Regulations for the Prevention of Air Pollution & Improving the Energy Efficiency of International Shipping

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SNAME UK COLLEGIUM
London, 16th October, 2012

IMO INTERNATIONAL MARITIME ORGANIZATION

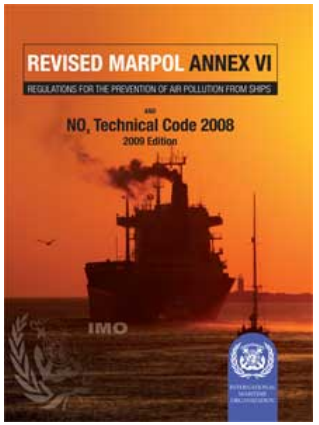
CLIMATE CHANGE: A CHALLENGE FOR IMO TOO!

MARPOL Annex VI – Regulations for the Prevention of Air Pollution from Ships

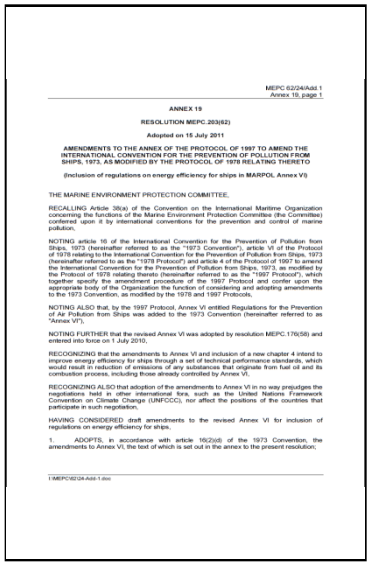
1997 Protocol adopted 26 September 1997

Entered into force **19 May 2005**

Revisions to Annex VI
adopted October 2008 and
entered into force **1 July 2010**



Chapter 4 (energy efficiency)
will enter into force
1 January 2013



MEPC 62/24/Add.1
Annex 19, page 1

ANNEX 19

RESOLUTION MEPC.203(62)

Adopted on 15 July 2011

AMENDMENTS TO THE ANNEX OF THE PROTOCOL OF 1997 TO AMEND THE INTERNATIONAL CONVENTION FOR THE PREVENTION OF POLLUTION FROM SHIPS, 1973, AS MODIFIED BY THE PROTOCOL OF 1978 RELATING THERETO

(Inclusion of regulations on energy efficiency for ships in MARPOL Annex VI)

THE MARINE ENVIRONMENT PROTECTION COMMITTEE,

RECALLING Article 38(a) of the Convention on the International Maritime Organization concerning the functions of the Marine Environment Protection Committee (the Committee) conferred upon it by international conventions for the prevention and control of marine pollution,

NOTING article 16 of the International Convention for the Prevention of Pollution from Ships, 1973 (hereinafter referred to as the "1973 Convention"), article VI of the Protocol of 1978 relating to the International Convention for the Prevention of Pollution from Ships, 1973 (hereinafter referred to as the "1978 Protocol") and article 4 of the Protocol of 1997 to amend the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto (hereinafter referred to as the "1997 Protocol"), which together specify the amendment procedure of the 1997 Protocol and confer upon the appropriate body of the Organization the function of considering and adopting amendments to the 1973 Convention, as modified by the 1978 and 1997 Protocols,

NOTING ALSO that, by the 1997 Protocol, Annex VI entitled Regulations for the Prevention of Air Pollution from Ships was added to the 1973 Convention (hereinafter referred to as "Annex VI"),

NOTING FURTHER that the revised Annex VI was adopted by resolution MEPC.176(58) and entered into force on 1 July 2010,

RECOGNIZING that the amendments to Annex VI and inclusion of a new chapter 4 intend to improve energy efficiency for ships through a set of technical performance standards, which would result in reduction of emissions of any substances that originate from fuel oil and its combustion process, including those already controlled by Annex VI,

RECOGNIZING ALSO that adoption of the amendments to Annex VI in no way prejudges the negotiations held in other international fora, such as the United Nations Framework Convention on Climate Change (UNFCCC), nor affect the positions of the countries that participate in such negotiation,

HAVING CONSIDERED draft amendments to the revised Annex VI for inclusion of regulations on energy efficiency for ships,

1 ADOPTS, in accordance with article 16(2)(d) of the 1973 Convention, the amendments to Annex VI, the text of which is set out in the annex to the present resolution;

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Implementation status of Annex VI

- Number of Contracting States: 71
- The combined merchant fleets of which constitute approximately 94.29% of the gross tonnage of the world's merchant fleet
- Parties include: Bahamas, China, Cyprus, Finland, Germany, Greece, India, Japan, Liberia, Malaysia, Malta, Marshall Islands, Norway, Panama, Republic of Korea, Singapore, Sweden, USA

ref: IMO Status of Multilateral Conventions
30 September 2012

MARPOL Annex VI – Chapter 3

Ozone depleting substances (ODS)	Reg.12
Nitrogen oxides (NO_x)	Reg.13
Sulphur oxides and Particulate Matter (SO_x)	Reg.14
Volatile organic compounds (VOC)	Reg.15
Shipboard incineration	Reg.16
Reception Facilities	Reg.17
Fuel oil quality and availability	Reg.18

Regulation 13 Nitrogen Oxides - Application

Applies to ⇨ Marine diesel engines ⇨ with a power output more than 130 kW ⇨ installed on a ship constructed on or after 1st January 2000

Applies to ⇨ Marine diesel engines ⇨ with a power output more than 130 kW ⇨ which undergo a major conversion on or after 1st January 2000

Not applicable to ⇨

- Emergency diesel engines
- Engines installed in lifeboats
- Any device or equipment intended to be used solely in case of emergency
- Domestic ships subject to alternative NOx control measure

Regulation 13.2.2 Major conversion

2.2 For a major conversion involving the replacement of a marine diesel engine with a non-identical marine diesel engine or the installation of an additional marine diesel engine, the standards in this regulation in force at the time of the replacement or addition of the engine shall apply. On or after 1 January 2016, in the case of replacement engines only, if it is not possible for such a replacement engine to meet the standards set forth in paragraph 5.1.1 of this regulation (Tier III), then that replacement engine shall meet the standards set forth in paragraph 4 of this regulation (Tier II). Guidelines are to be developed by the Organization to set forth the criteria of when it is not possible for a replacement engine to meet the standards in paragraph 5.1.1 of this regulation

Regulation 13 - NOx emission limits

Tier I - Ships constructed 1 Jan 2000 to 31 Dec 2010

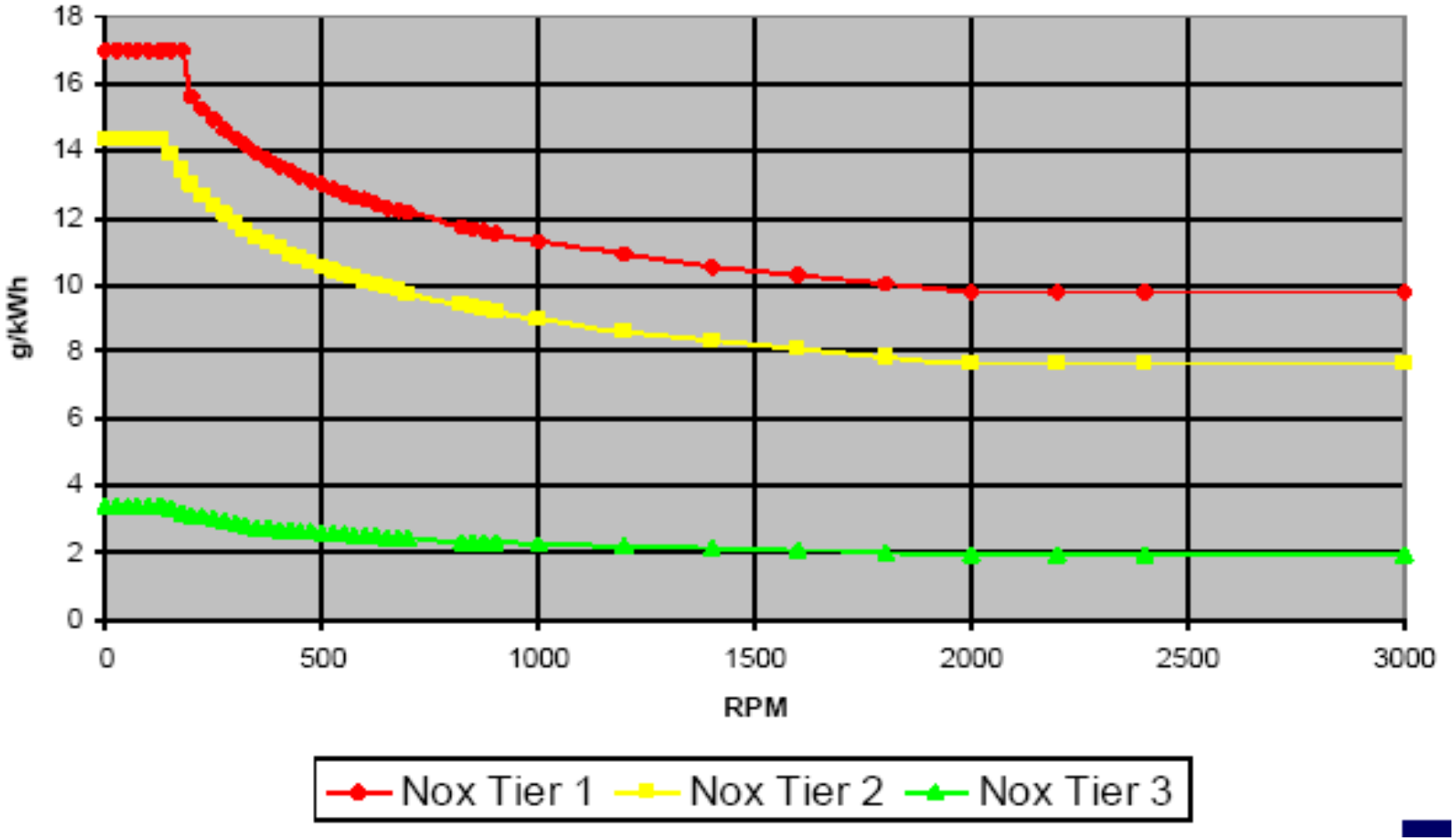
Tier II - Ships constructed 1 Jan 2011 onwards

Tier III* - Ships constructed 1 Jan 2016 onwards

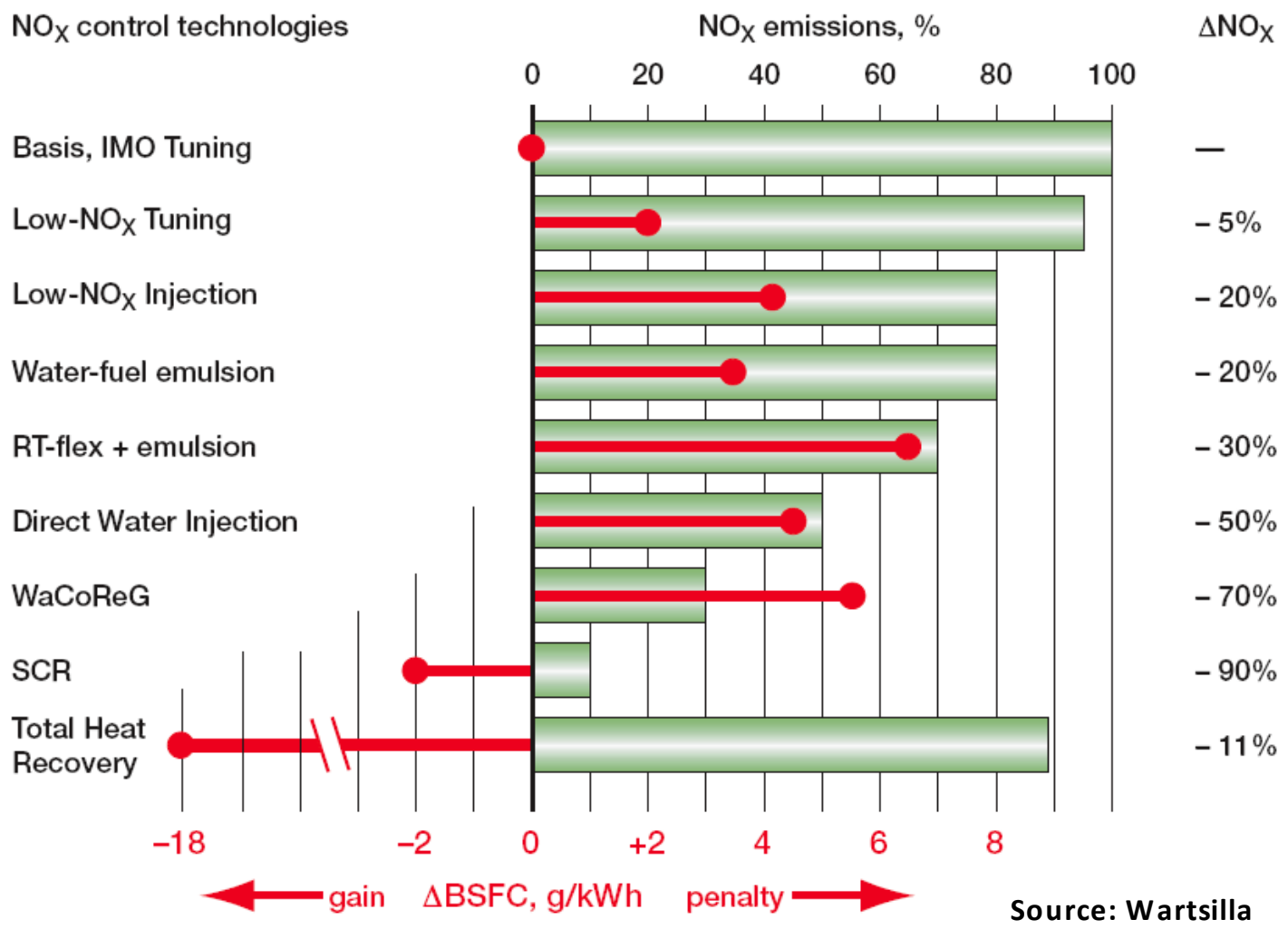
**** When a specified ship is operating within a designated ECA***

Tier	n < 130 rpm	130 ≤ n < 2000 rpm	n ≥ 2000 rpm
I	17.0 g/kWh	$45.0*n^{(-0.2)}$ g/kWh	9.8 g/kWh
II	14.4 g/kWh	$44.0*n^{(-0.2)}$ g/kWh	7.7 g/kWh
III	3.4. g/kWh	$9.0*n^{(-0.2)}$ g/kWh	2.0 g/kWh
n = rated engine speed – crankshaft rpm			

NOx emission standards - Tier 1, 2 and 3



Methods of engine's NOx reduction



Source: Wartsilla

WaCoReG = watercooled residual gas (EGR)
BSFC = Brake Specific Fuel Consumption

Selective Catalytic Reduction

- MEPC.217(63) – CERTIFICATION OF MARINE DIESEL ENGINES FITTED WITH SELECTIVE CATALYTIC REDUCTION SYSTEMS UNDER THE NO_X TECHNICAL CODE 2008

- MEPC.198(62) - 2011 GUIDELINES ADDRESSING ADDITIONAL ASPECTS TO THE NO_X TECHNICAL CODE 2008 WITH REGARD TO PARTICULAR REQUIREMENTS RELATED TO MARINE DIESEL ENGINES FITTED WITH SELECTIVE CATALYTIC REDUCTION (SCR)

Regulation 13.7.1 Approved Method

Application: Ships constructed 1 Jan 1990 to 31 Dec 1999
Marine diesel engine power output >5,000 kW
Per cylinder displacement 90 litres

If a method has been approved by Party according to chapter 7 of the NOx Technical Code 2008 then ship is required to fit the "approved method" to enable the engine to meet Tier I limits.

IMO to be notified of approved method

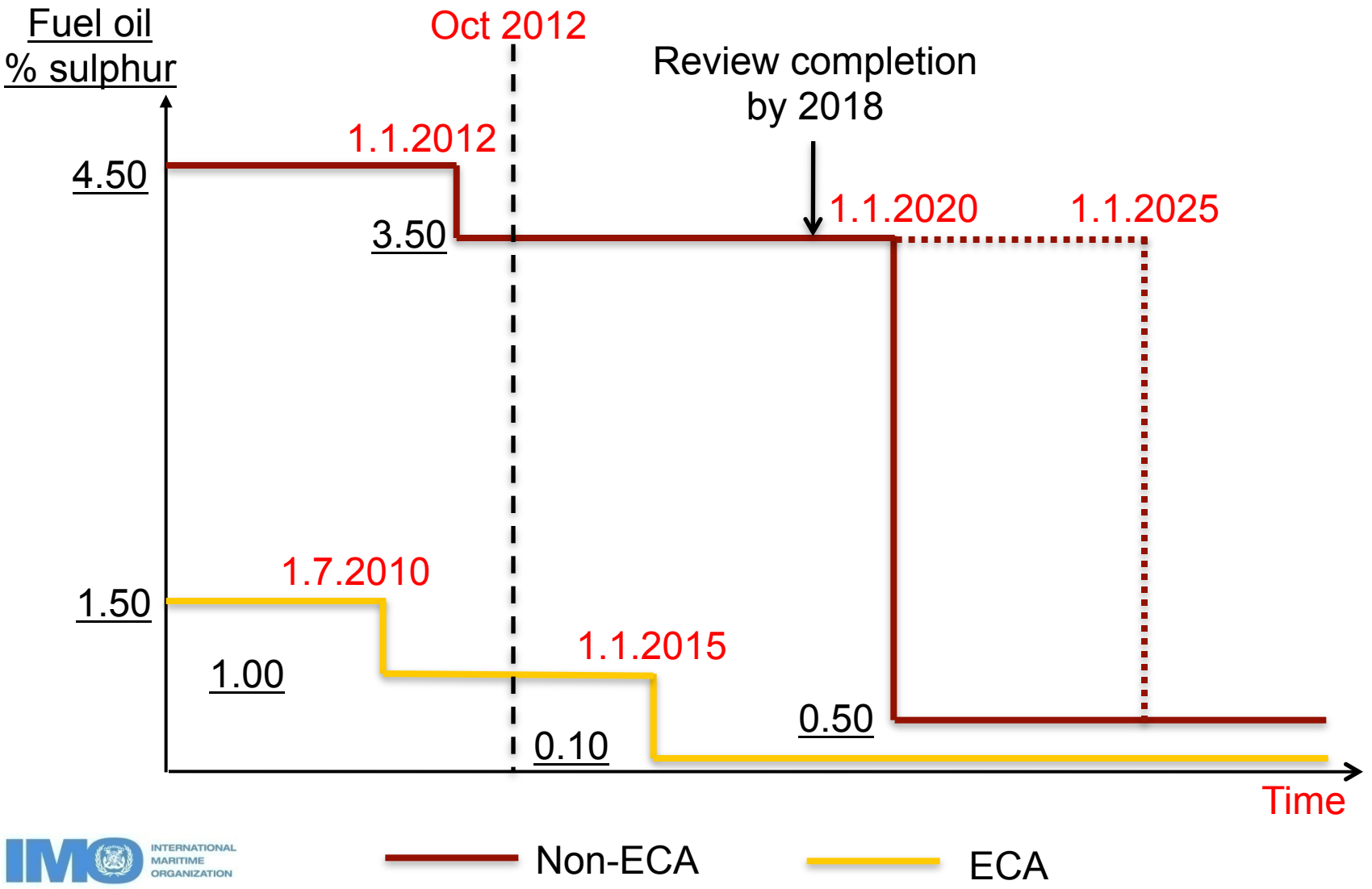
The approved method to be installed at first renewal survey 12 months or more after IMO notified the "method" is approved

Tier	n < 130 rpm	130 ≤ n < 2000 rpm	n ≥ 2000 rpm
I	17.0 g/kWh	$45.0*n^{(-0.2)}$ g/kWh	9.8 g/kWh

Tier III – review of technologies

- Reg. 13.10 requires review to be completed by 2013
- Status of technological developments to implement the standards set forth in regulation 13.5.1.1 of MARPOL Annex VI, with a view to reporting on the following:
  - range of technologies (engine fitting, material, appliance, apparatus, other procedures, alternative fuels or compliance methods);
  - the current use of these technologies on marine diesel vessels;
  - progress and expectations for bringing Tier III NOx technologies fully to market by 2016;
  - identification of any sub-sets of marine diesel engines where there will not be technologies;
  - where relevant, the global availability of consumable products used by a certain technology
- Interim report submitted to MEPC 64 (Oct 2012) - SCR, EGR & LNG
- Final report to MEPC 65 (May 2013)
- Recommendation as to whether 1 January 2016 entry into effect date can be met, otherwise amend effective date?

Regulation 14 Sulphur oxides and particulate matter (SOx & PM)



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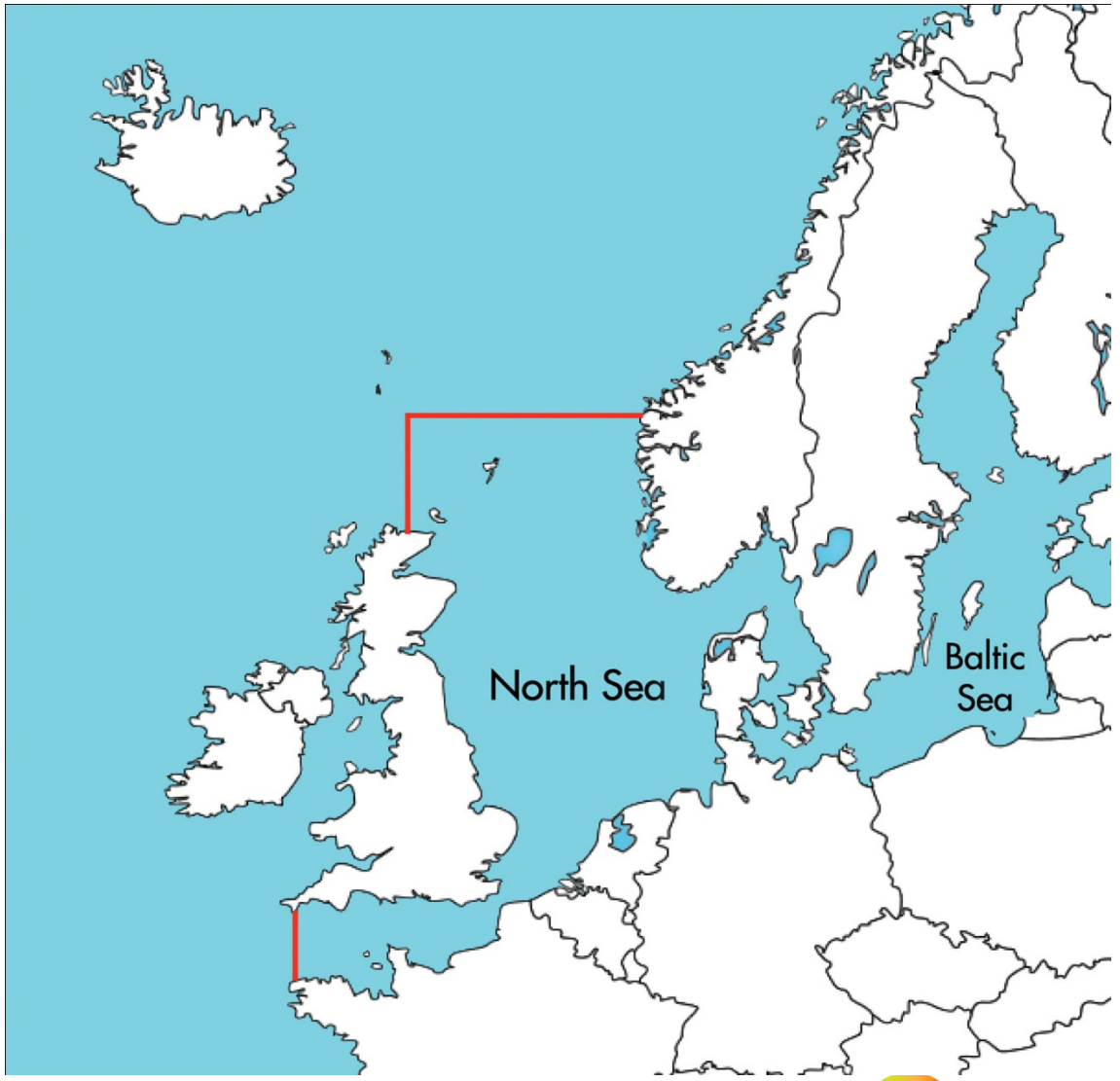
Sulphur Emission Control Areas

Baltic Sea –
19 May 2006

North Sea and
English Channel –
21 November 2007

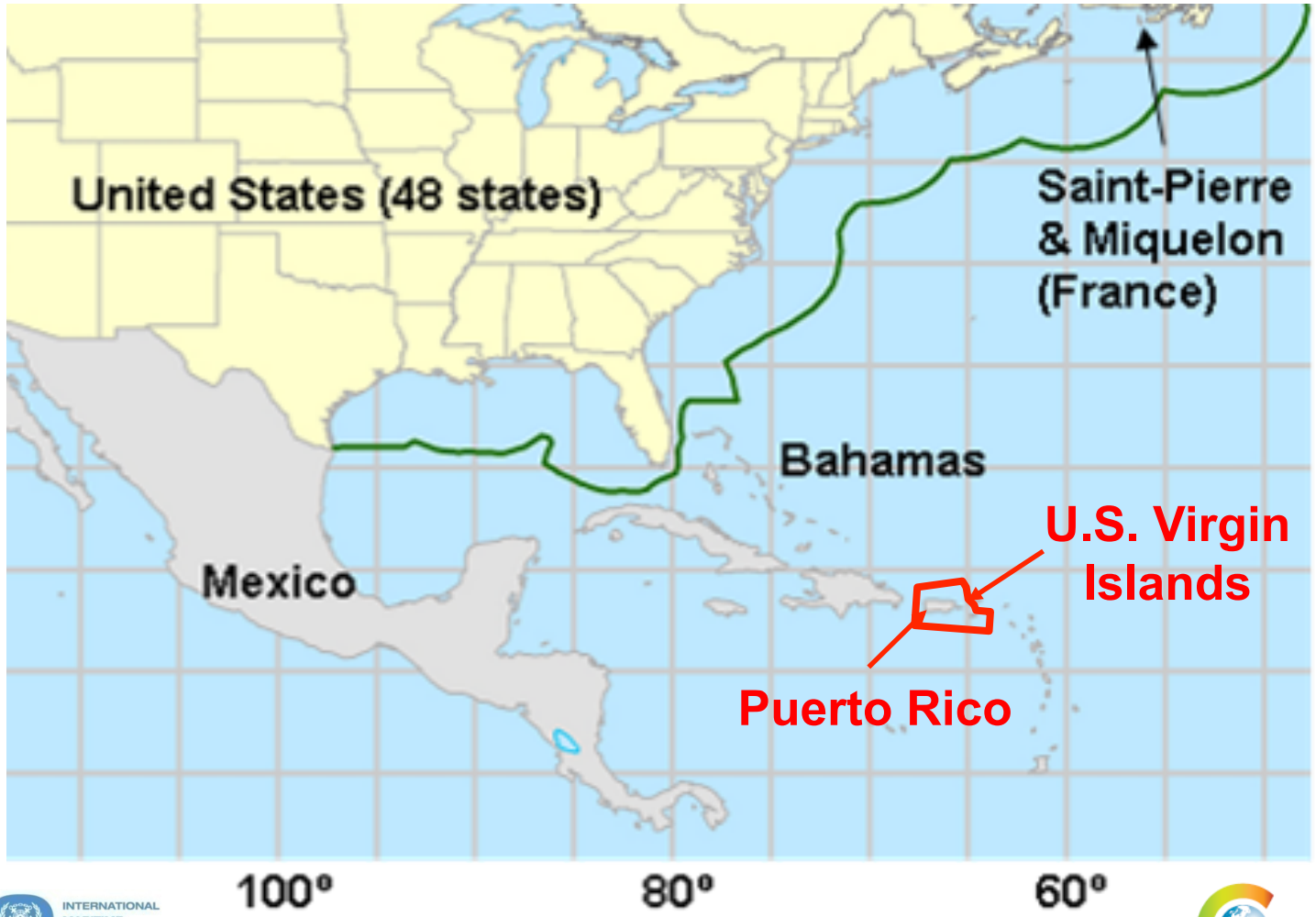


North American Emission Control Area

Entered into effect on 1 August 2012 (Reg. 14.7)

U.S. Caribbean ECA

Enters into force on 1 January 2013 and comes into effect on 1 January 2014 (Reg. 14.7)



ECA compliance strategies – SOx

A. Use compliant fuel oil

B. Use equivalent approach e.g., EGCS

Tools and guidance available including:

- **ABS *Fuel Switching Advisory Notice***
- **DNV *Survival Kit***
- **LR *compliance guide and calculator***

C. Use alternative fuels:

- **LNG, biodiesel/methanol**

D. Other: onshore power supply, emulsification, sulphur averaging (MEPC.1/Circ.789)

Exhaust Gas Cleaning Systems

- An alternative to low S fuel that enables continued use of high S fuel
- Party to approve (Reg.4.1)
- Guidelines MEPC.184(59)
- Compliance:

  ratio SO_2(ppm) to CO_2(% v/v)
- Considerations: space, initial cost, availability, power
- Split incentive
- Operation and maintenance
- Class/Port Authorities inspection

Alternative Fuels

- LNG
  - Correspondence group under Bulk Liquids and Gases sub-Committee further developing the draft International Code of safety for ships using gases or other low-flashpoint fuels (IGF Code) – report to BLG 17 in February 2013
  - Feasibility study into use of LNG in Wider Caribbean Region (final report due late 2012)
- Biodiesel/Methanol
  - development of guidelines?

Onshore Power Supply

- **ISO/IEC/IEEE 80005-1 (Published July 2012):**

"Cold ironing - Part 1: High Voltage Shore Connection (HVSC) Systems -- General requirements"

- **Ports include: Antwerp, Gothenburg, Helsingborg, Long Beach, Juneau, Los Angeles, San Diego, San Francisco, Seattle, Stockholm**
- **World Ports Climate Initiative**
  - **http://ops.wpci.nl/**
- **MEPC.1/Circ.794**

Black Carbon

- Deliberation of Black Carbon by IMO since October 2008
- BLG Sub-Committee (February 2013) agenda item:
  - "Consideration of the impact on the Arctic of emissions of Black Carbon from international shipping"
- Intersessional correspondence group:
  - definition for Black carbon emissions from international shipping
  - identify the most appropriate method for measuring Black carbon emissions from international shipping
  - identify and collate possible control measures
- IMO undertaking Canadian funded project investigating abatement technologies for Black Carbon emissions from international shipping

IMO work to address GHG emissions from international shipping

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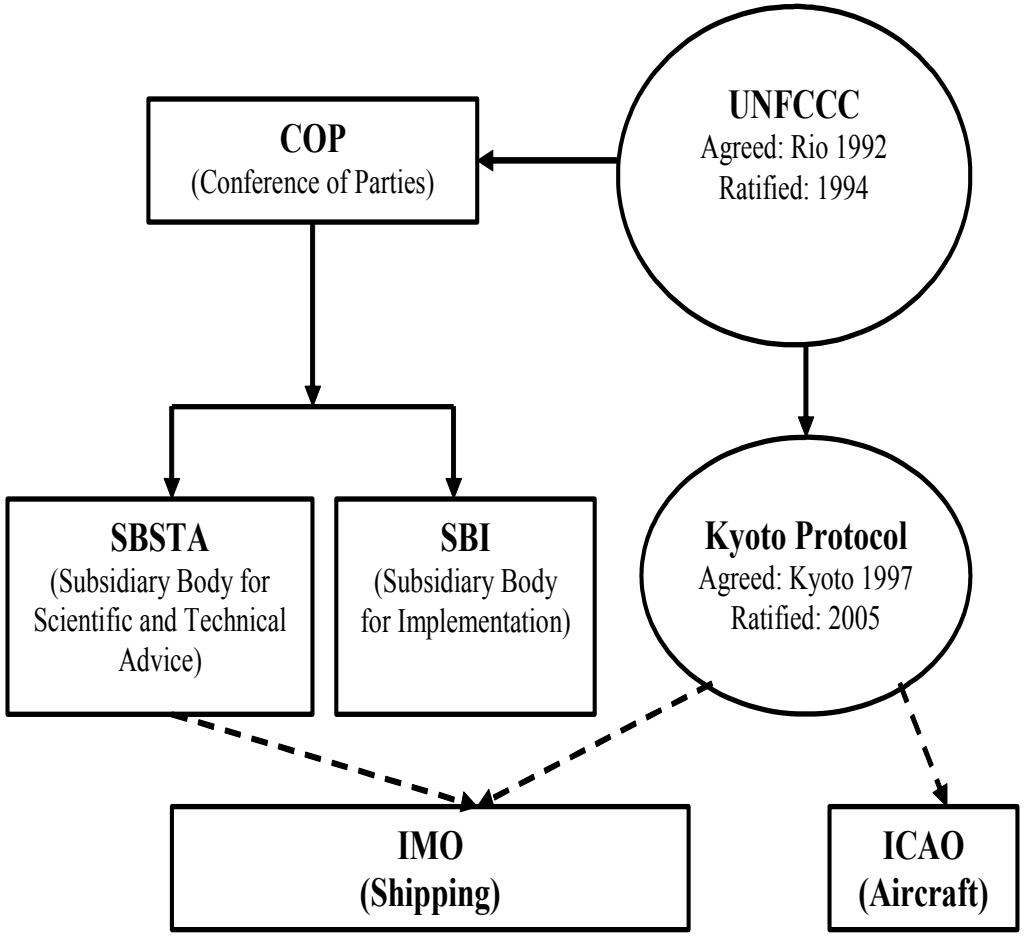
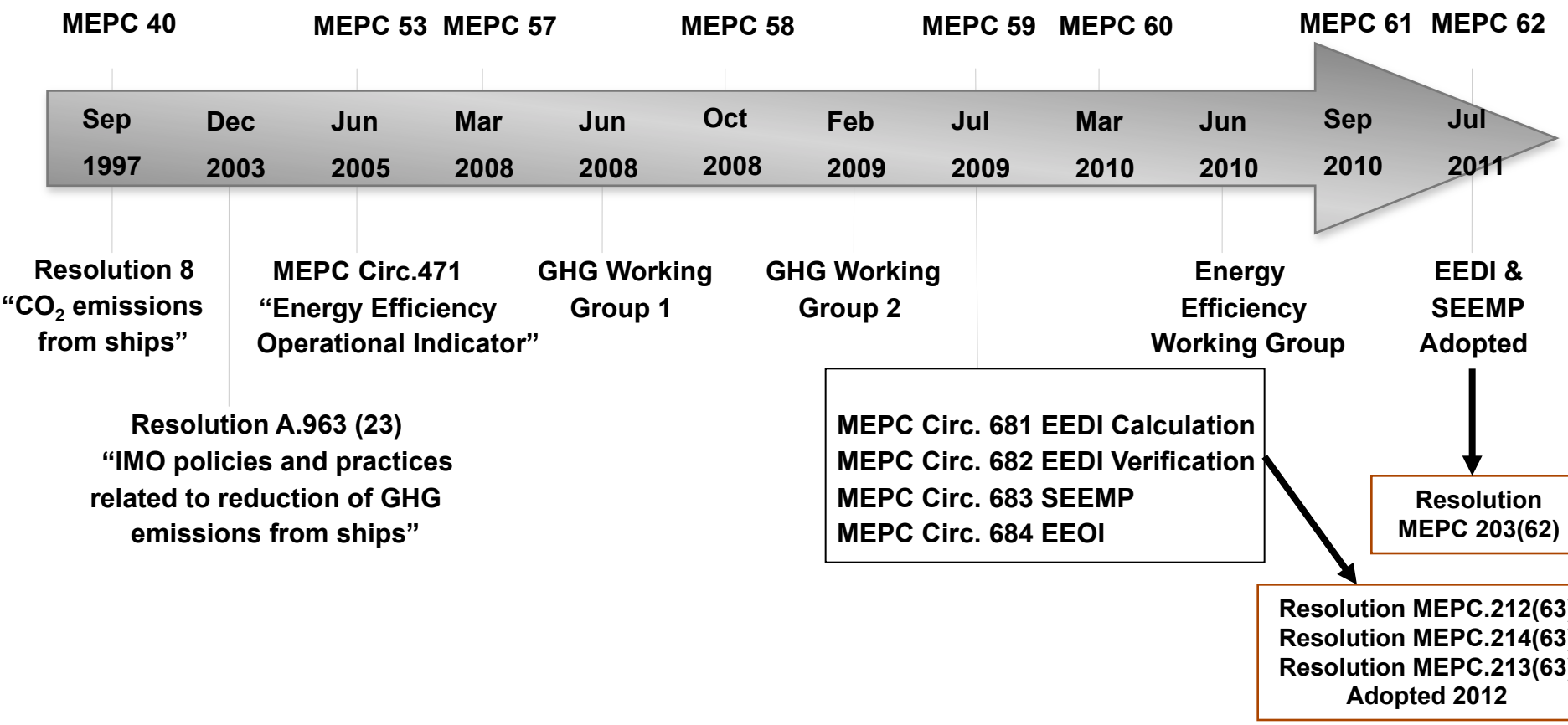
Why energy efficiency regulations for ships?

"The Parties included in Annex I shall pursue limitation of emissions of **GHG f**rom **marine bunker fuels**, working through the **International Maritime Organization**"



[Extracts from Article 2.2 of the Kyoto Protocol, 1997]

IMO MEPC energy efficiency activities



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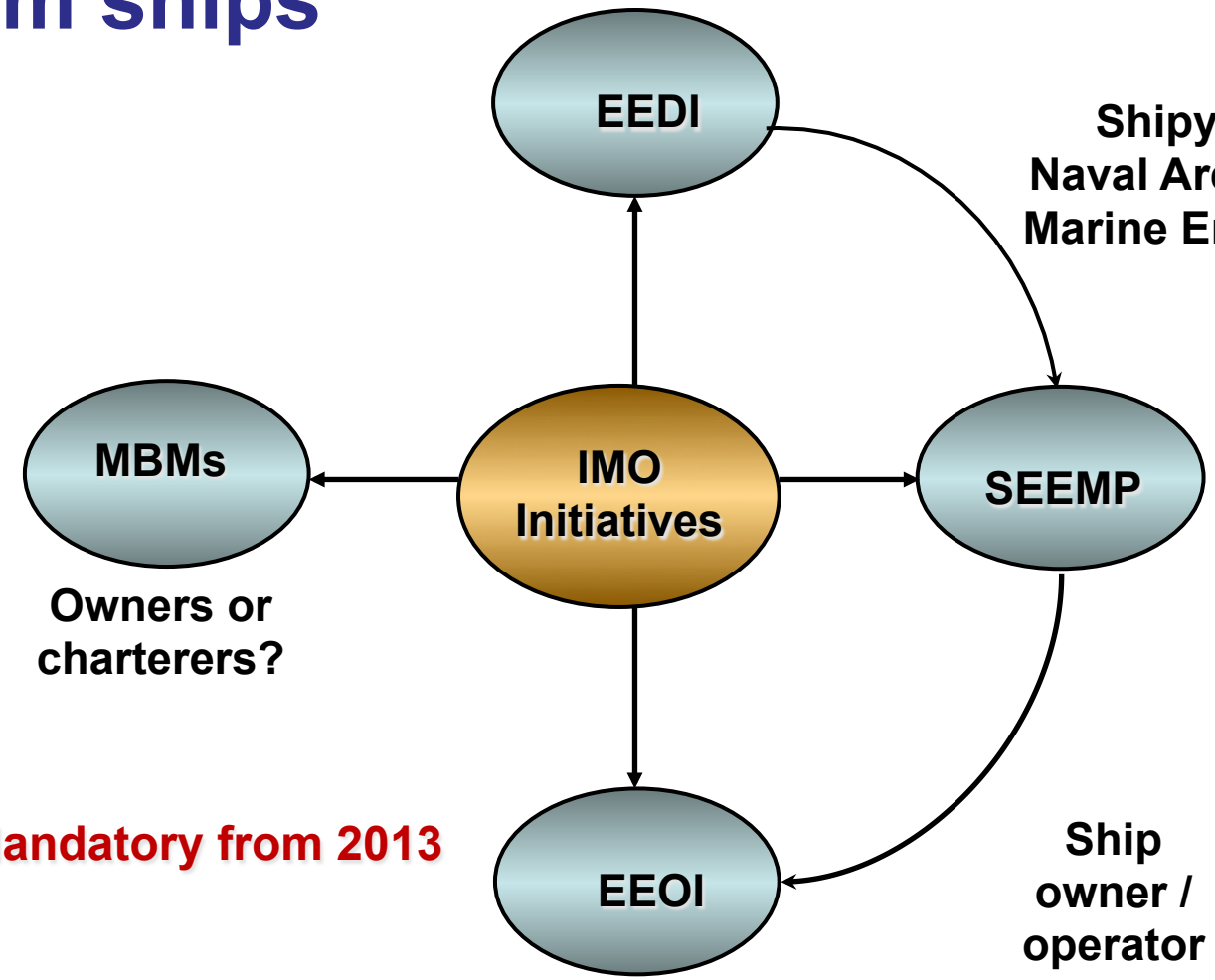
IMO initiatives for GHG emissions control from ships



EEDI and SEEMP: Mandatory from 2013

EEOI: Voluntary

MBMs: At early stages of discussion.

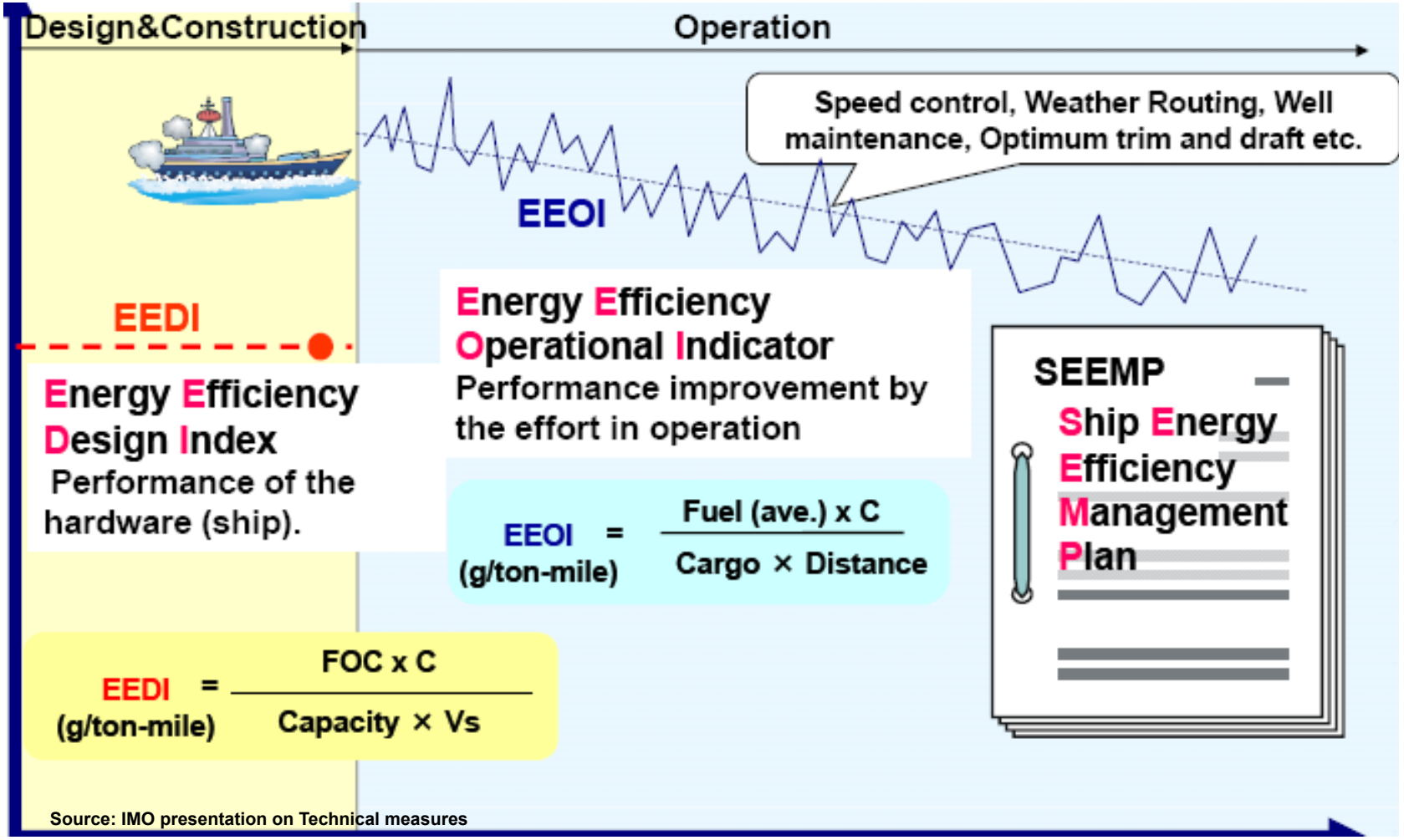
EEDI – Objectives & Definition

$$EEDI = \frac{\text{Impact to environment}}{\text{Benefit to society}} = \frac{\text{Power} \times \text{fuel consumption} \times CO_2 \text{ emission factor}}{\text{Capacity} \times \text{ship speed}}$$

(transportation work)

- The EEDI is likely to promote innovation at the design stage of ships for a reduction of their energy consumption at full load.
- The EEDI is applicable to ship types responsible for approximately 70% of CO_2 emissions from international shipping

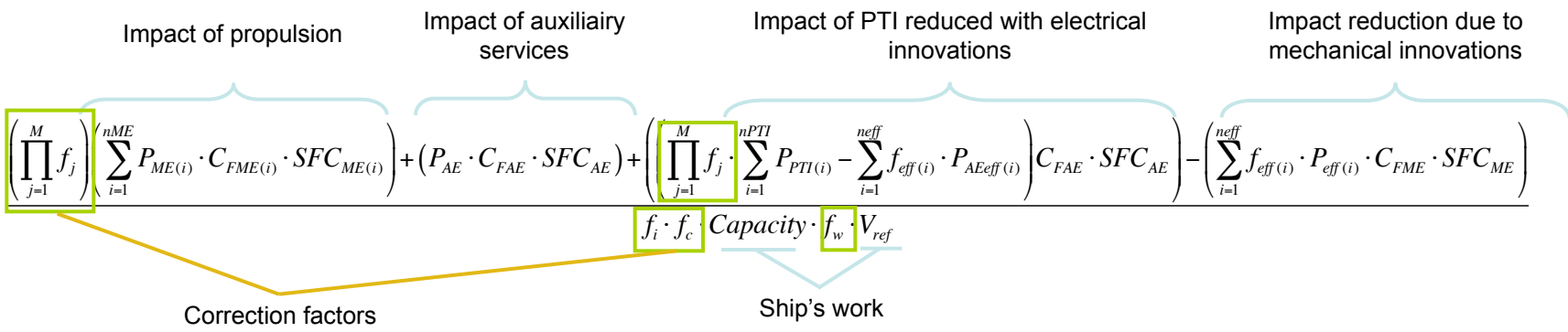
EEDI, EEOI and SEEMP links



Source: IMO presentation on Technical measures

EEDI – Calculation

Resolution MEPC.212(63):



f	Correction factors
C_F	CO_2 emission factor (fuel type)
SFC	Specific Fuel Consumption (g/kWh)
P	Power (kW)
Capacity	tonnage
V	Speed (knots)
"ME"	Subscript for parameters related to Main Engine(s)
"AE"	Subscript for parameters related to Aux. Engine(s)

EEDI units

Grams CO_2 emitted per (tonnes*nautical mile)

MARPOL Annex VI Regulation 19 Application

1 This chapter shall apply to all ships of 400 gross tonnage and above.

2 The provisions of this chapter shall not apply to:

.1 ships solely engaged in voyages within waters subject to the sovereignty or jurisdiction of the State the flag of which the ship is entitled to fly. However, each Party should ensure, by the adoption of appropriate measures, that such ships are constructed and act in a manner consistent with chapter 4, so far as is reasonable and practicable.

3 Regulation 20 and regulation 21 shall not apply to ships which have diesel-electric propulsion, turbine propulsion or hybrid propulsion systems.

4 Notwithstanding the provisions of paragraph 1 of this regulation, the Administration may waive the requirement for a ship of 400 gross tonnage and above from complying with regulation 20 and regulation 21.

MARPOL Annex VI Regulation 20 "Attained EEDI"

1 The attained EEDI shall be calculated for:

.1 each new ship;

.2 each new ship which has undergone a major conversion; and

.3 each new or existing ship which has undergone a major conversion, that is so extensive that the ship is regarded by the Administration as a newly constructed ship

which falls into one or more of the categories in regulations 2.25 to 2.35. The attained EEDI shall be specific to each ship and shall indicate the estimated performance of the ship in terms of energy efficiency, and be accompanied by the EEDI technical file that contains the information necessary for the calculation of the attained EEDI and that shows the process of calculation. The attained EEDI shall be verified, based on the EEDI technical file, either by the Administration or by any organization[3] duly authorized by it.

2 The attained EEDI shall be calculated taking into account guidelines[4] developed by the Organization.

[4] Guidelines on the method of calculation of the Energy Efficiency Design Index for new ships.

New ship (Reg. 2.23)

- "New ship" means a ship:
  - for which the building contract is placed on or after 1 January 2013; or
  - 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
  - the delivery of which is on or after 1 July 2015.

- UI approved at MEPC 64 for term 'new ship' (MEPC.1/Circ. 795)

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 of the present 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.

- UI approved at MEPC 64 for term 'major conversion' (MEPC.1/Circ. 795)

Ship types definitions (Reg. 2.25 to 2.35)

25 "Bulk carrier" means a ship which is intended primarily to carry dry cargo in bulk, including such types as ore carriers as defined in SOLAS chapter XII, regulation 1, but excluding combination carriers.

26 "Gas carrier" means a cargo ship constructed or adapted and used for the carriage in bulk of any liquefied gas.

27 "Tanker" in relation to chapter 4 means an oil tanker as defined in MARPOL Annex I, regulation 1 or a chemical tanker or an NLS tanker as defined in MARPOL Annex II, regulation 1.

28 "Container ship" means a ship designed exclusively for the carriage of containers in holds and on deck.

29 "General cargo ship" means a ship with a multi-deck or single deck hull designed primarily for the carriage of general cargo. This definition excludes specialized dry cargo ships, which are not included in the calculation of reference lines for general cargo ships, namely livestock carrier, barge carrier, heavy load carrier, yacht carrier, nuclear fuel carrier.

30 "Refrigerated cargo carrier" means a ship designed exclusively for the carriage of refrigerated cargoes in holds.

31 "Combination carrier" means a ship designed to load 100% deadweight with both liquid and dry cargo in bulk.

32 "Passenger ship" means a ship which carries more than 12 passengers.

33 "Ro-ro cargo ship (vehicle carrier)" means a multi deck roll-on-roll-off cargo ship designed for the carriage of empty cars and trucks.

34 "Ro-ro cargo ship" means a ship designed for the carriage of roll-on-roll-off cargo transportation units.

35 "Ro-ro passenger ship" means a passenger ship with roll-on-roll-off cargo spaces.

MARPOL Annex VI Reg. 21 "Required EEDI"

1 For each:

.1 new ship;

.2 new ship which has undergone a major conversion; and

.3 new or existing ship which has undergone a major conversion that is so extensive that the ship is regarded by the Administration as a newly constructed ship

which falls into one of the categories defined in regulation 2.25 to 2.31 and to which this chapter is applicable, the attained EEDI shall be as follows:

$$\text{Attained EEDI} \leqq \text{Required EEDI} = (1-X/100) \times \text{Reference line value}$$

where X is the reduction factor specified in Table 1 for the required EEDI compared to the EEDI Reference line.

2 For each new and existing ship that has undergone a major conversion which is so extensive that the ship is regarded by the Administration as a newly constructed ship, the attained EEDI shall be calculated and meet the requirement of paragraph 21.1 with the reduction factor applicable corresponding to the ship type and size of the converted ship at the date of the contract of the conversion, or in the absence of a contract, the commencement date of the conversion.

MARPOL Annex VI Reg. 21 "Required EEDI"

$$EEDI_{ATTAINED} \leq EEDI_{REQUIRED}$$

$$EEDI_{REQUIRED} = \left(1 - \frac{X}{100}\right) \times EEDI_{REFERENCE\ LINE}$$

Table 1

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 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*

$$EEDI_{REFERENCE\ LINE} = a \times b^{-c}$$

Table 2

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

Resolution MEPC.215(63)

Reference lines derived from ships constructed 1 Jan 1999 to 1 Jan 2009

Ship types subject to current EEDI requirements

Attained EEDI: Following ships over 400 GT*:

- **Bulk carrier**
- **Gas carrier**
- **Tanker**
- **Container ship**
- **General cargo ship**
- **Refrigerated cargo carrier**
- **Combination carrier**
- **Passenger ships**
- **Ro-ro cargo ship (vehicle carrier)**
- **Ro-ro cargo ship**
- **Ro-ro passenger ship**

Required EEDI: Following ships above cut off limits given in Table 1:

- **Bulk carrier**
- **Gas carrier**
- **Tanker**
- **Container ship**
- **General cargo ship**
- **Refrigerated cargo carrier**
- **Combination carrier**

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* excluding ships with diesel-electric, turbine or hybrid propulsion

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.

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.

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."

- **UI approved at MEPC 64 unified interpretation on the timing for existing ships to have on board a SEEMP under regulations 5.4.4 and 22.1 of MARPOL Annex VI (MEPC.1/Circ. 795)**

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 ..... ☐

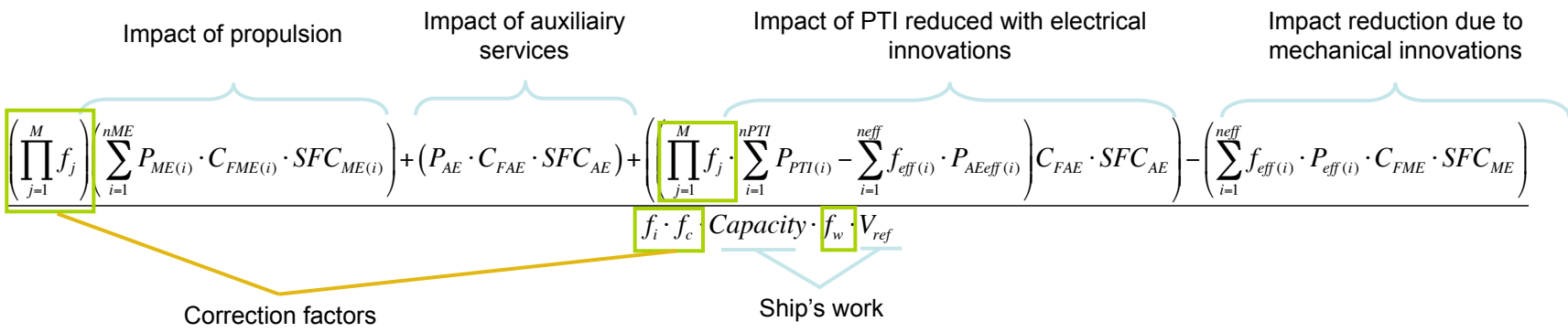
Supporting Guidelines/Guidance

- Resolution MEPC.212(63): 2012 Guidelines on the Method of Calculation of the Attained EEDI for new ships
- Resolution MEPC.213(63) 2012 Guidelines for the Development of a SEEMP
- Resolution MEPC.214(63): 2012 Guidelines on Survey and Certification of the EEDI
- Resolution MEPC.215(63): Guidelines for Calculation of Reference Lines for use with the EEDI
- MEPC.1/Circ.796 "Interim guidelines for the calculation of the coefficient f_w for decrease of ship speed in representative sea condition for trial use" approved at MEPC 64

- MEPC 64/INF.22 FIRST INDUSTRY GUIDELINES FOR CALCULATION AND VERIFICATION OF THE ENERGY EFFICIENCY DESIGN INDEX (EEDI)

EEDI – Calculation

Resolution MEPC.212(63):



f	Correction factors
C_F	CO_2 emission factor (fuel type)
SFC	Specific Fuel Consumption (g/kWh)
P	Power (kW)
Capacity	tonnage
V	Speed (knots)
"ME"	Subscript for parameters related to Main Engine(s)
"AE"	Subscript for parameters related to Aux. Engine(s)

EEDI units

Grams CO_2 emitted per (tonnes*nautical mile)

EEDI – Calculation Resolution MEPC.212(63):

Capacity:

Cargo ships : 100% Deadweight
Container ships : 70% Deadweight
Passenger ships : Gross Tonnage (ITC 1969, Annex I, reg 3)

DWT (t) = Displacement – Lightweight

at summer load draught
(certified in approved stability booklet)
in water relative density 1.025 kg/m^3

SFC – Specific Fuel Consumption (g/kWh):

To be taken from approved NOx Technical File (NOx Technical Code 2008),
Main Engines : E2 or E3 test cycles => SFC taken at 75% MCR
Aux. Engines : D2 or C1 test cycles => SFC taken at 50% MCR.
SFC to be corrected according to ISO 15550:2002 / ISO 3046-1:2002 using standard lower calorific value of the fuel oil of 42,700 kJ/kg (LNG SFC in kJ/kWh, use 48,000 kJ/kg)

EEDI - Calculation Resolution MEPC.212(63):

C_F – Fuel type coefficient

Non-dimensional conversion factor between fuel consumption and CO_2 emission

Corresponds to fuel used when determining SFC included in NOx Technical File

	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

P_{ME} - Main Engine(s) Power for propulsion

$P_{ME(i)} = 75\%\ MCR_{ME(i)}$

In case of Shaft generator : $P_{ME(i)} = 0.75\ (MCR_{ME(i)} - P_{PTO(i)})$

75% of rated electrical output power of each shaft generator

EEDI - Calculation Resolution MEPC.212(63):

P_{AE} – Auxiliary power

Required auxiliary engine(s) power to supply normal maximum sea load Propulsion machinery/systems and accommodation (main engine pumps, navigational systems and equipment and living onboard)
Excluding : thrusters, cargo pumps, cargo gear, ballast pumps, etc.

For ships with total propulsion power ≥ 10 000 kW:

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

75% of rated power consumption of each shaft motor divided by efficiency of generators

For ships with total propulsion power < 10 000 kW:

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

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Note: Resolution MEPC.224(64) amendments

CLIMATE CHANGE: A CHALLENGE FOR IMO TOO!

EEDI - Calculation Resolution MEPC.212(63):

P_{AE} Auxiliary power

If estimated P_{AE} is significantly different from total used aux. power (e.g. for passenger ships), P_{AE} could be estimated with verified Electric Power Table at EEDI ship speed (V_{ref}), divided by average efficiency of the generator(s) weighted by power

Guidelines for the development of Electric Power Table (EPT-EEDI) given in Appendix 2 of 2012 Guidelines for EEDI Calculation (MEPC.212(63))

P_{eff} Mechanical innovations

Output of the innovative mechanical energy efficient technology for propulsion at 75% main engine power (MCR)

P_{AEeff} Electrical innovations

Auxiliary power reduction due to innovative electrical energy efficient technology measured at $P_{ME(i)}$.

EEDI - Calculation

Resolution MEPC.212(63):

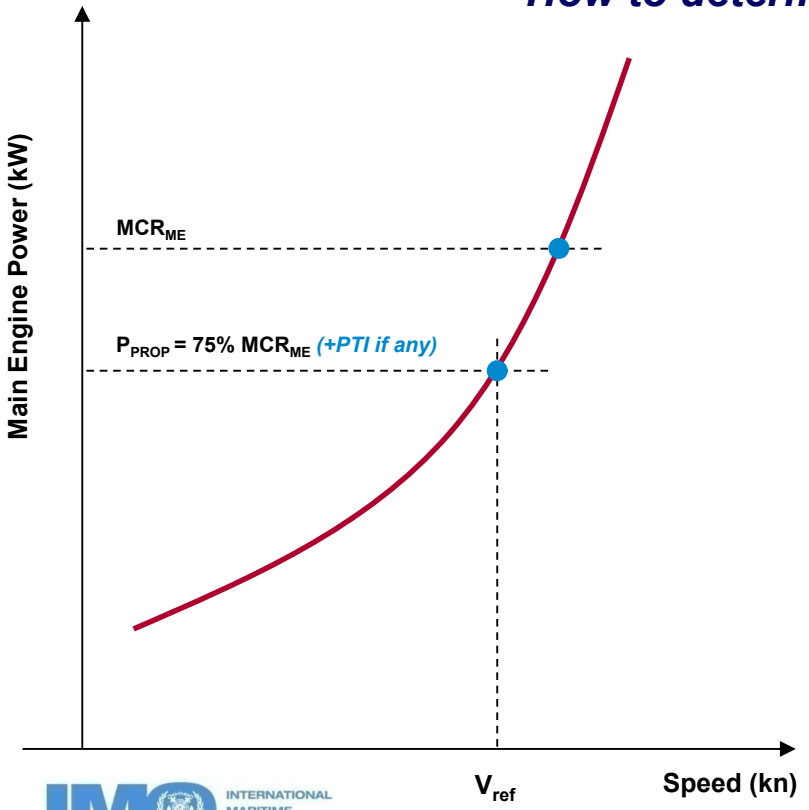
V_{ref} – EEDI ship speed

Ship speed measured at EEDI Capacity and shaft power (75% MCR for main engines).

V_{ref} is ship speed assuming the weather is calm with no wind and no waves.

Resolution MEPC.214(63):

How to determine V_{ref} at design stage ?



V_{ref}

Sea trial (full scale)

$$\frac{V_{ballast,\ 75\%\ MCR,\ full\ scale}}{V_{ballast,\ 75\%\ MCR,\ model}} = \frac{V_{design,\ 75\%\ MCR,\ full\ scale}}{V_{design,\ 75\%\ MCR,\ model}}$$

Tank test (model)

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EEDI - Calculation Resolution MEPC.212(63):

f - Correction factors

Take into account design constraints inducing increase of lightship weight (reinforcements).

- f_j : power correction factors ($0 < f_j < 1$)
- f_i : capacity correction factors ($f_i > 1$)

f_i, f_j Ice Class

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	$2.10 L_{PP}^{-0.12}$	$1.60 L_{PP}^{-0.08}$	$1.25 L_{PP}^{-0.04}$

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	$\frac{0.0227 \cdot L_{PP}^{2.483}}{\sum_{i=1}^{nME} P_{ME(i)}}$	$0.31 L_{PP}^{0.16}$	$0.43 L_{PP}^{0.12}$	$0.56 L_{PP}^{0.09}$	$0.67 L_{PP}^{0.07}$

EEDI - Calculation Resolution MEPC.212(63):

f - Correction factors

f_j for shuttle tankers

- f_j **= 0.77** for shuttle tankers with propulsion redundancy
- 80 000-160 000 DWT

Shuttle Tankers with Propulsion Redundancy are tankers used for loading of crude oil from offshore installations equipped with dual-engine and twin-propellers needed to meet the requirements for dynamic positioning and redundancy propulsion class notation.

$f_{i,VSE}$ for ship specific voluntary structural enhancement

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

Where:

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

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

EEDI - Calculation Resolution MEPC.212(63):

f - Correction factors

f_{iCSR} for bulk carriers and oil tankers

Applicable for ships built in accordance with Common Structural Rules (CSR notation)

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

f_c cubic capacity correction factor for chemical tankers (MARPOL Annex II, reg. 1.16.1)

$f_c = R^{-0.7} - 0.014$, where R is less than 0.98

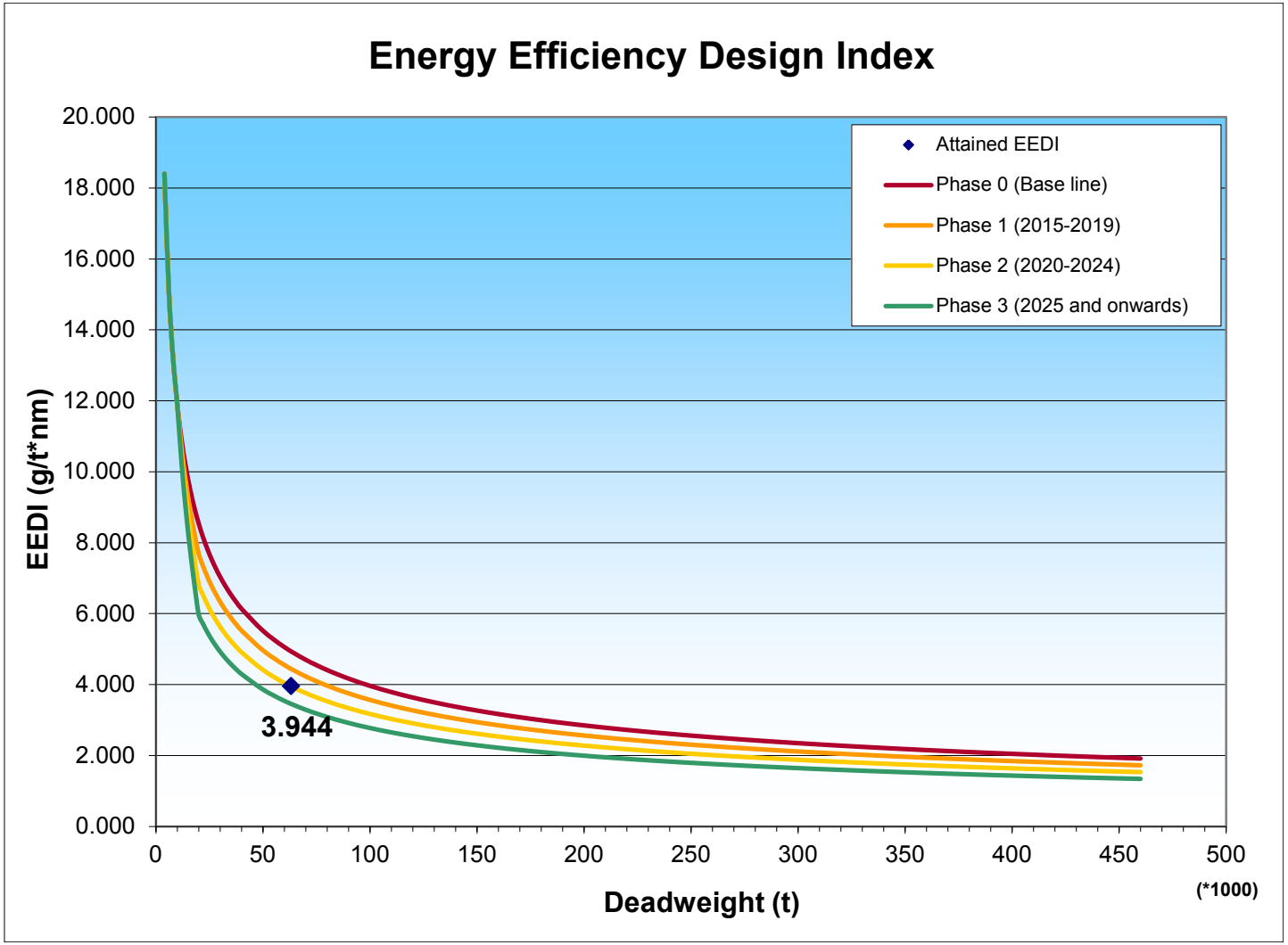
$f_c = 1.000$, where R is 0.98 and above;

f_{cLNG} for gas carrier with direct diesel propulsion system

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

R = DWT (t) / cubic capacity of cargo tanks (m^3)

Is new ship design compliant with EEDI requirements?



Further work on energy efficiency for ships

- MEPC 64 approved, subject to concurrent decision by MSC 91 (November 2012), the draft MEPC-MSC Circular for the interim guidelines for determining minimum propulsion power to maintain the manoeuvrability of ships in adverse conditions
- Inclusion of ro-ro passenger and cargo ships in EEDI framework (MEPC 65)
- Work plan and schedule agreed at MEPC 63 including:
  - Ro-ro vehicle carrier
  - Cruise passenger ships
  - Other propulsion systems

Thank you for your attention

For more information please see:
www.imo.org