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CONTROL OF GREENHOUSE GAS EMISSIONS FROM SHIPS ENGAGED IN INTERNATIONAL TRADE

Submitted by the International Maritime Organization (IMO)

Second IMO GHG study 2009

Executive summary

This study on greenhouse gas emissions from ships has been undertaken by an international consortium led by MARINTEK in partnership with the following institutions:

- MARINTEK, Norway (Coordinator)
- CE Delft, The Netherlands
- Dalian Maritime University, China
- Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Germany
- Det Norske Veritas (DNV), Norway
- Energy and Environmental Research Associates (EERA), United States of America
- Lloyd's Register – Fairplay Research, Sweden
- Manchester Metropolitan University, United Kingdom
- Mokpo National Maritime University (MNMU), Korea
- National Maritime Research Institute (NMRI), Japan
- Ocean Policy Research Foundation (OPRF), Japan

CLIMATE CHANGE:
A CHALLENGE FOR IMO TOO!

The following individuals were the main contributors to the report:

Øyvind Buhaug (Coordinator and Task leader, Emission Reductions), James J. Corbett (Task leader, Emissions and Scenarios), Veronika Eyring (Task leader, Climate Impacts), Øyvind Endresen, Jasper Faber, Shinichi Hanayama, David S. Lee, Donchool Lee, Håkon Lindstad, Agnieszka Z. Markowska, Alvar Mjelde, Dagmar Nelissen, Jørgen Nilsen, Christopher Pålsson, Wu Wanquing, James J. Winebrake, Koichi Yoshida.

Preface

This study of greenhouse gas emissions from ships was commissioned as an update of International Maritime Organization's (IMO) *Study of Greenhouse Gas Emissions from Ships* which was delivered in 2000. It has been prepared on behalf of the IMO by an international consortium led by MARINTEK in partnership with the institutions on the previous page. The Steering Committee for the study decided that it should be titled: **Second IMO GHG Study 2009**.

This document presents the final report on the study covering the full scope of work and incorporating changes listed in document MEPC 59/INF.10/Corr.1 as well as some editorial corrections made by the IMO Secretariat.

The main objectives of the study were to assess: (i) present and future emissions from international shipping; (ii) the potential for reduction of these emissions through technology and policy; and (iii) impacts on climate from these emissions.

In the course of their efforts, the research team has gratefully received input and comments from a number of individuals and organizations including the International Energy Agency (IEA), the Baltic and International Maritime Council (BIMCO), the International Association of Independent Tanker Owners (INTERTANKO), the Government of Australia, the Government of Greece and the IMO secretariat.

The views and conclusions drawn in this work are those of the scientists writing the report.

It is our hope that this report will be a helpful reference in the work of IMO and its Marine Environment Protection Committee to reduce emissions of greenhouse gases from ships.

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Trondheim, Norway, September 2009

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List of abbreviations

AIS	Automatic identification system
AFFF	Aqueous film-forming foams
AMVER	Automated Mutual-assistance Vessel Rescue system
BC	Black carbon
CBA	Cost–benefit analysis
CDM	Clean development mechanism
CFC	Chlorofluorocarbons
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
COADS	Comprehensive Ocean–Atmosphere Data Set
CORINAIR	Core Inventory of Air Emissions – Programme to establish an inventory of emissions of air pollutants in Europe
ECA	Emission Control Area
EEDI	Energy Efficiency Design Index
EEOI	Energy Efficiency Operational Indicator
EJ	Exajoule (10^{19} joules)
EIA	United States Energy Information Administration
EGR	Exhaust gas recirculation (NO_x reduction technology)
EU ETS	European Union Emissions Trading Scheme
FAME	Fatty Acid Methyl Ester (a type of bio-diesel)
FTD	Fischer–Tropsch Diesel (a type of synthetic diesel)
GCM	Global climate model
GDP	Gross domestic product
GHG	Greenhouse gas
GT	Gross tonnage
GTP	Global temperature change potential
GWP	Global warming potential
HCFC	Hydrochlorofluorocarbons
HFC	Hydrofluorocarbons
HFO	Heavy fuel oil
HVAC	Heat, Ventilation and Air Conditioning
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
LNG	Liquefied natural gas
LRFPR	Lloyd's Register – Fairplay Research
MARPOL	International Convention for the Prevention of Pollution from Ships
MCR	Maximum continuous rating
MDO	Marine diesel oil (distillate marine fuel with possible residual fuel traces)
MEPC	Marine Environment Protection Committee
MGO	Marine gas oil (distillate marine fuel)
NO_x	Nitrogen oxides
NMVOC	Non-methane volatile organic compounds
NSV	Net standard volume
O_3	Ozone
OECD	Organisation for Economic Co-operation and Development
OPRF	Ocean Policy Research Foundation
PAC	Polycyclic aromatic hydrocarbons
PFOS	Perfluorooctane sulphonates
PM	Particulate matter/material
PM_{10}	Particulate matter/material with aerodynamic diameter 10 micrometres or less

POM	Particulate organic matter/material
RF	Radiative forcing
RTOC	Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee
SCR	Selective catalytic reduction
SECA	SO_x Emission Control Area
SF_6	Sulphur hexafluoride
SO_x	Sulphur oxides
SRES	Special Report on Emissions Scenarios (IPCC)
UNCTAD	United Nations Conference on Trade and Development
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
VOC	Volatile organic compounds

Definitions

International shipping	Shipping between ports of different countries, as opposed to *domestic shipping*. International shipping excludes military and fishing vessels. By this definition, the same ship may frequently be engaged in both international and domestic shipping operations. This is consistent with IPCC 2006 Guidelines.
Domestic shipping	Shipping between ports of the same country, as opposed to *international shipping*. Domestic shipping excludes military and fishing vessels. By this definition, the same ship may frequently be engaged in both international and domestic shipping operations. This definition is consistent with IPCC 2006 Guidelines.
Coastwise shipping	Coastwise shipping is freight movements and other shipping activities that are predominantly along coastlines or regionally bound (e.g. passenger vessels, ferries, offshore vessels) as opposed to ocean-going shipping. The distinction is made for the purpose of scenario modelling and is based on ship types, i.e. a ship is either a coastwise or an ocean-going ship.
Ocean-going shipping	This is a term used for scenario modelling. It refers to large cargo-carrying ships engaged in ocean-crossing trade.
Total shipping	This is defined in this report as international and domestic shipping plus fishing. It excludes military vessels.

Chapter 1

Executive summary

Conclusions

- Shipping is estimated to have emitted 1046 million tonnes of CO_2 in 2007, which corresponds to 3.3% of the global emissions during 2007. International shipping is estimated to have emitted 870 million tonnes, or about 2.7% of the global emissions of CO_2 in 2007.

- Exhaust gases are the primary source of emissions from ships. Carbon dioxide is the most important GHG emitted by ships. Both in terms of quantity and of global warming potential, other GHG emissions from ships are less important.

- Mid-range emissions scenarios show that by 2050, in the absence of regulations, carbon dioxide emissions from international shipping may grow by a factor of 2 to 3 (compared to the emissions in 2007) as a result of the growth in shipping.

- A significant potential for reduction of GHG through technical and operational measures has been identified. Together, if implemented, these measures could increase efficiency and reduce the emissions rate by 25% to 75% below the current levels. Many of these measures appear to be cost-effective, although non-financial barriers may discourage their implementation, as discussed in chapter 5.

- A number of policies to reduce GHG emissions from ships are conceivable. This report analyses options that are relevant to the current IMO debate. The report finds that market-based instruments are cost-effective policy instruments with a high environmental effectiveness. These instruments capture the largest amount of emissions under the scope, allow both technical and operational measures in the shipping sector to be used, and can offset emissions in other sectors. A mandatory limit on the Energy Efficiency Design Index for new ships is a cost-effective solution that can provide an incentive to improve the design efficiency of new ships. However, its environmental effect is limited because it only applies to new ships and because it only incentivizes design improvements and not improvements in operations.

- Shipping has been shown, in general, to be an energy-efficient means of transportation compared to other modes. However, not all forms of shipping are more efficient than all other forms of transport.

- The emissions of CO_2 from shipping lead to positive "radiative forcing" (a metric of climate change) and to long-lasting global warming. In the shorter term, the global mean radiative forcing from shipping is negative and implies cooling; however, regional temperature responses and other manifestations of climate change may nevertheless occur. In the longer term, emissions from shipping will result in a warming response as the long-lasting effect of CO_2 will overwhelm any shorter-term cooling effects.

- If a climate is to be stabilized at no more than 2°C warming over pre-industrial levels by 2100 and emissions from shipping continue as projected in the scenarios that are given in this report, then they would constitute between 12% and 18% of the global total CO_2 emissions in 2050 that would be required to achieve stabilization (by 2100) with a 50% probability of success.

Background

1.1 The 1997 MARPOL Conference (September 1997) convened by the IMO adopted resolution 8 on "CO_2 emissions from ships". This resolution invited, *inter alia*, the IMO to undertake a study of emissions of GHG from ships for the purpose of establishing the amount and relative percentage of GHG emissions from ships as part of the global inventory of GHG emissions. As a follow-up to the above resolution, the IMO Study of Greenhouse Gas Emissions from Ships was completed and presented to the forty-fifth session of the MEPC (MEPC 45) in June 2000, as document MEPC 45/8.

1.2 MEPC 55 (October 2006) agreed to update the "IMO Study of Greenhouse Gas Emissions from Ships" from 2000 to provide a better foundation for future decisions and to assist in the follow-up to resolution A.963(23). MEPC 56 (July 2007) adopted the Terms of Reference for the updating of the study, which has been given the title "Second IMO GHG Study 2009". This report has been prepared by an international consortium, as set out in the preface to this report.

Scope and structure

1.3 As set out in the terms of reference, this study provides estimates of present and future emissions from international shipping. "International shipping" has been defined in accordance with guidelines developed by The Intergovernmental Panel on Climate Change (IPCC). These guidelines divide emissions from water-borne navigation into two primary categories: domestic and international, where "international waterborne navigation" is defined as navigation between ports of different countries. Total estimates that include emissions from domestic shipping and emissions from fishing are also included in this report.

1.4 The study addresses greenhouse gases (CO_2, CH_4, N_2O, HFCs, PFCs, SF_6) and other relevant substances (NO_x, NMVOC, CO, PM, SO_x) that are defined in the terms of reference for this study.

1.5 The report has been organized into the following main parts:

.1 Annual inventories of emissions of greenhouse gases and other relevant emissions from shipping from 1990 to 2007 (chapter 3);

.2 Analysis of the progress in reducing emissions from shipping through implementation of MARPOL Annex VI (chapter 4);

.3 Analysis of technical and operational measures to reduce emissions (chapter 5);

.4 Analysis of policy options to reduce emissions (chapter 6);

.5 Scenarios for future emissions from international shipping (chapter 7);

.6 Analysis of the effect of emissions from shipping on the global climate (chapter 8); and

.7 A comparison of the energy efficiency and CO_2 efficiency of shipping compared to other modes of transport (chapter 9).

Emissions 1990–2007

1.6 The analysis in this report shows that exhaust gas is the dominating source of emissions from shipping. Additionally, emissions originating from leaks of refrigerant and release of volatile organic compounds in conjunction with the transport of crude oil are quantified in this study. Other emissions include diverse sources, such as emissions from testing and maintenance of fire-fighting equipment. These are not considered significant and are not quantified in this report.

1.7 Emissions of exhaust gases from international shipping are estimated in this study, based on a methodology where the total fuel consumption of international shipping is first determined. Emissions are subsequently calculated by multiplying fuel consumption with an emission factor for the pollutant in question.

1.8 Fuel consumption for the year 2007 was estimated by an activity-based methodology. This is a change in methodology compared to the first IMO study on greenhouse gas emissions from ships, published in 2000, which relied on fuel statistics. The investigations that are presented in this study suggest that international fuel statistics would under-report fuel consumption. The difference between the fuel statistics and the activity-based estimate is about 30%.

1.9 Guidebook emission factors from CORINAIR and IPCC were used for all emissions except for NO_x, where adjustments were made to accommodate the effect of the NO_x regulations in MARPOL Annex VI. Estimates of emissions of refrigerants were retrieved from the 2006 United Nations Environmental Programme (UNEP) assessment of refrigerant emissions from transport. The emissions of VOC from crude oil were assessed in this study on the basis of several data sources.

1.10 An estimate of the share of the total emissions of exhaust gases from ships that can be attributed to international shipping was made on the basis of the estimate for total fuel consumption by shipping and statistics for fuel consumption by domestic shipping in 2007. An emissions series from 1990 to 2007 was generated by assuming that ship activity was proportional to data on seaborne transport published by Fearnresearch. The estimate of GHG emissions for 2007 is presented in table 1-1. Emissions of SF_6 and PFCs are considered negligible and are not quantified. Emissions of CO_2 from shipping are compared with global total emissions in figure 1-1.

Table 1-1 Summary of GHG emissions from shipping* during 2007

	International shipping	**Total shipping**	
	million tonnes	**million tonnes**	**CO_2 equivalent**
CO_2	870	1050	1050
CH_4	Not determined*	0.24	6
N_2O	0.02	0.03	9
HFC	Not determined*	0.0004	= 6

*A split into domestic and international emissions is not possible

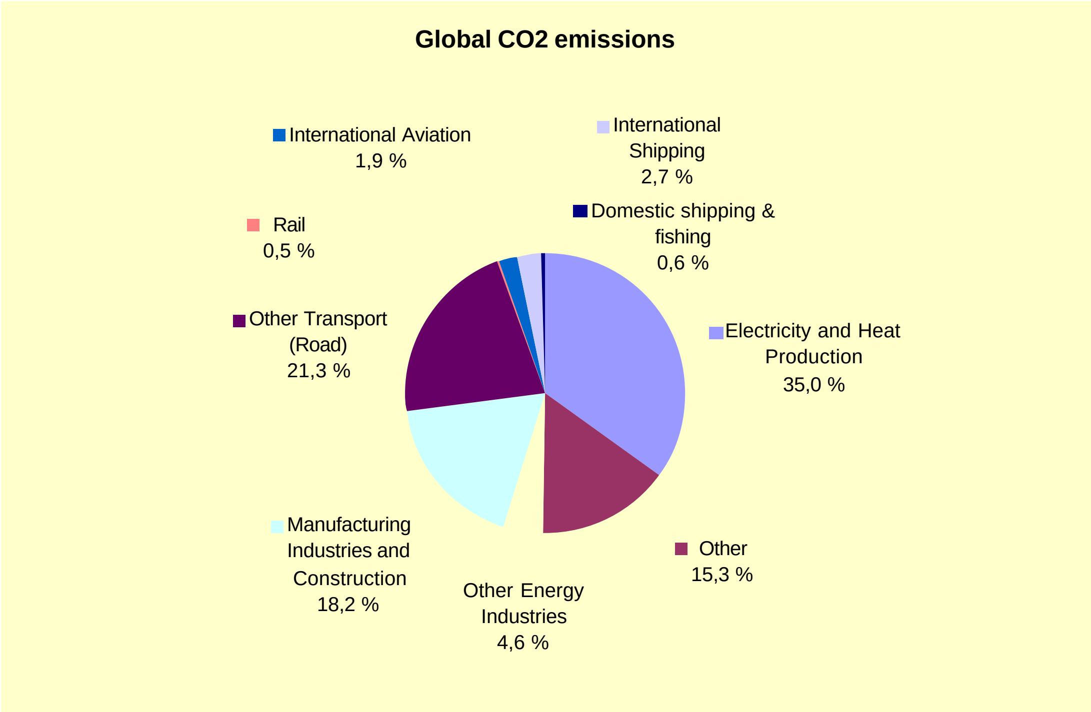

Figure 1-1 – Emissions of CO_2 from shipping compared with global total emissions

Emission reductions achieved by implementation of MARPOL Annex VI

1.11 Progress to date in reducing emissions was assessed by analysing the reductions in the emissions that are regulated in MARPOL Annex VI.

1.12 Reductions in emissions of ozone-depleting substances (ODSs) from ships have been achieved as a result of several international agreements, including the Montreal Protocol and MARPOL Annex VI. Reductions in these emissions have been estimated on the basis of figures in the 1998 and 2006 reports published by the UNEP Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee (RTOC). The base year for the 2006 RTOC report is 2003; however, a base year is not available in the 1998 report. Nevertheless, these data indicate the following:

.1 CFC – 735 tonnes reduction (98%);

.2 HCFC – 10 900 tonnes reduction (78%); and

.3 HFC – 415 tonnes increase (315%).

1.13 Emissions of HFC have increased, because HFC are used as a substitute for CFC and HCFC.

1.14 Where emissions of NO_x are concerned, a reduction in emissions of about 12–14% per tonne of fuel consumed has been identified for regulated (Tier I) engines as compared to pre-regulation (Tier 0) engines. In 2007, about 40% of the installed engine power of the world fleet had been built since 1 January 2000 and was thus assumed to be Tier I-compliant. The net reduction in international emissions of NO_x from shipping in 2007 was thus about 6% compared to a no-regulation baseline. However, NO_x emissions from international shipping are estimated to have increased from 16 million tonnes in 2000 to 20 million tonnes in 2007.

1.15 Reductions in SO_x emissions have been estimated for 2008, since this is the first year in which both of the sulphur emission control areas (SECAs) have been fully in force. Based on a set of assumptions, including an average content of sulphur in the fuel that is used in SECAs, in the hypothetical unregulated scenario it is estimated that emissions of sulphur oxides from shipping in the SECA areas had been reduced by about 42%.

1.16 A reduction in emissions of VOC has not been quantified. The most tangible result of implementing regulation 15 in MARPOL Annex VI is the introduction of standardized VOC return pipes, through which tankers can discharge VOC to shore during loading. Most tankers now have this capability, although the frequency of their use is variable.

Technological and operational options for reduction of emissions

1.17 A wide range of options for increasing the energy efficiency and reducing emissions by changing ship design and ship operation has been identified. An overall assessment of the potential of these options to achieve a reduction of CO_2 emissions is shown in table 1-2. Since the primary gateway to reduction of CO_2 emissions is increased energy efficiency, these reduction potentials generally apply to all emissions of exhaust gases from ships.

Table 1-2 Assessment of potential reductions of CO_2 emissions from shipping by using known technology and practices

<table>
<tr><th>DESIGN (New ships)</th><th>Saving of CO_2/tonne-mile</th><th>Combined</th><th>Combined</th></tr>
<tr><td>Concept, speed & capability</td><td>2% to 50%+</td><td rowspan="6">10% to 50%+</td><td rowspan="10">25% to 75%+</td></tr>
<tr><td>Hull and superstructure</td><td>2% to 20%</td></tr>
<tr><td>Power and propulsion systems</td><td>5% to 15%</td></tr>
<tr><td>Low-carbon fuels</td><td>5% to 15%*</td></tr>
<tr><td>Renewable energy</td><td>1% to 10%</td></tr>
<tr><td>Exhaust gas CO_2 reduction</td><td>0%</td></tr>
<tr><td>OPERATION (All ships)</td><td></td><td></td></tr>
<tr><td>Fleet management, logistics & incentives</td><td>5% to 50%+</td><td rowspan="3">10% to 50%+</td></tr>
<tr><td>Voyage optimization</td><td>1% to 10%</td></tr>
<tr><td>Energy management</td><td>1% to 10%</td></tr>
</table>

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

* CO_2 equivalent, based on the use of LNG.

1.18 A considerable proportion of the potential abatement appears to be cost-effective at present. However, non-financial barriers may currently limit the adoption of certain measures, as discussed in chapter 5.

1.19 Renewable energy, in the form of electric power generated by solar cells and thrust generated by wind, is technically feasible only as a partial source of replacement power, due to the variable intensity and the peak power of wind and sunlight.

1.20 Carbon dioxide is the most important GHG emission from shipping, and the potential benefits from reducing emissions of the other GHG are small in comparison.

1.21 Fuels with lower life-cycle CO_2 emissions include biofuels and liquefied natural gas (LNG). The use of biofuels on board ships is technically possible; however, use of first-generation biofuels poses some technical challenges and could also increase the risk of losing power (e.g. due to plugging of filters). These challenges are, nevertheless, overshadowed by limited availability and unattractive prices that make this option appear unlikely to be implemented on a large scale in the near future. However, it is believed that LNG will become economically attractive, principally for ships in regional trades within ECAs where LNG is available.

1.22 Emissions of other relevant substances (NO_x, SO_x, PM, CO and NMVOC) as exhaust gas pollutants will be reduced as the energy efficiency of shipping is improved. Long-term reductions in emissions that are mandated or expected from implementation of the revised Annex VI are shown in table 1-3. Significant reductions in emissions can be achieved by increasing numbers or extending the coverage of Emission Control Areas.

Table 1-3 Long-term reductions in emissions in the revised MARPOL Annex VI

	Global	ECA
NO_x (g/kW·h)	15–20%	80%
SO_x* (g/kW·h)	80%	96%
PM (mass)† (g/kW·h)	73%	83%

* Reduction relative to fuel that contains 2.7% sulphur.
† Expected PM reduction arising from change of composition of fuel.

1.23 Future (sulphur) emission control areas ((S)ECAs) will limit the maximum sulphur content of the fuels that are used within these areas to 0.1%. This is a radical improvement from the present-day average of 2.7% of sulphur in residual fuel, although it will still be 100-times higher than the levels of sulphur in automotive diesel fuels (10 ppm, 0.001%). Reductions in emission levels that are significantly beyond the ECA levels indicated in table 1-3 would create a need for stricter fuel-quality requirements.

Policy options for reduction of emissions

1.24 Many technical and operational measures that may be used to reduce GHG emissions from ships have been identified; however, these measures may not be implemented unless policies are established to support their implementation. A number of policies to reduce GHG emissions from ships are conceivable. This report sets out to identify a comprehensive overview of options. The options that are relevant to the current IMO debate are analyzed in detail. These options are:

.1 A mandatory limit on the Energy Efficiency Design Index (EEDI) for new ships;

.2 Mandatory or voluntary reporting of the EEDI for new ships;

.3 Mandatory or voluntary reporting of the Energy Efficiency Operational Indicator (EEOI);

.4 Mandatory or voluntary use of a Ship Efficiency Management Plan (SEMP);

.5 Mandatory limit on the EEOI value, combined with a penalty for non-compliance;

.6 A Maritime Emissions Trading Scheme (METS); and

.7 A so-called International Compensation Fund (ICF), to be financed by a levy on marine bunkers.

1.25 The analysis of the options is based on the criteria for a coherent and comprehensive future IMO regulatory framework on GHG emissions from ships, developed by MEPC 57. Based on these criteria, the following qualitative conclusions can be drawn with respect to options being discussed within IMO at present:

.1 A mandatory limit on Energy Efficiency Design Index (EEDI) for new ships appears to be a cost-effective solution that can provide a strong incentive to improve the design efficiency of new ships. The main limitation of the EEDI is that it only addresses ship design; operational measures are not considered. This limits the environmental effectiveness. The effect is also limited, in the sense that it applies only to new ships;

.2 Mandatory and/or voluntary reporting of either the EEDI or the EEOI would have no environmental effect in itself. Rather, environmental effectiveness and cost-effectiveness would depend on incentive schemes being set up to make use of the information. The assessment of the large number of conceivable incentive schemes was beyond the scope of this report;

.3 The Ship Efficiency Management Plan (SEMP) appears to be a feasible approach to increase awareness of cost-effective measures to reduce emissions. However, since this instrument does not require a reduction of emissions, its effectiveness will depend on the availability of cost-effective measures to reduce emissions (i.e. measures for which the fuel savings exceed the capital and operational expenditures). Likewise, it will not incentivize innovation and R & D beyond the situation of “business as usual”;

.4 A mandatory limit on EEOI appears to be a cost-effective solution that can provide a strong incentive to reduce emissions from all ships that are engaged in transport work. It incentivizes both technical and operational measures. However, this option is technically very challenging, due to the difficulties in establishing and updating baselines for operational efficiency and in setting targets;

.5 Both the Maritime Emission Trading Scheme (METS) and the International Compensation Fund for GHG Emissions from Ships (ICF) are cost-effective policy instruments with high environmental effectiveness. They have the largest amount of emissions within their scope, allow all measures in the shipping sector to be used and can offset emissions in other sectors. These instruments provide strong incentives to technological change, both in operational technologies and in ship design; and

.6 The environmental effect of the METS is an integral part of its design and will therefore be met. In contrast, part of the environmental effect of the ICF depends on decisions about the share of funds that will be spent on buying emission allowances from other sectors. With regard to cost-effectiveness, incentives to technological change and feasibility of implementation, both policy instruments seem to be quite similar.

Scenarios for future emissions from international shipping

1.26 Future emissions of CO_2 from international shipping were estimated on the basis of a relatively simple model, which was developed in accordance with well-established scenario practice and methodology. The model incorporates a limited number of key driving parameters, as shown in table 1-4.

Table 1-4 Driving variables used for scenario analysis

Category	Variable	Related elements
Economy	Shipping transport demand (tonne-miles/year)	Population, global and regional economic growth, modal shifts, shifts in sectoral demand
Transport efficiency	Transport efficiency (MJ/tonne-mile) – depends on fleet composition, ship technology and operation	Ship design, advances in propulsion, vessel speed, regulations aimed at achieving other objectives but that have consequences for emissions of GHG
Energy	Carbon fraction of the fuel that is used by shipping (g of C/MJ of fuel energy)	Cost and availability of fuels (e.g. use of residual fuel, distillates, biofuels, or other fuels)

1.27 In this study, carbon emissions are explicitly modelled as a parameter of the scenario. Other levels of pollutant emissions are calculated on the basis of energy consumption and MARPOL regulations. Scenarios are based on the framework for global development and storylines that have been developed by the Intergovernmental Panel on Climate Change (IPCC) in the Special Report on Emission Scenarios (SRES).

1.28 A hybrid approach, considering both historic correlations between economic growth and trade as well as analysis considering regional shifts in trade, increased recycling, and new transport corridors, has been employed, *inter alia*, to derive the projections of future demand for transport.

1.29 No regulations regarding CO_2 or fuel efficiency have been assumed, and the improvement in efficiency over time reflects improvements that would be cost-effective in the various scenarios rather than the ultimate technological potential.

1.30 Assumptions about future use of fuel reflect that the availability of energy in the SRES scenarios would permit the continued use of oil-based fuels until 2050 for shipping. Therefore, in these scenarios, in which there is non-regulation of GHG emissions, the move from oil-derived fuels would have to be motivated by economic factors. The effect of MARPOL Annex VI on the fuel that is used is considered.

1.31 Scenarios are modelled from 2007 to 2050. The main scenarios are named A1FI, A1B, A1T, A2, B1 and B2, according to terminology from the IPCC Special Report on Emission Scenarios (SRES). These scenarios are characterized by global differences in population, economy, land-use and agriculture which are evaluated against two major tendencies: (1) globalization versus regionalization and (2) environmental values versus economic values. The background for these scenarios is discussed in chapter 7 of this report.

1.32 Annual increases of CO_2 emissions, in the range of 1.9–2.7%, are found in base scenarios, with extreme scenarios indicating increases of 5.2% and -0.8%, respectively. The increase in emissions is driven by the expected growth in seaborne transport. The scenarios with the lowest emissions show reductions in CO_2 emissions in 2050 compared to emissions during 2007. Results from the scenarios are shown in figure 1-2.

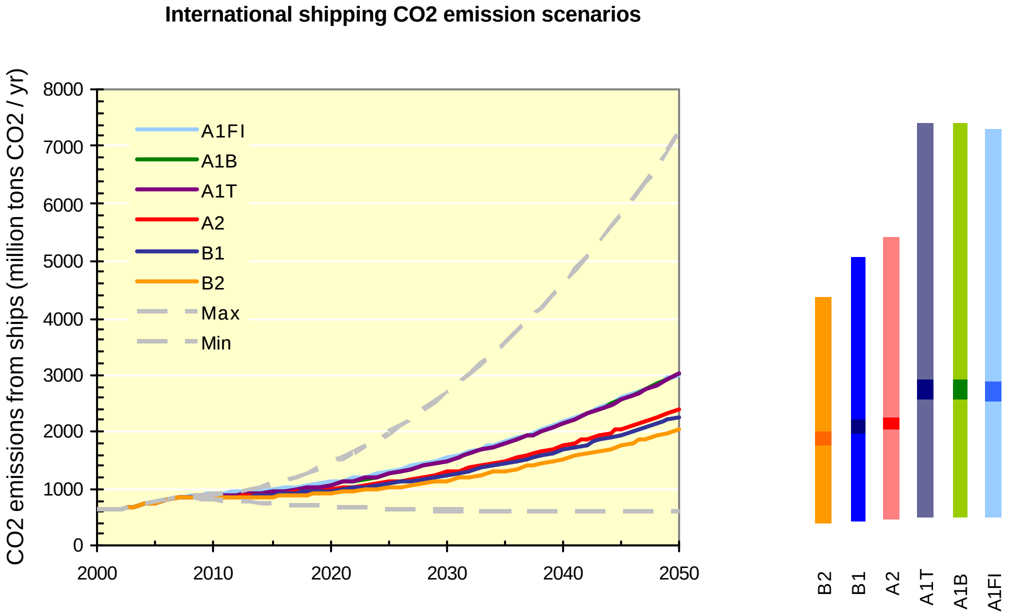

Figure 1-2 – Trajectories of the emissions from international shipping. Columns on the right-hand side indicate the range of results for the scenarios within individual families of scenario.

Climate impact

1.33 A detailed analysis of the climate impacts of emissions from ships was performed, using state-of-the-art modelling and references to and comparison with other relevant research. Emissions from international shipping produce significant impacts on atmospheric composition, human health and climate; these are summarized below:

.1 Increases in well-mixed GHGs, such as CO_2, lead to positive 'radiative forcing[1]' (RF) and to long-lasting global warming;

.2 For 2007, the RF from CO_2 from shipping was calculated to be 49 mW m^{-2}, contributing approximately 2.8% of total RF from anthropogenic CO_2 in 2005;

.3 For a range of 2050 scenarios, the RF of CO_2 from shipping was calculated to be between 99 and 122 mW m^{-2}, bounded by a minimum/maximum uncertainty range (from the scenarios) of 68 mW m^{-2} and 152 mW m^{-2};

.4 The total RF for 2007 from shipping was estimated to be -110 mW m^{-2}, dominated by a rather uncertain estimate of the indirect effect (-116 mW m^{-2}) and not including the possible positive RF from the interaction of black carbon with snow, which has not yet been calculated for ship emissions. We also emphasize that CO_2 remains in the atmosphere for a long time and will continue to have a warming effect long after it was emitted. This has been demonstrated here by showing how the residual effects of emissions from shipping prior to 2007 turn from a negative effect on temperature to a positive effect. By contrast, sulphate

[1] A common metric to quantify impacts on climate from different sources is 'radiative forcing' (RF), in units of W/m^2, since there is an approximately linear relationship between global mean radiative forcing and change in global mean surface temperature. RF refers to the change in the Earth–atmosphere energy balance since the pre-industrial period. If the atmosphere is subject to a positive RF from, for example, the addition of a greenhouse gas such as CO_2, the atmosphere attempts to re-establish a radiative equilibrium, resulting in a warming of the atmosphere.

has a residence time in the atmosphere of approximately 10 days, and the duration of response of the climate to sulphate is of the order of decades, whilst that of CO_2 is of the order of centuries to millennia;

.5 Simple calculations of global means have been presented here for RF and temperature response, and are in agreement with other studies in the literature. As highlighted by others, global mean temperature response is only a first-order indicator of climate change. Calculations presented here show that the radiative forcing from shipping has a complex spatial structure, and there is evidence from other, more general, studies of indirect cloud-forcing effects that significant changes in precipitation patterns may result from localized negative RFs, even if the localized temperature response is not so variable. Such alterations in precipitation, even from negative forcing, constitute climate change. This is a complex subject, and more work on this aspect is needed;

.6 While the control of emissions of NO_x, SO_2 and particles from ships will have beneficial impacts on air quality, acidification and eutrophication, reductions of emissions of CO_2 from all sources (including ships and other freight modes) will be required to reduce global warming. Moreover, a shift to cleaner combustion and cleaner fuels may be enhanced by a shift to technologies that lower the emissions of CO_2; and

.7 Climate stabilization will require significant reductions in future global emissions of CO_2. The projected emissions from shipping for 2050 that have been developed for this work – which are based on SRES non-climate intervention policy assumptions – constitute 12% to 18% of the WRE450 stabilization scenario, which corresponds to the total permissible global emissions of CO_2 in 2050 if the increase in global average temperature is to be limited to 2°C with a probability greater than 50%.

Comparison of emissions of CO_2 from ships with emissions from other modes of transport

1.34 The ranges of CO_2 efficiency of various forms of transport were estimated, using actual operating data, transport statistics and other information. The efficiency of ships is compared with that of other modes of transport in figure 1-3. Efficiency is expressed as mass of CO_2 per tonne-kilometre, where the mass of CO_2 expresses the total emissions from the activity and "tonne-kilometre" expresses the total transport work that is done. The ranges that have been plotted in the figure show the typical average range for each of them. The figure does not indicate the maximum (or minimum) efficiency that may be observed.

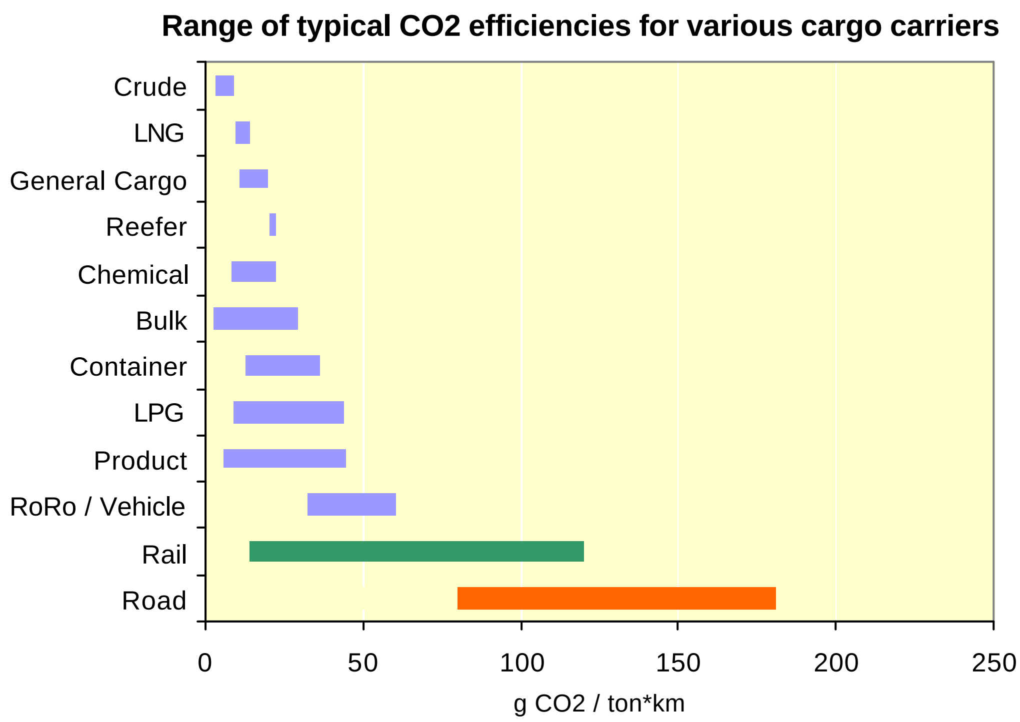

Figure 1-3 – Typical ranges of CO_2 efficiencies of ships compared with rail and road transport

Chapter 2

Introduction to shipping and its legislative framework

2.1 This chapter presents a short introduction to the structure of the shipping industry and its legislative framework. The chapter also emphasizes fundamental background information that is of relevance to present-day shipping and emissions as well as for the generation of future emissions scenarios.

Seaborne trade and contribution to the economy

2.2 Pollutant emissions from shipping are linked to shipping activity, which is driven by the world economy. Understanding this mechanism for seaborne transport and other shipping activities is therefore vital to establishing emissions inventories and trends.

2.3 According to UNCTAD [2], about 80% of world trade by volume is carried by sea where demand for seaborne transport is closely linked to the development of the economy. The activity of the shipping industry is expressed in tonne-miles, which is the amount of cargo shipped multiplied by the average distance that it is transported. The volumes of various categories of cargo are shown in figure 2-1, which is based on data from Fearnleys, as printed in the 2007 ISL Statistical Yearbook [1]. More detailed information reports on trade and shipping are published annually by UNCTAD [2].

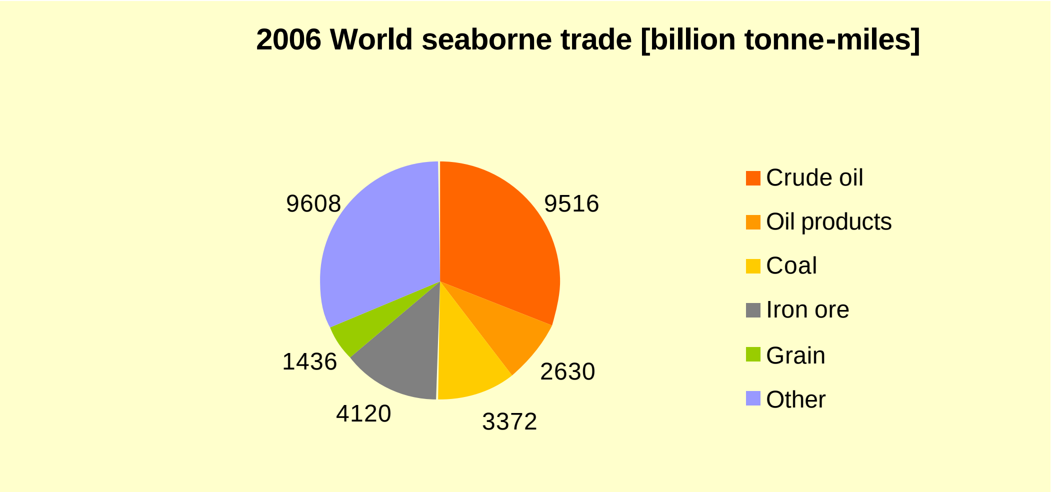

Figure 2-1 – World seaborne trade in 2006

2.4 Seaborne transport services the global demand for food, energy, raw materials and finished products. Ships carry essential food such as grains, rice, maize, meat, fish, sugar, and vegetables, vegetable oils, etc., as well as fertilizers to produce more and better crops. Energy, in the form of crude oil, refined petroleum products, coal and gas, is responsible for a significant share of the tonne-miles transported. Furthermore, raw materials such as iron ore, minerals, lumber, scrap iron, cotton, wool, rubber and more are transported, as are semi-finished and finished products. Apart from trade and transportation, various other tasks are performed by special ships. These include offshore service activities, infrastructure development (such as cable laying, pipe laying and dredging), fishing, exploration and research, towing services, etc.

2.5 Seaborne trade has grown with the world economy. Average annual growth rates in tonne-miles for the twenty-year period 1986–2006 are shown in figure 2-2 and total seaborne trade, expressed in billion tonne-miles, is shown in figure 2-3. These data were originally generated by Fearnleys by tracking a subset of the world cargo fleet, using ship movement data from Lloyd's Marine Intelligence Unit and data on specific cargoes carried. These data are published, *inter alia*, in the 2007 ISL Statistical Yearbook [1].

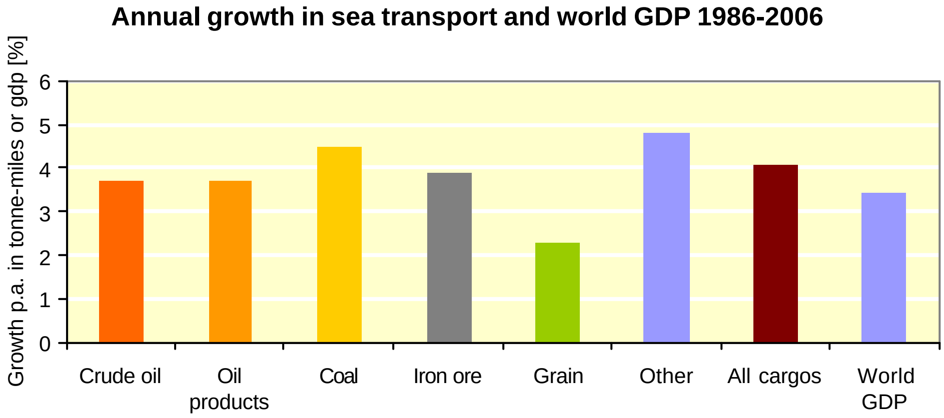

Figure 2-2 – Average annual growth in world seaborne transport and world GDP between 1986 and 2006 [Fearnleys]

Figure 2-3 – Seaborne trade 1970–2007 in billion tonne-miles [Fearnleys]

2.6 The overall average annual growth in tonne-miles has been 4.1%. Coal and "other" cargoes have displayed the highest rates of growth (4.5% and 4.8% respectively), while grain has had the smallest annual growth rate (2.3%). In the same period, world economic growth, expressed as real GDP, rose by 3.4% each year on average [3].

2.7 Due to its close connection to trade, international shipping also plays a vital role in facilitation of trade as the most cost-effective means of transport. With economic growth, this shipping industry expanded gradually, and total turnover of marine activities is estimated to be roughly US$ 1.3 trillion in 2004 (Stopford [4]) with an 8% increase compared to 1999, as can be seen in table 2-1. About one third is related to merchant shipping. The table also demonstrates the growth of the contribution of merchant shipping (22%) over the timeframe.

Table 2-1 - Contribution of marine and shipping activities to the economy

	US$ millions		Growth	Share in
	1999	**2004**	**99–04 (% pa)**	**2004 (%)**
1a. Merchant shipping	160 598	426 297	22	31
1b. Naval shipping	150 000	173 891	3	13
1c.Cruise industry	8 255	14 925	12	1
1d. Ports	26 985	31 115	3	2
Total operations	**345 838**	**646 229**	**13**	**47**
2. Shipbuilding	133 170	173 482	5	13
3. Marine resources	95 278	116 933	4	8
4. Marine fisheries	185 817	206 103	2	15
5. Other	179 466	243 898	6	18
Total – US$ millions	939 570	1 386 645	8	100
World GDP (current US$)	31 025 816	41 732 430		
GDP contribution – marine	**3.03%**	**3.32%**		
GDP contribution – shipping	**1.01%**	**1.11%**		

Source: based on Stopford (2009) [4] and figures from the World Bank [5]

2.8 Today, the industry employs about 1.23 million seafarers and about half of the total fleet are cargo-carrying ships, operating in over 3,000 major ports [4]. Largest supporting industries for the shipping industry are the shipbuilding and marine equipment industry, with a turnover of US$ 46.9 billion and US$ 90.6 billion in 2004 [4]. The total contribution of marine and shipping activities to world GDP, based on GDP figures from the World Bank [5], can be calculated to be roughly 3% and 1% respectively.

2.9 Other studies value the world marine market at US$ 2.7 trillion [6], with the shipbuilding industry as the largest global market value. The United Nations Conference on Trade and Development (UNCTAD, 2006) [2] estimates an economic contribution to the global economy of US$ 380 billion in freight rates deriving from the operation of ships.

2.10 The year-on-year changes in world seaborne trade shown in figure 2-3 have been used in this study to backcast and forecast emissions where necessary. For instance, emissions from 1990 to 2007 have been estimated from the 2007 inventory, assuming that emissions have grown in proportion with world seaborne trade.

Geographical distribution of ship traffic

2.12 The geographical distribution of ship traffic has been investigated in the literature, based on the International Comprehensive Ocean–Atmosphere Data Set (ICOADS), and the Automated Mutual-assistance Vessel Rescue system (AMVER) dataset. ICOADS is a dataset of voluntarily reported ocean and atmospheric observations with ship locations, which is freely available. AMVER is a computer-based and voluntary global ship reporting system, sponsored by the United States Coast Guard but used worldwide by search and rescue authorities to arrange for assistance to persons in distress at sea. While each of these datasets can demonstrate biases, they clearly demonstrate that ship traffic is most prominent in the northern hemisphere and along coastlines. A representation, based on ICOADS data, is shown in figure 2-4.

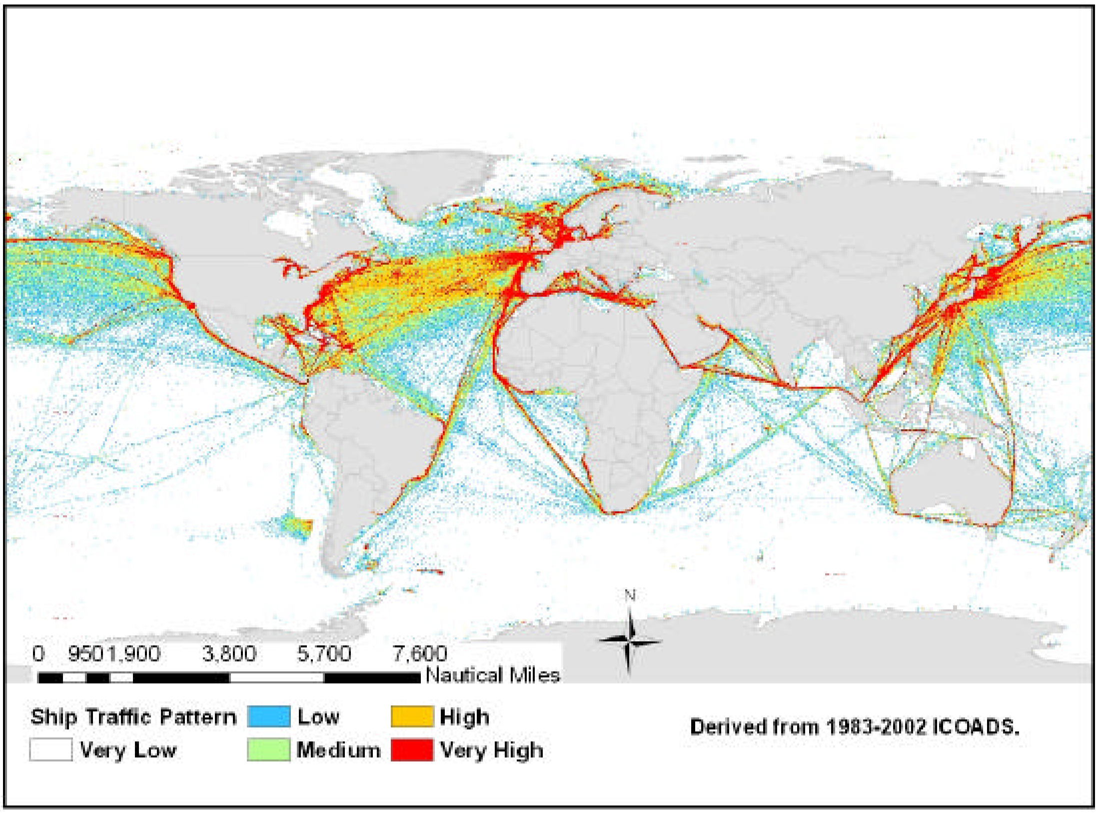

Figure 2-4 – Approximation of ship traffic distribution, based on ICOADS data

2.13 A combined dataset of ICOADS and AMVER data of a total of 1,990,000 daily ship observations at a 1° × 1° spatial resolution has been produced [7]. These data provide the following indication of ship traffic with respect to distance from shore:

.1 within 200 nautical miles from shore: 70%;

.2 within 50 nautical miles from shore: 44%; and

.3 within 25 nautical miles from shore: 36%.

The world fleet

2.14 Some key figures regarding the world fleet, based on the Lloyd's Register – Fairplay (LRF) database, are shown in figure 2-5. Due to its link with the mandatory IMO registration, LRF's database can be relied upon to contain virtually all ships engaged in international trade and also many ships that are not. When the IMO ship identification number scheme was introduced in 1987, through the adoption of resolution A.600(15), Lloyd's Register was chosen by IMO to maintain the register on behalf of IMO. The IMO numbering scheme ensures that a permanent number is assigned to each ship for identification purposes. That number remains unchanged upon transfer of the ship to other flag(s) and is inserted in the ship's certificates. The IMO number became mandatory for all ships (with certain limitations) as of 1 January 1996.

2.15 As shown in figure 2-5, the world fleet in 2007 comprises more than 100,000 ships of more than 100 GT, of which just less than half are cargo ships. However, cargo ships account for 89% of total gross tonnage, clearly indicating the relatively large size of cargo ships.

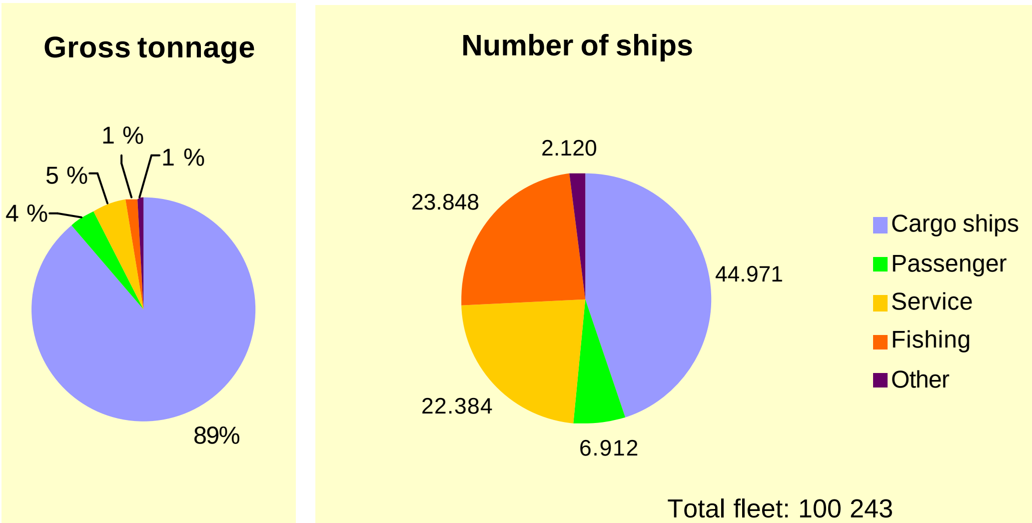

Figure 2-5 – Composition of the world fleet [Lloyd's Register – Fairplay, 2007]

2.16 A comparison of typical sizes of major cargo ship categories is shown in figure 2-6 and the respective fleet growth per million dwt for major ship types is given in figure 2-7. Figure 2-8 visualizes the growth in numbers of the total fleet above 100 GT for the time period 1960 to 2007, based on various publications from Lloyd's Register – Fairplay [8]. The graphs clearly demonstrate the growth in world fleet of merchant vessels in numbers and ship sizes over the years.

2.17 Ships are characterized by the type of cargo they are designed to carry. Table 2-2 lists the definitions of primary ship categories that have been used in the emissions inventory for this study. More detailed description of the various ship types can be found in general literature such as [9] and [10] and other reference resources, such as on the internet [13 and14]. Ships that are constructed to carry refrigerated or frozen cargo are commonly referred to as "reefer ships".

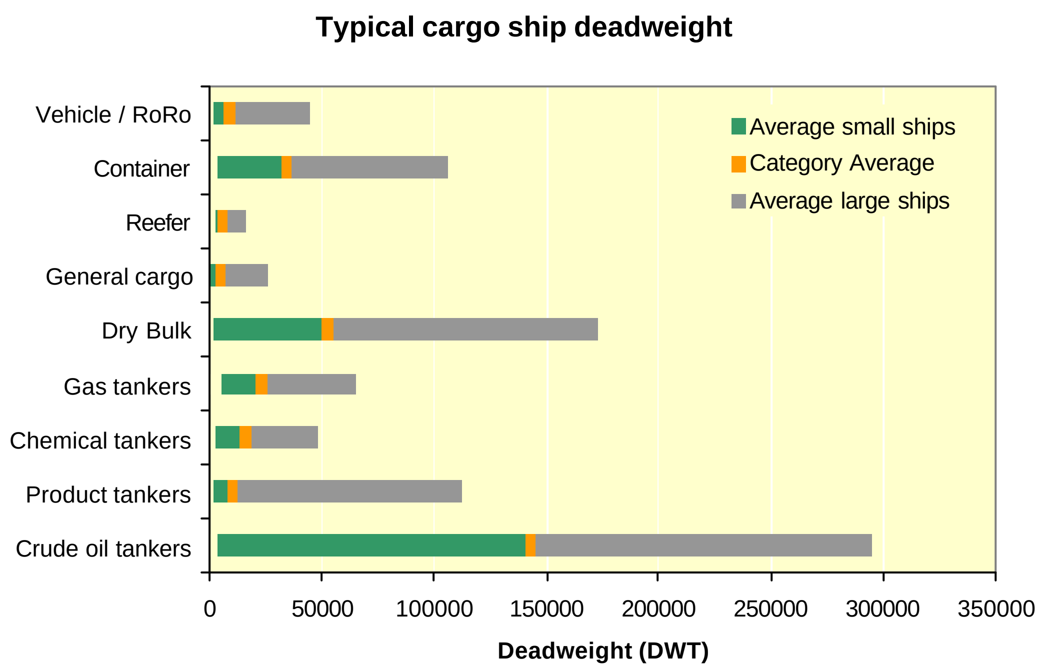

Figure 2-6 – Deadweight of major cargo ship types. High and low end represent average deadweight of the upper and lower ship size categories that were used in the study, not of individual ships, which may be significantly larger or smaller [Lloyd's Register – Fairplay, 2007]

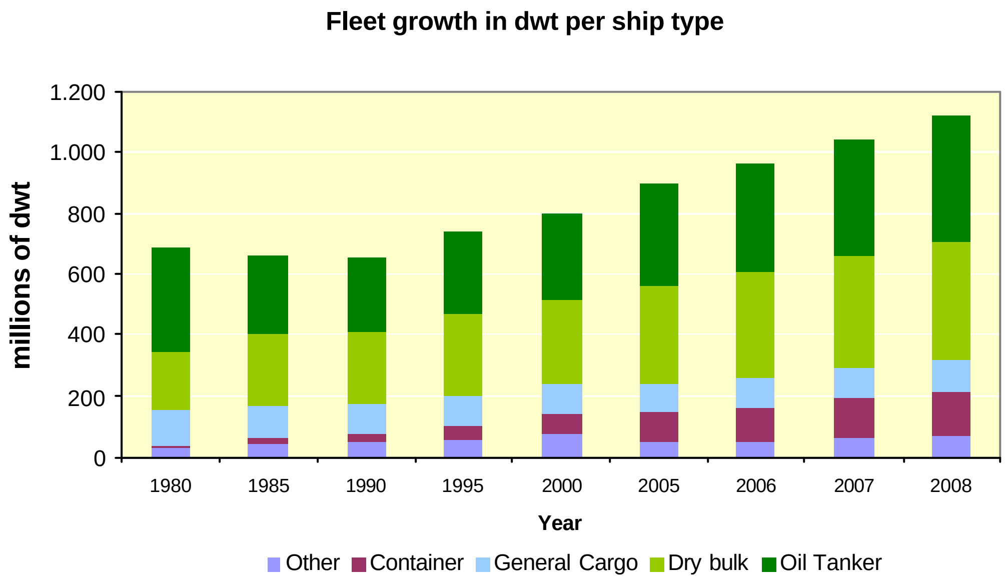

Figure 2-7 – Fleet growth in millions of dwt per major ship type, 1980 to 2008 [UNCTAD, 2008]

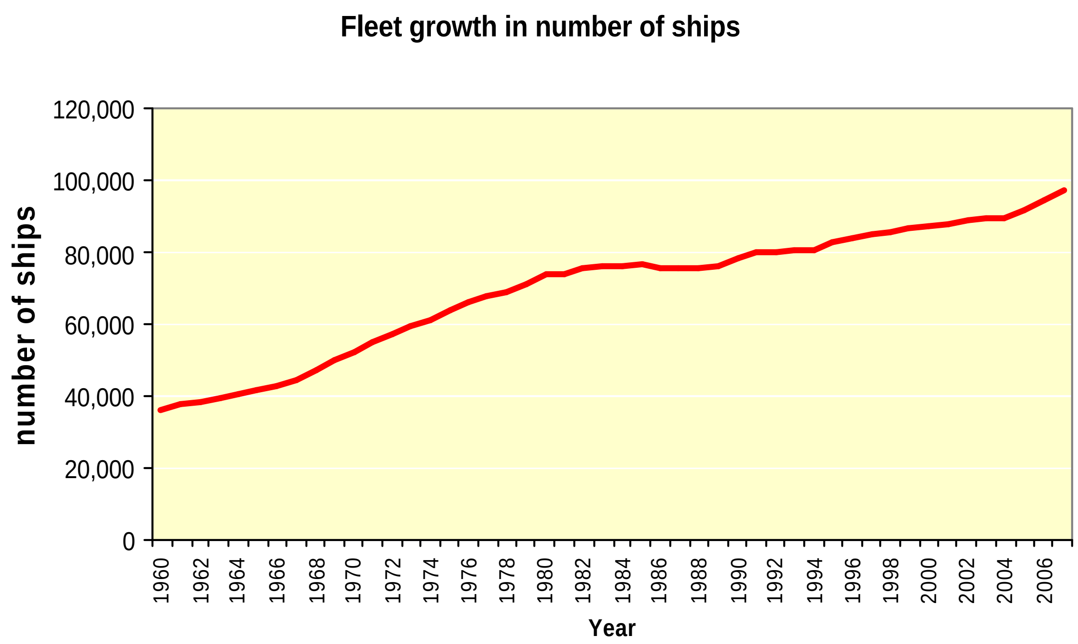

Figure 2-8 – Fleet growth, in numbers of ships, 1960 to 2007 [Lloyd's Register – Fairplay]

Table 2-2 - Definitions of the ship categories that have been used in the emissions inventory for this study

Cargo ships	**Crude carrier** This category includes tankers which are intended for carrying crude oil. **Products tanker** These are tankers that carry various types of refined petroleum products. **Chemical tanker** These are tankers that carry various types of industrial chemicals. **LPG tanker** Specialized tankers for the carriage of Liquefied Petroleum Gas and often also other products, for example ammonia. **LNG tanker** Specialized tankers for the carriage of Liquefied Natural Gas. **Other tanker** This group includes a large number of bunker tankers and also those that carry a wide range of liquid niche products such as orange juice, bitumen, wine

	and water. **Bulk carrier** These are ships designed to carry bulk goods such as grain, iron ore, coal and more. **General cargo carrier** This category includes a wide variety of cargo ships from small one-hold vessels to highly advanced Multi-Purpose Vessels. Some of the ships are designed to carry containers as well as break-bulk cargoes. Many of these ships are equipped with their own lifting gear. **Other dry carrier** These are carriers of refrigerated cargo and other special dry cargo ships. **Container** These are pure containerships that are built to carry containerized cargo and nothing else, i.e. fully cellular ships designed to carry containers both on deck and under deck. **Vehicle** These are ships designed to carry (new) cars, trucks and sometimes other special cargo on wheels. **Ro–ro** These are ships that are loaded and discharged by driving the cargo on board on wheels.
Other	**Ferry** These ships carry cars and passengers on regular schedules. This also includes overnight ferries. **Cruise** These ships carry passengers on pleasure voyages. **Yacht** These are large pleasure vessels. **Offshore** This category encompasses a wide range of platform supply vessels and offshore support vessels. Drilling rigs are not included in this figure. **Service** These are mainly tugs but also work-boats, dredgers, research vessels and more. **Fishing vessels** Vessels designed to capture fish.

2.18 The age profile of the world fleet, also from Lloyd's Register – Fairplay, is shown in figure 2-9, where it can be observed that, by number of vessels, approximately half of the world fleet is more than 20 years old (constructed before 1987). When gross tonnage, rather than number of ships, is considered (see figure 2-10), we can see that ships older than 20 years amount only to 25% of the total gross tonnage. In terms of gross tonnage, about half of the fleet is 10 years old or less. Combined, these figures show that a large number of smaller vessels of some age are in service. These ships represent a smaller share of the total transport capacity.

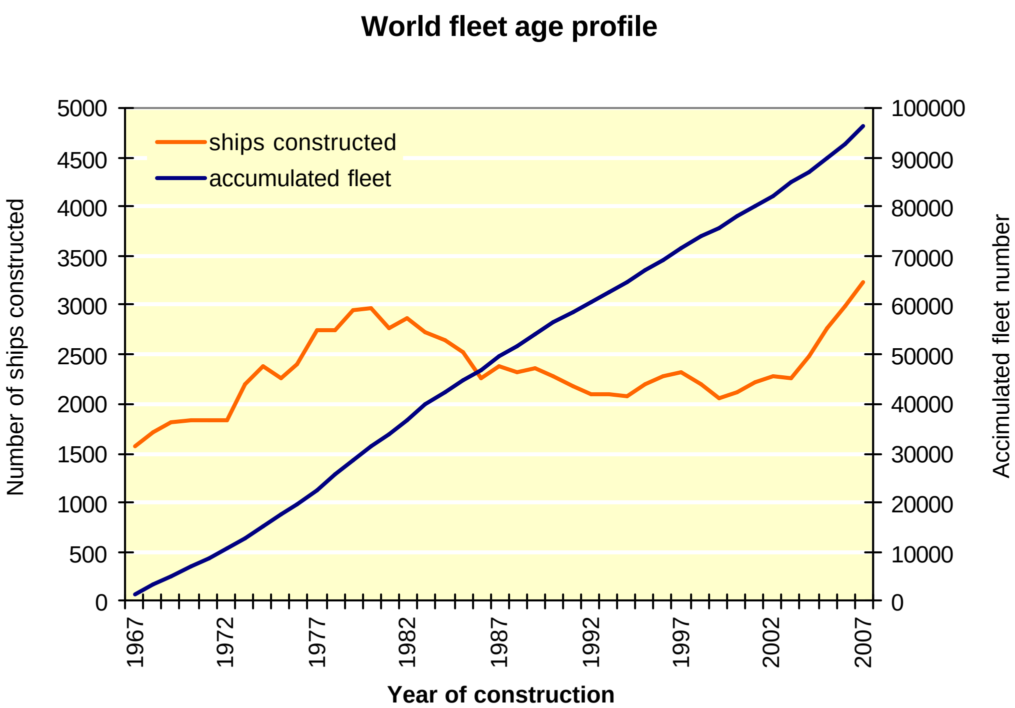

Figure 2-9 – Age profile of the world fleet [Lloyd's Register – Fairplay, 2007]

2.19 A comparison of the deadweight tonnage of the current fleet and the order book for dry and wet bulk (tankers and dry bulk carriers) is shown in figure 2-11. Due in part to the current global financial situation in 2009, there is reason to believe that a significant number of these ships may not be built.

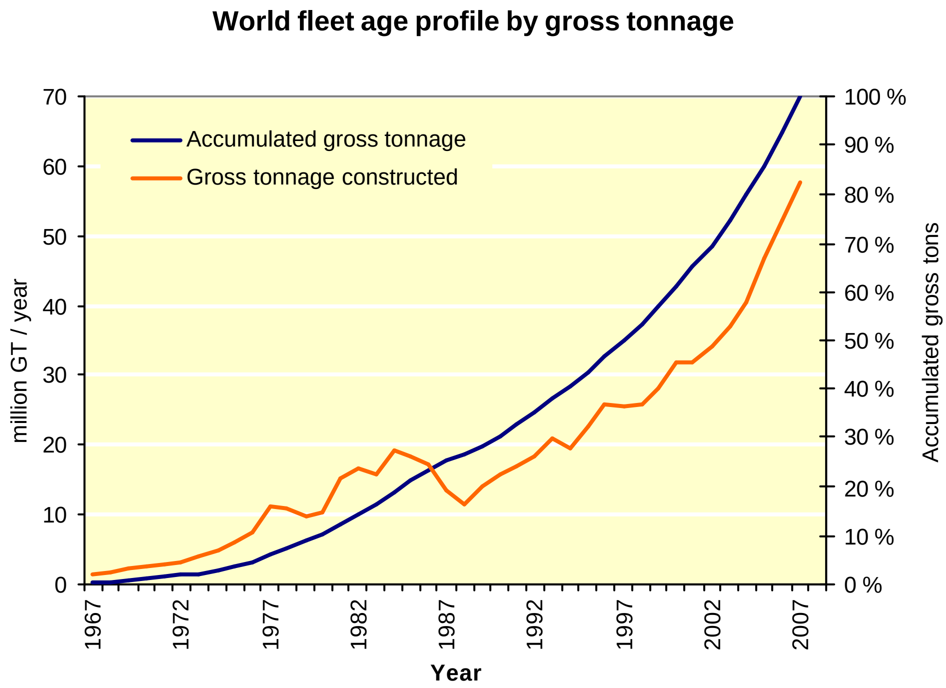

Figure 2-10 – Age profile of the world fleet by gross tonnage [Lloyd's Register – Fairplay, 2007]

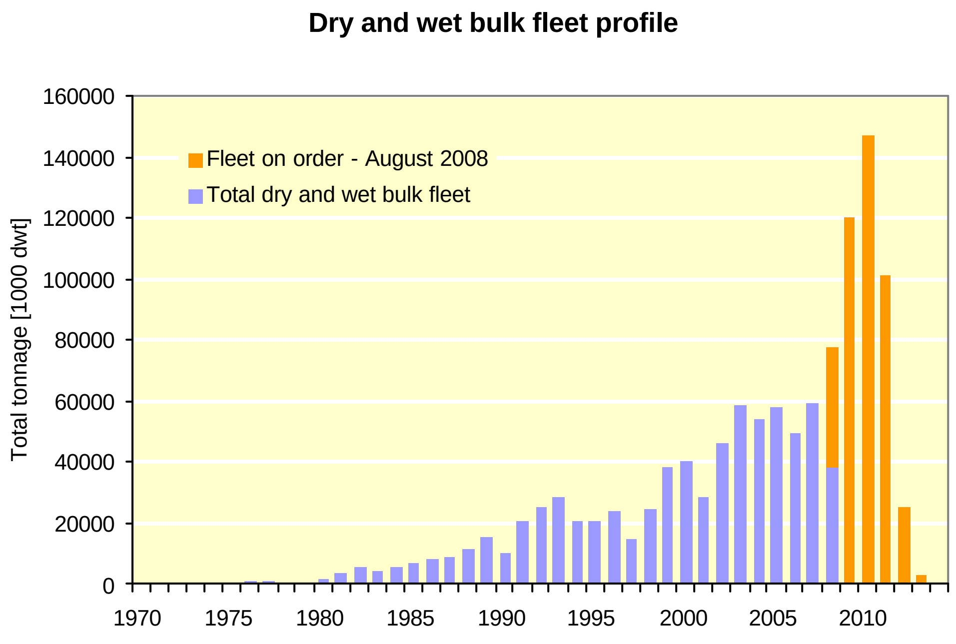

Figure 2-11 – Dry and wet bulk fleet and order books [Fearnleys, August 2008, and Lloyd's Register – Fairplay]

Flag and ownership structures of the world fleet

2.20 The structures and mechanisms which govern the shipping industry are complex, due to its international nature. While all ships are uniquely registered in a national register, it is not always easy to identify the "country of domicile" of ships' controlling interests since there are many types of ownership structures in shipping. For instance, stockholding companies may be owned by a large number of nationals from different countries. A company may be holding shares of less than 100 per cent in companies in third countries, etc. In spite of these difficulties, statistics on "country of domicile" of ships' controlling interests are presented by UNCTAD [2]. Some key facts and figures are shown here and are also brought into relation to trading volumes.

2.21 The top ten ship registries by deadweight are shown in table 2-3. In addition, the number of ships, the share of deadweight to total deadweight and their growth are given. Together, these registers control about 69% of the global total deadweight tonnage.

Table 2-3 - Top ten ship registers [UNCTAD, 2008]

Flag of registration	Number of ships	Total tonnage (1,000 DWT)	Share of world total DWT (%)	% dwt growth 2008/07
Panama	7616	252 564	22.6	8.8
Liberia	2173	117 519	10.5	11.7
Greece	1477	61 384	5.5	11.3
Bahamas	1422	59 744	5.3	8.2
Marshall Islands	1097	59 600	5.3	9.1
Hong Kong, China	1238	59 210	5.3	9.0
Singapore	2243	55 550	5.0	8.8
Malta	1442	45 218	4.1	12.5
China	3816	37 124	3.3	6.3
Cyprus	982	29 431	2.6	-0.7

2.22 For many years there has been a trend towards more and more ships being registered under a foreign flag. UNCTAD [2] indicates that the percentage of foreign-flagged vessels grew from 41.50% in 1989 to 66.35% in 2007. However, a very marginal decrease from 2006 to 2007 is a signal that a saturation point may have been reached. If second registries, such as the NIS (Norwegian Shipping Register), as well as ships registered under the flag of the Netherlands Antilles for the Netherlands are included, the share of "foreign-flagged" vessels becomes more than 71% of the world fleet's deadweight tonnage [2].

2.23 Table 2-4 presents the top ten controlling nations[2] as of January 2008. In terms of deadweight tonnage, these nations control 70.2% of the world fleet. Percentage changes from 2007 to 2008 and the share of deadweight tonnage under national registry, as of 2008, are also presented.

[2] According to UNCTAD and based on the definition of Lloyd's Register – Fairplay, the controlling nation is represented by the country of ownership with the true controlling interest. Sometimes this is not straightforward to distinguish in shipping.

Table 2-4 - Top ten controlling interests by domicile [UNCTAD, 2008]

Controlling interest's country of domicile	Number of ships	Total tonnage (1,000 dwt)	Share of world total dwt (%)	% Dwt growth 2008/2007	% Share of dwt in national registry
Greece	3115	174 570	16.8	-0.6	31.9
Japan	3515	161 747	15.6	0.5	7.2
Germany	3208	94 222	9.1	0.4	15.5
China	3303	84 881	8.2	1.0	40.5
Norway	1827	46 872	4.5	-0.5	30.3
United States	1769	39 828	3.8	-1.1	51.0
Korea, Republic of	1140	37 703	3.6	0.3	50.7
Hong Kong, China	657	33 424	3.2	-1.4	54.5
Singapore	869	28 632	2.8	0.1	57.4
Denmark	861	27 434	2.6	0.4	38.2

Table 2-5 - Top fifteen trading nations, with respective fleet and ownership profiles [UNCTAD, 2008]; trade data are for 2007, fleet data are for 2008

Top trading nations	% share of world trade in terms of value	% of world fleet in terms of dwt	% of ownership of fleet in terms of dwt
United States of America	11.38	1.09	3.84
Germany	8.51	1.34	9.07
China	7.81	3.32	8.18
Japan	4.77	1.32	15.58
France	4.16	0.71	0.63
United Kingdom	3.76	0.42	2.5
Netherlands	3.72	0.56	0.83
Italy	3.55	1.19	1.71
Belgium	3.01	0.58	1.17
Canada	2.88	0.28	1.81
Republic of Korea	2.62	1.89	3.63
Hong Kong, China	2.56	5.3	3.22
Spain	2.18	0.25	0.43
Russian Federation	2.16	0.64	1.74
Mexico	2.04	0.14	n/a
Total – top 15	**65.11**	**19.03**	**54.34**
Total – top 25	**78.02**	**28.16**	**64.93**

2.24 In order to provide an overview of the international nature of shipping, table 2-5 presents the top 15 trading nations and presents their respective fleet and ownership profiles. One can easily see that the top 15 trading nations account for 65% of the world trade in terms of value and their owning interest lies in 54% of the world fleet in terms of deadweight. However, their corresponding share in registration lies only by 19% of the world fleet in terms of deadweight.

2.25 Furthermore, in comparing table 2-5 with tables 2-4 and 2-3, one can observe that the biggest registries, such as Panama, Liberia and the Bahamas, do not appear in the top controlling nations nor in the top trading nations. An exception is Greece with respect to controlling interest, where 31.9% of the tonnage under Greek-controlled interests is also carrying the national flag. In general, the motivation for a vessel owner to use a foreign flag may include more favourable tax regimes, conditions to finance ships and the possibility of employing foreign seafarers. These are all common practices in shipping, and underline the international structure of the shipping industry.

Regulation of shipping

2.26 Marine activities such as international shipping are regulated by a mixture of the international law of the sea and the law of a particular State. *The United Nations Convention on the Law of the Sea* (UNCLOS) is the cornerstone of international maritime law. UNCLOS endorses the right of any sovereign State to have a ship register and thus become a flag State, and it provides ships with the right to innocent passage through territorial waters and economic zones. International law, such as UNCLOS, regulates the affairs between States but does not apply directly to individual ships [10].

2.27 Ships are regulated by applicable laws and regulations of the country in which the ship is registered, i.e. the flag State. Some countries may require specific criteria to be fulfilled before granting a ship access to the registry. Such criteria could be that the ship is built in their territory, that the shipowning company is registered in the country, that the owners are citizens of the country and more. Other countries have few or no restrictions on access, and are commonly referred to as "open registries". If the ship is to engage in international shipping, i.e. entering foreign or international waters, the flag State is obliged to ensure that the ship complies with regulations set down in international conventions and agreements to which the flag State is party.

2.28 Regional and national regulations can be applied within areas of jurisdiction by coastal States. Generally, such national regulations define legal boundaries for the operation of the ships, since the provisions for innocent passage that are defined by UNCLOS mean that such laws and regulations shall not apply to the design, construction, manning or equipment of foreign ships unless they are giving effect to generally accepted international rules or standards.

2.29 Figure 2-12 provides an overview of the various players in the industry in shipping and presents their respective roles with respect to enforcing the legislative framework. The legislative framework for international shipping today consists of 50 conventions and protocols created by the International Maritime Organization (IMO), of which 41 are in force, and relevant legislative measures of the International Labour Organization (ILO) for seafarers. It is the Contracting Government's responsibility to transpose international law into their national legislation and enforce it. The right-hand side of figure 2-12 presents the various other industry interests around the shipowner, such as banks who finance ships, insurance companies who insure ships and companies who are involved in the commercial and day-to-day operation of a vessel (ship operator, manager).

2.30 The International Maritime Organization has been established *"to provide machinery for cooperation among Governments in the field of governmental regulation and practices relating to technical matters of all kinds affecting shipping engaged in international trade; to encourage and facilitate the general adoption of the highest practicable standards in matters concerning maritime safety, efficiency of navigation and prevention and control of marine pollution from ships."* [11]. The Organization is also empowered to deal with administrative and legal matters related to these purposes.

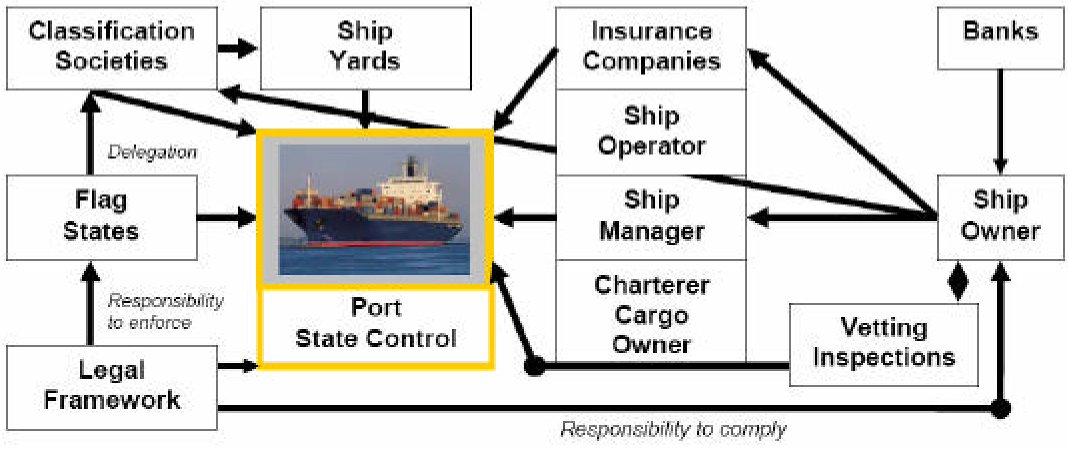

Figure 2-12 – Players of the legislative framework for shipping [15]

2.31 IMO's role is thus primarily to adopt legislation, while enforcement lies with the Contracting Governments (the flag States). Governments decide whether or not to ratify legislation negotiated by IMO Member States. When a Government ratifies an IMO convention, the Government effectively agrees to make the regulation part of its own national law and sometimes delegates survey activities to classification societies, which then act on behalf of the flag State. Classification societies are companies who deal with the technical aspect of shipping and sometimes also conduct surveys on behalf of the flag State. In this case, they are often called a "recognized organization" (RO).[3] Classification societies also play an important role for the construction of vessels, since ships are normally constructed according to classification rules.

2.32 Each convention includes appropriate provisions stipulating conditions which have to be met before it enters into force. Typically, entry into force is conditional on a certain number of countries, representing a certain share of the world fleet gross tonnage, ratifying the agreement. When an IMO instrument has entered into force, it is considered to be generally accepted international rules or standards, and UNCLOS no longer prohibits rules applying to the design, construction, manning or equipment of foreign ships in innocent passage [12].

2.33 When an IMO instrument has entered into force, countries that have ratified the instrument can apply it not only to ships of their own flag but to all ships, regardless of flag. Therefore, ships wanting to enter the ports or waters under the jurisdiction of a county that has ratified an IMO instrument will have to abide by that convention, regardless of flag. This is an important principle, commonly referred to as the principle of "no more favourable treatment". It refers to port States enforcing applicable standards in a uniform manner to all ships in their ports, regardless of flag.

2.34 Due to this principle and the international nature of shipping, an IMO regulation affects, *de facto*, most ships, regardless of flag, once it has entered into force. On the other hand, there are no legal barriers to prevent a ship from not conforming to a given IMO regulation provided it operates solely outside the area of jurisdiction of countries that have ratified the convention in question.

[3] See IMO resolutions A.739(18) "Guidelines for the authorization of organizations acting on behalf of the Administration", and its amendment in MSC.208(81), and A.789(19) "Specifications on the survey and certification functions of recognized organizations acting on behalf of the Administration".

2.35 Flag States are responsible for implementing and enforcing legislation on ships in their registries. Additionally, many of IMO's most important technical conventions contain provisions to allow ships to be inspected when they visit foreign ports, to ensure that they meet IMO requirements. This is referred to as "Port State Control" (PSC). Ships that fail to meet the standards when subjected to PSC can be detained until repairs are carried out and the ship is released from detention. In order to ensure a harmonized and coordinated approach for PSC inspections, many countries have organized themselves into groups, based on memoranda of understanding (MOUs), and are therefore grouped in regional PSC regimes. There are currently nine such port State control regimes, covering most coastal States, as follows:

.1 Europe and North Atlantic (Paris MoU), signed in 1982;

.2 Asia and the Pacific (Tokyo MoU), signed in 1993;

.3 Latin America (Acuerdo de Viña del Mar), signed in 1992;

.4 Caribbean (Caribbean MoU), signed in 1996;

.5 West and Central Africa (Abuja MoU), signed in 1999;

.6 Black Sea (Black Sea MoU), signed in 2000;

.7 Mediterranean (Mediterranean MoU), signed in 1997;

.8 Indian Ocean (Indian Ocean MoU), signed in 1998; and

.9 Arab States of the Gulf (Riyadh MoU), signed in 2004.

2.36 In addition, the United States Coast Guard (USCG) has also established a foreign vessel inspection service which is not part of any of the MOUs but which follows any of the developments and harmonization efforts of the other PSC regimes.

2.37 In addition to inspections carried out by port State control officers, the industry also carries out vetting inspections, primarily for tankers and dry bulk carriers. These vetting inspections are driven by cargo interests or shipowners, depending on the scheme.

UNFCC, the Kyoto Protocol and shipping

2.38 The United Nations Framework Convention on Climate Change (UNFCCC) was signed in 1992, entered into force in 1994, and in March 2009 has 192 Parties [16]. Under the Convention, parties gather and share data, launch national strategies to address emissions and cooperate for the adaptation to climate change. In December 1997, the Kyoto Protocol was adopted and entered into force in February 2005; in March 2009, 184 parties [16] have ratified the Protocol.

2.39 While the Convention does not provide commitments to stabilize emissions, the Protocol sets binding targets for the Annex I countries. These countries agreed to reduce their overall emissions of six greenhouse gases by an average of 5.2% below 1990 levels between 2008 and 2012. In doing so, the Kyoto Protocol offers several mechanisms to reduce emissions, as follows: (1) emissions trading, (2) the clean development mechanism (CDM) and (3) the joint implementation (JI) mechanism. Joint implementation allows a country to earn emission-reduction units (ERUs) from either an emission-reduction or an emission-removal project while the CDM allows a developed country to earn saleable certified emission reductions (CER) for emission-reduction projects in developing countries.

2.40 While emissions from aviation and maritime transport have been part of the UNFCCC agenda, these emissions were not included under the Kyoto Protocol. Article 2.2 of the Kyoto Protocol reads [16]:

> "The Parties included in Annex I shall pursue limitation or reduction of emissions of greenhouse gases not controlled by the Montreal Protocol from aviation and marine bunker fuels, working through the International Civil Aviation Organization and the International Maritime Organization, respectively."

2.41 A topic of debate within IMO is how the wording of Article 2.2 of the Kyoto Protocol should be interpreted and if the principle agreed under UNFCCC of "common but differentiated responsibility" should apply to a GHG regime for international shipping rather than IMO's basic principle of "no more favourable treatment" explained earlier.

2.42 For clarification purposes, the principle of "common but differentiated responsibility" recognizes the differences in the contributions of developed and developing countries in addressing global environmental issues, such as addressing the emissions of greenhouse gases. The principle is enshrined in Article 3.1 of the UNFCC Convention [16] as follows:

> "The Parties should protect the climate system for the benefit of present and future generations of humankind, on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities. Accordingly, the developed country Parties should take the lead in combating climate change and the adverse effects thereof".

2.43 Following the discussions at IMO [17], a number of countries maintained the view that any measures to reduce emissions of GHGs to be adopted by IMO should only be applicable to Annex I parties to the UNFCCC and its Kyoto Protocol, in accordance with the principle of "common but differentiated responsibility". Some delegations therefore have the view that reduction of emissions related to international shipping should be on a voluntary basis for developing countries.

2.44 As the legal advice from IMO's Sub-Division for Legal Affairs in document MEPC 58/4/20 clearly indicates, there is no potential treaty law conflict between the Kyoto Protocol and the provisions that may be developed by the Organization on control of GHG emissions from international shipping.

2.45 Other delegations have expressed the opinion that, given the global mandate of IMO as regards safety of ships and the protection of the marine and atmospheric environment from all sources of ship pollution, the IMO regulatory framework on GHG emissions should be applicable to all ships, irrespective of the flags they fly.

2.46 As demonstrated earlier, the ownership and management chain surrounding ship operations can involve many players, located in various countries. In addition, the registration of a ship can move between jurisdictions several times over its lifetime. It is worth noticing that about three quarters of the world tonnage, by deadweight, of all merchant vessels engaged in international trade is registered in developing countries (not in Annex I of the Kyoto Protocol), hence making it a large portion of the world fleet; it would be ineffective for any regulatory regime to act only on the remaining portion, namely one quarter of the world fleet.

2.47 Given IMO's global mandate, given by the IMO Convention itself as well as from UNCLOS, there is no precedence in any of the more than fifty IMO treaty instruments currently in existence where measures are applied selectively to ships according to their flag. On the other hand, there are several international environmental agreements which have a differentiated approach, such as The Montreal Protocol (on substances that deplete the ozone layer), yet, when IMO has dealt with the same issues, the principle of differentiated approach has not been taken on board.

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