Greenhouse Gases Efficiency & Emissions

MARPOL Annex VI

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Unit 1.1 Sustainability

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EMSA

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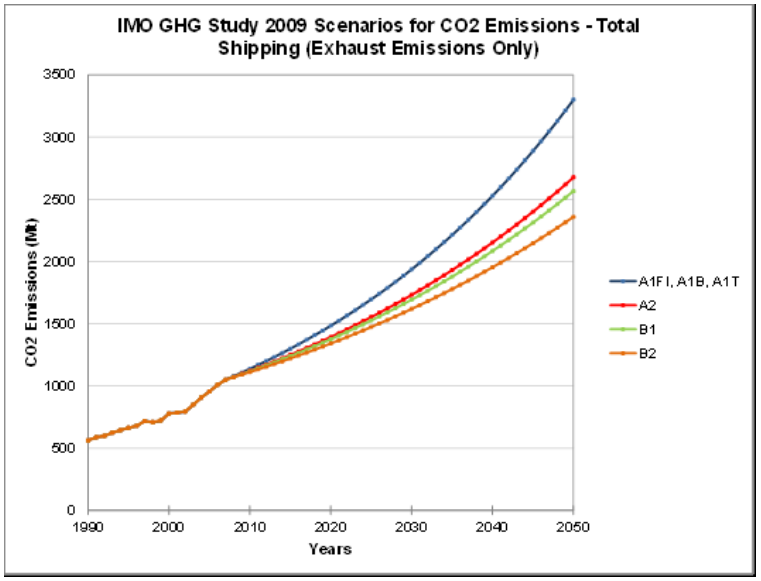
Q: What are Ship Emissions?
A: GHG and other Relevant Substances

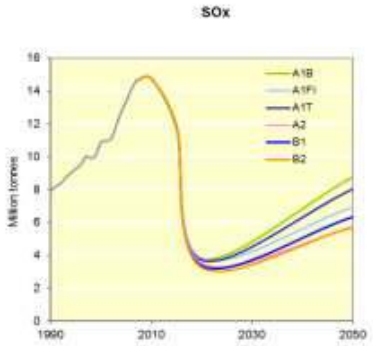
• **GHG (Greenhouse Gases)** - **CO2** (Carbon Dioxide), **CH4** (Methane), N2O (Nitrous Oxide), HFCs (Hydro Fluorocarbons), PFCs (Perfluorcarbons) and SF6 (Sulphur Hexafluoride)

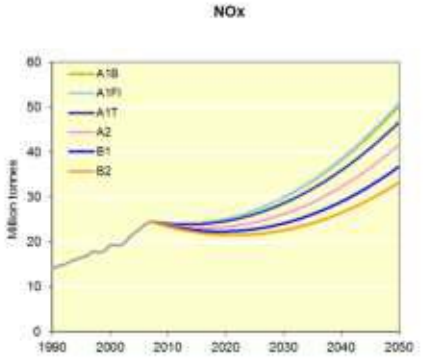
• **Other Relevant Substances** - **NOx** (Nitrogen Oxides), **SOx** (Sulphur Oxides), NMVOC (Non-Methane Volatile Organic Compounds), CO (Carbon Monoxide) and **PM** (Particulate Matter, including Black Carbon).
• **Main difference**

- Greenhouse Gases have a global effect (global warming, sea level rise, climate change)
- Relevant substances (or air pollution) have a local effect on the direct surroundings (human health & environment)

Modelling Total Shipping Scenarios







Business as Usual
(different economic trends)
2009 - 1118 MT
2020 - 1300 MT
2050 - 3600 MT

Emission Scenarios
2008 revised Marpol Annex VI rules (2nd IMO GHG study 2009)

Introducing GHGs

Shipping is one of the most energy efficient and environmentally friendly modes of transport (around 3% of the total CO_2 emissions)

- Moving a tonne of cargo by air produces up to 100 times as much CO2 as moving it the same distance by sea;
- Modern ships emit as little as 15 grams of CO_2 per tonne-kilometer compared to about 50 grams per tonne-kilometer for heavy trucks;

➢ Hence, promoting a **modal shift** or 'Short Sea Shipping' and 'Motorways of the Seas' as an alternative for congested roads is an EU policy priority

MARPOL Annex VI
International rules addressing GHG

• **The Kyoto Protocol (adopted in Japan December 1997)** is an international agreement linked to the *United Nations Framework Convention on Climate Change* (**UNFCCC**), which **commits** its Parties by setting internationally binding emission reduction targets.
• Recognizing that developed countries are principally responsible for the current high levels of GHG emissions in the atmosphere as a result of more than 150 years of industrial activity, the Protocol places a heavier burden on developed nations under the principle of *common but differentiated responsibilities* (**CBDR**).

Shipping - bunker fuels falls out of the Kyoto scope

International Regulations & Guidance addressing GHG - IMO

•

Revised MARPOL ANNEX VI - Resolution MEPC.203 (62), adopted in July 2011

- Inclusion of regulations on Energy Efficiency for Ships, CO_2
- Related Guidelines on the EEDI/SEEMP, adopted in 2012:

Method of Calculation of the Attained EEDI
Development of SEEMP
Survey and Certification of the EEDI
Calculation of Reference Lines for the EEDI

• **MEPC.1/Circ.684, 2009** - Voluntary Guidelines for the EEOI

…and all the revisions/amendments adopted afterwards!

What is the EEDI? Energy Efficiency Design Index (EEDI)

The concept behind the EEDI is fairly simple and it is intended to represrent ship CO2 efficiency at a determined design pint (Speed Power Draught DWT

$$EEDI = \frac{\text{Environmental Impact}}{\text{Benefit to society}} = \frac{\text{Ship CO2 Emissions}}{\text{Performed Work}}$$

And so ….

$$EEDI = \frac{\text{CO2 Main Engine + CO2 Auxillary Engines}}{\text{Capacity x Speed}}$$

and after some assumptions, calculations, corrections, conversions, etc., the EEDI is expressed in math terms as:

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

…a lower EEDI value means a more Energy-Efficient Ship Design!

Several correction factors were included in the formula to account for:

- Ship specific design elements (e.g. ice-class, power redundancy)
- Decrease of speed in representative sea and weather conditions
- Innovative energy efficiency technologies (mechanical & electrical)
- Technical/regulatory limitation on capacity (e.g. voluntary structural enhancements, capacity correction factors)
- Cubic capacity correction factors (chemical tankers and gas carriers)

EEDI regulations agreed on Ship's coverage Type, Size, Required Reduction Targets (in%). Ships' coverage is around 70% against total CO_2 emissions.

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*

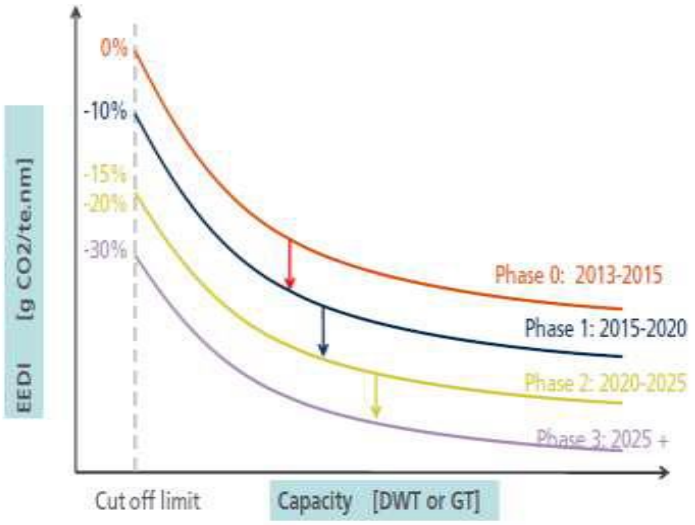
Ship Type	Size	Phase 0 1 Jan 2013 – 31 Dec 2014	Phase 1 1 Jan 2015 – 31 Dec 2019	Phase 2 1 Jan 2020 – 31 Dec 2024	Phase 3 1 Jan 2025 and onwards
General Cargo ships	15,000 DWT and above	0	10	15	30
	3,000 – 15,000 DWT	n/a	0-10*	0-15*	0-30*
Refrigerated cargo carrier	5,000 DWT and above	0	10	15	30
	3,000 – 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*

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

n/a means that no required EEDI applies.

Reference line value = a x b^-c			
Ship type (as defined in MARPOL Annex VI Chapter 4, Regulation 2)	a	b	c
Bulk carrier	961.79	DWT of the ship	0.477
Gas carrier	1120.00	DWT of the ship	0.456
Tanker	1218.80	DWT of the ship	0.488
Container ship	174.22	DWT of the ship	0.201
General cargo ship	107.48	DWT of the ship	0.216
Refrigerated cargo carrier	227.01	DWT of the ship	0.244
Combination carrier	1219.00	DWT of the ship	0.488
Passenger ship	Not initially subject to reference lines. Attained EEDI still needs to be calculated.		
Ro-ro cargo ship			
Ro-ro passenger ship			

Table 1: Parameters for determination of reference values for the different ship types (MARPOL Annex VI, Regulation 21)



Calculation of reference lines

13 To calculate the reference line, an estimated index value for each ship contained in the set of ships per ship type is calculated using the following assumptions:

.1 the carbon emission factor is constant for all engines, i.e. $C_{F,ME} = C_{F,AE} = CF$ = 3.1144 g CO_2/g fuel;

.2 the specific fuel consumption for all ship types is constant for all main engines, i.e. $SFC_{ME} = 190$ g/kWh;

.3 $P_{ME(i)}$ is 75% of the total installed main power ($MCR_{ME(i)}$);

.4 the specific fuel consumption for all ship types is constant for all auxiliary engines, i.e. $SFC_{AE} = 215$ g/kWh;

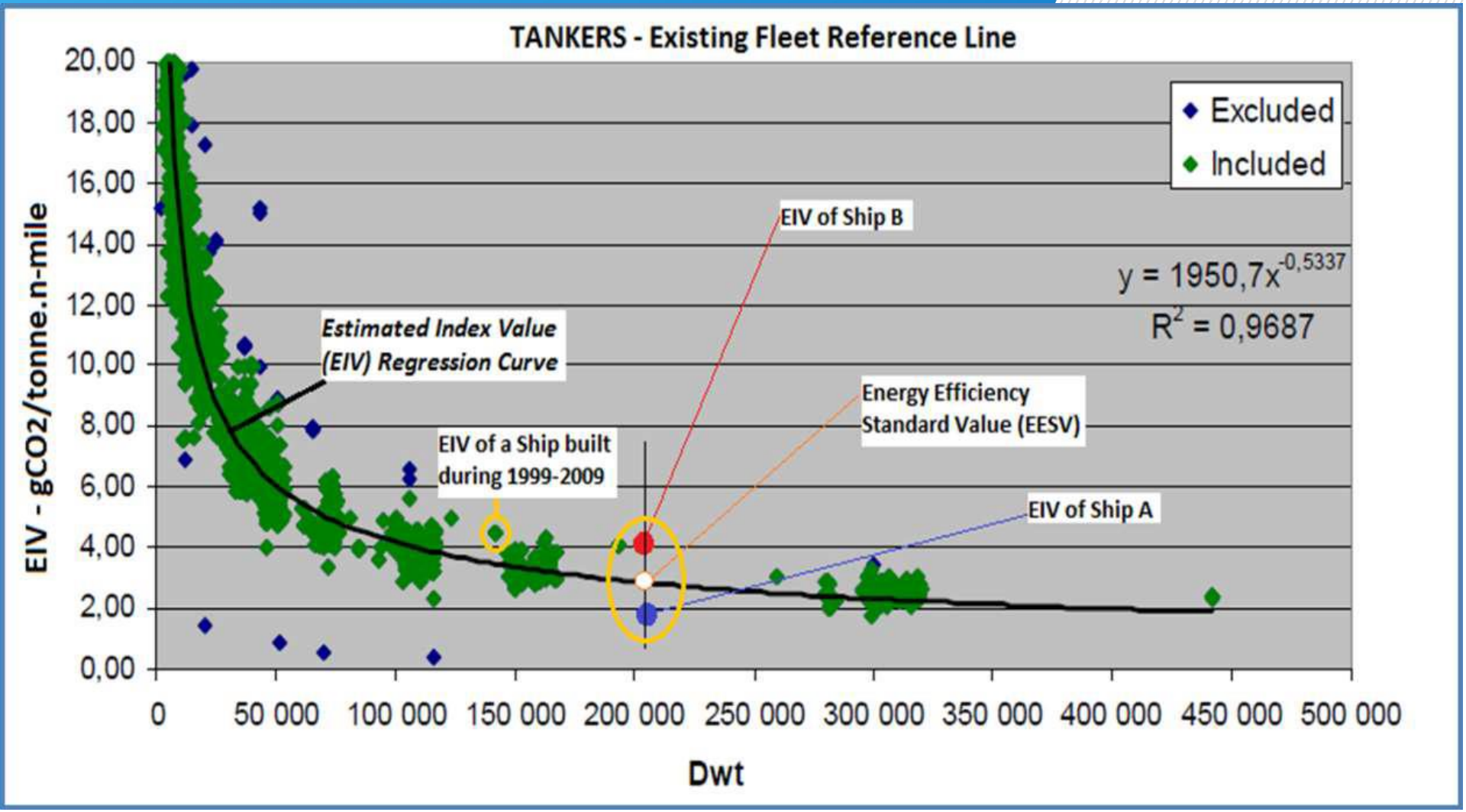
.5 P_{AE} is the auxiliary power and is calculated according to paragraphs 2.5.6.1 and 2.5.6.2 of the annex to MEPC.XXX(63);

.6 no correction factors are used; and

.7 innovative mechanical energy efficiency technology, shaft motors and other innovative energy efficient technologies are all excluded from the reference line calculation, i.e. $P_{AEeff} = 0$, $P_{PTI} = 0$, $P_{eff} = 0$.

14 The equation for calculating the estimated index value for each ship (excluding containerships – see paragraph 15) is as follows:

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


TANKERS - Existing Fleet Reference Line
EIV - gCO2/tonne.n-mile
20,00
18,00
16,00
14,00
12,00
10,00
8,00
6,00
4,00
2,00
0,00
0
50 000
100 000
150 000
200 000
250 000
300 000
350 000
400 000
450 000
500 000
Dwt
Excluded
Included
EIV of Ship B
y = 1950,7x-0,5337
R2 = 0,9687
Estimated Index Value (EIV) Regression Curve
Energy Efficiency Standard Value (EESV)
EIV of a Ship built during 1999-2009
EIV of Ship A

Several vessel types have been initially excluded from the regulations due to their specific trading and operation schemes, design criteria, lack of proper categorization, additional safe speed and power requirements, use of nonconventional propulsion…etc.

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
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*

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

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

*** Reduction factor applies to those ships constructed on or after 1 September 2015, as defined in paragraph 43 of regulation 2.

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

International Regulations & Guidance

- **Energy Efficiency Operational Indicators/Performance**

Data is available through either Mandatory and Voluntary information

Fuel Type supplied and consumed

- Mandatory: Bunker Delivery Notes / Oil Record Book / Fuel Oil Sampling, kept on-board - *PSC survey and verification*

- Voluntarily but recognised as normal practice among the shipping industry: On-board monitoring fuel oil consumption - Main & Auxiliary Engines, Oil-fired Boilers, IG Generators and Incinerators

Note: Verifying fuel oil quality testing according to International Standards e.g. **ISO 8217:2010** on Petroleum products - Fuels (class F) - Specifications of marine fuels

International Regulations & Guidance

- **Energy Efficiency Operationa l Indicators/Performance**

Cargo Carried

➢ Mandatory (SOLAS & MARPOL): Cargo/Load Manifest, Cargo Record Book, kept on-board - *PSC survey and verification*

➢ Voluntarily: CDWT information obtained through Displacement *vs* Lightweight; draught measurements and stability documentation.

Distance travelled

➢ Mandatory (SOLAS): Navigation Log Book, Nautical Charts, ECDIS, Positioning Systems like AIS, LRIT, records on-board - *PSC survey and verification*

International Regulations & Guidance

• Amendments MARPOL ANNEX VI - Resolution MEPC.278(70), adopted in October 2016

- Inclusion of Data Collection System (DCS) for fuel oil consumption

Regulation 22 A - SEEMP *From calendar year 2019, each ship of 5,000 gross tonnage and above shall collect the data specified in appendix IX to this Annex, for that and each subsequent calendar year or portion thereof, as appropriate, according to the methodology included in the SEEMP.*

- Related Guidelines on Verification & Database, adopted in July 2017:

Res. MEPC.292(71) - *Administration Verification of fuel oil consumption data*
Res. MEPC.293(71) - *Development & Management of IMO DCS Database*

"Appendix IX

Information to be submitted to the IMO Ship Fuel Oil Consumption Database

Identity of the ship
- IMO number

Period of calendar year for which the data is submitted
- Start date (dd/mm/yyyy)
- End date (dd/mm/yyyy)

Technical characteristics of the ship
- Ship type, as defined in regulation 2 of this Annex or other (to be stated)
- Gross tonnage (GT)[1]
- Net tonnage (NT)[2]
- Deadweight tonnage (DWT)[3]
- Power output (rated power[4]) of main and auxiliary reciprocating internal combustion engines over 130 kW (to be stated in kW)
- EEDI (if applicable)
- Ice class[5]

Fuel oil consumption, by fuel oil type[6] in metric tonnes and methods used for collecting fuel oil consumption data

Distance travelled

Hours underway

ANNEX 11

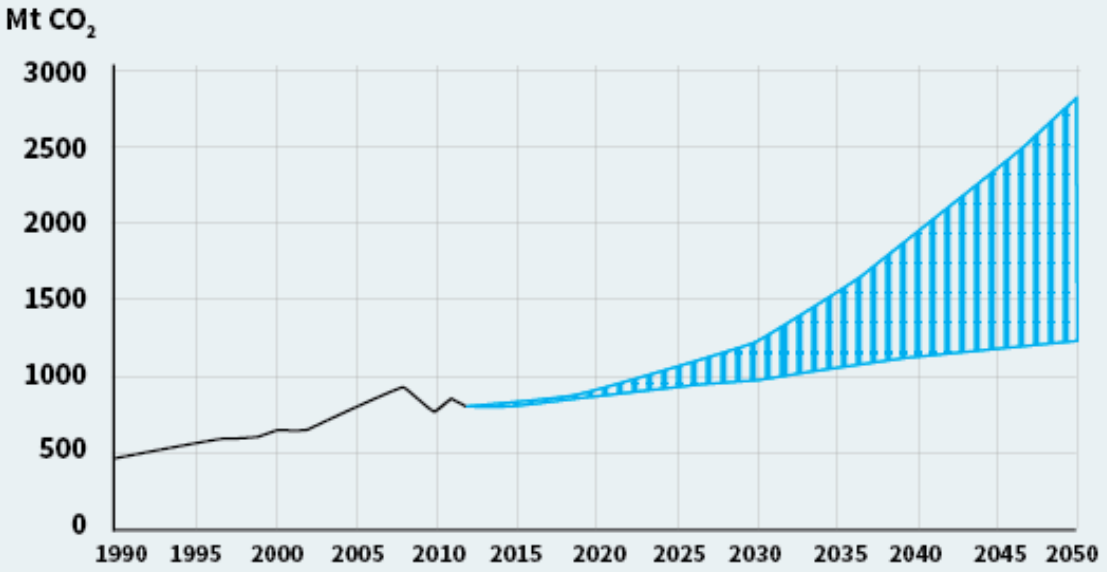
ROADMAP FOR DEVELOPING A COMPREHENSIVE IMO STRATEGY ON REDUCTION OF GHG EMISSIONS FROM SHIPS

In order to build upon, and bring together, the various streams of activity that have already been taking place in IMO in relation to the reduction of GHG emissions from international shipping, including the technical and operational measures (EEDI and SEEMP) in force since 2013, the adoption of the data collection system at MEPC 70 and various technical cooperation activities and major projects, the MEPC approved the *Roadmap for developing a comprehensive IMO strategy on reduction of GHG emissions from ships*, set out below.

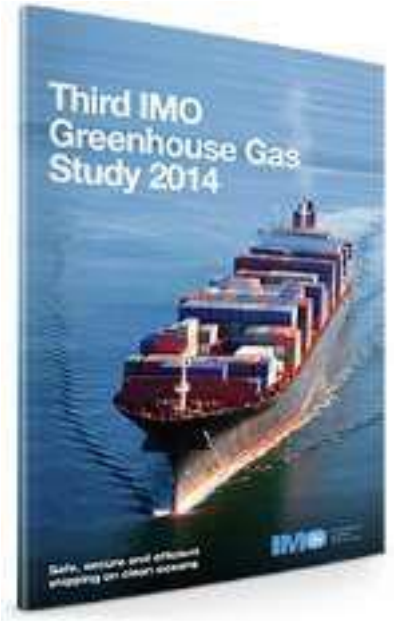
October 2016 (MEPC 70)	- Adoption of Data Collection System (DCS) - Voluntary data collection and submission begins - Approval of Roadmap
Week before MEPC 71	- Intersessional meeting to start discussions on a comprehensive IMO strategy on reduction of GHG emissions from ships, taking into account inputs such as: (1) Third IMO GHG Study; (2) submissions on the elements below and on existing activities related to GHG emissions reductions by States and stakeholders; and (3) a technical paper by the Secretariat compiling a list of existing IMO activity related to reducing GHG emissions in the shipping sector. The discussions should include but not be limited to the elements below: • Levels of ambition and guiding principles for the strategy; • Emissions scenarios; • Assessment of the projected future demand for shipping; • Parameters/indicators on energy efficiency of ships (current status and long-term potential); • Emission reduction opportunities (near-, mid- and long-term actions), including alternative fuels; • Costs and benefits; • Capacity building and technical cooperation; • Barriers to emissions reductions and how to overcome them; • Priority areas for R&D, including in relation to technology; • Impact of EEDI; • Impacts on States, taking into account the HLAP (resolution A.1098(29)); and • Impacts of other regulations on GHG emissions

May 2017 (MEPC 71)	- Discussion continues[1]
September 2017	- Intersessional meeting
Week before MEPC 72	- Intersessional meeting
Spring 2018 (MEPC 72)	- Adoption of initial IMO Strategy[2], including, inter alia, a list of candidate short-, mid- and long term further measures with possible timelines, to be revised as appropriate as additional information becomes available
January 2019	- Start of Phase 1: Data collection (Ships to collect data)

Range of expected increase in GHG emissions from shipping



Source: Third IMO GHG Study (2014)
Transport & Environment



EMSA's Research/Studies - Example

From 2010 **EMSA** has been working together with the **FMI** (Finish Meteorological Institute) on the ***S.T.E.A.M.*** (Ship Traffic Emission Assessment Model) Project.

Upon agreement with the EU MSs (AIS ownership) an MoU was signed between EMSA and the FMI to proceed accordingly.

Goals:

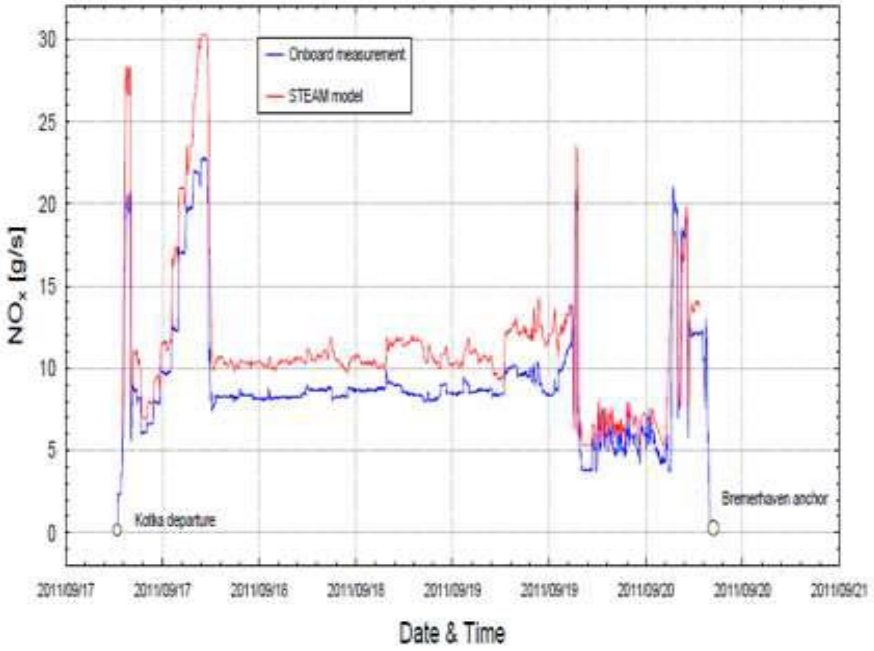
To calculate ships' emissions (GHG & Relevant Substances) for the whole EU sea-area

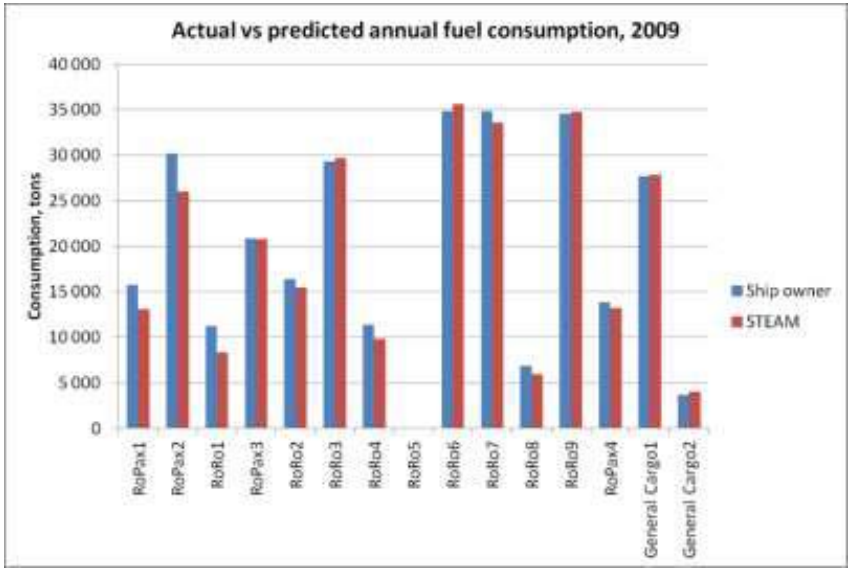
To make the calculations for the whole year of 2011

EMSA's Research/Studies – Example

Quality Control / Model Validation

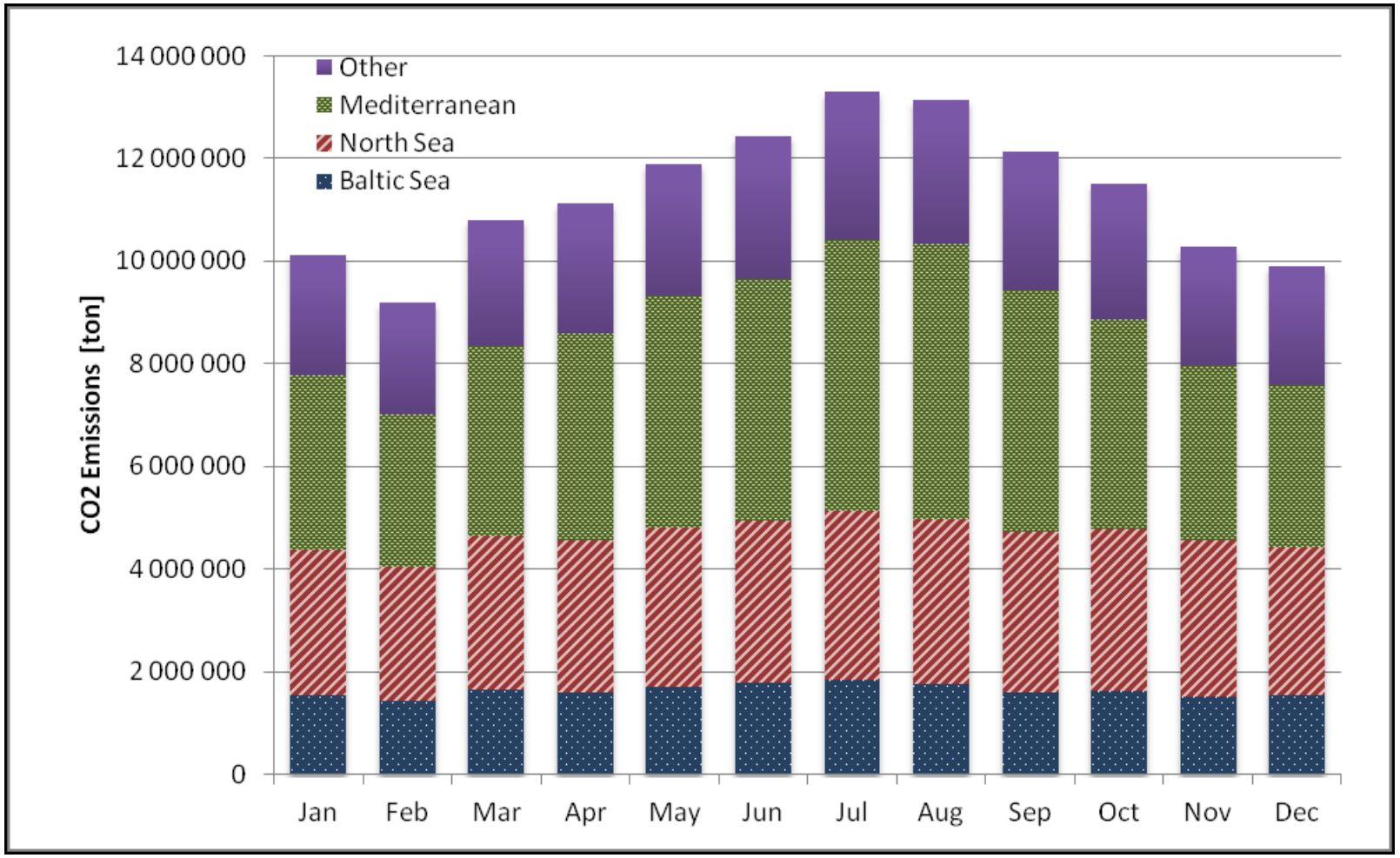
Predicted emissions can be easily and directly compared to:
on-board measurements and/or ship owner/operator fuel reports





EMSA's Research/Studies - Example

Emissions Project 2012 - Results, CO_2 by EU Sea Areas



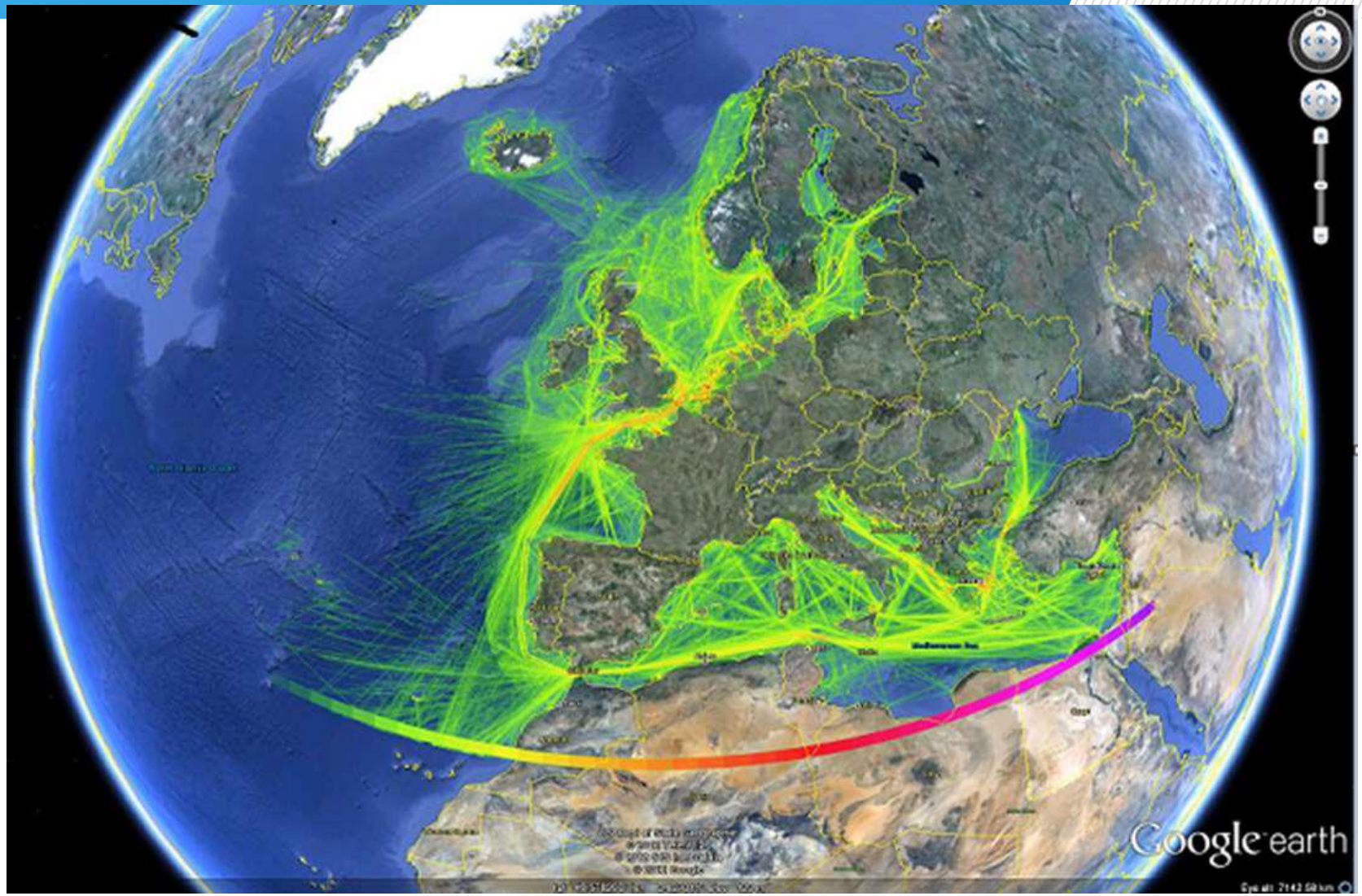


Illustration output of the whole SSN area CO2 emissions calculated by STEAM

Thank you!

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