where calculated P_{AE} is significantly different from actual P_{AE}, the ship **Electric Power Table**s should be used to estimate P_{AE} .

Engine Specific Fuel Consumption - SFC

- For engines certified to the E2 or E3 test cycles of the NOx Technical Code 2008, the engine $SFC_{ME(i)}$ is … at 75 per cent of MCR power.
- For engines certified to the D2 or C1 test cycles of the NOx Technical Code 2008, the engine $SFC_{AE(i)}$ is … at 50 per cent of MCR power.
- There are more details on SFC for cases:
  - When there is no certified value (manufacturer value …)
  - For pure gas or dual fuel engines (conversion to standard 48000 MJ/kg base).
  - For LNG ships with steam turbines
  - C_F and SFC shall be compatible

Factors and Correction Factors

Factors in EEDI formula

- C_F is the carbon factor to take into account the type of fuel
- f_w **:** Weather factor indicating the decrease of speed due to representative sea conditions of wave height, wave frequency and wind speed (e.g., Beaufort Scale 6).
- $f_{eff(i)}$ is the availability factor of each innovative energy efficiency technology.
- ***Correction factors:*** There are a number of **correction factors** including **fi, fi, fc**, etc.

C_F (carbon factor) [Clause2.1]

- *C_F: C*onversion factor between fuel consumption and CO2 emission.
- C_F corresponds to the fuel used when determining *SFC* listed in the NOx Technical File (part of EIAPP certificate).

	Type of fuel	Reference	Carbon content	C_F (t-CO_2/t-Fuel)
1	Diesel/Gas Oil	ISO 8217 Grades DMX through DMB	0.8744	3.206
2	Light Fuel Oil (LFO)	ISO 8217 Grades RMA through RMD	0.8594	3.151
3	Heavy Fuel Oil (HFO)	ISO 8217 Grades RME through RMK	0.8493	3.114
4	Liquefied Petroleum Gas (LPG)	Propane	0.8182	3.000
		Butane	0.8264	3.030
5	Liquefied Natural Gas (LNG)		0.7500	2.750
6	Methanol		0.3750	1.375
7	Ethanol		0.5217	1.913

Availability factor feff(i)

- $f_{eff(i)}$ is the availability factor of each innovative energy efficiency technology.
- Guidelines for estimation of availability factor for wind power, solar power, etc. has been developed in the relevant Guidelines.
- Currently availability factor of 1.0 is used for waste heat recovery.

Correction factors

- **Power correction factor (f_j)**
  - Ice-classed ships (f_j)
  - Shuttle tankers with propulsion redundancy(80,000~160,000 DWT) (f_j)
  - Ro-Ro ships, all types (f_{jRoRo})
  - General cargo ships
- **Capacity factor (f_i)**
  - Ice-classed ships (f_i)
  - Ship specific voluntary structural enhancement (f_{iVSE})
  - Bulk carriers and oil tankers, built in accordance with Common Structural Rules (f_{iCSR})
- **Cubic capacity correction factor (f_c)**
  - Chemical tanker's (f_c)
  - Gas carriers having direct diesel driven propulsion system (f_{cLNG})

fj design correction factor for propulsion power

- fj for ice-class ships: the greater value of *fj0* and *fj,min:*

Ship type	f_{j0}	$f_{j,min}$ depending on the ice class			
		IA Super	IA	IB	IC
Tanker	$\frac{0.308 L_{PP}^{1.920}}{\sum_{i=1}^{nME} P_{ME(i)}}$	$0.15 L_{PP}^{0.30}$	$0.27 L_{PP}^{0.21}$	$0.45 L_{PP}^{0.13}$	$0.70 L_{PP}^{0.06}$
Bulk carrier	$\frac{0.639 L_{PP}^{1.754}}{\sum_{i=1}^{nME} P_{ME(i)}}$	$0.47 L_{PP}^{0.09}$	$0.58 L_{PP}^{0.07}$	$0.73 L_{PP}^{0.04}$	$0.87 L_{PP}^{0.02}$
General cargo ship	$\frac{0.0227 \cdot L_{PP}^{2.483}}{\sum_{i=1}^{nME} P_{ME(i)}}$	$0.31 L_{PP}^{0.16}$	$0.43 L_{PP}^{0.12}$	$0.56 L_{PP}^{0.09}$	$0.67 L_{PP}^{0.07}$

- *fj = 0.77 for shuttle tankers of* with propulsion redundancy between 80,000 and 160,000 deadweight.
- *fjRoRO an fj for general cargo ship according to specific formulas*
- *Fj = 1.0 for all other ships.*

fi correction factor for ship capacity for technical/regulatory limitations (1)

- fi for ice-class ships: the greater value of *fi0* and *fi,max:*

Ship type	f_{i0}	$f_{i,max}$ depending on the ice class			
		IA Super	IA	IB	IC
Tanker	$\frac{0.00138 \cdot L_{PP}^{3.331}}{capacity}$	$2.10 L_{PP}^{-0.11}$	$1.71 L_{PP}^{-0.08}$	$1.47 L_{PP}^{-0.06}$	$1.27 L_{PP}^{-0.04}$
Bulk carrier	$\frac{0.00403 \cdot L_{PP}^{3.123}}{capacity}$	$2.10 L_{PP}^{-0.11}$	$1.80 L_{PP}^{-0.09}$	$1.54 L_{PP}^{-0.07}$	$1.31 L_{PP}^{-0.05}$
General cargo ship	$\frac{0.0377 \cdot L_{PP}^{2.625}}{capacity}$	$2.18 L_{PP}^{-0.11}$	$1.77 L_{PP}^{-0.08}$	$1.51 L_{PP}^{-0.06}$	$1.28 L_{PP}^{-0.04}$
Containership	$\frac{0.1033 \cdot L_{PP}^{2.329}}{capacity}$	$2.10 L_{PP}^{-0.11}$	$1.71 L_{PP}^{-0.08}$	$1.47 L_{PP}^{-0.06}$	$1.27 L_{PP}^{-0.04}$
Gas carrier	$\frac{0.0474 \cdot L_{PP}^{2.590}}{capacity}$	1.25	$2.10 L_{PP}^{-0.12}$	$1.60 L_{PP}^{-0.08}$	$1.25 L_{PP}^{-0.04}$

- f_{iVSE} for ship specific Voluntary Structural Enhancement:

$$f_{iVSE} = \frac{DWT_{reference\ design}}{DWT_{enhanced\ design}}$$

Where:

$$DWT_{reference\ design} = \Delta_{ship} - lightweight_{reference\ design}$$

$$DWT_{enhanced\ design} = \Delta_{ship} - lightweight_{enhanced\ design}$$

fi correction factor for ship capacity for technical/regulatory limitations (2)

- for bulk carriers and oil tankers, built in accordance with Common Structural Rules (CSR)

$$f_{iCSR} = 1 + (0.08 \cdot LWT_{CSR} / DWT_{CSR})$$

Where, DWT_{CSR} is the deadweight determined by paragraph 2.4 and LWT_{CSR} is the light weight of the ship.

- fi = 1.0 for all other ships.

fc : Cubic Capacity correction factor

- For chemical tankers:

  $f_c = R^{-0.7} - 0.014$, where R is less than 0.98
  or
  $f_c = 1.000$, where R is 0.98 and above;

  where: R is the capacity ratio of the deadweight of the ship (tonnes) as determined by paragraph 2.4 divided by the total cubic capacity of the cargo tanks of the ship (m^3).

- For RoRo Passenger ship:

$$f_{cRoPax} = \left(\frac{\left(DWT/_{GT} \right)}{0.25} \right)^{-0.8}$$

- For diesel electric LNG ship:

$$f_{cLNG} = R^{-0.56}$$

where: R is the capacity ratio of the deadweight of the ship (tonnes) as determined by paragraph 2.4 divided by the total cubic capacity of the cargo tanks of the ship (m^3).

Summary on Attained EEDI calculations

- Attained EEDI is calculated for “EEDI Condition” that represents:
  - Capacity at summer load line draft
  - Ship speed at 75% of main shaft power MCR and the above capacity.
- Required engine data are derived from engine NOx Technical File.
- A large number of “correction factors” are included in the formula.
- Method of calculation of correction factors are defined within the Guidelines.

Guidelines on Survey and Verification of EEDI

- 2014 Guidelines on survey and certification of the energy efficiency design index (EEDI), Resolution MEPC.254(67), as amended by Resolution MEPC.261(68)

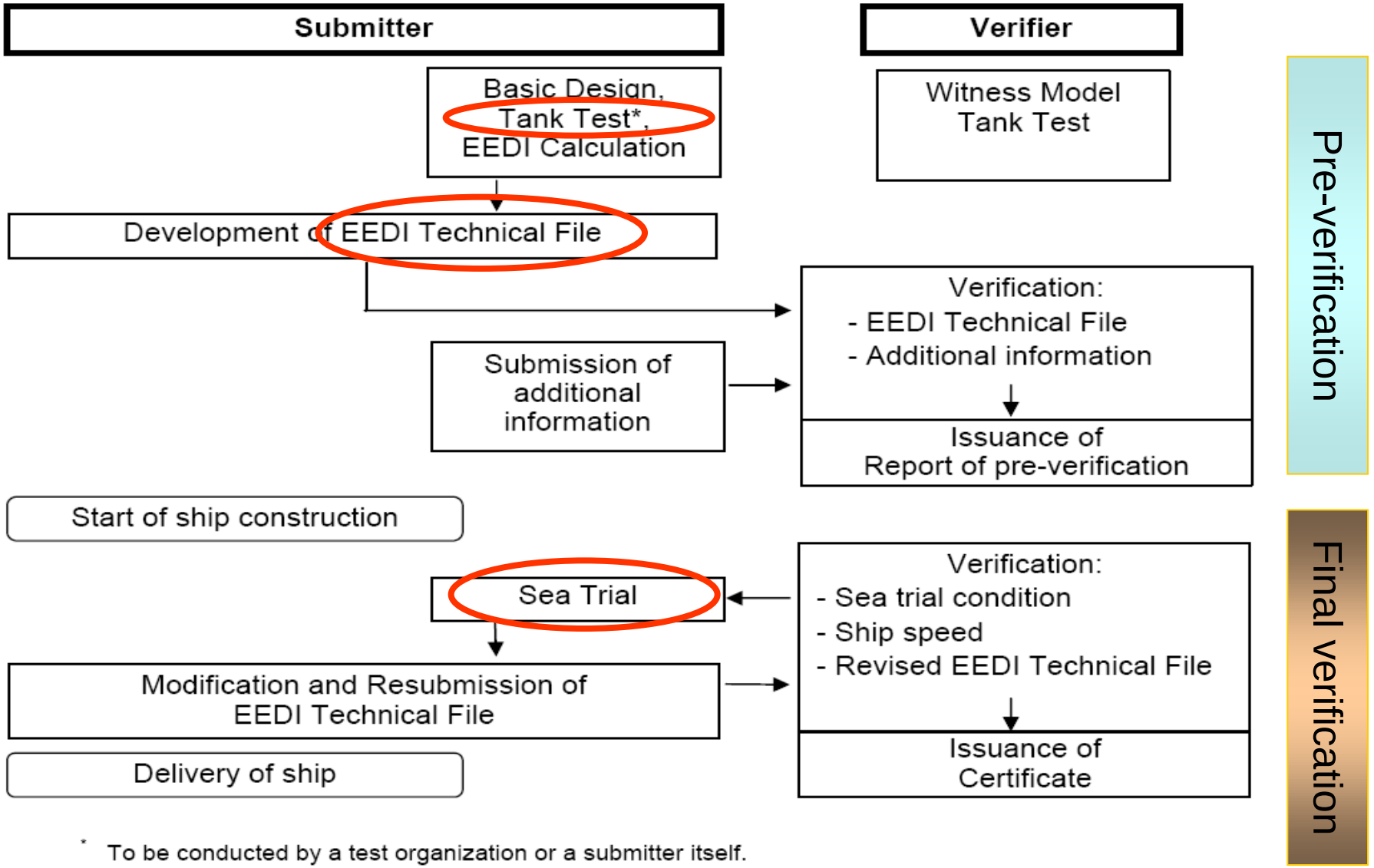
Content

- Introduction
- Verification process
- Preliminary verification
- Final verification
- Verification of major conversions
- Summary

Verification stages

- Survey and certification of the EEDI should be conducted on two stages:
  - **Preliminary verification** at the design stage, and
  - **Final verification** at the sea trial.

Verification process (Clause 4.1)



* To be conducted by a test organization or a submitter itself.

Preliminary Verification

Preliminary verification

- For the preliminary verification at the design stage, the following should be submitted to the verifier:
  - An application for an initial survey
  - An EEDI Technical File containing the necessary information
  - Other relevant background documents

Tank test aspects

- The power curves used for the preliminary verification should be based on results of tank test.
- A tank test for an individual ship may be omitted based on technical justifications such as availability of the results of tank tests for ships of the same type.
- In addition, omission of tank tests is acceptable for a ship for which sea trials will be carried under the EEDI Condition ….
- Model tank test should be witnessed by the verifier.

Additional information

- The verifier may request the submitter for additional information such as:
  - Descriptions of a tank test facility.
  - Lines of the model and the actual ship for the verification of the similarity of model and actual ship.
  - Lightweight of the ship and displacement table for the verification of the deadweight;
  - Detailed report … the tank test; this should include at least the tank test results at sea trial condition and under the EEDI Condition.
  - Detailed calculation process of the ship speed ….
  - Reasons for exempting a tank test, if applicable; … plus relevant information ….

Final Verification

Sea trials

- Sea trial conditions should be set as EEDI Conditions, if possible.

- Prior to the sea trial, the following should be submitted to the verifier:
  - Test procedure to be used for the speed trial,
  - Final displacement table and the measured lightweight, or a copy of the survey report of deadweight,
  - NOx Technical File as necessary.

- The test procedure should include, as a minimum, descriptions of all necessary items to be measured, measurement methods….

Sea trials

- The verifier should attend the sea trial and confirm:
  - Propulsion and power supply system,
  - Particulars of the engines, and other relevant items described in the EEDI Technical File;
  - Draught and trim;
  - Sea conditions;
  - Ship speed; and
  - Shaft power and RPM of the main engine.

Parameters to be checked

- **Draught and trim:** should be confirmed by the draught measurements taken prior to the sea trial.
- **Sea conditions:** Sea conditions should be measured in accordance with ITTC Recommended Procedure 7.5-04-01-01.1 Speed and Power Trials Part 1; 2014 or ISO 15016:2015.
- **Ship speed:** Should be measured in accordance with ITTC Recommended Procedure 7.5-04-01-01.1 Speed and Power Trials Part 1; 2014 or ISO 15016:2015, and at more than two points of engine power …...
- **The main engine output:** Should be measured by shaft power meter or a method which the engine manufacturer recommends and the verifier approves.

Speed trial – Power curve

- The submitter should develop power curves …. from results of sea trial.
- The effect of wind, current, waves, shallow water, displacement, water temperature and water density in accordance with ITTC Recommended Procedure 7.5-04-01-01.2 Speed and Power Trials Part 2; 2014 or ISO 15016:2015.
- The submitter should compare the power curves obtained as a result of the sea trial and the estimated power curves at the design stage.
- In case differences, the attained EEDI should be recalculated.

Verification of the attained EEDI for major conversions

- In case of a major conversion, the ship-owner should submit to a verifier an application for an Additional Survey with the revised EEDI Technical File and relevant background documents.

- The background documents should include at least but are not limited to:
  - Documents explaining details of the conversion;
  - EEDI parameters changed after the conversion …;
  - Reasons for other changes made in the EEDI Technical File.
  - Calculated value of the attained EEDI, with the calculation summary for each value of the calculation parameters and the calculation process …

Other EEDI Relevant Guidelines

Guidelines on Ship Minimum Power

- **Resolution MEPC.232(65) as amended by 225(67) and 262(68):** the 2013 Interim Guidelines for determining minimum propulsion power to maintain the manoeuvrability of ships in adverse conditions.

- **Purpose:** To assist Administrations and ROs in verifying that ships, complying with EEDI, have sufficient installed propulsion power to maintain the manoeuvrability in adverse conditions, as specified in Regulation 21.5.

- Adverse conditions

Significant wave height h_s, m	Peak wave period T_P, s	Mean wind speed V_w, m/s
5.5	7.0 to 15.0	19.0

- Currently applicable to:
  - Tankers
  - Bulk carriers
  - Combination carriers

Minimum power: Assessment method

- **Assessment Level 1 – Minimum power lines assessment**
  - Check if the ship has an installed power not less than the minimum power defined by line below:

Minimum Power Line Value [MCR, kW] = *a*(DWT) + b*

- a and b are constants and varies with ship type.

- **Assessment Level 2 – Simplified assessment**

- The assessment procedure consists of two steps:
  1. Definition of the required advance speed in head wind and waves, ensuring course-keeping in all wave and wind directions.

  2. Assessment whether the installed power is sufficient to achieve the above required advance speed .

Further details on Assessment Level 2 are given in the Guidelines

Guidelines on Innovative EE Technologies

- **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.

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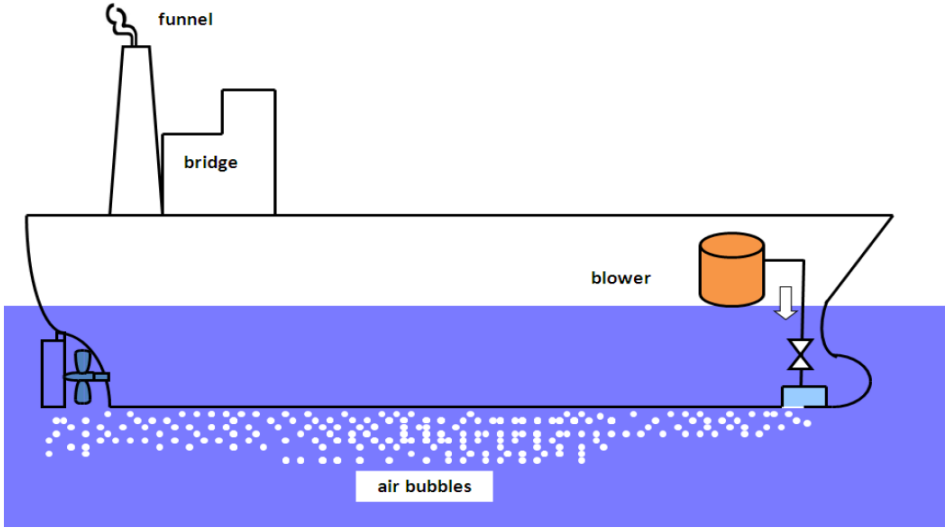
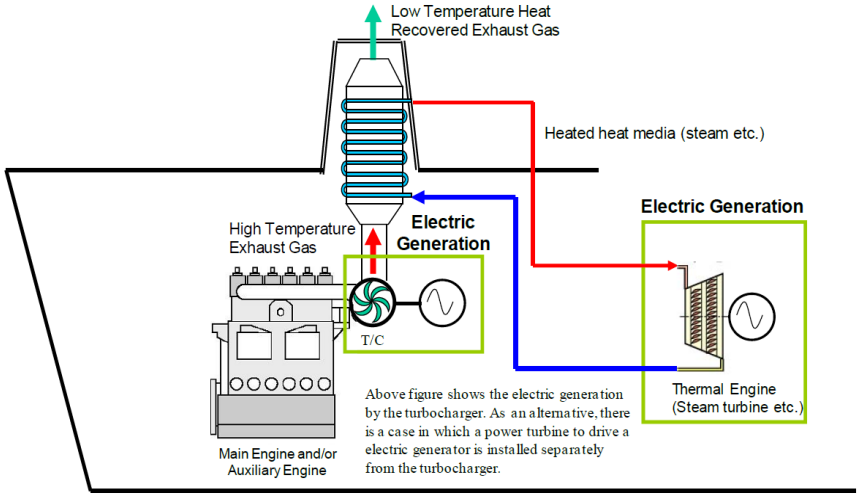
The technologies covered so far

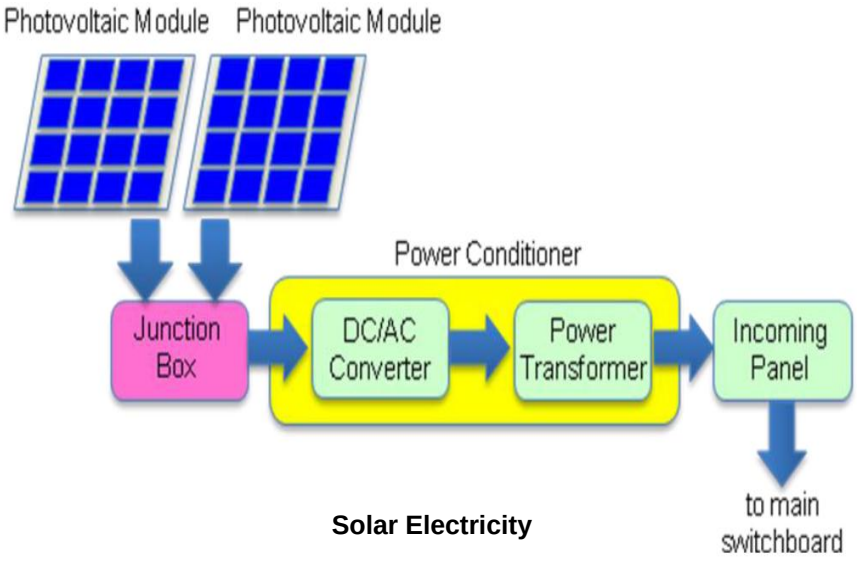


Hull Air Lubrication



Waste Heat Recovery

Wind Power



Solar Electricity

Categories of Innovative EE Technologies

Innovative Energy Efficiency Technologies				
Reduction of Main Engine Power			Reduction of Auxiliary Power	
Category A	***Category B-1***	***Category B-2***	***Category C-1***	***Category C-2***
Cannot be separated from overall performance of the vessel	Can be treated separately from the overall performance of the vessel		Effective at all time	Depending on ambient environment
	$f_{eff} = 1$	$f_{eff} < 1$	$f_{eff} = 1$	$f_{eff} < 1$
– low friction coating – bare optimization – rudder resistance – propeller design	– hull air lubrication system (air cavity via air injection to reduce ship resistance) (can be switched off)	– wind assistance (sails, Flettner-Rotors, kites)	– waste heat recovery system (exhaust gas heat recovery and conversion to electric power)	– photovoltaic cells

Details on how to deal with the above technologies for EEDI calculations are given in the Guidelines.

Summary on EEDI verification

- EEDI verification will be performed in two stages:
  - Preliminary verification at design stage
  - Final verification at commissioning sea trials.

- Pre-verification is based on model tank test results.

- Final verification is based on actual speed trial results.

- Verifier is required to witness both tank test and sea trials.

- Development of speed power curve for EEDI Condition will involve use of tank test data, speed trial data, + use of ISO standard for data correction.

- EEDI Technical File should be developed as part of the process.

PART 3 – Guidelines on SEEMP and EEOI

Content

- SEEMP Guidelines
- SEEMP main features
- Implementation aspects
- EEOI Guidelines
- EEOI calculation process
- Discussion

Guidelines for Development of SEEMP

Resolution MEPC.213(63): 2012 Guidelines for the Development of a SEEMP, Adopted on 2 March 2012

Introduction

- The SEEMP Guidelines have been developed to assist with the preparation of the SEEMP that is required by Regulation 22 of MARPOL Annex VI.

- A SEEMP provides:
  - A possible approach for improving ship and fleet efficiency performance over time; and
  - Some options to be considered for optimizing the performance of the ship.

- SEEMP purpose
  - The purpose of a SEEMP is to establish a mechanism for a company and/or a ship to improve the energy efficiency of a ship's operation.

SEEMP for ship OR company?

- The SEEMP should be developed as a ship-specific plan by the company.

- … SEEMP should be adjusted to the characteristics and needs of individual companies and ships.

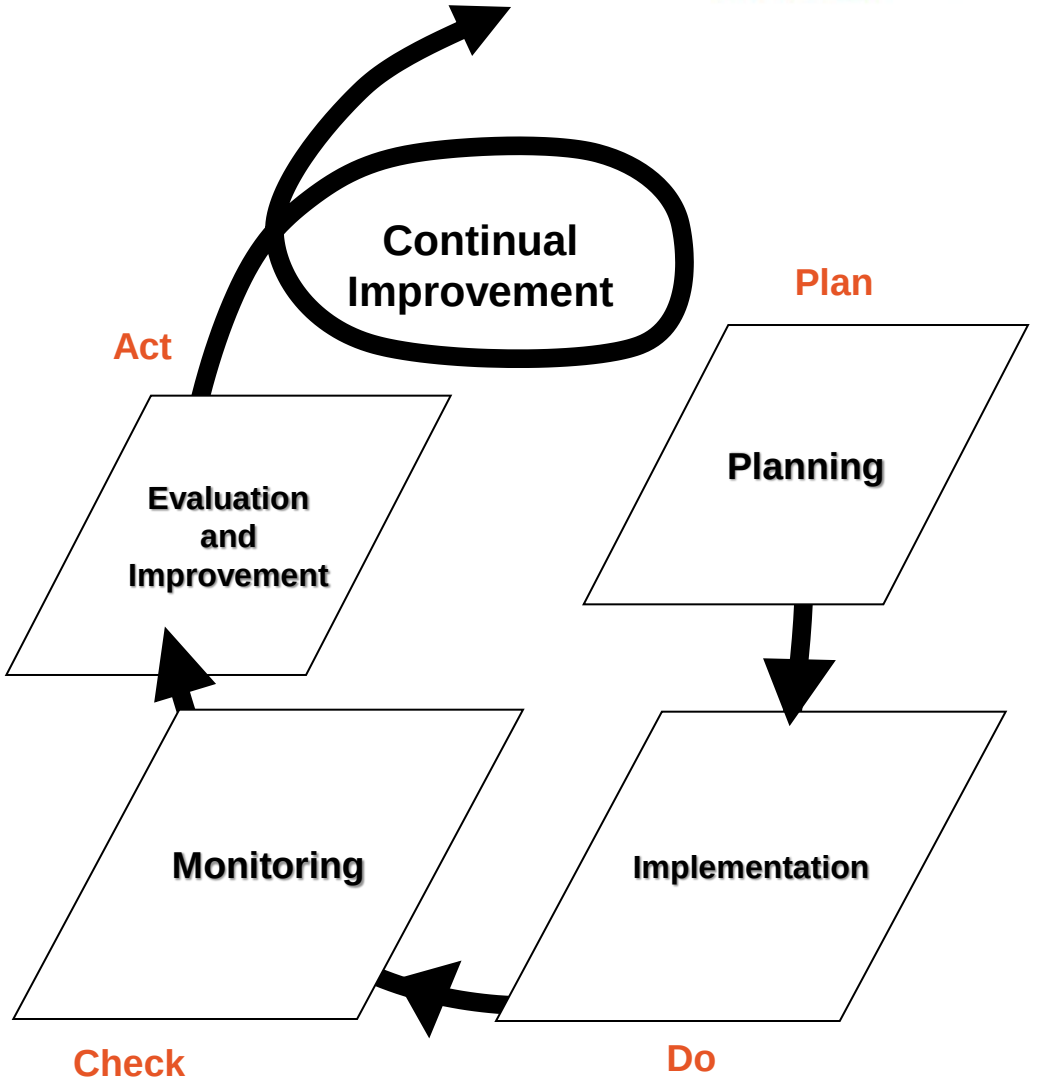
- … it is recommended that a company also establishing an “energy management plan” to improve fleet energy performance and stakeholders’ coordination.

SEEMP Framework and Main Elements

SEEMP framework

- The SEEMP works through four steps:
  - Planning,
  - Implementation
  - Monitoring, and
  - Self-evaluation

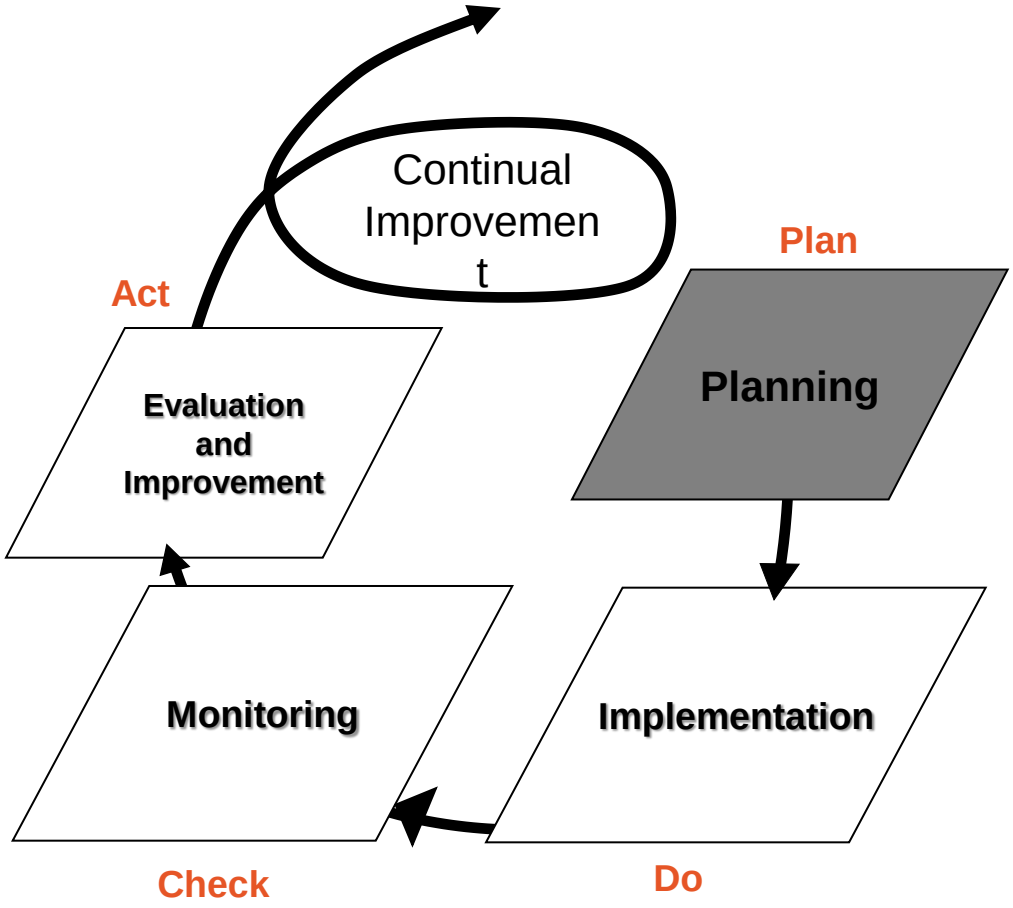
- These components play a critical role in the continuous cycle to improve ship energy management.



Planning

Planning - Importance

- Planning is the most crucial stage of the SEEMP.
- It primarily determines both the current status of ship energy usage and the expected improvements.
- Therefore, it is encouraged to devote sufficient time to planning.



Planning – Identification of ship-specific "energy efficiency measures"

- Recognizing that:
  - There are a variety of options to improve efficiency.
  - That the best measures differs to a great extent for ship type, cargoes, routes and other factors,
  - The specific measures for the ship to improve energy efficiency should be identified in the first place.
- After identification of the EEMs (Energy Efficiency Measures), they should be listed as a package for implementation.

Planning – Company energy management plan

- The improvement of energy efficiency of a ship does not necessarily depend on ship management only. A number of stakeholders are involved.
- More coordination between stakeholders is more rewarding …
- Company should do the coordination rather than the ship.
- … a "company energy management plan" is recommended to manage the fleet and make stakeholders' coordination.

Human resources development

- Raising awareness and providing necessary training for personnel both on-shore and on-board are an important element.

- Such human resource development is encouraged and should be considered as an important component of planning as well as a critical element of implementation.

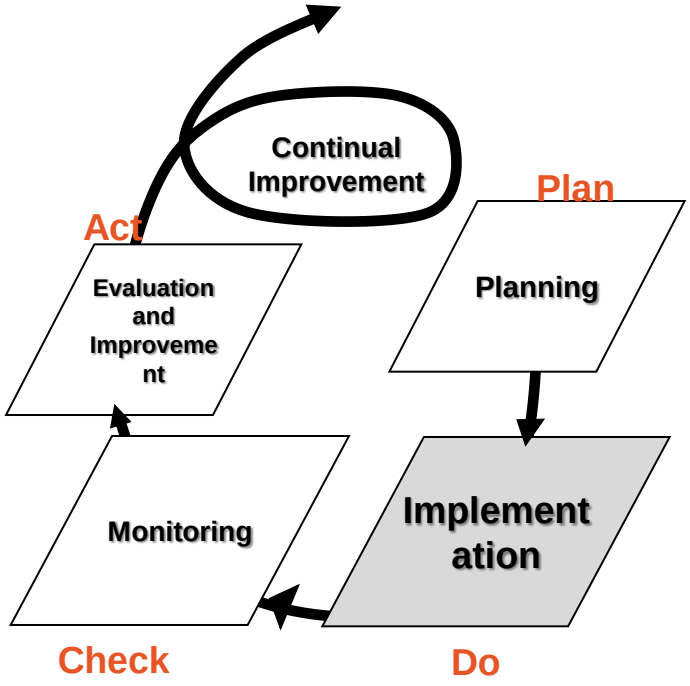
Planning - Goal setting

- Goal setting is part of planning.
- Goal settings are voluntary and there is no need for announcement to public nor are they subject to external inspection.
- Purpose of goal setting is to increase commitment to improving energy efficiency.
- The goal can take any form:
  - Annual fuel consumption
  - EEOI targets
- The goal should be measurable and easy to understand.

Implementation

Implementation – Establishment of implementation system

- A system for implementation of the selected measures by developing the procedures, tasks and responsibilities ...
- The SEEMP should describe how each measure should be implemented and who the responsible person(s) is.
- The implementation period (start and end dates) of each selected measure should be indicated.
- The development of such a system can be considered as a part of planning, and therefore may be completed at the planning stage.



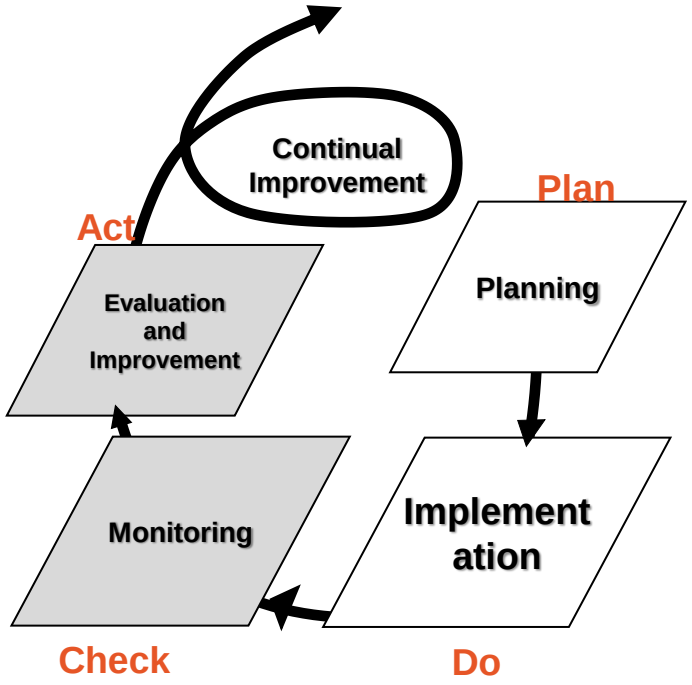
Implementation – Record keeping

- The planned measures should be implemented in accordance with the predetermined implementation system.

- Record-keeping for the implementation of each measure is beneficial for self-evaluation and should be encouraged.

- If any identified measure cannot be implemented for any reason(s), the reason(s) should be recorded for internal use.

Monitoring and Evaluation



Monitoring tools

- Consistent data collection is the foundation of monitoring.
- The monitoring system, including the procedures for collecting data and the assignment of responsible personnel, should be developed.
- The development of such a system can be considered as a part of *planning*, and therefore should be completed at the planning stage.
- … to avoid … burdens on ships' staff, monitoring should be carried out as far as possible by shore staff, ……..…

Self-evaluation and improvements

- Self-evaluation and improvement is the final phase of the management cycle.
- This phase should produce meaningful feedback for the next improvement cycle.
- The purpose of self-evaluation is to evaluate the effectiveness of the planned and implemented measures.
- For this process, procedures for self-evaluation of ship energy management should be developed.
- Furthermore, self-evaluation should be implemented periodically by using data collected through monitoring.

SEEMP format

- A proposed format is included in the Guideline.

A SAMPLE FORM OF A SHIP EFFICIENCY ENERGY MANAGEMENT PLAN

Name of Vessel:		GT:	
Vessel Type:		Capacity:	

Date of Development:		Developed by:	
Implementation Period:	From: Until:	Implemented by:	
Planned Date of Next Evaluation:			

1 MEASURES

Energy Efficiency Measures	**Implementation** (including the starting date)	**Responsible Personnel**
Weather Routeing	<Example> Contracted with [Service providers] to use their weather routeing system and start using on-trial basis as of 1 July 2012.	<Example> The master is responsible for selecting the optimum route based on the information provided by [Service providers].
Speed Optimization	While the design speed (85% MCR) is 19.0 kt, the maximum speed is set at 17.0 kt as of 1 July 2012.	The master is responsible for keeping the ship's speed. The log-book entry should be checked every day.

2 MONITORING

Description of monitoring tools

3 GOAL

Measurable goals

4 EVALUATION

Procedures of evaluation

Summary on SEEMP Guidelines

- SEEMP framework is based on Plan-Do-Check-Act continuous improvement cycle.

- When developing SEEMP, all the above elements needs to be defined at the planning phase.

- At its core, SEEMP has a number of EEMs together with their:
  - Implementation methods
  - Monitoring and checking
  - Self assessment
  - Roles and responsibility
  - Processes and procedures.

Guidelines for Calculation of the EEOI

MEPC.1/Circ.684 Guidelines for Voluntary use of the Ship Energy Efficiency Indicator (EEOI), 17 August 2009

Content on EEOI

- EEOI Guidelines purposes
- EEOI formula and data requirements
- Calculation aspects
- Typical calculations

EEOI Guidelines: IMO Circular MEPC.1/Circ.684

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MEPC.1/Circ.684
17 August 2009

GUIDELINES FOR VOLUNTARY USE OF THE SHIP ENERGY EFFICIENCY OPERATIONAL INDICATOR (EEOI)

1 The Marine Environment Protection Committee, at its fifty-ninth session (13 to 17 July 2009), agreed to circulate the Guidelines for voluntary use of the Ship Energy Efficiency Operational Indicator (EEOI) as set out in the annex.

2 Member Governments are invited to bring the Guidelines to the attention of all parties concerned and recommend them to use the Guidelines on a voluntary basis.

3 Member Governments and observer organizations are also invited to provide information on the outcome and experiences in applying the Guidelines to future sessions of the Committee.

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EEOI Guidelines: Some extracts from Circ.684

- These Guidelines present the concept of an indicator for the energy efficiency of a ship, ……..
- These Guidelines can be used to establish a consistent approach for voluntary use of an EEOI.
- It will assist ship-owners/operators …… in the evaluation of the performance of their fleet with regard to CO2 emissions.
- These Guidelines are recommendatory in nature and present a possible use of an operational indicator.
- Ship-owners …. are invited to implement either these Guidelines or an equivalent method in their environmental management systems.

EEOI Formula

$$EEOI = \frac{\sum_j FC_j \times C_{Fj}}{m_{cargo} \times D}$$

- ***j*** is the fuel type
- ***i*** is the voyage number;
- FC_j 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 mass (tonnes) or work done (number of TEU , passengers, etc.) depending on ship type.
- ***D*** is the distance in nautical miles corresponding to the cargo carried or work done

Definitions (1)

- **Fuel consumption (FC)**
  - *Fuel consumption, FC*, is defined as all fuel consumed at sea and in port or for a voyage or period in question, by main and auxiliary engines including boilers and incinerators

- **Distance sailed (D)**
  - *Distance sailed* means the actual distance sailed in nautical miles

- **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

Definitions (2)
Cargo mass carried (m_{cargo})

- For cargo ships (dry, wet, etc.):
  - **Metric tonnes (t)** of the cargo carried.

- For containerships (carrying solely containers):
  - **Number of containers (TEU)** or **metric tons (t)** of the total mass of cargo and containers.

- 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.

- Passenger ships, including Ro-Ro passenger ships
  - **Number of passengers** or **gross tonnes** of the ship.

- Etc.

Establishing the EEOI

- Main steps for establishing an EEOI are:
  1. Define the period for which EEOI is calculated (or the voyage)
  2. Define data sources for data collection
  3. Collect data
  4. Calculate EEOI

- Port operation and ballast voyages, as well as voyages which are not used for transport of cargo, such as voyage for docking service, should also be included

- Voyages for the purpose of securing the safety of a ship or saving life at sea should be excluded.

EEOI Calculation

Calculation of the EEOI - Formula

- Basic expression of the EEOI

$$\text{EEOI} = \frac{\sum_j FC_j \times C_{Fj}}{m_{cargo} \times D}$$

- Average EEOI (rolling average)

$$\text{Average EEOI} = \frac{\sum_i \sum_j (FC_{ij} \times C_{Fj})}{\sum_i (m_{cargo,i} \times D_i)}$$

  - 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
  - D is the distance in nautical miles corresponding to the cargo carried or work done.

Calculation of the EEOI – Rolling average

- EEOI is normally calculated for one voyage.
- Average EEOI for a number of voyages can be carried out.
- Rolling average, when used, can be calculated in a suitable time period, for example:
  - One year or
  - Number of voyages, for example six or ten voyages.
- For calculation of rolling average for three voyages, the average for the following voyages need to be calculated:
  - Average of voyages 1,2 and 3 will give the 1st rolling average
  - Average of voyages 2, 3 and 4 will give the 2nd rolling average
  - Average of voyages 3, 4 and 5 will give the 3rd rolling average
  - And so on.

Calculation of the EEOI – Data sources

- Data sources
  - Bridge log-book
  - Engine log-book
  - Deck log-book
  - Other official records

- Fuel mass to CO_2 mass conversion factors (C_F)

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

Calculation of the EEOI – Data sheet template

CO_2 Indicator reporting sheet

NAME AND TYPE OF SHIP						
Voyage or day (i)	Fuel consumption (FC) 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						

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

Calculation of the EEOI (example)

- Example (includes a single ballast voyage)

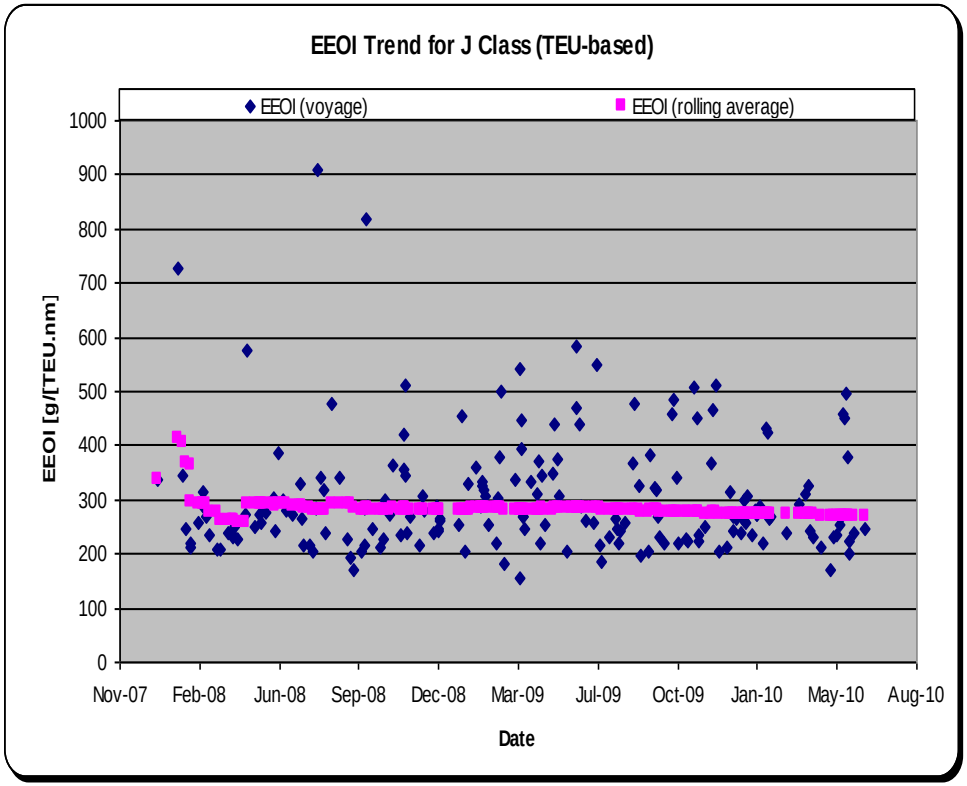
NAME AND TYPE OF SHIP						
Voyage or day (i)	Fuel consumption (FC) at sea and in port in tonnes				Voyage or time period data	
	Fuel type (HFO)	Fuel type (LFO)	Fuel type ( )		Cargo (m) (tonnes or units)	Distance (D) (NM)
1	20	5			25,000	300
2	20	5			0	300
3	50	10			25,000	750
	10	3			15,000	150

$$EEOI = \frac{100 \times 3.114 + 23 \times 3.151}{(25{,}000 \times 300) + (0 \times 300) + (25{,}000 \times 750) + (15{,}000 \times 150)} = 13.47 \times 10^{-6}$$

- unit: tonnes CO2/(tons x nautical miles)

EEOI calculations and variability

- Calculations over two years for a container ship
- Significant variability (voyage to voyage)
- Reasons for changes could include:
  - Ship size/type
  - Cargo level (load)
  - Ship speed
  - Length of ballast voyages
  - Idle and waiting times
  - Weather and current
  - Measurement errors



Thank you for your attention

For more information please see:
www.imo.org