

# Module 1: Climate Change and the Shipping Response



## 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

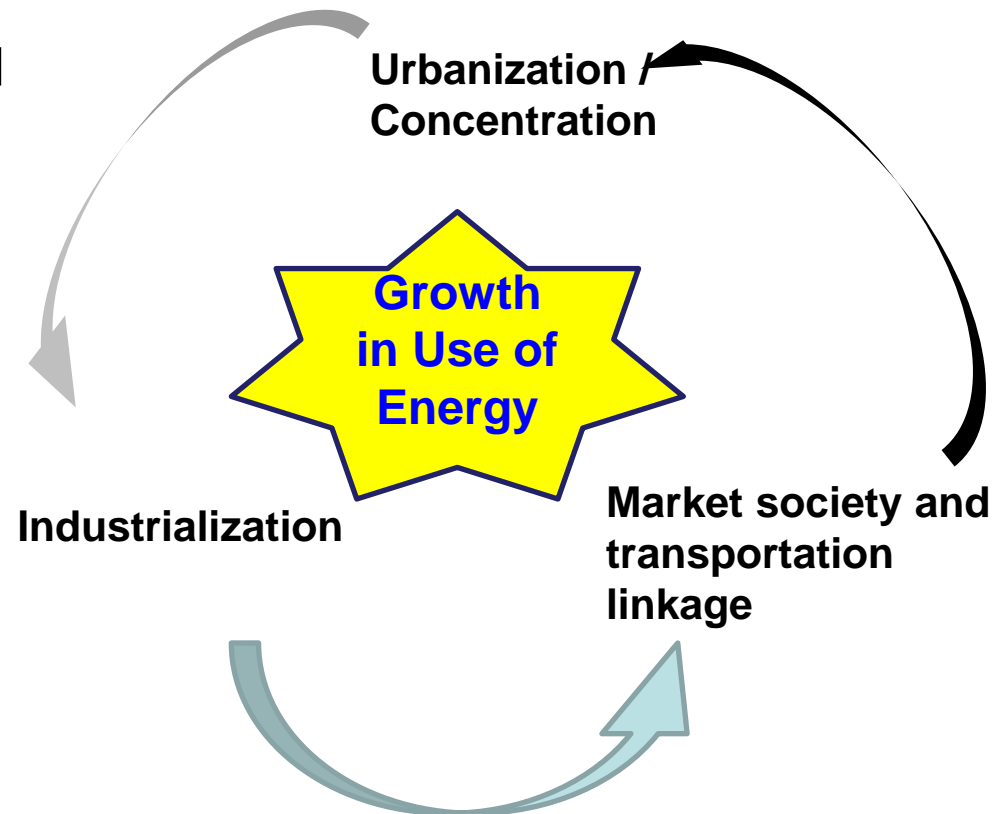
- Origins of the air pollution and climate change
- Climate change and GHG emissions
- International (global) response
- International shipping response
- Main IMO instruments and historical developments

# The origins

- The population / social factors
- The energy / technical choices

# Air Pollution and social factor

- Air pollution initially was identified in large cities.
- Numerous sources in restricted areas.
- Closely linked to:
  - Industrialization
  - Urbanization
  - Growth in energy use



## Main energy source of the **pre-industrialized** world

- Man & animal
- Wind
- Water
- Wood

## Main energy source of the **industrialized** world

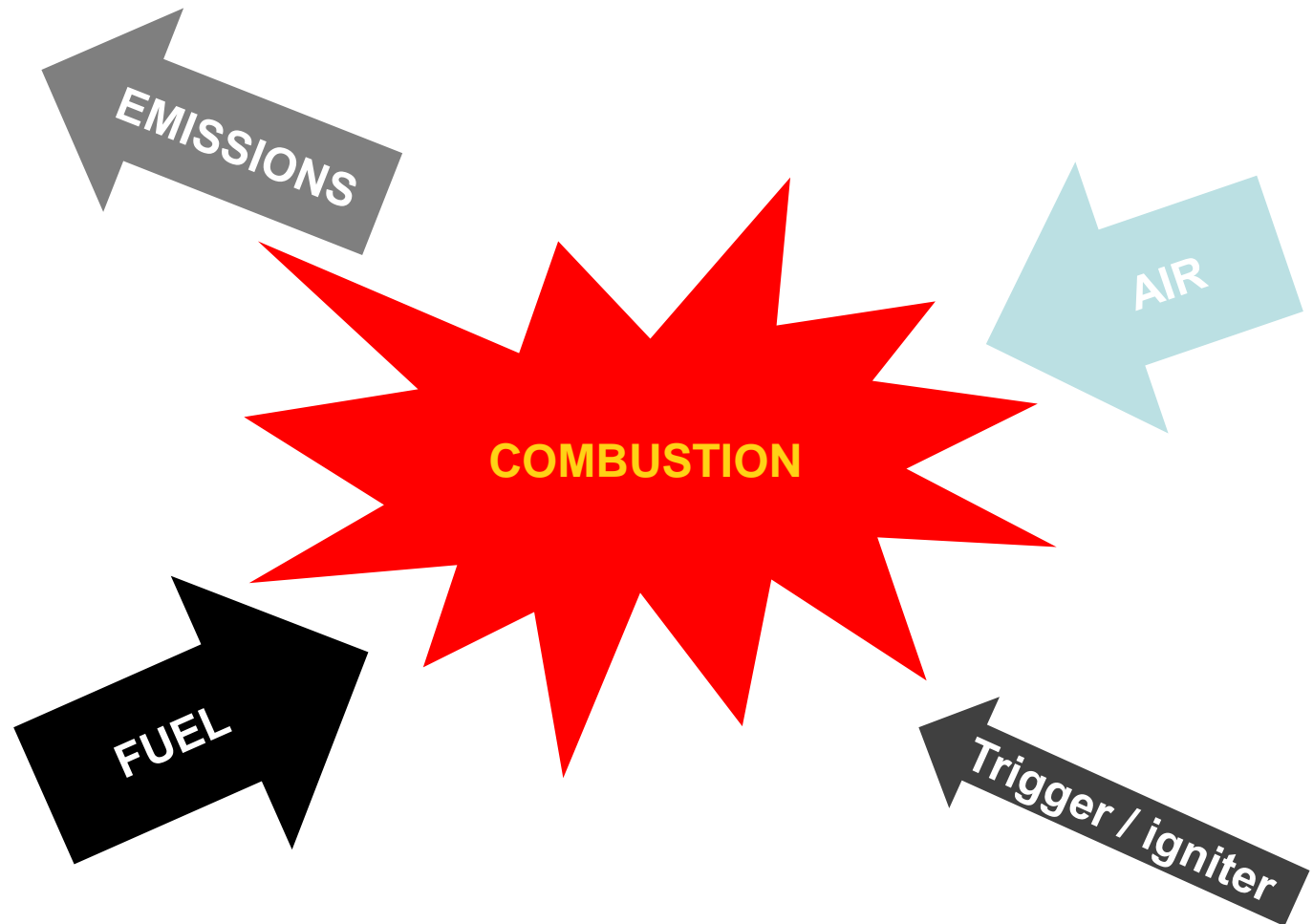
### **FOSSIL FUELS**

(reliable, flexible, controllable,  
easy to use, etc.)

(unfortunately generate significant  
level of air emissions)

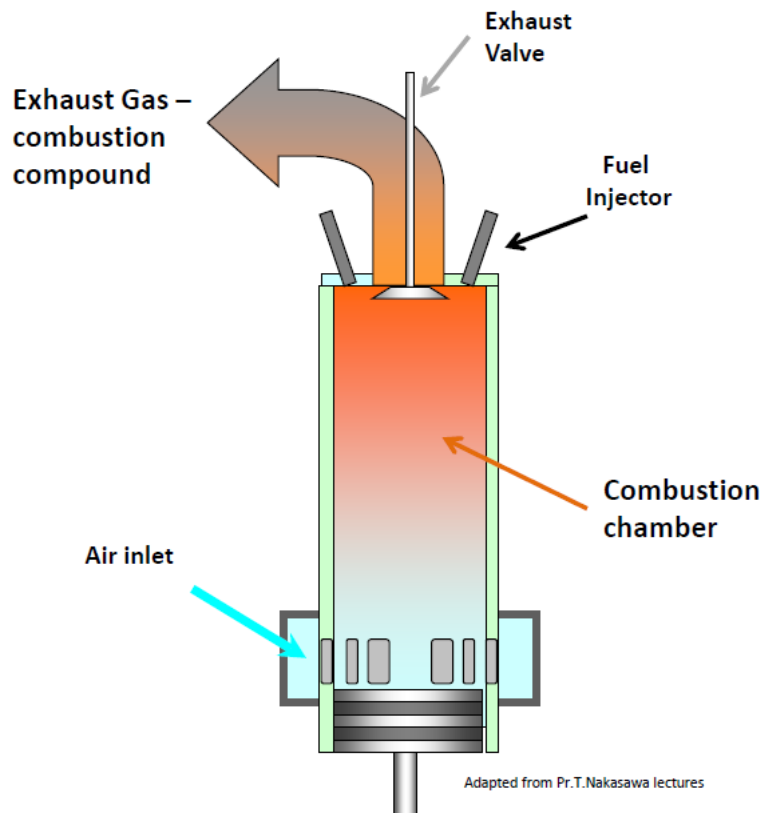
The other sources of energy are  
largely overwhelmed by fossil fuels

# Energy use and combustion principle



# Combustion case: Engines and emissions

Internal combustion engine - two stroke diesel engine



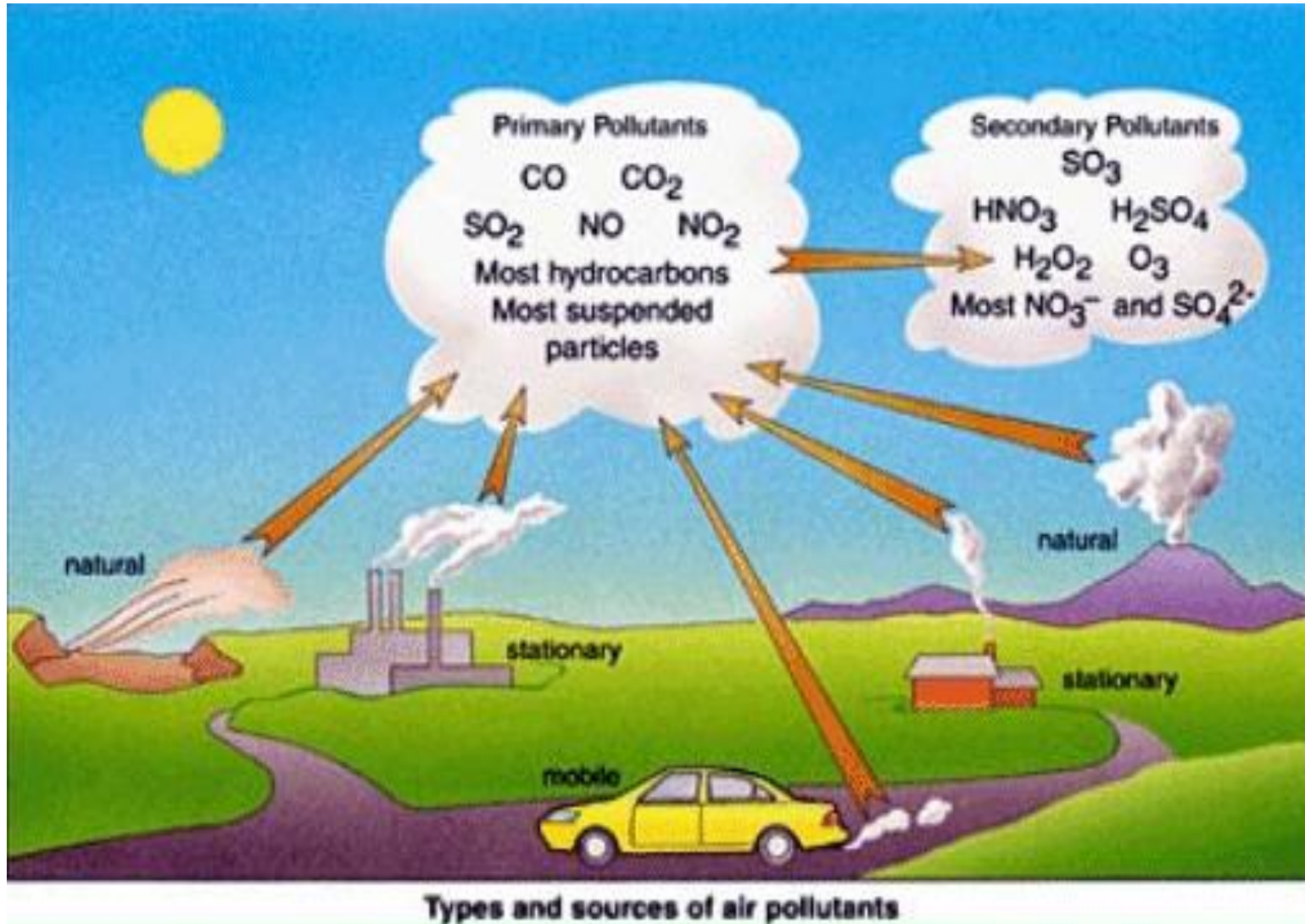
**Fossil fuel + Air**



**Carbon Dioxide + Water +  
Nitrogen**

**+ Various gas compounds +  
Particulate Matters**

# Sources of air emissions



**Energy use is the major source of man-made air emissions**



# Shipping air emissions and their impacts

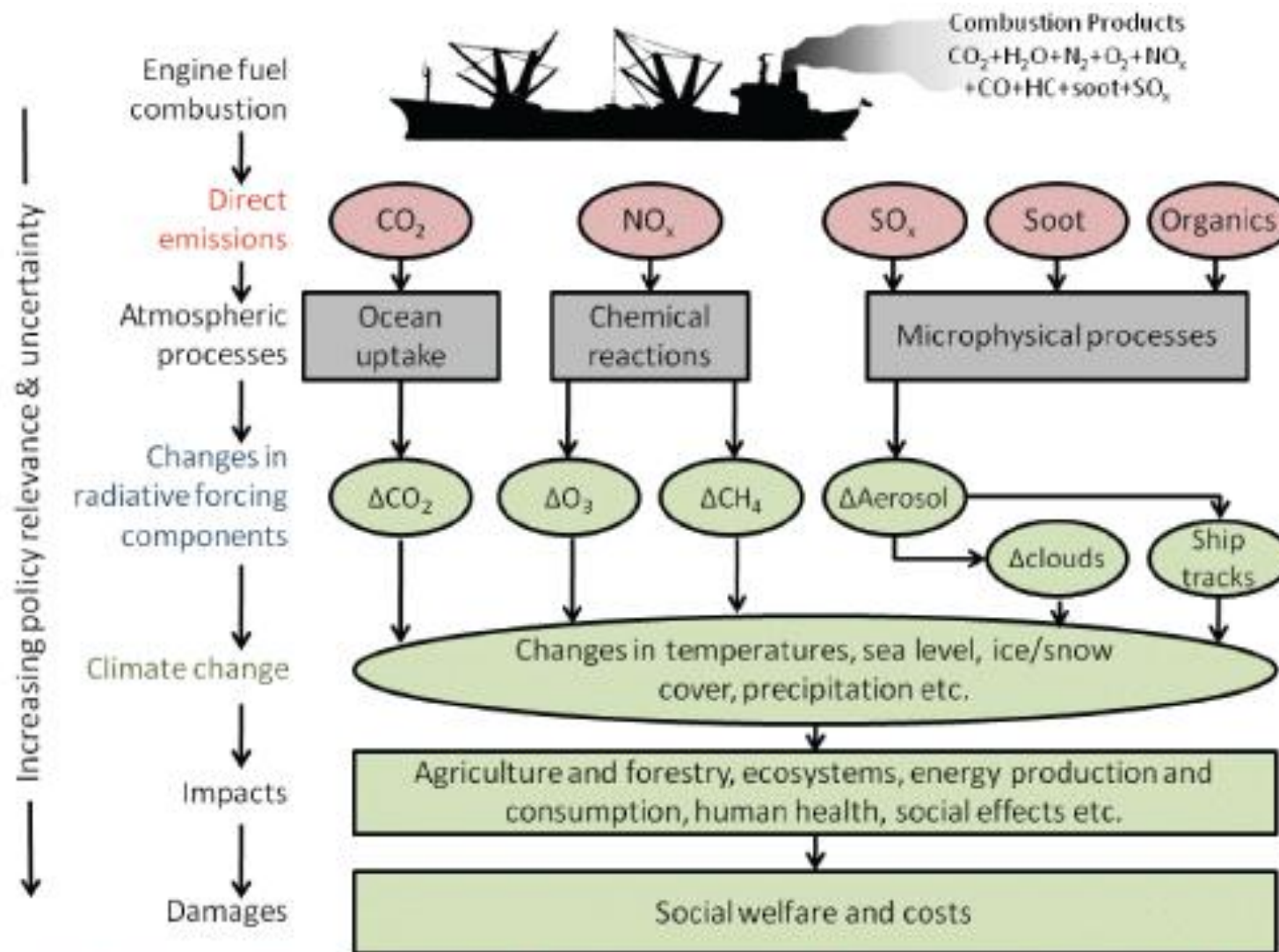


Figure 8.1 Schematic diagram of the overall impacts of emissions from the shipping sector on climate change (from Lee et al., 2009a)

# Why energy efficiency matters?

## Context

- Energy resources scarcity
- Environmental damages
- Sustainability

## Possible policies

- Energy efficiency
- Renewable energy
- Alternative energy sources
- Societal changes

## Benefit of energy efficiency as a strategy/policy:

- **Avoids major destabilizing changes.**
- **Leads to economic benefits**
- **Support innovation and growth**
- **Secures less use of scarce resources.**
- **Leads to lower environmental damage.**

# Air pollution and the Issue of GHG

- Air Pollution
- Climate system
- GHG emissions & impacts

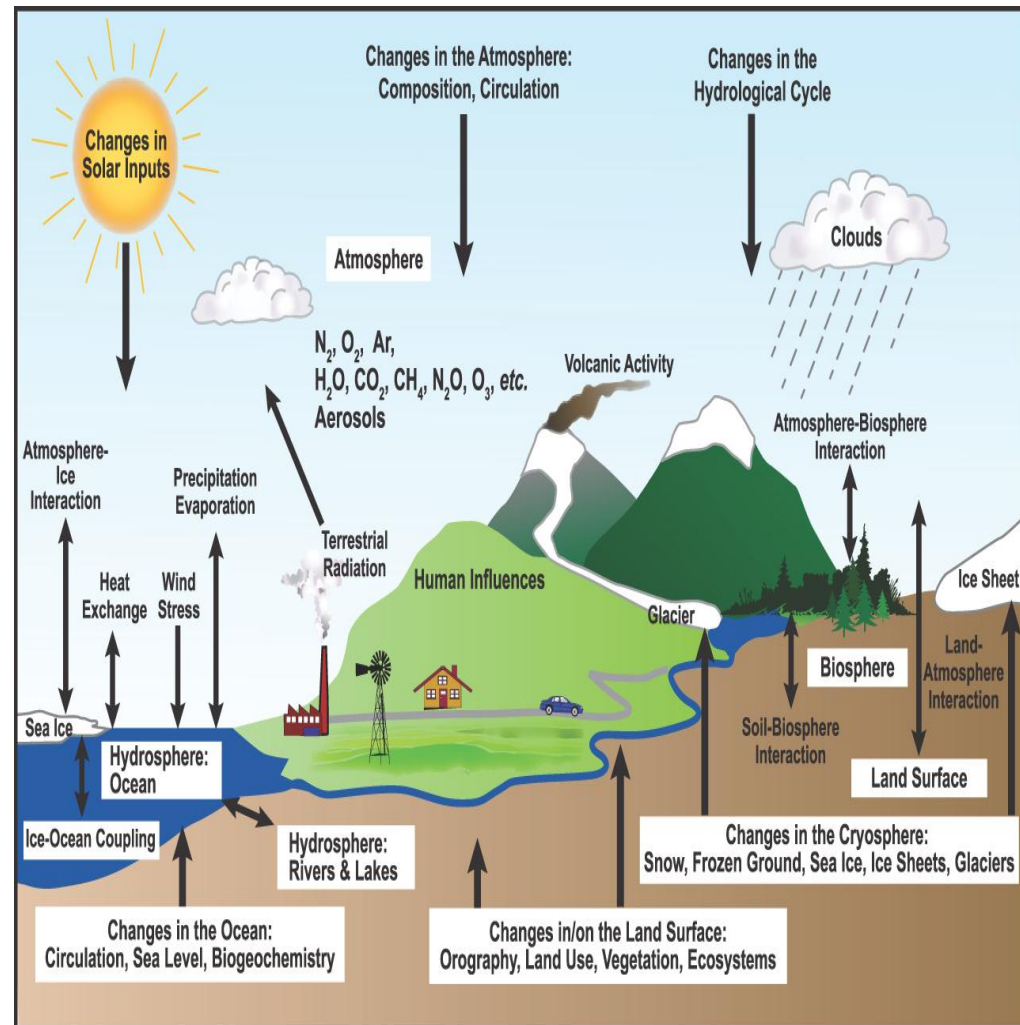
## Main air emissions

- Nitrogen Oxides: NO<sub>x</sub>
- Sulphur Oxides: SO<sub>x</sub>
- Particulate Matters or organic aerosols
- Oxides of carbon: CO and CO<sub>2</sub>
- Carbon compounds - such as CH<sub>4</sub> and VOC
- Ozone (O<sub>3</sub>)
- Fluorocarbon and Chlorofluorocarbon compounds - such as CFC, PFC, SF<sub>6</sub> and HFC
- Halogen compounds - such as chlorides, fluorides and bromides
- Etc.

# Climate system dynamics

Earth as a whole includes:

- The atmosphere (i.e. gases);
- The hydrosphere (i.e. the waters);
- The lithosphere (i.e. solid layer of earth);
- The cryosphere (i.e. frozen waters); and the
- Biosphere (i.e. the living).
- All the above are changing with time, influenced by a variety of things including human activities.

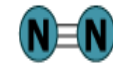


Schematic view of the components of the climate system, their processes and interactions. IPCC Fourth Assessment Report, Climate Change 2007 (AR4) WG I

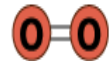
# GHG emissions

- **Carbon dioxide:** Most of the atmospheric GHG emissions are CO<sub>2</sub>.
- Other gases to consider?
  - **Methane:** Agriculture and livestock, mining, transportation, and use of certain fossil fuels, sewage, and decomposing garbage in landfills.
  - **Nitrous oxide:** The industrial agriculture and use of fertilizers accounts for the majority of the Nitrous oxide release.
  - **Halocarbon:** They are non-natural but manufactured compounds. Extensively used as refrigerants.
  - Other gases like ozone or water vapour have GHG properties.

## Abundant Atmospheric Gases

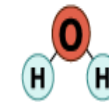


Nitrogen, N<sub>2</sub>

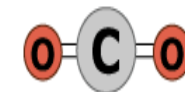


Oxygen, O<sub>2</sub>

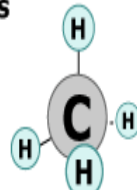
## Greenhouse Gases



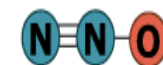
Water, H<sub>2</sub>O



Carbon Dioxide, CO<sub>2</sub>



Methane, CH<sub>4</sub>



Nitrous Oxide, N<sub>2</sub>O

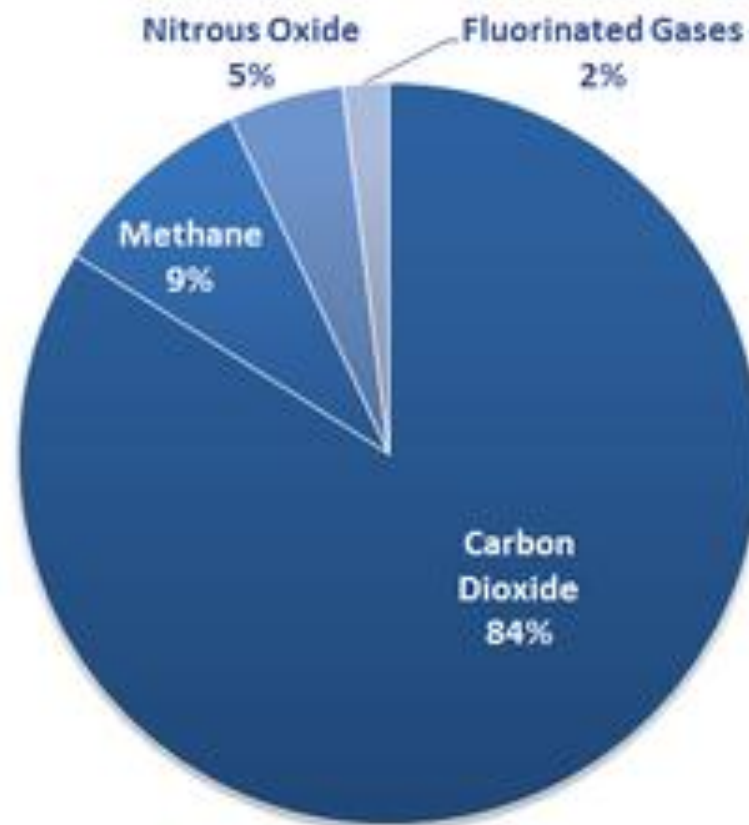


Ozone, O<sub>3</sub>

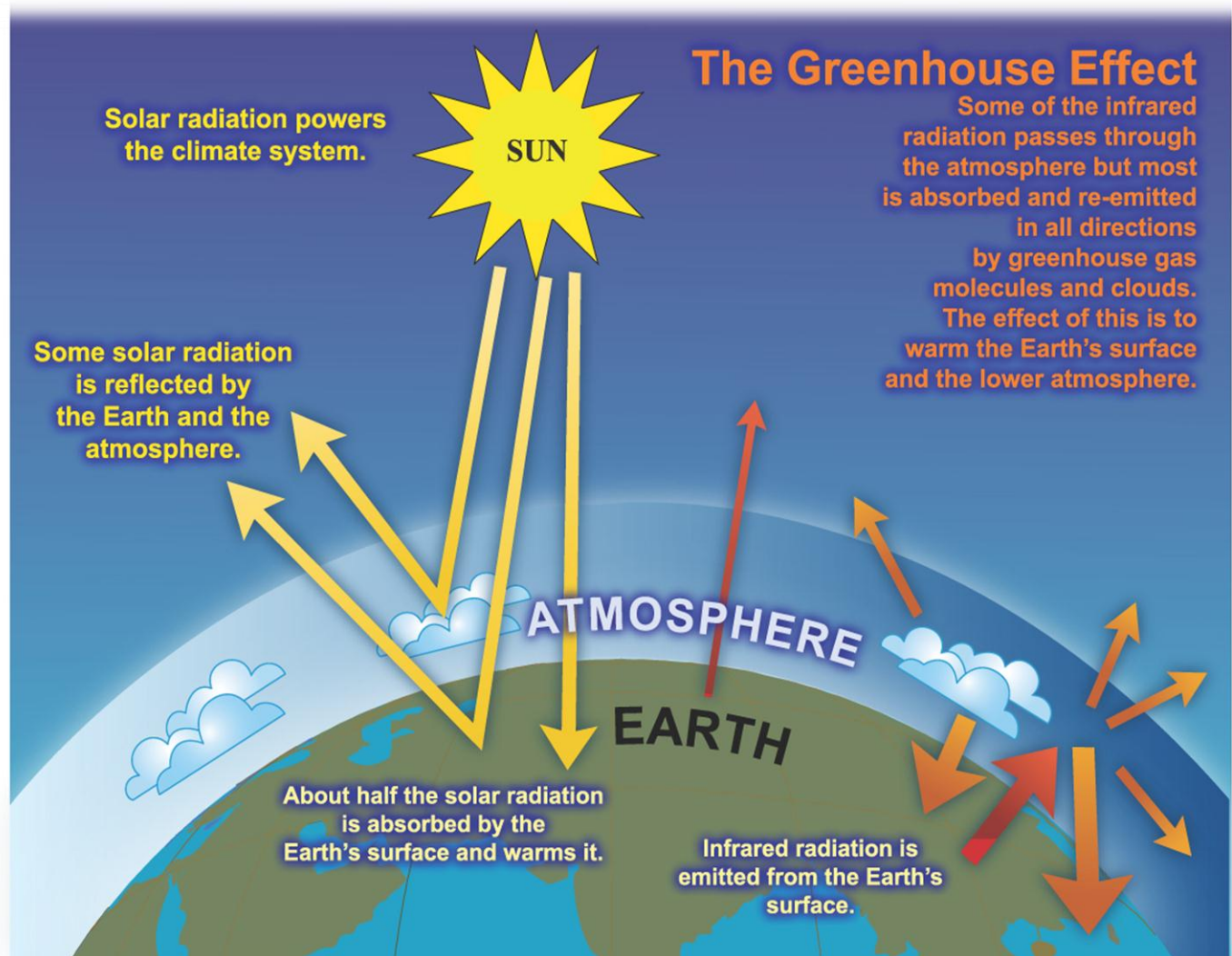
# Man-made GHG emissions

➤ Kyoto Protocol has identified six main gases as:

- Carbon dioxide (CO<sub>2</sub>);
- Methane (CH<sub>4</sub>);
- Nitrous oxide (N<sub>2</sub>O);
- Hydrofluorocarbons (HFCs);
- Perfluorocarbons (PFCs);
- Sulphur hexafluoride (SF<sub>6</sub>).



# GHG warming effect

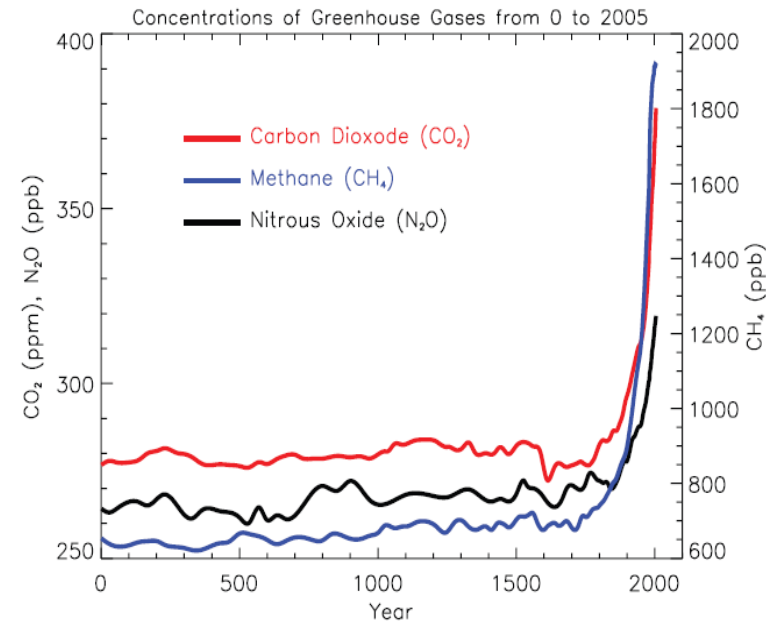


An idealised model of the natural greenhouse effect. [IPCC 2007 AR4 WG I]

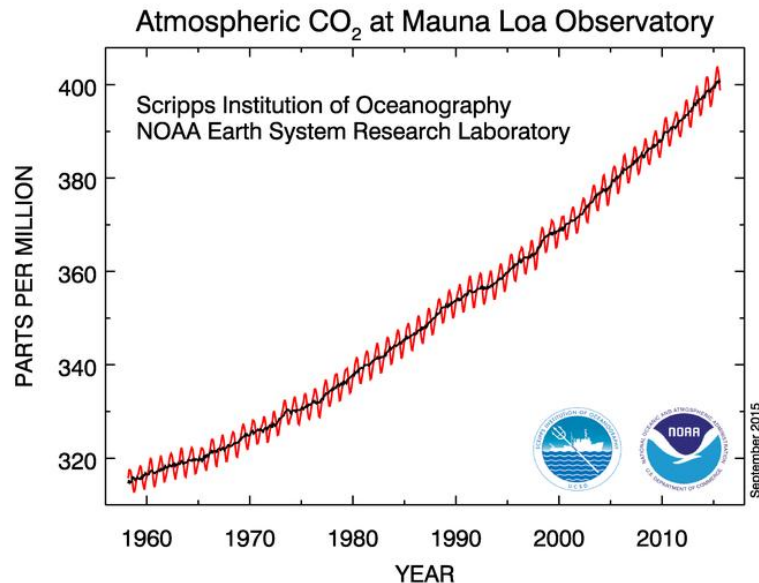


# Evolution of GHG emissions in the atmosphere over time

- The link between air emissions and industrial activities are unequivocal.
- All types of GHG emissions show a sharp rise since industrialisation



**FAQ 2.1, Figure 1.** Atmospheric concentrations of important long-lived greenhouse gases over the last 2,000 years. Increases since about 1750 are attributed to human activities in the industrial era. Concentration units are parts per million (ppm) or parts per billion (ppb), indicating the number of molecules of the greenhouse gas per million or billion air molecules, respectively, in an atmospheric sample. (Data combined and simplified from Chapters 6 and 2 of this report.)



## The International Response

- Rational
- Various steps

## Triggers for action

- Local pollution
- Visibility of the consequences of air pollution
  
- Global disturbance
- Visibility of climate change

**GLOBAL ISSUES NEED GLOBAL APPROACHES**

**CLIMATE CHANGE IS A TRULY GLOBAL ISSUE**

# Organizations and instruments

- United Nations Environmental Program (UNEP)
- Intergovernmental Panel on Climate Change (IPCC)
- United Nations Framework Convention on Climate Change (UNFCCC)
- Kyoto Protocol
- Vienna Convention & Montreal Protocol on Ozone-Depleting Substances
- IMO for international shipping
- Etc.

# United Nations Environmental Program (UNEP)



- UNEP established in 1972
- Mandate is to coordinate the global response to environmental challenges.
- In the field of climate change, the UNEP supports countries in the following areas:
  - Adapting to climate change
  - Mitigating climate change
  - Reducing emissions from deforestation and forest degradation
  - Enhancing knowledge and communication



# Intergovernmental Panel on Climate Change (IPCC)



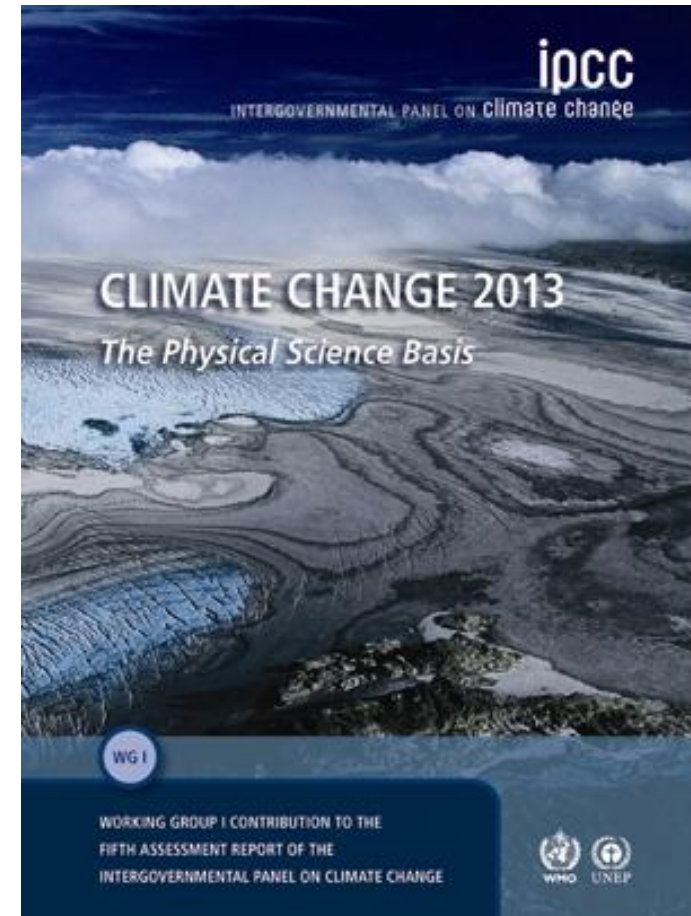
- Created under the auspices of the UNEP and the WMO (World Metrological Organization)
- The IPCC was endorsed by the UN in 1988.
- Its mission is to:
  - Review the state of knowledge of the science of climate change;
  - Carry out studies on the social and economic impact of climate change, including global warming;
  - Propose possible response strategies to delay, limit or mitigate the impact of adverse climate change;
- Acts as a major **knowledge-organisation** on climate change.

**IPCC**  
INTERGOVERNMENTAL  
PANEL ON  
CLIMATE CHANGE



# IPCC assessment reports

- IPCC have produced 5 major assessment reports so far.
- The IPCC's AR5-2014 (Fifth Assessment Report) was released in four principal sections:
  - Contribution of W/G I (WGI):  
**The Physical Science Basis**
  - Contribution of W/G II (WGII):  
**Impacts, Adaptation and Vulnerability**
  - Contribution of W/G III (WGIII):  
**Mitigation of Climate Change**
  - Contribution of W/G I, II, and III:  
**The Synthesis Report**



# United Nations Framework Convention on Climate Change (UNFCCC)

- The UNFCCC is a framework Convention which aims to limit the level of climate change.
- It focuses on promoting cooperation on understanding and reducing the effects of human activities on climate
- It adopts legislative or administrative measures against activities likely to have adverse effects.
- This instrument does not set precise objectives/targets.
- For target and limits, Kyoto Protocol later on was adopted.



**United Nations**  
Framework Convention on  
Climate Change



# UNFCCC requirements

- As indicated, despite UNFCCC declarations, it does not set quantitative targets.
- In requires that all Parties:
  - Develop and report “national inventory of anthropogenic emissions by sources and removals by sinks”.
  - Commit to develop measures related to GHG control.
  - Promote “technology transfer and the sustainable management, conservation, etc. ....” on climate change
  - Consider climate change in social, economic and environmental policy development.
  - Cooperate in sciences, techniques and education as well as exchange of information related to climate change.
  - Promote public awareness and education.

# Kyoto Protocol

- The Kyoto Protocol (1997) concluded a first part of efforts to create stronger commitment for the developed countries.
  - Annex I countries accepted binding reduction targets.
  - Non-Annex I countries accepted to support the process within CBDR (Common But Differentiated Responsibility) framework.
- The GHG emissions are categorised as six main items including CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, HFCs, PFCs and SF<sub>6</sub>.
- To reach their targets, Annex I countries can reduce their emission and/or offset their emissions via:
  - Joint Implementation
  - Clean Development
  - Emission Trading

# Post Kyoto

- Kyoto Protocol commitments are extended to 2020.
- Currently, climate change negotiations are underway for post-Kyoto arrangement.
- Paris (December 2015) may make new binding decisions for post-Kyoto.

## Montreal Protocol – Prevention of Ozone Depletion

- The **Montreal Protocol** is designed to protect the ozone layer by phasing out the production of ODS (Ozone Depleting Substances).
- **Entered into force 1 January 1989**
- **Gases considered in terms of Ozone Depletion Potential (ODP):**
  - The ODP is based on the amount of chlorine which is released by the refrigerant as it degrades.
  - Reference ODP is for **CFC R11** (also known as Freon-11, CFC-11, or R-11) which is taken as 1.
- Most of refrigerants are strong GHG emissions and thus limitation of ODS will help climate change as well.

# **GHG and Shipping**

- UNCLOS and pollution
- Emissions from shipping
- MARPOL Annex VI & its chapter 4

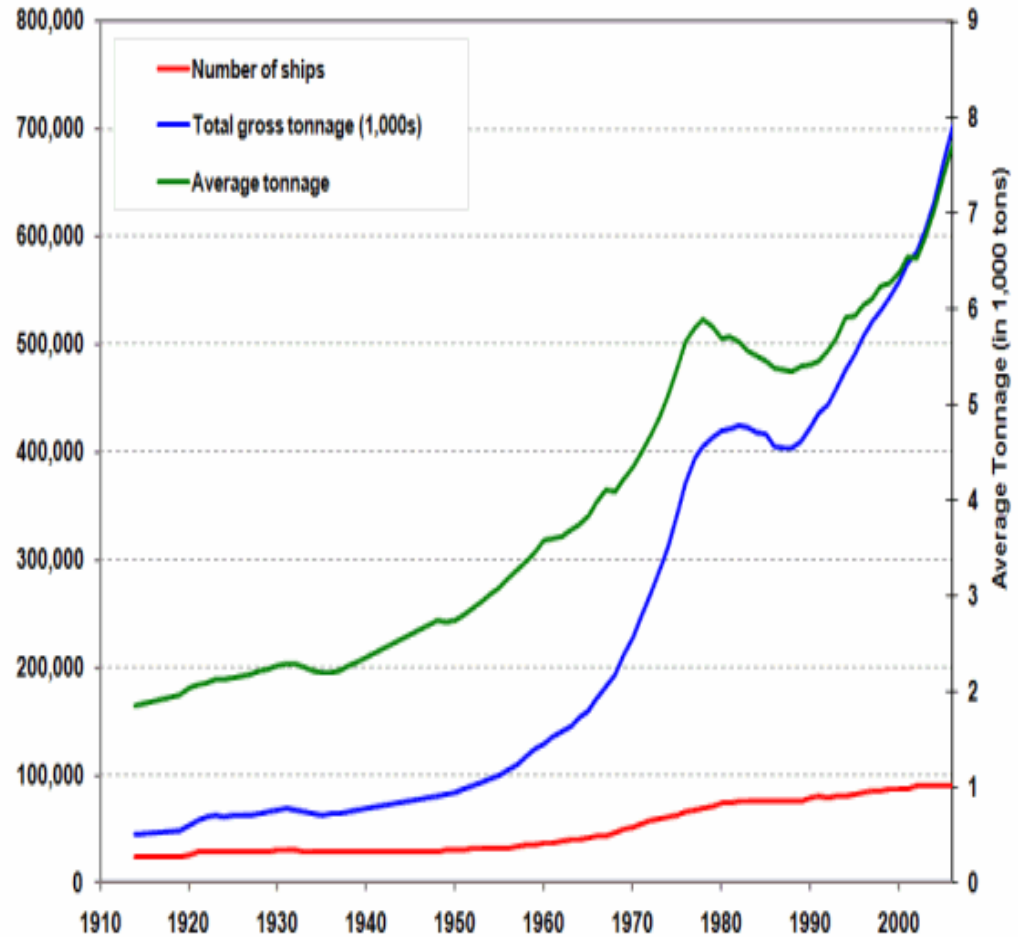
# Climate change impact on oceans

- Oceans are a major sink for air emissions.
- Ocean water properties changes as a result.
- Ecosystems and marine habitats are disturbed by the modification of the ocean properties.
- **Oceans acidification:** Due to absorption of CO<sub>2</sub> and acid rains. A lower pH by 0.1 units already in place.
- The high speed acidification may impair the ability of many organisms to cope with changing water properties.
- **Ocean dilatation (sea-level rise)** endanger the coastal ecosystems and accelerates erosion.

# World Fleet evolution from 1914-2007

➤ Continuous increase in:

- Number of ships
- Growth tonnage
- Average tonnage (size)



Source: Lloyd's Register, Statistical Tables, World fleet statistics 2000

# United Nations Convention on the Law Of the Seas (UNCLOS)

- The UNCLOS possesses extensive references to the protection of the environment.
- In its preamble, the UNCLOS recalls the importance to:
  - “Promote the peaceful uses of the seas and oceans, the equitable and efficient utilization of their resources, the conservation of their living resources, and **the study, protection and preservation of the marine environment.**”
- UNCLOS demonstrates the importance of protecting the environment via developing proper enforcement mechanisms.





# UNCLOS Principles

The UNCLOS reaffirms:

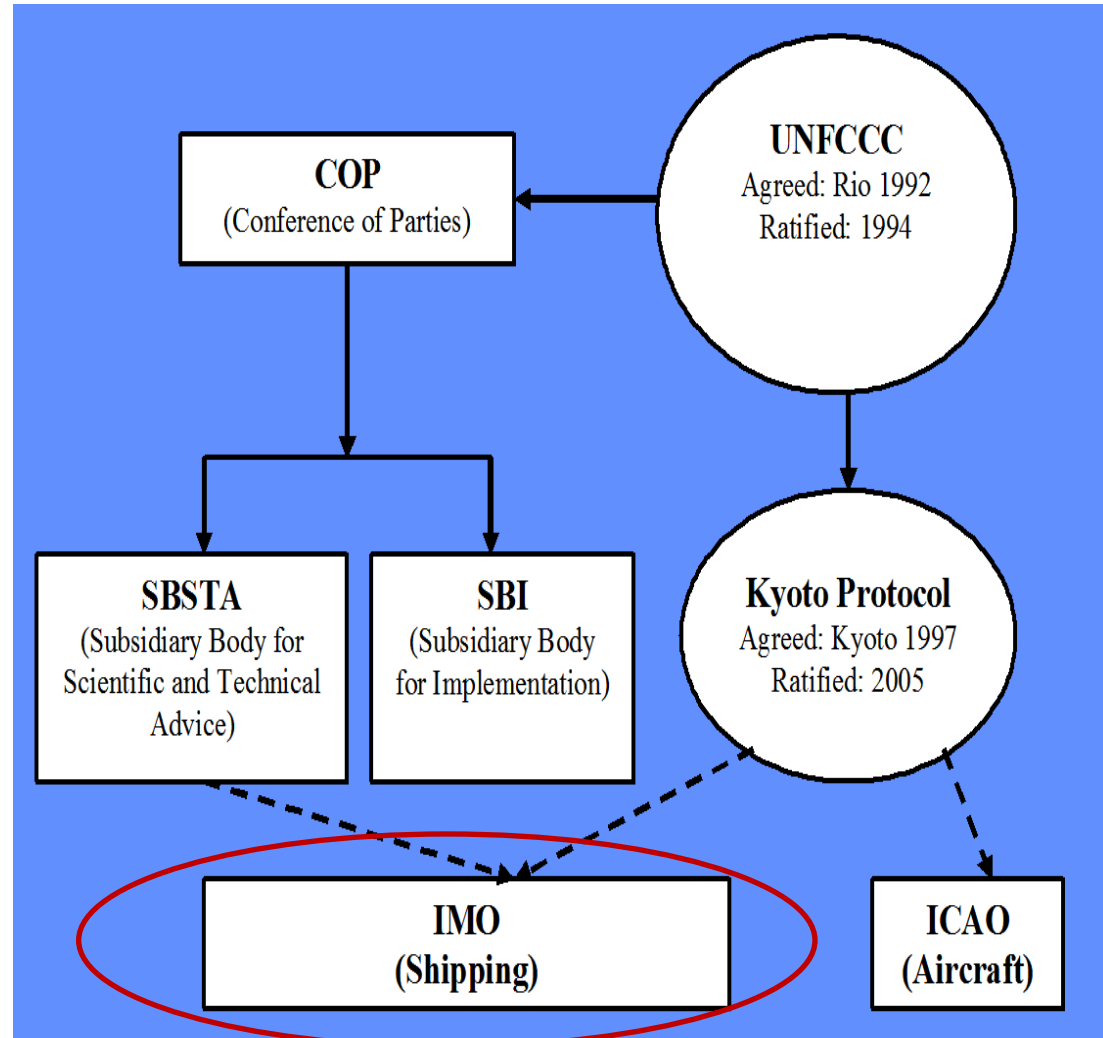
- State duty to protect the environment and responsibility not to harm others.
- The measures developed should not transfer the damage or risks.
- The global and regional cooperation are paramount in environmental protection.
- The risks and effects of pollution must be assessed scientifically.
- The air pollution is an established concern.
- Compliance Monitoring and Enforcement systems have to be developed to verify the compliance of the activities.

# Why IMO energy efficiency regulation?

Within Kyoto Protocol, IMO is mandated to deal with international shipping GHG emissions.

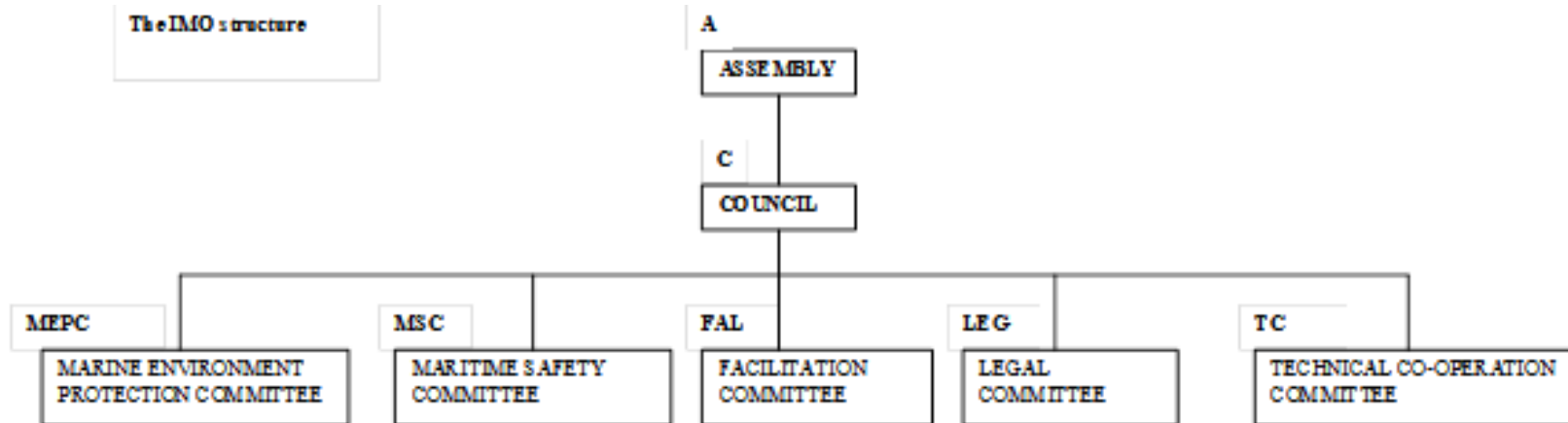
“The Parties included in Annex I shall pursue limitation emissions of GHG from marine bunker fuels, working through the International Maritime Organization”

[Extracts from Article 2.2 of the Kyoto Protocol]

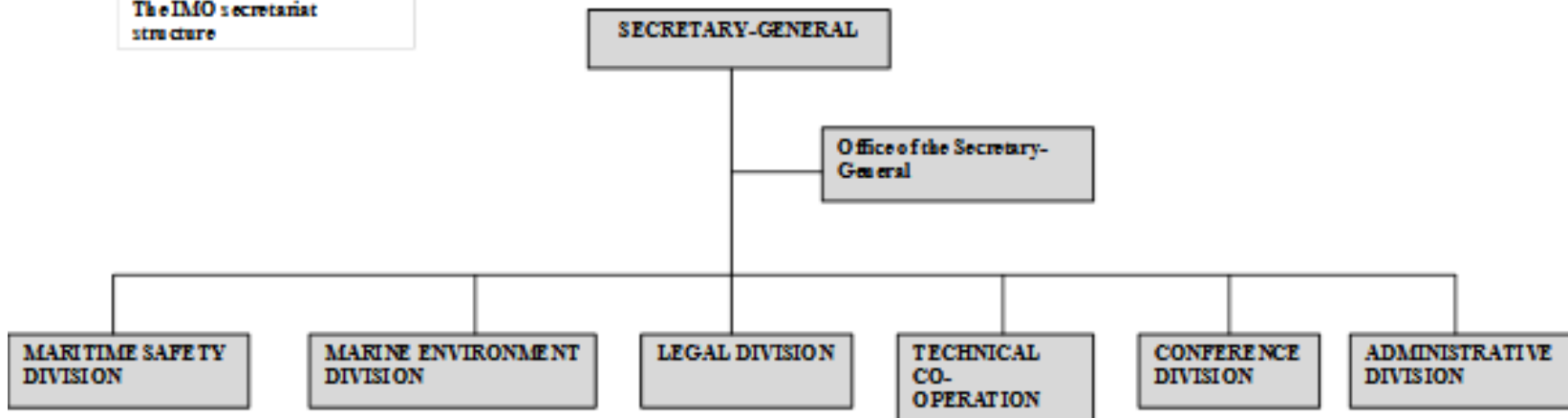


# IMO structure

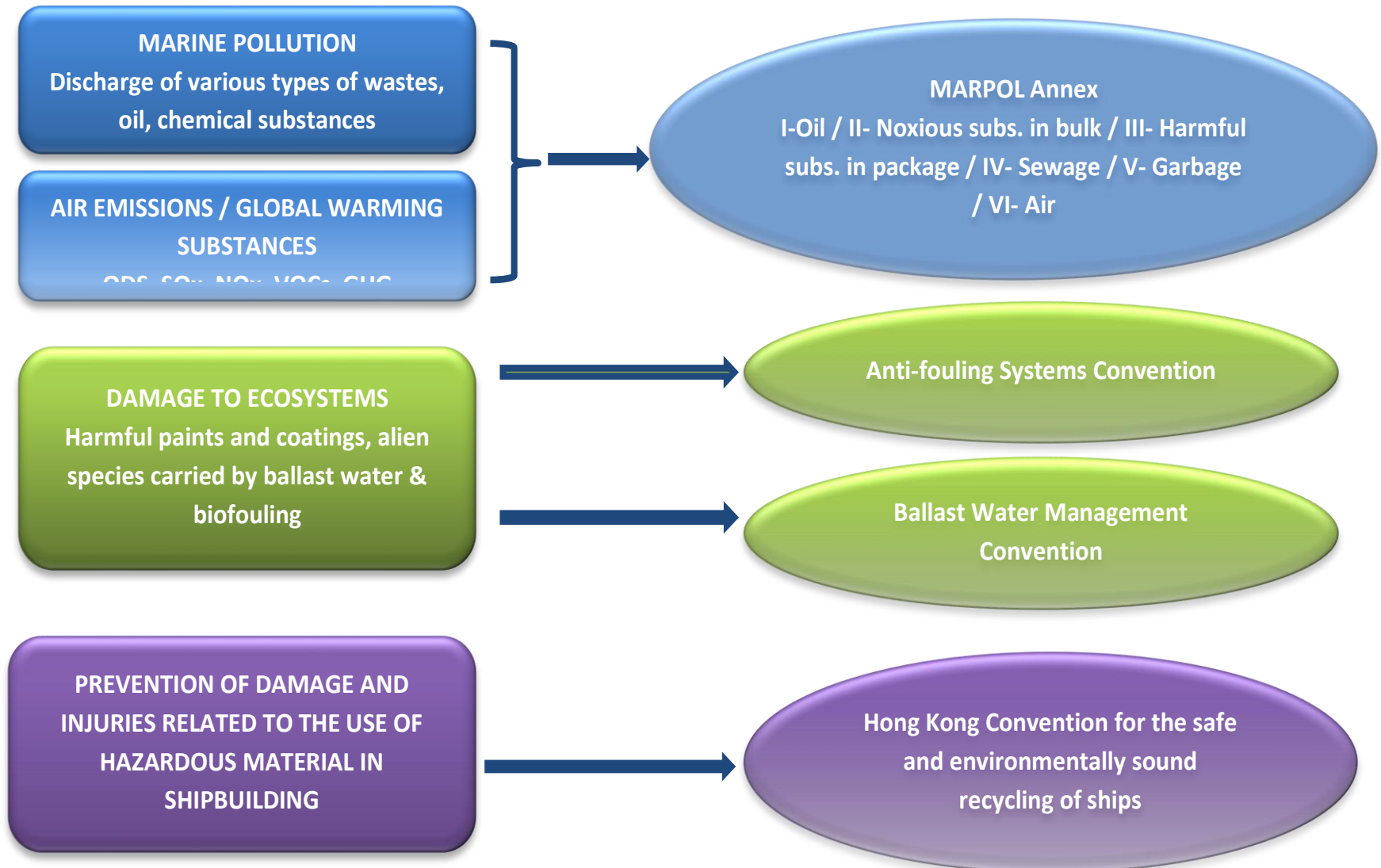
The IMO structure



The IMO secretariat structure



# IMO Conventions relating to environmental protection

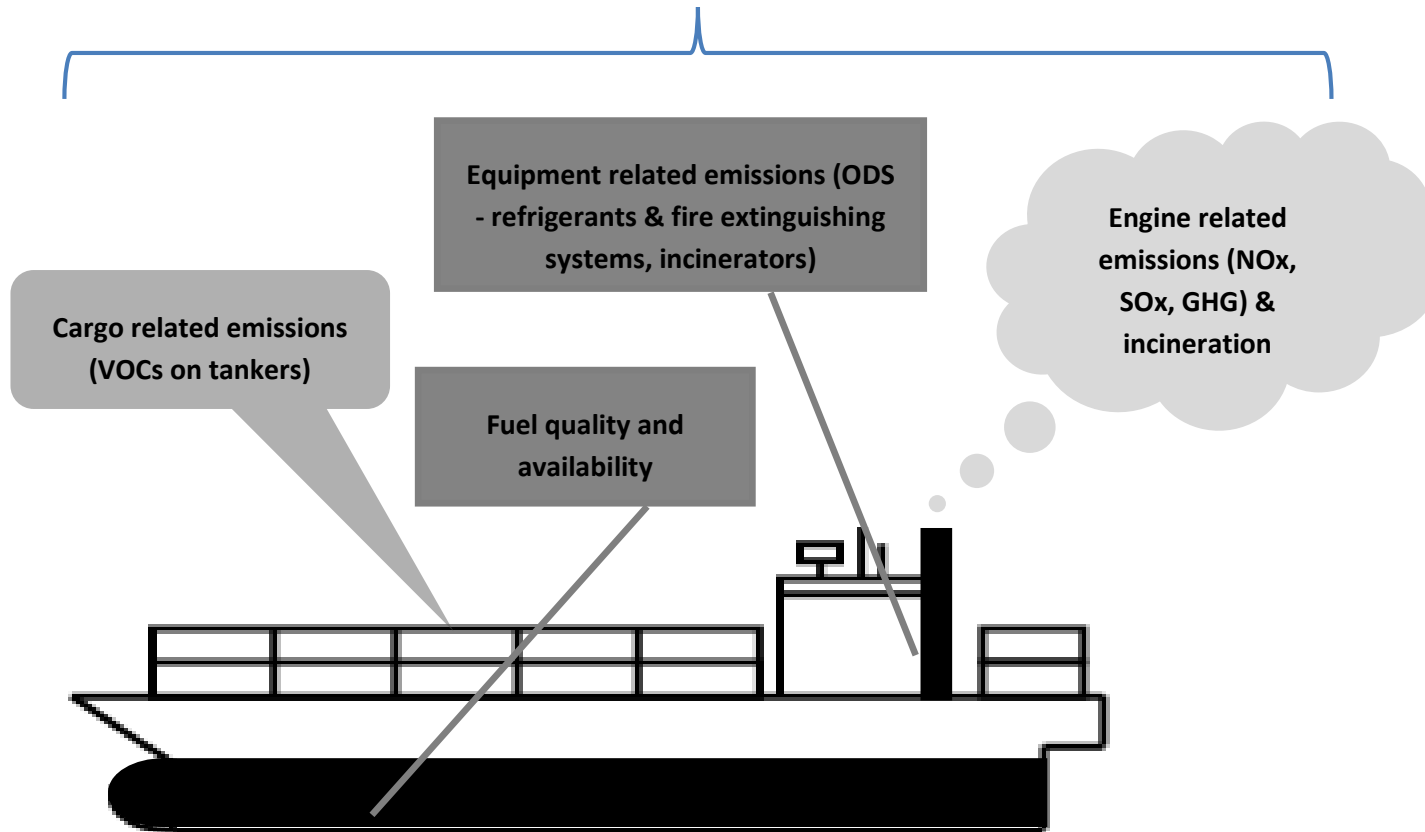


# MARPOL Convention

- **Annex I** - Regulations for the Prevention of Pollution by **Oil** (entered into force 2 October 1983)
- **Annex II** - Regulations for the Control of Pollution by **Noxious Liquid Substances in Bulk** (entered into force 2 October 1983)
- **Annex III** - Prevention of Pollution by **Harmful Substances Carried by Sea in Packaged Form** (entered into force 1 July 1992)
- **Annex IV** - Prevention of Pollution by **Sewage** from Ships (entered into force 27 September 2003).
- **Annex V** - Prevention of Pollution by **Garbage** from Ships (entered into force 31 December 1988).
- **Annex VI** - Prevention of **Air Pollution** from Ships (entered into force 19 May 2005).

# MARPOL Annex VI scope

Regulated by MARPOL ANNEX VI

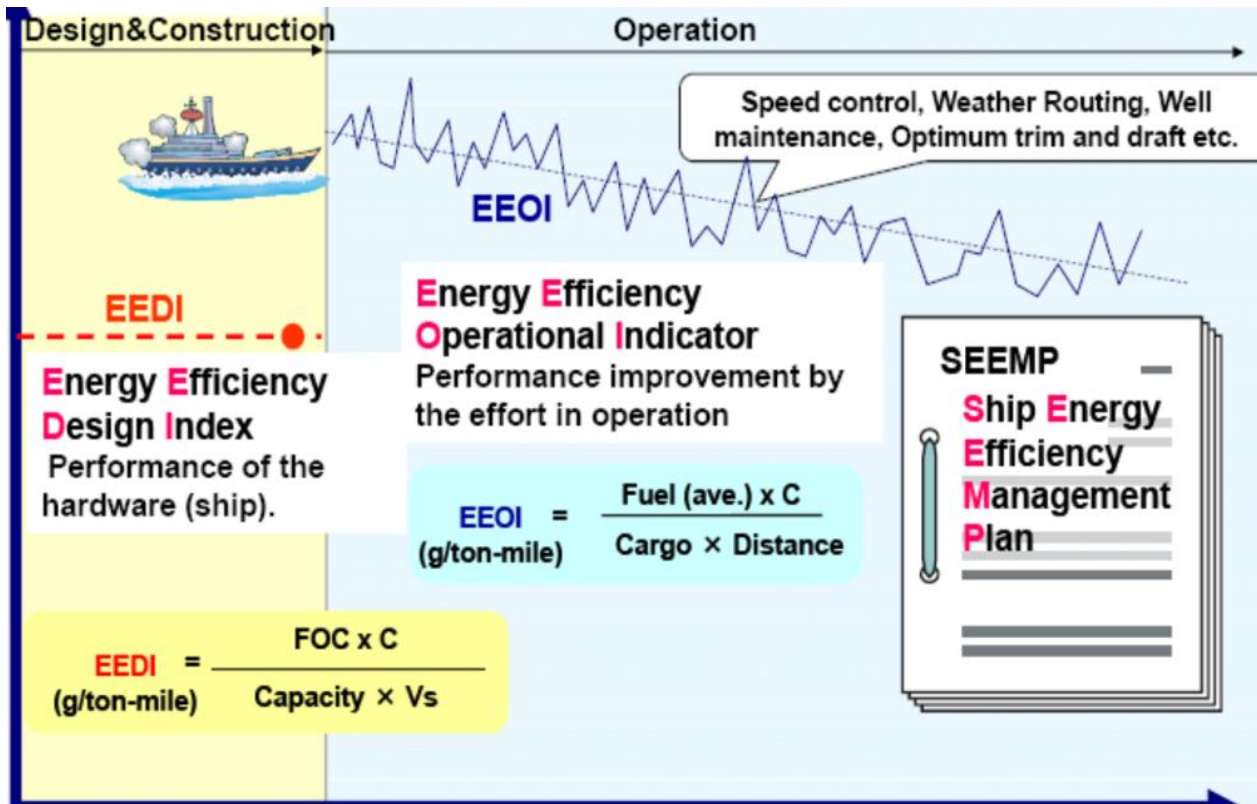


- **Chapter 1 – General:** introduces some of the basics of the Convention as well as certain useful definitions.
- **Chapter 2 – Survey, certification and means of control:** describe the Survey requirements, certification system and control principles including Port State Control issues and violation detection and enforcement.
- **Chapter 3 – Requirement for control of emissions from ships:** this chapter details the measures to address various air pollutants and important related issues as bunker management and incinerator.
- **Chapter 4 – Regulation on energy efficiency for ships:** the purpose of the chapter is to regulate some operational and design aspects. Some elements of this new part of the Annex VI enters into force in January 2013

# MARPOL Annex VI - Chapter 4

## IMO developed framework

- Regulations 19, 20, 21, and 22 deal with EEDI and SEEMP.



Source: IMO presentation on Technical measures



# Overview of IMO Activities on GHG Emissions

## IMO major studies

- 1<sup>st</sup> IMO GHG Study 2000.
- 2<sup>nd</sup> IMO GHG Study 2009.
- 3<sup>rd</sup> IMO GHG Study 2014.

## 2<sup>nd</sup> IMO GHG Study 2009 content

- Introduction to shipping and its legislative framework
- Emissions from shipping 1990–2007
- Technological and operational potential for reduction of emissions
- Policy options for reductions of GHG emissions ...
- Scenarios for forecast of future shipping emissions
- Climate impact
- Comparison of emissions of CO<sub>2</sub> from ships with emissions from other modes of transport

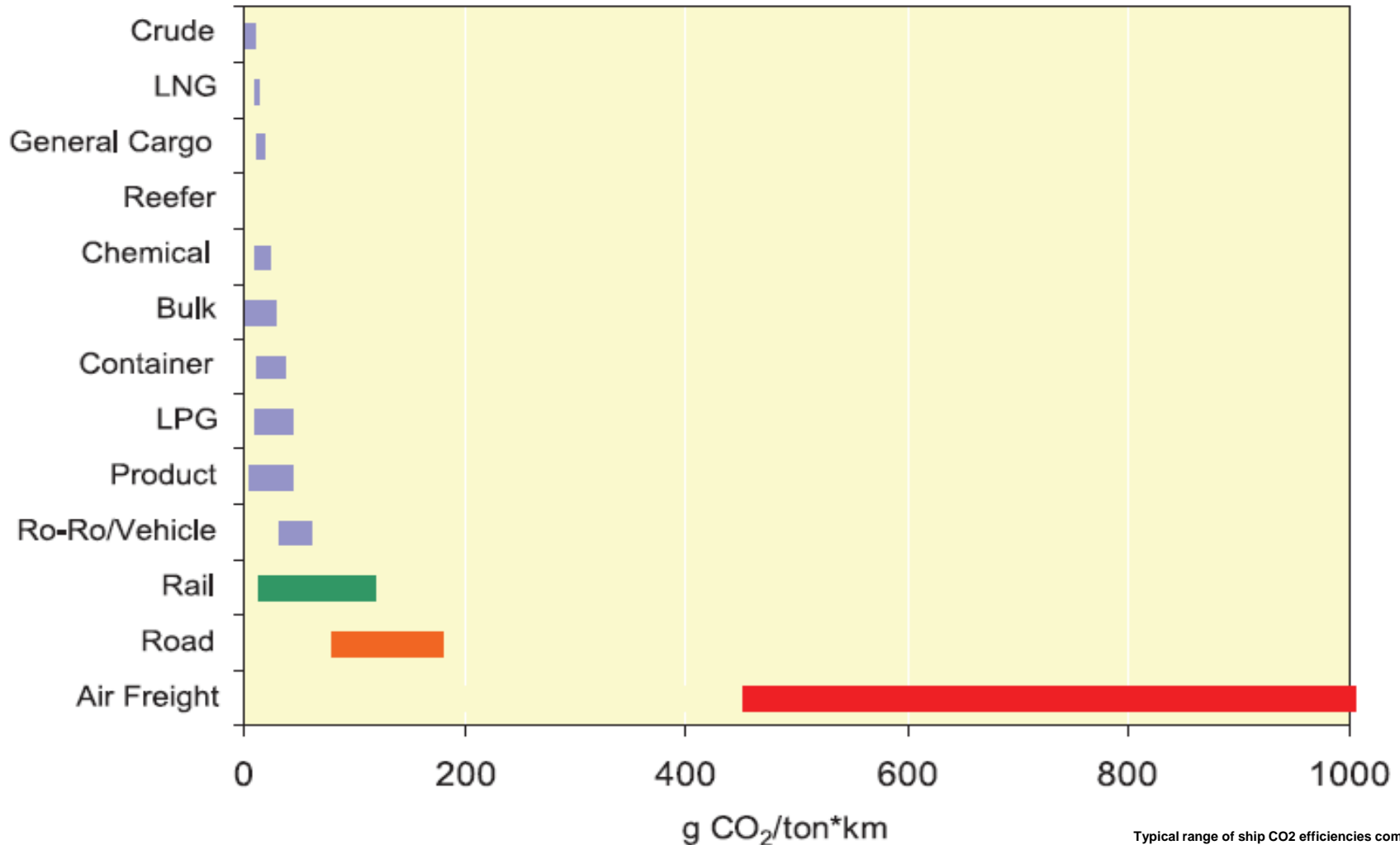
# 2nd GHG Study findings: Breakdown of shipping GHG emissions

	International shipping (million tonnes)	Total shipping	
		million tonnes	CO <sub>2</sub> equivalent
CO <sub>2</sub>	870	1050	1050
CH <sub>4</sub>	Not determined*	0.24	6
N <sub>2</sub> O	0.02	0.03	9
HFC	Not determined*	0.0004	≤6

\* A split into domestic and international emissions is not possible.

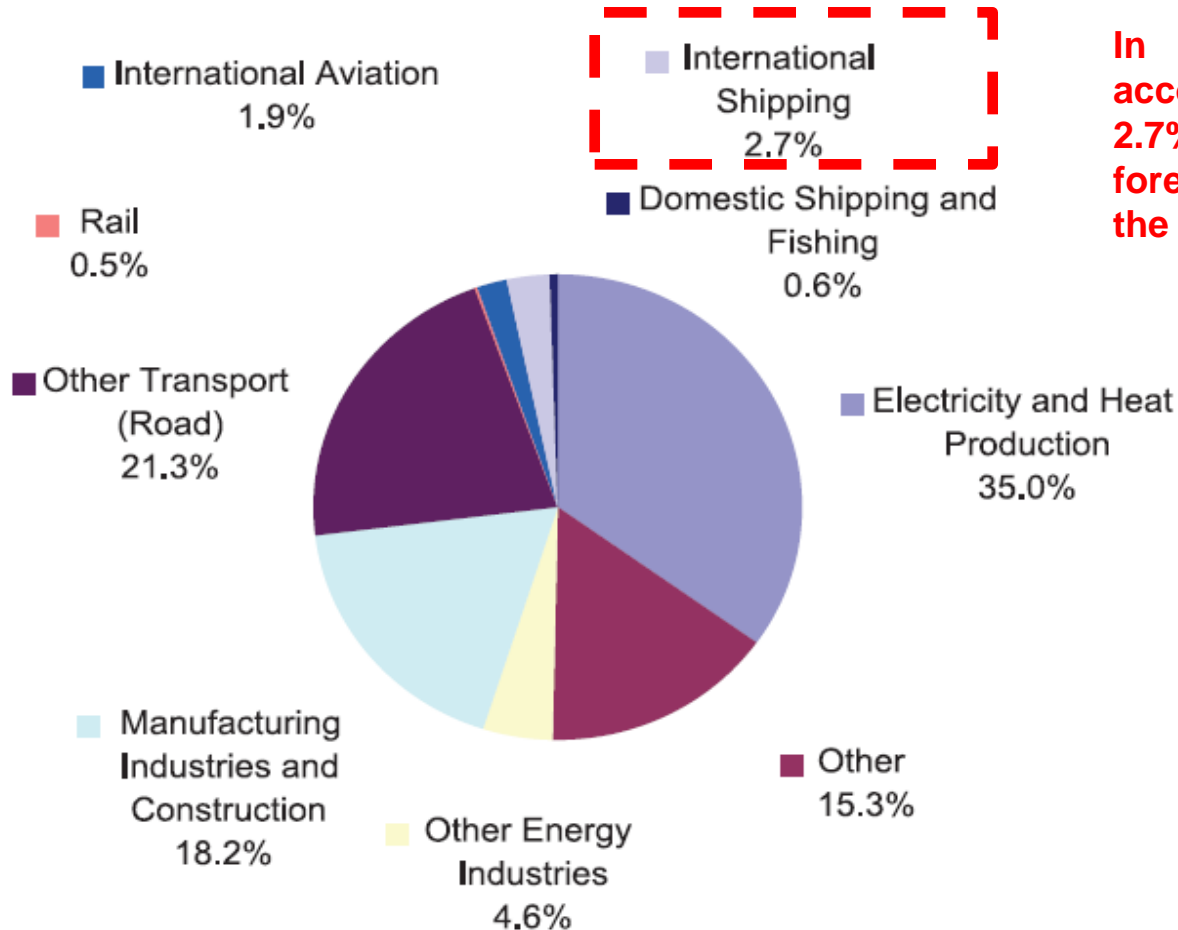
**CO<sub>2</sub> is the main shipping GHG emission.**

# 2nd GHG Study findings: Shipping relative efficiency



Typical range of ship CO<sub>2</sub> efficiencies compared to rail, road and air freight - in the Second IMO GHG Study 2009

# 2nd GHG Study findings: Shipping compared to other industries (global)



**In 2009, Shipping accounted for less than 2.7%. This share is forecast to increase in the future**

# 2nd GHG Study findings: Potential for reduction of CO<sub>2</sub>

	Saving of CO <sub>2</sub> /tonne-mile	Combined	Combined
<b>DESIGN (New ships) EEDI &amp; technology related measures</b>			
Concept, speed and capability	2% to 50% <sup>†</sup>		
Hull and superstructure	2% to 20%		
Power and propulsion systems	5% to 15%	10% to 50% <sup>†</sup>	
Low-carbon fuels	5% to 15%*		
Renewable energy	1% to 10%		25% to 75% <sup>†</sup>
Exhaust gas CO <sub>2</sub> reduction	0%		
<b>OPERATION (All ships) SEEMP &amp; operation related measures</b>			
Fleet management, logistics & incentives	5% to 50% <sup>†</sup>		
Voyage optimization	1% to 10%	10% to 50% <sup>†</sup>	
Energy management	1% to 10%		

\* CO<sub>2</sub> equivalent, based on the use of LNG.

† Reductions at this level would require reductions of operational speed.

**Vessel dependent**

**Company dependent**

# 2nd GHG Study findings: Policy approaches to reduce GHG

## Policy approaches at the IMO

Technical

Operational

Command and control  
policy focus on Ships  
and management

Included in  
Annex VI  
Chapter 4

Economical

Market-based  
instrument focus  
on Global  
objective

Deferred  
for later  
discussion



# 2nd GHG Study findings:

## Main findings

- Shipping was estimated to have emitted 3.3% of the global emissions during 2007.
- International shipping was estimated to have emitted 870 million tonnes, or about 2.7% of the global emissions in 2007.
- Carbon dioxide is the most important GHG emitted by ships.
- A significant potential for reduction of GHG emissions through technical and operational measures had been identified.
- Energy efficiency of ships could potentially be 25% to 75% below the current levels.
- A number of policies to reduce GHG emissions from ships were conceivable.
- Shipping had been shown, in general, to be an energy-efficient means of transportation compared to other modes.

# 3<sup>rd</sup> IMO GHG Study 2014

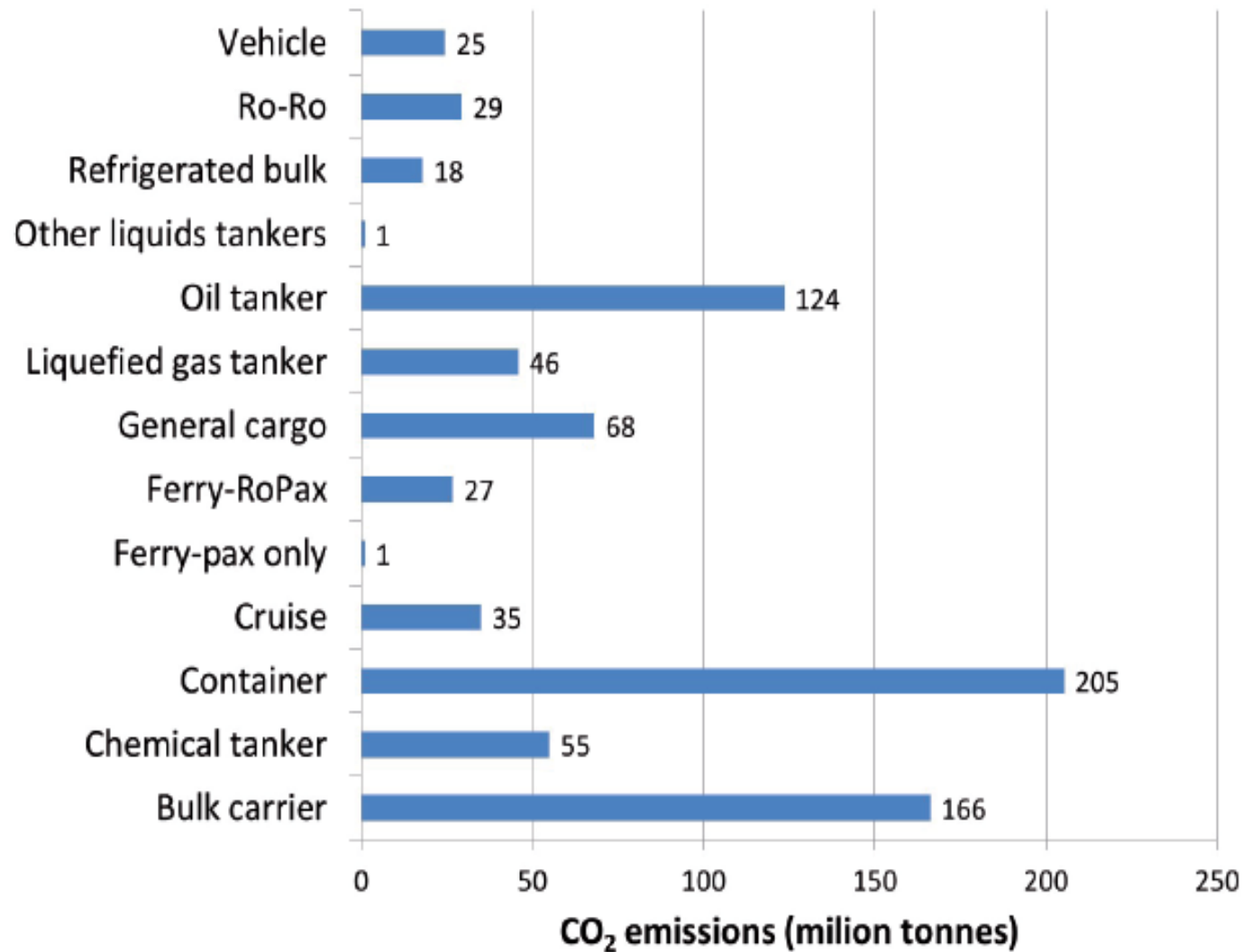
- The Third IMO GHG Study 2014 aimed to update the 2nd IMO GHG Study 2009.
  
- The main objective was to focus on the following topics:
  - Development of the inventories of CO<sub>2</sub> emissions from international shipping for 2007–2012
  - Development of the inventories of other air emissions from international shipping for 2007–2012
  - Development of future shipping scenarios and projection of shipping emissions for 2012–2050

# 3<sup>rd</sup> IMO GHG study findings: Shipping share of global CO<sub>2</sub> emissions

Year	Global CO <sub>2</sub> <sup>1</sup>	IMO GHG Study 2014 CO <sub>2</sub>			
		Total shipping	Percent of global	International shipping	Percent of global
2007	31,409	1,100	3.5%	885	2.8%
2008	32,204	1,135	3.5%	921	2.9%
2009	32,047	978	3.1%	855	2.7%
2010	33,612	915	2.7%	771	2.3%
2011	34,723	1,022	2.9%	850	2.4%
2012	35,640	938	2.6%	796	2.2%
<b>Average</b>	<b>33,273</b>	<b>1,015</b>	<b>3.1%</b>	<b>846</b>	<b>2.6%</b>

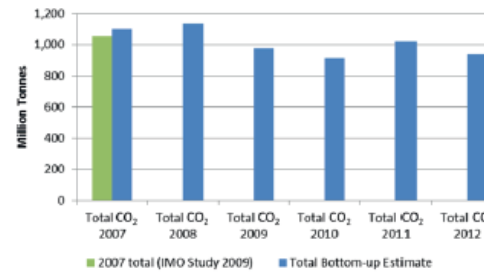
**International shipping share of total global GHG emissions has been 2.2% in 2012**

# 3<sup>rd</sup> GHG Study findings: GHG emissions per ship type for 2012

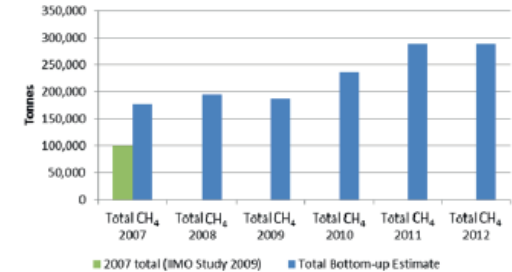


# 3<sup>rd</sup> GHG Study findings: Emissions estimates

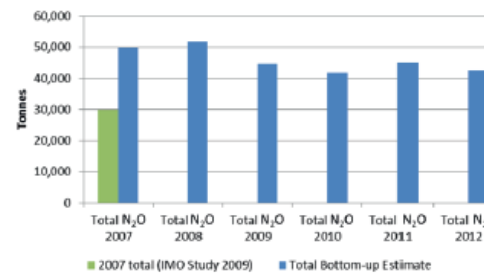
- Emissions estimates for all shipping for period 2007 to 2012.
- Green bar represents the 2nd IMO GHG Study 2009 estimate



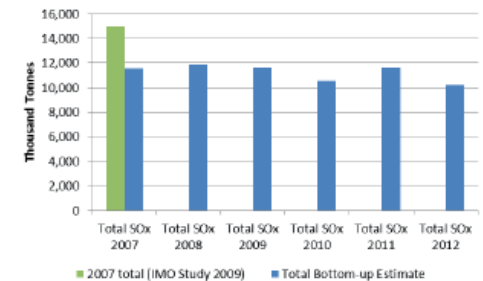
a. CO<sub>2</sub>



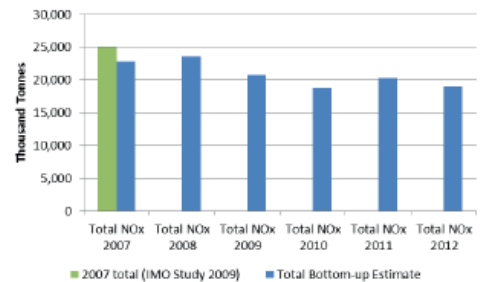
b. CH<sub>4</sub>



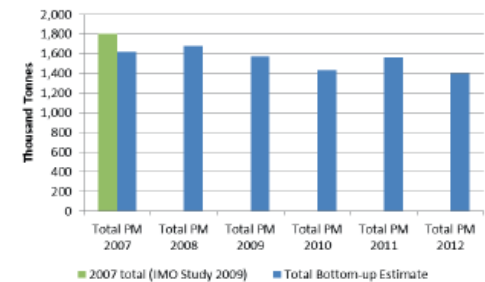
c. N<sub>2</sub>O



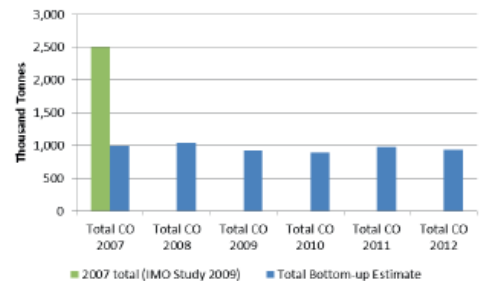
d. SO<sub>x</sub>



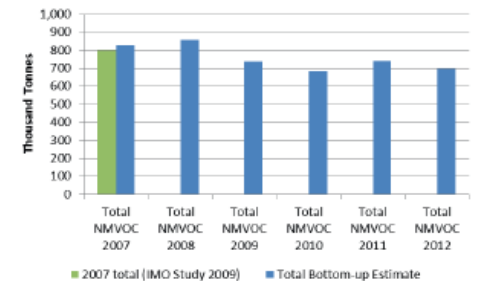
e. NO<sub>x</sub>



f. PM



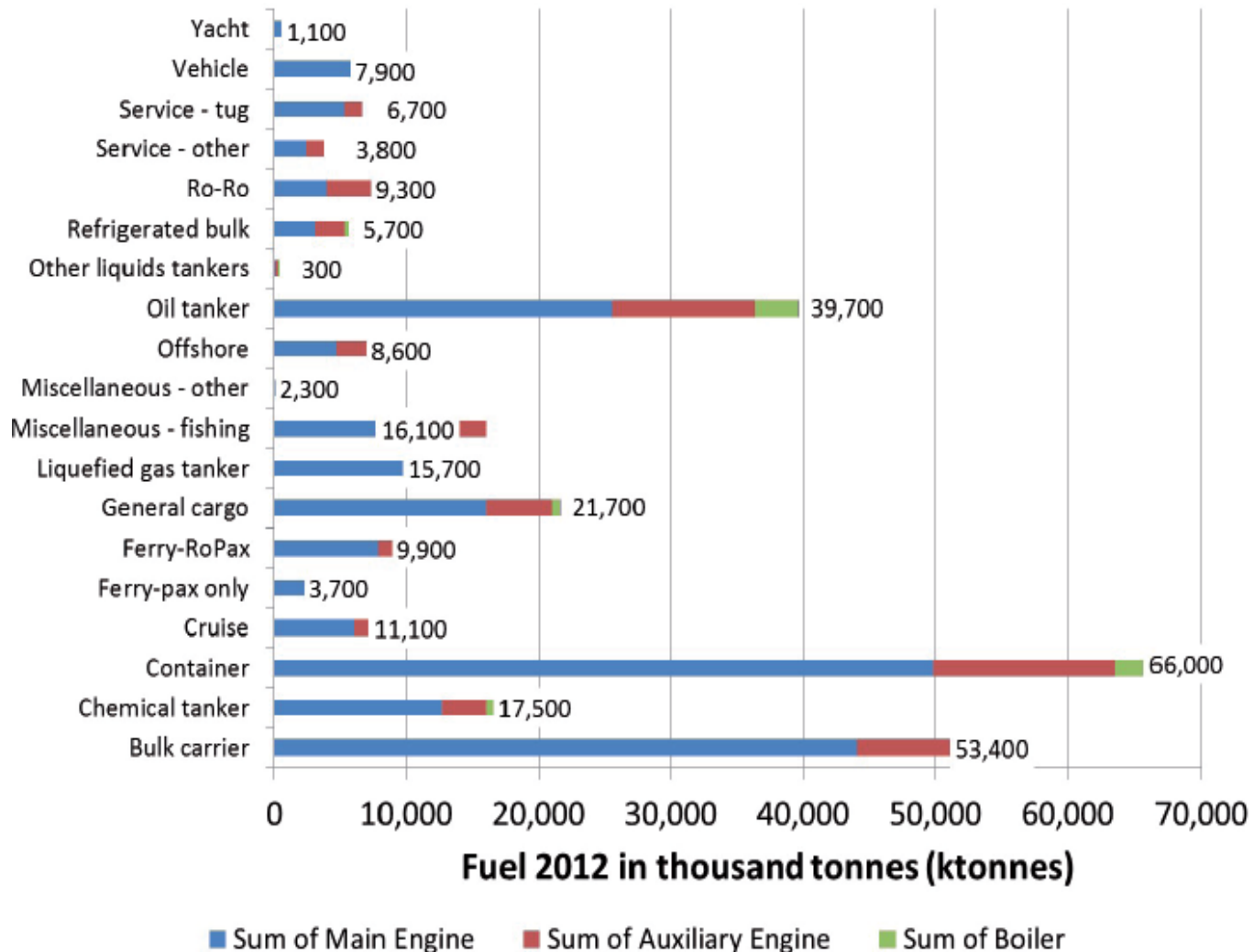
g. CO



h. NMVOC

# 3<sup>rd</sup> GHG Study findings: Fuel consumption details by ship type and system

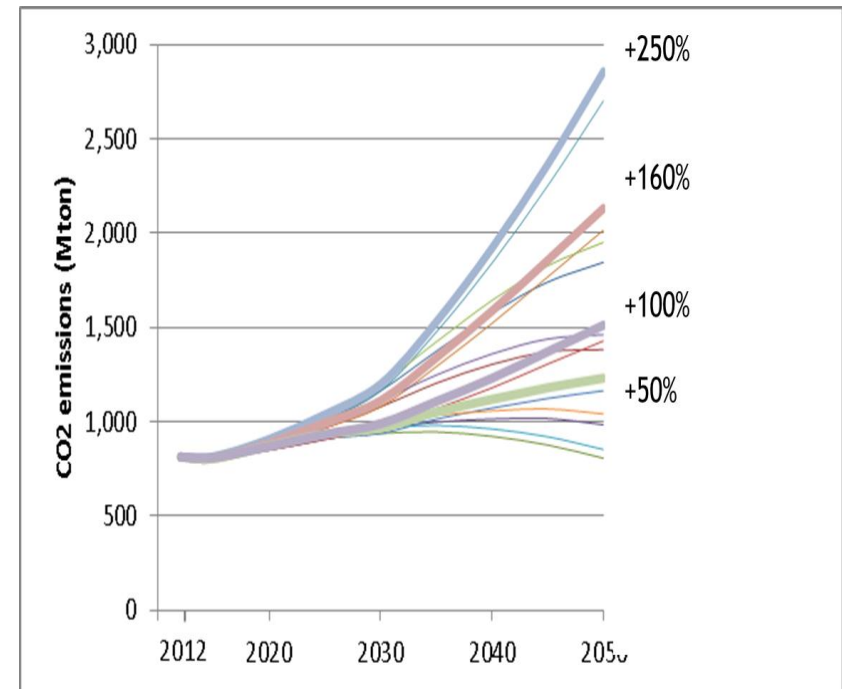
## Annual shipping fuel consumption per ship type and combustion system



# 3<sup>rd</sup> IMO GHG Study findings

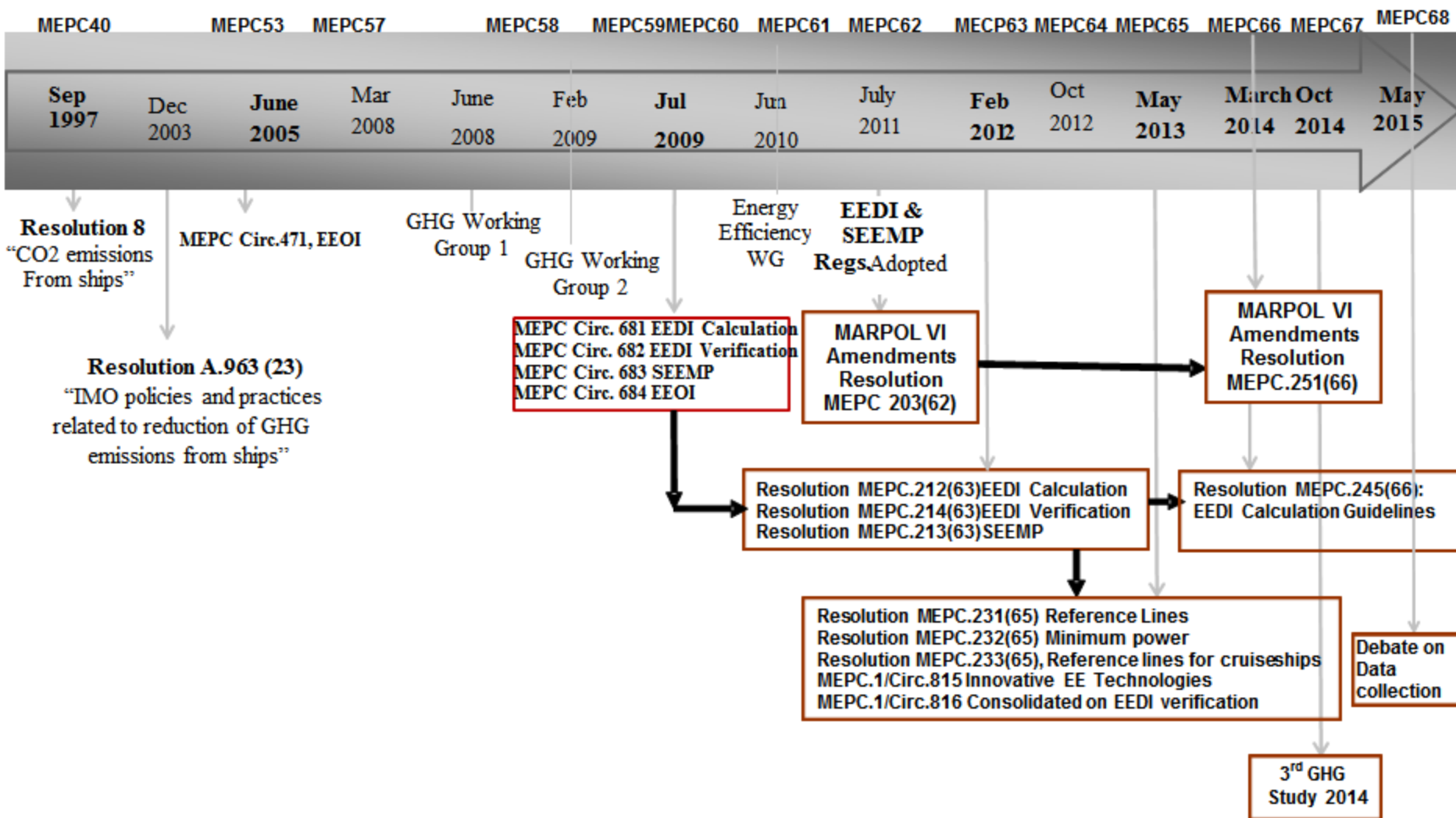
## CO<sub>2</sub> emissions projections

- Various scenarios modelled.
- An average increase of 50% to up to 250% of shipping emissions by 2050.
- This study plus a number of other past studies all point to the fact that future shipping GHG emissions will increase.
- Regulators aim to stabilise or reduce future emissions.



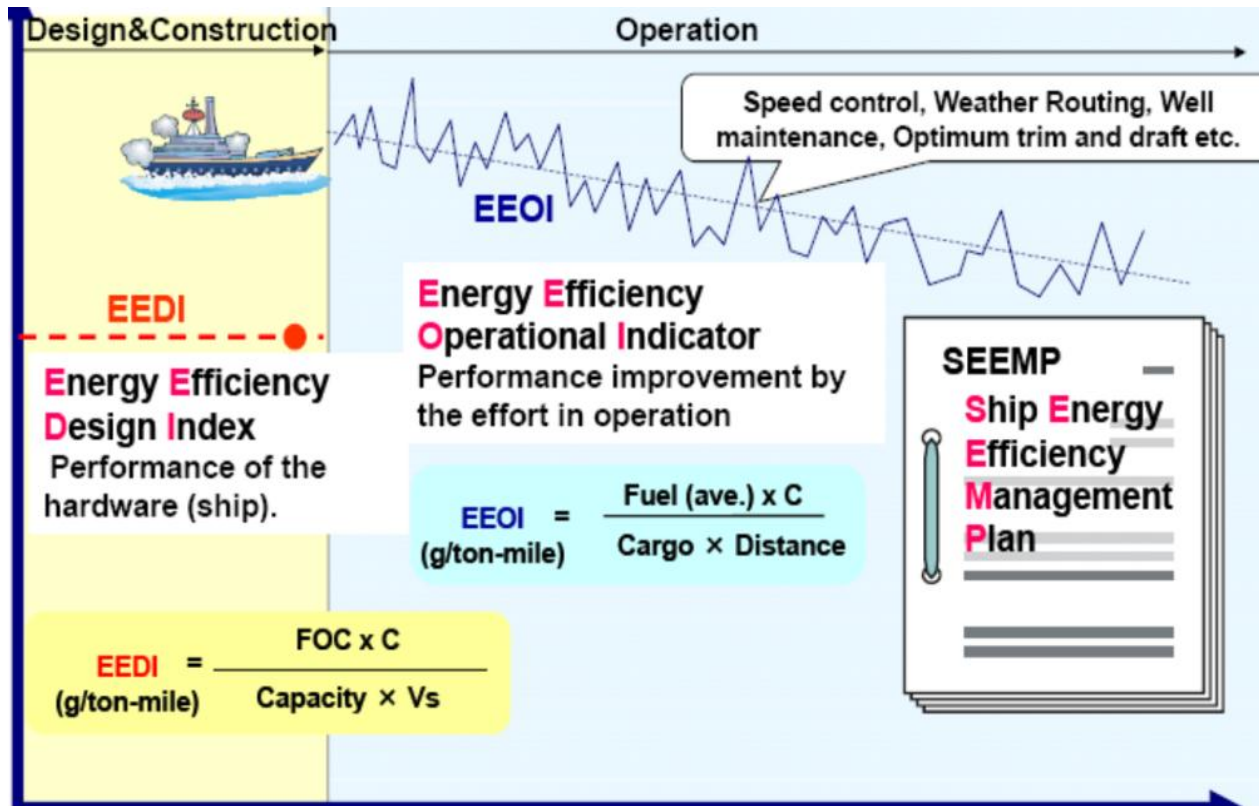
# Activities leading to Chapter 4 of MARPOL Annex VI

## IMO Energy Efficiency Regulatory Developments





# Developed current regulatory framework



Source: IMO presentation on Technical measures

Will be fully described under Module 2

# IMO Further measures

- All studies shows that absolute level of shipping emissions and its global share will increase despite the current agreed measures.
- Thus further measures for energy efficiency are being debated.
- Currently, it is on a “data collection system” that primarily aim to regulate the ship’s fuel consumption measurement.
- Since April 2014, IMO reached preliminary conclusions on a general description of such a global data collection system.
- The draft developed data collection system identifies three core elements including:
  1. data collection by ships;
  2. flag State functions in relation to data collected including verification; and
  3. establishment of a centralized database by the IMO.

# IMO Further measures

- The main features of the IMO data collection system are:
  - Applicable to ships of gross tonnage more than 5000 GT
  - Annual reporting
  - IMO number for ship identification
  - Confidentiality of data such as transport work will be observed.
  - Guidelines will be developed to deal with various details of data collection and verification activities.
  - Registered owner will be responsible for submission of data to Administration
  - Administration will be responsible for verification (can be delegated to Recognized Organizations).
  - A Statement of Compliance (SoC) will be issued by the Administration to each ship annually.
- This work still under progress.

# Further measures – Debate on Market Based Measures (MBM)

- Despite significant debate on MBM in the past, discussion on this subject is currently suspended.

# Summary of learning points

- Consequence of combustion outcome
- Global impact on ecosystems
- International actions:
  - UNEP
  - IPCC
  - UNFCCC and Kyoto Protocol
- International shipping and IMO
  - UNCLOS
  - MARPOL Convention
  - IMO GHG studies and their findings
- MARPOL Annex VI
- Overview of IMO activities leading to energy efficiency regulations and further measures.

Thank you for your attention

**ANY QUESTIONS?**

**For more information please see:**  
**[www.imo.org](http://www.imo.org)**