Multi-year Expert Meeting
On Transport and Trade Facilitation:

Maritime Transport and the Climate Change Challenge

16-18 February 2009

IMO Study On Greenhouse Gas Emissions From Ships 2008/2009

by

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IMO STUDY ON GREENHOUSE GAS EMISSIONS FROM SHIPS 2008/2009

Information by the International Maritime Organization (IMO)

Background

1 IMO's initial Study on Greenhouse Gas (GHG) Emissions from Ships was published in 2000 and is the most comprehensive assessment to date of the contribution made by international shipping to climate change. The Study estimated that ships in international trade in 1996 contributed about 1.8% of the world's total anthropogenic CO_2 emissions and clearly stated that there was no other mode of transport with a better CO_2 record on a tonne-mile basis.

2 The twenty-third session of the IMO Assembly adopted, in December 2003, resolution A.963(23) on "IMO Policies and Practices related to the Reduction of Greenhouse Gas Emissions from Ships". The resolution urges IMO's Marine Environment Protection Committee (MEPC) to, *inter alia*, identify and develop the mechanisms needed to achieve limitation or reduction of GHG emissions from international shipping and to consider the methodological aspects related to reporting, recognizing that CO_2 is the most prominent GHG emitted by ships.

3 MEPC 55, in October 2006, acknowledged that the threat from global warming was far too serious to be ignored and agreed that international shipping, although an already environmentally friendly and fuel efficient mode of transport, should take appropriate action. Subsequently, MEPC 55 decided to update the 2000 IMO GHG Study to provide a better foundation for future decisions and to assist in the follow-up to resolution A.963(23).

4 MEPC 56, in July 2007, approved Terms of Reference for the update of the 2000 IMO GHG Study that had been divided into two Phases:

.1 Phase 1, covering a CO_2 emission inventory from international shipping and future emission scenarios, was reported to MEPC 58 in October 2008; and

.2 Phase 2, covering greenhouse gases other than CO_2 and other relevant substances in accordance with the methodology adopted by UNFCCC, as well as the identification and consideration of future reduction potentials by technical, operational and market-based measures, will be submitted to IMO in April 2009 for consideration by MEPC 59 in July 2009.

5 Following a tendering process targeting selected institutes, the contract to update the IMO GHG Study was awarded to an international consortium of ten entities comprising six of the 12 invited institutes. The consortium is co-ordinated by MARINTEK of Norway and is made up of the following institutes and individual key experts: CE Delft, The Netherlands; Dalian Maritime University, China (Peoples Republic of); David Lee, Manchester Metropolitan University, United Kingdom; Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Germany; DNV, Norway; Energy and Environmental Research Associates (EERA), United States of America; Lloyd's Register-Fairplay Research, Sweden; MARINTEK, Norway; Mokpo National Maritime University (MNMU), Republic of Korea; National Maritime Research Institute (NMRI), Japan; and Ocean Policy Research Foundation (OPRF), Japan.

Phase 1 report

6 MEPC 58, in October 2008, reviewed the Phase 1 report of the updated IMO Study on GHG emissions from ships and noted with interest, *inter alia*, the following findings:

.1 CO_2 emissions from international shipping have been estimated both from activity data and from international fuel statistics. It was concluded that the activity-based estimates with the use of detailed activity data (for different ship sizes and types) gave a better assessment of global fuel consumption and CO_2 emissions from international shipping than fuel statistics, due to apparent under-reporting of marine bunker sales;

.2 the consensus estimate for 2007 CO_2 emissions from international shipping (ships above 100GT) amounts to 843 million tonnes of CO_2 (2.7% of the world's total anthropogenic CO_2 emissions);

.3 by also including domestic shipping and fishing vessels (ships above 100GT but still excluding naval vessels), the amount would increase to 1,019 million tonnes of CO_2 (3.3% of the world's total anthropogenic CO_2 emissions); and

.4 future emissions from international shipping have been estimated based on global developments outlined by the Intergovernmental Panel on Climate Change (IPCC). **Assuming that there are no explicit regulations on CO_2 emissions from ships**, CO_2 emissions are predicted in the base scenarios to increase by a factor of 2.4 to 3.0 by 2050. For 2020, the base scenario predicts increases ranging from a factor of 1.1 to 1.3. These predictions take into account significant efficiency improvements resulting from expected long-term increases in energy prices.

7 The executive summary of the Phase 1 report is set out in the annex to this document. The full report may be found (in English only) at the IMO website: http://www.imo.org/home.asp?topic_id=1737

Phase 2 report

8 MEPC 59 will be held at IMO's Headquarters in London from 13 to 17 July 2009 and is expected to review the Phase 2 report as well as the full final report covering both phases.

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ANNEX

Updated Study on

Greenhouse Gas Emissions from Ships

Executive summary of Phase 1 Report

1st September 2008

Prepared for the International Maritime Organization (IMO) by:

- CE Delft, The Netherlands
- Dalian Maritime University, China
- David S. Lee, UK
- Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Germany
- DNV, Norway
- Energy and Environmental Research Associates (EERA) USA
- Lloyd's Register-Fairplay Research, Sweden
- MARINTEK, Norway
- Mokpo National Maritime University (MNMU), Korea
- National Maritime Research Institute (NMRI), Japan
- Ocean Policy Research Foundation (OPRF), Japan

Preface

This report constitutes Phase 1 of a study on greenhouse gas emissions from ships. This is an update of a study done for IMO in 2000. As in the 2000 report, a main objective of the update is to establish emission inventories and reduction potentials for greenhouse gas emissions from international shipping; however the scope of the updated study is broader and puts more emphasis on the trends and impacts of future emissions. As was also the case in the original study, the updated study is delivered to the International Maritime Organization by the consortium run by MARINTEK. This updated study benefits from a larger and more global team of expert contributors and the work is done in partnership with the following institutions:

CE Delft, Dalian Maritime University, Deutsches Zentrum für Luft- und Raumfahrt e.V., DNV, Energy and Environmental Research Associates (EERA), Lloyd's Register-Fairplay, Mokpo National Maritime University (MNMU), National Maritime Research Institute (Japan), Ocean Policy Research Foundation (OPRF).

The following individuals are the main contributors to the report:

Øyvind Buhaug (Coordinator), James J. Corbett, Øyvind Endresen, Veronika Eyring, Jasper Faber, Shinichi Hanayama, David S. Lee, Donchool Lee, Håkon Lindstad, Alvar Mjelde, Christopher Pålsson, Wu Wanquing, James J. Winebrake, Koichi Yoshida.

In the course of this work, the research team has gratefully received input and comments from the International Energy Agency (IEA), the Baltic and International Maritime Council (BIMCO) and the International Association of Independent Tanker Owners (INTERTANKO).

The objectives of Phase 1 of the study have been as follows: (1) to undertake an assessment of present day CO_2 emissions from international shipping; (2) to estimate future CO_2 emissions from international shipping emissions towards 2050; (3) to compare CO_2 emissions from shipping with other modes of transport; and (4) to assess the impact of CO_2 emissions from shipping on the climate. This report will be followed by a Phase 2 report which will address other greenhouse gases than CO_2 and the possibilities and mechanisms for reductions in GHG emissions.

Recommended Citation: Buhaug, Ø.; Corbett, J. J.; Endresen, Ø.; Eyring, V.; Faber, J.; Hanayama, S.; Lee, D. S.; Lee, D.; Lindstad, H.; Mjelde, A.; Pålsson, C.; Wanquing, W.; Winebrake, J. J.; Yoshida, K. *Updated Study on Greenhouse Gas Emissions from Ships: Phase I Report*; International Maritime Organization (IMO) London, UK, 1 September, 2008.

List of abbreviations

AIS	Automatic Identification System
CO_2	Carbon dioxide
EIA	United States Energy Information Administration
FAME	Fatty Acid Methyl Ester (a type of bio diesel)
FTD	Fischer Tropsh Diesel (a type of synthetic diesel)
GDP	Gross domestic product
GHG	Greenhouse gas
GT	Gross Tonnage
HFO	Heavy fuel oil
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
LNG	Liquefied Natural Gas
MDO	Marine diesel oil
OECD	Organisation for Economic Co-operation and Development
OPRF	Ocean Policy Research Foundation
PM	Particulate Matter
RF	Radiative Forcing
SRES	IPCC Special report on emissions scenarios
UNCTAD	United Nations Conference on Trade and Development
UNFCCC	United Nations Framework Convention on Climate Change

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. 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 This definition is consistent with IPCC 2006 Guidelines
Coastwise shipping	Coastwise shipping is freight movements and other shipping activities that are predominantly along coast lines or regionally bound (e.g., passenger vessels, ferries, offshore vessels) as opposed to ocean-going shipping. The distinction between is made for the purpose of scenario modelling and is based on ship types, i.e. a ship is either Coastwise or an ocean-going ship
Ocean-going shipping	Ocean-going shipping is a term used for scenario modelling. It refers shipping refers to large cargo carrying ships engaged in ocean crossing trade.

1 Executive Summary

1.1 Introduction

This report has been prepared by an international consortium as set out in the preface to this report. The report covers Phase 1 of a study that will be conducted in two phases. Phase 1 concentrates on CO_2 emissions only. The report covers four main elements:

1. An inventory of current emissions of CO_2 from international shipping.
2. Estimates of future emissions of CO_2 from international shipping.
3. A comparison of CO_2 emissions from various types of ships with CO_2 emissions from other sources in the transport sector.
4. An analysis of the impact of CO_2 emissions from international shipping on climate change.

1.2 Main Conclusions

The Intergovernmental Panel on Climate Change (IPCC) developed guidelines for national greenhouse gas emissions inventories. These guidelines divide emissions from water borne navigation into two primary categories: domestic and international. International waterborne navigation is defined as navigation between ports of different countries. As set out in the terms of reference, this study provides estimates of present and future CO_2 emissions from international shipping. International shipping has been defined in accordance with the IPCC Guidelines. Total estimates that include domestic shipping emissions and emissions from fishing are also included in this report.

CO_2 emissions from international shipping have been estimated both from activity data and from international fuel statistics. Following discussion and analysis it is concluded that the activity-based estimates with use of detail activity data (for different ship sizes and types) give a better prediction of global fuel consumption and CO_2 emissions from international shipping than fuel statistics due to apparent under-reporting of marine bunker sales.

Previous activity-based estimates have relied on different sources of activity data resulting in differences in estimated emissions. The research team behind this study, whose members include lead authors and main contributors from all peer reviewed scientific studies on this topic and a participant from the IMO Informal Cross Government/Industry Scientific Group of Experts agreed to a consensus estimate for CO_2 emissions in 2007. This estimate is based both on analysis of new activity data that is unique to this study in addition to data from previous studies. The activity based model developed cannot differentiate between international and domestic emissions. In order to provide an estimate for emissions from international shipping by use of on the activity based model, domestic emissions as reported in bunker statistics have been subtracted from the total shipping emissions.

Table 1. Consensus estimate 2007 CO_2 emissions [million tonnes CO_2]

	Low bound	Consensus estimate	High bound	Consensus estimate % Global CO_2 emissions
Total ship emissions[1]	854	**1019**	1224	3.3
International shipping[2]	685	**843**	1039	2.7

1 Activity based estimate including domestic shipping and fishing, but excluding military vessels.
2 Calculated by subtracting domestic emissions estimated from fuel statistics from the activity based total excluding fishing vessels.

IPCC has developed scenarios for future global development. Future emissions from international shipping have been estimated in this report based on global developments outlined by IPCC. Assuming that there are no explicit regulations on CO_2 emissions from ships, CO_2 emissions are predicted in the base scenarios to increase by a factor of 2.4 to 3.0 by 2050. For 2020, the base scenario predicts increases ranging from 1.1 – 1.3. These predictions take into account significant efficiency improvements resulting from expected long-term increases in energy prices.

Climate stabilization will require significant reductions of CO_2 emissions by 2050. To reduce CO_2 emissions from international shipping, it appears necessary to either modify the current path of continued growth in seaborne transport, since the efficiency gains expected cannot deliver net reductions in the face of such growth; and / or develop mechanisms that will result in the introduction of technologies with significantly lower emissions than what is anticipated in these scenarios.

1.3 Current CO_2 emissions from international shipping

This study estimates international marine bunker fuel consumption and CO_2 emissions based on activity data and compares these with statistical data for global fuel sales to establish a consensus estimate for 2007 CO_2 emissions from international shipping.

1.4 CO_2 estimate based on fuel statistics (top-down estimate)

A global inventory was established based on statistical data for fuel use, derived from IEA summaries of marine fuel sales. The methodology used for the fuel-based estimate conforms to the methodology used and reported in the 2000 IMO Study of Greenhouse Gases. This approach is limited by the quality of the statistical data, and the way in which fuel sales volumes are assigned as either international or domestic.

Annual fuel consumption data were obtained from the IEA database for all reporting years from 1971 to 2005, the most recent data available. CO_2 emissions were calculated using the emission factors for marine fuels established by the IMO Informal Cross Government/Industry Scientific Group of Experts. CO_2 emissions for 2005 and an estimate for 2007 are shown in Table 2.

Table 2. CO_2 Emissions from shipping based on IEA data [million tonnes CO_2]

Year	2005	2007 est.
International shipping	531	582
Domestic shipping	101	111
Fishing	18	20
Total	651	713

As discussed in the main section of the report, issues such as the classification of fuel sales and the availability of statistical data from various countries result in a risk of under-reporting global total fuel sales. This also applies to other global data sets of marine fuel consumption or emissions such as data from EIA which largely rely on the same data as IEA. Therefore, as called for in the terms of reference an activity-based estimate was also made for the purpose of comparison.

1.3.2 Activity-based estimate (bottom-up estimate)

A global inventory was established for all ships greater than 100 GT based on data from the Lloyds Register Fairplay database for the year 2007, and using the best available data on vessel activity, engine and fuel characteristics, and carbon dioxide emission rates. The methodology used for the activity-based estimate has been applied in a number of scientific studies of this topic. This approach was also used in the work of the Informal Cross Government/Industry Scientific Group of Experts established by the IMO Secretary General.

The input data must be estimated for each ship category based on available background data. Although there is uncertainty in all of these figures, some of them can be estimated with high accuracy (number of ships, average power of main and auxiliary engines, specific fuel oil consumption, and fuel carbon content), and emission rates based upon fuel and combustion conditions can be described within well-understood ranges that give a satisfactory level of confidence. Other activity inputs vary by vessel service and voyage conditions and these are more difficult to assess. Comparisons with estimates for different periods would result in expected differences (e.g., from year to year, among vessel types, among routes, and even voyage to voyage) as they depend on the transport demand and the fleet size. In this study, an extensive set of AIS data collected from a global network has been used to assist the assessment of ship activity; AIS information and information on engine operating hours, fleet operating practices, etc., provide us with the ability to produce a consensus estimate inventory for shipping that is bounded by the range of reasonable estimates largely driven by activity-based inputs.

Since the estimate is based on all ships greater than 100 GT, the inventory includes domestic shipping and fishing vessels. In order to explore the uncertainty in the estimate, low and high bounds estimates were made. These bounding estimates represent feasible results but are less likely than the consensus estimate.

Table 3. Activity-based 2007 estimate of CO_2 emissions [million tonnes CO_2]

	Low bound	Consensus estimate	High bound
Total ship emissions[1]	854	1019	1224
- Oceangoing	474	593	681
- Coastwise	240	275	357
- Other	140	150	186

[1] All non-military ships greater than 100 GT.

1.3.3 Comparison of fuel consumption estimates

Previous activity-based estimates have been reported for different years (2000, 2001, and 2007). In order to be able to compare them with the results from this study (2007), backcasts and forecasts for these point estimates are calculated from the time evolution of freight tonne-miles from Fearnleys (2007). The result is shown in Figure 1 which also presents international bunker sales statistics and the historical estimates from Eyring et al. (2005a) and Endresen et al. (2003) from 1950 to 2007. Since some of these studies included emissions from military vessels, auxiliary engines and boilers while others did not, corrections have been applied to allow comparison as detailed in the main report. Also, these studies typically estimate totals for the fleet of ships listed in national ship registries, as summarized in the Lloyds ship registry data; therefore, they represent what has been termed the World Fleet within which international shipping as defined by IPCC would be a subset.

The activity-based estimate from the present study is shown as a blue dot in Figure 1. Light blue whisker lines extend from this point to indicate the range of uncertainty given by the high and low bound estimates. The activity-based estimate from the present study is lower than the estimate from the IMO expert group and forecasts based on Eyring et al. (2005a); however it agrees well with the result of Corbett and Kohler (2003) when military vessels are removed from their original figures. The 2007 estimate of this study is higher than that of Endresen et al. (2007), and higher than fuel statistics.

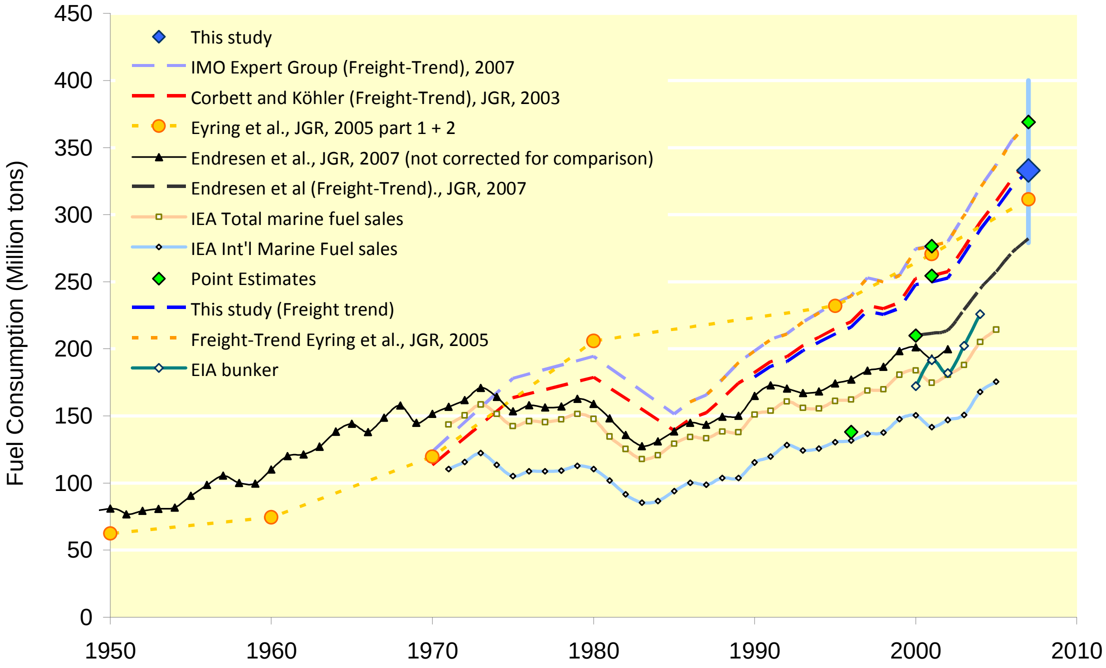

Figure 1. **World fleet fuel consumption (except military vessels) from different activity based estimates and fuel statistics. The blue square shows the consensus estimate from this study and the whiskers the high and low bound estimates**

1.3.4 Consensus estimate 2007 CO_2 emissions from International Shipping

Activity-based estimates consistently predict fuel consumption values that are higher than what is indicated in fuel statistics. While these activity-based estimates share many common inputs and assumptions and as such are not fully independent, statistical data on the other hand show some inconsistencies and could be expected to under-report consumption. Vessels can be categorized by activity as shown in Table 3, although this grouping does not explicitly match IPCC delineation of international and national shipping; for example, the sum of coastwise and other vessel activity categories exceeds the IEA statistics for domestic and fishing by more than three times, which indicates that significant coastwise and other shipping activity would likely be international.

Following the discussions detailed in Section 1.3.3 of this report, the international team of scientists behind this study concluded that the activity-based estimate is a more correct representation of the total emissions from the world fleet including in national ship registries than what is obtained from fuel statistics. Our team agreed that the activity-based estimate (Table 4) should be used as the consensus estimate from this study. Since the activity based model cannot separate domestic shipping from international shipping, domestic shipping emissions figures from bunker statistics have been used to calculate international shipping. Upper and lower bound estimates are about 20% higher and lower than the consensus figure.

Table 4. Consensus estimate 2007 CO_2 emission for international shipping [million tonnes CO_2]

	Low bound	Consensus	High bound
Total shipping emissions[1] (activity based)	854	1019	1224
Total less fishing (activity based)	796	954	1150
IEA domestic shipping (statistical data)	111	111	111
International shipping (hybrid estimate)	685	**843**	1039

1 All non-military ships greater than 100 GT.

1.4 Future CO_2 emissions from international shipping

Future CO_2 emissions from international shipping were estimated on basis of a relatively simple model developed in accordance with well-established scenario practice and methodology. The model incorporates a limited number of key driving parameters as shown in Table 5. These driving factors affect the various categories of ships in different ways. Therefore, the international shipping fleet was separated into three primary categories to allow differentiation of the overall effects of the above factors. These categories are:

- Coastwise shipping- Smaller ships used in coastal operations;
- Ocean-going shipping - Larger ships used long distance /intercontinental trade; and,
- Container ships (all sizes).

Table 5. 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, sectoral demand shifts.
Transport efficiency	Transport efficiency (MJ/tonne*mile) – depends on fleet composition, ship technology and operation;	Ship design, propulsion advancements, vessel speed, regulation aimed at achieving other objectives but that have a GHG emissions consequence
Energy	Shipping fuel carbon fraction (gC/MJ fuel energy)	Cost and availability of fuels (e.g., use of residual fuel, distillates, biofuels, or other fuels)

Scenarios are based on the framework for global development and storylines developed by the Intergovernmental Panel on Climate Change (IPCC) in the special report on emission scenarios (SRES).

- Storyline A1: a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and rapid introduction of new and more efficient technologies. Major underlying themes are economic and cultural convergence and capacity building, with a substantial reduction in regional differences in per capita income. In this world, people pursue personal wealth rather than environmental quality.
    - A1 is modeled in three variations: A1FI – emphasis on fossil fuels, A1T emphasis on technology and A1B, balanced emphasis

- Storyline A2: a very heterogeneous world with continuously increasing global population and regionally oriented economic growth that is more fragmented and slower than in other storylines.

- Storyline B1: a convergent world with the same global population as in the A1 storyline but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies.

- Storyline B2: a world in which the emphasis is on local solutions to economic, social, and environmental sustainability, with continuously increasing population (lower than A2) and intermediate economic development.

1.4.1 Economy and future shipping transport demand

Transport demand governs the size and activity level of the world fleet and is the most important driver for emissions from ships. The number of tonnes to be transported will depend on developments in trade, locations of factories, consumption of raw materials and other factors, while the distance will be affected by issues such as changing trade patters or possible new sea routes.

When determining future tonne-mile projections, GDP projections in the SRES scenarios have been the primary consideration. A hybrid approach considering both historic correlations between economic growth and trade as well as detailed analysis considering regional shifts in trade, increased recycling, new transport corridors, inter alia has been employed to derive the projections for future trade.

1.4.2 Future transport efficiency

Changes in the fleet composition can feasibly improve efficiency since larger ships are potentially more energy efficient. The effect of using larger ships has been modelled by predicting a change in the world fleet based on current trends towards 2020 as estimated by Lloyds Register Fairplay Research. Due to the uncertainties in predicting a 2050 fleet composition, no structural change is explicitly modelled from 2020 to 2050.

Economical optimal speed may decrease since fuel costs are expected to increase relative to other costs; hence market-driven speed changes are modelled.

Improvements can be made to new and existing ships to increase their energy efficiency. A detailed review of this topic will be made for Phase 2 of this study; however a preliminary assessment has been made to facilitate the scenario modelling. Since there are no regulations regarding fuel consumption, the change in the technology factor reflects improvements that are cost effective in the various scenarios rather than the technological potential. In addition to technological improvements, regulatory developments to improve other aspects of shipping may have impacts on the energy efficiency of ships. These factors are discussed and their impacts considered when determining scenario values for technological improvements.

1.4.3 Developments in marine fuels

The amount of CO_2 emitted from ships depends on the fuel type. For instance, certain fuels may contain more carbon per energy output than other fuels, and hence may produce more CO_2 emissions per unit work done. To capture this effect, future scenarios contain assumptions about future fuel use. When considering the market penetration of new fuels for the various scenarios it is noted that:

- Oil is a significant primary energy source in 2020 and 2050 in all scenario families (16-28% of world primary energy in 2050)
- In 2050, fossil fuels contribute from 57-82% of all primary energy in the SRES scenarios
- Previous estimates based on SRES scenarios range fuel consumption for shipping in 2050 from 400-810 million tonnes. This corresponds to 15-32 EJ or 10-15% of the global primary oil energy as specified for 2050 in the SRES scenarios.

It is thus considered that the SRES scenarios permit the continued use of oil-based fuels, although the cost would be expected to be higher. Therefore, in these non-GHG regulation scenarios, the move from oil-derived fuels would have to be motivated by economic factors. Since there are already binding emission targets for GHG reductions on land it is assumed that biofuels would fetch a better price there and would not be used by ships. The same situation would apply for the use of non-emitting or renewable energy from land.

1.4.4 Emission predictions

Key results from the scenario model are shown in Figure 2. Significant increases of CO_2 emissions are predicted. The emission increase is driven by the expected growth in seaborne transport. The scenarios with the lowest emissions deliver small reductions in 2050 compared to current emissions.

Our highest CO_2 emissions are essentially based on extrapolations of business as usual and minimum levels of efficiency improvements. Sustained low energy prices towards 2050 are a prerequisite for these scenarios. Therefore, the highest CO_2 emission scenarios do not appear likely. None of the scenarios show significant reductions in 2050 emissions. Such reductions would require radical changes compared to the assumptions in our model. Examples include:

- Abrupt decoupling between seaborne trade and global economic growth. In our model, the growth in transport demand is already lower than the correlation with GDP suggests, hence such decoupling must be rapid and very significant.
- Global economic growth rates significantly lower than the B2 scenario.
- Extreme fossil energy shortages compared to the SRES scenarios. According to SRES scenarios, by 2050, total primary energy consumption ranges from 160-284% of 2010 values and fossil fuels cover from 57-82% of global primary energy demand.
- Introduction of unexpected technologies.

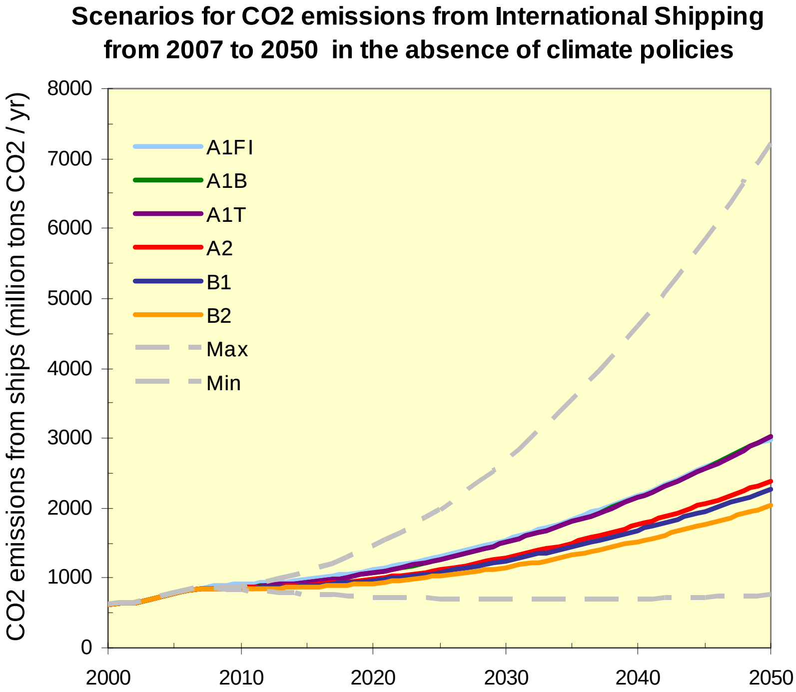

Figure 2. Emission trajectories for different scenarios. Legend refers to IPCC SRES. The scenario terminology is explained in Section 0 of this summary

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

Efficiency ranges of various forms of transport was 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 3. Efficiency is expressed as mass CO_2 / tonne-kilometre where the CO_2 expresses the total emissions from the activity and tonne-kilometre expresses the total transport work done. Total CO_2 emissions from ships have been compared to other transport modes based on fuel consumption data reported for other sectors in IEA statistics. This is shown in Figure 4. In this figure, the term ‘Road diesel’ refers to the total amount of diesel sold for road use, including cargo freight, passenger transport and diesel cars.

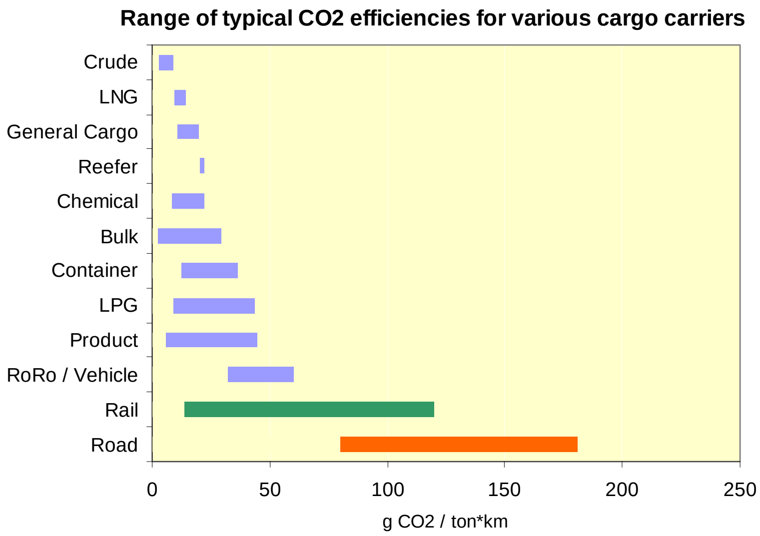

Figure 3. Typical ranges of ship CO_2 efficiencies compared to rail and road

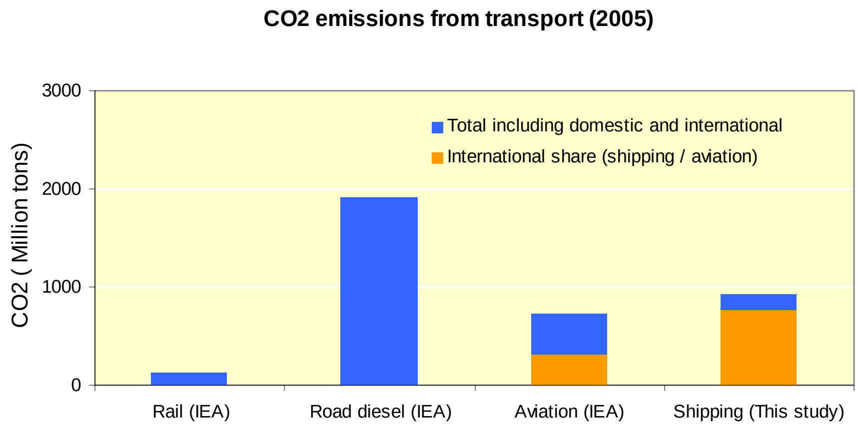

Figure 4. 2005 CO_2 emissions from shipping compared to other modes of transport

1.6 Radiative forcing impacts of CO_2 emissions from shipping

Increases in well-mixed greenhouse-gases such as carbon dioxide lead to positive radiative forcing (RF) and to global warming. Other radiative effects from shipping emissions will be considered in Phase 2.

CO_2 remains in the atmosphere for a long time and will continue to have a warming effect long after its emission. Therefore, emissions data from ships starting as early as 1870 has been used when calculating the RF of shipping CO_2 emissions. Since the historic data does not distinguish between international and domestic shipping, RF calculations are based on total shipping emissions rather than international shipping only.

In order to calculate the RF from shipping we use a linear climate response model to calculate the contribution of CO_2 emissions to marginal CO_2 concentrations and the consequential radiative forcing. This model takes emission rates, calculates the resultant atmospheric concentrations of CO_2 and then the RF which arises from changes in CO_2 concentration.

The RF from shipping CO_2 for 2005 was calculated to be 46 mW m^{-2}, contributing approximately 2.8% to the total anthropogenic CO_2 RF. For comparison, aviation has a similar – if slightly smaller – present day annual emission rate (733 Tg CO_2, 2005) but the RF is only 28 mW m^{-2}. The somewhat larger forcing from shipping in this comparison may be easily explained by both the residence time of CO_2 in the atmosphere and the time period of the activity.

Stabilization of atmospheric CO_2 concentrations by the end of the 21st century will require significant reductions in future global CO_2 emissions. The resultant temperature from stabilizing CO_2 concentrations at various levels (450 ppm, 550 ppm etc.) depends on climate sensitivity. Climate sensitivity is common test of climate models to the global mean surface temperature arising from a doubling of the CO_2 concentration. This is usually estimated to be between 2 and 4.5°C. A recent assessment of climate stabilization concluded that at 550 ppm, a target of 2°C would be exceeded, and 450 ppm would result in a 50% likelihood of achieving this target. To achieve this goal, total global CO_2 emissions must be limited to the values shown in WRE 450 in Figure 5 below. For comparison, the WRE 550 emission trajectory is also shown.

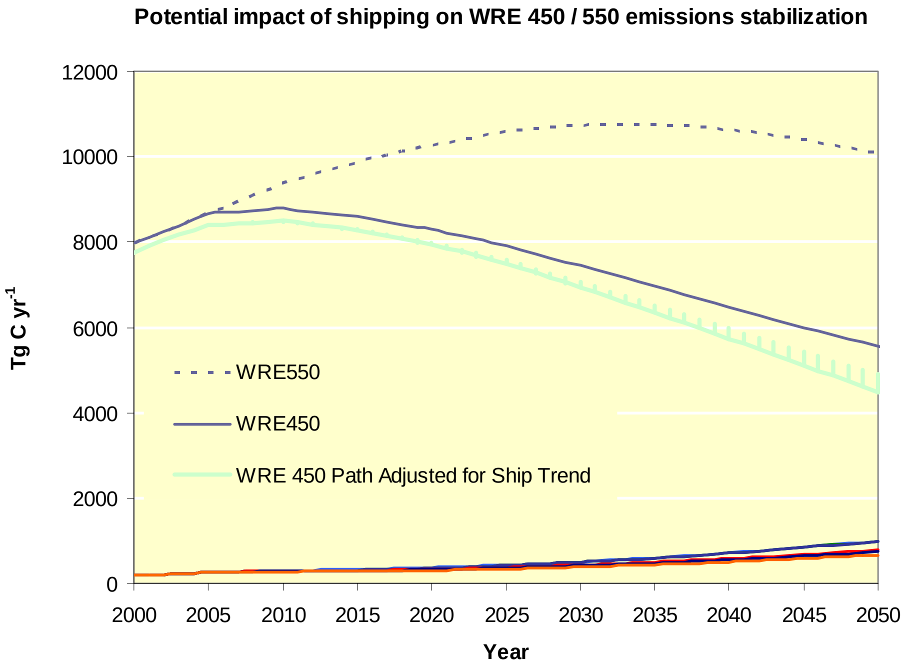

Figure 5. Comparison of modelled shipping emissions, lines for WRE 450 and WRE 550, and WRE 450 adjusted for ship emissions (Global total less shipping emissions). To achieve stabilization of atmospheric CO_2 at 450 ppm, global CO_2 emissions must follow the WRE 450 line

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