Technical support for European action to reducing Greenhouse Gas Emissions from international maritime transport
ANNEXES

Tender DG ENV.C3/ATA/2008/0016

Report
Delft, December 2009

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With assistance from DNV on some issues

Publication Data

Bibliographical data:
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Delft, CE Delft, December 2009

Maritime transport / Greenhouse gases / Emissions / Reduction / Technology / EC / Policy

Publication number: 09.7731.78

CE-publications are available from www.ce.nl.

Commissioned by: European Commission.
Further information on this study can be obtained from the contact person Jasper Faber.

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1 Estimation of the Marginal CO_2 Abatement Cost Curve

1.1 Introduction

The marginal CO_2 abatement cost curve as presented in chapter 4 is derived taking twenty-nine different technical and operational measures into account, allocated to twelve measure groups. In the following we will first give a list of the individual measures and very roughly describe the group they fall into. Subsequently, the way the individual measures are incorporated in the analysis are described in greater detail, and finally an overview is given of the assumed applicability of these measures to the different ship categories.

1.2 List of Individual Measures

1. Propeller/propulsion system upgrades:
   - a Propeller/rudder upgrade.
   - b Propeller upgrade.
   - c Propeller boss cap fins.
2. Propeller maintenance:
   - a Propeller perfomance monitoring.
   - b Propeller brushing (increased frequency).
   - c Propeller brushing.
3. Retrofit hull improvement:
   - a Transverse thruster opening (flow optimization, grids).
4. Hull coating and maintenance:
   - a Hull performance monitoring.
   - b Hull coating (type 1).
   - c Hull coating (type 2).
   - d Hull brushing.
   - e Hull hydro-blasting.
   - f Dry-dock full blast (for old ships).
5. Air lubrication:
   - a Air cavity system.
6. Main engine retrofit measures:
   - a Main engine tuning.
   - b Common rail upgrade.
7. Waste heat recovery.
8. Auxiliary systems:
   - a Low-energy/low-heat lighting.
   - b Speed control of pumps and fans.
   - c Power management.
9. Wind energy:
   - a Towing kite.
   - b Wind engines.
10. Solar energy.
11. Voyage and operations options:
    Optimization by using;
    - a A shaft power meter.
    - b A fuel consumption meter.
    - c Weather routing.

d Autopilot upgrade/adjustment.

12. Speed reduction:
    a Speed reduction of 10%.
    b Speed reduction of 20%.

In the first two groups are measures that aim at reducing the energy losses of the propulsion system and the propeller. In group three is a measure to reduce the drag of the hull, whereas the measures in group four and five are measures which reduce the frictional resistance of the hull of a vessel. Energy losses of the main engines could be reduced by retrofitting the main engine or making use of waste heat recovery (groups six and seven). Further options to abate CO_2 emissions are measures that reduce the energy consumption of the auxiliary systems (group eight), is the employment of renewable energy sources (groups nine and ten) and an optimization of the operation of a vessel (groups eleven and twelve).

1.3 The Individual Emission Abatement Measures

1.3.1 Hull Coating

By reducing the frictional resistance of a hull, consumption of bunker fuel and thus emissions of CO_2 can be reduced. One way of reducing the frictional resistance is to enhance the smoothness of a hull by means of coatings that prevent/reduce fouling.

We tried to estimate the cost efficiency and the maximum abatement potential of two different coatings, which we will call, in the following, 'coating 1' and 'coating 2'. We therefore had to make an estimation of the extra costs that have to be incurred and the extra benefits that can be reaped by using these coatings in comparison to regular TBT-free coatings. In the following we will briefly describe the estimation methods that were applied and the respective outcomes. Note that the results have to be considered not as a precise calculation but rather as a rough estimation, due to the lack of data.

The starting point of the estimation of the incremental costs of the coatings, in comparison to regular TBT-free coating, is the cost data given for a Panamax bulker. These costs can be estimated to lie in a range of US$ 43,000 to US$ 51,600 for coating 1 and in a range of US$ 221,000 to US$ 265,200 for coating 2.

We assume that the incremental costs vary between the different ship categories, since these differ in the size of the hull surface to be treated. To make an estimation of the incremental costs that have to be incurred by the different ship categories, we applied a cost factor to the costs given for the Panamax bulker, based on the gross tonnage of the different ship categories. This cost factor is derived, making the simplifying assumption that the hull surface to be painted is proportional to the 2/3-power of the gross tonnage of the ship and that the incremental costs vary linearly with this estimated surface. For the calculation of the cost efficiency, we assumed that the estimated costs have to be borne every five years to be able to gain the fuel/emission benefit as specified below. For simplicity, we use one cost figure for retrofitting and non-retrofitting of the coating.

The starting point of the estimation of the incremental benefits, in comparison to regular TBT-free coating, is again the data given for a Panamax bulker. These incremental fuel/CO_2 savings can be estimated to lie in a range of 0.5–2% for coating 1 and in a range of 1–5% for coating 2. We assume that these benefits differ between the different ship types. To make the distinction of the different fuel savings per ship type, we make use of the fuel savings that are guaranteed by one manufacturer in the initial period for one of its coatings and assign the difference between the ship types given there to the range of fuel saving given for the Panamax bulker.

1.3.2 Air Lubrication

The frictional resistance of a vessel's hull can be reduced by a so-called 'air-cavity system' (ACS). The ACS is a non-retrofit measure whose lifetime is assumed to be 30 years. Tankers, bulk carriers and container vessels may make use of the system. Since the length of a vessel should be minimal 225 metres (LOA), we decided to consider the following vessels as potential users:

- Crude oil tanker and bulk carriers > 60,000 dwt.
- LPG tankers with 50,000 m^3 capacity and more.
- All LNG tankers.
- Full container vessels > 2000 TEU.

Recently, the first sea-trial with a test ship and operational tests in open water have been conducted. The technology was commercially available at the end of 2008. As to the potential reduction in fuel consumption and CO_2 emissions, the producer gives the following ranges: 10-15% for tanker and bulkers and 5-9% for container vessels. We used in our analysis half of this lower bound as the low reduction potential and the high reduction potential as given by the producer. Operational costs of an ACS translate into 0.3 to 0.5 tonnes of fuel per day, depending on sea conditions. Note that researchers from the Stichting FOM and the University of Twente pointed out that the potential fuel savings of a system like the air-cavity system depend highly on the smoothness of the hull. Good maintenance is thus required to actually realize the projected fuel savings. The operational costs for maintenance may therefore rise due to the application of an ACS. These extra costs are here not taken into account.

The incremental non-recurring costs are expected to be 2-3% of the price of a conventional newly built vessel (without ACS). We deduced the prices for newbuilts from UNCTAD (2008), applying a correction factor of 0.7.

1.3.3 Waste Heat Recovery

With a waste heat recovery (WHR) system the waste heat of the engines can be used to drive turbines for electricity production. Thus, when using WHR, less fuel is needed for the production of electricity. A WHR system is reasonably applied to ships with a high production of waste heat and a high consumption of electricity. Therefore it is being assumed that only those ships apply WHR for which holds that the main engines' average performance is higher than 20,000 kW and the auxiliary engines' average performance is higher than 1,000 kW. When using a WHR system not only fuel savings can be realized but also maintenance costs and costs for lubricants do decrease. In Wärtsilä (2007) a case study is given for high efficiency WHR. In this case study the lubrication oil saving is bout 7% and the maintenance cost saving bout 31%. For a capesize bulk carrier about 8% and 4% of the operational costs are on average related to lubricants and maintenance respectively (Stopford, 2008). When simplifying assuming that across ship types the relative saving due to WHR and the relative composition of the operational costs are the same, it can be concluded that a WHR system leads to a saving of operational costs of about 2%. As to the emission reduction potential, different numbers can be found in the literature. For higher output engines Wärtsilä assesses a high efficiency WHR plant to be able to recover up to about 12% of the engine shaft power (WHR, 2007). In the case study given in the same leaflet the saving amounts to 11.3 %. On the other hand, the upper percentage of the potential annual saving in fuel costs is given to be lower than 10% (Wärtsilä, 2008). Siemens (2009) estimates the saving of energy costs of a combination of an electrical booster drive and WHR to be approximately 12%. Given these figures we decided to stick to an emission reduction potential of 8-10%. We calculated the capital costs of the technology by making use of the information provided by Wärtsilä (Wärtsilä, 2008), namely that the payback time is medium (with a high payback time being more than 15 years and low payback time being lower than a year). Assuming that this payback time is based on a fuel price of 300$/ton and given the reduction potential and the saving in operational costs as mentioned above the capital costs are determined.

1.3.4 Towing Kites

A towing kite makes use of wind energy to substitute power of the engine. The system can be retrofitted. It can be used on vessels with a minimum length of 30 m and works best on ships with an average speed no higher than 16 knots. Due to this speed restriction, only tankers (crude oil, product, chemical, LPG, LNG, other) and bulk carriers are being considered as potential users (see Corbett et al. (2006) for the average speed per vessel type).
Until now, kites that have an area of up to 640 m^2 for cargo vessels, fishing trawlers and yachts are available and kite systems have been installed on three vessels: a testing ship and two commercial ships, both multipurpose cargo vessels. One of the commercial ships is a newly built vessel, the other was retrofitted. Both vessels are equipped with a 160 m^2 kite. Kites up to an area of 5,000 m^2 are planned. For the calculation of the cost efficiency and the maximum abatement potential of a towing kite, we assume that, in 2030, kites up to 5,000 m^2 are available in the market.
It is difficult to determine the potential reduction of fuel usage (and hence of CO_2 emitted) of a towing kite, since the potential does not only depend on the area of a kite applied, but also on the route a vessel takes and the respective weather conditions. In the following table, the engine equivalent powers we used for the different kite sizes are given. These numbers hold under standard conditions[1].

Table 1 Approximate engine equivalent power used for the different kites

Kite area (m^2)	Engine equivalent power (kW)
160	600
320	1,200
640	2,500
1,280	4,900
2,500	9,600
5,000	19.200

For the lower (higher) bound estimate we assume that the kite can be used 1/3 (2/3) of the days at sea.
The cost data that were used in our calculations are given in the following table. The purchase price varies with the kite system that is used. Installation and operational costs are taken to be a certain share of the purchase price. For simplicity, we use the same percentage for the installation costs of retrofit and non-retrofit systems. Note that the cost data are such that possible reinvestments during the lifetime of a vessel, i.e. 30 years, are included.

1 The standard conditions are defined as follows: the vessel cruises at a speed of 10 knots at a true wind course of 130°, the wind speed is 25 knots, waves are up to 60 cm high and the kite is manoeuvred dynamically.

Table 2 **Cost estimates of for a towing kite system**

	Kite area (m^2)				
	320	**640**	**1280**	**2500**	**5000**
Purchase price (Euro)	350,000	670,000	1,280,000	1,890,000	2,500,000
Installation costs (% of purchase price)	7.5%	7.5%	7.5%	7,5%	7,5%
Operational costs per annum (% of purchase price)	5-7%	7-9%	9-11%	11-13%	13-15%

1.3.5 Wind Engines

Rotors placed on deck of a ship can generate thrust, taking advantage of the so-called Magnus effect. Greenwave estimates that vessels upwards of 10,000 tonnes dwt of the following types could be 'most immediately' applicable for wind energy technology from the 'available footprint'[2] point of view: crude oil tankers, chemical tankers, product tankers, and bulk carriers. Greenwave carried out tests with two configurations of wind engines. A four engine system that is preferable for bulk carriers, with the engines being out of the way of the cargo holds and a three engine system which may be applied to tankers where crane operations are not involved. Greenwave estimates that the costs for manufacturing and installing of four wind engines lies in the range of US$ 0.8 m – US$ 1 m. For a Supramax bulker with 55,000 dwt equipped with a four wind engine system (rotor height 20 m and rotor diameter 2.3 m) that is 246 days at sea per annum Greenwave estimates an average fuel consumption saving of 1,023 tonnes per year.
Simplifying assuming:

1. That crude oil carriers, product tankers and bulk carriers with a dead weight ton of more than 60,000 can be equipped with wind engines[3].
2. That bulk carriers re equipped with four engine system and tankers with three engine system.
3. That the costs for manufacturing and installing rotors is liner in the number of wind engines.
4. That no operational costs accrue.
5. That the reduction potential for the different ship types is in absolute terms per rotor and per day the same s the one featured by the Supramax bulker.

We derived the following relative fuel reduction potentials for 2030.

[2] Footprint means the area that is required on deck for the installation of a rotor.

[3] We choose that threshold because the cost data is available for a package of four wind engines and can thus be related to the savings of the Supramax bulker of 55,000 dwt that is equipped with four engines. A threshold of 60,000 dwt is chosen instead of 55,000 dwt, since this is the size threshold used in the classification of the IMO (IMO, 2009). Because there are only very few chemical tankers bigger than 60,000 dwt we did not take these into account.

Table 3 **Estimation of the Relative Emission Reduction Potential of Wind Engines**

	dwt	Reduction potential in 2030 (%)
Crude oil tanker	> 200,000	3.6
Crude oil tanker	120,000 - 199,999	4.5
Crude oil tanker	80,000 - 119,000	5.2
Crude oil tanker	60,000 - 79,999	6.6
Product tanker	> 60,000	4.4
Bulk carrier	> 200,000	7.2
Bulk carrier	100,000 - 199,999	8.3
Bulk carrier	60,000 - 99,000	12.4

1.3.6 Solar Energy
Solar cells can only be placed on ships that have sufficient deck space available. Therefore it is assumed that they can be used by tankers, vehicle carriers and RoRo vessels. For a car carrier that installed 40kW of solar cells the investment costs are known to be 150,000,000 Yen (Tsukimori, 2008). Due to a lack of further cost data we simplifying assume that if a ship makes use of solar energy it installs solar cells to the same extent as it has been installed on this car carrier and at the same costs, leading to an emission reduction to 0.2% for a big crude oil tanker to a reduction to 3.75% for a small chemical tanker.

1.3.7 Speed Reduction
In the measure group'speed reduction', we consider two possibilities: either that a ship, existing or newly built, slows down by 10% or that it slows down by 20%. Emissions from a vessel are roughly related to the square of the vessel's speed. A speed reduction of, for example, 10% can thus lead to a reduction of emissions of 19% on a tonnekilometre basis. Since a reduction of speed affects the amount of freight that can be transported by a vessel over a particular time period, an operator has to make use of additional capacity in order to avoid losses (AEA, 2008). In our analysis we assume that the extra capacity is provided by new vessels. In other words, the basic assumption is that, in the initial situation, the market is in an equilibrium with no overcapacity. Thus the reduction of a ship's speed will not result in higher load factors of the existing ships or in an existing ship being able to sail extra days per year. The non-recurring costs of the measure 'speed reduction' are the costs for purchasing the extra vessels. The recurring costs are the annual operational costs of the extra vessels, including the fuel consumption at the lower speed. The emission reduction of the 'original' fleet has to be offset against the extra emissions of the additional vessels.

1.3.8 The Other Emission Abatement Measures
In the following we will briefly present the other emission abatement measures, not described in greater detail yet. For several measures, the cost data will not be given explicitly. The data for these measures were taken from Wärtsilä (2008). In this brochure, the reduction potential and the payback time of different measures are specified. Assuming that the price of bunker fuel underlying these data is US$ 300/tonne, and making use of the IMO fuel consumption data of the fleet in 2007, we derived the corresponding costs of the measures for the different ship types. Since the reduction potential and the payback time are not differentiated with respect to ship types, whereas fuel consumption is, the costs for a measure differ per ship type. In Table 4 you find these measures, the respective average relative reduction potentials per ship and the payback times that were used in our calculation. You find the lifetime/the frequency of the investment that were assumed in the third column.

Table 4 Overview on the Data Used for the Emission Abatement Measures Taken from Wärtsilä (2008)

Measure	Average Relative Reduction Potential Per Ship	Payback Time	Life time/Frequency of Investment
Propeller/rudder upgrade	4%	10	10
Propeller upgrade	2.5%	10	10
Propeller performance monitoring	2.25%	0.5	10
Propeller brushing	3.5%	0.5	10
Transverse thruster opening (flow optimization, grids)	3%	0.5	10
Main engine tuning	0.45%	10	10
Common rail upgrade	0.3%	5	10
Low-energy/low-heat lighting	0.45%	10	10
Speed control of pumps and fans	0.6%	10	10
Power management	2.25%	10	10
Autopilot upgrade/adjustment	1.75%	0.5	10

As to the residual measures, the data are, if not otherwise mentioned, based on an expert assessment of the consortium of the IMO study (IMO, 2009). In the following table a brief overview is given on the data and the assumptions that have been used with respect to these measures.

Table 5 Overview on the Data/Assumptions Used for the Residual Emission Abatement Measures

	Cost Data/Assumptions	Reduction Potential Data (Ship Basis)	Other
Propeller boss cap fins	US$ 20,000 for 735 kW engine and US$ 146,000 for 22,050 kW engine (Frey and Kuo, 2007); Linear relationship between kW of main engine and price; No recurring costs	4-5%	
Propeller brushing (increased frequency)	US$ 3,000 – 4,500 per five year period; Costs are the same for every ship type.	0.5 – 3%	
Hull performance monitoring	US$ 45,000 per five year period; US$ 5,000 p.a.; Costs are the same for every ship type.	0.5 - 5%	
Hull brushing	US$ 26,000-39,000 per five year period; To differentiate costs between ship types, the same cost factor is being applied as for the hull coating measures.	1 – 10%	

	Cost Data/Assumptions	Reduction Potential Data (Ship Basis)	Other
Hull hydro blasting	US$ 33,000-49,500 per five year period; To differentiate costs between ship types, the same cost factor is being applied as for the hull coating measures.	1 – 10%	
Dry dock full-blast	US$ 86,000-81,600; To differentiate costs between ship types, the same cost factor is being applied as for the hull coating measures.	5 – 10%	Full blast, instead of a spot blast; Applied once to old ships to restore condition (assumed to be 25 year old vessels).
Shaft power meter	US$ 26,000-31,200 (purchase costs of meter) per ten year period; Costs are the same for every ship type.	0.5 - 2%	Benefit from optimizing ballast, load and trim.
Fuel consumption meter	US$ 46,000-55,200 (purchase costs of meter) per ten year period; Costs are the same for every ship type.	0.5 - 2%	Benefit from optimizing ballast, load and trim.
Weather routing	US$ 800-1,600 p.a.; Costs are the same for every ship type.	0.1 – 4%	Applied by ships with route flexibility.

1.4 Applicability of Emission Abatement Measures

In Table 6 an overview is given on the applicability of the twenty-nine different emission abatement measures to the fifty-three different ship categories. Thereby ‘R’, ‘N’, and ‘O’ stand for retrofit, newbuilts and operational respectively, meaning that the measure under consideration is assumed to be a measure that can be retrofitted, to be a measure that can only be applied to newly built ships or to be an operational measure. Note that applicability does not mean that as a result all the measures that can be applied to a ship category are actually being applied. As described in chapter 4, the individual, each other excluding measures are allocated to measure groups with only one measure out of this group being applied to a ship category.

Table 6 Applicability of the Different Emission Abatement Measures as assumed in this study (R: retrofit, N: newbuilts, O: operational)

		Propeller/rudder upgrade	Propeller upgrade	Propeller boss cap fins	Propeller performance monitoring	Propeller brushing (increased frequency)	Propeller brushing	Transverse thruster opening (grids etc.)	Hull performance monitoring	Hull coating (type 1)	Hull coating (type 2)	Hull brushing	Hull-hydro blasting	Dry dock full blast (old ships only)	Air lubrication	Main engine tuning	Common rail upgrade	Waste heat recovery	Low -energy/l-hearing lighting	Speed control of pumps and fans	Power Management	Towing kite	Wind engine	Solar cells	Shaft power meter	Fuel consumption meter	Weather routing	Autopilot upgrade/adjustment	Speed reduction 10%	Speed reduction 20%
Crude oil	200,000+ dwt	R	R	R	O	O	O	R	O	O	O	O	O	O	N	R	R	R		R	N	R	R	R	O	O	O	O	O	O
Crude oil	120-199,999 dwt	R	R	R	O	O	O	R	O	O	O	O	O	O	N	R	R	R		R	N	R	R	R	O	O	O	O	O	O
Crude oil	80-119,999 dwt	R	R	R	O	O	O	R	O	O	O	O	O	O	N	R	R			R	N	R	R	R	O	O	O	O	O	O
Crude oil	60-79,999 dwt	R	R	R	O	O	O	R	O	O	O	O	O	O	N	R	R			R	N	R	R	R	O	O	O	O	O	O
Crude oil	10-59,999 dwt	R	R	R	O	O	O	R	O	O	O	O	O	O		R	R			R	N	R		R	O	O	O	O	O	O
Crude oil	-9,999 dwt	R	R	R	O	O	O	R	O	O	O	O	O	O		R	R			R	N	R		R	O	O	O	O	O	O
Product	60,000+ dwt	R	R	R	O	O	O	R	O	O	O	O	O	O		R	R			R	N	R	R	R	O	O	O	O	O	O
Product	20-59,999 dwt	R	R	R	O	O	O	R	O	O	O	O	O	O		R	R			R	N	R		R	O	O	O	O	O	O
Product	10-19,999 dwt	R	R	R	O	O	O	R	O	O	O	O	O	O		R	R			R	N	R		R	O	O	O	O	O	O
Product	5-9,999 dwt	R	R	R	O	O	O	R	O	O	O	O	O	O		R	R			R	N	R		R	O	O	O	O	O	O
Product	-4,999 dwt	R	R	R	O	O	O	R	O	O	O	O	O	O		R	R			R	N	R		R	O	O	O	O	O	O
Chemical	20,000+ dwt	R	R	R	O	O	O	R	O	O	O	O	O	O		R	R			R	N	R		R	O	O	O	O	O	O
Chemical	10-19,999 dwt	R	R	R	O	O	O	R	O	O	O	O	O	O		R	R			R	N	R		R	O	O	O	O	O	O
Chemical	5 -9,999 dwt	R	R	R	O	O	O	R	O	O	O	O	O	O		R	R			R	N	R		R	O	O	O	O	O	O
Chemical	-4,999 dwt	R	R	R	O	O	O	R	O	O	O	O	O	O		R	R			R	N	R		R	O	O	O	O	O	O

		Propeller/rudder upgrade	Propeller upgrade	Propeller boss cap fins	Propeller performance monitoring	Propeller brushing (increased frequency)	Propeller brushing	Transverse thruster opening (grids etc.)	Hull performance monitoring	Hull coating (type 1)	Hull coating (type 2)	Hull brushing	Hull-hydro blasting	Dry dock full blast (old ships only)	Air lubrication	Main engine tuning	Common rail upgrade	Waste heat recovery	Low -energy/l-hearing lighting	Speed control of pumps and fans	Power Management	Towing kite	Wind engine	Solar cells	Shaft power meter	Fuel consumption meter	Weather routing	Autopilot upgrade/adjustment	Speed reduction 10%	Speed reduction 20%
LPG	50,000+ cbm	R	R	R	O	O	O	R	O	O	O	O	O	O	N	R	R			R	N	R		R	O	O	O	O	O	O
LPG	-49,999 cbm	R	R	R	O	O	O	R	O	O	O	O	O	O		R	R			R	N	R		R	O	O	O	O	O	O
LNG	200,000+ cbm	R	R	R	O	O	O	R	O	O	O	O	O	O	N	R	R	R		R	N	R		R	O	O	O	O	O	O
LNG	-199,999 cbm	R	R	R	O	O	O	R	O	O	O	O	O	O	N	R	R	R		R	N	R		R	O	O	O	O	O	O
Other tanker		R	R	R	O	O	O	R	O	O	O	O	O	O		R	R			R	N	R		R	O	O	O	O	O	O
Bulker	200,000+ dwt	R		R	O	O	O	R	O	O	O	O	O	O	N	R	R			R	N	R	R		O	O	O	O	O	O
Bulker	100-199,999 dwt	R		R	O	O	O	R	O	O	O	O	O	O	N	R	R			R	N	R	R		O	O	O	O	O	O
Bulker	60-99,999 dwt	R		R	O	O	O	R	O	O	O	O	O	O	N	R	R			R	N	R	R		O	O	O	O	O	O
Bulker	35-59,999 dwt	R		R	O	O	O	R	O	O	O	O	O	O		R	R			R	N	R			O	O	O	O	O	O
Bulker	10-34,999 dwt	R		R	O	O	O	R	O	O	O	O	O	O		R	R			R	N	R			O	O	O	O	O	O
Bulker	-9,999 dwt	R		R	O	O	O	R	O	O	O	O	O	O		R	R			R	N	R			O	O	O	O	O	O
General cargo	10,000+ dwt	R		R	O	O	O	R	O	O	O	O	O	O		R	R			R	N				O	O	O	O	O	O
General cargo	5,000-9,999 dwt	R		R	O	O	O	R	O	O	O	O	O	O		R	R			R	N				O	O	O	O	O	O
General cargo	-4,999 dwt	R		R	O	O	O	R	O	O	O	O	O	O		R	R			R	N				O	O	O	O	O	O
General cargo	10,000+ dwt, 100+ TEU	R		R	O	O	O	R	O	O	O	O	O	O		R	R			R	N				O	O	O	O	O	O
General cargo	5,000-9,999 dwt, 100+ TEU	R		R	O	O	O	R	O	O	O	O	O	O		R	R			R	N				O	O	O	O	O	O
General cargo	-4,999 dwt, 100+ TEU	R		R	O	O	O	R	O	O	O	O	O	O		R	R			R	N				O	O	O	O	O	O

		Propeller/rudder upgrade	Propeller upgrade	Propeller boss cap fins	Propeller performance monitoring	Propeller brushing (increased frequency)	Propeller brushing	Transverse thruster opening (grids etc.)	Hull performance monitoring	Hull coating (type 1)	Hull coating (type 2)	Hull brushing	Hull-hydro blasting	Dry dock full blast (old ships only)	Air lubrication	Main engine tuning	Common rail upgrade	Waste heat recovery	Low -energy/l-hearing lighting	Speed control of pumps and fans	Power Management	Towing kite	Wind engine	Solar cells	Shaft power meter	Fuel consumption meter	Weather routing	Autopilot upgrade/adjustment	Speed reduction 10%	Speed reduction 20%
Other dry cargo	Reefer	R		R	O	O	O	R	O	O	O	O	O	O		R	R			R	N				O	O	O	O	O	O
Other dry cargo	Special	R		R	O	O	O	R	O	O	O	O	O	O		R	R			R	N				O	O	O	O	O	O
Container	8,000+ TEU	R		R	O	O	O	R	O	O	O	O	O	O	N	R	R	R		R	N				O	O	O	O	O	O
Container	5 -7,999 TEU	R		R	O	O	O	R	O	O	O	O	O	O	N	R	R	R		R	N				O	O	O	O	O	O
Container	3 -4,999 TEU	R		R	O	O	O	R	O	O	O	O	O	O	N	R	R	R		R	N				O	O	O	O	O	O
Container	2 -2,999 TEU	R		R	O	O	O	R	O	O	O	O	O	O	N	R	R	R		R	N				O	O	O	O	O	O
Container	1 -1,999 TEU	R		R	O	O	O	R	O	O	O	O	O	O		R	R			R	N				O	O	O	O	O	O
Container	-999 TEU	R		R	O	O	O	R	O	O	O	O	O	O		R	R			R	N				O	O	O	O	O	O
Vehicle carrier	4,000+ CEU	R		R	O	O	O	R	O	O	O	O	O	O		R	R			R	N			R	O	O	O	O	O	O
Vehicle carrier	-3,999 CEU	R		R	O	O	O	R	O	O	O	O	O	O		R	R			R	N			R	O	O	O	O	O	O
RoRo	2,000+ lm	R		R	O	O	O	R	O	O	O	O	O	O		R	R	R		R	N			R	O	O	O	O	O	O
RoRo	-1,999 lm	R		R	O	O	O	R	O	O	O	O	O	O		R	R			R	N			R	O	O	O	O	O	O
Ferry	Pax Only, 25kn+			R	O	O	O	R	O	O	O	O	O	O			R		R	R	N				O	O		O		
Ferry	Pax Only, <25kn			R	O	O	O	R	O	O	O	O	O	O			R		R	R	N				O	O		O		
Ferry	RoPax, 25kn+			R	O	O	O	R	O	O	O	O	O	O			R		R	R	N				O	O		O		
Ferry	RoPax, <25kn			R	O	O	O	R	O	O	O	O	O	O			R		R	R	N				O	O		O		
Cruise	100,000+ gt			R	O	O	O	R	O	O	O	O	O	O			R	R	R	R	N				O	O		O		
Cruise	60-99,999 gt			R	O	O	O	R	O	O	O	O	O	O			R	R	R	R	N				O	O		O		
Cruise	10-59,999 gt			R	O	O	O	R	O	O	O	O	O	O			R	R	R	R	N				O	O		O		
Cruise	2-9,999 gt			R	O	O	O	R	O	O	O	O	O	O			R		R	R	N				O	O		O		
Cruise	-1,999 gt			R	O	O	O	R	O	O	O	O	O	O			R		R	R	N				O	O		O		

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Annex B

EU's competencies to regulate international shipping emissions

EU's competencies to regulate international shipping emissions

Overview of the EU's competence to implement legislation in the maritime field outside its territorial waters and consideration of existing international law in this area

Competence under the EC Treaty

A primary consideration is whether the EC Treaty (**ECT**) gives a legal basis for the EU to implement a climate policy for CO_2 maritime emissions. Article 2 ECT explicitly tasks the Community with creating "a high level of protection and improvement of the quality of the environment". Furthermore Article 6 ECT directs that environmental protection requirements "must be integrated into the definition and implementation of the Community policies and activities", and "in particular with a view to promoting sustainable development". In confirmation of this legal basis Article 174 and 175 ECT impose environmental obligations upon the EU and in particular Article 174 requires Community policy on the environment to aim "at a high level of protection" and to be "based on the precautionary principle". Furthermore case law from the International Court of Justice has established that the Community's external powers extend beyond those listed in the Treaty. Henrik Ringbom emphasises that "Community powers to enter into international agreements may also "flow from other provisions of the Treaty and from measures adopted, within the framework of those provisions, by the Community institutions""[1].

Notable action was taken within the EU in the aftermath of the *Erika* and *Prestige* pollution incidents. France and Spain banned certain ships from their 200 nm exclusive economic zones; however these unilateral measures did not comply with international law, particularly the United Nations Convention on the Law of the Sea, considered below.

The response to the *Erika* and *Prestige* incidents at a Community level included Regulation 1726/2003 amending Regulation 417/2002 on accelerating the phasing out of single hull oil tankers and Directive 2005/35 creating a sanction regime for ship-source pollution offences. Henrik Ringbom makes the point that the measures following the *Prestige* and *Erika* incidents represented a shift in Community policy, and that "some of the measures clearly demonstrated a more independent stance in relation to international standards than had been the case previously"[2]. The Regulation and Directive have been referred to as "controversial"[3], and one commentator specifically notes that "by adopting port State regulation, the Community has been able to bypass jurisdictional limitations and impose international standards on all ships calling on its ports"[4]. Ringbom notes that Regulation 1726/2003 was adopted on a unilateral basis "while (re)amendment negotiations were still underway at the IMO…which meant that there was an 18-month period during which there were serious inconsistencies between the two sets of rules"[5]. The phasing out of single hull tankers covered in Regulation 1726/2003 applied to ships that are also subject to MARPOL rules (considered below). Ringbom considers the legal difficulties with this situation but notes that "the virtual absence of protests or legal challenges against this Regulation may seem surprising, but it is probably largely due to the fact that the IMO eventually agreed to largely similar rules only some months later and that the rules in the meantime had relatively little effect on single-hulled ships entering the EU"[6]. Furthermore a challenge to Directive 2005/35 was made and rejected before the ECJ in Case C-308/06 *The Queen on the application of Intertanko and others v Secretary of State for Transport.*

[1] "The EU Maritime Safety Policy and International Law" Henrik Ringbom 2008 at p55 Referring to Case 22/70 , AETR [1971] ECR P263 at para 15-16
[2] The EU Maritime Safety Policy and International Law" Henrik Ringbom 2008 at p44
[3] Rosa Greaves in "EC Maritime Transport Law and Policy" [2007] ICQL 415
[4] Rosa Greaves in "EC Maritime Transport Law and Policy" [2007] ICQL 415
[5] The EU Maritime Safety Policy and International Law" Henrik Ringbom 2008 p347
[6] The EU Maritime Safety Policy and International Law" Henrik Ringbom 2008 p352

EU competency in internal seas, ports and the territorial sea

The EU is a signatory to the United Nations Convention on the Law of the Sea 1982 (**UNCLOS**), which defines the rights and responsibilities of nations in their use of the world's oceans.

Article 2 UNCLOS (set out in Part II section 1 (General Provisions)) relates to the legal status of the territorial sea, of the air space over the territorial sea and of its bed and subsoil. More specifically Article 2 provides that:

1 *The sovereignty of a coastal State extends, beyond its land territory and internal waters and, in the case of an archipelagic State, its archipelagic waters, to an adjacent belt of sea, described as the territorial sea.*

2 *This sovereignty extends to the air space over the territorial sea as well as to its bed and subsoil.*

3 *The sovereignty over the territorial sea is exercised subject to this Convention and to other rules of international law.*

Article 3 UNCLOS clarifies the meaning of "territorial sea"; explaining that "every State has the right to establish the breadth of its territorial sea up to a limit not exceeding 12 nautical miles, measured from baselines determined in accordance with this Convention".

It is therefore clear under international law that the right of a port state to exercise its jurisdiction within its territory (i.e. its internal waters) is presumed. As ports are located within a state's territory, all ports fall within that state's territorial sovereignty. In support of this, customary international law also acknowledges that a port is entitled to exercise its state's jurisdiction at the port, always subject to and in accordance with generally accepted principles of international law and the provisions of UNCLOS.

The term "generally accepted international rules and standards", often referred to as "GAIRAS", is of critical importance for state jurisdiction and is not further defined by UNCLOS. The range of views on its meaning are wide, and encompass "the customary principles and rules of international law" to "a rule fairly balancing the interests of all states and adopted by a majority of states, including almost all states with any special interest in that rule". The lack of clarity in this respect may amount to the application of discretion by states in determining the degree to which they should be bound by international rules and standards.

EU Competency in the Exclusive Economic Zone

A coastal state also has a level of jurisdiction over its Exclusive Economic Zone (**EEZ**).

Article 55 UNCLOS states that "The exclusive economic zone is an area beyond and adjacent to the territorial sea", and Article 57 UNCLOS determines that "the exclusive economic zone shall not extend beyond 200 nautical miles from the baselines from which the territorial sea is measured". Jurisdiction in the EEZ is considered in Article 56 UNCLOS, and includes jurisdiction with regard to "the protection and preservation of the marine environment". However, it is important to bear in mind that Article 58 UNCLOS makes clear that freedom of navigation under Article 87 UNCLOS also applies to the EEZ, and this may limit particular policy options as considered below.

EU Competency beyond the EEZ

Part VII UNCLOS deals with the "High Seas" and Article 86 UNCLOS states that this Part applies to "all parts of the sea that are not included in the exclusive economic zone, in the territorial sea or in the internal waters of a State, or in the archipelagic waters of an archipelagic State". Therefore beyond the 200nm EEZ are the high seas, and Article 87 UNCLOS makes explicit that "the high seas are open to all States". Furthermore Article 89 UNCLOS asserts that "no State may validly purport to subject any part of the high seas to its sovereignty". It is therefore difficult to argue that the EU has any competence to exercise jurisdiction beyond the EEZ of EU states.

However, according to the definition of 'international organisation' set out in Article 1 of Annex IX UNCLOS the EU has competence on behalf of its member states regarding matters covered by UNCLOS, including "the competence to enter into treaties in respect of these matters". This is useful as a number of UNCLOS provisions provide scope for the EU to fulfil its policy aims in this context.

The provisions of Article 25.2 (Rights of protection of the coastal State) UNCLOS suggest that a port is entitled to refuse the admission of a vessel into its internal waters if the vessel does not comply with that state's conditions of entry:

> *In the case of ships proceeding to internal waters or a call at a port facility outside internal waters, the coastal State also has the right to take the necessary steps to prevent any breach of the conditions to which admission of those ships to internal waters or such a call is subject.*

As such, while non-EU states may be able to challenge the EU's jurisdiction to charge taxes or implement emissions standards outside EU waters, in implementing the provisions of an EU Regulation or Directive an EU member state would nonetheless be permitted to refuse the access of a ship to EU waters if that ship had not complied with the relevant emissions laws and regulations. This is justified on the grounds that the member state was acting so as to prevent any breach of those laws or regulations.

Part XII of UNCLOS sets out the principles governing the protection and preservation of the marine environment and, while the effect of certain of the provisions contained in this section would not apply directly to any of the options proposed to be adopted by the EU, they provide a useful insight into how any emissions regime adopted by the EU would interact with UNCLOS and the potential additional international consultation procedures the EU may be required, or which it may be prudent, to undertake.

Though not providing a remit to states to act extra-territorially, under Article 192 (General obligation) UNCLOS states do have an obligation to protect and preserve the marine environment and in addition UNCLOS stipulates that "States should cooperate on a global and, as appropriate, on a regional basis, directly or through competent international organizations" in the interests of protecting and preserving the marine environment by way of international rules, standards and recommended practices (Article 197); as such, while these provisions do not permit the EU to act unilaterally, they do justify any unilateral action taken by the EU in an attempt to fulfil such obligations.

In considering the effects of acting extra-territorially, the EU should also bear in mind that Article 202 (Scientific and technical assistance to developing States) UNCLOS requires it to *"promote programmes of scientific, educational, technical and other assistance to developing States for the protection and preservation of the marine environment and the prevention, reduction and control of marine pollution."* As such, in implementing an EU-wide scheme which is to apply to all ships calling at an EU port, the EU should consider the impact that any regime it may implement will have on developing countries and should consider whether it should or is obliged to assist developing states in order that they can comply with any EU-wide regime.

In particular Article 203 (Preferential treatment for developing States) UNCLOS would require the EU to grant preference to developing countries in any scheme it implements for the purposes of prevention, reduction and control of pollution of the marine environment whether that be in relation to the allocation of appropriate funds and technical assistance or the utilisation of the specialised services of the EU.

Article 211 (Pollution from vessels) UNCLOS also sets out provisions to govern states' powers to regulate, reduce and control pollution:

> *1 States, acting through the competent international organization or general diplomatic conference, shall establish international rules and standards to prevent, reduce and control pollution of the marine environment from vessels and promote the adoption, in the same manner, wherever appropriate, of routeing systems designed to minimize the threat of accidents which might cause pollution of the marine environment, including the coastline, and pollution damage to the related interests of coastal States. Such rules and standards shall, in the same manner, be re-examined from time to time as necessary.*

2 *States shall adopt laws and regulations for the prevention, reduction and control of pollution of the marine environment from vessels flying their flag or of their registry. Such laws and regulations shall at least have the same effect as that of generally accepted international rules and standards established through the competent international organization or general diplomatic conference.*

3 *States which establish particular requirements for the prevention, reduction and control of pollution of the marine environment as a condition for the entry of foreign vessels into their ports or internal waters or for a call at their off-shore terminals shall give due publicity to such requirements and shall communicate them to the competent international organization.*

Whenever such requirements are established in identical form by two or more coastal States in an endeavour to harmonize policy, the communication shall indicate which States are participating in such cooperative arrangements.

Every State shall require the master of a vessel flying its flag or of its registry, when navigating within the territorial sea of a State participating in such cooperative arrangements, to furnish, upon the request of that State, information as to whether it is proceeding to a State of the same region participating in such cooperative arrangements and, if so, to indicate whether it complies with the port entry requirements of that State. This article is without prejudice to the continued exercise by a vessel of its right of innocent passage or to the application of article 25, paragraph 2.

4 *Coastal States may, in the exercise of their sovereignty within their territorial sea, adopt laws and regulations for the prevention, reduction and control of marine pollution from foreign vessels, including vessels exercising the right of innocent passage. Such laws and regulations shall, in accordance with Part II, section 3, not hamper innocent passage of foreign vessels.*

5 *Coastal States, for the purpose of enforcement as provided for in section 6, may in respect of their exclusive economic zones adopt laws and regulations for the prevention, reduction and control of pollution from vessels conforming to and giving effect to generally accepted international rules and standards established through the competent international organization or general diplomatic conference.*

6 *…*

7 *The international rules and standards referred to in this article should include inter alia those relating to prompt notification to coastal States, whose coastline or related interests may be affected by incidents, including maritime casualties, which involve discharges or probability of discharges.*

Any laws or regulations regarding the reduction or control of emissions must comply with Article 212.1 (Pollution from or through the atmosphere) UNCLOS which provides that internationally agreed rules, standards and recommended practices and procedures must be taken into account when implementing such laws.

One UNCLOS provision which would seem to support the EU acting extra-territorially in preventing and reducing carbon emissions is Article 212.3 which states that

> *"states, acting especially through competent international organizations or diplomatic conference, shall endeavour to establish global and regional rules, standards and recommended practices and procedures to prevent, reduce and control such pollution"*.

Furthermore the jurisdiction of the port state is quite far reaching, as evidenced by Article 218 (1) (Enforcement by port States) UNCLOS which provides that:

> *"when a vessel is voluntarily within a port or at an off-shore terminal of a State, that State may undertake investigations and, where the evidence so warrants, institute proceedings in respect of*

any discharge from that vessel outside the internal waters, territorial sea or exclusive economic zone of that state in violation of applicable international rules and standards established through the competent international organization or general diplomatic conference".

Essentially this provision allows port states to exercise enforcement jurisdiction over foreign vessels in its ports regarding violations outside of its territorial waters and exclusive economic zone. These vessels must be "voluntarily in port" under Article 218(1) UNCLOS. However, Ho-Sam Bang has noted that the port states exercise of jurisdiction may be concurrent with flag state or coastal state jurisdiction, and that "this is a weakness in extraterritorial jurisdiction"[7]. Furthermore, whilst under 218(1) UNCLOS as quoted above the port state may take legal proceedings for discharge violations, if the discharge occurred on the high seas Article 228(1) UNCLOS allows the Flag state to intervene and suspend those proceedings. Article 218 (2) UNCLOS also restricts the port states jurisdiction where a discharge takes place in the internal waters, territorial sea or EEZ of another state unless they or the flag state request the current port state to take action. In terms of implementation of this port state jurisdiction Directive 2005/35, considered above, requires EU member states to institute legal proceedings for illegal discharges on the high seas[8], although this has been challenged before the ECJ.[9]

In purporting to exercise extra-territorial jurisdiction in the interests of the protection and preservation of the marine environment, the EU would have to ensure that it applies its rules and regulations equally to all ships calling at EU ports in order to avoid contravening its obligation under Article 227 UNCLOS which states that:

"In exercising their rights and performing their duties under this Part, States shall not discriminate in form or in fact against vessels of any other State."

Despite the fact that the above UNCLOS provisions encourage a state to exercise its territorial jurisdiction in the interests of controlling and reducing pollution levels and also to permit a state to refuse the admission of a foreign ship into its waters, it is not clear whether these provisions in practice permit the exercise of extra-territorial jurisdiction.

Commentary on the exercise of extra-territorial jurisdiction suggests that a state does not have any *right* to exercise such jurisdiction but rather that it *could* exercise jurisdiction on the basis of principles of international law. While the EU can rely on the above UNCLOS provisions for support and cite the interests of the international community and/or the universality principle (i.e. the EU is entitled to act extra-territorially given that the reduction of carbon emissions is in the international community's interests regardless of where the emissions have taken place or whether those emissions have occurred only within the jurisdiction of a member state) the EU is nonetheless likely to be challenged on extra-territoriality grounds by non-EU states and industry bodies.

In particular this challenge could be based on the right of innocent passage through territorial waters, this is to be distinguished from the high seas, which are defined in Article 86 UNCLOS above. Section 3 (Innocent Passage in the Territorial Sea) of UNCLOS establishes the guidelines for the innocent passage of all ships in the territorial sea and Article 17 UNCLOS states that:

"Subject to this Convention, ships of all States, whether coastal or land-locked, enjoy the right of innocent passage through the territorial sea."

Article 18.2 UNCLOS states that passage is to be continuous and expeditious, which includes stopping and anchoring which is incidental to ordinary navigation or rendered necessary by distress. Passage must take place in conformity with UNCLOS and other rules of international law (Article 19.1).

By incorporating the right of innocent passage UNCLOS upholds a party's right to freedom of navigation while also setting out the parameters of a coastal state's jurisdiction and sovereign rights.

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[7] Ho-Sam Bang "Port State Jurisdiction and Article 218 of the UN Convention on the Law of the Sea" Journal of Maritime Law & Commerce Vol 40, No 2, April 2009
[8] Directive 2005/35 Article 3(1)
[9] Case 308/06 Intertanko & Ors, R v Secretary of State for Transport

Article 26 UNCLOS states that:

1 *No charge may be levied upon foreign ships by reason only of their passage through territorial sea.*

2 *Charges may be levied upon a foreign ship passing through the territorial sea as payment only for specific services rendered to the ship. These charges shall be levied without discrimination.*

The EU may be challenged on any assertion of its right or decision to act extra-territorially on the ground that imposing a further charge on ships or requiring vessels to surrender an allowance at entry into an EU port which does not solely relate to specific services rendered to the ship but to the ship's emissions outside EU waters contravenes Article 26 UNCLOS. It should also be noted that the US has opposed the inclusion of aviation in the EU ETS on similar grounds (based on the Chicago Convention 1944) and intends to lodge an appeal with the WTO.

EU Competence in special circumstances

As a general rule coastal states can only enact or prescribe laws that give effect to international prevailing and generally accepted rules and standards. However provision is made in UNCLOS for states to impose stricter conditions in certain circumstances. Article 234 UNCLOS provides that "*Coastal states have the right to adopt and enforce non-discriminatory laws and regulations for the prevention, reduction and control of marine pollution from vessels in ice covered areas within the limits of the exclusive economic zone, where particularly severe climactic conditions and the presence of ice covering such areas for most of the year create obstructions or exceptional hazards to navigation, and pollution of the marine environment could cause major harm to or irreversible disturbance of the ecological balance*". This is further supported by Article 211 UNCLOS, considered above.

By establishing internationally accepted criteria as minimum and maximum levels for coastal state jurisdiction, the international regulatory process seeks to ensure the uniformity and reasonableness of safety and pollution control laws worldwide.

Choice of Flag

Article 94 UNCLOS determines that "every State shall effectively exercise its jurisdiction and control in administrative, technical and social matters over ships flying its flag". Similarly Article 211 (2) UNCLOS quoted above gives flag states the competence to adopt laws and regulations for the prevention, reduction and control of pollution. This allows the EU significant scope to impose environmental requirements on vessels flagged in an EU state. However, vessels are commonly 'flagged for convenience', and this is often in a non-EU state thereby making it much more difficult for the EU to legitimately exert influence. Furthermore relying on the flag state to impose a form of greenhouse gas emission reduction scheme poses the further difficulty of the political will which is required for any tangible effect. Commentators such as Ho-Sam Bang have noted Article 218 UNCLOS relating to enforcement by a port state (as considered above) goes some way towards addressing these "drawbacks"[10].

Further International Law provisions

There is a significant body of international law relevant in this context, primarily UNCLOS as above. This section of the paper will focus on IMO conventions, regional agreements, trade agreements and the United Nations Framework Convention on Climate Change (**UNFCCC**) which must all be factored into the policy consideration.

IMO Conventions

[10] Ho-Sam Bang Prt State Jurisdiction and Article 218 of the Un Convention on the Law of the Sea" Journal of Maritime Law & Commerce Vol 40, No 2, April 2009

The International Maritime Organisation has a broad mandate, including serving as the specialised agency of the United Nations in the field of shipping and the effect of shipping on the marine environment (Article 59 of the Convention on the International Maritime Organisation). Furthermore Article 2.2 of the Kyoto Protocol refers specifically to the IMO when imposing the requirement on Annex I parties to pursue the limitation or reduction of emissions of greenhouse gases.

The Secretary General of the IMO, Mr Mitropoulos, asked the IMO to discuss a system which can demonstrate a real reduction of carbon emissions and which can be applied to the whole of international shipping. The IMO's position is that to be effective and fair, any scheme must apply equally to all ships if it is not to radically alter the structure of shipping, distort competition and reduce safety standards. The Marine Environment Protection Committee (**MEPC**) 57 came up with a set of 9 principles which any system must exhibit to be acceptable and which are paraphrased below.

Any scheme must be:

- Effective in reducing GHG emissions
- Binding and applicable to all flag states
- Cost effective
- Able to limit any economic distortion of the industry
- Based on sustainable development without penalising trade or growth
- Based on a goal based approach and avoid being prescriptive
- Supportive of technical innovation and research and development of technology to reduce emissions
- Accommodating to leading technologies in the field of fuel efficiency
- Practical, transparent and easy to administer

This set of principles has widely been accepted as a sensible way forward at the IMO but the difficulty has been finding a consensus on how to achieve these aims.

At the MEPC 58 meeting, a group of nations including Australia, Canada, Denmark, the US and others including, significantly, Panama and the Marshall Islands, suggested that the second principle should be amended to apply to all ships, rather than flag states, without this requiring States to accept similar regulations/standards in other fora. This was meant to reassure developing states that by agreeing to proposals for shipping, they would not be accepting more general obligations under the Kyoto Protocol. This would be significant given the difficulty in exerting control over vessels flagged in a non-EU state as considered above.

In July 2009 the MEPC 59 meeting was held, and a number of matters appear to have been taken forward. In reaching their conclusions the Committee took into account the results of the 'Second IMO GHG Study 2009', said by the IMO to provide the most comprehensive and authoritative figures on the impact of shipping on climate change.

The Committee agreed to circulate interim and voluntary technical and operational measures to reduce greenhouse gas emissions from shipping. This includes the Committee issuing interim guidelines on the method of calculation and voluntary verification of an Energy Efficiency Design Index for new ships. The hope is that this measure will stimulate innovation and technical development of elements influencing the Ships energy efficiency from its design phase. Furthermore the Committee will issue guidance on the development of a Ship Energy Efficiency Management Plan incorporating best practice for the fuel efficient operation of ships along with guidelines for new and existing ships to voluntarily use the Ship Energy Efficiency Operational Indicator. The intention here is to enable operators to measure their Ship's fuel efficiency. The measures are essentially being run on trial until the MEPC 60 meeting in March 2010 when the aim will be to determine the scope of the measures application and enactment.

In terms of market based instruments the MEPC 59 meeting agreed a work plan for further consideration of this issue at the MEPC 60 meeting. The aim is that this will enable the Committee to take into account the outcomes of the Climate Change Conference which the United Nations are to convene in December 2009. The outcome of the MEPC 59 on GHG emissions from ships will be reported at the December Climate Change Conference and the agenda for that Conference includes debate on a successor to the Kyoto Protocol to the UNFCCC. It was agreed by the Committee that the

IMO was the most competent international body to develop and enact any regulatory scheme to be applied to GHG emissions from international shipping.

The International Convention for the Prevention of Pollution From Ships, 1973 as modified by the Protocol of 1978 ("MARPOL")

The MARPOL Convention is the main IMO international Convention which governs the prevention of pollution of the marine environment by ships through operational or accidental causes. It is the combination of two treaties established in 1973 and 1978, as well as various amendments throughout the years. There are six technical annexes. Annex VI "Prevention of Air Pollution from Ships" is most relevant when considering how best to reduce greenhouse gas ("**GHG**") emissions in the shipping industry. Of the six technical annexes, only the first two are compulsory - the remaining four annexes (including Annex VI) are voluntary and states can choose whether or not to ratify them.

Annex VI entered into force on 19 May 2005. The regulations in Annex VI set limits on SO_x and NO_x emissions from ship exhausts, as well as prohibiting the deliberate emissions of ozone depleting substances. It includes a global cap of 4.5% m/m on the sulphur content of fuel oil and requires the IMO to monitor the worldwide average sulphur content of fuel. Limits are set upon NO_x emissions from diesel engines and a mandatory NO_x Technical Code, developed by the IMO, indicates how the limits are to be achieved. The Annex also contains provisions which allow special "Emission Control Areas" to be set up with tougher controls on sulphur emissions. The Baltic Sea is one such special area, as is the North Sea. The sulphur cap in these areas is 1.5% m/m prior to 2010 (when the % is steadily reduced) - alternatively, exhaust gas cleaning systems must be fitted to the ship, or other methods must be used to limit sulphur emissions. States are able to propose to the IMO that their area be designated as an "Emission Control Area" if they can demonstrate the need to prevent, reduce and control air pollution from SO_x emissions from ships. At the MEPC 59 meeting the IMO approved a proposal to designate certain parts of the coastal waters of the United States and Canada as an Emission Control Area, and the draft amendments to the revised Annex VI will be submitted to the MEPC 60 meeting in March 2010 for adoption.

The 2008 amendments to MARPOL introduced new fuel quality requirements beginning from 1 July 2010, Tier II and Tier III NO_x emission standards for new engines, and Tier I NO_x requirements for existing pre-2000 engines. Tier I and II are for global application whereas Tier III standards relate to NO_x emission levels in Emission Control Areas. The "Emission Control Areas" now include NO_x and particulate matter (PM), and can be in respect of one emission or all three types of emissions. Some countries that are signatories to MARPOL but which have not yet adopted Annex VI are known to be considering local emission control regulations as an alternative to the Emission Control Areas.

EU member states have also agreed that as well as ratifying Annex VI, tougher regulations would be imposed on vessels operating in their territorial waters. This was brought into force by EU Directive 1999/32/EC which set the maximum permitted sulphur content of heavy fuel oil, gas oil and marine gas oil used within the EU. This Directive was amended by EU Directive 2005/33/EC to include sulphur emissions from all types of marine fuel used by international shipping in EU waters. The EU instructed that all passenger ships on a regular service in the territorial sea or EEZ of any member state must use low sulphur fuel - even if their journey began outside these areas. The EU also directed that from 1 January 2008, marine gas oil used in their national waters was not allowed a sulphur content of greater than 0.1%.

Annex VI does not cover the emission of GHGs from ships.

In order for a ship to comply with the regulations in an Emission Control Area, its air emissions must be within the permitted limits from the moment the ship crosses into the Area and for the duration of its passage.

Compliance with Annex VI is determined by periodic inspections and surveys (with the exception of very small ships). When these inspections are successfully passed by a ship, the ship is issued with an "International Air Pollution Prevention Certificate" which is valid for up to 5 years.

The certificates issued to each ship can be accepted at ports as proof that the ship complies with the requirements of the Convention. Annex VI requires ships to maintain rigorous records. All log books must be completed accurately and bunker delivery notes and samples must be kept on board for at least 3 years after delivery. In most circumstances, the vessel will be monitored by an examination of the relevant paperwork and/or taking a fuel sample in order to analyse its content. There are IMO guidelines for fuel sampling. Equipment is highly developed to ensure that results are available quickly and on board the vessel.

Any violation of MARPOL within the jurisdiction of any Party is punishable either under the law of that Party or the law of the Flag state. If it is reasonably suspected that the ship either does not meet the standards as stated on its certificate, or the ship does not have a certificate then the ship can be detained in port while the inspection continues and until the authority carrying out the inspection is confident that the ship can continue to sea without posing an undue threat of damage to the marine environment.

Amendments to the technical annexes of MARPOL (including Annex VI) can be adopted using the "tacit acceptance" procedure, whereby amendments enter into force on a specified date unless an agreed number of state parties object by an agreed date. In practice, amendments are usually adopted either by the IMO's MEPC, or by a Conference of Parties to MARPOL.

CDEM Standards - rights and responsibilities of States in implementing these

Construction, design, equipment and manning ("**CDEM**") standards are a further pollution control instrument adopted by IMO to prevent, reduce or control the different forms of vessel-source pollution. CDEM standards relate to the seaworthiness and structural qualities of vessels as well as the competence of the crew and play an indirect but crucial role in reducing vessel-source pollution. The United States led efforts to universalise the regulation of ship attributes associated with CDEM and this approach is codified in UNCLOS.

A general obligation of states to establish such international rules and standards concerning the prevention, reduction and control of pollution from ships and to re-examine them from time to time as necessary is set out in Article 211.1 UNCLOS, noted above. However, there exist many difficulties in effective implementation of the existing global and regional Conventions and other multilateral instruments of the IMO establishing anti-pollution standards and rules. For instance, the MARPOL Convention is also of primary importance when governing international rules and standards in relation to vessel-source pollution (see above). Such rules are further extensively developed in the regional Conventions applicable to the North Sea, and Baltic area and they are also covered by the UNEP Regional Seas Programme, as well as several Baltic agreements. All these Conventions and agreements implement the general principles and rules on prior notification and pollution emergencies contained in Article 211.7 and Articles 194-199 UNCLOS.

A coastal state cannot take any action (apart from requiring information) against a sub-standard vessel in breach of CDEM standards and posing a serious threat to the environment which has not actually caused a discharge or become a maritime casualty in the EEZ. Further Article 21 UNCLOS states that:

> *"1. The coastal state may not adopt laws and regulations, in conformity with the provisions of this Convention and other rules of international law, relating to innocent passage through the territorial sea, in respect of all or any of the following:*
>
> *(f) the preservation of the environment of the coastal State and the prevention, reduction and control of pollution thereof;*
>
> *…*
>
> *2. 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."*

If the violation relates purely to a breach of CDEM standards, the coastal state may only request information pursuant to Article 220.3 UNCLOS. If the ship enters the territorial sea of a state with its CDEM violations subsisting, the full enforcement powers of Article 220.2 UNCLOS apply. Article 220.2 states that "*where there are clear grounds for believing that a vessel navigating in the territorial sea of a State has, during its passage therein, violated laws and regulations of that State adopted in accordance with this Convention or applicable international rules and standards for the prevention, reduction and control of pollution from vessels, that State, without prejudice to the application of the relevant provisions of Part II, section 3, may undertake physical inspection of the vessel relating to the violation and may, where the evidence so warrants, institute proceedings, including detention of the vessel in accordance with its laws, subject to the provisions of section 7.*"

Article 211.6(a) UNCLOS allows a coastal state to designate clearly defined areas of its EEZ within which special mandatory measures for pollution prevention can be adopted for recognised technical reasons in relation to the area's oceanographical and ecological conditions, as well as the utilisation or protection of its resources and the particular character of its traffic. In this regard, the IMO must be consulted, and no such area can be designated and measures prescribed without IMO agreement. The measures that coastal states can prescribe under Article 211.6(a) UNCLOS would be those international rules and standards or navigational practices that are made applicable, through IMO, for special areas.

Port states may prescribe and enforce national CDEM standards as conditions for the use of its ports. This is entirely consistent with the sovereign rights of states to apply stricter national laws and to impose conditions for entry into ports. Neither Article 25.2 nor Article 211.3 UNCLOS imposes any substantive restriction on the port state's prescriptive and enforcement jurisdiction. There is no general right of access into ports i.e: states can deny access to vessels and prescribe whatever conditions for access, even though this is subject to the principle of non-discrimination. A port state need only give due publicity to such conditions and notify the IMO of their existence. Port states are not reluctant to prosecute for violations of CDEM regulations. The energies of active port state control administrations in Europe, US and Australia are usually channelled towards inspecting for CDEM deficiencies.

Pollution control standards may be enforced by:

- flag state (where the ship is registered);
- coastal state which has jurisdiction over the surrounding waters and is the zone where the vessel has committed the violation; or
- port state (state whose port and internal waters the vessel sails into).

Given that some flag states have little incentive to monitor compliance of their vessels (as noted above vessels are often registered with flags of convenience and have little real contact with their flag states), coastal states are becoming more assertive in claiming greater control over foreign-flagged vessels in their waters. Much of this is permitted under IMO Conventions and non-binding voluntary agreements such as memoranda of understanding ("**MOU**") have been signed on a regional basis to establish a degree of control over such shipping. The Paris MoU is an example of the MoU in Europe. Such states are increasingly dictating the development of new international regulations which accord them greater powers to deal with pollution and safety matters.

The various Memoranda on Port State Control derive from regional initiatives to increase the standards of shipping using the ports and waters of a particular region and to restrict and in certain cases ban vessels that do not come up to the required standards as set out in the following international Conventions:

1 International Convention on Load Lines 1966 and Protocol of 1988;

2 International Convention for the Safety of Life at Sea 1974 and Protocols of 1978 and 1988;

3 International Convention on Standards of Training, Certification and Watchkeeping for Seafarers 1978;

4 Convention on International Regulations for Preventing Collisions at Sea 1972;

5 International Convention of Tonnage Measurements of Ships 1969;

6 International Convention for Prevention of Pollution from Ships 1973 and Protocols of 1978 and 1997;

7 Merchant Shipping (Minimum Standards) Convention 1976 and Protocol of 1996;

8 International Convention on Civil Liability for Oil Pollution Damage 1992; and

9 International Convention on the Control of Harmful Anti-Fouling Systems on Ships 2001.

The various MoUs set out that authorities will carry out inspections of the ship and its documents to ensure compliance with the abovementioned Conventions and will secure rectification of all deficiencies detected and will detain a ship until this has been achieved. Information is exchanged between the MoU states and, for instance, ships can be banned if they are found not to carry valid International Safety Management Certificates. Similar MoUs can be found in Asia Pacific (Tokyo MoU), the Caribbean, Black Sea, Indian Ocean and Latin American regions. The right of the coastal states to take such action is founded not so much on UNCLOS, although the Convention anticipated such measures in Articles 218-220, but under inspection rights contained within the international Conventions, for instance MARPOL.

CDEM standards link in to the principle of comity between states and it is important to factor this principle into the consideration of any policies. Essentially the principle of comity reflects the practice of reciprocity between states in relation to their policies and legislation. It is vitally important to maintain this, if the EU were to fail to recognise the obligations imposed upon it by international law, then aside from legal consequences states may feel reluctant to assist or comply with the EU on the basis that the EU has chosen to disregard their policies. This is particularly important to consider given that the legality of any unilateral action by the EU is so questionable. Current international legislation such as UNCLOS is binding both legally and politically as states have made a choice to ratify the instrument. However it is likely that states would resent legislation being imposed on them without consultation, and also view this as going against the principle of comity.

Competence under UNFCCC

Article 3 UNFCCC states that “the Parties should protect the climate system for the benefit of present and future generations of humankind”. This clearly gives scope for the EU to make policies in the maritime field, but it is important to note that this objective is to be achieved “on the basis of equity and in accordance with [the Parties] common but differentiated responsibilities and respective capabilities”. This principle is often referred to as the “common but differentiated responsibilities” principle (**CBDR principle**), which, essentially, recognises the developed countries’ historical responsibility for climate change and therefore requires them to take the lead in financing and implementing the climate change mitigation and adaptation measures. Similarly, whilst the Kyoto Protocol to the UNFCCC requires parties to “Implement and/or further elaborate policies and measures to limit /and or reduce emissions of greenhouse gases not controlled by the Montreal Protocol” (Art 2.1 (vi)), this is qualified by the statement that this should be “in accordance with [the relevant parties] national circumstances”.

Competence under the General Agreement on Tariffs and Trade and General Agreement on Trade in Services

World Trade Organisation agreements must also be taken into consideration. The General Agreement on Tariffs and Trade (**GATT**) makes provision for some regional measures to be put in place to preserve and protect the environment. In particular such measures are possible on the basis that they “protect human, animal or plant life health” under Article XX (b), and under Article XX (g) measures “relating to the conservation of exhaustible natural resources if such measures are made effective in conjunction with restrictions on domestic production or consumption” are permissible. Furthermore Article XIV of the General Agreement on Trade in Services (**GATS**) provides an exception to allow the adoption of measures which are “necessary to protect human, animal or plant life or health”. It is vital however that under the requirements of GATS and GATT any measures do not constitute arbitrary or unjustifiable discrimination between countries or a disguised restriction on international trade

Possible challenges from non-EU countries and international bodies to an EU scheme to tackle CO_2 maritime emissions

There are a number of challenges that could be made against any unilateral action the EU may take with regard to regulating greenhouse gas emissions from international shipping. The challenges include the following:

Contravention of the principle of "common but differentiated responsibilities" (CBDR)

The CBDR principle, as described above, forms the basis of the UNFCCC and manifests itself throughout the text of the Convention.

The preamble to the Kyoto Protocol specifically refers to the fact that it is being adopted "recalling the provisions of the Convention" and "being guided by Article 3 of the Convention". Hence the CBDR principle is of direct relevance to the Kyoto Protocol, evidenced, importantly, by the fact that Article 3(1) of the Protocol imposes binding emission reduction targets (contained in Annex B of the Protocol) only on the developed country Parties and certain economies in transition. Furthermore, Article 2(3) of the Kyoto Protocol requires the developed country Parties to implement policies and measures aimed at tackling climate change in such a way as to minimise adverse effects, including "effects on international trade, and social, environmental and economic impacts on other Parties, especially developing country Parties […] taking into account Article 3 of the Convention".

Finally, Article 2 of the UNFCCC, which defines the objectives of the Convention, states that "the ultimate objective of this Convention *and any related legal instruments that the Conference of the Parties may adopt*, is to achieve, *in accordance with the relevant provisions of the Convention*, stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" (emphasis added). Thus, it may be argued that any further legal instruments adopted under the auspices of the current international climate change regime ought to be consistent with the principle of CBDR[11].

In summary, therefore, a challenge may be made that by adopting a unilateral measure that tackles greenhouse gas emissions from shipping in a way which does not differentiate between countries on the basis of the level of their development, the EU would be acting inconsistently with the Convention. In this regard, it could also be argued that the EU would be imposing emission reduction obligations on the developing countries "through the back door" in contravention of the Kyoto Protocol.

Undermining the International Maritime Organisation's mandate

Article 2(2) of the Kyoto Protocol states that "the Parties included in Annex I [of the UNFCCC] 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 Organisation [**ICAO**] and the International Maritime Organisation [**IMO**], respectively". The Protocol, therefore, gives a shared mandate to the developed country Parties and the IMO to pursue the limitation of greenhouse gas emissions from international shipping under the Convention. This is consistent with the general construction of the Convention and the Kyoto Protocol whereby Parties are required to take responsibility for all emission sources located in their territory, regardless of nationality, but not for emissions occurring outside their territory. Hence the fact Annex I Parties are called to work through the ICAO and IMO respectively under Article 2(2) of the Kyoto Protocol; hence, too, the recommendation by the Revised 1996 Guidelines for National Greenhouse Gas Inventories of

[11] Please note that although on strict interpretation the wording of Article 2 of the Convention only refers to instruments adopted by the Conference of the Parties, pursuant to Article 31(a) of the 1969 Vienna Convention on the Law of the Treaties, treaties are to be interpreted in good faith in accordance with the ordinary meaning given to the terms of the treaty in their context and in the light of a treaty's objective and purpose. Thus, the interpretation ought not to be informed by legal technicalities where such an interpretation does not reflect the purposes of the treaty (see C.Pisani, *Fair at Sea: the Design of a Future Legal Instrument on Marine Bunker Fuels Emissions within the Climate Change Regime*, Ocean Development & International Law, 33:57 - 76, 2002).

the International Panel on Climate Change (IPCC)[12] that emissions from fuel sold to ships (or aircraft) engaged in international transport should not be included in national totals, but ought to be reported separately[13].

In summary, therefore, it may be argued that due to their international nature, emissions from international aviation and shipping are best tackled by working through ICAO and IMO respectively, as indeed the Kyoto Protocol calls the developed country Parties to do, rather than by taking unilateral action.

EU measures constitute an unlawful restriction on trade

GATT, noted above, prohibits discrimination between trading partners (the concept of "**most-favoured nation**"). It also requires that WTO members provide national treatment to all WTO member trading partners ("**national treatment**"). National treatment under GATT Article III requires non-discriminatory treatment between domestic and imported goods. It targets (1) tax discrimination and (2) discrimination by laws or other requirements[14]. It might be argued that certain regulatory options under consideration to address greenhouse gas (**GHG**) emissions from ships discriminate (either directly or indirectly, regardless of equal application to all ships) among imported goods shipped by different third parties, or discriminate between goods shipped by EU operators and by foreign operators/vessels.

In addition, GATS, in its regulation of trade in services, including marine transport[15] is based on comparable principles to those applicable to GATT. It might be argued that a measure that prohibits the admission of vessels from third countries based on their GHG emissions or technical specifications function as restriction on trade in services.

Finally, Article 3(5) of the UNFCCC provides that "the Parties should cooperate to promote a supportive and open international economic system that would lead to sustainable economic growth and development in all Parties, particularly developing country Parties, thus enabling them better to address the problems of climate change. Measures taken to combat climate change, including unilateral ones, should not constitute a means of arbitrary or unjustifiable discrimination or a disguised restriction on international trade." It might be argued that certain regulatory options are actually (or will function as) barriers to trade, creating an additional expense for ships, cargo and/or goods from third country Parties, negatively impacting their sustainable development.

Potential counterarguments supporting EU unilateral action

The arguments listed above may be countered, however, upon further consideration of the relevant international legislation, as outlined in the following paragraphs.

- *The CBDR principle is not incompatible with the principle of equal application applied by the IMO[16]:* Whilst the Kyoto Protocol, elaborated under the framework of the UNFCCC, sets out objectives to be achieved in relation to greenhouse gas emissions, it does not preclude the application of specific technical requirements and obligations developed pursuant to particular treaty law areas, such as a maritime law; indeed, this notion is inherent in the granting of a mandate to the IMO.

- *Applying CBDR to shipping emissions would be inconsistent with the IMO's mandate:* The IMO was founded well before the UNFCCC[17] and consequently, when adopting Article 2(2) of the

[12] IPCC, *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories.* The decision to use these guidelines in order to estimate and report on the anthropogenic emissions by sources and removals by sinks of greenhouse gases not controlled by the Montreal Protocol was adopted by the third Conference of the Parties (**COP**) to the Convention (see decision 2/CP.3).
[13] The recommendation was adopted as a result of a failure by the negotiating Parties to agree on the allocation of the international aviation and shipping emissions.
[14] See http://211.173.74.24/pub/docu/en/AE/02/AE022008BAA/AE02-2008-BAA-003.PDF
[15] See http://www.wto.org/english/docs_e/legal_e/49-dsmar_e.htm
[16] The following analysis is based on the IMO Legal Affairs' note "Legal Aspects of the Organisation's Work on Greenhouse Gas Emissions in the Context of the Kyoto Protocol", 1 August 2008.
[17] The IMO was established in 1948 as a specialised agency of the UN.

Kyoto Protocol, Parties were aware of the principle of equal application espoused by the IMO. Moreover, the fact that Kyoto Parties have agreed to "work through" the IMO in addressing greenhouse gas emissions from shipping does not mean that any outcomes of the IMO's decision-making process must be restricted to Annex I countries. Such an interpretation would be inconsistent with the IMO's well-known approach to international regulation and would undermine its mandate. If principles from other Conventions, such as CBDR, were permitted to be incorporated into the IMO's work, IMO's approaches would be significantly undermined, as ship owners would simply change flag to evade the regulations, which would frustrate the relevant IMO treaties and goals.

IMO's mandate, as derived from the IMO Convention[18] and the UNCLOS and shaped by the complexities of the international shipping trade, is based on the understanding that technical regulations, aimed at ensuring the safety and security of commercial shipping as well as protecting the marine and atmospheric environment will be developed on the basis of universal and non-discriminatory rules applicable to all ships engaged in international commercial navigation. Any differences in the application of such rules would be based on factors such as ship type, structure, manning and operational features, but not the level of development of the flag state or the State of nationality of the owner or the operator of the ship.

Consequently, the principle of CBDR has limited, if any, application in IMO-based Conventions. The fact that the Kyoto Protocol leaves the control of international shipping emissions to the IMO implies the recognition of the unique nature of the shipping industry, as well as an acknowledgement that the universal application of the IMO rules is the appropriate means of tackling greenhouse gas emissions from ships.

- *EU unilateral action does not contradict principles agreed by the IMO on the regulation of greenhouse gas emissions:* The requirement for the Annex I Parties to "work" through the IMO does not of itself prohibit unilateral measures from being taken by individual states, provided this does not contradict a position endorsed by the IMO. While no position has been adopted by the IMO as yet, the 57th session of the Marine Environment Protection Committee (**MEPC**) held on 31 March - 4 April 2008 endorsed a proposal from the IMO Secretary General to expedite the Organisation's work on greenhouse gas emissions and adopted a set of principles as its reference for further debate. The principles propose that a coherent and comprehensive future IMO framework should be, inter alia, effective and contribute to the reduction of total global greenhouse gases, be binding and equally applicable to all flag States in order to avoid evasion; cost effective and able to limit, or at least, effectively minimise, competitive distortion. While consensus is yet to be reached on these principles, they were formally endorsed by MEPC 57 and do, therefore, represent the current working framework of the IMO. Provided any regulatory measures adopted by the EU are consistent with the overall framework endorsed by the IMO, there will be no conflict between the respective approaches.

- *The Kyoto Protocol anticipates and encourages unilateral measures to address greenhouse gas emissions*: Unilateral measures are not prohibited under the Protocol[19], as evidenced by the general requirement (contained in Article 2(1) of the Kyoto Protocol) for the Annex I Parties to implement further "policies and measures in accordance with [their] national circumstances", including "measures to limit and/or reduce emissions of greenhouse gases not controlled by the Montreal Protocol in the transport sector". Therefore, it is arguable that whilst the Kyoto Protocol provides that the Parties shall "work through" the IMO, given the urgency of the climate change challenge and in light of Article 2(1) of the Protocol, as well as given the obligation on the Kyoto Parties to address national emissions from the shipping sector, nothing prohibits unilateral measures by the Parties taken in the absence of progress by the IMO, as long as they are consistent with the overall IMO approach and further the goals of the Protocol.

  This is further reinforced by the text of the UNFCCC, whereby, under Article 4(1)(b), all Parties to the Convention are obliged to "implement […] programmes containing measures to mitigate climate change by addressing anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol" as well as, more specifically, under

[18] Convention on the International Maritime Organisation, 6 March 1948.
[19] See, for example, Articles 3(5) and 4(1) of the Protocol.

Article 4(1)(c) to "promote and cooperate in the development, application and diffusion, including transfer, of technologies, practices and processes that control […] emission of greenhouse gases not controlled by the Montreal Protocol in all relevant sectors, including […] transport". Each developed country Party further commits to adopt national policies and take corresponding measures on the mitigation of climate change, by limiting its anthropogenic emissions of greenhouse gases and protecting and enhancing its greenhouse gas sinks and reservoirs" with a view to demonstrating that developed countries "are taking the lead in modifying longer-term trends in anthropogenic emissions consistent with the objective of the Convention" (Article 4(2)(a)). It can be argued, consequently, that the UNFCCC places an obligation on all Parties, but the developed country Parties especially, to adopt measures aimed at controlling greenhouse gases generally, and those arising from the transportation sector specifically. While each developed country Party is expected to control "its" emissions, there is an overarching obligation to take the lead in modifying longer-term trends in anthropogenic emissions which does not seem to contain a territorial element. In the absence of international solutions, therefore, it would appear that the developed country Parties are required to take national initiatives. This position is further enhanced by the wording of Article 4(1)(b) of the Convention, whereby all Parties express a commitment to "formulate, implement, publish and regularly update national, and where appropriate, *regional* programmes containing measures to mitigate climate change" (emphasis added). Given that the EU's 27 members would be endorsing the regulatory measures proposed by the Commission, it could be argued that the EU measures amount to a regional programme as envisaged under the Convention.

- *EU measures are not inconsistent with the GATT/GATS:* It may be argued (focusing in the first instance on GATT) that even where measures are found to be inconsistent with GATT, such measures are justified under Article XX of GATT as measures "necessary to protect human, animal or plant life or health" under the exception contained in Article XX(b).
  Alternatively, the measures can be said to be justified under Article XX(g) of the GATT as measures "relating to the conservation of exhaustible natural resources if such measures are made effective in conjunction with restrictions on domestic production or consumption."
  The measures additionally can be argued to satisfy the chapeau of Article XX, in that "such measures are not applied in a manner which would constitute a means of *arbitrary or unjustifiable discrimination* between countries where the same conditions prevail, or a disguised restriction on international trade" (emphasis added). More specifically:

  - The measures will not constitute **arbitrary discrimination**. The proposed restrictions will be applied in an open and transparent way, with due publication and notification. The EU will apply the measures following extensive engagement with the potential stakeholders, including actively engaging in negotiations in IMO sessions on air pollution from greenhouse gases and participating proactively in negotiations on aviation and maritime emissions under the Kyoto Protocol. Moreover, the EU has expressed its willingness to cooperate and engage in serious good faith negotiations before enacting these measures.

  - The measures do not constitute **unjustifiable discrimination**. It is arguable that the measures are necessary and proportionate (XX(b)); alternatively and in addition, they can be said to relate closely to the conservation of natural resources (XX(g)). Firstly, the measures are necessary (and relate to the conservation of natural resources) because of the rising climate change impacts of maritime emissions. They are also necessary in light of the fact that EU's internal efforts to reduce emissions by EU carriers, EU-owned vessels, and vessels carrying EU-owned and produced goods both inside and outside the EU will suffer if unilateral measures are not taken (notably, the EU has always maintained that it will refrain from unilateral action if an international agreement to regulate shipping emissions satisfactorily can be reached). Secondly, such measures would be proportionate because they would be narrowly tailored to address the environmental challenge and would not pursue other objectives.

In addition, it can be argued that the EU's measures are justified under Article XIV of the GATS, which allows for the adoption of measures necessary to protect human, animal or plant life or health, as long as the measures are not applied in a manner which would constitute a means of arbitrary or unjustifiable discrimination or a disguised restriction on trade in services (as to which please see the arguments above).

- *The measures do not constitute disguised restrictions on trade under the UNFCCC Article 3(5)* in light of the arguments used above (including the EU's open engagement with other Parties; the clear, transparent and non-discriminatory nature of the measures etc).

The above paragraphs have briefly summarised the key challenges that may be initiated against the EU in the context of the UNFCCC, the Kyoto Protocol and the relevant WTO agreements if the EU were to take unilateral action in controlling international greenhouse gas maritime emissions; as well as the potential arguments that may be put forward to counter any such challenges.

Policy Options and Potential Challenges

1. EU Emissions Trading Scheme (EU ETS)

As a potential scheme this is broken down into several sub-policies, firstly the option of including maritime transport emissions in the EU ETS, secondly creating a separate maritime emissions trading scheme linked to the EU ETS, or thirdly a closed maritime emissions scheme.

While the inclusion of shipping in or the linking of shipping to the existing ETS or the establishment of a separate maritime ETS would appear to be consistent with the provisions of UNCLOS and customary international law we nonetheless anticipate that the establishment of such a scheme by the EU will be challenged on jurisdictional grounds by non-EU states (principally the US) and potentially also industry bodies. That being said the International Chamber of Shipping has recently issued a statement confirming that it would whole-heartedly support an ETS for the shipping industry, though it was silent on what form it considers such an ETS should take and assumed that such would be introduced worldwide.

Notwithstanding this so long as the provisions of any ETS comply with UNCLOS and customary international law principles, in accordance with Article 2 UNCLOS the EU has the power to adopt laws and regulations which would require a ship to report its emissions for its entire journey upon arrival at an EU port and surrender allowances to cover those emissions even in circumstances where a proportion or even the majority of a ship's emissions may have occurred outside EU waters. While the emissions for part of the journey will have been accrued outside EU waters, the EU could argue that it would only be exercising its jurisdiction over its territorial sea by requiring ships to surrender allowances only at entry to an EU port and not at any other point outside EU waters.

Any such ETS would also have to respect the spirit of and comply with the IMO principles set out above.

There are as we see it two main advantages to developing a closed maritime emissions trading scheme as opposed to including or linking shipping in or to the existing ETS. Firstly if a stand-alone ETS were established, the EU would be able to create a trading scheme specifically tailored not just to the shipping industry generally but it would also allow the EU to create a system which encompasses all the different types of shipping as set out above. In addition we would anticipate that an independent shipping trading scheme would be more palatable to the wider international shipping community; in the shipping arena the general view towards including shipping in the existing ETS is that it is an indirect way of forcing non-Kyoto countries to comply with a wider emissions trading scheme and if the EU were able to establish an independent scheme not linked to existing emissions provisions the EU would potentially be exposed to lower risk of challenges and criticism on this ground.

The primary risk of evasion with such a scheme is that many vessels may decide to call at ports closely located to but nonetheless located outside of EU waters, for example Kaliningrad, Gibraltar or the Ukraine. However while the EU would have the authority to exercise its jurisdiction over its own territorial waters and require vessels calling at an EU port to surrender allowances, such jurisdiction would not extend to preventing vessels from calling at non-EU ports which would otherwise call at ports within the EU and neither would it have any jurisdiction to request the assistance of those port authorities located adjacent to EU waters with the implementation of any emissions trading scheme; such assistance could only be achieved if any ETS were established on a global basis by the IMO.

A further issue considering the ETS option is that of whether the policy would be route based or time based. As regards the legal feasibility of either a route or time based shipping ETS, the argument against both is that to be effective, the scheme must operate extraterritorially - in other words for periods when the vessel is outside EU waters. As discussed above, this is unlawful as the EU has no right to impose rules where it has no sovereignty or jurisdiction and a legal challenge is likely. In response, the EU could argue that it was not attempting to exercise jurisdiction over waters outside its territorial sea. The scheme would simply apply as a condition of entry into EU ports. Both UNCLOS and GATT allow regional measures to be put into place to preserve and protect the environment. However as mentioned previously the introduction of any such scheme is likely to be challenged by non-EU states on jurisdiction grounds and there are no provisions in UNCLOS or any other IMO conventions which could fully protect the EU from such challenges to the extraterritorial effect of the regulations.

With regard to enforcement of such schemes:

Route based scheme

While a route based scheme is more likely to be subject to evasion (as discussed in the section below), it would nonetheless appear to be the more attractive option in terms of enforcement and ensuring that the terms and spirit of an ETS are fully complied with.

In particular it will be relatively easy for the port state authority to assess the level of emissions from a ship during its journey from its load port to the discharge port in the EU according to the records held onboard the ship and the ability to assess emissions and the carbon efficiency of the vessel during the voyage. Formal notices can be provided to the ship regarding the emissions and whether the vessel has exceeded the cap. Accounts for each ship can be held and maintained in the EU so that balancing payments can be made in relation to the ship at the end of the accounting period.

Evasion

It has been argued that a route based scheme would suffer from problems of evasion. A ship sailing from Australia to Europe may put into a North African port so that the relevant voyage to an EU port for carbon purposes is a short one and hence the carbon emitted considerably less than for a non-stop voyage. The policy may encourage emitters to avoid European ports altogether and to discharge cargos in non-European ports close to the EU and then truck the goods to destination. As road transport is a more emission-intensive way of moving goods, this would be counter to the overriding aim of reducing overall GHG emissions.

However regulations can be made to avoid this by port authorities examining the origin of the cargo or port of loading as identified on the bill of lading so as to determine the proper duration/length of the voyage into the EU. Also economics will prevent large scale evasion - in most cases it would be much more expensive to unload a bulk carrier outside the EU and transport cargo by truck to its final destination in the EU than for the ship to proceed direct to the destination to discharge. There may be certain areas such as the Baltic States and South East Europe where the economics of container and other trades make such transhipment worthwhile and a study should be considered at a later stage but these are expected to be marginal. However, short sea voyages and hire voyages, where container vessels call regularly at closely spaced ports in and outside the EU make calculations difficult due to the nature of the trade.

Time based scheme

A time based scheme would apply to vessels that visited EU ports by way of working back over a fixed period of time before and after the port visit to determine total emissions during that period. This avoids some of the difficulties of a route based scheme described above as the calculation of emissions would not depend on the vessel’s actual movements and port visits.

In contrast with a route based scheme, a time based scheme poses a number of issues not only in terms of legal enforcement but also in terms of potential challenges and we would anticipate that a time based scheme would be vociferously opposed by the industry due to its extraterritorial effect.

The difficulty with such a system would be in determining the length of time to be used. It would not apply to vessels that were permanently or semi-permanently in EU waters (a definition of the latter would have to be devised) but would apply to vessels that visited the EU from time to time. The problem with setting a fixed time is that in the, for instance, 30 days before arrival at the EU, the vessel may have been trading between ports on the North African coast during which time they will have been subject to the EU ETS. This would include periods when lying alongside unloading in non-EU ports. The time limit would have to be different for different trades - e.g. trade centred in the Mediterranean and Middle East as against trade with the Far East and South America. To determine a workable and transparent system of determining the amount of time seems, on first analysis, to be insuperable and would lead to manifest unfairness in certain circumstances. Also, ships are flexible units and may be switched from trade to trade.

In addition, during any period of time the ownership of a vessel may change and during the course of a single year several operators and charterers could potentially make use of a vessel and such could equally be the case even where ownership of the vessel has not changed. Such changes will complicate fuel documentation and monitoring and this would pose almost insurmountable obstacles in terms of enforcing compliance with a time based ETS upon entry into an EU port (rather than requiring the surrender of allowances only for a single journey).

A further issue, which will have trade and economic consequences, is that charterers or operators will not want to take on a vessel for a single journey to an EU port if upon entry to that port it is going to become liable for that ship's emissions for the specific allocated period of time prior to entry. These might have been incurred by previous operators and charterers; in such circumstances it is highly unlikely that the previous operator/charterer would agree to be liable for the allowances required to be made and as such a time based scheme would likely result in a distortion of competition. It would also be very unpopular as the lack of transparency would mean that passing such costs onto cargo and sub-charters would be problematic.

Further, in terms of the integrity of an EU ETS, it would appear that the operation of such a scheme should at least be based on a link between emissions in the EU and the ship's entry into EU waters. In circumstances where operators could be held liable not only for emissions incurred outside EU waters but further as in respect of journeys which were in no way connected with or destined for the EU, it is highly unlikely that the operation of such a scheme would be met with a warm reception by the international industry and would likely lead to a very high level of evasion, perhaps even higher than that for a route based scheme.

EU Climate Change law

Should a decision be made to include maritime transport emissions within the EU ETS then the EU ETS Directive would need to be amended to incorporate shipping emissions with a separate cap. This could be done by way of a further Directive using the co-decision procedure.

Furthermore we recommend that a similar approach to the Aviation Directive is followed in the use of shipping allowances. The Registries Regulation chapter 3 (EC/994/2008) requires that all transactions in EUA's be backed up by assigned amount units (AAU's). As international shipping emissions are not covered by the Kyoto Protocol shipping emission allowances cannot be backed by AAU's. Therefore providing other EU ETS sectors with access to shipping emissions could create accounting issues. Following the Aviation Emissions Directive would be an option here, with the result that shipping allowances could not be used by other sectors covered by the EU ETS.

Further consideration is also necessary if the preferred option is to create a separate maritime emissions trading scheme which is closed or linked to the EU ETS. Primarily a separate Directive would be required for either option, and again could be adopted under the co-decision procedure. In addition the Effort Sharing Decision (406/2009/EC) would require amendment. If a linked scheme was chosen then the EU ETS Directive would also need amendment in order to provide for linkages with the shipping emissions Directive.

2. An Emissions tax without hypothecated revenues

Aside from jurisdictional issues considered above which would apply equally in this context, this policy option raises the primary difficulty of tax being an area of Member State competence and as such this policy would require member state unanimity.

Furthermore it is a basic principle of international law that no country will enforce the claims or judgments of another country for the payment of taxes. This principle is not overridden by the Brussels Convention on Jurisdiction and the Enforcement of Judgments in Civil and Commercial Matters.

EU internal competence

Any emissions tax to be introduced in the EU would have to satisfy the requirements of Articles 25 and 90 ECT, which are principally concerned with the elimination of tax discrimination on the importation and exportation of goods. Shipping comprises a wide range of activities, including: transport of cargo; dredging; offshore; support and fishing. There are potential arguments that the imposition of an emissions tax on some of these activities could be in breach of Articles 25 and 90. For example, in the context of transport of cargo, an emissions tax collected in ports would be a tax collected as goods crossed a border and which could result in higher taxation applying to imported products.

Article 25 ECT directs Member States to refrain from introducing between themselves any new custom duties on imports or exports or any charges having equivalent effect. Article 25 does not apply to charges for services. However, the European Court has insisted that, for a charge to escape Article 25 ECT on this basis the trader must receive a separate identifiable benefit in return for the sum paid and the sum paid must be proportionate to the benefit[20]. As mentioned above, in the case of the emissions tax the trader would not be receiving a separate identifiable benefit in return for the sum paid and so the emissions tax would not represent a charge for a service.

In the context of the transport of goods by sea, an emissions tax collected in EU ports could arguably represent a charge having equivalent effect to a customs duty. However, even if collected in ports, it is arguable that the reason for imposing the emissions tax is not because the goods have crossed a frontier.

Discriminatory or protectionist taxation is prohibited by Article 90 ECT. Discrimination arises when similar goods are taxed in a different way so as to benefit domestic products at the expense of imported ones. Protectionist tax arises when products which are in competition with each other are taxed in such a way so as to afford an advantage to domestic products. An emissions tax on shipping would represent an additional cost on the import of goods by ship; however, it is not specifically discriminating against products from other member states and would apply to exported goods as well as imported goods. It is arguable that the emissions tax results in imported products being taxed more heavily than domestic products. For Article 90 to apply, the charge has to be applicable equally to domestic and imported products (i.e. Article 90 relates to internal taxation), but the emissions tax would not apply to domestic products (other than as regards imported components etc).

Even if the emissions tax has a more burdensome effect on imported products, it will not be in breach of Articles 25 or 90 ECT if it can be objectively justified by legitimate public policy aims. Discrimination can be accepted on the basis of “objective criteria”, such as the nature of the product used or the production process employed, as long as it pursues “economic policy objectives“ compatible with EC law. The same principle applies if the object is to protect the

[20] As such, a charge levied at a frontier as part of a general system of quality control has been struck down (*W. Cadsky SpA v Instituto nazionale per il Commercio Estero, Case 63-74*)

environment. As such, the legitimate economic and/or environmental policy objective behind reducing carbon emissions may be sufficient to prevent the application of Articles 25 and 90.

The final point to note is that, whilst there are arguments that an emissions tax could breach Articles 25 and/or 90, the emissions tax would have been imposed by the EC (and would have required unanimous Member State approval) so it is difficult to envisage a successful challenge on the basis of Articles 25 or 90 ECT.

Member State competence and the principle of subsidiarity

The principle of subsidiarity is a fundamental principle of European Union law[21] and means that the EU may only act (i.e. make laws) where action of individual Member States is insufficient. The present formulation as follows[22]:

> *"In areas which do not fall within its exclusive competence, the Community shall take action, in accordance with the principle of subsidiarity, only if and in so far as the objectives of the proposed action cannot be sufficiently achieved by the Member States and can therefore, by reason of the scale or effects of the proposed action, be better achieved by the Community".*

The following guidelines have been provided for the application of the principle[23]:

(a) The issue under consideration has transnational aspects which cannot be satisfactorily regulated by action by Member States.

(b) Action by Member States alone or lack of Community action would conflict with the requirements of the Treaty (such as the need to correct distortion of competition or avoid disguised restrictions on trade, or strengthen economic and social cohesion) or would otherwise seriously damage Member States' interests.

(c) Action at community level would produce clear benefits by reason of its scale or effects compared with action at the level of the Member States.

The principle of subsidiarity is justifiable; however, the ECJ has not yet revealed its attitude towards the scope of the principle in the more difficult situations involving legislation adopted under the legal bases dealing with environmental measures. As such, what restraints upon centralised decision making would be brought about by strict reference to the principle of subsidiarity in the context of environmental measures has yet to be proven by major constitutional clashes. It may be possible in the field of carbon emissions and climate change to demonstrate that there is some need for collective action at the Community level, rather than relying on action of Member States individually.

As part of the legislative process, it is necessary to show how Article 5 ECT is satisfied. However, judicial review is likely to be confined to examining whether the assessment reached by the responsible institution has been vitiated by manifest error or abuse of powers, or whether the institution has manifestly exceeded the limits of its discretion. In the context of tax law, where legislation would have to receive the unanimous support of each Member State individually, it is difficult to envisage a challenge on the basis of non-compliance with the principle of subsidiarity.

We understand that hypothecation of revenues may be unconstitutional in some Member States. In addition, the hypothecation of revenues would not seem to fit within the criteria of the principle of subsidiarity. Looking at the guidelines listed in paragraphs (a) to (c) above, there does not seem to be any compelling reasons why the use of funds raised by the emissions tax should not remain a matter for Member States to control. However, if the proposed structure for the emissions tax were to include hypothecation of the revenues raised, on the basis that all

[21] Established in the 1992 Treaty of Maastricht.
[22] Article 5 ECT
[23] Treaty of Amsterdam, Protocol on the application of the principles of subsidiarity and proportionality, at paragraph 5

Member States must unanimously approve the imposition of the emissions tax, it is difficult to envisage a challenge to the hypothecation of revenues on the basis of the principle of subsidiarity as the decision would have effectively been made at Member State level in any case.

EU external competence

The imposition of an emissions tax raises questions of territoriality. As stated above, Article 89 UNCLOS prevents States from any exercise of jurisdiction over foreign vessel upon the high seas.

In view of the fact that States cannot exercise any kind of jurisdiction over foreign vessels upon the high seas, it is unlikely that an emissions tax could be charged by reference to shipping activities taking place on the high seas or otherwise outside of the member state's territorial waters. To be effective, the tax could only be imposed by reference to emissions relating to the operation of the ship in the member state's territorial waters.

Even within territorial waters there could still be a challenge to the imposition of an emissions tax under Article 26 UNCLOS, which provides that no charge may be levied on foreign vessels by reason only of their passage through the territorial sea, but only for specific services rendered to the ship. However, it is important to highlight that Article 26 UNCLOS only applies in relation to innocent passage through the territorial sea. It would not apply if a ship called at a port (which, we understand, would be a condition of the imposition of the emissions tax). In addition, Article 26 UNCLOS applies to charges and (as discussed above) there can be a distinction between a charge and a tax. But the potential remains for entities operating foreign ships to claim that the emissions tax is contrary to Article 26 UNCLOS. This may be a more significant problem for ships flagged in jurisdictions outside the EU (i.e. jurisdictions that would not have agreed to the implementation of the emissions tax).

Some defence to any challenge of the legality of the emissions tax by non-EU states may be found in Article 16 of the 1992 Rio Declaration on Environment and Development, which provides that:

> *"National authorities should endeavour to promote the internationalisation of environmental costs and the use of economic instruments, taking into account the approach that the polluter should, in principle, bear the cost of pollution, with due regard to the public interest and without distorting international trade and investment."*

However, the content of this polluter pays principle is vague and doubts have been expressed by reputable authorities about its legal status.

Double tax treaties

It should be possible to structure an emissions tax in such a way as to ensure that it does not fall within the scope of current double tax treaties. Taking the US-UK double tax treaty as an example, the taxes covered are taxes on income and capital gains including all taxes imposed on total income, or on elements of income, including taxes on gains from the alienation of property. For the UK, this covers income tax, capital gains tax, corporation tax and petroleum revenue tax. Any identical or substantially similar taxes subsequently imposed would also be covered. However, a tax calculated by reference to emissions should not fall within these categories (as it is not calculated by reference to income or gains) and so is arguably not covered by the double tax treaty. The position should be similar for all double tax treaties, which follow a common model.

Even if an argument could be made that the emissions tax would fall within the scope of a double tax treaty, the treaty articles dealing with shipping relate to the apportionment of the rights of each contracting state to tax the profits of an enterprise of one of the contracting states from the operation of ships in international traffic. So, for example, the US-UK double tax treaty would prevent the UK from imposing a tax on the profits of a US company derived from the operation of ships in international traffic. However, the point arises again that an emissions tax would most likely be structured in such a way that it would not represent a tax on profits (e.g. the tax would be due regardless of whether any profit had been made by the shipping entity and the amount of tax due would not depend on the level of any profit). This is a point that would need to be borne in mind in structuring the basis of calculation for any emissions tax.

As noted above the implementation of a tax on emissions is likely to be challenged on the ground that it contravenes Article 26 UNCLOS. That being said it would appear that if such a tax regime were to be implemented it would not be efficacious only to implement the charge upon voyages between EU ports as the revenue from any such tax scheme would be minimal and may also disproportionately affect some ship operators more than others: e.g. vessels which rarely pass through EU waters or call at EU ports would only be subject to a nominal charge even though they may be responsible for a much higher level of CO_2 emissions that those vessels whose primary purpose is to travel back and forth between EU ports e.g. cargo ships travelling between Harwich and the Hook of Holland. As such any emissions tax would be more easily applied to all ships calling at an EU port and not only to voyages between EU ports.

In addition any such tax would have to be levied at port and consequently could not be applied to ships in transit passing through EU waters.

The EU Commission is concerned that directing any revenues generated from such a tax solely into the maritime sector, as opposed to directing the revenues into other sectors as well, may induce a rebound resulting in a long-term increase of overall emissions as a direct consequence of increase in supply. However, resistance to such a tax from non-EU states and industry bodies is likely to be reduced if the revenues generated were directed, similar to light dues, by way of subsidies solely into the shipping industry e.g. by way of investment into research and development or training for the purpose of reducing the levels of emissions from shipping.

While any emissions tax scheme will be the subject of evasion (ships are likely to call at ports outside the EU in order to avoid paying the tax), if the EU were able to obtain unanimous agreement on the implementation of the tax from all its member states, the EU would be able to make the payment of the tax a condition of entry into an EU port. As a consequence in the event that a ship fails and/or refuses to pay the tax, the EU would be able to ban that ship from its territorial waters in accordance with Article 25.2 UNCLOS as set out above.

However from a tax perspective we note the following. Given that seas are categorised under UNCLOS as territorial seas (which are subject to state sovereignty) and the high seas (which are not capable of being placed under state sovereignty and subsequently no state may exercise any kind of jurisdiction over foreign ships upon the high seas), it is likely that any emissions tax charged by reference to shipping activities taking place on the high seas or otherwise outside of EU territorial waters would be subject to challenge. As such for any EU wide emissions tax to be immune from challenge the tax would only have to be applied by reference to emissions relating to the operation of ships within EU territorial waters - however the environmental effectiveness of such a scheme would be extremely limited.

Regardless of legality, the practical problems of collecting tax from ships not calling at EU ports would be immense. Such attempt has not been made on aircraft for similar reasons. Further, the impositions of such a tax will lead to evasion attempts with ships taking longer routes to avoid entering EU waters. This would have the opposite effect to reducing emissions.

As discussed above it may be possible for the EU to justify the imposition of an EU wide emissions tax by making the payment of the tax a condition of entry into EU ports in accordance with Article 25.2 UNCLOS.

The eventual monitoring of such a scheme also requires consideration of its compatibility with EU law. On a purely practical note it is anticipated that a tax without hypothecated revenue will not be as attractive to the shipping industry given that they will not directly benefit from R & D investment for the shipping industry as a whole.

3. Agreement to reduce the operational CO_2 index-Voluntary or Mandatory.

This policy may be imposed on either a voluntary or mandatory basis. The voluntary option clearly removes the majority of legal challenges or questions of EU competence. However, member states must respect principles of proportionality, non discrimination and state aid rules.

More notably in legal terms is the potential difficulty in enforcing a voluntary scheme, particularly as it would not be possible to apply a charge to the ship as this would contravene Article 26 UNCLOS. Further it is possible that, even if the states had agreed to be subject to a fine or charge in the event of violating the terms of the voluntary agreement, any charge levied as a result of a breach would constitute a penalty which is not permitted under English law; this would of course be subject to the governing law of the voluntary agreement and the drafting of the relevant provisions[24].

That being said the courts generally consider that parties should be free to contract between themselves and agree upon the consequences of a breach of an agreement. They are therefore reluctant to disrupt the parties' bargain by characterising a clause negotiated between commercial parties as a penalty.

Considering a mandatory system a state has jurisdiction over its ports and territorial seas as set out above and consequently in principle the EU is at liberty to require adherence with an EU-wide CO_2 operational index limit value as a condition of entry into an EU port, failing which the offending vessel would be banned from an EU member state's territorial sea.

However compliance with an operational CO_2 index limit value, which would require ships to operate at or below a certain level of efficiency for their vessel type to obtain entry to EU ports, could potentially result in vessels having to change their engines and/or equipment on board in order to comply with the efficiency limit. This would then in turn mean that vessels would be forced to comply with enhanced CDEM standards outside the territorial seas of the EU and so outside the EU's jurisdiction. This would contravene Articles 21 and 211 UNCLOS.

Article 1(4) UNCLOS defines 'pollution of the marine environment' as

> *"the introduction by man, directly or indirectly, of substances or energy into the marine environment, including estuaries, which results or is likely to result in such deleterious effects as harm to living resources and marine life, hazards to human health, hindrance to marine activities, including fishing and other legitimate uses of the sea, impairment of quality for use of sea water and reduction of amenities"*.

Article 21.1(f) UNCLOS states that:

> *"the coastal state may adopt laws and regulations, in conformity with the provisions of this Convention and other rules of international law, relating to innocent passage through the territorial sea, in respect of…the preservation of the environment of the coastal state and the prevention, reduction and control of pollution thereof"*.

However Article 21.4 UNCLOS limits a state's powers to take such actions by imposing a limitation on states to the effect that any such laws or regulations can only require vessels to comply with internationally accepted CDEM standards.

Consequently the EU is only permitted under UNCLOS to adopt and require compliance with laws and regulations imposing internationally accepted CDEM standards for vessels sailing in their territorial seas and as a result would be in contravention of UNCLOS and acting illegally if it were to unilaterally impose its own standards above and beyond generally accepted international CDEM standards by way of a mandatory design or operational efficiency limit value and this would constitute a breach of a foreign vessel's right to innocent passage.

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24 Briefly, under English law a clause in a contract which provides for a fixed or pre-determined amount to be payable on breach of contract may be recoverable as liquidated damages. However, if the amount payable is not seen to be a genuine pre-estimate of loss that would be caused by the relevant breach at the time when the contract was made it will be deemed to be a penalty clause.

To this extent there is equal potential for an operational efficiency limit value to contravene internationally accepted CDEM standards.

Article 211 UNCLOS establishes the framework within which states are permitted to prevent reduce and control pollution from vessels and in particular Article 211.1 UNCLOS states that:

> *"states, acting through the competent international organisation or general diplomatic conference, shall establish international rules and standards to prevent, reduce and control pollution of the marine environment from vessels"*.

The EU, as a competent international organisation, is empowered under UNCLOS to establish rules to prevent, control and reduce pollution and in particular Article 211.3 UNCLOS further provides that:

> *"states which establish particular requirements for the prevention, reduction and control of pollution of the marine environment as a condition for the entry of foreign vessels into their port or internal waters or for a call at their off-shore terminals shall give due publicity to such requirements and shall communicate them to the competent international organisation…Every state shall require the master of a vessel flying its flag or of its registry, when navigating within the territorial sea of a state participating in such cooperative arrangements, to furnish, upon the request of that state, information as to whether it is proceeding to a state of the same region participating in such cooperative arrangements and, if so, to indicate whether it complies with the port entry requirements of that state. <u>This article is without prejudice to the continued exercise by a vessel of its right of innocent passage or to the application of article 25, paragraph 2</u>.*

As such while states are permitted to prescribe laws and regulations to prevent, reduce and control pollution in its territorial waters, such laws and regulations are subject always to a vessel's right of innocent passage and consequently any laws or regulations introduced by the EU in its member states must not contravene the provisions of Article 21.4 UNCLOS set out above.

> Article 25.2 UNCLOS is set out above and again the exercise of a state's right to take such action against a vessel could only be exercised in circumstances where the CDEM standards which were being applied by an EU member state were not greater than those standards which are internationally accepted. This is supported by Article 211.5 UNCLOS, which states that coastal states may
>
> *"in the exercise of their sovereignty within their territorial sea, adopt laws and regulations for the prevention, reduction and control of marine pollution from foreign vessels, including vessels exercising the right of innocent passage. Such laws and regulations shall, in accordance with Part II, section 3, not hamper innocent passage of foreign vessels".*

Pursuant to Article 211.5 UNCLOS, coastal states may:

> *"<u>for the purpose of enforcement as provided for in section 6</u>* [emphasis added]*, in respect of their exclusive economic zones adopt laws and regulations for the prevention, reduction and control of pollution from vessels conforming to and giving effect to generally accepted international rules and standards established through the competent international organisation or general diplomatic conference"*.

Article 211.6 UNCLOS permits coastal states to implement such laws and regulations as provided in Article 211.5 UNCLOS only in circumstances where the state has reasonable grounds for believing that a particular, clearly defined area of their respective exclusive economic zones is an area where the adoption of special mandatory measures for the prevention of pollution from vessels is required for recognised technical reasons in relation to its oceanographical and ecological conditions and as such these particular UNCLOS provisions cannot be relied on to justify the implementation of a requirement that higher CDEM standards than are already required at an international level be imposed in the EU's EEZs in an attempt to reduce GHG emissions.

We understand that the EU anticipates that the operation of the index would require vessels to comply outside as well as within EU waters and consequently a mandatory operational CO_2 index limit value will be challenged on grounds of jurisdiction by non-EU states.

Further given the indirect effect that an operational index limit value could have on the design and equipment of a vessel, the EU would not be permitted to require vessels calling at or departing from an EU port to comply indirectly with enhanced CDEM standards as a condition of entry into EU ports and as such the implementation of an operational CO_2 index limit value at EU ports would constitute a breach of internationally accepted CDEM standards.

In addition it would be very challenging to establish an operational index with fair baseline levels as it would not be able to take account of external factors which can affect a ship's efficiency, even if it were based on annual data. A further challenge would be for the EU to create and be able to enforce an operational index which could equally be applied to all types of ships and shipping without resulting in indirect discrimination against certain types of vessels. In particular the EU would have to consider excluding tramp shipping from any such scheme due to the infrequency with which such vessels would be visiting EU ports.

Should the mandatory route be followed then in terms of initial competence the EU can look to Article 175 ECT. However further examination is also necessary regarding the proposed consequences for non-compliance to assess any potential impacts on EU competence

4. Agreement to reduce the design CO_2 index

As with a policy to form agreement to reduce the operational C02 index this may be done on a voluntary or mandatory basis. As above, this means the only real issues of concern are on what basis any charge may be imposed if the scheme was voluntary, and the risk of breaching Articles 21 and 211 UNCLOS should the scheme be mandatory.

5. Research and Development subsidy for improvement of maritime infrastructure

Competence of the EU to implement such a scheme is essentially not in issue in this context. However, of primary concern is the fact that any policy involving innovation subsidies for ship owners from EU Member States would have to comply with existing EC rules on state aid. As part of the process of designing a scheme which would provide for innovation support to be implemented by individual Member States, the application of state aid rules would have to be carefully considered.

Under Article 87 ECT, subject to a number of limited exceptions, any aid granted by a Member State involving the transfer of state resources, or which confers an economic advantage on a select group of undertakings is prohibited. Based on our current understanding, the innovation support from Member States would be targeted at the maritime sector, making it highly likely that such measures could be classified as state aid.

It is not clear at this stage what type of innovation support is being contemplated. However, the notion of "state resources", developed through the case law of the European Courts, is very broad, so that not only direct subsidies, but other forms of economic assistance are also caught by the rules. This means that fiscal advantages in the form of tax incentives and other types of indirect assistance would also need to be examined.

The rules against state aid will apply regardless of whether the support is granted directly by a Member State or is channelled through an intermediary body (either public or private) appointed by the state. According to the case law, in order to be classified as aid within the meaning of Article 87(1) ECT, the advantage must be granted directly or indirectly through state resources and must be imputable to the state.[25] In addition, the aid must have the potential to distort competition between Member States, although we consider that any aid to the shipping industry would easily meet this test.

Under the applicable EC rules, Member States are not allow to put any state aid into effect without obtaining the prior authorisation of the European Commission. Any aid which is granted without such approval is deemed to be unlawful aid and the European Commission may order recovery from beneficiaries. It is also possible that a recipient of aid may be sued by a competitor for damages.

There are a number of specific guidelines which have been drawn up by the Commission to clarify the circumstances under which aid may be granted by Member States in ways which are compatible with their EC Treaty obligations. A specific framework exists for state aid to shipbuilding[26] and for Research, Development and Innovation[27]. Specific guidelines have also been drawn up by the European Commission to address the issue of state aid for environmental protection[28]. Depending on the type of innovation support being contemplated, each of these guidelines may have to be examined in more detail to determine the compatibility of the proposed scheme with the state aid rules.

The effect of the EC Treaty prohibition on state aid means that any innovation support to ship owners by Member States (either directly or indirectly through a public/private intermediary body appointed by the State) would have to be structured in such a way so as to be compatible with the existing rules. Failure to do so would run the risk of the support being struck down and potentially expose the recipient companies to the risk of litigation from competitors.

Legal constraints - Agreement on Subsidies and Countervailing Measures

The WTO Agreement on Subsidies and Countervailing Measures (**SCM Agreement**) deals with government subsides and seeks to tackle subsidies given by a government to its producers which give those producers an advantage in the market place. The SCM Agreement sets out multilateral disciplines regulating the provision of subsidies and the use of countervailing measures (being steps taken to negate the effect of an action, event, or occurrence) to offset injury caused by subsidised imports.

The SCM Agreement:

- defines subsidies which distort trade;
- establishes rules for multilateral trade actions countries are permitted to pursue through the WTO Dispute Settlement Body to counter the subsidisation of other countries; and
- establishes guidance on action countries can take unilaterally by way of countervailing measures.

The SCM Agreement defines three types of subsidies:

Prohibited

These subsidies are considered to be the most likely to distort trade. Prohibited subsidies take two forms and can either be those subsidies which are contingent on export performance or those which are contingent on the use of domestic over imported goods.

Actionable

These subsidies are not prohibited but are nonetheless subject to trade action under the SCM Agreement.

[25] Case C-482/99 France v Commission [2002] ECR I, para 24.
[26] Framework on State Aid to Shipbuilding, OJ C 317, 30.12.2003, pages 11-14 and the Communication from the Commission concerning the prolongation of the Framework on State aid to shipbuilding adopted 3 July 2008 OJ C 173 of 8.7.2008, p. 3.
[27] Community Framework for State aid for Research and Development and Innovation, OJ C 323 of 30.12.2006. page 1.
[28] Community Guidelines on State Aid for Environmental Protection, OJ C 82 of 01.04.2008, page 1.

Non-actionable

These are subsidies which are generally considered to be the least likely to distort trade and consequently are generally available and are not subject to trade action.

The SCM Agreement applies to industrial products (e.g. the manufacture of ships) and to agricultural goods and therefore it is possible that the provisions of the SCM Agreement would apply to any innovation support offered to the shipping industry as part of any scheme to reduce carbon emissions from ships.

We note that an R&D subsidy for technical innovation in ships would be limited to EU-based ships, given the political difficulty of including ships that are registered outside the EU.

At this preliminary stage, and before further detail is provided as to how such R&D subsidy would operate, we are not able to comment fully on whether any such subsidy would breach the terms of the SCM Agreement. However if such subsidy were found to be either a prohibited or actionable subsidy, it is possible that the subsidy could be challenged either unilaterally or multilaterally by non-EU states under the SCM Agreement.

Annex C

Taking responsibility: setting a CO_2 emissions cap for the aviation and shipping sectors in a 2-degree world

Taking responsibility: setting a CO_2 emissions cap for the aviation and shipping sectors in a 2-degree world

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Abstract

Emissions of CO_2 from international aviation and shipping have proven difficult to allocate to parties in international climate agreements and are excluded from the Kyoto Protocol. In the absence of policy intervention, aviation CO_2 emissions are predicted to increase over 2005 levels of 0.2 Gt C yr^{-1} by 1.9–4.5 fold (0.37–0.89 Gt C yr^{-1}) in 2050, and shipping from 0.26 Gt C yr^{-1} in 2005 by 1.3–3.8 fold (0.34–0.98 Gt C yr^{-1}) in 2050. If global mean surface temperature is not to increase by more than 2 ºC by 2100 over preindustrial levels, deep cuts in all sources of CO_2 are necessary. Cumulative emissions have been shown to be a robust metric for such a temperature target. Two methodologies are proposed here, by which global aviation and shipping are given a cumulative emissions cap, compatible with a 450 ppm CO_2 stabilization scenario. *Option I* involves scaling a future cumulative cap to the historical cumulative emissions of these sectors, allowing 5.6 Gt C (aviation) and 10.9 Gt C (shipping) to 2050. *Option II* involves scaling a future cumulative cap to more recent (2000–2005) proportions of these sectors' emissions, allowing 8.0 Gt C (aviation) and 9.9 Gt C (shipping) to 2050. The CO_2 radiative forcing and temperature responses for all aviation and shipping scenarios (non-policy intervention and policy-intervention) were calculated against the 450 ppm CO_2 stabilization scenario. *Options I* and *II* were compared with (a) the EU Copenhagen negotiating position for these sectors of -10% (aviation) and -20% (shipping) below 2005 levels by 2020, (b) industry-declared targets for global aviation and a hypothetical global emissions-trading scheme, and (c) the scenarios in the absence of policy intervention. For aviation, the 450 ppm compatible *Options I* (and *II*) deliver the best (second best) performance and the IATA-I scenario the poorest. The EU-ETS and EU-COP15 scenarios are indistinguishable and are close to the performance of *Option II*. For shipping, the best performing policy scenario is *Option II*, closely followed by the EU-COP15 scenario.

Key words: Climate change, aviation, shipping, stabilization, greenhouse gases

PACS: 89.60.-k to 89.60.Fe

Submitted to: Environmental Research Letters

1 Introduction

Emissions of CO_2 from international aviation and shipping are excluded from the Kyoto Protocol targets for Annex I countries. Owing to difficulties in allocating these emissions to parties, under Article 2.2, Annex I countries have an obligation to reduce these emissions working through the International Civil Aviation Organization (ICAO) and the International Maritime Organization (IMO).

Because of the lack of progress on tackling aviation emissions within ICAO, the European Union (EU) has extended its Emissions Trading Scheme (ETS) to include aviation from 2012 onwards and is considering how it may be extended to include shipping emissions. The EU-ETS is an 'open' scheme, whereby emission permits are traded freely between sectors, and will cover all international flights arriving at European destinations. The cap at the outset of the scheme in 2012 is planned to be 97% of the mean 2004–2006 aviation emissions (of the order 0.06 Gt CO_2), falling to 95% in 2013.

The issue of sectoral cap-setting has been mostly a political debate, rather than a scientific exercise. Recent scientific work has shown that to a first order, limiting the total amount of CO_2 emitted to the atmosphere is a reliable means of not exceeding some specified temperature target (Allen *et al* 2009, Meinshausen *et al* 2009, Matthews *et al* 2009, Zickfeld *et al* 2009, WBGU 2009).

The WRE 450 ppm CO_2 emission pathway (Wigley *et al* 1996) provides a means of limiting increases in global mean surface temperatures to no more than 2 ºC over preindustrial levels by 2100, within a certain probability. *How* this might be achieved, in terms of emissions responsibility, or future allowances, has only been recently (e.g. WBGU 2009, Chakravarty *et al* 2009). The German Advisory Council on Global Change (WBGU 2009) has proposed a scientifically-based carbon-budget approach, with the CO_2 budget distributed amongst the world's population on a per capita basis, through national CO_2 budgets. The WGBU envisaged three groups of countries decarbonizing at different rates to ensure equity for developing nations. The WBGU recognized that international emissions from aviation and shipping did not easily fit into their proposal and recommended a levy on these sectors.

Here, an analytically-derived cap for aviation and shipping CO_2 emissions is proposed, utilizing concepts similar to the two Options proposed by WBGU (2009) in implementing the budget approach. *Option I* considers 'Historical responsibility' and *Option II* 'Future responsibility' (WBGU 2009). It is this concept of "responsibility" that is picked up in this work (and reflected in its title).

In addition to *Options I* and *II*, analyses of what might be achieved under a simplistic assumption of hypothetical global coverage of the principals of the EU-ETS, the EU negotiating position for Copenhagen, and industry targets for aviation are presented.

2 Methods

2.1 Historical, future, and policy scenarios

Historical data (1751–2006) for emissions of fossil-fuel burning, cement manufacture and gas flaring were taken from the database of Boden and Marland (2009). The WRE450 emissions pathway of CO_2 from fossil fuels (Wigley *et al* 1996) was extracted from the MAGICCv5.3 model (Wigley 2008).

Historical emissions of aviation (1940–2005) and shipping (1870–2007) were taken from Lee *et al* (2009) and Buhaug *et al* (2009), respectively (figure 1).

Future emissions scenarios for aviation were taken from Owen *et al* (2009) and FESG (2009), and for shipping from Eyring *et al* (2005), Behrens (2007) and Buhaug *et al* (2009). Most scenarios were based on SRES A1, A2, B1, and B2 assumptions (IPCC 2000). The FESG (2009) data commence at 2006 and are incomplete in coverage (i.e. other aviation kerosene usage, imperfect inventories through flight operations etc.) and were adjusted upwards by 42 Tg C yr^{-1} to match 2006 kerosene sales data from the International Energy Agency. The magnitude of current-day emissions from shipping has previously been disputed but now resolved with a 2007 best estimate from Buhaug *et al* (2009). Therefore, the emissions projections of Eyring *et al* (2005) and Behrens (2007) were adjusted upwards to match the 2007 emissions of Buhaug *et al* (2009). These scenarios in the absence of policy intervention are shown in figures 2a/2b.

A range of policy intervention scenarios for aviation and shipping (figures 2c/2d) were formulated as follows.

Aviation and shipping scenarios compatible with the WRE450 scenario were calculated in two ways. Firstly, on a similar basis to '*Option I – Historical Responsibility*' of WBGU (2009), whereby the sectors are allocated a fractional share of the WRE450 cumulative emissions over the period 2006–2050, based on their historical share of cumulative emissions. Historical emissions from aviation (1940–2005) and shipping (1870–2005) were 5.8.Gt C and 11.24 Gt C, 1.8% and 3.5% of total cumulative fossil fuel emissions (320.8 Gt C, 1751–2005). This implies cumulative emission caps for 2006–2050 of 5.6 Gt C (aviation) and 10.9 Gt C (shipping) for the WRE450 scenario.

A second approach, similar to WBGU's '*Option II – Future Responsibility*', utilized the mean 2000–2005 fractions of total fossil fuel emissions, which were 2.6% (aviation) and 3.2% (shipping). This implies cumulative emissions caps for 2006–2050 of 8.0 Gt C (aviation) and 9.9 Gt C (shipping) for the WRE450 scenario.

Additional scenarios were devised from the EU negotiating position for Copenhagen, 'EU COP-15'. For the EU COP-15 scenario, declarations of the Council of the European Union (EU 2009) were implemented, which states that CO_2 emissions should be -10% and -20% below 2005 levels by 2020 for aviation and shipping. Again, post-2020 emissions were not specified, so constant levels until 2050 were assumed.

For the aviation sector, two additional scenarios were derived (figure 2c). The first one follows the EU-ETS. It was assumed for simplicity that it is implemented globally (as opposed to the actual scope of the scheme). Thus, aviation emissions increase until 2011 and are thereafter limited to 97% of the mean 2004–2006 emissions, and 95% of these from 2013 until 2020, maintained at this level to 2050 (post-2020 emissions are not specified by the EU). The second scenario is based on industry-declared emissions targets for global aviation by the International Air Transportation Association (IATA).

IATA's short-term target is to improve fuel efficiency (on a CO_2 per revenue tonne-kilometre basis) by 1.5% yr^{-1} until 2020, allowing emissions to increase; the mid-term target is to stabilize CO_2 emissions from 2020 onwards; and their long-term aspirational goal is to reduce CO_2 emissions by 50% by 2050 over 2005 levels (HLM-ENV/09-WP/19 2009). These targets have been interpreted in two ways; 'IATA-I' in which emissions remain constant from 2020 to 2050, and 'IATA-II' in which emissions decline non-linearly (in order to represent the delay from fleet-rollover) from 2020 levels to half of 2005 levels. The FESG (2009) low, central and high growth scenarios for 'technology 6' were used, which assumed "*Optimistic technology and operational improvement*" such that all aircraft entering the fleet after 2006 have a fuel burn improvement of 1.5% per year to 2036 and an additional fleet-wide operational efficiency improvement of 3% to 2016 (FESG 2009).

2.2 CO_2 concentrations, radiative forcing (RF), and climate response

Two simplified climate response models (SCMs) were used to calculate RF and changes in global mean temperature response (ΔT). The MAGICC model v5.3 (Wigley 2008) was used to generate the background WRE450 CO_2 concentrations used for all scenarios, and a sectoral-specific SCM, LinClim (Lim *et al* 2007, Lee *et al* 2009) was used to calculate the marginal CO_2 concentrations arising from shipping and aviation emissions. Changes in ΔT were calculated using the methodology of Hasselmann et al (1993) such that the SCM's response was tuned to a parent coupled ocean-atmosphere general circulation model, ECHAM4/OPYC3 (Roeckner *et al* 1999).

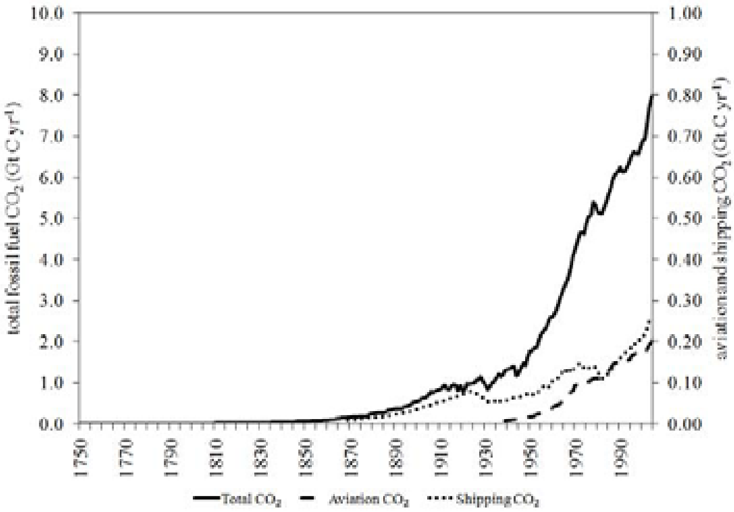

Figure 1. Historical total emissions of CO_2 (Boden and Marland, 2009), and those from aviation (Lee *et al* 2009) and shipping (Buhaug *et al* 2009).

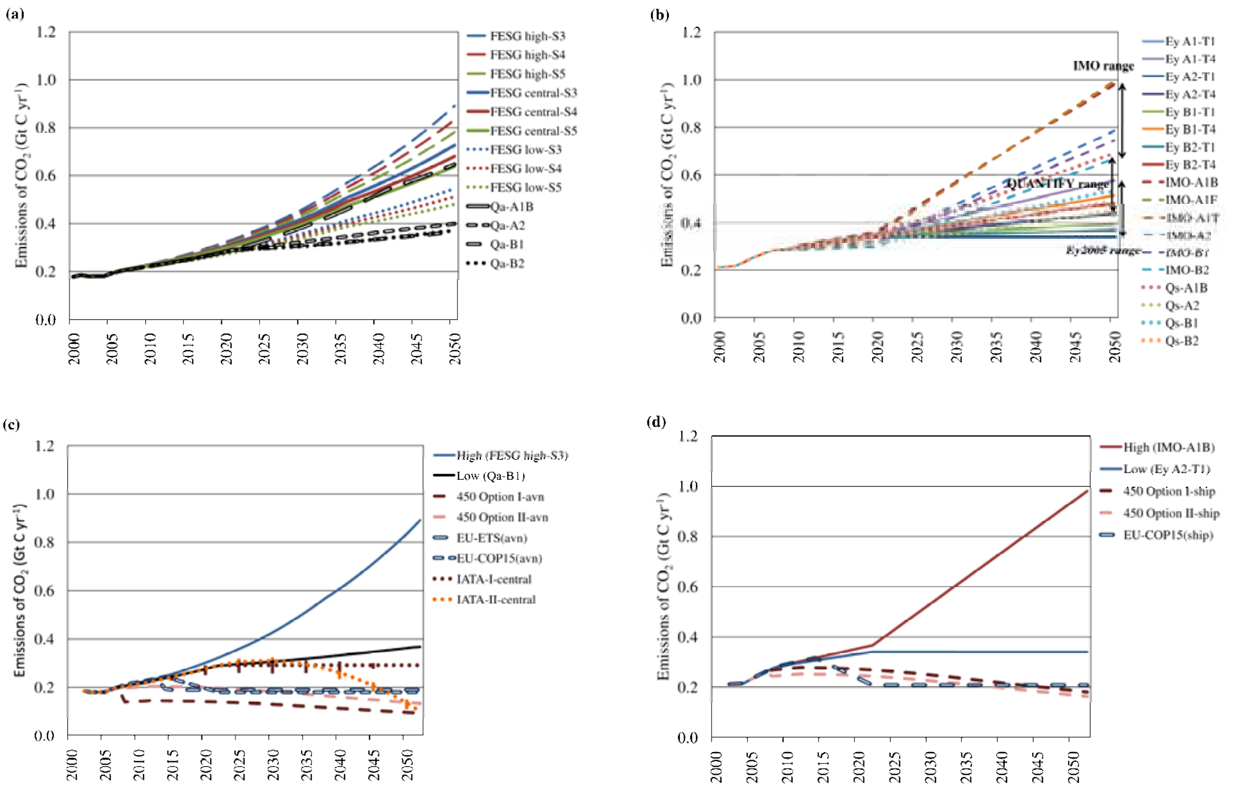

Figure 2. Scenarios of CO_2 emissions in the absence of policy intervention from aviation (Owen *et al* 2009, FESG 2009) (a) and shipping (Buhaug *et al* 2009, adjusted emissions of Eyring *et al* 2005 and Behrens 2007) (b); and policy scenarios for aviation (c) and shipping (d). (Note, for 4c the range of low to high IATA scenarios is indicated by a vertical bar).

3 Results

Emissions data for 2050, percentages of these emissions to WRE450 rates, cumulative emissions for 2006–2050 and corresponding percentages of cumulative WRE450 emissions to 2050 are given in tables 1 (aviation) and 2 (shipping). The CO_2 RF (mW m^{-2}) and global mean temperature response (ΔT, mK) are given in tables 3 (aviation) and 4 (shipping).

Cumulative fossil fuel emissions from 1751–2005, were 321 Gt C. Under the assumption of the WRE450 scenario from thereon, this would imply that 310 Gt C are 'available' for 2006–2050, and 184 Gt C for 2051–2100, totalling somewhat less than the 1000 Gt C (1 Tt) 'allowable' suggested by Allen *et al* (2009).

Of the 310 Gt C available between 2006 and 2050 under WRE450, scenarios in the absence of policy intervention indicate that 13.3–21.1 Gt C (4.3–6.8%) might be used for aviation, and 15.5–25.4 Gt C (5.0–8.2%) for shipping, which for both sectors yields a range between 28.8 and 46.5 Gt C (9–15%). This would mean a significant increase of the shares compared to the historical contribution to total cumulative fossil fuel emissions (1.8% for aviation and 3.5% for shipping).

Under these scenarios in the absence of policy intervention, CO_2 RF for aviation will increase from 28 mW m^{-2} (2005) to 72–108 mW m^{-2} in 2050 (2.6–3.9 fold increase), whilst shipping CO_2 RF will increase from 47 mW m^{-2} (2005) to 92–139 mW m^{-2} in 2050 (2.0–3.0 fold increase). The ΔT attributable to CO_2 in 2050 will increase by between 3.6–4.3 fold (aviation) and 2.0–2.5 fold (shipping) over 2005, see figure 3. The percentage contribution of aviation CO_2 RF increased from ~1.7% (2005) to between 2.9% and 4.4% of the WRE450 CO_2 scenario and for shipping, this increased from ~2.9% to between 3.5% and 5.5%.

The time-development of RF and ΔT for the maximum and minimum of the scenarios, along with the policy scenarios is shown in figure 4. For aviation RF, *Options I* (and *II*) deliver the best (second best) performance, reducing 2050 RF from ~72–109 mW m^{-2} (low, high non-intervention scenarios) to ~37–48 mW m^{-2} (*Option I, II*), i.e. 1.9–2.8 fold (*Option I*). The IATA-I scenarios perform the worst, reducing 2050 RF from ~72–109 mW m^{-2} (low/high) to ~61–67 mW m^{-2} (IATA-I/II, central). The aviation EU-ETS and EU-COP15 scenarios are indistinguishable and are close to the performance of *Option II*. For shipping, the best performing policy scenario is *Option II*, reducing 2050 RF from ~90–139 mW m^{-2} (low, high non-intervention scenarios) to ~68 mW m^{-2}, i.e. 1.3–2.0 fold, closely followed by the EU-COP15 scenario (~71 mW m^{-2}).

Table 1. Emissions of CO_2 for background and aviation scenarios; 2050 end-point and cumulative 2006–2050.

Scenario	2050 emissions (Gt C yr^{-1})	Percentage of WRE450 2050 emissions	Cumulative emissions 2006–2050 (Gt C)	Percentage of WRE450 cumulative emissions (2006-2050)	Scenario family or type	Source (notes)
Background						
WRE450	5.15	100	310.5	100	WRE450	Wigley *et al* 1996
Aviation						
FESG high-S3	0.89	17.3	21.1	6.8	High demand	FESG 2009
FESG high-S4	0.83	16.2	20.4	6.6	High demand	FESG 2009
FESG high-S5	0.78	15.2	19.7	6.3	High demand	FESG 2009
FESG central-S3	0.73	14.1	18.9	6.1	Central demand	FESG 2009
FESG central-S4	0.68	13.2	18.3	5.9	Central demand	FESG 2009
FESG central-S5	0.64	12.4	17.7	5.7	Central demand	FESG 2009
FESG low-S3	0.54	10.6	15.9	5.1	Low demand	FESG 2009
FESG low-S4	0.51	9.9	15.4	4.9	Low demand	FESG 2009
FESG low-S5	0.48	9.3	14.9	4.8	Low demand	FESG 2009
Qa-A1B	0.65	12.5	17.4	5.6	A1B	Owen *et al* 2009
Qa-A2	0.40	7.7	13.9	4.5	A2	Owen *et al* 2009
Qa-B1	0.36	7.1	13.3	4.3	B1	Owen *et al* 2009
Qa-B2	0.37	7.2	13.3	4.3	B2	Owen *et al* 2009
Aviation policy scenarios						
EU-ETS(avn)	0.19	3.7	8.7	2.8	policy-global	this work
EU-COP15(avn)	0.18	3.5	8.7	2.8	policy-global	this work
IATA-I-high	0.31	5.9	12.9	4.2	industry	this work
IATA-I-central	0.29	5.7	12.4	4.0	industry	this work
IATA-I-low	0.27	5.2	11.5	3.7	industry	this work
IATA-II-high	0.10	1.9	11.7	3.8	industry	this work
IATA-II-central	0.10	1.9	11.2	3.6	industry	this work
IATA-II-low	0.10	1.9	10.3	3.3	industry	this work
450 Option I-avn	0.09	1.8	5.6	1.8	WRE450	this work
450 Option II-avn	0.13	2.6	8.0	2.6	WRE450	this work

Table 2. Emissions of CO_2 for background and shipping scenarios; 2050 end-point and cumulative 2006–2050.

Scenario	2050 emissions (Gt C yr^{-1})	Percentage of WRE450 2050 emissions	Cumulative emissions 2006–2050 (Gt C)	Percentage of WRE450 cumulative emissions (2006-2050)	Scenario family or type	Source (notes)
Background						
WRE450	5.15	100	310.5	100	WRE450	Wigley *et al* 1996
Shipping						
Ey A1-T1[a]	0.44	6.6	16.7	5.4	A1	Eyring *et al* 2005
Ey A1-T4	0.58	11.2	18.9	6.1	A1	Eyring *et al* 2005
Ey A2-T1	0.34	6.6	14.9	4.8	A2	Eyring *et al* 2005
Ey A2-T4	0.44	8.6	16.4	5.3	A2	Eyring *et al* 2005
Ey B1-T1	0.39	7.7	15.9	5.1	B1	Eyring *et al* 2005
Ey B1-T4	0.51	10.0	17.8	5.7	B1	Eyring *et al* 2005
Ey B2-T1	0.37	7.2	15.5	5.0	B2	Eyring *et al* 2005
Ey B2-T4	0.48	9.4	17.2	5.5	B2	Eyring *et al* 2005
IMO-A1B	0.98	19.0	25.4	8.2	A1B	Buhaug *et al* 2009
IMO-A1F	0.99	19.3	25.3	8.1	A1FI	Buhaug *et al* 2009
IMO-A1T	0.99	19.2	25.2	8.1	A1T	Buhaug *et al* 2009
IMO-A2	0.78	15.2	21.4	6.9	A2	Buhaug *et al* 2009
IMO-B1	0.75	14.5	20.7	6.7	B1	Buhaug *et al* 2009
IMO-B2	0.67	13.0	19.2	6.2	B2	Buhaug *et al* 2009
Qs-A1B	0.69	13.4	20.5	6.6	A1B	Behrens 2007
Qs-A2	0.43	8.3	16.1	5.2	A2	Behrens 2007
Qs-B1	0.53	10.2	17.9	5.8	B1	Behrens 2007
Qs-B2	0.48	9.3	17.2	5.5	B2	Behrens 2007
Shipping policy scenarios						
EU-COP15(ship)	0.21	4.0	10.4	3.3	policy-global	this work
450 Option I-ship	0.18	3.5	10.9	3.5	WRE450	this work
450 Option II-ship	0.16	3.2	9.9	3.2	WRE450	this work

[a]Eyring *et al* (2005) describe four technology scenarios (T1–T4), however, CO_2 emissions from T1–T3 are identical.

Table 3. CO_2 concentrations, RF and global mean temperature response at 2050 for background and aviation scenarios.

Scenario	2050 CO_2 concentration (ppm)	2050 CO_2 RF (mW m^{-2})	Percentage of WRE450 2050 CO_2 RF	ΔT at 2050 from CO_2 (mK)	Percentage of WRE450 ΔT at 2050 from CO_2
Background					
WRE450	440	2,456	100	1,205.2	100
Aviation					
FESG high-S3	8.8	108.0	4.4	32.6	2.7
FESG high-S4	8.5	104.5	4.3	32.1	2.7
FESG high-S5	8.2	101.2	4.1	31.5	2.6
FESG central-S3	7.9	97.4	4.0	30.9	2.6
FESG central-S4	7.7	94.5	3.8	30.4	2.5
FESG central-S5	7.5	91.7	3.7	29.9	2.5
FESG low-S3	6.8	83.5	3.4	28.4	2.4
FESG low-S4	6.6	81.2	3.3	28.0	2.3
FESG low-S5	6.5	79.0	3.2	27.6	2.3
Qa-A1B	7.6	92.8	3.8	30.0	2.5
Qa-A2	6.1	75.0	3.1	27.3	2.3
Qa-B1	5.9	72.1	2.9	26.8	2.2
Qa-B2	5.9	72.1	2.9	26.8	2.2
Aviation policy scenarios					
EU-ETS(avn)	4.2	51.4	2.1	22.0	1.8
EU-COP15(avn)	4.2	51.0	2.1	22.1	1.8
IATA-I-high	5.7	69.3	2.8	26.6	2.2
IATA-I-central	5.5	67.0	2.7	26.0	2.2
IATA-I-low	5.2	63.1	2.6	25.0	2.1
IATA-II-high	5.1	62.9	2.6	26.3	2.2
IATA-II-central	5.0	60.6	2.5	25.6	2.1
IATA-II-low	4.7	56.9	2.3	24.5	2.0
450 Option I-avn	3.2	38.6	1.6	18.4	1.5
450 Option II-avn	3.9	47.9	1.9	21.5	1.8

Table 4. CO_2 concentrations, RF and global mean temperature response at 2050 for background and shipping scenarios.

Scenario	2050 CO_2 concentration (ppm)	2050 CO_2 RF (mW m^{-2})	Percentage of WRE450 2050 CO_2 RF	ΔT at 2050 from CO_2 (mK)	Percentage of WRE450 ΔT at 2050 from CO_2
Background					
WRE450	440	2,456	100	1,205.2	100
Shipping scenarios					
Ey A1-T1	8.0	98.1	4.0	40.8	3.4
Ey A1-T4	8.8	108.1	4.4	42.4	3.5
Ey A2-T1	7.3	89.6	3.6	39.2	3.3
Ey A2-T4	7.9	96.9	3.9	40.4	3.4
Ey B1-T1	7.7	94.2	3.8	40.1	3.3
Ey B1-T4	8.4	103.0	4.2	41.5	3.4
Ey B2-T1	7.5	92.3	3.8	39.7	3.3
Ey B2-T4	8.2	100.5	4.1	41.0	3.4
IMO-A1B	11.3	138.6	5.6	47.2	3.9
IMO-A1F	11.2	138.4	5.6	47.2	3.9
IMO-A1T	11.2	138.3	5.6	47.4	3.9
IMO-A2	9.8	120.8	4.9	44.0	3.6
IMO-B1	9.6	117.5	4.8	43.4	3.6
IMO-B2	9.0	110.6	4.5	42.1	3.5
Qs-A1B	9.4	115.9	4.7	43.6	3.6
Qs-A2	7.8	95.5	3.9	39.8	3.3
Qs-B1	8.5	104.0	4.2	41.6	3.4
Qs-B2	8.2	100.3	4.1	40.9	3.4
Shipping policy scenarios					
EU-COP15(ship)	5.8	70.5	2.9	34.6	2.9
450 Option I-ship	5.9	72.3	2.9	35.4	2.9
450 Option II-ship	5.6	68.2	2.8	34.1	2.8

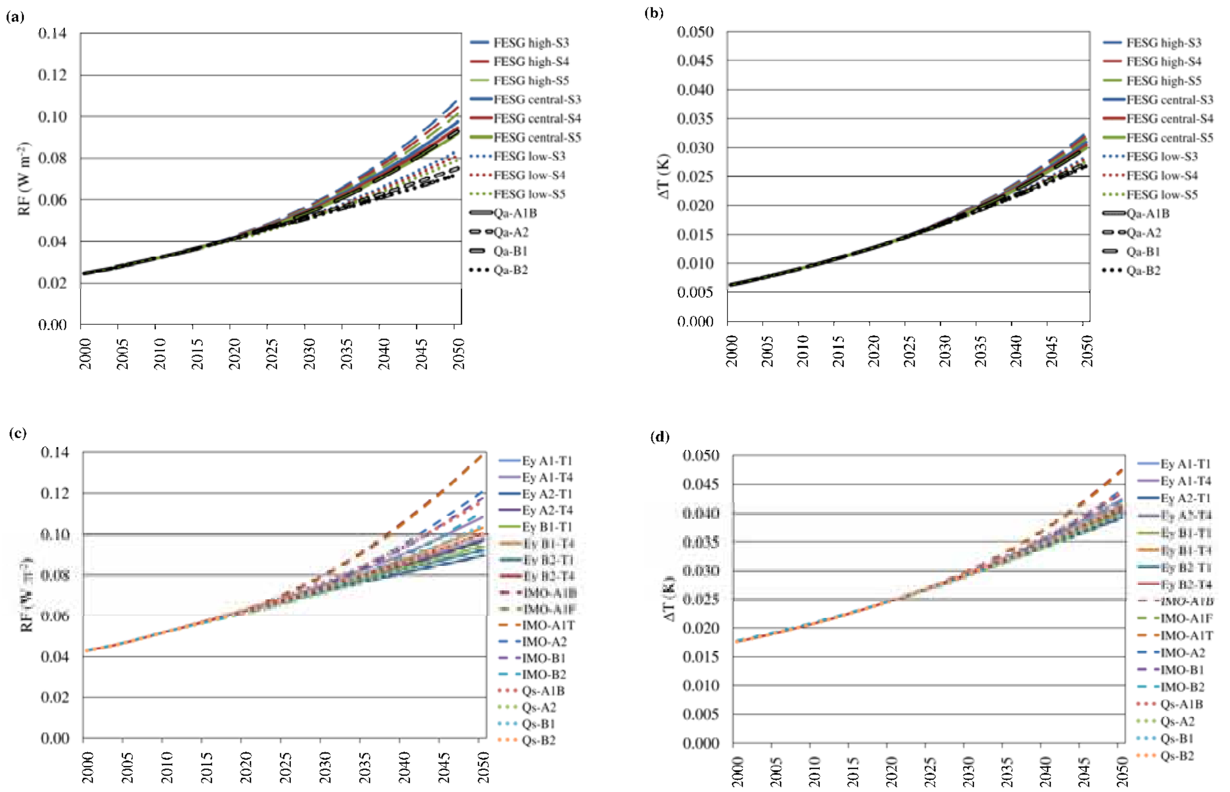

Figure 3. CO_2 RF and ΔT response for aviation (a, b) and shipping scenarios (c, d) against WRE450 background.

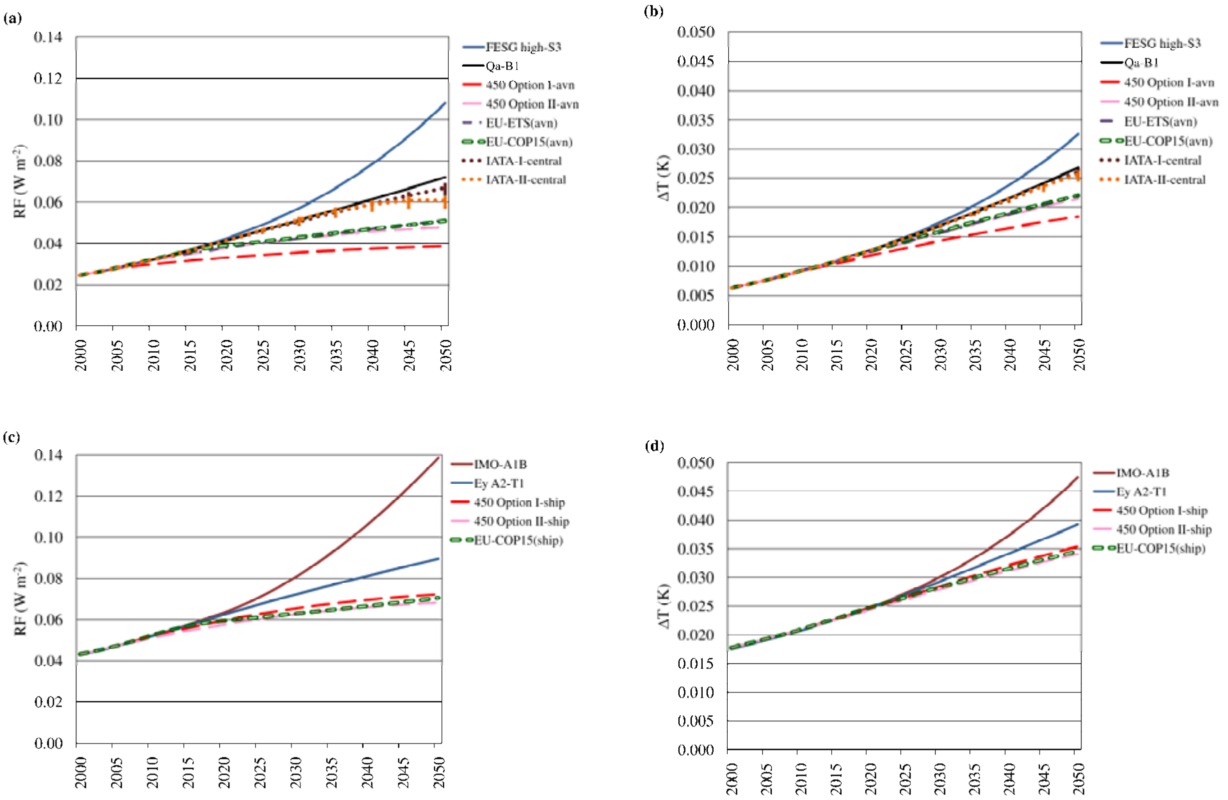

Figure 4. CO_2 RF and ΔT response from aviation (a, b) and shipping scenarios (c, d) against a WRE450 ppm CO_2 background for maximum and minimum non-policy scenarios compared with policy scenarios (note, for 4a and 4b, the range of low to high IATA scenarios is indicated by a vertical bar).

4 Discussion

Future CO_2 emission scenarios for aviation and shipping indicate that these sectors' emissions are expected to increase strongly in the absence of policy intervention over the coming decades. Aviation emissions of CO_2 are projected to increase from 0.20 Gt C yr^{-1} (2005) to between 0.36 and 0.89 Gt C yr^{-1} (2050), and shipping emissions from 0.26 Gt C yr^{-1} (2005), to between 0.34 and 0.98 Gt C yr^{-1} (2050).

If these increases in emissions are calculated against a WRE450 CO_2 stabilization scenario background, then the CO_2 RFs from these sectors increase by 2.6–3.9 fold (aviation) and 2.0–3.0 fold (shipping).

Cumulative emissions are a good indicator of impacts on climate, in contrast to annual emission rates of CO_2 (despite them being widely discussed in policy). The RF metric quantifies 'effect' since it integrates the CO_2 emissions over time and accounts for accumulation of CO_2 in the atmosphere, and ΔT is even closer to an actual effect but introduces more uncertainties (model-dependence). Nonetheless, RF only quantifies an effect to a given point in time, and does not account for the residual future effect of the emissions, which an integrated RF does (IRF, W m^{-2} yr). Metrics like the IRF are not clear to non-scientists, requiring a certain level of scientific understanding, hence the cumulative emissions concept (e.g. Allen *et al* 2009), or "budget approach" (WBGU 2009) is attractive to policy-makers as it creates an effective 'short cut' between emissions and temperature response.

A further attraction of the cumulative emissions approach is that they may be directly allocated to nations or sectors, an approach advocated by WBGU (2009) and others (e.g. Chakravarty *et al* 2009), indeed the premise of shared responsibility is the foundation of international climate agreements. But, allocating responsibility to the aviation and shipping sectors has proved to be difficult and does not easily fit in with allocation to states (WBGU 2009). Here, it is shown that this can be done with the cumulative emissions approach, only requiring agreement over the basis of the shared responsibility – whether it is based in history (*Option I*) or some recent performance of the industry (*Option II*). How *Options I* and *II* fit into the 450 ppm stabilization concept, and thus allow definition of a cap on cumulative emissions has been illustrated. This provides a 'hard target' that will, in an equitable world, ensure the contribution of aviation and shipping sectors to stabilized CO_2 levels. Previously, targets and ambitions have been discussed for these sectors with no real understanding of their environmental performance. The shipping sector has embraced the principle of emission reduction targets at least as ambitious as any international agreement (ICS 2009).

As to *how* cumulative emission caps are implemented, a number of means might be used to achieve them, e.g. technology improvements, emissions trading, carbon offsets etc. Moreover, it might be argued that marginal abatement costs for aviation and shipping emissions are high (particularly so in the case of aviation) and that other sectors will need to have a higher burden of emissions reductions. The focus of this work is to set the constraints of the environment itself and use natural science to demonstrate how emissions targets might be defined for the aviation and shipping sectors.

5 Conclusions

Cumulative emissions caps on aviation and shipping for 2006–2050 have been proposed on a physical science-based argument; cumulative emissions of CO_2 are a robust metric for limiting global mean temperature increases, and have been calculated under the example of the WRE450 stabilization scenario.

Cumulative emission caps for aviation and shipping were based on two options, similar to those proposed by the WBGU (2009). *Option I* was retrospective, using the past contribution of these sectors to total cumulative emissions, *Option II* was based on more recent percentages of the mean 2000–2005 emission *rate* and scaling this to the WRE450 'available' emissions for 2006–2050.

The cumulative emission caps for 2006–2050 under *Option I* are 5.6 Gt C for aviation and 10.9 Gt C for shipping: under *Option II*, they are 8.0 Gt C for aviation and 9.9 Gt C for shipping.

The basis for proposing this methodology is that all sources and sectors need to decarbonize quickly, and by taking either retrospective or recent fractions of the available C budget, this places a constraint on the aviation and shipping sectors that is equitable with other sectors. The *method* by which the emissions are capped is not prescriptive; this might be achieved by, for example, technological improvements, emissions trading, carbon-offsetting, biofuels (where the complete life-cycle is considered), demand reduction, or some combination of these.

These idealized caps were compared with non policy-intervention scenarios and it was shown that aviation and shipping are predicted to consume much larger fractions of the total allowable C budget under the WRE450 pathway than they have previously, either on a long-term or more recent basis. Cumulative (non-policy) emissions from aviation were projected to be 4.3–6.8% of allowable emissions for 2006–2050, *cf.* its long-term historical consumption of 1.8% and 2000–2005 mean of 2.6%. Corresponding cumulative emissions from shipping were 4.8–8.2% of allowable emissions, 2006-2050, *cf.* with its long-term historical consumption of 3.5% and 2000-2005 mean of 3.2%.

A number of other 'policy' scenarios were examined in terms of cumulative emissions, effects on CO_2 RF and ΔT; a global inclusion of aviation into an emissions trading scheme using the EU Emissions Trading Scheme caps, recent EU targets for the forthcoming Copenhagen (COP15) event, and industry targets for aviation. None of these scenarios performed as well as *Options I* and *II* did, although they came close to optimal for shipping. For aviation, a global implementation of the EU-ETS was indistinguishable from the EU-COP15 ambitions of emissions reductions. For aviation, the worst-performing policy scenarios were the industry targets.

Acknowledgements

DSL, HP, LLL, BO, acknowledge funding from the UK DfT and DSL, VE and JF for funding from the European Commission. We are grateful for discussions with; Mark Major, European Commission and Ben Combes, United Kingdom Committee on Climate Change Secretariat.

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Annex D

Emissions of black carbon from shipping and effects on climate

Emissions of black carbon from shipping and effects on climate

—ad hoc paper for European Commission—

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Abstract

This ad hoc paper considers the emissions of black carbon (BC) from global shipping activities. Recent literature was reviewed for directly measured emission factors of BC from ships, which were found to be of the order 0.1–0.3 g BC kg^{-1} fuel, with a best estimate of 0.17 g BC kg^{-1} fuel. Using this best estimate, the global emissions of BC from shipping was estimated to be 57 Gg (range 47–68) for 2007, using the uncertainty range of global fuel usage from the IMO GHG study. Shipping emissions represent 1–2.4% of global fossil fuel emissions of BC. Only 1% of shipping BC is emitted at latitudes greater than 60 ^{0}N but this may be a significant local source, particularly in the Arctic. The impacts of BC on climate are complex, and can result in warming through the direct effect of trapping long-wave radiation. In the Arctic, other effects of BC come into play: BC may enhance low-level clouds, trapping outgoing long-wave radiation; BC deposited on snow and ice changes the albedo of the surface, warming it, and accelerates snowmelt. Climate change is affecting temperatures at the North Pole more than anywhere else on the planet, and sea-ice extent shows a clear decline over time from satellite observations. With decreasing sea-ice extent, this will enable shipping in the future to use the North West Passage (over Canada) and the Northern Sea Route (over Siberia) during summer months. Whilst these routes have the potential to shorten transit distances (e.g., the Northern Sea Route reduces a voyage from Shanghai to Rotterdam by ~25% over the route via the Suez Canal) and reduce CO_2 emissions, the additional warming effect of BC emissions deposited to snow and ice could potentially *increase* overall effective BC CO_2-equivalent emissions (via a Global Warming Potential), despite the shorter distance. Studies that are much more detailed are required of these tradeoffs between BC emissions and CO_2 emissions but this study indicates that any increase in BC emissions in the Arctic will have harmful localized warming effects and that should polar routes open up in the future, emissions control of particles would be a prudent precaution to minimize this effect.

1 Introduction

The Second IMO Greenhouse Gas Study (Buhaug et al., 2009) presented a comprehensive study on emissions from shipping pertaining to climate and air quality. The report quantified emissions and made projections for the future, examined potential climate impacts, and reviewed potential technological and policy options for emissions reductions. Emissions of black carbon (sometimes referred to as 'soot' although the two are not exactly synonymous) from shipping were mentioned by Buhaug et al. (2009) but not dealt with in any detail. Rather, particle emissions were quantified in a more general sense as 'PM10', using emission factors from CORINAIR (Thomas et al., 2002).

Particle emissions (from any combustion source) can be described in a number of ways; by their size (strictly, their aerodynamic diameter), their number density, their chemical composition, and their volatility. In the general sense, black carbon (BC) is understood to be less than 10 μm in diameter (since that is normally a restriction of measurements) unless otherwise specified, largely composed of carbon, and is the non-volatile fraction of particle emissions (the volatile fraction being largely composed of sulphur and organic compounds). Black carbon is a primary aerosol emitted directly from the combustion source arising from incomplete combustion.

Aerosols of the size typically associated with fossil-fuel BC emissions have a lifetime of hours to a few weeks in the atmosphere, depending upon the location and time of emission, and size of the particle. Most of the BC will eventually be removed by wet deposition (rain, snow, fog), since dry deposition of particles of this size is a relative inefficient process. Whilst in the atmosphere, BC particles may influence the radiative balance directly, and indirectly, through their ability to alter cloud properties and lifetime. In addition, BC, if deposited on snow and ice surfaces, may reduce the reflectivity (albedo), changing the local radiative balance of the atmosphere. It is this effect that is potentially of significance to changes in future climate and shipping routes, and the Arctic environment.

It is potential changes in the Arctic environment and the consequential opening up of shipping routes that is of particular concern in terms of increasing pollution in a sensitive environment (Eyring et al., 2009). This is examined in more detail in section 2.

In section 3, global emissions of BC and their trends over time are briefly reviewed. In section 4, the emissions from shipping are reviewed and put into global context. The effects of BC on climate are described in section 5. In section 6, mitigation technologies for BC are outlined and in section 7, some brief conclusions are drawn as to what future climate change may mean in terms of BC emissions from shipping and how they may affect climate.

2 Changes in the Arctic

The Arctic Climate Impact Assement (ACIA, 2005) and the IPCC (2007) have both drawn attention to the fast-changing climate of the Arctic. Key findings from the IPCC's Fourth Assessment Report (IPCC SR, 2008) regarding physical changes to the Arctic include:

- Arctic temperatures have increased at almost twice the average global rate in the past 100 years;
- Satellite data since 1978 have shown that Arctic sea-ice extent has shrunk by 2.7% decade^{-1} with larger summer decreases of 7.4% decade^{-1};
- Temperatures at the top of the permafrost layer in the Arctic have increased since the 1980s by up to 3 °C;
- Sea ice extent in the Arctic shrinks in all SRES future scenarios and in some projections, late summer sea-ice disappears almost entirely by the late 21st century (see also Boé et al., 2009).

The extent of Arctic sea-ice is important for climate as it represents a large area of high albedo, which forms a strong contrast over ice-free sea. This reflects solar radiation back to space and serves to reduce heat loss from the northern oceans. In addition, the denser water found from high salinities play a role on ocean circulation and reduced sea-ice alters atmospheric circulation patterns (Budikova, 2009).

Sea-ice extent reached a minimum in September 2007 (see Figure 1). Since then, the long-term decline has continued but not reached the record low of 2007.

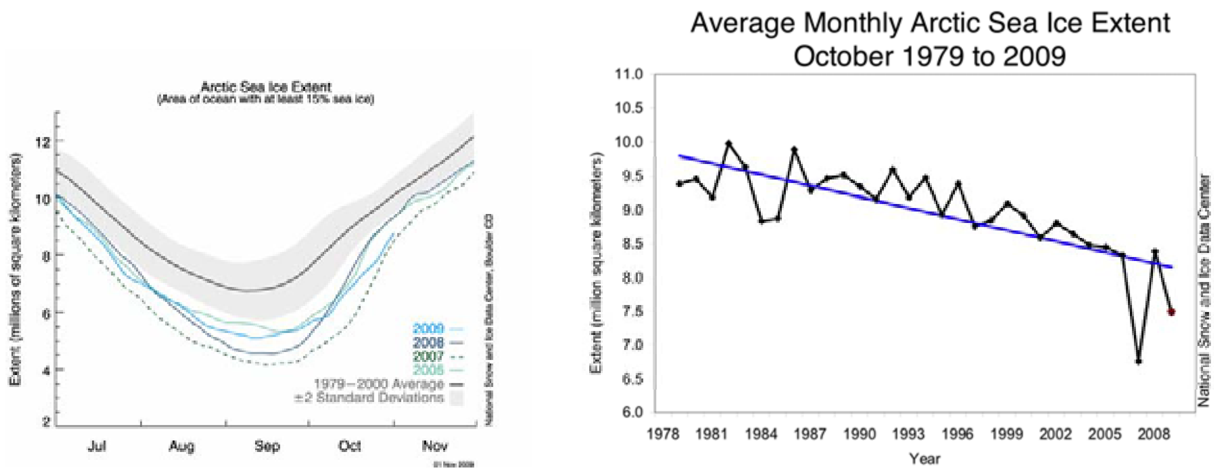

***Figure 1**. Arctic sea ice extent by month for recent years compared with long-term average (1979 – 2000) and long-term trend in October sea-ice extent (source: National Snow and Ice Data Center).*

It is these long-term trends in sea-ice extent that may eventually make extensive shipping activity more viable. Two basic routes may become opened up to commercial traffic in the summer months in the Arctic, the Northwest Passage from the Atlantic to the Pacific over the north of the USA and Canada, and the Northern Sea Route (NSR), from the Asian Pacific via the Bering Straits and Barents Sea to Europe (see Figure 2).

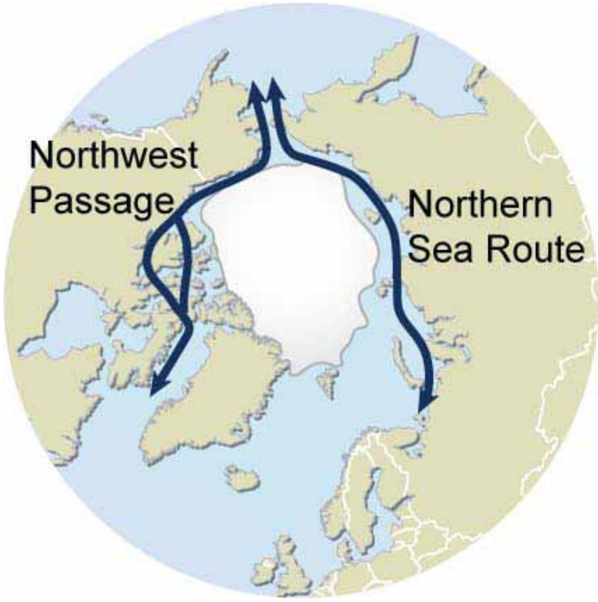

***Figure 2**. The Northwest Passage and Northern Sea Route (source: http://maps.grida.no)*

Utilization of these sea routes is not necessarily straightforward, even with retreating sea-ice. Ships with reinforced hulls are needed and currently, ice-breaking escort vessels are required, although a German vessel of the Beluga Group claimed in 2009 to have completed a voyage without assistance from icebreakers[1]. The nature and occurrence of ice-type also plays a role; for example Stewart et al. (2007) commenting on the role of future cruise tourism in the Canadian Arctic have argued that diminishing sea-ice will not necessarily open up the Passage in the short-term, since potentially hull-penetrating multi-year ice will be liberated, making navigation dangerous. Moreover, there are still issues of legal governance under dispute for the Northwest Passage (Rayfuse, 2007). In terms of the Northern Sea Route, significant losses of sea-ice have been observed in not only summer, but also winter and spring such that the White Sea has lost two thirds of its May cover since the 1970s and changes of >50% being observed in the winter for most of the Barents Sea (Rodrigues, 2008).

Liu and Kronbak (2009) have examined the economic viability of the NSR. Using the example of a voyage from Asia (Yokohama) to Europe (Rotterdam), they point out that a 40% distance saving does not equate to a 40% saving in operational costs, since ice-classed ships need to be used, speed are lower (which may save additional emissions, if it is not necessary to break ice), and navigational difficulties and risks increase. Escort services by ice-breakers may also be necessary. The key economic factor found by Liu and Kronbak (2009) was the ice-breaking and navigation fees involved. If these were not prohibitive in the future, the NSR was a better prospect than a

[1] http://www.barentsobserver.com/german-vessels-ready-for-the-northern-sea-route.4616626-16175.html.

conventional route through the Suez Canal. Somanathan et al. (2009) made a similar economic evaluation of the Northwest Passage, comparing voyages from New York and St. Johns to Yokohama via the Northwest Passage and the Panama Canal. An increased number of trips was found to be possible, despite slower speeds but the cost comparison was less clear; however, with thinning ice in the future facilitating faster speeds, the costs were projected to be lower on the Northwest Pasage route.

In addition to potentially increased container-vessel shipping utilization, it is also envisaged that climate change and increased access to the Arctic may initiate mineral, and oil and gas extraction and exploitation. This aspect has been examined by Dalsøren et al. (2007), who examined the potential environmental impacts on particle, SO_x and NO_x emissions.

3 Global emissions of black carbon

Emissions of BC arise from a number of sources, including power generation, transportation (road, rail, shipping, and aviation), the steel industry, domestic fuel burning, and biofuels (Bond et al., 2007). Similar to many other emissions estimates, the quality and uncertainty associated with such data is dictated by statistics on fuel usage and the emission factors. Since BC is a product of incomplete combustion, which in turn depends on the emission source, its age and condition, the emission factors tend to have the greater uncertainty.

The Intergovernmental Panel on Climate Change (IPCC) recently reviewed data on global BC emissions. The IPCC (Forster et al., 2007) cited the study of Bond et al. (2004), who estimated an emission of 8.0 Tg C for 2000, of which 4.6 Tg C was from fossil fuels and biofuels, and 3.3 Tg C was from open biomass burning, with an overall uncertainty of factor 2. A smaller estimate for fossil fuel sources of 2.8 Tg C for 2000 was made by Ito and Penner (2005). Bond et al. (2007) recently presented trends in calculated emissions, comparing them with previous trend work of Ito and Penner (2005) and Novakov et al. (2003): all studies found increasing emissions over time up until 2000, the largest discrepancy in terms of magnitude and rate of change being found for fossil fuels (see Figure 3). The largest fraction of BC from 1990 onwards from fossil fuels has come from diesel engine emissions (Bond et al., 2007).

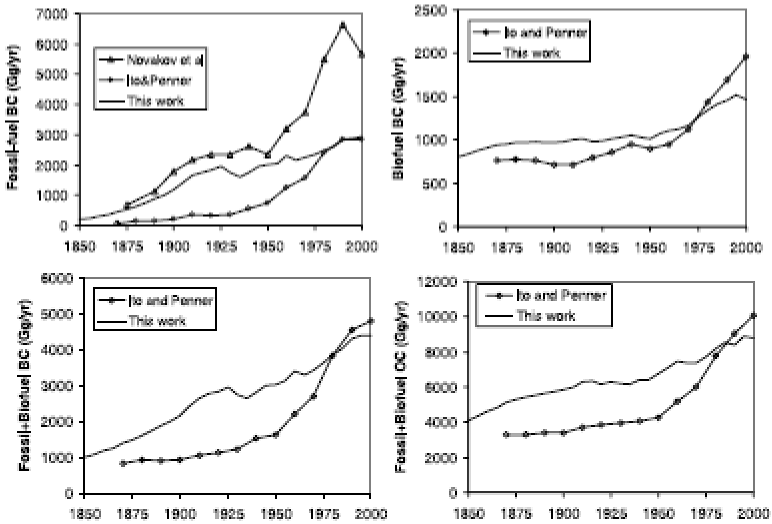

Figure 3. *Trends in emissions of BC fractions from different sources over time, taken from Bond et al. (2007) (i.e. "this work" is that of Bond et al.)*

4 Shipping emissions of black carbon

Direct measurements of BC from ship engines (principally large diesel engines running on heavy fuel oil) are rather limited and the available literature values are summarized in Table 1.

Table 1 Emission factors (g BC kg fuel^{-1}) of BC from ship engines

Emission factor	Notes	Reference
0.18 (± 0.02)	Plume encounters of a tanker and a container ship using diesel (residual high viscosity oil and intermediate fuel oil); BC estimated to be 4% of total particulate matter	Sinha et al. (2003)
0.179 (± 0.018) 0.174 (± 0.043)	Test-bed measurement of 4 stroke diesel using heavy fuel oil Plume encounters (average)	Petzold et al. 2008
0.304	Interpretation of measurements of PM, assuming 4% BC of two stroke diesel using heavy fuel oil	Haglind 2008
0.04 (± 0.01)	Stack measurement from container ship, two-stroke using heavy diesel oil	Murphy et al. (2009)
0.85 (± 0.76, *n*=100)	Plume encounters (100)	Lack et al. (2009)
0.13	Plume sample, cargo vessel	Moldanová et al. (2009)

It is difficult to summarize such a limited number of measurements made in a variety of ways. The overall emission factor is of the order 0.1–0.3 g BC kg^{-1} fuel, with two notable exceptions. The measurements of Murphy et al. (2009) yielded a much smaller emission factor (0.04 g BC kg^{-1} fuel), and those of Lack et al. (2009) who, using an optical technique, found a much greater emission factor (~0.9 g BC kg^{-1} fuel). Clearly, more work is needed to understand these discrepancies and the speciation between organic and elemental carbon (the latter here is interpreted as 'black carbon').

Given the uncertainties outlined above, an average of the emission factors from Table 4 of 0.17 g BC kg^{-1} fuel is used in this work. This excludes the interpreted emission factor of Haglind, 2008, and the 'outliers' of Murphy et al., 2009 and Lack et al., 2009. Such an emission factor is essentially similar to the emission factor used by Eyring et al. (2005) in their global inventory, who used the emission factor of Sinha et al. (2003). Thus, global emissions in 2007 using the IMO total fuel usage of 333 Tg (range 279–400), would imply a global emission of BC from shipping of 57 Gg (range 47–68), or 0.057 Tg (range 0.047–0.068 Tg).

Using the IMO estimate of 2000 fuel usage (Buhaug et al., 2009) of 248 Tg (range, 208–298 Tg) and the global emissions of BC estimated in section 2, shipping represented 0.7% of total global BC according to Bond et al. (2004), or 1.2% of fossil-fuel and biofuel-related emissions (range 1.0–1.5%, considering uncertainty in estimate of shipping fuel usage alone). If the fossil fuel-related emissions estimate of Ito and Penner (2005) for BC is used, this would imply that shipping represented ~2% of global BC emissions (range 1.7%–2.4%, considering uncertainty in estimate of shipping fuel usage alone).

The latitudinal distribution of shipping BC emissions is shown in Figure 2. This shows that approximately 1% occurs at latitudes greater than 60 ^{0}N. Whilst this is a small fraction of the BC emissions, BC from shipping is potentially a significant source of warming because of the extra warming effects of BC at these.

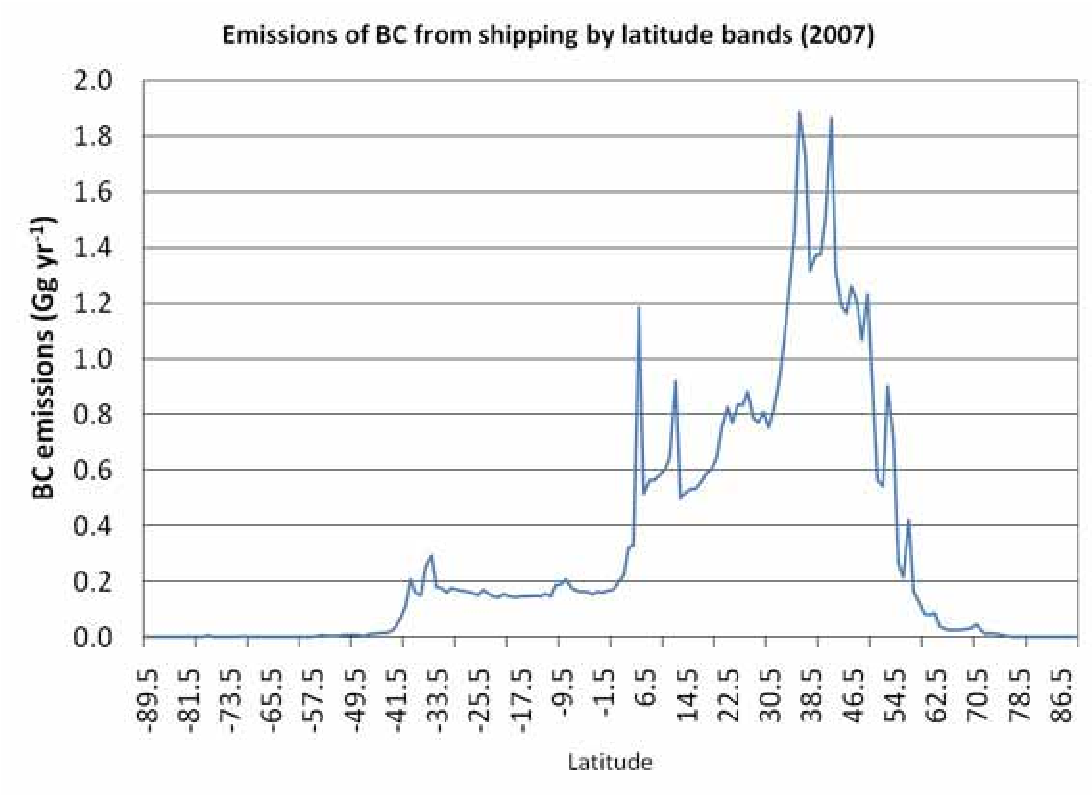

Figure 2. *Emissions of black carbon from shipping (see text) by latitude, using IMO fuel usage distribution for 2007.*

5 Effects of black carbon

5.1 Radiative effects of black carbon – mechanisms

The climate effects of aerosols are extremely complex. The direct effects arise from scattering and absorption of solar radiation causing both heating and cooling. The first indirect effect is the increased reflectivity of clouds from aerosols causing an increase in concentration of smaller water droplets; smaller cloud droplets may in turn affect the lifetime of clouds through suppressed precipitation (second indirect effect); lastly, heating may cause cloud 'burn-off', the semi-direct effects (see summary of Forster et al., 2007). Whether aerosols are scattering or absorbing depends on their colour. BC aerosols are strong absorbers of solar radiation and heat the lower atmosphere but may cause a local surface cooling. This results in a redistribution of energy over the atmospheric column, which in turn can cause indirect effects on clouds and the hydrological cycle. Also aerosols can BC can be mediated by a number of mechanisms as follows:

- Absorption of solar radiation and heating of the lower atmosphere – a direct warming effect (Satheesh and Ramanathan, 2000) but this can also cool the surface such that a redistribution of energy occurs in the atmospheric column (Kaufmann et al., 2002), this will be particularly effective if the absorbing aerosol is above a bright surface such as snow, ice, clouds etc.;

- As BC ages, it becomes more hydrophilic and becomes a cloud condensation nucleus and may produce more cloud droplets resulting in an increased cloud fraction and albedo – a cooling effect;
- Nucleating more cloud droplets can result in deeper clouds – a heating effect;
- Absorbing aerosols heating the atmosphere can evaporate clouds (the semi-direct effect) – a heating effect.

Particularly pertinent to the Arctic environment:

- Deposition of BC on snow and ice surfaces reduces albedo – a heating effect (Clarke and Noone, 1985);
- Triggering of low-level clouds trapping outgoing long-wave radiation (Garrett and Zhao, 2006).

5.2 Occurrence of black carbon over ice and snow

The effect of BC can be enhanced at northerly latitudes where it can be deposited on snow and ice. Atmospheric concentrations and deposition of BC to the Arctic has been studied for a number of years and 'dirty snow' and atmospheric haze was noted by early Arctic explorers (Law and Stohl, 2007). By examining ice cores, it has been possible to trace BC deposition trends over time, and industrial emissions have increased BC concentrations in ice by sevenfold since ~1850 with peak concentrations being found between 1900–1950 with peak local RFs of 3 W m^{-2} being estimated (McConnell et al., 2007). More recently, continuous measurements of atmospheric concentrations of BC have been available from two northerly locations, which show that concentrations declined at Alert and Barrow by 54% and 27%, respectively between 1989 and 2003 but that there are indications of a more recent increase in concentrations (Sharma et al., 2006).

The sources of BC in the Arctic are both local and distant: local sources include industrial emissions from northerly cities (e.g. Murmansk), the oil industry and shipping (AMAP, 2006, cited by Law and Stohl, 2007). However, long-range transport of pollutants can make a significant contribution to Arctic BC deposition on snow and ice. The most important sources of long-range transport are northern mid latitudes and South Asia (Bond et al., 2004, Koch and Hansen, 2005, McConnell et al., 2007, Quinn et al, 2008). 'Natural' sources such as forest fires in North America and Siberia can also contribute to BC deposition (Flanner et al., 2007).

5.3 Warming effects of black carbon over ice and snow

Fossil fuel BC in the atmosphere has a direct positive radiative effect of 0.2 (±0.15) W m^{-2} (Forster et al., 2007, their Table 2.12). Total BC emissions result in a direct effect of 0.34 W m^{-2}, from fossil fuel, biofuel, and biomass burning (Forster et al., 2007, their Table 2.13), both for 2005. In the Arctic, BC can play an important role in warming both in the atmosphere and when deposited to ice and snow surfaces. In addition to the direct effect of BC aerosols, BC may have an indirect effect by thickening low-level clouds, which then trap more of the earth's emitted heat (Garrett and Zhao, 2006). Lastly, an additional effect can be caused by the deposition of BC on snow and ice surfaces, altering the albedo (reflectivity) of the surfaces and affecting rates of snowmelt. This effect was suggested to be significant by Hansen et al. (2000), who estimated a positive RF of 0.2 W m^{-2}. Hansen and Nazarenko (2004) used measurements of BC concentrations in ice and snow from a number of Arctic locations and revised the RF estimate of this effect to be 0.15 W m^{-2}, subsequently revised by Hansen et al. (2005) to be 0.08 W m^{-2}. Flanner et al. (2007) subsequently estimated this effect to be ~0.05 W m^{-2} and Rypdal et al. (2009) using a similar methodology to Flanner et al. but with a different global chemistry-transport model and radiative transfer code found a value of 0.03 W m^{-2}.

Both Hansen et al. (2005) and Flanner et al. (2007) suggested that the climate 'efficacy' of BC forcing from changes in albedo [2] was > 1. Hansen et al. (2005) estimated the efficacy for BC on snow and ice to be 1.7, and Flanner et al. (2007) estimated it to be ~3 (range 2.1–4.5). Essentially this means that the BC on ice and snow has an effect on temperature greater than that implied by the calculated RF (since RF is used to indicate a proportionality between RF, which is relatively easily calculated, and temperature, which is computationally more difficult to calculate because of computing power and difficulties with signal-to-noise ratios of temperature responses of small RFs).

5.4 Global warming potential of black carbon

The Global Warming Potential (GWP) of BC for a 100 year time horizon (GWP_{100}) has been estimated in a number of studies but has shown to be both regionally-dependent and of rather uncertain value (Fuglestvedt et al., 2009). Fuglestvedt et al. (2009) summarized the available studies, which indicate regional BC $GWP_{(100)}$ values ranging between 340 and 1400 from four studies (Koch et al., 2007; Naik et al., 2007; Reddy and Boucher, 2007; Berntsen et al., 2006). Global mean GWPs were also summarized by Fuglestvedt et al. (2009), of 460 and 680 (Schultz et al., 2006; Bond and Sun, 2005). The global mean BC GWP100 derived by Reddy and Boucher (2007) was 480. The concept of the GWP allows the calculation of a CO_2 emissions-equivalence (CO_2-*e*) that relates the integrated RF over a given time horizon for a unit pulse emission of a substance, relative to that of CO_2.

[2] 'efficacy' is defined as the ratio of the climate sensitivity, λ (the equilibrium surface temperature change per unit radiative forcing) for a given forcing mechanism to that of λ for a doubling of CO_2.

Taking the total global emissions of CO_2 from shipping to be 1,046 Mtonnes in 2007, and the emission of BC to be 0.057 Mtonnes, applying a mean GWPs of 540 (of 460, 480, 680), this result in CO_2*e* emissions from BC of 30.6 Mtonnes, or 2.8% of total CO_2-*e* emissions.

However, as noted above, BC has an additional RF effect over its direct effect in the atmosphere, from the change in albedo of snow and ice surfaces from its deposition, causing an additional warming (see section 4.3). There are only two estimates of the GWP_{100} from this additional effect; Reddy and Boucher (2007) estimated a global value to be 281 (but based on an analysis of latitudes >60ºN and 60 ºS), and Rypdal et al. (2009) estimated regional values that varied between 10 and 220.

In addition, it has been suggested that the 'snow and ice' albedo BC RF mechanism has a stronger effect on temperature than that from CO_2, its 'efficacy'. This effect may be simply incorporated into the GWP calculation by multiplying the numerator of a GWP by the efficacy (Fuglestvedt et al., 2003).

A range of BC CO_2-*e* emissions has been calculated, by latitude using the distribution from Buhaug et al. (2009) and incorporating the indirect BC snow and ice albedo effect at latitudes > 60 ºN and 60 ºS. This calculation makes the very simple assumption that all BC emitted in these latitudes from ships is deposited to snow and ice, which will inevitably be an overestimate. The simple assumptions made here can only provide broadly indicative data. However, better data could only be derived from a complex calculation of shipping emissions along routes and estimation of deposition from a chemical-transport model.

In addition, efficacy weighting factors have been applied to the indirect albedo BC GWP_{100} values. Thus, a mean direct BC GWP_{100} of 540 has been used at all latitudes, along with an additional indirect albedo BC GWP_{100} of 190–281 (to approximate to a range of relevant values from Fuglestvedt et al., 2009, and Reddy and Boucher, 2007) with a range of efficacies of 2.1–4.5 (mean of 3.17) from Flanner et al. (2007) for latitudes > 60 ºN and 60 ºS.

The resulting range of the proportion of CO_2-*e* emissions from the indirect BC GWP_{100} at these latitudes is ~42–70%. This demonstrates that these latitudes are sensitive to additional shipping emissions of BC, depending on the assumptions made over values of GWP_{100} and the BC indirect GWP_{100} efficacy.

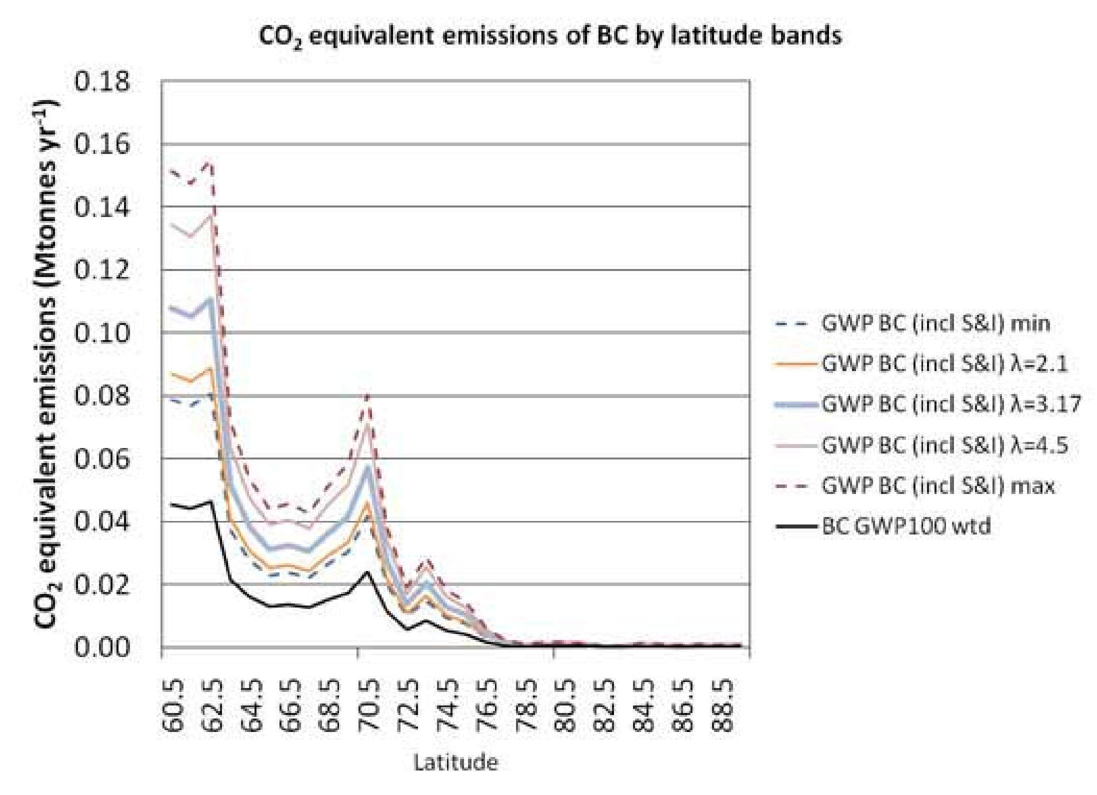

***Figure x**. CO_2-e emissions of BC at northerly latitudes from shipping emissions (2007) from mean direct and indirect albedo (snow and ice, 'S&I') GWP_{100} using efficacies of 2.1, 3.17, 4.5 and minimum (min GWP, min λ) and maximum (max GWP, max λ).*

The point of illustrating different GWP_{100} values for BC, accounting for a range of efficacy weighting values applicable to snow and ice is that this facilitates, via the GWP concept, a simple comparison of the effect of reduced emissions of CO_2 if Arctic sea routes are opened up but increased emissions of BC locally to the Arctic.

To take a worked example, Verny and Grigentin (2009) discuss the possibility of container shipping along the Northern Sea Route (NSR), contrasting the distance between Shanghai and Rotterdam via the Suez Canal of 10,200 nautical miles with that via the NSR of 7,700 nautical miles, a saving of 2,500 nautical miles. If it is assumed that fuel consumption scales approximately with distance, and that ~66% of the NSR distance is at latitudes > 60 ºN that BC affects snow and ice albedo, then BC emissions are reduced by ~25% (using distance as a scalar), but for 66% of the shorter distance, an additional BC 'snow and ice' indirect GWP_{100} comes into force. This simple illustrative calculation for this route indicates that the shorter NSR increases overall BC CO_2-*e* emissions by a factor of ~1.1–1.9) over the *longer* sea route via the Suez Canal, because of the additional factor from BC emissions over snow and ice.

It is emphasized that these calculations are very simplified and the inherent uncertainties rather large. The uncertainties arise from the more fundamental scientific studies of BC GWP_{100} values, both for the direct and indirect effects, along with efficacy values. The simplified nature of the calculations arises from the assumption of deposition being equal to emissions at latitude bands: much more complex calculations of this are need to verify the data presented here.

6 Potential mitigation of black carbon emissions from shipping

In principle, it is possible to reduce particulate BC emissions from ship exhaust. However, pollution control technologies tend to be 'end of pipe' and require other conditions, or techniques are used in conjunction with other emission-reduction technologies, enhancing co-benefits.

A conventional way to reduce particulate BC emissions is to use a diesel particulate filter (DPF), which have been deployed with success in road vehicles. Such control technology requires lower levels of S than currently allowed in marine bunker fuel to be effective (May, pers. Comm. 2009). The low levels of S in marine fuel of 0.1% to be used in the future with reductions required by the International Maritime Organization (IMO) in Sulphur Emission Control Areas (SECAs) are still ~100 times the current S limit for automotive diesel in the European Union (Buhag et al., 2009). Thus, if DPF were to be used for marine diesel engines, it is likely that additional S reduction techniques, such as wet-scrubbing using sea-water would be necessary. A DPF is fitted to the exhaust flow, often working in conjunction with NO_x catalysts, and collects particles where they are burned off. Given low-S conditions, it has been shown to be possible to remove large fractions of BC by both mass and number from heavy-duty diesel engines (May et al., 2008).

7 Conclusions

Black carbon emissions from shipping currently form a small overall fraction of global emissions, of the order 1–2%. Overall, BC is thought to have a warming effect on the atmosphere although some of its complex interactions with clouds can result in cooling effects. Deposition of BC and snow and ice surfaces causes an unequivocal warming effect that is thought to be at least two to three times more powerful than expected by the relationship between RF and temperature (its 'efficacy').

The emission factor for BC from current shipping is rather uncertain, with only a few measurements available but a best estimate is 0.17 g kg $fuel^{-1}$. This results in a global emission of the order 57 Gg yr^{-1}, using current fuel usage rates from the IMO Greenhouse Gas Study (Buhaug et al., 2009).

Changes in the Arctic environment are occurring rapidly and large reductions of sea-ice coverage have been observed by satellite since 1979. Climate models have not been able to predict this unprecedented decline in the 2000s, but best available simulations predict an ice-free North Pole by the end of the century. These changes will have impacts on climate in themselves through positive feedback mechanisms.

Ice-free conditions in the future years may allow commercial shipping to utilize the Northwest Passage and the Northern Sea Route for at least some of the summer months, and some successful voyages have already been made. Whilst this is likely to facilitate reductions in CO_2 emissions because of the shorter voyages, it will expose a very sensitive almost pristine environment to localized pollution from ship emissions. In this context, in the absence of emissions control, this will result in snow and ice surfaces remaining to be susceptible to BC deposition, enhancing warming of the Arctic and exacerbating snowmelt conditions. Very simplified calculations of an example route from Asia to Europe have shown that using a BC GWP_{100} for the direct effect of BC, and the indirect effect from deposition to snow and ice, the CO_2-*e* emissions of BC may be increased over the shorter voyage via the Northern Sea Route compared with the longer route via the Suez Canal. More detailed calculations and comparisons are needed to confirm this result.

From examples of other applications of heavy-duty diesel engines, it has been shown possible to reduce a large fraction of BC emissions by mass and particle number. However, this is not possible using particulate filter traps without reducing S levels dramatically in the exhaust. However, this may be achieved by using wet scrubbing of seawater to remove the S, which would be a co-benefit.

The indication of this review is that whilst CO_2 emissions may be reduced in the future by utilization of Arctic routes, it will be essential to protect this environment by additional emissions control, as effects of BC emissions from shipping could exacerbate damage and warming of the Arctic.

Acknowledgements

We are grateful for fruitful discussions with Dr Jan Fuglestvedt of CICERO, University of Oslo, Norway and information kindly provided by John May of the Association for Emissions Control by Catalyst (AECC), Brussels.

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Annex E Impact of NO_x and other ozone prescursor emissions from ships on the chemical composition and climate

Impact of NO_x and other ozone precursor emissions from ships on the chemical composition and climate

—ad hoc paper for European Commission—

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Abstract. Shipping is a significant source of NO_x emissions, representing ~15% of global anthropogenic sources. NO_x and other ozone precursor emissions are reactive in the atmosphere and result in changes in atmospheric composition that affects the radiative balance of the atmosphere and result in significant contributions to local and regional air pollution. It is shown that NO_x emissions increase concentrations of ozone (O_3), a greenhouse gas, and reduce ambient concentrations of methane (CH_4, another greenhouse gas) emitted from other sources. However, the impacts of NO_x as calculated with global models are rather uncertain, since NO_x chemistry is known to be strongly non-linear. Since shipping emissions often occur in pristine environments, and in slowly-dispersing plumes, there is some evidence that small-scale processes are not correctly represented in large-scale models. When plume-scale effects are accounted for, this generally has the effect of reducing the ozone impact calculated with large-scale models. However, more measurements and better modelling are required to understand the nature of this effect on both regional air quality and climate. The net global radiative forcing of the O_3 and CH_4 perturbations appears to be slightly negative. However, the climate response is not yet fully understood because these perturbations occur on different spatial and temporal scales, and 'no effect on climate' cannot be necessarily inferred because of localized forcing. Preliminary work has shown that the latitudinal distributions of O_3 and CH_4 forcings are very similar, which may suggest cancellation. However, such a conclusion is premature since the climate effect of these perturbations (temperature, precipitation, etc.) has not been examined in any study. Clearly, emission reductions of NO_x have benefits for air quality and regional acidification/eutropication and may have co-benefits for climate.

1. Introduction

Emissions of nitrogen oxides (NO_x) from shipping are a significant component of anthropogenic budget of oxidized nitrogen (N) species (*Buhaug et al.*, 2009, *Eyring et al.*, 2005a; 2009). Over the past few decades, the world merchant fleet, its fuel consumption and emissions have substantially increased. The results of *Eyring et al.* (2005a) suggest that the fuel consumption increased from 64.5 million metric tons (Mt) in 1950 to 280 Mt in the year 2001.

Shipping emitted around 800 Mt CO_2 and contributed ~2.7% to all anthropogenic CO_2 emissions in 2000. For comparison, aviation and road transport contributed ~ 2.2% and 14%, respectively, see Figure 1. Other comparisons suggest that shipping accounted for ~ 15% of all global anthropogenic nitrogen oxide (NO_x) emissions and for ~ 8% of sulphur dioxide (SO_2) emissions in 2000. The relative contributions of shipping NO_x and sulphur (S) emissions are disproportionately large to fuel usage, compared with other sources, because most marine engines operate at high temperatures and pressures without effective NO_x emission reduction technologies and marine fuels have a high average sulphur content (2.4%-2.7%).

Future scenarios demonstrate that significant reductions are needed to offset increased emissions due to the predicted growth (*Eyring et al*., 2005b; *Buhaug et al.*, 2009). Recent annual average growth rates of total seaborne trade in ton miles were 5.2% from 2002 to 2007, greater than in preceding decades (*Fearnleys*, 2007). Accordingly, the fuel consumption from 2001 to 2006 increased significantly as the total installed power increased by about 25% (*Lloyd's Register Fairplay*, 2006). Regulations of SO_2 and NO_x emissions have in the meantime been enforced within the International Maritime Organization (IMO), because of shipping's contribution to regional acidification and air pollution. The Marine Environment Protection Committee (MEPC) of the IMO adopted NO_x regulations and progressive reduction in SO_2 emissions from ships (*IMO*, 2008). Progressive reductions in NO_x include the most stringent controls on so-called "Tier III" engines, i.e. those installed on ships constructed on or after 1 January 2016, operating in Emission Control Areas (ECAs). The revised Annex VI will allow for designation of an Emission Control Area for SO_x and particulate matter, or NO_x, or all three types of emissions from ships, subject to a proposal from a Party or Parties to the Annex. This would be considered for adoption by IMO, if supported by a demonstrated need to prevent, reduce and control one or all three of those emissions from ships.

Overall, ship emissions have been shown to have significant impacts on atmospheric composition, climate, and human health (*Eyring et al.,* 2009). The chain of impacts of ship emissions on chemistry and climate are complex, and are summarized conceptually in Figure 2. Emissions of NO_x, SO_2 etc. give rise to changes in the abundance of many trace species in the atmosphere. These emission species may undergo atmospheric reactions, alter microphysical processes, or be absorbed/removed to land and water surfaces through wet and dry deposition. These changes may then affect the radiative balance of the atmosphere through changes in the abundance of trace species, in atmospheric composition, and in the properties of clouds and aerosols. Such changes in RF may then affect climate in a variety of ways, e.g. global and local mean surface temperature, sea level, changes in precipitation, snow and ice cover, etc. In turn, these physical impacts have societal impacts through their effects on agriculture, forestry, energy production, human health, etc. Ultimately, all of these effects have a social cost, which can be very difficult to quantify. Clearly, as one steps through these impacts, they become more relevant but correspondingly more complex and uncertain in quantitative terms.

In this paper, we discuss the impact of NO_x and other O_3 precursors from shipping on atmospheric composition (Section 2). This includes a discussion on the overall potential magnitude of shipping NO_x effects considering plume-scale processes that may transform NO_x to higher oxidized forms of N, reducing its ability to contribute to tropospheric O_3 formation. This is a more recently considered phenomenon in the scientific literature. The paper also assesses our current knowledge on ship-induced O_3 increases on human health (Section 3). Finally, a best estimate for the contribution of shipping through O_3 precursors to both positive (through O_3) and negative (through CH_4 removal) radiative forcing is given in Section 4.

2. Impact on atmospheric composition

The majority of emissions from shipping are injected into the atmosphere in form of coherent plumes, often in relatively pristine parts of the atmosphere. To assess the impact of shipping on the atmospheric composition, global models are used in which the emission totals are distributed over the globe via spatial proxies of global ship traffic derived in various ways. These emissions are instantaneously spread onto large inventory grid boxes, usually 1° longitude x 1° degree latitude, without accounting for dispersion, transformation, and loss processes on the sub-grid scale. Ship emissions result in high atmospheric concentrations relative to the background, and are diluted by mixing with ambient air. During the dilution process the emitted species are chemically transformed, secondary species (e.g., ozone) are formed and some fraction removed from the atmosphere by wet and dry deposition. These processes depend non-linearly on the concentrations of the primary emissions, the atmospheric background concentrations, and on the meteorological state of the atmosphere such as height and stability of the marine boundary layer, vertical wind profile or the presence of clouds. Other important factors include the insolation, which depends on cloud cover, latitude, season, and time of the day. Neglecting the plume processes in global models may lead to an overestimation of local O_3 formation as pointed out by several studies. However, many uncertainties remain on what this actually means for global model simulations which is further discussed below..

2.1 Near-field processes

Several studies have investigated ship plume effects with box models which are computationally less expensive than global models and can be run at higher resolution. From these studies, it is recognised now that subgrid-scale processes should be accounted for in global models with a resolution of several hundred kilometres because of nonlinearities in atmospheric processes. In-plume processes that need to be considered include oxidation of NO_x, scavenging of HNO_3, ozone formation, oxidation and heterogeneous removal of SO_2, impact of ship-emitted and background particles on plume chemistry and processing of particles affecting their physical properties.

Fast oxidation of NO_x in concentrated plumes due to elevated OH levels could lead to a substantial decrease in lifetime of NO_x compared with the background (*Davis et al.*, 2001, *Charlton-Perez et al.*, 2009). In highly concentrated parts of the plume and in cases when the plume is emitted to a NO_x pre-polluted background with already enhanced OH levels being also a sink for OH, reaction of NO_2 with OH (giving HNO_3) can cause OH depletion in the plume, which leads to a contrary case of *increased* NO_x lifetime in the plume. *Chen et al.* (2005) inferred from measurements in a ship plume a chemical NO_x lifetime of about 2 hours, almost four times shorter than calculated for background air. Ship plume modelling studies of *Song et al.* (2003) and *von Glasow et al.* (2003) also showed NO_x lifetimes of a factor of 2.5 to 10 shorter in the ship plume than in the background. A modelling study by *Franke et al.* (2008) found an increased NO_x lifetime compared with the NO_x lifetime in the background during the first hours of the simulation which was only slightly reduced later on. The NO_x emission source strength in the *Franke et al.* (2008) study was much greater than in previous studies (a large container ship emitting 145 g NO_x/s, compared with an average ship emitting 47g NO_x/s) leading to much larger NO_x mixing ratios at the initial stage of the plume. Also, model simulations of the ship plume measured by *Schlager et al.* (2008) showed an increased lifetime of NO_x during 1-2 hours after the emission. A sensitivity study has shown that at high NO_x background concentrations, when the O_3 formation is in peroxy-radical limited regime, the increased lifetime would persist over the entire lifetime of the plume.

Von Glasow et al. (2003) quantified the effect of neglecting the plume processes in a grid of a global model by comparing a box model including multiple plumes with a box model including continuous homogeneous emissions of the same magnitude. They found O_3 mixing ratios that were 50% smaller when the plume dispersion was considered. *Franke et al.* (2008) compared box model simulations of a single plume entraining background air using the Gaussian plume model parameterization (PD case) with a box model in which the same ship emissions were instantaneously dispersed into a large grid box (ID case). The ozone formation in the PD case was found to be 70% less than in the ID case. Similarly, a high-resolution chemical transport model of the marine boundary layer was used by *Charlton-Perez et al.* (2009) to investigate the detailed chemical evolution of a ship plume in a tropical location. They showed that OH concentration, NO_x lifetime and ozone production efficiency of the model changed by 8%, 32% and 31% respectively between the highest (200m×200m×40 m) and lowest resolution (9600 m × 9600 m × 1920 m) simulations. Interpolating to the resolution of a typical global chemical transport model (CTM, 5°×5°), suggests that a global model overestimates OH, NO_x lifetime and ozone production efficiency by approximately 15%, 55% and 59% respectively. On the other hand, while domain mean NO_x concentrations decrease steadily as the model resolution is coarsened, O_3 concentrations do not change appreciably as resolution is changed, although the maximum domain mean O_3 is found at the coarsest (C48) resolution.

It is worth noting that all simulations with box models or chemical transport models mentioned above were carried out for certain meteorological conditions and ship emission strengths and that results differ from case study to case study which makes the development of a sophisticated parameterization difficult. Because of this, parameterizations for subgrid-scale ship plume processes in global models are not well-developed yet, and due of computational limits, global models cannot be run at horizontal resolutions that would resolve plumes. Therefore, there is considerable uncertainty over how current estimates of the impacts of ship emissions on atmospheric composition would change if these processes were correctly represented and further research is required to answer this question. Future work should develop parameterizations of ship emissions in global models which could, for example use the "equivalent emissions" concept introduced in *Esler* (2003), the "effective emissions" method developed by *Franke et al.* (2008) or an extension of the plume parameterization for aircrafts developed by *Cariolle et al.* (2009) to ship plumes.

2.2 Large-scale chemistry effects of ozone precursor emissions

2.2.1 Impact on NO_x and ozone

Since NO_x is a short-lived species in the atmosphere, its enhancement from ship emissions is closely dependent on the routes. NO_x increases of 200 ppt to more than 1000 ppt in shipping lanes were simulated by *Lawrence and Crutzen* (1999), and increases of 200-500 ppt derived from the multi-model mean of ten state-of-the-art atmospheric chemistry models were found by *Eyring et al.* (2007). Both studies used the EDGAR emissions dataset. Other emissions datasets (COADS, AMVER, PF) are more realistic and more spread out. Using one of the latter emission distributions, NO_x increases of over 200 ppt were calculated by *Kasibhatla et al.* (2001) over the northern Atlantic and Pacific oceans. Increases of 100-150 ppt over the same regions were calculated by *Dalsøren et al.* (2007), *Endresen et al.* (2003) and *Davis et al.* (2001). In the coastal regions of North America and Europe, NO_x enhancements from shipping of 200-300 ppt were calculated with a higher resolution model (*Dalsøren et al.*, 2007). Use of the EDGAR emissions database (*Eyring et al.*, 2007; *Collins et al.*, 2009) results in large NO_x values in the Baltic because of a known overestimate of emissions from this area in the inventory.

Some comparisons of shipping-generated NO_x in large-scale models with observations have shown significant overestimation (*Kasibhatla et al.*, 2000; *Davis et al.*, 2001; *Endresen et al.*, 2003). These studies suggested that subgrid-scale processes not included in the global models rapidly convert NO_x to total reactive nitrogen (NO_y) in ship plumes. However, these models overestimated NO_x concentrations even without shipping. The amount of observational data available, especially in oceanic regions, with which model results may be compared are limited and comparisons are sensitive to the choice of the dataset. *Eyring et al.* (2007) found disagreement between their multi-model average NO_2 simulations and the observations used in *Davis et al.* (2001), but agreement with a larger observational dataset from *Emmons et al.* (2000).

Observations from satellite have confirmed the existence of high NO_2 concentrations along shipping lanes (*Beirle et al.*, 2004; *Richter et al.*, 2004, see Figure 3). The implications of neglecting small-scale plume chemistry for regional-scale impacts depend largely on the resolution of the models, and the extent of the shipping lanes. At present, there are not enough observational data to confirm or refute the accuracy of large-scale impacts of the various emission datasets used by global models. There are sound chemical reasons why spreading shipping plumes over the size of grid squares used in global models could overestimate the NO_x, OH and ozone responses (see Section 2.1). However, plume modelling studies have not yet come up with a simple reduction factor for NO_x emissions that could be justifiably applied in global models (see Section 2.1). Thus, in a crude attempt to compensate for plume effects, global models tend to use a lower NO_x emission total of ~3 Tg(N) yr^{-1} for 2000.

Modelling studies generally simulate increases in ozone from shipping NO_x emissions of up to 12 ppb in the central North Atlantic, and central North Pacific in July. Ozone enhancements tend to peak in mid-ocean, and not in the coastal regions, because of the greater NO_x levels there from continental sources which limits O_3 production rates. In January, ozone increases of 2-4 ppb were found in the tropical and sub-tropical oceans except in the *Eyring et al.* (2007) study which has lower tropical emissions. In winter, *Eyring et al.* (2007) found shipping NO_x leads to ozone destruction in northern Europe. This is strongest over the Baltic and countries bordering it and is arises from the removal of HO_x ($OH + HO_2$) through the reaction of NO_2 with OH. In the winter at highlatitudes, where there is little insolation, HO_x levels are already low so that the OH + CO or CH_4 oxidation is the rate-determining step for ozone production. This ozone destruction has not been found in other studies and may be exacerbated by known overestimation of shipping emissions in the Baltic in the EDGAR dataset.

To identify changes in coastal ozone production requires a high resolution model (by global modelling standards). The *Dalsøren et al.* (2007) study used a model with 1.8°×1.8° resolution and identified regions of high ozone production from shipping in smaller seas with busy shipping, such as the North Sea, Baltic, Mediterranean, Red Sea and Persian Gulf where enhancements exceeded 14 ppb (see Figure 4).

2.2.2 Methane lifetime

Emissions of NO_x increase the concentrations of OH and hence reduce the methane lifetime, since reaction with OH is the principal sink-term for CH_4 in the atmosphere. Reductions in methane lifetime from shipping NO_x vary between 1.5% (*Dalsøren et al.*, 2007; *Eyring et al.*, 2007) to 0.4 years (~5%) (*Lawrence and Crutzen*, 1999; *Endresen et al.*, 2003). The reaction between methane and the OH radical is very temperature dependent so that methane is oxidised principally in the tropics in the lower troposphere. Thus it might be expected that the models using the EDGAR distribution, which has little NO_x enhancement in the tropics, would show the least effect on methane lifetime. However, there seems little obvious relationship between the methane impact in the model results published so far and the emission distribution used. It is likely that other aspects of the model formulations are more important. Four of the five models reporting methane lifetimes in *Eyring et al.* (2007) calculated decreases of 0.13 years (1.56%) with the fifth model calculating nearly twice this amount.

Hoor et al. (2009) showed that compared with other forms of transport, shipping NO_x emissions have the greatest effect on methane lifetime. This is because the NO_x emissions are released into a cleaner, environment and have larger contributions in the tropics than land-based transport. Aircraft have a smaller effect as their emissions are away from the lower troposphere where most methane oxidation occurs.

The decrease in methane lifetime and consequent decrease in the methane concentrations leads to a secondary longerterm decline in ozone concentrations that may offset some or all of the direct ozone production from the NO_x emissions when considered over longer time periods, since CH_4 contributes to ozone production through its role in regenerating peroxy radicals. *Derwent et al.* (2008) found that the ozone response to the methane decrease arising from land-based NO_x emissions from Asia cancelled out about half of the direct ozone production as a global average. The ozone decrease is much more globally homogenous than the increase thus it is important for climate forcing (Section 4) but less important for air quality.

3 Impacts on air quality and human health

About 70% of the emissions from oceangoing shipping occur within 400 km of coastlines along the main trade routes (*Corbett et al.*, 1999). Thereby, ship emissions can have an impact on air quality in coastal regions and may partly offset the decline of emissions from land-based sources and coastal pollution resulting from national control measures (*Schlager and Pacyna*, 2004). The addition of NO_x (and SO_2) from ships also contributes to acidification of the ocean (*Doney et al.*, 2007). On the global scale, these effects are small, but could be more significant in shallower coastal waters where shipping is concentrated.

Coastal areas of north-western Europe and north-western North America are substantially impacted by nitrate (and sulphate) deposition from shipping emissions. In Europe, the modelled maximum annual sulphate deposition from ship emissions of 400 mg S m^2 yr^{-1} occurs over the North Sea and Baltic Sea (*Derwent et al.*, 2005). This is about 50% of the total sulphur deposition in these regions. Along the western coasts of the UK and Scandinavia, the calculated percentage of total sulphur deposition from shipping range between 10-25% (*Dore et al.*, 2006; *Dalsøren et al.*, 2007; *Collins et al.* 2009).

Shipping emissions may also impact upon air quality in the vicinity of major harbours, in particular, from NO_x, SO_2, PM, and VOCs emissions. Ship manoeuvring in harbours contributes about 6% of NO_x and 10% of SO_2 to total shipping emissions (*Corbett and Fischbeck*, 1997). Besides manoeuvring, loading and unloading of tankers also contribute substantially to harbour emissions since this is a highly energy consuming process (*Wismann and Oxbol*, 2005). Harbour emissions often occur near major residential areas and can be transported far inland by local land-sea breezes. For example, near the waterways of the port of Rotterdam, shipping causes an enhancement of the surface NO_2 mixing ratio of 5-7 ppb (*Keuken et al.*, 2005).

Local and regional air quality problems in coastal areas and harbours with heavy traffic are of concern because of their impact on human health. Furthermore, emissions from ships can be transported in the atmosphere over several hundreds of kilometres, and can thus contribute to air quality problems inland. This pathway is especially relevant for ozone and the deposition of nitrogen (and sulphur) compounds, which cause acidification of natural ecosystems and freshwater bodies and threaten biodiversity through excessive nitrogen input (*Cofala et al.*, 2007).

Due to the non-linear nature of ozone chemistry, the effects of shipping depend on the magnitude of the emission change, and on the choice of scenario for the land-based emissions. Ozone is toxic to plants (*Ashmore*, 2005), affecting growth (e.g., crop yield) and appearance. The potential for sulphate and nitrate deposition to cause ecosystem change can be defined by the critical loads concept. On average, shipping increases current sulphate and nitrate deposition over Europe by about 15% (*Collins et al.*, 2009). Sulphate and nitrate deposition increases the acidity of soils, rivers, and lakes causing ecosystem damage. Nitrate deposition may also increases the available nitrogen of soils (eutrophication; *Stevens et al.,* 2004; *Galloway et al.*, 2003; *Cofala et al*., 2007). This can harm ecosystems through asymmetric growth in nitrogen poor regions (e.g., algae in rivers and lakes, and lichens and mosses in hillsides), in some regions encouraging invasive alien species.

Shipping emissions also impact upon human health through the formation of ground-level ozone and particulate matter. *Cofala et al.* (2007) provided an assessment of the health and environmental impacts of shipping scenarios in Europe for the year 2020. They find that compared with land-based sources, at least some of the maritime emissions have less health and environmental impacts since they are released sometimes far from populated areas or sensitive ecosystems. However, they also find that in harbour cities, ship emissions are in many cases a dominant source of urban pollution and need to be addressed when compliance with EU air quality limit values for e.g. fine particulate matter is an issue. An increase in ship emissions will counteract the envisaged benefits of the costly efforts to control the remaining emissions from land-based sources in Europe. Technologies exist to reduce emissions from shipping beyond what is currently legally required.

4. Radiative forcing from NO_x emissions

4.1 Global-mean radiative forcing

The climate impact of the extra ozone generated by emissions of NO_x from shipping largely depends on the change to the total ozone column. The distribution and magnitude are quite sensitive to the emissions distribution used, and how convection is represented in the model, since the RF effect of ozone increases with height. In *Dalsøren et al.* (2007) these changes are generally concentrated in a band from the equator to 45°N (2-3 DU) with a local maximum over the Persian Gulf and Arabian Sea (up to 5 DU). The *Eyring et al.* (2007) simulations do not show this zonal band. They have a maximum south of India of 1.2 DU, otherwise increased ozone columns of up to 1.0 DU are found over the North Atlantic. Again, the lack of ozone changes at lower latitudes is likely to be due to the EDGAR shipping distribution and will have a significant effect on the calculated radiative forcing from shipping (Section 5.2).

Given that the EDGAR emissions distribution is known to be inadequate, other shipping emissions databases such as that of *Eyring et al.* (2005a) and *Buhaug et al.* (2009) should be used in future work. However, these databases have larger overall emissions of NO_x (~ 5.7 Tg N yr^{-1}, cf 3 Tg N yr^{-1} for 2000) and may need to be scaled downwards in order to compensate for plume-scale effects that are currently not well represented in large-scale models (see Section 2.1).

Despite these various constraints, the overall RF from shipping for 2005 has been presented by *Eyring et al.* (2009), shown in Figure 5. The mean RF for O_3 perturbations is 26 mW m^{-2} (range 10 to 50 mW m^{-2}) and occurs over oceanic spatial scales. The corresponding CH_4 response is of similar magnitude but of opposite sign, -33 mW m^{-2} (range -69 to -14 mW m^{-2}); this forcing operates over a global scale.

These RF estimates are for 2005 based upon extrapolated NO_x emissions from 2000, of 6 Tg N yr^{-1}. The recent emissions estimates of *Buhaug et al.* (2009) indicate NO_x emissions of 7 Tg N for 2005, which is in reasonable agreement with this extrapolation. Given the state of knowledge over plume-scale effects and their impact on global estimates of O_3 production, which is quite poor, this smaller emission rate used for the RFs presented by *Eyring et al.* (2009) for 2005 is probably adequate and there is no compelling justification to modify this. It is recommended that further research on plume-scale effects be conducted and comparisons made with available observations. Moreover, some efforts should be made to use the more recent and spatially-representative emissions estimates with global models, and study the effects of grid resolution, albeit at their limited scales.

4.2 Spatial patterns and climate responses other than temperature

The question arises as to whether there is no climate effect from shipping NO_x emissions, if the net RF from O_3 and CH_4 perturbations is zero, or even negative. At present, this is not yet clear for shipping effects. This is because the forcings from O_3 and CH_4 operate on different spatial and temporal scales, and do not necessarily mirror the emissions patterns or even the O_3 perturbation patterns. As outlined above, the surface O_3 perturbation from shipping emissions shows maxima typically in the northern Pacific, the north-eastern Atlantic, and Indian Ocean (see Figure 4 as an example). However, the RF response is dictated more by the O_3 column change, and particularly that close to the tropopause (see Section 4.1). This distribution is controlled by a combination of the surface perturbation and the vertical transport in global models.

Here, some preliminary unpublished results are presented based on work-in-progress (*Lee et al*., in prep., 2009). In Figure 6, the spatial pattern of RF from O_3 is shown, which shows a different pattern to that of the surface perturbations, of which Figure 4 shows a typical response. This shows that the maxima of forcing occurs in the tropics from O_3 transported to high altitudes, principally via convection. The hemispheric patterns of forcing are shown in Figure 7 for both O_3 and CH_4 and mirror each other's pattern quite remarkably. However, the spatial pattern of CH_4 forcing (not shown) lacks some of the 'hot spots' that the O_3 forcing exhibits, so whether these cancel in terms of regional forcing is not clear.

The overall relationship between regional forcing and regional temperature response is a topic of current research and not well characterized. This is because of difficulties in separating small signals of forcing from a 'noisy' temperature response, inherent in global climate models. The current literature suggests that the regional responses in temperature are largely controlled by internal feedbacks within the climate system and are rather stable to the pattern of forcing (*Boer and Yu*, 2003); however, there is also literature that suggests that patterns of temperature may also be modified by regional forcing.

It should be remembered that climate change it manifests itself in many ways; changes in precipitation, circulation patterns all result in 'climate change'. It has been shown in some climate experiments (principally with aerosols) that regional responses in forcing can result in changes in regional precipitation, although the two responses do not coincide (*Jones et al.*, 2009).

5 Conclusions and Outlook

Uncertainties in the simulated ozone contributions from ships for different model approaches are found to be significantly smaller than estimated uncertainties stemming from the ship emission inventory and the neglect of plume processes. This reflects that the net ozone change from ship emissions under relatively clean conditions in global models is rather similar and suggests that the atmospheric models used in global model studies (e.g. *Eyring et al.*, 2007) are suitable tools to study these effects.

From the point of view of large-scale composition impacts, there is not enough observational data to confirm or refute the various emission datasets used by global models. There are sound chemical reasons why spreading shipping plumes over the size of grid squares used by global models should overestimate the NO_x, OH and ozone responses. Plume model studies have not yet come up with a simple reduction factor for the NO_x emissions that could be applied to global models. So far the results are based on one given background environment. The step from case studies under a particular meteorological condition for a specific emissions strength to a suitable parameterisation of subgrid-scale ship plume processes in global models has yet to be made. To reach this, more measurements and model studies are needed to understand plume processes.

Evaluation of the global models' response to ship emissions is still at a preliminary stage and is currently limited by the coarse spatial resolution of the models, the uncertainty in the measurements, the lack of sufficient in situ measurements over the ocean, and the difficulty to separate ship emissions from other even stronger emission sources close to land. Additional in situ measurements inside single ship plumes, but also in the corridor of the shipping lanes are needed and the set up of a measurement network onboard ships similar to MOZAIC (Measurements of OZone and water vapour by in-service AIrbus airCraft; *Marenco et al.* [1998]) or CARIBIC (Civil Aircraft for Global Measurement of Trace Gases and Aerosols in the Tropopause Region; *Brenninkmeijer et al.* [2007]) onboard civil aircrafts would be desirable. Unambiguous detection of ship emissions in satellite data is currently only available for the region of the Red Sea and the Indian Ocean [*Beirle et al.*, 2004; *Richter et al., 2004; Franke et al., 2009*], where shipping routes are close to the coastal area. Reduction in measurement uncertainties through use of long-term averages and data from more instruments (e.g. OMI and GOME-2) combined with better constraints on land-based sources and higher spatial resolution in the models should facilitate such an intercomparison in the future.

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FIGURES

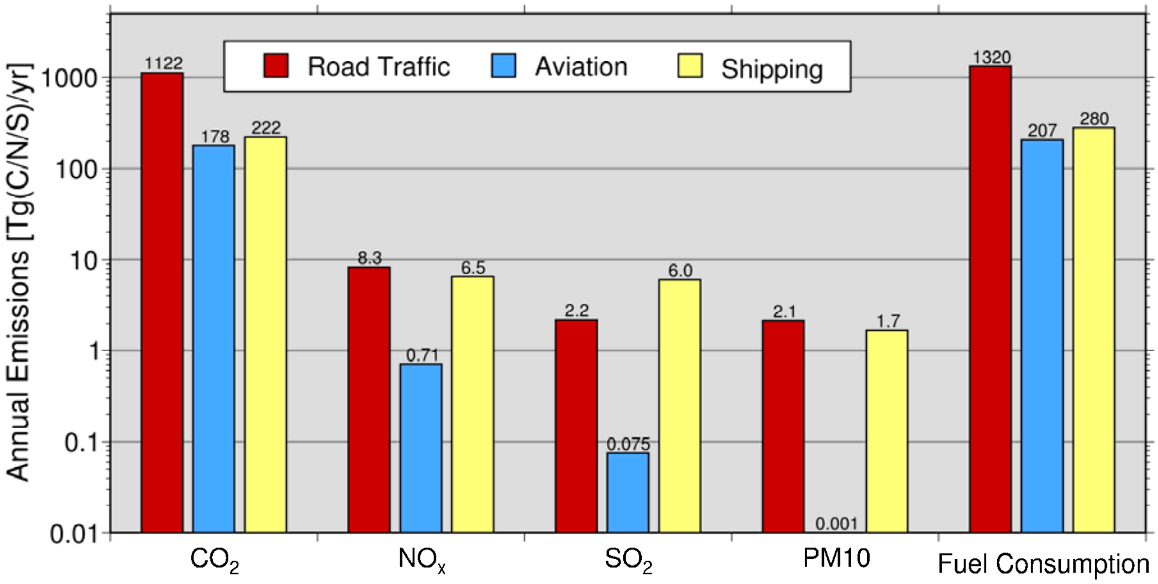

Figure 1, Transport-related annual emissions of CO_2 in Tg (C), NO_x in Tg (N), SO_2 in Tg (S) and PM_{10} in Tg (PM < 10 µm) and the fuel consumption in Mt estimated for the year 2000. From (*EY4*).

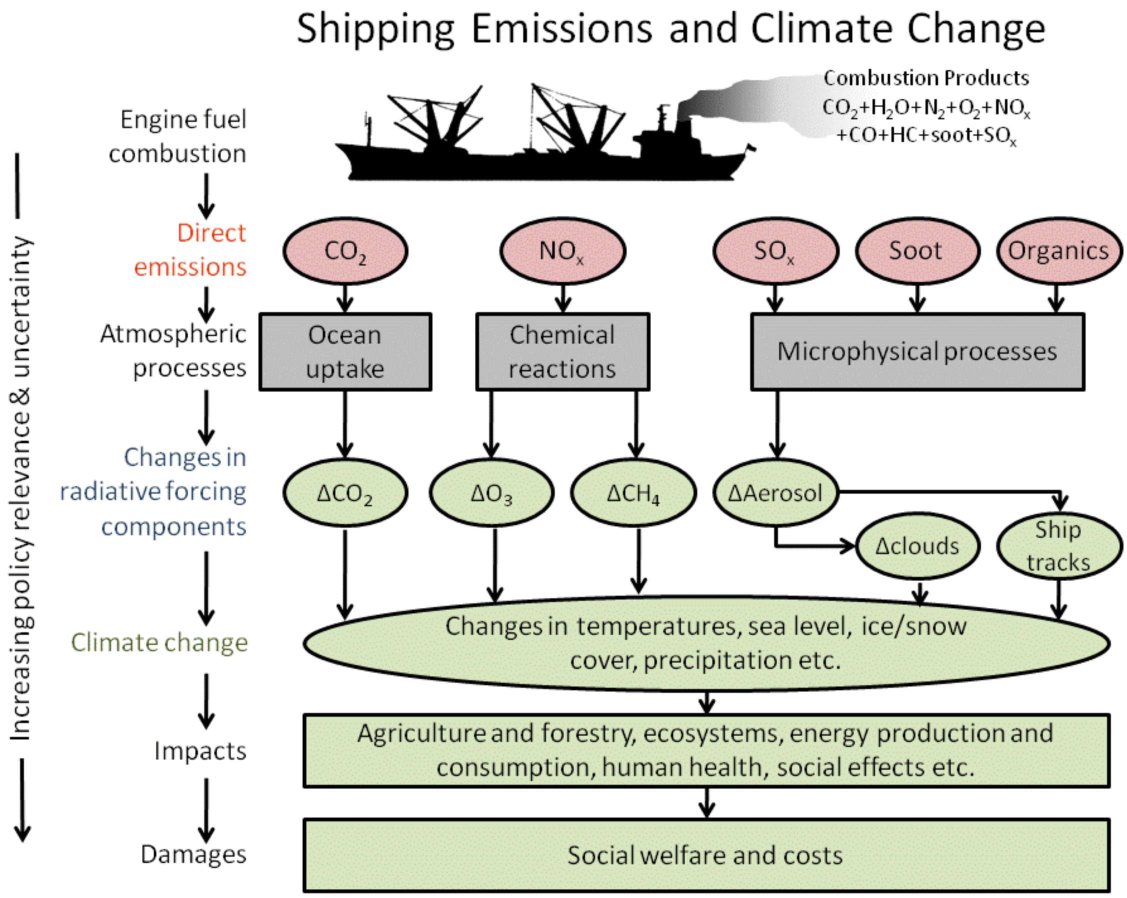

Figure 2. Schematic diagram of the overall impacts of emissions for the shipping sector (from *Lee et al.* (2009, in preparation).

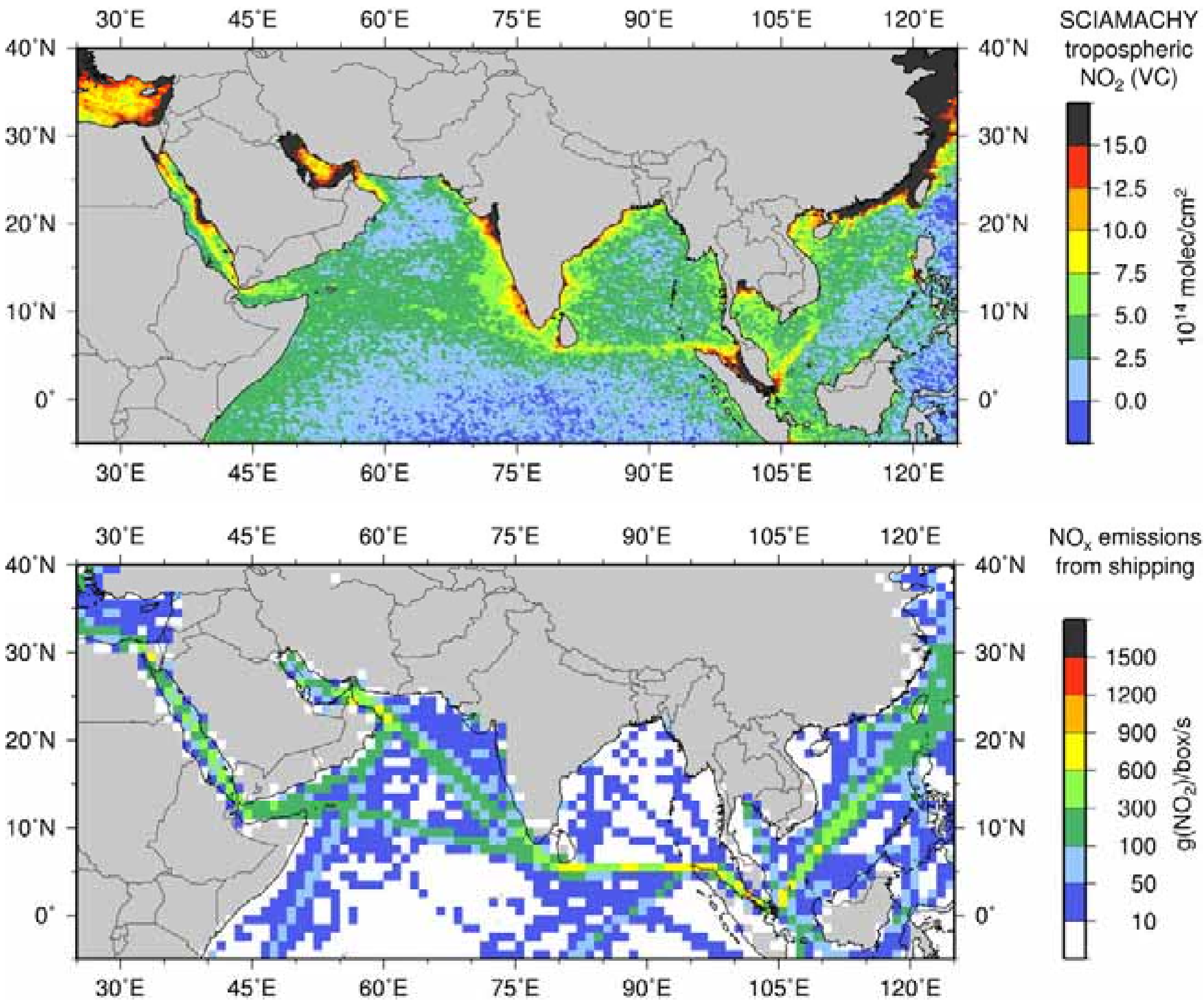

Figure 3. NO_x signature of shipping in the Indian Ocean. Upper panel: Tropospheric NO_2 columns derived from SCIAMACHY data from August 2002 to April 2004. Lower panel: Corresponding distribution of NO_x emissions from shipping taken from an emission inventory (from *Richter et al.*, 2004, their Figure 3; Copyright 2004 American Geophysical Union; Reproduced by permission of American Geophysical Union).

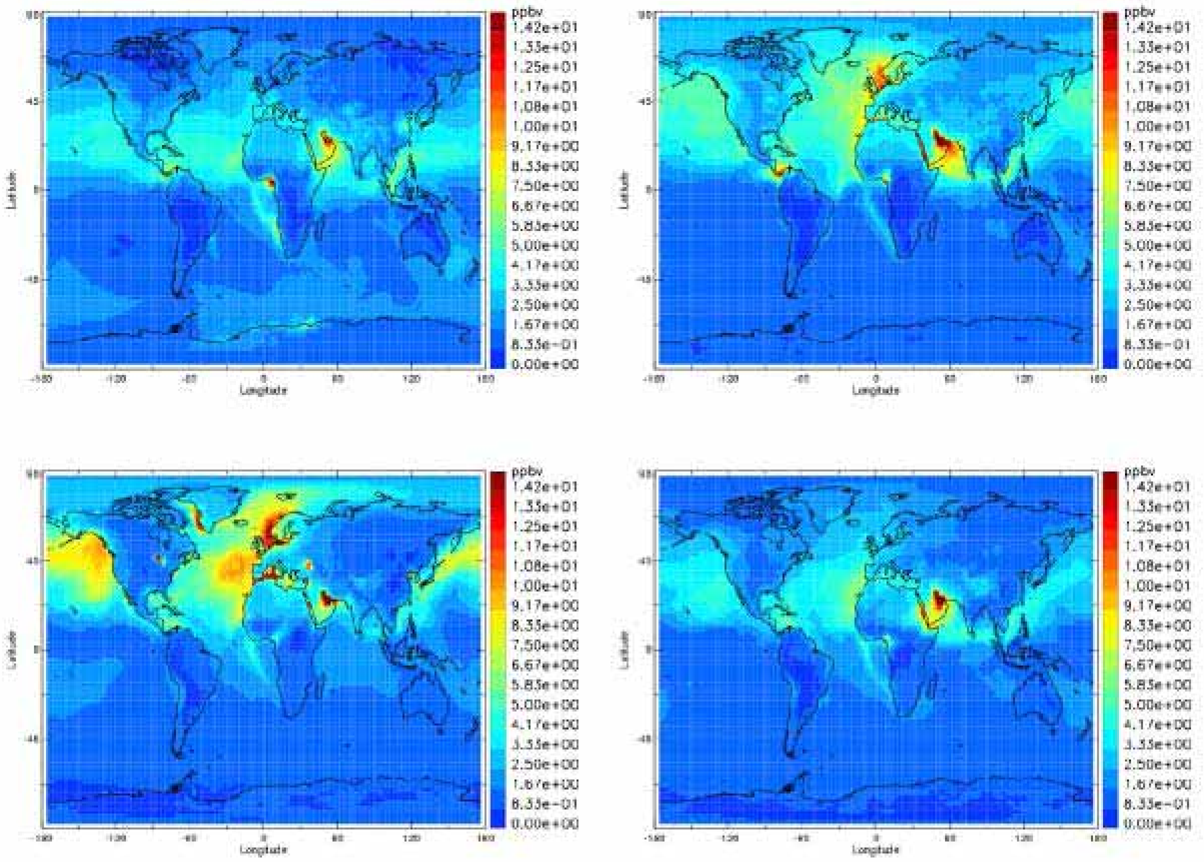

Figure 4. Ozone change at the surface due to year 2000 ship emissions simulated by the OsloCTM2 for the months (top left) January, (top right) April, (bottom left) July and (bottom right) October (from *Dalsøren et al.* 2007, their Figure 5; Copyright 2007 American Geophysical Union; Reproduced by permission of American Geophysical Union).

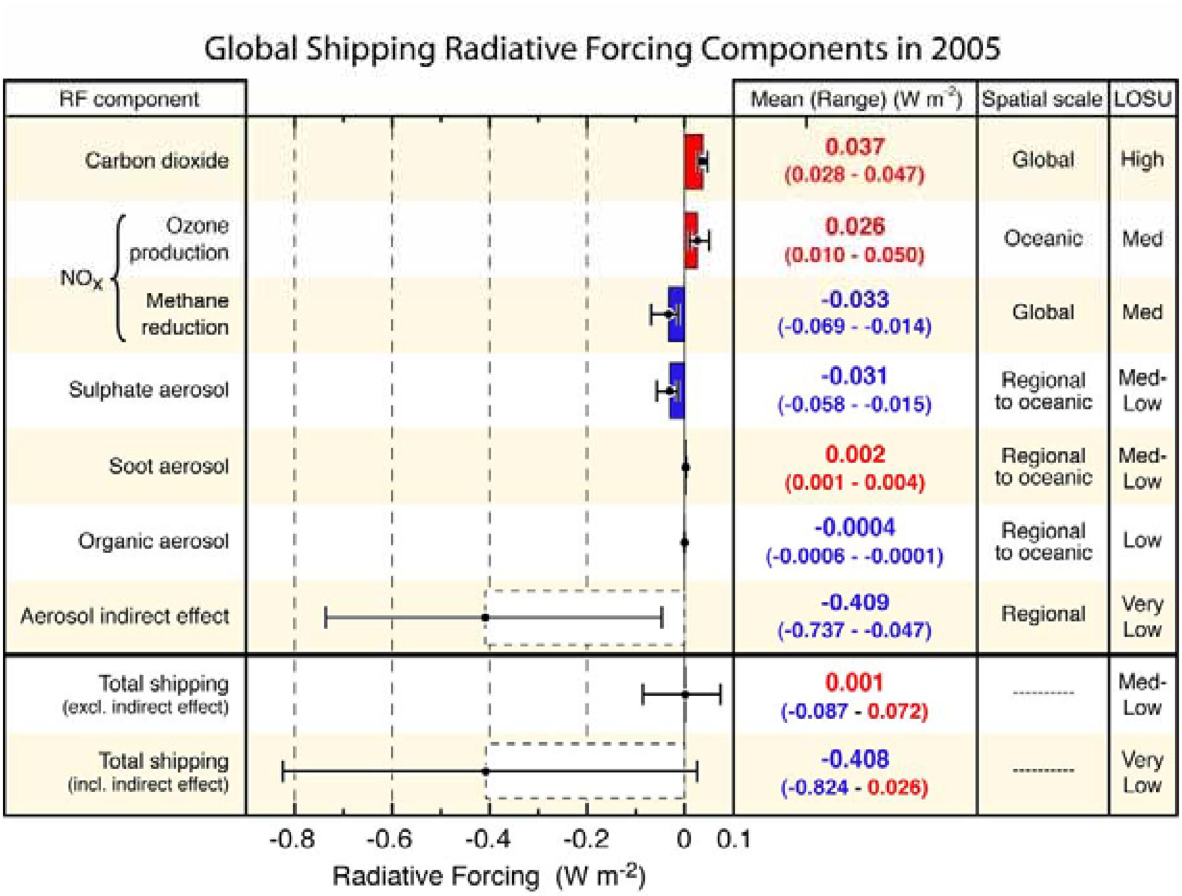

Figure 5. Global average annual mean radiative forcing (RF) and literature ranges due to emissions from oceangoing shipping in Wm^{-2} for 2005. The boxes show the mean of the lower and upper estimate reported in the literature and the whiskers show the range of literature values given by the highest and lowest estimate. The typical geographical extent (spatial scale) of the RF and the level of scientific understanding (LOSU) is given in addition. The RF contributions with very low LOSU are displayed in dashed lines. The figure does not include the positive RF that could possibly occur from the interaction of BC with snow which has so far not been investigated for ships. From *Eyring et al.* (2009), their Figure 14. Copyright 2009 Elsevier**.**

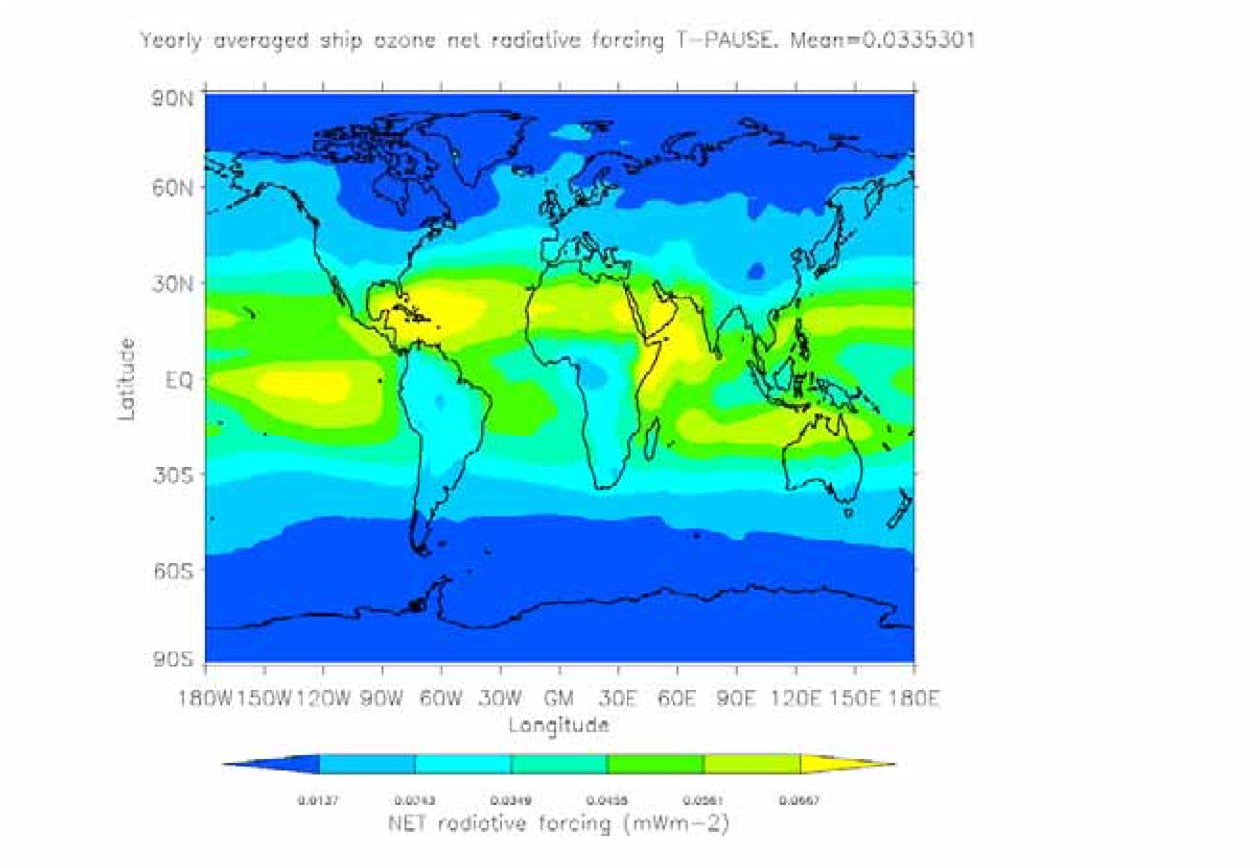

Figure 6. Annual radiative forcing pattern from O_3, from shipping NO_x emissions using MOZART-2 chemistry transport model and Edwards-Slingo radiative transfer model (*Lee et al.*, in preparation, 2009).

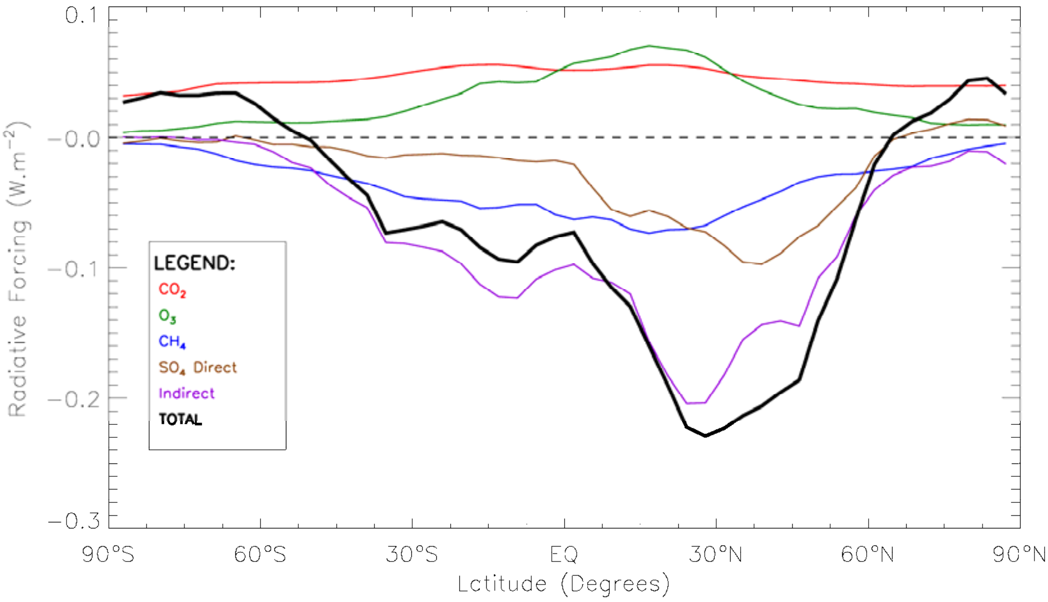

Figure 7. Zonal mean annual RF pattern from shipping for the IMO estimates of RF in 2007 (modified from *Lee et al.* (2009, in preparation).

Annex F

Ship aerosol impacts on climate and human health

Ship aerosol impacts on climate and human health

—ad hoc paper for European Commission—

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Abstract. In this discussion paper, we summarize and assess scientific literature on the impact of emissions from oceangoing ships on human health, aerosols and the Earth's radiation budget. Shipping-related particulate matter (PM) emissions were responsible for around 60 000 cardiopulmonary and lung cancer deaths in 2001, with highest increase in $PM_{2.5}$ and most deaths occurring near coastlines in Europe, East Asia, and South Asia. Concerns about health effects due to emissions from ships have magnified international policy debate regarding low-sulphur fuel mandates for marine fuel. Recent modelling studies show that premature deaths would be reduced by ~43 500 if the sulphur (S) content is limited to 0.1% within 200 nautical miles of coastal areas and be reduced by ~41 200 if the S content is reduced globally to 0.5%. These health benefits are associated with a reduction in the negative radiative forcing (RF) from ships that is mainly caused by a reduced indirect aerosol effect. Today, the cooling due to altered clouds far outweighs the warming effects from greenhouse gases such as carbon dioxide (CO_2) or ozone from shipping, overall causing a negative RF. Current efforts to reduce sulphur and other pollutants from shipping modify this. However, given the short residence time of sulphate compared to CO_2, the climate response from sulphate is of the order decades while that of CO_2 is centuries. The climatic trade-off between positive and negative radiative forcing is still a topic of scientific research, but from what is currently known, a simple cancellation of global mean forcing components is potentially inappropriate and a more comprehensive assessment metric is required. Further work is needed to reach a complete synthesis of the results. Current uncertainties of global modelling studies on the effects of emissions from shipping on aerosols and clouds are high and depend crucially on simulated key properties such as the aerosol size-distribution and the activation of aerosol particles in clouds. Further model development is needed in addition to extended measurement data e.g. of the size-distribution and composition of particles emitted by ships to reduce current uncertainties in these estimates.

1. Introduction

International shipping contributes significantly to emissions from the transportation sector (*Eyring et al.,* 2005; *Buhaug et al.*, 2009), thereby affecting the chemical composition of the atmosphere, climate and regional air quality, as well as human health. Key compounds emitted are sulphur and nitrogen oxides (SO_x and NO_x, respectively) and particulate matter (PM), as well as greenhouse gases (GHGs) such as carbon dioxide (CO_2).

PM emissions from ships are related to the sulphur content of marine fuel. In the case of oceangoing vessels, fuel sulphur content averages around 2.7% (27,000 ppm) with upper limits as high as 4.5% S (45,000 ppm) today. The dominant aerosol component resulting from ship emissions is sulphate (SO_4), which is formed by the oxidation of sulphur dioxide (SO_2). In 2000, shipping contributed quite a high fraction of around 8% to all anthropogenic SO_2 emissions, resulting in considerable impacts on climate and human health (*Lauer et al.*, 2007; *Corbett et al.*, 2007; *Eyring et al*., 2009).

The nature of the contribution to climate change is complex: In addition to warming by CO_2 emissions, ship emissions of SO_2 cause cooling through effects on atmospheric particles and clouds, while nitrogen oxides (NO_x) increase the levels of the GHG ozone (O_3) and reduce those of the GHG methane (CH_4), causing warming and cooling, respectively. The result is a net global mean radiative forcing (RF) from the shipping sector that is strongly negative, leading to a global cooling effect today (*Lauer et al., 2007; Eyring et al.,* 2009).This, however, ignores future impacts from accumulated CO_2, which will eventually result in an overall positive radiative forcing from the shipping sector (*Fuglestvedt et al.*, 2009).

Regulations of SO_2 emissions have been discussed for over a decade within the International Maritime Organization (IMO), because of shipping's contribution to regional acidification and air pollution. The Marine Environment Protection Committee (MEPC) of the IMO recently adopted NO_x regulations and progressive reduction in SO_2 emissions from ships, with the global cap (a fuel S content limit) initially reduced from the current 4.5 to 3.5% by 2012, to be followed by progressive reduction to 0.5% by 2020, subject to a feasibility review by 2018. In addition, the S limits in emission control areas will be reduced from the current level of 1.5 to 1% in 2010, and further to 0.1% in 2015. These new regulations for SO_2 and NO_x, whilst reducing air pollution and its harmful effects on health and water/soil acidification, might modify the impact of ship emissions on the Earth radiation budget.

In this discussion paper, we summarize and assess scientific literature on the impact of emissions from oceangoing ships on human health (Section 2) and on aerosols and the Earth's radiation budget (Section 3). Based on existing work, we produce a best estimate of the effect of aerosol and aerosol precursor emissions from ships on climate and human health today. Recent literature has also discussed the potential impacts of these effects under various near-term policy scenarios, which are discussed in addition to results for present-day conditions in Sections 2 and 3.

2. Impact on human health

2.1. Present-day impacts on human health

About 70% of the emissions from oceangoing shipping occur within 400 km of coastlines along the main trade routes (*Corbett et al.*, 1999). Thereby, ship emissions can have an impact on air quality in coastal regions and may partly offset the decline of emissions from land-based sources and coastal pollution resulting from national control measures (*Schlager and Pacyna*, 2004). The addition of NO_x and SO_2 from ships also contributes to acidification of the ocean (*Doney et al.*, 2007). On the global scale, these effects are small but could be more significant in shallower coastal waters where shipping is concentrated. Local and regional air quality problems in coastal areas and harbours with heavy traffic are of concern because of their impact on human health. Furthermore, emissions from ships can be transported in the atmosphere over several hundreds of kilometres, and thus can contribute to air quality problems on land, even if they are emitted over the sea. This pathway is especially relevant for ozone and the deposition of sulphur and nitrogen compounds, which cause acidification of natural ecosystems and freshwater bodies and threaten biodiversity through excessive nitrogen input (*Cofala et al.*, 2007).

PM with aerodynamic diameters of 2.5 µm or less ($PM_{2.5}$) from international shipping poses special concerns for human health. Ambient concentrations of $PM_{2.5}$ have been associated with a wide range of health effects including asthma, heart attacks, and increased hospital admissions. Atmospheric $PM_{2.5}$ concentrations have also been closely associated with increases in premature cardiopulmonary and lung cancer mortalities in exposed populations (*Pope et al*., 2002; 2004).

Previous assessments of regional shipping-related health impacts focused on European or Western US regions, but ignored long-range and hemispheric pollutant transport (*California Air Resources Board*, 2006; *Cofala et al.*, 2007). This underestimates oceangoing shipping impacts within local and regional jurisdictions. The study by *Corbett et al.* (2007) was the first that used a global model approach to estimate premature mortality from ship emissions. They first determined pollutant emissions from ships and then applied atmospheric transportation and chemistry models to estimate the increased concentrations due to ships. In a third step they estimated increased risk to exposed population due to these additional concentrations and then calculated additional mortalities due to that increased risk. Their results indicate that shipping-related PM emissions were responsible for around 60,000 cardiopulmonary and lung cancer deaths in 2001, with highest increase in $PM_{2.5}$ and most deaths occurring near coastlines in Europe, East Asia, and South Asia (see Figure 1). This number is bounded by a range of 20,000 to 104,000 premature deaths when considering the uncertainties due to emission inventories and models used in this study. Based on previous estimates of global $PM_{2.5}$-related mortalities (*Cohen et al.*, 2005), the *Corbett et al.* (2007) estimates indicate that 3% to 8% of these mortalities are attributable to marine shipping. *Cohen et al.* (2005) estimate that approximately 712,000 cardiopulmonary deaths are attributable to urban outdoor $PM_{2.5}$ pollution annually. Thus, the relationship between concentrations and mortality appears nearly proportional within reasonable percentage uncertainty bounds.

2.2 Changes in human health impacts for near-term policy scenarios

Given these health impacts and other concerns related to pollution from high-sulphur fuels, policies aimed at reducing the sulfur content of marine fuel were adopted by theIMO under ANNEX VI of MARPOL 73/78 (the International Convention for the Prevention of Pollution from Ships). In particular, more stringent reductions are enforced now for sulphur emissions, see Section 1. The human health benefits associated with several near-term policy options have been quantified by *Winebrake et al.* (2009) recently. They quantified premature mortality due to emissions from ships operating under several sulphur emissions control scenarios. They do this by applying the global climate model ECHAM5/MESSy1-MADE as in *Corbett et al.* (2007) to a geospatial inventory of shipping emissions to determine worldwide concentrations of $PM_{2.5}$ from oceangoing vessels assuming no emissions control regimes. They then use those $PM_{2.5}$ concentrations in cardiopulmonary and lung cancer concentration-risk (C-R) functions and population models to estimate annual premature mortality from these emissions. The study compares a 2012 *No Control* scenario (assuming a global average of 2.7% or 27,000 ppm S) with three emissions control scenarios. The first two control scenarios represent cases where marine fuel is limited to 0.5% S (5,000 ppm) and 0.1% S (1,000 ppm) content, respectively, within 200 nm of coastal areas. The third control scenario represents a case where sulphur content is limited to 0.5% S globally. In this way, a global estimate of some human health benefits associated with different control options can be provided. The results suggest that by 2012 control scenarios could reduce premature deaths by ~43 500 if the S content is limited to 0.1% within 200 nautical miles (370 km) of coastal areas and be reduced by ~41 200 if the S content is reduced globally to 0.5% (see Figure 2).

3. Impact on the Earth radiation budget and climate

3.1 Radiative forcing in 2005

In addition to the impact on human health, aerosol emissions from ships have an impact on climate through changes in clouds and radiative forcing (RF). RF is a common metric to quantify climate impacts from different sources 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 (*IPCC*, 2007). Figure 3 shows the RF for the various components from ship emissions in 2005 (*Eyring et al.*, 2009). For some of the compounds (CO_2, O_3 and BC) the RF is positive while for others the forcing is negative (by the reflection of sunlight by sulphate particles (*IPCC*, 2007), and through reduced concentrations of atmospheric methane. The particles can also have an indirect effect on climate through their ability to alter the properties of clouds.

Current CO_2 emissions of the ocean-going fleet (including domestic shipping and fishing, but excluding military vessels) are ~1000 Tg CO_2/y for 2005. Since the mid-19th century, shippings' emissions of CO_2 had resulted in a RF of ~37 mW/m^2 by 2005. However, a potentially large negative global mean RF from sulphur emissions works in the opposite direction from that of CO_2. Sulphur is emitted mainly as gaseous SO_2 and is oxidized in the atmosphere to sulphate which will form particles. These particles have a direct impact on climate by scattering solar radiation and thus reducing the amount of shortwave radiation heating of the surface, amounting to a RF of -31 mW/m^2 in 2005. Additionally, SO_2 *indirectly* affects climate by acting as cloud condensation nuclei. Such activity increases droplet number densities and changes the reflectance and lifetimes of clouds, causing a RF of -740 to -47 mW/m^2. This contribution is significant because ships emit in regions with a clean environment and frequent low clouds. The potential impact of particulate matter due to shipping emissions is larger on the radiation budget given the relative albedo change over a dark ocean, as opposed similar emissions over more reflective land surfaces. Such perturbations of the marine stratiform cloud field are partly visible in satellite data and are characterised as long-lived, narrow, curvilinear regions of enhanced cloud reflectivity which occur downwind of ships, so-called ship tracks. An example of ship tracks appearing as bright features in satellite data is given in Figure 4.

Our understanding and ability to quantify the indirect effects of SO_2 are limited mainly due to insufficient knowledge of the processes involved, but also from uncertainties in estimates of particle size distributions and in quantification and location of emissions. Thus, there are large uncertainties in the estimates of the temperature effects of SO_2 emission. However, the model results clearly indicate that the cooling due to altered clouds far outweighs the warming effects from greenhouse gases such as carbon dioxide (CO_2) or ozone from shipping, overall causing a negative radiative forcing today. The indirect aerosol effect of ships on climate is found to be far larger than previously estimated contributing up to 39% to the total indirect effect of anthropogenic aerosols. This contribution is high because ship emissions are released in regions with frequent low marine clouds in an otherwise clean environment and the potential impact of particulate matter on the radiation budget is larger over the dark ocean surface than over polluted regions over land.

However, an overall global mean negative RF does not imply that it is benign or good for climate, cancelling its warming effects from CO_2. This is because the RF metric is a global mean and CO_2 is a long-lived species for which a global mean response is appropriate. Sulphate negative forcing, however, is regional and exhibits a highly heterogeneous pattern of forcing that cannot necessarily be said to cancel with a homogeneous positive forcing in terms of climate impacts (e.g. changes in surface temperature, precipitation patterns and circulation).

3.2 Change on the Earth radiation budget under near-term policy options

Lauer et al. (2009) examine the same scenarios that are assessed with respects to human health benefits by *Winebrake et al.* (2009) (see Section 3.1) for their changes in RF. They show that, if no control measures are taken, near surface sulfate increases by about 10-20% over the main trans-oceanic shipping routes from 2000 to 2012. A reduction of the maximum fuel sulfur (S) content allowed within 200 nautical miles of coastal areas ("global emission control areas") to 0.5% or 0.1% (5,000 or 1,000 ppm S, respectively) results in a distinctive reduction in near surface sulfate from shipping in coastal regions compared with the year 2002. The model results also show that if emissions of nitrogen oxides (NO_x) remain unabated, a reduction of the fuel sulfur content favors a strong increase in aerosol nitrate (NO_3) which could counteract sulfur emission reductions. The most important impact of shipping on the radiation budget is related to the modification of low maritime stratus clouds resulting in an increased reflectivity and enhanced shortwave cloud forcing, while the direct aerosol effect from shipping is small (see Figure 3). *Lauer et al.* (2009) show that one can expect a less negative (less cooling) radiative forcing due to reductions in the current fuel sulfur content of ocean-going ships, see Figure 5. The global annual average net cloud forcings due to shipping are in the range of -0.27 (year 2002) to -0.58 W/m^2 (year 2012) with regional cooling occurring most over the remote oceans.

Based on these results, *Lauer et al.* (2009) concluded that policies to reduce the current fuel sulfur content of ocean going-ships will produce less negative RF (less cooling). CO_2 remains in the atmosphere for a long time and will continue to have a warming effect long after its emission. In contrast, sulfate has a residence time in the atmosphere of approximately 1 week, and the climate response from sulfate is of the order decades whilst that of CO_2 is of the order of centuries. The CO_2 equivalent emissions using the Global Temperature Change Potential (GTP) metric indicate that after 50 years the net global mean effect of current emissions is close to zero through cancellation of warming by CO_2 and cooling by sulfate and nitrogen oxides (*Eyring et al.*, 2009). Possible cancellation of positive and negative RF remains a topic of scientific research, but these model results show that an asymmetry exists among relatively cooler marine regions and land-based populated regions where warming impacts are unabated by ship aerosol effects. This strongly suggests that simple cancellation of global means is inappropriate as a measure of offsetting effects and a more comprehensive assessment metric is required.

3.3 Spatial patterns and climate responses other than temperature

While the present-day radiative forcing of the different components of the shipping emissions are useful to evaluate the impact of historical emissions on climate (up until present), they are not directly useful to evaluate impacts of present and future emissions on the future climate. As discussed in *Fuglestvedt et al.* (2009) there is not a unique correct way to do this, but it depends on how the long term goals of a climate policy are determined. In the Kyoto Protocol to the UNFCCC it was decided to use the Global Warming Potential with a 100 year time horizon (GWP_{100}) for this purpose (see *Fuglestvedt et al.* (2009) for definition and discussion of the GWP and other metrics). Recently *Shine et al.* (2005; 2007) have proposed a new emission metric, the GTP, that is designed to serve a policy consistent with a long-term climate target of constraining the global mean surface temperature increase below a threshold (e.g. the EU's target of keeping it below 2 °C above pre-industrial levels).

Due to the short-lived nature of many of the key components of shipping emissions there are several fundamental problems of applying global and annual averaged metric values to these components. However, they can be readily calculated from the global model simulations (*Endresen et al.*, 2003; *Eyring et al.*, 2007; *Lauer et al.*, 2007). Indeed the CO_2 equivalent emissions using the GTP_{50} metric indicate that after 50 years the net effect of current emissions is nearly neutral through cancellation of warming by CO_2 and cooling by sulphate and NO_x (see *Fuglestvedt et al.* (2009) for further details on transport metrics). *Berntsen and Fuglestvedt* (2008) use a simple analytical climate model to calculate the time dependent contributions to global mean temperature change for current emissions from the different transport sectors. In the case of shipping their results for a one-year emission pulse are consistent with the results from simple analysis using GTPs, in that NO_x and SO_2 contribute to cooling, and that the long-term warming caused by CO_2 leads to a net warming after about 35 years.

The spatial dimension is also hidden by global average mean RF and temperature responses, Long-lived greenhouse gases, such as CO_2, display only small spatial variability in their RF patterns. However, shorter-lived forcing agents such as O_3, SO_4 aerosol and the indirect effect have very spatially inhomogeneous forcing patterns. In the case of NO_x emissions, the resultant O_3 forcing will have a larger spatial variability than the negative RF response of CH_4, because of the very different lifetimes (weeks versus years). The net forcing from NO_x emissions is, therefore, zero, or slightly negative through these two effects, and a global mean temperature response would also indicate either no change in global mean surface temperature from these effects or even a slight overall cooling. This is a limitation of the metric and the modelling rather than a lack of climate response. It is possible that a localized forcing is not cancelled by a homogeneous forcing of the opposite sign, even if they are of similar magnitudes at the global scale.

Determination of such localized versus global climate effects requires the use of coupled ocean–atmosphere global climate models, which are computationally expensive to run and also suffer from signal-to-noise ratio problems for small perturbations, requiring many simulations or very long equilibrium simulations. There is some evidence that the inherent feedbacks in the coupled Earth–ocean climate system result in similar spatial patterns of temperature response for different forcing patterns (*Boer and Yu*, 2003). However, 'climate' is not temperature alone, and there is evidence that different patterns of precipitation can arise from forcings of similar magnitude but with different spatial patterns (*Taylor and Penner*, 1994).

In order to determine the overall RF pattern for shipping, Lee *et al.* (2009) utilized results from the global tropospheric chemistry model MOZART v2 for O_3 and CH_4. They also used the global aerosol model E5/M1-MADE (*Lauer et al*., 2007) to simulate the zonal mean RF pattern of the direct and indirect aerosol effect, as well as a general circulation model (GCM) for aerosol and cloudiness response and a coupled ocean–atmosphere GCM for the CO_2 response. The resulting zonal mean RF pattern for the IMO estimates of RF in 2007 (−66 Wm^{-2} from *Fuglestvedt et al.*, 2008) is shown in Figure 6. The results clearly demonstrate the latitudinal variation in the forcings, as described above.

4. Conclusions and outlook

With emissions of international shipping taking place both in coastal areas and open oceans their impact on the atmosphere and contribution to climate as well as health and environmental impacts can be significant. At a local and regional-scale, ocean-going ships impact human health through the formation and transport of sulphur emissions and particulate matter (*Corbett et al.,* 2007; *Eyring et al.*, 2009; *Lauer et al.*, 2009; *Winebrake et al.*, 2009). In harbour cities, ship emissions are in many cases a dominant source of urban air pollution. Furthermore, emissions of NO_x, CO, VOCs, particles and sulphur (and their derivative species) from ships may be transported in the atmosphere over several hundreds of kilometres, and thus can contribute to air quality problems on land, even if they are emitted at sea (*Eyring et al.,* 2007). The potential contribution to annual premature mortalities due to cardiopulmonary disease and lung cancer attributed to particles caused by emissions from ships was estimated to be ~60 000 (20 000 – 104 000) in 2001 (*Corbett et al.*, 2007). Compared to previous estimates, these shipping-related deaths account for 3-8% of the total number of worldwide deaths related to atmospheric particles. By 2012 control scenarios would reduce premature deaths by ~43 500 if the sulphur (S) content is limited to 0.1% within 200 nautical miles (370 km) of coastal areas and be reduced by ~41 200 if the S content is reduced globally to 0.5% (*Winebrake et al., 2009*).

In addition to the impact on atmospheric composition and health, ship emissions have an impact on climate. A common metric to quantify climate impacts from different sources is radiative forcing' (RF) in units of W/m^2. The perturbation of a cloud layer by ship-generated aerosol changes the cloud reflectivity and is identified by elongated structures in satellite images, known as ship tracks. Compared to the surrounding cloud a significant increase in droplet number concentration and optical thickness as well as a decrease in effective radius is found within the ship tracks (*Schreier et al., 2006*). Ship tracks can change the radiation budget on a local scale, but are short lived and cover a very small fraction of the globe so that their radiative effect on the global scale is negligible (–0.4 to –0.6 mW/m^2 ±40%; *Schreier et al.*, 2007). Simulations with global aerosol models show instead a high impact of gaseous and particulate emissions from ocean-going ships on maritime clouds (*Lauer et al.*, 2007). The additional aerosol particles brighten the clouds above the oceans, which then are able to reflect more sunlight back into space. Although the uncertainties associated with this study are still high, the model results clearly indicate that the cooling due to altered clouds far outweighs the warming effects from greenhouse gases such as carbon dioxide (CO_2) or ozone from shipping, overall causing a negative radiative forcing today. This, however, ignores future impacts from accumulated CO_2, which will eventually result in an overall positive radiative forcing from the shipping sector (*Fuglestvedt et al.*, 2009).

We conclude that efforts to reduce CO_2 and other pollutants from ships should be strongly considered in light of the recent research that has identified: (1) the long-range fate and transport of these pollutants; (2) the impact of these pollutants on human health and climate; and (3) the cost-effectiveness of reducing such pollutants in the context of alternative reduction options.

With respect to local pollutants such as particulate matter and sulphur emissions, mounting evidence shows that the benefits of emissions reductions of these pollutants outweigh the costs of control for many regions of the globe. Policy action to reduce ship emissions is no longer in question, although the choice among a diverse set of policy strategies to achieve needed reduction targets may not be simple. Policymakers need to consider issues such as technological feasibility, economic efficiency, and total fuel cycle tradeoffs (*Winebrake et al.*, 2007; *Corbett and Winebrake*, 2007). However, these considerations will help determine the appropriate and necessary policy response paths given the evidence that action is needed. While more research is needed to better understand regional environmental and economic impacts of such reductions, we believe that these can be pursued along with climate-scale strategies for CO_2 and other greenhouse gases. The integration of science-based and policy-focused research continues to provide important insight and context to the policy dialogue that IMO needs to engage with.

As new research has indicated, reductions in sulphur emissions could result in human health benefits (*Winebrake et al.*, 2009) together with regional reductions in its resultant negative radiative forcing (*Lauer et al.*, 2009). The climatic trade-off between positive and negative radiative forcing is still a topic of scientific research, but from what is currently known, a simple cancellation of global means is potentially inappropriate and a more comprehensive assessment metric is required. We emphasize that CO_2 remains in the atmosphere for a long-time and will continue to have a warming effect long after its emission. In contrast, sulphate has a residence time in the atmosphere of approximately 10 days, and the climate response from sulphate is of the order decades whilst that of CO_2 is of the order of centuries. While the control of NO_x, SO_2 and particle emissions from ships will have beneficial impacts on air quality, acidification and eutrophication, CO_2 reductions from all sources, including ships and other freight modes, are urgently required to reduce global warming.

The results by *Winebrake et al.* (2009) on changes in human health impacts under various near-term policy scenarios confirm that meaningful benefits are achieved from either a 0.5% S or 0.1% S control strategy. The findings demonstrate that upwards of 45,000 premature mortalities could be prevented annually across the globe with a movement towards lower sulphur fuels in the future. Of course, reduced premature mortality is directly, but non-linearly, related to the geographic use of clean fuels: lower sulphur fuels lead to larger health benefits, particularly when used in a near-coastal environment. The premature mortality impacts are only one of many impacts that are related to shipping emissions and fuel quality. Climate change, acidification, visibility, eutrophication, and other environmental effects are closely related to the type of fuel used. The studies that have been published so far on this topic offer important input to current science and policy discussions about the application of low sulphur fuel regulations for international shipping. However, current uncertainties of global modelling studies on the effects of emissions from shipping on aerosols and clouds are high and depend crucially on simulated key properties such as the aerosol size-distribution and the activation of aerosol particles in clouds. Minor changes of these properties can have a significant impact on the simulated indirect effect. Furthermore, changes in cloud properties such as cloud liquid water content, cloud cover and precipitation formation due to ship emissions impact on atmospheric chemistry via wet deposition and changes in scavenging efficiency. Changes in atmospheric chemistry such as ozone or OH concentrations result in a feedback on aerosols e.g. via modified oxidation rates of SO_2. Further model development in particular on the representation of aerosol size-distribution, aerosol activation, aerosol-cloud interaction and extension of feedback mechanisms is needed in addition to extended measurement data e.g. of the size-distribution and composition of particles emitted by ships to reduce current uncertainties in global model studies.

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FIGURES:

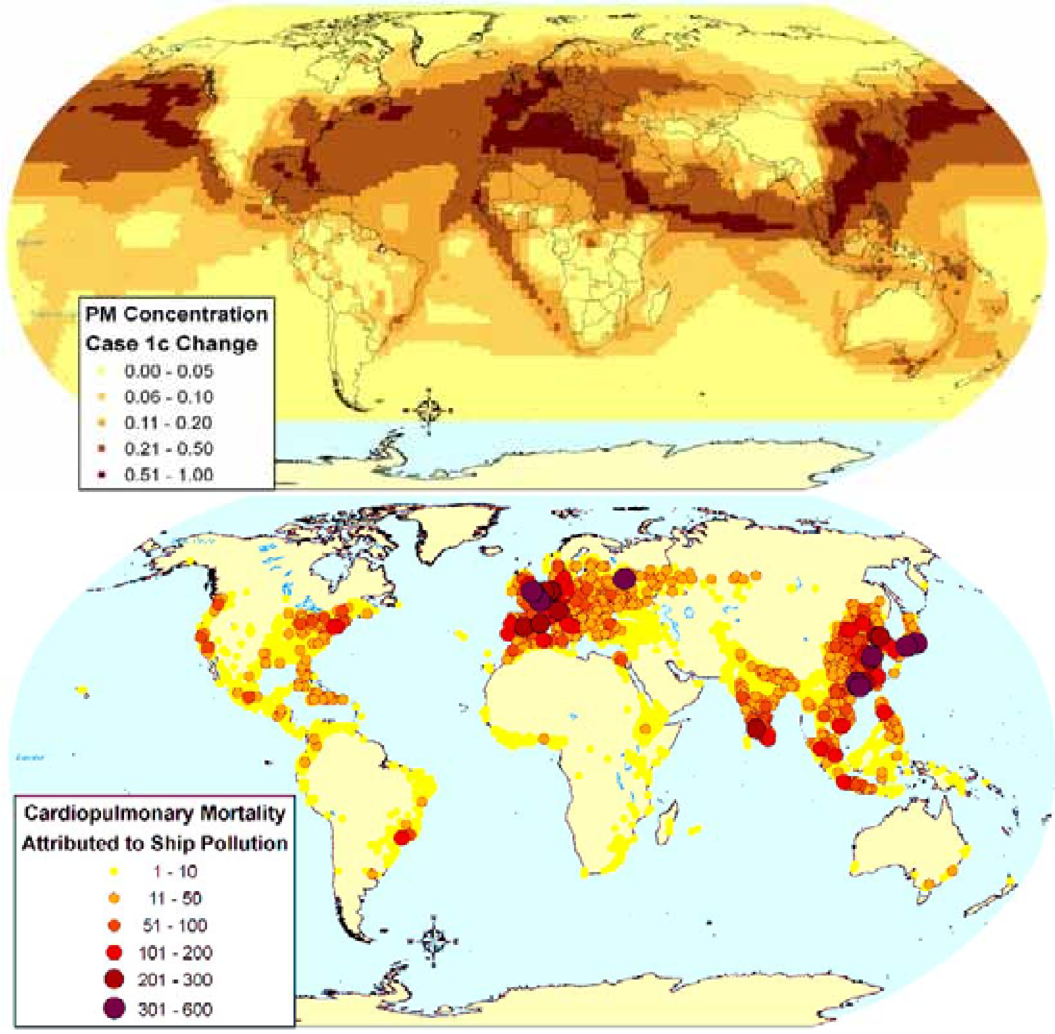

Figure 1. Annual average contribution of shipping to PM2.5 concentrations (in μg/m3, upper panel) and cardiopulmonary mortality attributable to ship PM2.5 emissions worldwide (lower panel) using the Automated Mutual-assistance Vessel Rescue System (AMVER) derived ship distribution from *Eyring et al.* (2005) and the global aerosol model ECHAM 5/Messy-MADE. From *Corbett et al.,* (2007), their Figure 1 and 2. Copyright 2007 American Chemical Society.

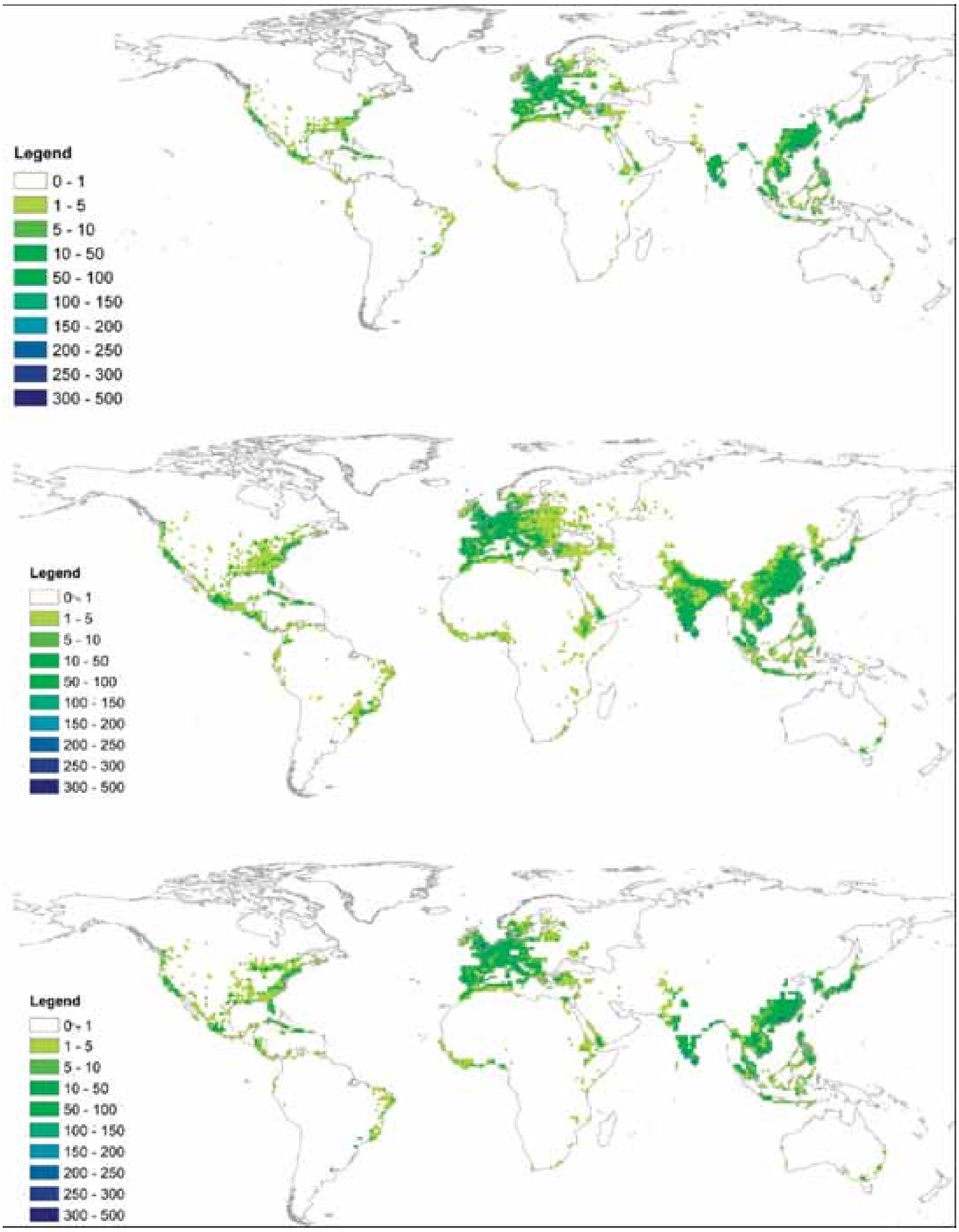

Figure 2. Annual avoided premature mortality for the three control scenarios: (a) Coastal 0.5, (b) Coastal 0.1, and (c) Global 0.5 for the International Comprehensive Ocean-Atmosphere Data Set (ICOADS) data set. Reductions in estimated premature mortality use the 50th-percentile beta values in the C-R function and are relative to the *No Control* scenario. From *Winebrake et al.* (2009), their Figure 4. Copyright 2009 American Chemical Society.

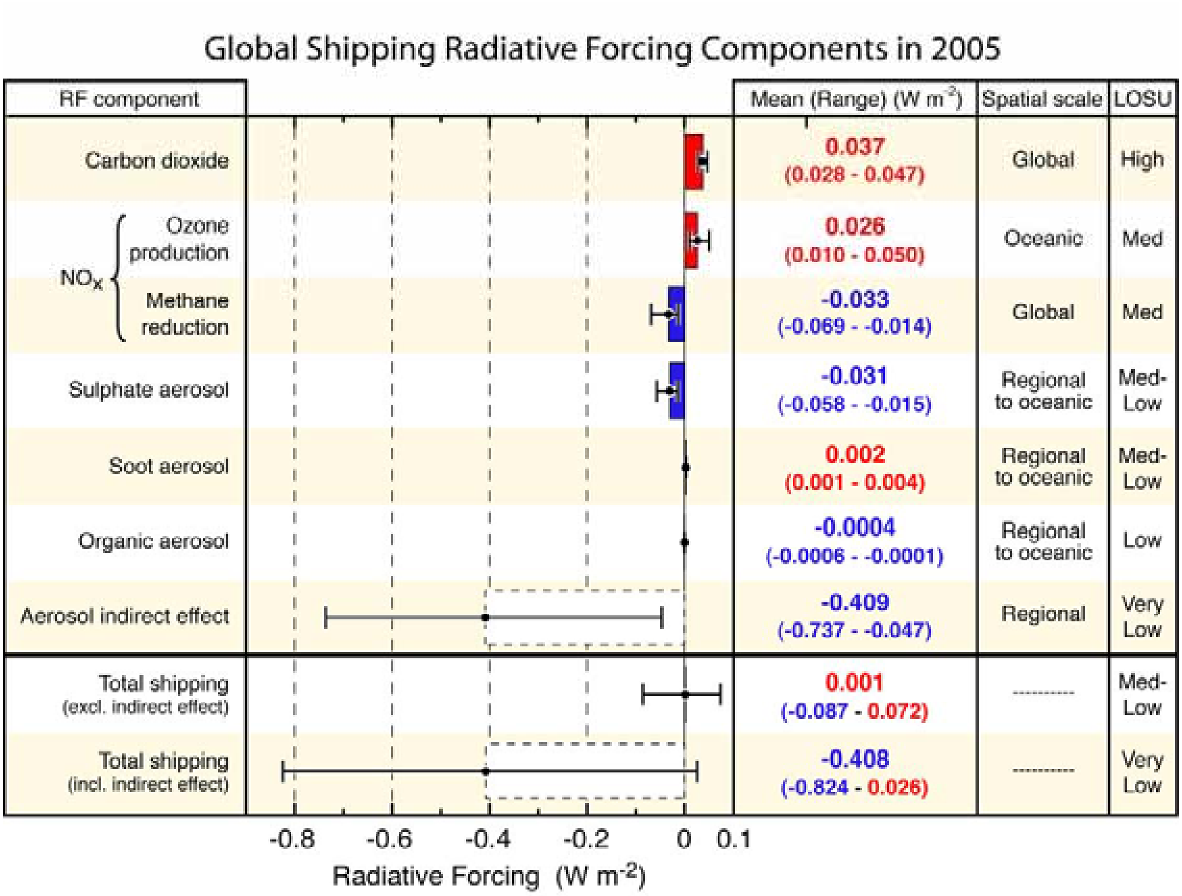

Figure 3. Global average annual mean radiative forcing (RF) and literature ranges due to emissions from oceangoing shipping in Wm^{-2} for 2005. The boxes show the mean of the lower and upper estimate reported in the literature and the whiskers show the range of literature values given by the highest and lowest estimate. The typical geographical extent (spatial scale) of the RF and the level of scientific understanding (LOSU) is given in addition. The RF contributions with very low LOSU are displayed in dashed lines. The figure does not include the positive RF that could possibly occur from the interaction of BC with snow which has so far not been investigated for ships. From *Eyring et al.* (2009), their Figure 14. Copyright 2009 Elsevier**.**

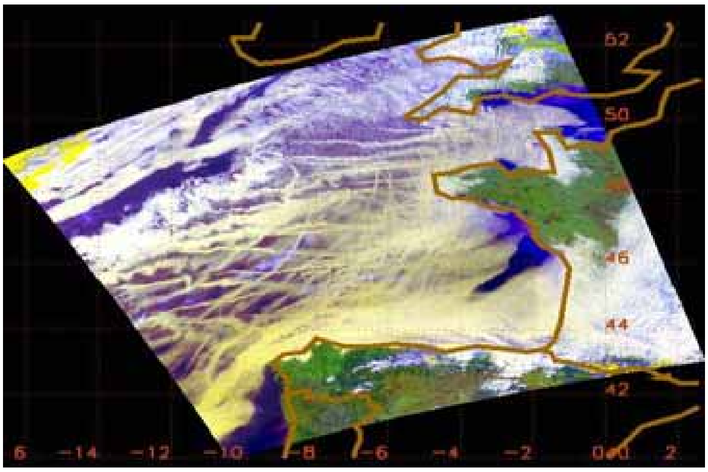

Figure 4. Ship tracks over the Gulf of Biscay (colour composition from AVHRR on 27 January 2003). From *Eyring et al.* (2009), their Figure 12. Copyright 2009 Elsevier**.**

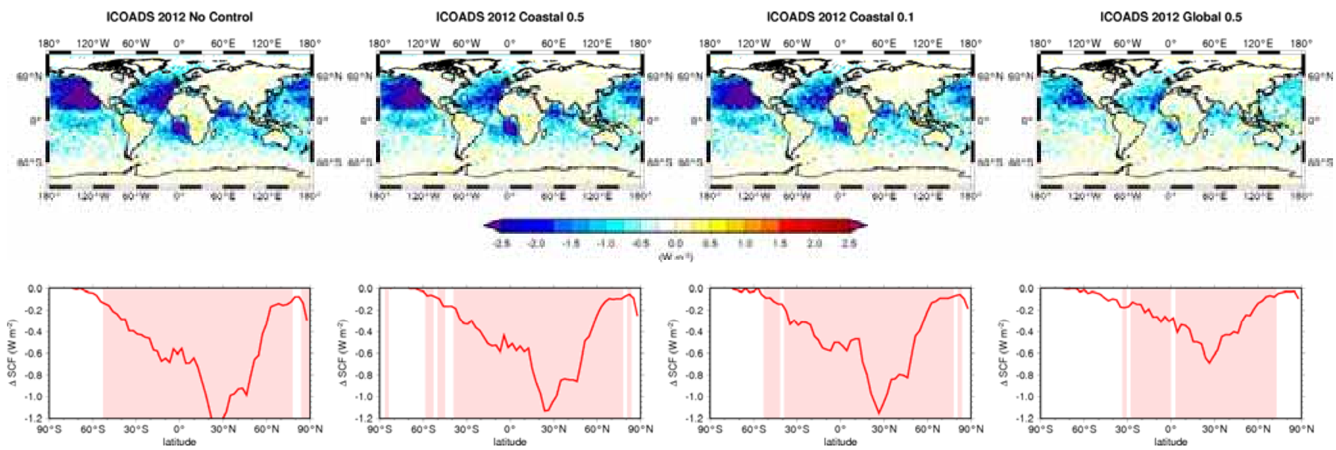

Figure 5. Multi-year average of simulated changes in shortwave cloud forcing due to shipping for ICOADS emission scenarios at the top of the atmosphere (ToA) in Wm^{-2}. From left to right: 2012 *No Control*, 2012 *Coastal 0.5*, 2012 *Coastal 0.1* and 2012 *Global 0.5*. Upper row shows the geographical distribution, lower row zonal averages. Hatched areas (upper row) and light-red shaded areas (lower row) show differences which are significant at the 99% confidence level compared with the inter-annual variability. From *Lauer et al.* (2009), their Figure 3. Copyright 2009 American Chemical Society.

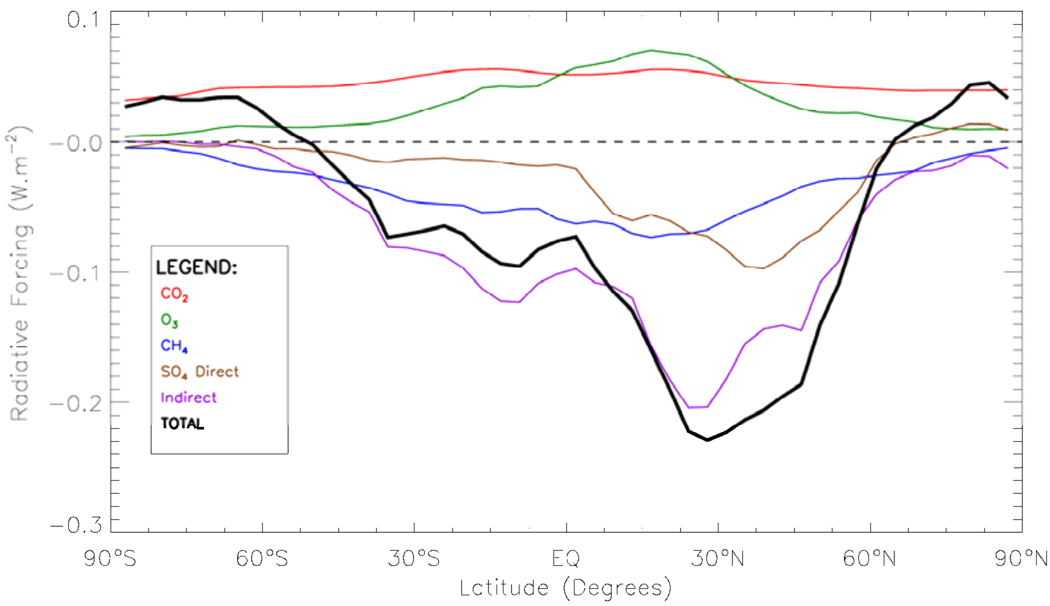

Figure 6. Zonal mean annual RF pattern from shipping for the IMO estimates of RF in 2007 (modified from *Lee et al.* (2009, in preparation).

Annex G

Greenhouse Gas Emissions from Port Congestion

REPORT

CE DELFT

GREENHOUSE GAS EMISSIONS FROM PORT CONGESTION

PROJECT NO. 582635

REVISION NO. 00

REPORT

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GREENHOUSE GAS EMISSIONS FROM PORT CONGESTION

CE DELFT

Issue Log					
Revision	**Issue Date**	**Prepared by**	**Reviewed by**	**Approved by**	**Comments**
00	May 2009				

PROJECT NO. 582635
REVISION NO. 00
December 2009

Approved By:
Stephen Bligh
Director & Head Maritime Advisory Services UK

Management Summary

As part of the European Commission's (EC) project "Technical support for European action to reducing Greenhouse Gas Emissions from international maritime transport", this report assesses the impact of port congestion on emissions of Greenhouse Gasses (GHG) from International Shipping.

Due to limited statistics on port congestion, estimating its contribution to GHG emissions is difficult, however container ships and particularly liner services are expected to contribute the most GHG emissions, due to frequent port calls by a large number of vessels, unreliability of arriving on time and high installed auxiliary power.

Potential GHG emissions for bulk carriers and container ships due to port congestion were calculated. For the worst delay of nine days, GHG emissions from one bulk carrier was estimated between 75 and 250 tonnes of CO_2, depending on vessel size. For container ships, a delay of 10 days, resulted in GHG emissions ranging from 221 tonnes CO_2 for the smallest container ship to 1,034 for the largest (>8000 teu).

Port utilisation was increasing year on year prior to the economic downturn with ports in Scandinavia, the East Baltic and North East Continent predicted to be congested again by 2015 (>80% utilisation). While the global economic downturn has provided a period of grace, potentially delaying this predicted date, the problems of port congestion are expected to return.

Avoiding port congestion is key with EU policy to shift freight onto more efficient modes of transport, co-operation between ports would ensure spare capacity is utilised and avoid congestion in the larger ports, while spare capacity remains unutilised in others.

CONTENTS

APPENDICES

1. INTRODUCTION

1.1 Background

As part of the European Commission's (EC) project "Technical support for European action to reducing Greenhouse Gas (GHG) Emissions from international maritime transport", the EC has requested an ad-hoc paper on the impact of port congestion on the emission of GHG from International Shipping.

1.2 Scope

This paper discusses and assesses the GHG emissions associated with port congestion within the following limitations:

- International shipping, in the context of this study, will mean vessels on an international voyage from one country to another, involving at least one European Union (EU) Member State, thus excluding marine traffic within territorial waters and inland waterways of a single EU Member State;
- Port congestion GHG emissions, in the context of this study, will mean GHG emissions generated during vessel's waiting time outside an EU port for a free berth, excluding GHG emissions from manoeuvring, waiting at berth or from the port's own activities/operations; and
- GHG emissions, in the context of this study, will be limited to carbon dioxide (CO_2) emissions only - the main contributor of GHGs from shipping.

1.3 Objectives

The objective of this report is to identify the contribution to GHG emissions from international shipping due to waiting times at European ports, with the aim of ascertaining whether waiting time has a significant impact to the overall GHG emissions from shipping.

1.4 Approach

The report covers the following key aspects:

- An overview of the current port congestions monitoring/recording practices and their limitations;
- An assessment of the contribution of port congestion on the overall GHG emissions from international shipping using available information, including case studies, where feasible;
- A high level review of the potential differences in GHG emissions due to port congestion between various trades and ports; and
- Summary of results and conclusions.

2. PORT CONGESTION

Port congestion is a consequence of ships being unable to discharge or load their cargo, causing them to wait at anchor resulting in subsequent delays and a backlog of vessels for the port/terminal to deal with. In an ideal situation a ship would arrive at a port with a berth and cargo handling facilities available and ready for immediate use. When a berth is unavailable, the ship is forced to wait at anchor until one is made available or find an alternative port, causing delays throughout the supply chain, escalating costs (BIMCO, 2006). The performance and efficiency of a port is a critical factor in preventing congestion, however there are frequently reasons beyond a port's control that can contribute to their ability to turnaround vessels efficiently and in a timely manner.

Port congestion can be caused by a number of different factors. A sudden peak in trade and ship traffic might leave the port with limited ability to quickly adjust to the increase in demand. Industrial action or an accident can result in instantaneous severe delays resulting in back log of ships and massive delays.

A period of exceptionally bad weather may result in difficulties in handling ships and cargo, increasing the turnaround time or a combination of environmental factors contrive to make berthing ships impossible. For example, when spring tides, storms and wind direction resulted in the Maeslant and Hartel flood barriers being closed due to high water levels, shipping on the Nieuwe Waterweg (New Waterway) and Hartel canal was brought to a halt for 24 hours (Port of Rotterdam, 2007)

The availability of berths is not the only factor that causes congestion in ports. The inability to move the discharged cargo from the quayside results in land-side based congestion that is passed onto ships. In March 2008, during a period of severe congestion in European ports, the main culprit for congestion was reported to be empty containers sitting on limited terminal space, combining with tight schedules forcing container ships to sail without loading their full compliment of empties, with dwell times of up to 14 days reported in Rotterdam (Port Strategy, 2008).

The effects of port congestion are numerous and not just limited to the ability to berth and load / unload ships. One delay in a logistics chain can impact on the whole supply chain. In a reply to a survey from the European Conference of Transport Ministers (ECMT) on congestion and its consequences, the European association for forwarding, transport, logistic and customs services (CLECAT, 2006) suggests, at a port-only level, that congestion affects:

- Carriers by causing vessel delays, extra fuel costs and missed feeders;
- Terminal operators, extra manpower and yard congestion;
- Road hauliers, waiting time; and
- Shippers with longer transit times, delayed inventories and longer lead times.

Port congestion can also seriously affect the quality of life of the citizens living in port or close to ports or anchorages, by reducing the local air quality. Time lost in port needs to be regained during the voyage, leading to faster sailing speeds and elevated GHG emissions.

Limiting port congestion is of increasing importance to support current EU policy promoting the switch from land transport to more energy efficient modes.

The Marco Polo and Marco Polo II initiatives aim to move 12 billion tonne-kilometres a year of road freight onto Short Sea Shipping, rail and inland waterways. This places increasing importance on efficiencies within ports and the logistic chain to co-ordinate activities to ensure port congestion and undue vessel delays are kept to a minimum.

“Motorways of the Sea” is another initiative developed by the EU aiming to use shipping to bypass land based bottlenecks in Europe by offering frequent services that can compete with road transport in terms of transit time and costs, including two new “Motorways of the Sea” announced recently linking ports on Spain’s northern Atlantic seaboard with France (Lloyd’s List, 2009). These initiatives are seen as possible contributors to fulfilling the objectives of the Kyoto Protocol.

Port congestion is not a temporary issue and not limited to European ports. It is difficult to identify major ports in any country that have not faced congestion issues in the past. Mitigating port congestion can be difficult in the short and longer term with already high utilization of certain ports and capital expenditure programmes taking a long time to implement, due to prolonged planning processes and objections by environmentalists (Sanyal, 2006).

3. MONITORING OF PORT CONGESTION

Monitoring of Vessel Movements

The International Convention for the Safety of Life at Sea (SOLAS) requires an Automatic Identification System (AIS) transponder onboard all ships of 300 gross tonnage and above engaged in International voyages, cargo ships of 500 gross tonnage and above not engaged in international voyages, as well as all passenger vessels. AIS automatically transmits information enabling the tracking of other ships with the system installed, including the ship's IMO number, type, position, heading, speed and navigational status.

While the AIS network does not cover all ship movements globally as it is limited to a network of shore based stations, it was utilised in the Updated 2000 Study on Greenhouse Gas Emissions from Ships: Phase 1 Report for the IMO (IMO,2008). However the AIS network coverage enables identifying ships at anchor at ports. The IMO report defined four categories from the collected AIS data as shown in Table 1, including "at anchor", but the report did not perform analysis of GHG emissions specifically from ships at anchorage due to waiting for a berth.

Table 1: Definition of data categories from AIS data utilised by IMO report

Category	Description
Port	Hours within range of AIS network with navigation status "moored"
Anchor	Hours within range of AIS network, with navigational status "at Anchor"
Slow	Hours within and outside AIS network, calculated average speed <80% of service speed
Normal	Hours within and outside AIS network, calc. average speed >80% service speed

In busy waters and harbours, a local Vessel Traffic Service (VTS) may also exist utilising AIS services to manage ship traffic.

Port Congestion Statistics

Port waiting times / port efficiency and delay statistics can be both commercially sensitive to the port and to the operator. This is especially the case in Europe where ports are not only competing against each other but also against each port's logistic chain with numerous potential routes and intermodal transport links. Therefore, information of delays due to port congestion is not readily available in the public domain due to the commercial sensitivity of this information.

During research for this paper only one port congestion index was easily identifiable and available and that was the Global Ports Congestion Index[1] (GPCI), which is a weekly newsletter detailing current delays in berthing in major coal and ore ports worldwide. European ports that fall into this category include the terminals in the Netherlands and Spain detailed below.

- Netherlands
  - Rotterdam (EMO)
  - Rotterdam (EECV)
  - Rotterdam (St Laurenshaven Terminal)
  - Amsterdam (OBA Terminal / Rietlanden)
  - Ijmuiden (Outer Quay No.2-Corus)
- Spain
  - Algeciras
  - Carboneras
  - Gijon
  - San Ciprian
  - Tarragona

Unlike in other regions for example the Middle East where the selection of ports is limited, in Europe the relative proximity of ports and alternative modes of transport and logistical chains means this performance information is rarely communicated externally. Case in point a major European port was approached early in the preparation stages of this study, however co-operation was not achieved.

[1] www.globalports.co.uk/

4. PORT CONGESTION'S CONTRIBUTION TO GHG EMISSIONS

4.1 Methodology

Previous studies on GHG emissions from shipping have typically concentrated on "At Sea/Manoeuvring/At Berth" modes or "At Sea/In Port" and therefore information specifically on "At Anchor" due to port congestion has not been identified.

However data on other required parameters such as average installed power, average load (% Maximum Continuous Rating (%MCR)) Specific Fuel Oil Consumption (SFOC), vessel type and size etc has been readily utilized and reported in numerous studies.

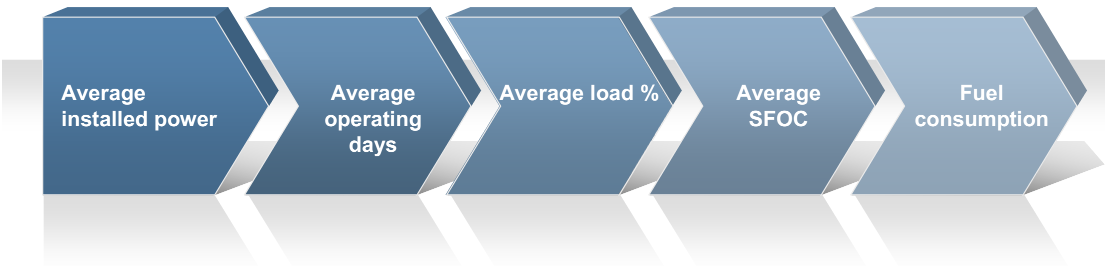
The following sections outline the methodology, assumptions and data sources that have been utilized in order to estimate the GHG emissions from port congestion for two case studies and from international shipping as a whole.

As a result of the above and due to the limitations and scope of this report and availability of relevant published information, a number of assumptions have been made in order to estimate meaningful GHG emissions due to port congestion.

4.1.1 Calculation GHG Emissions

GHG emissions emitted during waiting times for a berth, is a function of the fuel combusted while at anchor multiplied by an emission factor. Fuel consumption calculations have been conducted in line with the bottom up approach described by IMO (2008) as summarised in Figure 1.

Figure 1: Calculation of fuel consumption summary (IMO, 2008)



The methodology above was utilised for calculating the fuel consumption of the main engine, however the process is also applicable to auxiliary engines and has been be modified slightly to fit the purposes of this study.

Emissions of GHG, in this instance CO_2, were calculated by multiplying the fuel consumption by a CO_2 emission factor, which is a well established and accepted methodology.

4.1.2 General Assumptions & Data Sources

This section details the assumptions and data that is utilised later in the report for calculating GHG emissions from international shipping due to port congestion.

Average installed power

Information collected on delays due to port congestion for this report did not include any specific ship data about individual vessels. Therefore, calculations are based on ship category and size/type.

Average installed power for auxiliary engines per ship category and size has been sourced from the IMO GHG study (IMO, 2008). Table 2 details average per engine auxiliary power for bulk and container ships, which are used in the two case studies. A more comprehensive list of ship categories are in included in Appendix I.

Table 2: Summary table – input data used in the inventory

Category	Size / Type	Ave. per engine Aux kW
Bulk	>200,000 dwt	794
Bulk	100-199,999 dwt	697
Bulk	60-99,999 dwt	549
Bulk	35-59,999 dwt	533
Bulk	10-34,999 dwt	458
Bulk	<9,999 dwt	237
Container	>8,000 teu	3081
Container	5-7,999 teu	2433
Container	3-4,999 teu	1782
Container	2-2,999 teu	1359
Container	1-1,999 teu	985
Container	<999 teu	600

Average Auxiliary Engine Load

Published information detailing auxiliary engine load for ships at anchor was not found during the research for this paper. While at anchor all non-critical systems will be shut down and power requirements limited to functions for the accommodation, fuel heating and any cargo related functions. In consultation with DNV technical experts an engine load of 20% for auxiliary engines was considered standard, which is consistent with reported "in port" auxiliary engine load for bulk carriers and container vessels (Dalsøren *et al, 2009*) as per the two case studies.

This figure is expected to be slightly conservative and potentially over estimates GHG emissions while at anchor due to the average load including geared vessels, hatch covers and self un-loaders that will have higher power requirements in port while loading / discharging.

Table 3 shows main and auxiliary engine loads for at sea and in port as reported by Dalsøren *et al, (2009)*.

Table 3: Average engine load for "at sea" and "in port" modes for bulk and container vessels (% Maximum Continuous Rating) (Dalsøren *et al, 2009*)

	Load at sea		Load in port	
Ship type	**Main Engines**	**AUX**	**Main Engines**	**AUX**
Bulk Vessels	70	0%	0%	20%
Container Vessels	70	0%	0%	20%

Average Specific Fuel Oil Consumption (SFOC)

SFOC of auxiliary engines is defined by IMO (2008) in two categories, above and below 800kW. This also takes into account that auxiliary engines are expected to operate extensively on part load and will be used for calculations as shown in Table 4.

Table 4: Specific Fuel Oil Consumption for auxiliary engines (IMO, 2008)

Engine Age	Above 800kW	Below 800 kW
Any	220 g/kWh	230 g/kWh

Emission Factors

Emission factors have been reported in numerous publications and are all within relatively close proximity of each other. For the purposes of this study, the value as reported by Dalsøren *et al*. (2009) is utilised which is shown in Table 5. This is independent of fuel type (HFO/MDO), vessel category and size, thus the one figure of 3,179 kg CO_2 per tonne of fuel combusted will be applied.

Table 5: Emissions Factors for converting fuel consumption to CO_2 emissions for bulk and container ships. (Dalsøren *et al, 2009*)

	Emission Factors kg CO_2/tonne fuel	
Vessel Type	**At Sea**	**In-port**
Bulk	3,179	3,179
Container	3,179	3,179

Calculating GHG emissions due to Port Congestion

To estimate GHG emissions, first it is necessary to calculate the fuel consumption due to port congestion. This is calculated by multiplying the average installed auxiliary engine power by the port delay, average load of the engine and the Specific Fuel Oil Consumption for the selected ship of selected category and size as shown in equation (1). GHG emissions are then calculated using an emission factor as shown in equation (2).

$$FC_i = P_{MCR,i} \cdot t \cdot F(\%) \cdot SFOCi \quad (1)$$

$$E_{(CO2)i} = 3.179 \cdot FC_i \quad (2)$$

Where:

- FC *Fuel Consumption (g)*
- P_{MCR} *Average installed aux engine power (kW)*
- t *Port delay (hrs)*
- F(%) *Average load on auxiliary engine (% MCR)*
- SFOC *Average Specific Fuel Oil Consumption of installed auxiliary engines (g/kWh)*
- i *Category and size/type*

4.2 Case Studies

Limited information on port congestion is published, especially within Europe so for purposes of demonstrating the potential GHG emissions from a period of port congestion, two cases have been selected:

- Bulk coal / Ore terminal in Rotterdam
- Container terminal congestion in South California

4.2.1 Bulk Coal and Ore Ports

Of the ports detailed in Sections 3, for the period of 11 July 2008 to 6 February 2009, there were no delays recorded for the Spanish ports, while over the same period the Netherlands ports all recorded 0-1 day (averaged at 0.5), for all terminals, except for Rotterdam (EMO) Coal – Ore which experienced delays as detailed in Table 6.

Table 6: Days delay at Rotterdam EMO terminal

Date	Delay	Date	Delay
15-Aug-08	9	24-Oct-08	3
22-Aug-08	1.5	31-Oct-08	3
29-Aug-08	5.5	07-Nov-08	2.5
05-Sep-08	4.5	14-Nov-08	2.5
12-Sep-08	5	21-Nov-08	3.5
19-Sep-08	5	28-Nov-08	3.5
25-Sep-08	5	05-Dec-08	3.5
03-Oct-08	5	12-Dec-08	3.5
10-Oct-08	5	19-Dec-08	3.5
17-Oct-08	3	31-Dec-08	3.5

Details on the specific bulk carrier sizes at anchor during this period of delay were not available, so equations (1) and equations (2) were used to calculate GHG emissions for all bulk carrier vessel sizes per reported days delay.

Figure 2: Upper and lower bounds (dwt) of GHG emissions from bulk carriers at anchor at Rotterdam per ship

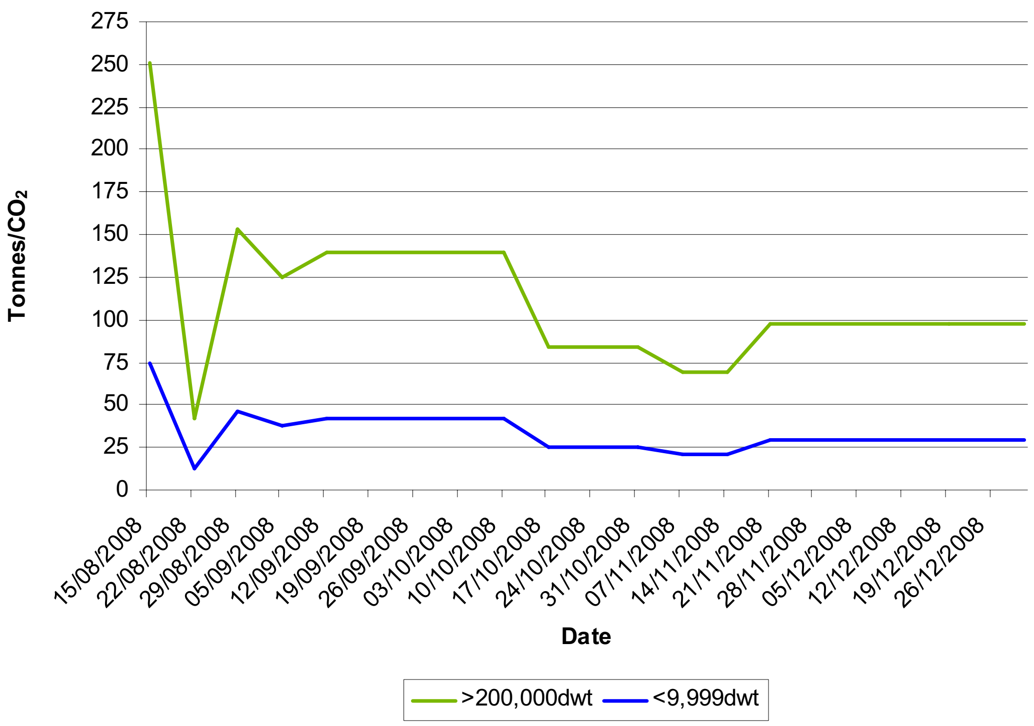


Figure 2 demonstrates the potential GHG emissions for a single vessel delayed ranging from the largest size of bulk carrier (>200,000 dwt) to the smallest (<9,999 dwt), with intermediary sizes in between these two values. As a result, for the worst delay of nine days one bulk carrier would be expected to emit approximately between 75 and 250 tonnes of CO_2, depending on vessel size.

In order to gain an insight into the total GHG emissions over this period of congestion, the number and sizes of vessels would need to be known. However, as this information is not available we can estimate the numbers using some assumptions. In 2008, the Port of Rotterdam received 9,430 bulk cargo carriers (Port of Rotterdam, 2008), of which bulk carriers accounted for 1,074, ore carriers 43, ore-bulk-oil carriers 16 and tankers 8,297.

Therefore the total ore and coal bulk carriers berthing at the Port of Rotterdam in 2008 was 1,117 (bulk carriers + ore carriers). This was divided by 52 to give an approximate estimation of 21 vessels a week calling at the port. Assuming that all bulk deliveries were limited to the three terminals at Rotterdam as listed in Section 3, and that the traffic was split evenly between the terminals, we can assume seven vessels a week berthed at the EMO terminal.

Using this assumption we can estimate the upper and lower bound limits of GHG emissions of ships at anchor waiting for a berth for the whole period of delay, by calculating the assumed seven vessels waiting at each time period and summing the results.

Table 7 shows the estimated CO_2 emissions over the time period of 11 July 2008 to 6 February 2009 for the terminal, which includes a total of 564 ship waiting days and between 4,687 and 15,703 tonnes CO_2 emitted due to port congestion (depending of ship sizes).

Table 7: Total GHG emitted due to period of congestion

	Total CO_2 emissions (tonne)	
Total ship day delays	**Lower Limit**	**Upper Limit**
564	4,687	15,703

4.2.2 Container Ports

Detailed information was not easily identifiable for European container terminals largely due to the commercial sensitivity of this information, however due to the importance of container shipping in Europe and its effect on congestion it was deemed important to estimate emissions in an example.

Notteboom (2006) reports that due to congestion in southern Californian terminals during 2004, fully laden container vessels were backed up for ten days waiting to berth and unload. As explained elsewhere in this report, long delays in European container terminals are less likely to be as significant due to numerous other relatively local ports, with the exception of the biggest container ships that are limited to the biggest ports. Therefore we can consider this example as worse case scenario.

As in the bulk carrier example, no specific information was available detailing vessel size, so calculations have been made for all vessel sizes to give the range of potential GHG emissions. Table 8 shows the calculated fuel consumption and CO_2 emissions per vessel size for the reported ten day delay, with estimated GHG emissions ranging from 221 tonnes CO_2 for the smallest container ship to 1,034 for the largest >8000 teu container ships.

Table 8: Estimated fuel consumption and GHG emissions for container ships due to a ten day delay in berthing

Size (teu)	**Fuel Consumption** (tonne)	**CO_2 Emitted** (tonne)
>8000	325	1,034
5-7,999	257	817
3-4,999	171	544
2-2,999	144	456
1-1,999	104	331
<999	66	211

Whether a ten day delay would occur in European container terminals is not clear. The nature of logistical chains in Europe ensures that containers can generally be re-routed to avoid such a serious congestion period in one port. This is discussed later in this report, but it gives an idea of the potential magnitude of GHG emissions caused by such a severe delay.

4.3 Contribution of Congestion to Overall GHG Emissions

The limitations placed on this report due to the unavailability of relevant data makes a meaningful assessment of the overall contribution that port congestion has on the total GHG emissions from international shipping very difficult. Therefore, we shall use the two case studies and available information to assess the relative contribution of the two congestion periods detailed therein.

Fuel consumption figures while at sea and in port is reported by Dalsøren *et al.* as shown in Table 9. Using the emission factor for CO_2 established earlier of 3.179 tonne CO_2/tonne of fuel, we can estimate total CO_2 emissions by ship type (Table 9) and percentage contribution of emissions by each mode (at sea/in port) to the total GHG emissions from international shipping (Table 10).

Table 9: Emissions by trade for At Sea and In Port modes.
(Fuel consumption values from Dalsøren *et al, 2009*)

	Total (Kt)		At Sea (Kt)		In Port (Kt)	
Ship Type	**Fuel Cons**	**CO_2**	**Fuel Cons**	**CO_2**	**Fuel Cons**	**CO_2**
Bulk	30,186	95,961	28,874	91,790	1,312	4,171
Container	47,083	149,677	45,711	145,315	1,371	4,358
Chemical Tanker	8,670	27,562	7,726	24,561	944	3,001
General Cargo	19,319	61,415	18,044	57,362	1,275	4,053
Liquefied Gas Tanker	9,701	30,839	9,052	28,776	649	2,063
Oil Tanker	29,603	94,108	27,362	86,984	2,241	7,124
Passenger Vessel	19,250	61,196	18,496	58,799	754	2,397
Reefers	4,583	14,569	4,315	13,717	269	855
Ro-Ro	10,214	32,470	9,829	31,246	385	1,224

Table 10: Percentage of GHG emissions by trade and activity

Ship Type	% Port Emissions	% At Sea
Bulk	4.35%	95.65%
Container	2.91%	97.09%
Chemical Tanker	10.89%	89.11%
General Cargo	6.60%	93.40%
Liquefied Gas Tanker	6.69%	93.31%
Oil Tanker	7.57%	92.43%
Passenger Vessel	3.92%	96.08%
Reefers*	5.87%	94.15%
Ro-Ro	3.77%	96.23%

** error due to fuel consumption figures from Dalsøren et al, (2009)* In the Dalsøren *et al*. study "In Port" fuel consumption is calculated based on summarised data for time in port for each ship call, estimated from "sail date" minus "arrival" date. Therefore "In Port" fuel consumption solely records consumption while berthed (loading/unloading), as the "At Sea" fuel consumption includes manoeuvring.

As Table 9 shows the biggest contributor to overall GHG emissions is container vessels with a total of 149,677 Kt CO_2,followed by bulk carriers (95,961 Kt CO_2), oil tankers (94,108 Kt CO_2), and general cargo and passenger vessels (61,415 Kt CO_2 and 61,196 Kt CO_2 respectively).

While container ships have the largest overall emissions, they have the smallest percentage (2.91%) associated with the "In Port" mode of the trades listed in Table 10, which reflects the quick turnaround time in port for loading/unloading containers. Bulk liquid vessels (chemical and oil tankers) have the highest proportion of emissions related to "In Port", reflecting the time required for example pumping cargo during loading and unloading, tank cleaning and inert gas generation.

In the methodology employed in the Dalsøren *et al,* (2009) study, any time at anchor would be included in the "At Sea" mode. Knowing roughly a typical unloading / loading period would allow a basic comparison of estimated emissions from a period of port congestion, as the assumed auxiliary engine loads (bulk and container) while at anchor for the purposes of this study are the same as the "In Port" engine load.

A direct comparison for bulk carriers is difficult as time in port for loading / unloading is highly dependent on the size and design of the ship, as well as port facilities and techniques for cargo transfer.

Unloading can take up to 120 hours for the largest bulk carriers, while containerisation has reduced port turn around form three weeks to less than 24 hours, taking between 10 and 20 hours to unload 1,000 TEUs (Rodrigue *et al.,* 2006). For the purposes of making a comparison with the case studies we will assume 2-3 days for bulk carriers and 0.5-1 days for containerships.

If we assume that the percentage split of emissions between at sea and in port represents an average voyage, we can assess the affect of these port congestion incidents would have on this an average voyage by ship category.

By dividing the time delay by the estimated time in port to calculate the percentage increase in time and multiplying by the percentage of emissions attributed to "In Port", we are able to calculate the percentage increase in emissions these delay periods would make to the averaged voyage overall emissions of the ship category.

$$\text{Increase in overall emissions (\%)} = \text{Emissions attributed to “In Port” (\%)} \left[\frac{\text{Delay Time}}{\text{Time in Port}} \right] \quad (3)$$

Table 11 shows the estimated time “In Port”, delay time due to port congestion and estimated percentage increase to overall emissions for the two case studies. For example the worse period of congestion in the coal and ore case would reflect a 13-20% increase and for the container terminal delay of 10 days a 29-58% increase is estimated. These figures are highly dependent of vessel type / size and time in port and do not take account of individual voyages, thus only provide an overview of the potential impact of port congestion on GHG emissions for international shipping.

Table 11: Estimated percentage increase in overall CO_2 emissions from case study port delay examples

Case	Estimated time in port (days)	% of emissions attributed to “in port”	Delay (days)	Percentage increase in overall emissions
Coal/Ore	2-3	4.35%	9	13-20%
	2-3	4.35%	5	7-11%
	2-3	4.35%	2.5	4-5%
Container	0.5-1	2.91%	10	29-58%

5. TRADES & PORTS

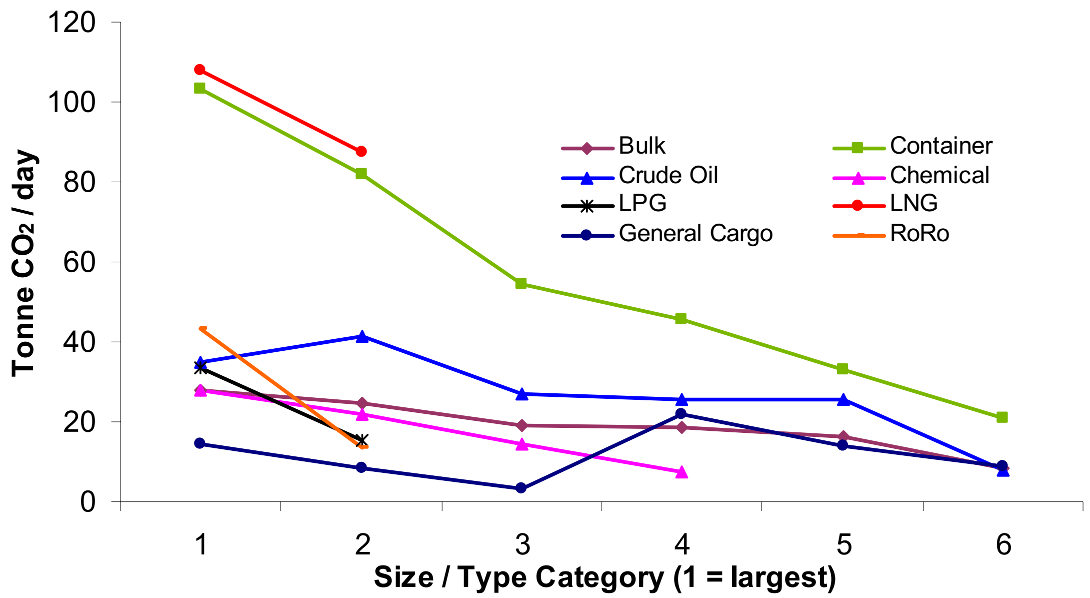
Occurrences of port congestion can be highly dependent on the type of trade and ports. In fact due to specialist terminals within ports, congestion and delays can be limited to certain types of terminals within a port. In this section we will discuss at a high level the potential differences in GHG emissions due to port congestion between various trades and ports.

5.1 Trades

Fuel consumption, and therefore CO_2 emissions (as reported by Dalsøren *et al,* (2009)), is dominated by bulk carriers, container vessels and oil tankers, accounting for 49% of the total fuel consumption of the world fleet. Non cargo vessels that make up half the fleet, by number, only contribute 15% of the total world fleet fuel consumption. Therefore congestion issues within one of these three trades (bulk, container and oil) will likely have the biggest impact in terms of GHG emissions should the trade by subjected to periods of port congestion.

As shown earlier in this report, GHG emissions due to port congestion is a function of the average installed power of the auxiliary engines multiplied by the average engine load. As we have assumed the load for all vessels is 20% at anchor, the potential effect of a port delay on a specific category and size of vessel can be given by comparing the installed auxiliary power. A comprehensive list of data is attached in Appendix I, and was used to produce Figure 3 which shows the calculated CO_2 emissions for a one day delay by vessel category and size/type.

Figure 3: Estimated GHG emissions for a days delay at anchor by ship category and size / type (categories 1-6 are detailed in Appendix I)



While it would appear that LNG vessels contribute significantly higher quantities of GHG per day delay, the number of LNG vessels should be considered. Clarksons[2] (April, 2009) reports the total number of LNG vessels at only 309, while bulk carriers number 6,980, total tankers (>10k dwt), 5,034 and container ships: 4,773.

Therefore containerships would have the largest potential impact on GHG emissions due to port congestion as they have the highest daily CO_2 emissions for any ship category with significant numbers of vessels, highest overall CO_2 emissions and a higher frequency of port calls.

Oil tankers, bulk carriers and container ships are discussed in more detail below.

5.1.1 Oil Tankers

Oil tankers are currently facing a unique problem as the demand for oil drops. Rotterdam, Europe's largest port is running out of space to store oil due to plummeting demand causing some oil tankers to drop anchor outside the port or be diverted elsewhere, according to Royal Dirkzwager (Pagnamenta, 2009). Additionally in the same article from the times, Mr Jensen of Frontline states of the 50 VLCCs (very large crude carriers) being used to store oil off shore globally, up to 20 are believed to be in the Rotterdam-Amsterdam area.

5.1.2 Bulk Carriers

In the European context major ore and coal importing ports are limited to the Netherlands and Spain, with very few reported incidents of congestion reported.

Major delays in this sector seem limited to ports in Australia, Brazil and China. For example at the start of 2008, the average waiting time was about three days in the Atlantic Basin (4+ in Brazil) and a little less in the Pacific (five days in Australia). In certain cases delays were much longer; 11 days in Brazilian iron ore load ports and 27 days in Australia coal load ports (Tyler, 2008).

The sheer number of bulk carriers means any port congestion has the potential to cause a large increase in GHG if vessels are forced to wait at anchor for a berth. The turnaround of bulk carriers is affected by the loading / unloading efficiency / methodology and the design of the vessel. Difficulties in cleaning holds prior to loading due to lack of "user-friendliness" can add significant time delays.

5.1.3 Container Ships

We have already seen container ships in Europe have potentially the highest likelihood to contribute to GHG emissions due to port congestion. This is especially the case for the liner trade. Given the integration of many liner services that are closely integrated, delays in one port can cascade throughout the whole liner service, affecting other ports of call, even ones with initially no delays (Notteboom & Rodrigue, 2008).

[2] www.clarksons.net

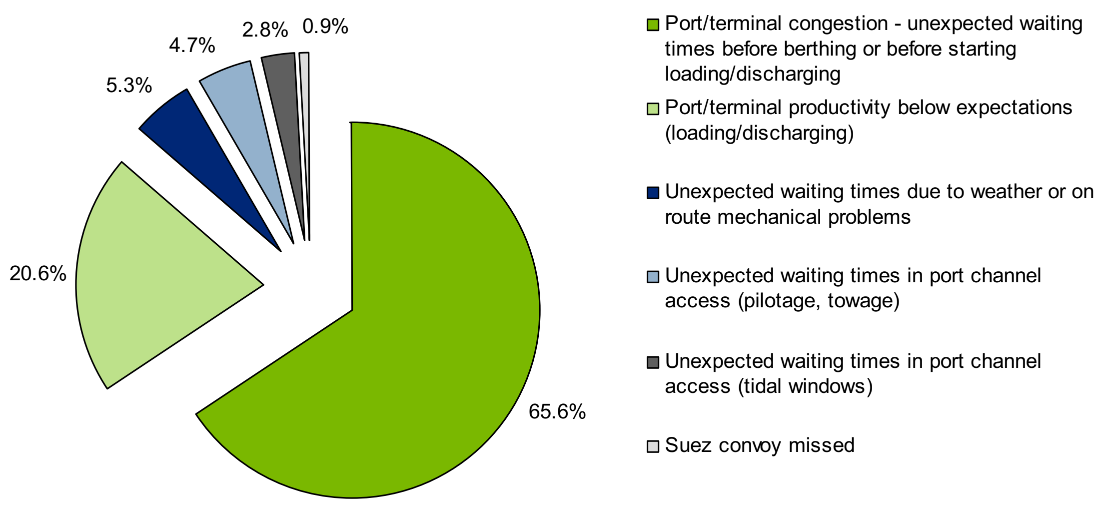
Table 12 provides an overview of the average schedule integrity for liner services in Europe. An arrival on time is considered when the ship arrives at the port of destination on the scheduled day or on the day immediately before the scheduled day of arrival. The table demonstrates that liner services are unreliable with only two of the eight trade routes shown achieving greater than 50% arrival on time performance.

Table 12: Schedule integrity of liner services on European trade routes
(Notteboom & Rodrigue, 2008; based on Drewry, 2006)

Trade route	Percentage of on-time vessel arrivals
Asia/Europe/Med	44%
Europe/Med/Africa	41%
Europe/Med/Aus/New Zealand	31%
Europe/Med/Caribbean/Central America	67%
Europe/Med/East Coast South America	62%
Europe/Med/Indian Sub/Mideast/Red Sea	46%
Europe/Med/North Coast South America	44%
Europe/Med/West Coast South America	24%

Arrival times can be affected by a number of factors, but port congestion as reported by Notteboom (2006) is clearly the largest contributor to unreliability in liner services as demonstrated in Figure 4.

Figure 4: Breakdown of Liner schedule inconsistency



The high numbers of container vessels, the unreliability of being on time and having one of the highest average installed auxiliary power means container ships and more specifically liner services potentially pose the biggest risk with regards to congestion incidents and highest volume of CO_2 emissions.

5.1.4 Inland Shipping

Inland shipping is potentially the biggest type of shipping negatively influence by port congestion. The European Sea Ports Organisation (ESPO) identifies the effect of unreliability in liner schedules on inland transport operators. ESPO (2007) acknowledges that inland barge operators have to accept that most terminal operators give priority over barge traffic, making securing a berth for inland operators increasingly difficult as deep-sea reliability decreases. In the past heavy pressure on container terminals has led to longer waiting times for inland shipping (Port of Rotterdam, 2007) and during the peak season of 2004 delays of up to 60 hours at deepsea terminals in Rotterdam and Antwerp for barge and feeder operators were experienced (ESPO, 2007).

5.2 Ports

In the UK alone there are more than 650 ports with granted statutory harbour authority powers, of which 120 are commercially active (House of Commons, 2007). Therefore, within the scope of this report it is not possible to go into specific port details so this is limited to regional and selected larger ports.

Dalsøren *et al,* (2009) identified time in port and number of port calls (Table 13) which shows that European ports calls appear more efficient than other regions with a ratio of time in port to calls of 0.79 compared to all other regions with a number above 1. Whether European ports are more efficient due to their competitive nature or due to higher volumes of short sea shipping (UK short sea traffic accounted for 39% of total container traffic in 2004 (House of Commons, 2007)) and inland shipping constituting a higher number of smaller vessels with shorter loading/unloading periods is unclear.

Table 13: Distribution of Port Calls and Percentage of time in Port

Continent	Time in Port (%)	Port Calls (%)	Ratio Time : Calls
Africa	9.5	6.7	1.42
America	15.1	15.0	1.01
Asia	42.2	37.1	1.14
Europe	30.5	38.7	0.79
Australia	2.7	2.5	1.08

Prior to the global economic downturn terminal operators were witnessing increasing utilization levels (ESPO, 2007). Due to several factors, including increasing trade with China, and the Far East generally, EU ports were struggling to cope with an ever increasing amount of cargo. Many EU seaports were thus either congested or on the point of being congested. According to CLECAT (2006), average traffic in European ports was increasing by 4% a year (7% for containers) for the last 20 years, however they were still not facing the alarming levels of congestion in US, Asian and Russian ports.

Table 14 shows the level of capacity utilisation for selected European reports in 2004 as reported by Drewry Shipping Consultants (2005). While it should be noted that actions by the ports in 2005 prevented a similar period of intense congestion in 2005, and the economic downturn will have reduced utilisation, a port is considered at full capacity when utilisation is above 80% (as there is little scope to deal with peaks). These examples show that ports were in a critical situation with regards to congestion especially when between 2005 and 2011, container traffic was predicted to grow by 7.8% a year and European port capacity by only 4.2% (CLECAT, 2006).

Table 14: Utilisation of North European Deep-Sea Ports in 2004
(*Drewry Shipping Consultants, 2005***)**

Port	Capacity Utilisation
Le Havre	89.6%
Antwerp	92.9%
Rotterdam	92.5%
Bremerhaven	95.5%
Hamburg	93.2%
Southampton	99.3%
Felixstowe	77.1%
Others	41.9%
Total average	86.6%

Predicted future capacity, demand and utilisation levels for containers is detailed in Table 15, predicting full capacity for the North Continent East, Scandinavia and the East Baltic by 2015. These figures will need to be revised due to reflect the reduction in trade caused by the global recession and reduction in demand, which may result in several years of lag until port utilisation levels increase once again.

Table 15: Forecast Container Handling Supply / Demand Balance to 2015 in mTEUs/year
(Ocean Shipping Consultants, (CLECAT, 2006))

		2005	2010	2015
North Continent East	Capacity	12.95	21.70	23.80
	Demand	11.42	17.06	23.63
	Utilisation	***88.2%***	***78.6%***	***99.3%***
North Continent West	Capacity	24.18	45.64	51.14
	Demand	18.52	25.41	32.89
	Utilisation	***76.6%***	***55.7%***	***64.3%***
Scandinavia	Capacity	5.13	6.56	6.51
	Demand	3.63	4.71	5.61
	Utilisation	***70.8%***	***71.9%***	***86.2%***
East Baltic	Capacity	3.13	6.51	8.89
	Demand	2.17	5.04	9.17
	Utilisation	***69.2%***	***77.4%***	***103.2%***

Typically the bigger the hinterland a port serves the higher the possibility a port faces from congestion. Ironically this can also coincide with under utilisation of capacity in other ports (Sanyal, 2006). However, European ports potentially are able to resist port congestion better than ports in other regions due to utilisation of other facilities and logistic chains, but would also require cross port co-operation in order to ensure cargo is shipped to ports with free capacity. As CLECAT (2007) states, “It is of the utmost importance to avoid a concentration of traffic at a few major ports”.

Changing ports and logistic chains is currently a shipper’s choice and not the port’s, for example the UK ports of Felixstowe and Southampton experienced the consequences of port congestion when some ship operators opted to unload cargo in Rotterdam or Antwerp and then fed the freight back to the UK by shipping on smaller vessels through alternative ports (CLECAT, 2006).

Throughput in ports is expected to fall substantially in 2009, offering a temporary respite to the problems of full capacity and port congestion. However this is expected to be only temporary, offering ports an opportunity to plan for the future. This view is supported by the Dutch transport minister Camiel Eurlings who recently told Fairplay (2009) that the recession came just in time to fix Rotterdam’s port connections to the hinterland. Eurlings stated that, “To do nothing whatsoever is a choice as well. If we do that, Rotterdam will be congested totally in 2020”….“Now is the momentum to tackle bottlenecks to be geared up for better times when they come”.

6. SUMMARY AND CONCLUSIONS

Port congestion statistics are not readily available, making an estimate of its contribution to GHG emissions from International shipping at this stage difficult. No relevant studies were identified during the research phase of this report and therefore to gain an in depth insight into the effect of port congestion, European wide port co-operation would be required. However within the scope of this report a number of conclusions can be made.

This paper shows clearly that for ships sailing to congested ports, emissions can increase by more than 10% if the delays extend over several days. However, although data is scarce, we have the impression that in most European ports, if there is congestion, it causes a delay of a couple of days at most for most of the time. If our impression is correct, this would imply that the emissions associated with congestion are less than 5% of total shipping emissions. While this may not be much, it could still be worthwhile to reduce congestion.

Amongst the ship categories included in this study, container ships and LNG vessels have the potential to produce the most GHG emission, if forced to wait at anchor due to port congestion, due to their high average installed auxiliary power. However, relatively low numbers of LNG vessels means container ships and particularly liner services would be expected to contribute the most GHG emissions, due to more frequent port calls by a large number of vessels and their reported unreliability of arriving on time, as well as the high installed power

Port utilisation was increasing year on year prior to the economic downturn with ports in Scandinavia, the East Baltic and North East Continent predicted to be congested again by 2015 (>80% utilisation). While the global economic downturn has provided a period of grace, potentially delaying this predicted date, the problems of port congestion are expected to return.

The diverse European port system offers, both advantages and disadvantages in mitigating port congestion. The competitive nature ensures ports operate efficiently, as alternative ports and logistic chains offer shippers numerous alternatives to shift freight to avoid congestion or a faster route to market. However, further co-operation between ports would be required to ensure spare capacity in European ports is utilised once demand is high in the key larger ports resulting in high utilisation levels.

Avoiding port congestion is key as EU policy is to shift freight onto more efficient modes of transport and with potentially increasing numbers of short sea and inland vessels, the volume of traffic in European ports can only be expect to return to, and surpass the levels seen prior to the downturn, once trade picks up.

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APPENDIX I: DATA TABLE

IMO, 2008			*Dalsøren et al, 2009*	
Category	**Size / Type**	**Ave. Per engine Aux kW**	**Load in Port**	
			Main engines	**AUX**
Bulk	>200,000 dwt **(1)**	794	0%	20%
Bulk	100-199,999 dwt **(2)**	697	0%	20%
Bulk	60-99,999 dwt **(3)**	549	0%	20%
Bulk	35-59,999 dwt **(4)**	533	0%	20%
Bulk	10-34,999 dwt **(5)**	458	0%	20%
Bulk	<9,999 dwt **(6)**	237	0%	20%
Container	>8,000 teu **(1)**	3,081	0%	20%
Container	5-7,999 teu **(2)**	2,433	0%	20%
Container	3-4,999 teu **(3)**	1,782	0%	20%
Container	2-2,999 teu **(4)**	1,359	0%	20%
Container	1-1,999 teu **(5)**	985	0%	20%
Container	<999 teu **(6)**	600	0%	20%
Crude Oil Tanker	>200,000 dwt **(1)**	1,034	0%	40%
Crude Oil Tanker	120-199,999 dwt **(2)**	1,232	0%	40%
Crude Oil Tanker	80-119,999 dwt **(3)**	769	0%	40%
Crude Oil Tanker	60-79,999 dwt **(4)**	731	0%	40%
Crude Oil Tanker	10-59,999 dwt **(5)**	729	0%	40%
Crude Oil Tanker	<9,999 dwt **(6)**	222	0%	40%
Chemical Tanker	>20,000 dwt **(1)**	837	0%	40%
Chemical Tanker	10-19,999 dwt **(2)**	623	0%	40%
Chemical Tanker	5-9,999 dwt **(3)**	416	0%	40%
Chemical Tanker	<4,999 dwt **(4)**	216	0%	40%
LPG Tanker	>50,000 cbm **(1)**	1,004	0%	40%
LPG Tanker	<49,999 cbm **(2)**	436	0%	40%
LNG Tanker	>200,000 cbm **(1)**	3,210	0%	40%
LNG Tanker	<199,999 cbm **(2)**	2,610	0%	40%
General Cargo	>10,000 dwt **(1)**	414	0%	20%
General Cargo	5,000-9,999 dwt **(2)**	235	0%	20%
General Cargo	<4,999 dwt **(3)**	90	0%	20%
General Cargo	>10,000+ dwt, >100 TEU **(4)**	628	0%	20%
General Cargo	5-9,999 dwt, >100 TEU **(5)**	401	0%	20%
General Cargo	<4,999 dwt, >100 TEU **(6)**	249	0%	20%
RoRo	>2,000 lm **(1)**	1293	0%	20%
RoRo	<1,999 lm **(2)**	381	0%	20%

Numbers in Red correspond to size/type categories in Figure 3

Annex H Potential for evasion

1 Introduction

A climate change policy with a limited geographical scope would be susceptible to evasion techniques. The possibility of evasion has often been mentioned, for example, as a major argument against an EU route-based emissions trading system calculating relevant emissions according to commodity 'transport distances' to the EU. Ships could seek to evade such a system by: (i) making an additional (artificial) port call (at an 'evasion port') just outside EU borders; or (ii) by offloading cargo in a port just outside the EU from where it is carried by another ship to the EU (transhipment); or (iii) by ship to ship transfers outside EU sovereign (or jurisdictional) waters (hereinafter 'evasion techniques'). The third option (ship to ship transfers) is excluded from the scope of this paper because this type of evasion is the topic of a separate paper.

Evasion techniques would shorten the transport distance for the relevant commodities and therefore deceive the system for calculating the total relevant emissions related to the transportation of the commodity. Such evasion would only make sense if the costs related to it would be lower than the benefits due to the reduced payments for CO_2 emissions under the given policy scheme.

The principle of evasion is shown at the Figure 1 below.

Figure 1 The principle of evasion

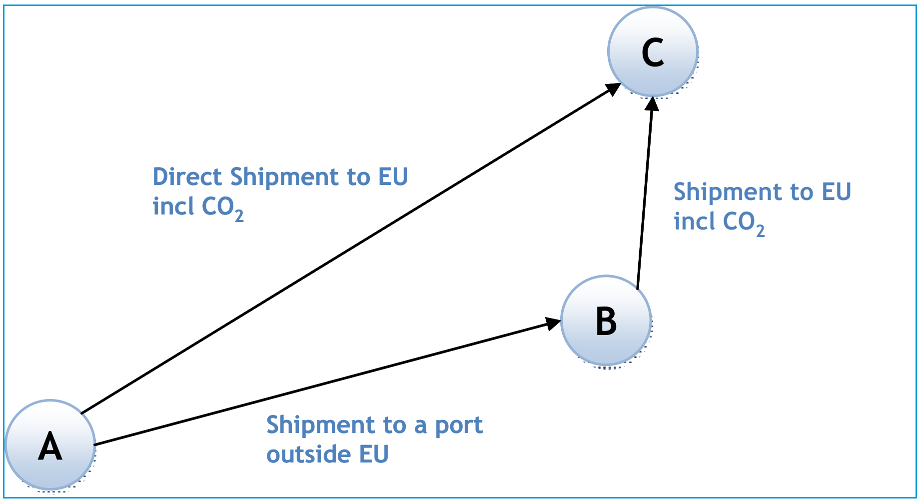


Figure 1 shows port A, B and C. Port A is the origin of the cargo. Port C is a port inside the EU. Port B is a port closer to EU than port A. All import into Port C has to include cost of the CO_2 resulting from a given policy scheme such as for example ETS. Ship operators, while considering a possibility to evade the policy scheme, would compare the costs of a direct freight with the costs of the freight to and from an evasion port. If the costs of a direct freight (including costs of CO_2 emissions along the whole route) are higher than the costs of freight including a visit to an evasion port, the operator will have a financial incentive to engage in this evasion possibility.

Thus the relevant comparison is as follows:

Freight-costs $_{DIRECT}$ + Emission-cost $_{DIRECT}$ ≥ Freight-costs$_{TO\ EVASIONPORT}$ + Freight costs $_{FROM\ EVASIONPORT}$ + Emission-cost $_{FROM\ EVASIONPORT}$.

Assuming that the policy would be route-based, the ship operators might consider making an artificial port call with or without transshipment of their cargo. In chapter 3, both freight costs with and without transshipment will be analyzed.

It is important to note that the freight rate is market dependent, and also who bears the CO_2 cost will be dependent on a market. If the markets are good, the ship operator will quote a freight including the CO_2 cost, trying to 'push' the CO_2 cost over onto the charterer. If the market is not so good, the CO_2 cost will be a matter of discussion in the contract, and if the market is very low it is possible that the ship operator must bear the cost.

We believe that there are certain criteria that make a commodity more exposed than other commodities for evasion. These criteria are discussed below:

- Long Distance Trade – A longer distance from country of origin to EU means more emissions released during the trip. If the sailing distance can be shorten, by for instance stopping at a port closer to EU, and shorten the last leg into EU this would reduce the emission tax.
- Large Volume – A larger volume of the commodity means basically more transportation which with an emission tax means more a total of more costs.
- Commodity Price – the price of the commodity is also an issue. A higher price on a commodity would mean that the transportation time is expected to be shorter; hence an extra stop outside EU would be of less interest.
- Weaker Markets – In weaker markets when margins are low the possibility for evasion is bigger, this is because in a pressed market every penny counts. In good markets on the other hand it is more important to get the commodity as fast as possible to the destination and get a new trip, making the most of the good market.

The rest of the paper is organised as follows. Chapter 2 focuses on geographical scope of evasion. Chapter 3 investigates possibilities for evasion by comparing freight costs including evasion port calls (with and without transhipment) with costs of direct freights according to three different scenarios. Summary and conclusions are given in chapter 4. The overview of commodity imports using maritime shipping is given in Annex A, and legal comments on evasion possibilities are included in Annex B.

2 Geographical scope of evasion

The following ports would be likely to be used as 'evasion ports' because of their geographical proximity to the EU ports and size:

- The largest North African ports: in Egypt (Alexandria, Damietta, Canapus, Mersa Matruh, Port Said, Tennis), Libya (Tripoli, Qasr Ahmed, Ras Lanuf, Bardia, Benghazi), Tunisia (Algeria (Algiers, Oran, and Morocco (Casablanca, Tanger, Nador, Jorf Lasfar).
- Southern European countries not being members of the EU: Croatia (Rijeka, Ploce, Split), Albania (Shen Gjin), Montenegro (Bar, Budva).
- East Mediterranean/Near East: Turkey (Adana, Antalya, Datca, Fethiye, Iskenderun, Marmaris), Syria (Latakie), Lebanon (Tripoli, Sidon, Beirut), Israel (Ashdod, Haifa, Tel Aviv).
- Northern European countries not being members of the EU: Russia[1] (Kaliningrad, Saint-Petersburg, Murmansk).

Many of these ports, especially in Africa, do not currently have sufficient capacity in terms of depth and port infrastructure to accommodate very large ships. Among the North-African ports, only Tanger and Jorf Lasfar in Morocco have a potential to accommodate large Panamax ships. In future, if a CO_2 emission reduction scheme is implemented, we could envisage that some of the existing ports could be rebuilt or expanded, maybe even solely for the purpose of transshipment of goods to avoid the EU CO_2 policy. However, if evasion of this type does not prove to be economically viable, such developments would not be expected.

[1] Norway and Island, being members of the European Economic Area (EEA), would be included within the scope of the policy.

3 Scenarios

For economic analysis, we have selected the following three scenarios to analyze:

1. Coal trade from Australia to Europe. This is a long trade with a relatively low price commodity. We believe the coal import into Europe will increase as more local mines are shut down.
2. Containers shipped from Shanghai to Hamburg. Shipping containers from China to Europe is, and will continue to be, an important segment of the maritime shipping market.
3. Diesel fuel trade from North America into Europe. This is one trade that has started to blossom as the cars in Europe utilize more and more diesel fuel.

These are currently established trades and are expected to be important also in future. They also involve long distances and large quantities.

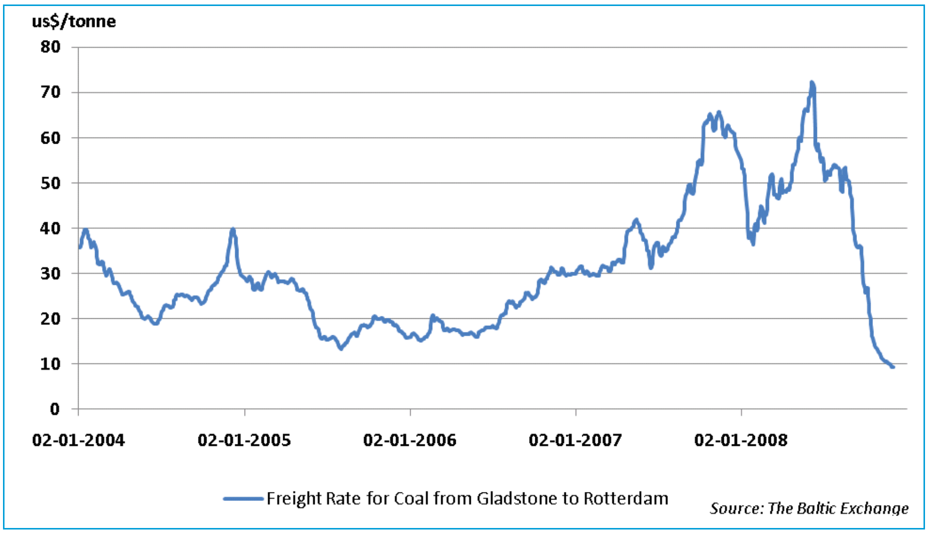
All the scenarios are based on the policy that it is the last port of call before the EU that counts as a starting point for the CO_2 emission fee. In the scenario 1 and 3 we will analyze cost differences in two options: with and without transshipment of cargo. Since there is limited knowledge on how much cargo handling and storage cost are, we will not take these into consideration, but we will focus mainly on the cost arising from the moment the cargo is loaded onboard the vessels until the moment it leaves the vessel (Manifold to manifold or loading belt to grab). Evasion port cost except harbor fee are also excluded, as such records are not available.

3.1 Scenario 1

Coal trade from Australia to Europe in 2006 constituted around 4% of the total global seaborne coal trade and 12% of Australia's export. 70% of the volumes imported to Europe are delivered in the UK or on the northern side of the European continent. This trade generates a lot of tonne-miles and makes a high share of tonnage in the market.

This trade is normally done by Capesize vessels ranging from 176,000 to 180,000 dwt. If we look at the freight market for this type of vessel, it has developed significantly during the recent years. Figure 2 shows freight rates from Gladstone to Rotterdam in the years 2004-2008.

Figure 2 **Freight rates Gladstone-Rotterdam**



This rate is based on the Baltic Exchange data and refers to the following parameters: Gladstone/Rotterdam 150,000 mt 10% coal free in and out and trimmed, 17 m load draft, 45,000 load/25,000 discharge.

The freight rate we will use is calculated from the period 02.01.2004 until 02.12.2008. The average is calculated to be US$ 31.11 per tonne, the lowest is US$ 9.32 per tonne, and the highest is US$ 72.33 per tonne. Doing a voyage calculation we can use the daily time charter equivalent to do the comparison, but first we have to make some assumptions to do the calculations.
The assumptions are:
- Intake 150,000 metric tonnes.
- Heavy Fuel Oil Price US$ 250 per tonne.
- Marine Diesel Oil US$ 400 per tonne.
- Port cost in Rotterdam is US$ 170,000.
- Port cost in Gladstone is US$ 95,000.
- Service speed is 14 knots.
- Heavy Fuel Oil consumption is 60 tonne per day.
- Marine Diesel Oil consumption 0.5 tonne per day.
- Loading Rate 45,000 tonnes per day.
- Discharge Rate 25,000 tonnes per day.
- Canal Dues Suez up and down US$ 327,200.

The total round trip time is:
- At sea: 70.30 days.
- Sea Margin 7.5%: 5.27 days.
- In Port: 9.33 days.
- Extra: 1 day.
- **Total: 85.90 days.**

We have not assumed that there will be any slow steaming in bad market or that this trip goes around Cape of Good Hope.

From the different freight rates, we can calculate a Time Charter Equivalent which shows how much the vessel will earn in US$/day.

We have different freight rates showing almost the last five years, with the market low, average and high. The TC equivalent will then be:

Freight market	TC Equivalent US$ per day	Freight US$ per tonne
Low	-4,218.80	9.32
Average	33,354.20	31.11
High	104,431.00	72.33

The lower limit is reflecting today's market where the ship operator is actually loosing money.

Next, we will calculate the CO_2 emissions and the costs related to it along this route. The vessel will be charged a CO_2 fee on the sailing leg from Gladstone to Rotterdam and the usage of generators in the Port of Rotterdam. From the Buhaug et al. (2008) we have:

Type of Fuel	Tonne CO_2/Tonne Fuel
Marine Diesel Oil (MDO)	3.09
Heavy Fuel Oil (HFO)	3.02

The vessel in this scenario consumes 60 tonnes of HFO per day and 0.5 tonne of MDO per day. The MDO consumption estimation covers usage of MDO in maneuvering in and out of harbor, generator usage in harbor and also some generator usage when sailing. The trip from Gladstone to Rotterdam takes 37.8 days giving us the following equations of the CO_2 emission.

$(\text{Consumption}_{HFO} * CO_2 \text{ factor}_{HFO}) + (\text{Consumption}_{MDO} * CO_2 \text{ factor}_{MDO}) * \text{Travel days} = \text{Total emission of } CO_2$

Which gives the following result: 6,907.76 tonnes CO_2.

Depending on the price of the CO_2, the fee will be:

CO_2 fee US$ per tonne CO_2	CO_2 fee for Gladstone to Rotterdam	CO_2 fee US$ per tonne coal
10	69,077.6	0.46
30	207,232.8	1.38
50	345,388.0	2.3

From this we can see that in a good market the CO_2 fee does not make a large share of the freight costs but now, when the market is poor and ship operator is loosing money this would be a large extra cost. In the following sections, we will analyze costs of evasion related to making an additional port call first with transshipment of cargo and then without transshipment.

3.1.1 Cost comparison in option with transshipment

So far we have calculated the left side of the general evasion equation that would justify evasion from an EU CO_2 tax scheme, as presented in Introduction (the side related to direct freight). It is now time to look at the right-hand side of the equation, related to freight costs including evasion. This is also a more complicated matter since this is outside any regular trade.

First of all we have to establish where port B should be located, and it is clear that it should be as close to the European continent. Since around 70% of the volumes are going to UK or the northern part of the continent, the port should be located around Gibraltar area. The largest port in the area is the Port of Casablanca. At the current moment this port cannot support the size of a Capesize vessel, due to maximum draught restrictions. But we will assume that the Port of Casablanca can receive Capesize vessels, and run the calculations to see if there are any economic reasons for doing this.

We will use the same assumptions as previously, except:
- Distance is 10,597 nm.
- Port Costs in Casablanca is US$ 100,000.
- Discharge Rate in Casablanca is 25,000 tonnes.

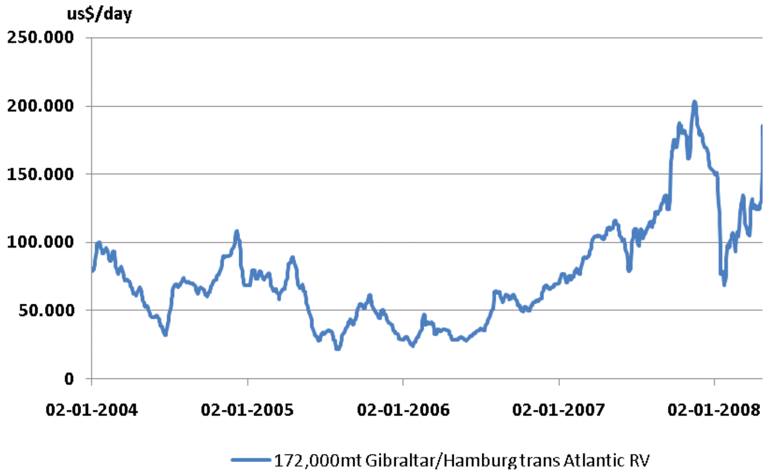
The total round trip time is:
- At sea: 63.08 days.
- Sea Margin 7.5%: 4.73 days.
- In Port: 9.33 days.
- Extra: 1 day.
- **Total: 77.38 days.**

Since this leg is very similar to the Gladstone to Rotterdam route, the same freight market will be used as a benchmark for this route. On the same day and in the same market the TC equivalent would be the same as we calculated before and by doing a reversed voyage calculation we can find the freight for the Gladstone to Casablanca voyage.

Freight Market	TC Equivalent US$ per day	Freight US$ per tonne
Low	-4,218.80	8.27
Average	33,354.20	28.09
High	104,431.00	65.59

Since Casablanca is in the Atlantic Ocean, we are now in the Transatlantic Round Voyage market, this market has developed as we see in Figure 3.

Figure 3 **Freight rates in Transatlantic Round Voyage market**



The calculated average for the period that is ranging from the 02.01.2004 until 02.12.2008, is US$ 80,661 per day, the lowest value is US$ 1,221 per day and the highest is US$ 235,600 per day. These values are given in a TC equivalent format, so it is necessary to do a reversed voyage calculation to get the freight in US$ per tonne.

The assumptions are as before, except:
- Port Cost in Casablanca is US$ 100,000.
- Port Cost in Rotterdam is US$ 170,000.
- Loading rate is 45,000 tonnes per day.
- Discharge rate is 25,000 tonnes per day.
- No Canal costs.

The total round trip time is:
- At sea: 8.45 days.
- Sea Margin 7.5%: 0.63 days.
- In Port: 8.04 days.
- Extra: 1 day.
- **Total: 18.12 days.**

We can then look what this TC equivalent means in US$ per tonne:

Freight Market	TC Equivalent US$ per day	Freight US$ per tonne
Low	1,221	2.93
Average	80,661	13.34
High	235,600	33.65

If we then calculate the CO_2 emissions for the trip from Casablanca to Rotterdam we get 829.66 tonnes of CO_2.

Depending on the price of the CO_2 fee the costs of CO_2 will be:

CO_2 fee US$ per tonne CO_2	CO_2 fee for Casablanca to Rotterdam	CO_2 fee US$ per tonne coal
10	8,296.62	0.06
30	24,889.80	0.17
50	41,483.00	0.28

Summarizing the calculations we find the following:

Table 1 Difference in costs with and without evasion according to the Scenario 1 with transshipment

Market	Low			Average			High		
CO_2 fee	*10*	*30*	*50*	*10*	*30*	*50*	*10*	*30*	*50*
Gladstone-Rotterdam Freight Rate	9.32	9.32	9.32	31.11	31.11	31.11	72.33	72.33	72.33
Gladstone-Rotterdam CO_2 fee	0.46	1.38	2.30	0.46	1.38	2.30	0.46	1.38	2.30
Total cost Gladstone-Rotterdam	9.78	10.70	11.62	31.57	32.49	33.41	72.79	73.71	74.63
Gladstone-Casablanca Freight Rate	8.27	8.27	8.27	28.09	28.09	28.09	65.59	65.59	65.59
Casablanca-Rotterdam Freight Rate	2.93	2.93	2.93	13.34	13.34	13.34	33.65	33.65	33.65
Casablanca-Rotterdam CO_2 fee	0.06	0.17	0.28	0.06	0.17	0.28	0.06	0.17	0.28
Total cost Gladstone-Rotterdam	11.26	11.37	11.48	41.49	41.60	41.71	99.30	99.41	99.52
Difference	-1.48	-0.67	0.14	-9.92	-9.11	-8.30	-26.51	-25.70	-24.89

The unit for Table 1 is in US$ per tonne coal transported. The negative (red) numbers show cases where the costs of freight with evasion are higher than the costs of direct freight without evasion, making evasion unprofitable. As we can see from the table, the only time evasion is economically justified in this scenario is when the freight market is low and the price on CO_2 is high. However we have not included the costs needed to upgrade the port of Casablanca to be able to accommodate Capesize vessels, and these costs would probably be substantial.

3.1.2 Cost comparison in option without transshipment

In this option, the same vessel will just call an additional port on the leg from port A to C, evasion port B. We assume that the time addition from this extra port call is 1 day, and we also have to add the extra harbor cost. The CO_2 fee will of course then be estimated from port C to B.

In the scenario with coal from Gladstone to Rotterdam we have to use the Time Charter equivalent to include the extra port dues and time, and then we will estimate a corrected freight in us$ per tonne coal transported. We then continue by adding the CO_2 fee and then we can compare the result with the direct route between Gladstone and Rotterdam.
The additional assumptions are:
– Port Cost in Casablanca is US$ 100,000.
– 1 extra day to the total voyage duration.

This gives the following freight rate in US$ per tonne:

TC Equivalent US$ per day	Freight US$ per tonne
-4,218.80	9.97
33,354.20	32.01
104,431.00	73.71

We already have the CO_2 calculated for the leg Casablanca to Rotterdam from the transshipment part:

CO_2 fee US$ per Tonne CO_2	CO_2 fee for Casablanca to Rotterdam	CO_2 fee US$ per tonne coal
10	8,296.62	0.06
30	24,889.80	0.17
50	41,483.00	0.28

Comparing these numbers with the direct shipment from Gladstone to Rotterdam we get the following (Table 2).

Table 2 **Difference in costs with and without evasion according to the Scenario 1 without transshipment**

Market	Low			Average			High		
CO_2 fee	*10*	*30*	*50*	*10*	*30*	*50*	*10*	*30*	*50*
Gladstone-Rotterdam Freight Rate	9.32	9.32	9.32	31.11	31.11	31.11	72.33	72.33	72.33
Gladstone-Rotterdam CO_2 fee	0.46	1.38	2.30	0.46	1.38	2.30	0.46	1.38	2.30
Total cost Gladstone-Rotterdam	9.78	10.70	11.62	31.57	32.49	33.41	72.79	73.71	74.63
Gladstone-Casablanca-Rotterdam Freight Rate	9.97	9.97	9.97	32.01	32.01	32.01	73.71	73.71	73.71
Casablanca-Rotterdam CO_2 fee	0.06	0.17	0.28	0.06	0.17	0.28	0.06	0.17	0.28
Total cost Gladstone-Rotterdam	10.03	10.14	10.25	32.07	32.18	32.29	73.77	73.88	73.99
Difference	-0.25	0.56	1.37	-0.50	0.31	1.12	-0.98	-0.17	0.64

With this kind of operation it is clear that especially with higher CO_2 fee the risk of evasion will be quite high. In a low market with high CO_2 fee the estimated profit will be around 12% by calling one extra port, and in a pressured market this is a lot. We will therefore conclude that there is a big risk for evasion for this scenario.

3.2 Scenario 2

In the second scenario, we will consider containers shipped from Shanghai to Hamburg. This is a long distance and container vessels burn much more fuel than Capesize vessels, which could mean that this type of freight would be more susceptible to evasion.

To find the true shipping cost for a container is difficult, the freight rates given are often including different service fees and adjustment factors. The United States Department of Agriculture presents the formula for calculating ocean freight on a per-container basis:

Container Rate = container rate + (container rate x CAF) + THC + BAF + ARB

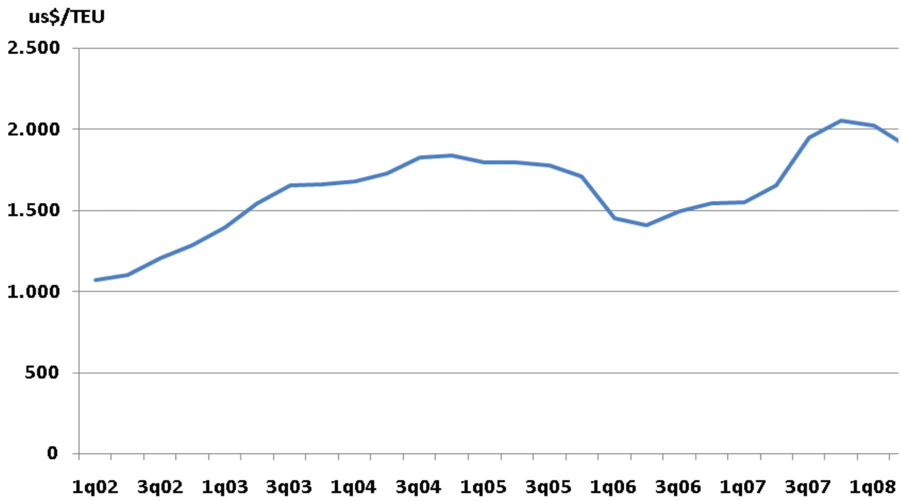
Where:
CAF = Currency Adjustment Factor (in %).
THC = Terminal Handling Charge.
BAF = Bunker Adjustment Factor.
ARB = Arbitrary Charge.

Unfortunately we do not posses any historical or current values for these factors, we very also not able to find this through our sources, so we will calculate this scenario in a different manner.
We will use the Far East to Europe (AE 20) route for this scenario. This is around 26 days trip by Maersk time table or 10,826 nm. The type of vessel we will use for this scenario is a vessel that is normally used in this trade with a capacity of 6,170 TEU with containers on 14 tonne homogeneous cargo, a

service speed on 25.2 knots and a total installed power on 65,880 kW or 89,570 hp.

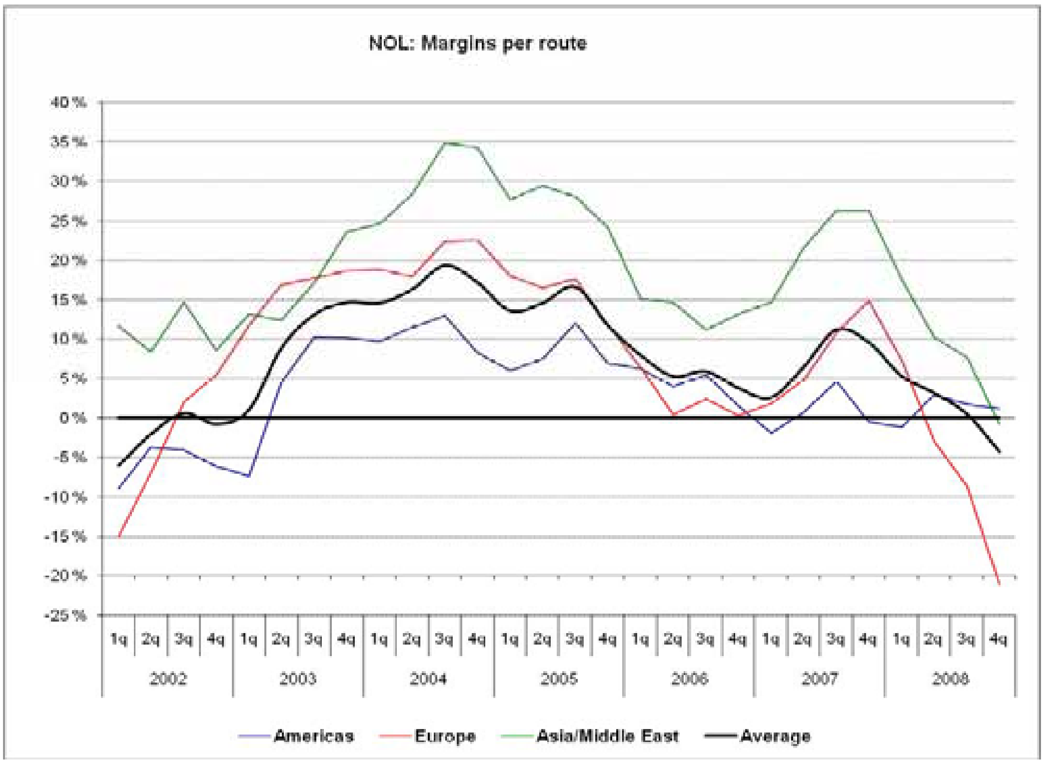
The freight market for this trip is taken from Container International database and is shown in Figure 4.

Figure 4 Freight rates for container vessels for the route from Far East to Europe, 2002-2008



The average over the period is US$ 1,382 per TEU, the lowest is US$ 912 TEU and the highest rate is US$ 1,746 per TEU. But these rates include the variables discussed earlier, meaning that we are not able to get a clear picture of what the true shipping cost for one container is. We will therefore look at the numbers presented by Neptune Oriental Line (NOL) in their quarterly results reports on margins and earnings – see Figure 5.

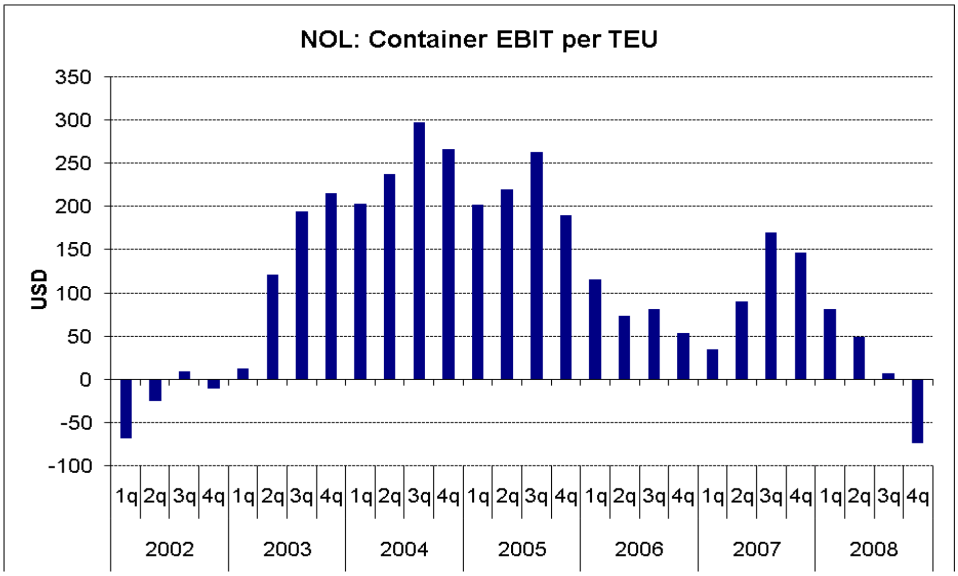
Figure 5 **NOL quarterly margins per route**



Source: NOL Quarterly reports and Fearnley Fonds.

Figure 5 shows an overview of the average margins NOL has on transporting containers to America, Europe and Middle East and intra Asia trade. The focus here is on the European margin and its correlation with the average margin. It is not a 100 percent match but with a correlation factor on 90 percent it is pretty close. Therefore we assume that the average numbers for earnings and volumes will be representative for the Asia to Europe trade. One other thing NOL reveals in its report is the average Earnings Before Interest and Tax (EBIT – see Figure 6) and average volumes, and still assuming that average values are representative we can estimate the EBIT for one container.

Figure 6 NOL container EBIT per TEU, 2002-2008



The reason for using EBIT is that the CO_2 tax will directly affect the EBIT. The historical highest earning per TEU was US$ 297, the lowest was US$ -73 and an average was US$ 112.7 for the period from the beginning of 2002 until the end of 2008.

EBIT level	Earnings US$ per TEU
Low	-73
Average	112.7
High	297

For estimation of the consumption and emission of CO_2 we use the numbers from the engine manufacture, which state that this type of engine burns about 170 grams per kilowatt hour. The total installed power, MCR is 65,880 kW and for service speed around 85% for of the MCR is used. The calculation for the consumption of HFO is then:

Installed power x MRC x Fuel Consumption x Hours x $\frac{1}{1000000}$ = Fuel Consumption per Day

$$65{,}880 \text{ kW} \times 85\% \times 170 \frac{g}{kWh} \times 24\text{h} \times \frac{1 tonne}{1{,}000{,}000 g} = \underline{228 \text{ tonne per day}}$$

There will also be consumption of MDO which amounts to 2 tonne per day. As mentioned before the trip from Shanghai to Rotterdam takes about 26 days, this gives us the estimated total emission of CO_2 for this trip in the amount of 18,063 tonnes.

Depending on the price of the CO_2, the fee will be:

CO_2 fee US$ per Tonne CO_2	CO_2 fee for Shanghai to Hamburg	CO_2 fee US$ per TEU
10	180,632.4	29.27
30	541,897.2	87.83
50	903,162	146.38

We can now combine the earnings in the different market levels with the CO_2 fee and look at what is then left of the EBIT (see Table 3).

Table 3 Impact of CO_2 fees on EBIT

Market in us$ per TEU	Low			Average			High		
CO_2 fee	*10*	*30*	*50*	*10*	*30*	*50*	*10*	*30*	*50*
Shanghai-Hamburg EBIT per TEU	-73	-73	-73	112.7	112.7	112.7	297	297	297
Shanghai-Hamburg CO_2 fee	-29.3	-87.8	-146.4	-29.3	-87.8	-146.4	-29.3	-87.8	-146.4
EBIT Shanghai-Hamburg with CO_2 fee	-102.3	-160.8	-219.4	83.4	24.9	-33.7	267.7	209.2	150.6

It is clear that the CO_2 fee will have a great impact on the container company's earnings per TEU, and it is very dependent on the CO_2 fee price.

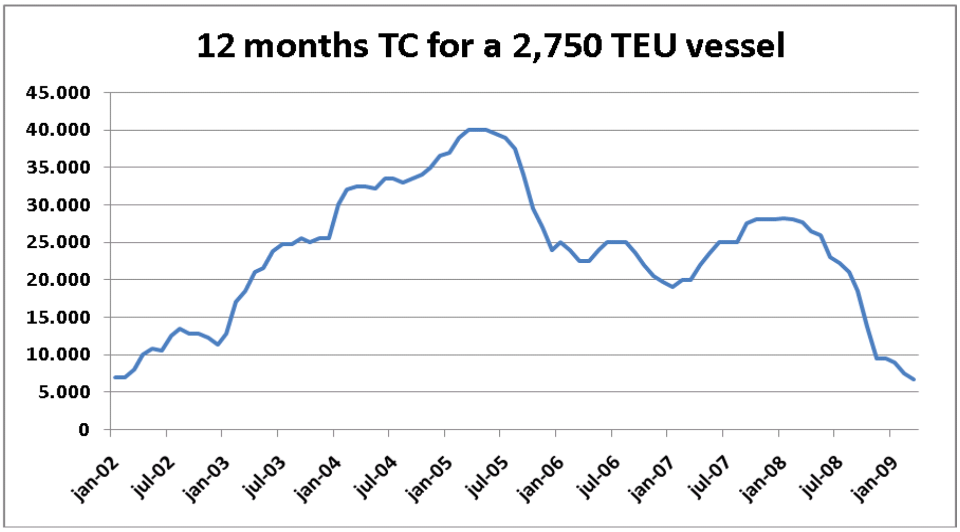
Until now we have established what a container vessel earns per TEU and the estimated CO_2 fee they will be charged per TEU transported. Now we will look at the costs related to the transport between an evasion-port and Hamburg. We have four candidates for evasion ports:
- Reykjavik, Iceland, 1,232 nm from Hamburg.
- Kaliningrad, Russia, 940 nm from Hamburg (473 nm if the Kiel canal can be used).
- St. Petersburg, Russia, 1,347 nm from Hamburg.
- Casablanca, Morocco, 1,676 nm from Hamburg.

As Kaliningrad is a very shallow port with draught restrictions at a maximum of 9.4 meters it is not possible that it would be used as a port for our scenario ship, which has typically a draft of around 14 meters. The shortest distance-wise is then Reykjavik on Iceland, which is not a member of the EU and therefore a possible evasion port. We will first establish the shipping cost for a container service between Reykjavik and Hamburg. The assumptions are:
- All infrastructure is present and there are no operation limitations in Reykjavik for these vessels.
- Vessels used to serve this route are two vessels with a capacity of 2,750 TEU per vessels, total capacity of 5,500 TEU. These two vessels will have an operation program that will meet the schedule and volume from Shanghai to Reykjavik.
- The cost estimation is based on round voyages from Reykjavik to Hamburg.
- The freight rate for these vessels is based on 12 months Time Charter rates.
- Distance is 1,323 nm.

- Installed power is 21,735 kW, service power is 19,560 kW.
- Specific fuel consumption is 171 g/kWh, giving a daily consumption on 80 tonne.
- MDO consumption is 0.5 tonne per day.
- Harbor cost in Hamburg and Reykjavik is estimated to be a total of US$ 20,000.
- Lifting rate in Reykjavik and Hamburg is 50 TEUs per hour.

The freight rate is based on a 12 months' Time Charter contract. This is a hire that has to be paid to the ship-owner. Development of the market freight rate is shown in Figure 7.

Figure 7 Freight rate for the route Reykjavik-Hamburg



The highest rate level was at US$ 40,000, the lowest was US$ 6,700 and the average was US$ 23,740.

The total round trip time is:
- At sea: 4.67 days.
- Sea Margin 7.5%: 0.35 days.
- In Port: 4.58 days.
- Extra: 1 day.
- **Total: 10.6 days.**

From all these assumptions we can now do a shipping cost analysis, which will reflect the shipping cost of operating two vessels from Reykjavik to Hamburg to distribute the containers from the 6,150 TEU vessels.

Freight Market	Total cost for a Round Voyage	US$ per TEU
Low	258,327	47
Average	292,372	53
High	324,877	59

The CO_2 emission for one 2,750 TEU vessel using 80 tonnes of HFO and 0.5 tonnes of MDO can be calculated at the level of 1,288 tonnes.

For the two vessels we will therefore get the following estimated costs of CO_2 fees:

CO_2 fee US$ per Tonne CO_2	CO_2 fee for Reykjavik to Hamburg	CO_2 fee US$ per TEU
10	25,774	4.2
30	77,322	12.6
50	128,870	21

Combining the freight with the CO_2 fee we will get the total picture of the shipping cost from Reykjavik to Hamburg.

Market	Low			Average			High		
CO_2 fee	*10*	*30*	*50*	*10*	*30*	*50*	*10*	*30*	*50*
Reykjavik- Hamburg Shipping Cost per TEU	47	47	47	53	53	53	59	59	59
Reykjavik-Hamburg CO_2 fee per TEU	4.2	12.6	21	4.2	12.6	21	4.2	12.6	21
Total Shipping Cost from Reykjavik-Hamburg per TEU	51.2	59.6	68	57.2	65.6	74	63.2	71.6	80

Table 4 gives comparison of the EBIT for the Shanghai-Reykjavik-Hamburg trip including CO_2 fee with the EBIT for direct container transportation between Shanghai and Hamburg.

Table 4 Comparison of EBIT rates with and without evasion in Scenario 2

Market	Low			Average			High		
CO_2 fee	10	30	50	10	30	50	10	30	50
EBIT Asia-Europe	-73	-73	-73	112.7	112.7	112.7	297	297	297
Total Shipping Cost from Reykjavik-Hamburg per TEU	-51.2	-59.6	-68	-57.2	-65.6	-74	-63.2	-71.6	-80
EBIT per TEU Shanghai-Reykjavik-Hamburg (with evasion)	-124.2	-132.6	-141	55.5	47.1	38.7	233.8	225.4	217
EBIT per TEU Shanghai-Hamburg with CO_2 fee (without evasion)	-102.3	-160.8	-219.4	83.4	24.9	-33.7	267.7	209.2	150.6
Difference	21.9	28.2	78.4	27.9	22.2	72.4	-33.9	16.2	66,4

Table 4 shows that the Shanghai-Hamburg route is much more susceptible to evasion due to CO_2 fees than the route analyzed in the first scenario. This is very understandable because of much long voyage. Calculating an average over the market and CO_2 fee level it is also apparent that the Shanghai-Reykjavik-Hamburg trip has an almost twice as high earning at US$ 46.67 as the Shanghai-Hamburg at US$ 24.4. But there are a lot of costs in the Reykjavik-Hamburg leg that are not included, namely handling cost, insurance, infrastructure cost, etc. This means that it is not so obvious if evasion through this port is profitable.

The conclusion to the second scenario is such that evasion in the container market with long hauls into EU could happen. According to our estimates such evasion is economically reasonable, however our estimates are based on some assumptions that do not show the total cost picture and therefore it is hard to make a definite conclusion.

For this scenario we do not have any estimates of costs of evasion without transshipment.

3.3 Scenario 3

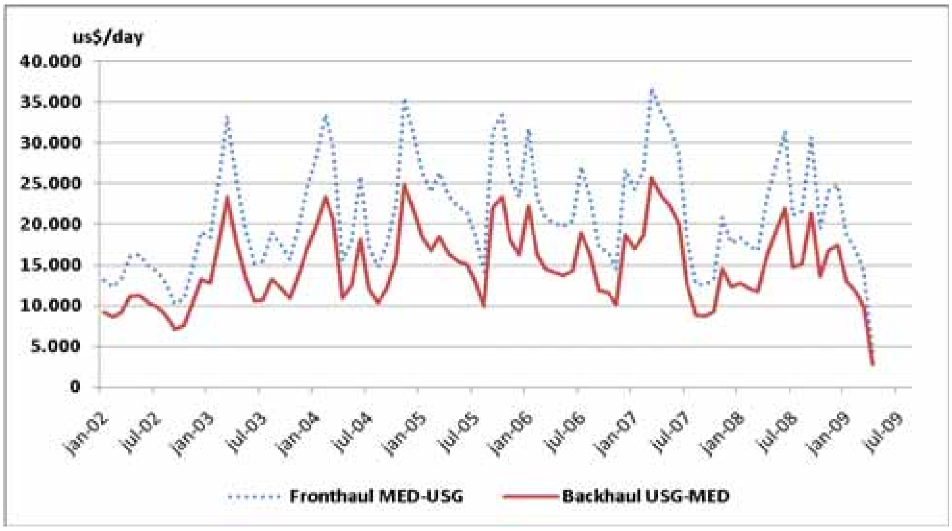
The trade chosen for the scenario 3 is shipping diesel fuel from Houston in the United States to Piraeus in Greece. With an increasing fleet of diesel cars, the European refineries have not been able to meet the demand for diesel fuel in Europe. What we can observe in the last years is that the product carriers who used to transport gasoline to the US before are now returning with diesel to the European market. As it looks now this might be a continuing trade for the future.

This trade is normally preformed by MR oil tankers or product vessels ranging from 30,000 to 55,000 dwt. We will use a state of the art MR tanker with the dwt of 47,128 tonnes and a cargo capacity of 46,500 tonnes of diesel. In the following sections, first we will analyze evasion potential for making an additional port call including transshipment, and then we will analyze evasion potential for a port call without transshipment.

3.3.1 Cost comparison in option with transshipment

The evasion port is chosen to be Marsa El Haiga port in Libya, which would be relatively close to the final destination. Since this route originally is a backhaul trade and the freight rates quotation are always given on fronthaul leg, we have to assume that the level for the US gulf to Mediterranean Sea trip is 70% lower than the front haul trip from the Mediterranean to the US gulf. This is changing, however, these days, as more volumes of diesel are transported from the US to Europe but for historical reasons we have to add a discount in the rate. The time charter equivalent rate has been the following – see Figure 8.

Figure 8 Freight rates from Mediterranean to the US gulf



Based on this data, the USG-Med route has a maximum value on US$ 25,704 per day, an average value of US$ 14,834 and a minimum value on US$ 2,831 per day.

Additional assumptions are:
- The distance from Houston to Piraeus is 6,279 nm.
- Loading/discharge rate is 23,250 tonne/hour.
- Speed is 14.5 knot.
- Costs are based on manifold to manifold and do not include any terminal expenses.
- Port costs are at a total of US$ 50,000.
- HFO consumption is 33 tonne per day.
- HFO costs are US$ 250 per tonne.
- MDO costs are US$ 400 per tonne.

The voyage time will then be:
- At sea: 18.04 days.
- Sea Margin 7.5%: 1.35 days.
- In Port: 4.0 days.
- Extra: 1 day.
- **Total: 24.39 days.**

With these assumptions and information we can now perform transportation cost analysis and find the freight in US$ per tonne diesel transported:

Freight Market	TC Equivalent US$ per day	Gross Freight	Freight US$ per tonne
Low	2,831	291,246	6.26
Average	14,834	591,584	12.72
High	25,704	863,571.8	18.57

Next, we will calculate the CO_2 emissions and the costs related to it along this route. The vessel will be charged a CO_2 fee on the sailing leg from Houston to Piraeus and the usage of generators in the Port of Piraeus.
In this scenario, the vessel consumes 33 tonnes of HFO per day and 0.5 tonne of MDO per day. The MDO consumption estimation covers usage of MDO in maneuvering in and out of harbor, generator usage in harbor and also some generator usage when sailing. The trip from Houston to Piraeus takes 19.4 days which results in calculation of CO_2 emission at the level of 1,963.38 tonnes (emission factors are the same as in the scenario 1).

Depending on the price of the CO_2, the fee will be:

CO_2 fee US$ per tonne CO_2	CO_2 fee for Houston to Piraeus	CO_2 fee US$ per tonne diesel
10	19,633.8	0.42
30	58,901.4	1.27
50	98,169.0	2.11

Under the EU trading scheme this route will have a total cost per tonne diesel shipped as follows – see Table 5:

Table 5 Impact of CO_2 costs on freight costs from Houston to Piraeus

Market	Low			Average			High		
CO_2 fee	*10*	*30*	*50*	*10*	*30*	*50*	*10*	*30*	*50*
Houston- Piraeus freight cost	6.26	6.26	6.26	12.72	12.72	12.72	18.54	18.54	18.54
Houston- Piraeus CO_2 fee per Tonne	0.42	1.27	2.11	0.42	1.27	2.11	0.42	1.27	2.11
Total Shipping Cost from Houston- Piraeus	6.68	7.53	8.37	13.14	13.99	14.83	18.96	19.81	20.65

If we then look at the cost for shipping this diesel trough the evasion port into the EU, we can calculate the shipping cost for the first leg on the voyage between Houston and Marsa El Hariga. First, the assumptions:
- The distance from Houston to Marsa is 6,307 nm.
- Loading/discharge rate is 23,250 tonne/hour.
- Speed is 14.5 knot.
- Costs are based on manifold to manifold and do not include any terminal expenses, meaning that we will not look into terminal and storage cost in the evasion port.
- Port costs are at US$ 40,000.
- HFO consumption is 33 tonne per day.
- HFO costs are US$ 250 per tonne.
- MDO costs are US$ 400 per tonne.
- The Time Charter maximum, average and minimum will be the same as for Houston to Piraeus, as the freight levels are quoted as a Med to US Gulf trip.

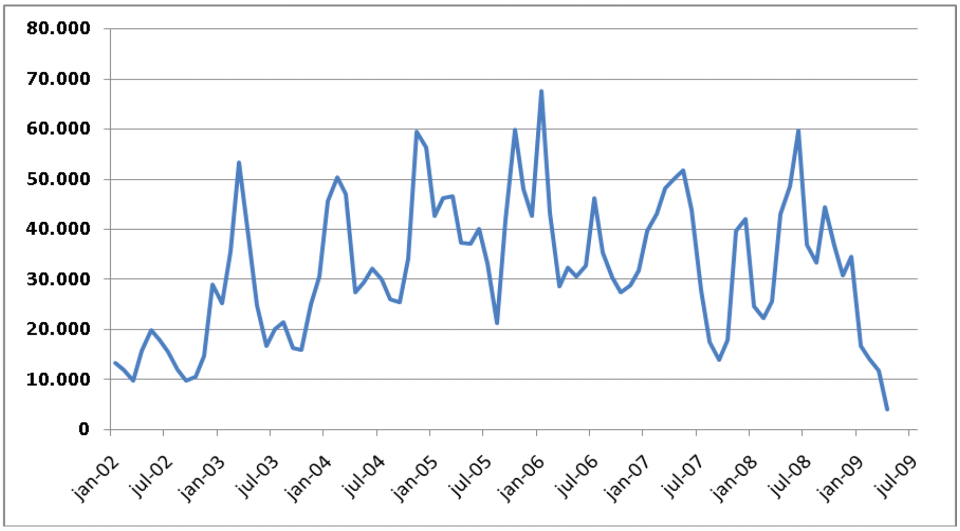
The voyage time will then be:
- At sea: 18.12 days.
- Sea Margin 7.5%: 1.36 days.
- In Port: 4.0 days.
- Extra: 1 day.
- **Total: 24.48 days**.

With these assumptions and information we can now perform transportation cost analysis and find the freight in US$ per tonne diesel transported:

Freight Market	TC Equivalent US$ per day	Gross Freight	Freight US$ per tonne
Low	2,831	281,991	6.06
Average	14,834	583,393	12.55
High	25,704	856,345	18.41

Looking at the second leg of the voyage between Marsa El Hariga and Piraeus we keep the same assumption as on the first leg. The Mediterranean market is however different from the Med-USG market – the freight rates are depicted in Figure 9.

Figure 9 Freight rates in the Mediterranean Sea



Thus, Cross Mediterranean route has a maximum value on US$ 67,534 per day, an average value of US$ 32,002, and a minimum value on US$ 3,981 per day.

The voyage time is:
- At sea: 1.04 days.
- Sea Margin: 2.5%: 0.03 days.
- In Port: 4.0 days.
- Extra: 1 day.
- **Total: 6.07 days.**

With these assumptions and information we can now calculate the freight costs in US$ per tonne of diesel fuel transported:

Freight Market	TC Equivalent US$ per day	Gross Freight	Freight US$ per tonne
Low	3,981	76,501	1.65
Average	32,002	250,841	5.39
High	67,534	471,914	10.15

If we then calculate the CO_2 emissions for the trip from Marsa El Hariga to Piraeus we get 108.30 tonnes.

Depending on the price of the CO_2 fee will be:

CO_2 fee US$ per Tonne CO_2	CO_2 fee for Casablanca to Rotterdam	CO_2 fee US$ per tonne coal
10	1,083.0	0.02
30	3,249.0	0.07
50	5,415.0	0.12

Summarizing the calculations we find the following comparison of costs with and without evasion - see Table 6.

Table 6 Difference in costs with and without evasion according to the Scenario 3 with transshipment

Market	Low			Average			High		
CO_2 fee	*10*	*30*	*50*	*10*	*30*	*50*	*10*	*30*	*50*
Houston-Piraeus Freight Rate	6.26	6.26	6.26	12.72	12.72	12.72	18.54	18.54	18.54
Houston-Piraeus CO_2 fee	0.42	1.27	2.11	0.42	1.27	2.11	0.42	1.27	2.11
Total cost Houston-Piraeus	6.68	7.53	8.37	13.14	13.99	14.83	18.96	19.81	20.65
Houston-Marsa El Hariga Freight Rate	6.06	6.06	6.06	12.55	12.55	12.55	18.41	18.41	18.41
Marsa El Hariga-Piraeus Freight Rate	1.65	1.65	1.65	5.39	5.39	5.39	10.15	10.15	10.15
Marsa El Hariga-Piraeus CO_2 fee	0.02	0.07	0.12	0.02	0.07	0.12	0.02	0.07	0.12
Total cost Houston-Marsa El Hariga-Piraeus	7.73	7.78	7.83	17.96	18.01	18.06	28.58	28.63	28.68
Difference	-1.05	-0.25	0.54	-4.82	-4.02	-3.23	-9.62	-8.82	-8.03

The same as in the scenario 1, it is only in a situation of a low market that for high CO_2 price we find the economic profit from evasion. But also in this scenario we have ignored some costs at the evasion port to simplify the estimation. Therefore, we cannot conclude that there will be no evasion but at least with the parameters we used it is highly unlikely.

3.3.2 Cost comparison in option without transshipment

In this option, the vessel will just call at an additional port on the leg from port A to C, with evasion in port B. We assume the additional time for this extra port call of 1 day, and we also have to add the extra harbor cost. The CO_2 fee will of course then be estimated from port C to B.

In this case with diesel from Houston to Piraeus we would have to use the Time Charter equivalent to include the extra port dues and time and then estimate a corrected freight in US$ per tonne diesel transported. We would also have to adjust for the extra distance this will add to the trip. We then continue by adding the CO_2 fee and then we can compare the result with the direct route between Houston and Piraeus.

The additional assumptions are:
- The distance from Houston to Piraeus to Marsa El Hariga is 6,669 nm.
- Port Cost in Marsa El Hariga is US$ 20,000.
- 1 extra day to the total voyage duration.

We have calculated the following freight rate in US$ per tonne:

Freight Market	TC Equivalent US$ per day	Gross Freight	Freight US$ per tonne
Low	2,831	325,828	7.01
Average	14,834	641,512	13.79
High	25,704	927,397	19.94

We already have the CO_2 calculated for the leg Marsa to Piraeus from the transshipment section:

CO_2 fee US$ per Tonne CO_2	CO_2 fee for Casablanca to Rotterdam	CO_2 fee US$ per tonne coal
10	1,083.0	0.02
30	3,249.0	0.07
50	5,415.0	0.12

Comparing these numbers with the direct shipment from Houston to Piraeus we get the following – see Table 7.

Table 7 Difference in costs with and without evasion according to the Scenario 3 without transshipment

Market	Low			Average			High		
CO_2 fee	*10*	*30*	*50*	*10*	*30*	*50*	*10*	*30*	*50*
Houston-Piraeus Freight Rate	6.26	6.26	6.26	12.72	12.72	12.72	18.54	18.54	18.54
Houston-Piraeus CO_2 fee	0.42	1.27	2.11	0.42	1.27	2.11	0.42	1.27	2.11
Total cost Houston-Piraeus	6.68	7.53	8.37	13.14	13.99	14.83	18.96	19.81	20.65
Houston-Marsa El Harita-Piraeus Freight Rate	7.01	7.01	7.01	13.79	13.79	13.79	19.94	19.94	19.94
Houston-Marsa El Harita-Piraeus CO_2 fee	0.02	0.07	0.12	0.02	0.07	0.12	0.02	0.07	0.12
Total cost Houston-Marsa El Harita-Piraeus	7.03	7.08	7.13	13.81	13.86	13.91	19.96	20.01	20.06
Difference	-0.35	0.45	1.24	-0.67	0.13	0.92	-1.00	-0.20	0.59

With this kind of operation it is clear that higher CO_2 fee implies higher risk of evasion. In a low market with high CO_2 fee the estimated profit would be around 15% by calling one extra port and in a pressured market this is a lot. We will therefore conclude that there is a big risk for evasion for this scenario.

4 Conclusions

Based on the analysis of the three selected scenarios described above, we can draw the following conclusions regarding the potential for evading the CO_2 emission reduction scheme for maritime ships:

- If 'port call' is defined so that no transshipment of cargo is necessary, potential for evasion is quite high, as the costs savings related to lower CO_2 fees are not counterbalanced with substantial costs related to such an additional port call. Therefore, the geographical scope of the policy scheme should be formulated in such a way as to exclude the possibility of evasion just by stopping by at an evasion port without transshipment.
- In options where a 'port call' is defined so that transshipment is necessary, the potential for evasion from an economic point of view would be very limited. However, based on our examples, some risk of evasive behavior can be observed in a situation of low market and high CO_2 fee. This risk is not very high, especially that in our scenarios not all costs related to additional port calls have been taken into account because of lack of data. In addition, in some non-EU ports, significant investments would have to be made before these ports could accommodate a potentially increasing demand for port calls related to ships involved in evasion operations.
- Potential for evasion on the basis of cost differences between direct freight and the freight including evasion ports would be relatively higher for longer routes than for shorter routes.
- Based on low profitability of evasion of the CO_2 reduction policy, we do not envisage investments in non-EU ports aimed specifically at accommodation of a higher number of ships calling at these ports due to evasion.

One can think of options of drafting the policy so as to prevent evasion. One of them would be to draft a route-based scheme in such a way as to include the entire journey of the vessel from the load port of the first cargo loaded onboard the vessel to be discharged in the EU port, rather than focusing on the emissions of the vessel from the last port of call to its EU port destination. However, the problem arises where there are multiple cargo onboard the vessel and it these circumstances it is neither easy not straightforward to establish the proportions in which each bill of lading holder should pay for the EU emissions charge. Further discussion of legal options to prevent evasion and their difficulties is provided in Annex B.

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Annex A Overview of commodity imports to the EU

A.1 Introduction

The analysis provided below describes the import of commodities to the European Union by their primary mode of travel, Liquid Bulk, Dry Bulk or Neo-Bulk. These modes are defined as follows:

- **Liquid Bulk:** commodities that are shipped in a liquefied state, by vessels designed to handle liquids. These include commodities such as Liquefied Natural Gas (LNG) and Animal and Vegetable Oils. Despite the fact that certain liquefied products, such as Liquefied Natural Gas (LNG), are highly specialised and move in ships that handle LNG exclusively, it is classified as moving in liquid bulk vessels because it is a liquid and must be handled as such at ports. Liquefied Petroleum Gas is included in Natural Gas data, which is classified as moving in liquid bulk vessels.
- **Dry Bulk:** commodities that are dry do not require specialised handling at ports, thus enabling homogeneous handling. These commodities move relatively unprocessed and are typically of high volume and lower value. Dry bulk includes commodities such as grain and coal
- **Neo-bulk (specialised):** commodities that the consultants classify as commodities requiring specialised shipping and handling at ports and including items such as motor vehicles and refrigerated commodities and/or goods. The vessels used to transport neo-bulk commodities are often designed to accommodate specific commodities, although commodities in the neo-bulk category vary in the degree of specialization required[2]. The data in this section of the Report accordingly covers all shipping in the above classification.

The numbers in this report are from the *Legal and Economic Analysis of Tramp Maritime Service* done by Fearnley Consultants, Global Insight, Holman Fenwick & Willan in 2007 for the European Commission. This report on the other hand did not include container trade, which has now been added.
This analysis details the import numbers to EU in 1995 and 2005, establishing both the commodity volume and the area from the commodity originates. Vessel sizes used by commodity will be included in a table found at the end of the demand section of this Report.

A.2 Methodology

All the trade data in the demand section below is provided by the consultants' own data systems and it is in metric tonnes by mode. Thus, all reference of growth in imports or exports is based on growth in tonnage. For example, discussion of natural gas trade is based on the consultants' data for liquid bulk metric tonnes of natural gas.

2 Global Insight data for Neo-bulk traffic includes travel on General Cargo vessels.

A.3 Liquid bulk demand analysis[3]

A.3.1 Clean Petroleum Products (CPP): Gasoline

Inbound EU-25

Table 8 illustrates Africa's dominance as a supplier of motor gasoline to the EU. Africa is clearly the largest supplier in both 1995 and 2005, despite strong growth from the Middle East, and Asia.

Table 8 **Gasoline Tonnage Inbound to the EU-25**

	1995	2005
Africa	370,000	1,153,000
Japan	2,000	0
Middle East	0	271,000
Mediterranean	0	31,000
North America	14,000	172,000
Other Asia	32,000	206,000
South America	43,000	38,000

A.3.2 Clean Petroleum Products (CPP): Naphtha

EU Inbound

Table 9 illustrates Africa's dominance as a supplier of Naphtha to the EU. Africa is clearly the largest supplier in both 1995 and 2005, despite strong growth from the Mediterranean.

Table 9 **Naphtha Tonnage Inbound to the EU-25**

	1995	2005
Africa	7,387,000	5,004,000
Japan	22,000	16,000
Middle East	1,641,000	862,000
Mediterranean	90,000	307,000
North America	330,000	328,000
Other Asia	428,000	1,000
South America	370,000	67,000

A.3.3 Clean Petroleum Products (CPP): Kerosene Jet Fuel

EU Inbound

Table 10 illustrates Asia and North America's dominance as a supplier of kerosene jet fuel to the EU. Supplies are no longer dominated by Africa but are dominated by the Middle East with significant tonnage coming from South America, North America and Asia.

3 Because this data did not come from the Global Insight World Trade Service, forecasts are not available. The IEA data may also capture pipeline tonnage.

Table 10 **Kerosene Jet Fuel Tonnage Inbound to the EU-25**

	1995	2005
Africa	649,000	942,000
Middle East	213,000	7,455,000
North America	0	1,158,000
Other Asia	0	1,088,000
South America	113,000	1,280,000
Norway	259,000	131,000

A.3.4 Dirty Petroleum Product: Crude Oil

EU Inbound

Table 11 illustrates Africa's dominance as a supplier of crude oil to the EU. Africa is clearly the largest supplier in both 1995 and 2005, despite strong growth from North America.

Table 11 **Crude Oil Tonnage Inbound to the EU-25**

	1995	2005
Africa	236,029,865	221,370,985
Australia	78,948	9,527
Mediterranean	10,046,366	6,078,894
Middle East	48,295,666	51,541,609
North America	551,254	12,689,707
Other Asia	42,098	33,293
South America	10,977,131	13,066,152

A.3.5 Dirty Petroleum Product: Fuel Oil

EU Inbound

Table 12 illustrates Africa's dominance as a supplier of fuel oil to the EU. Africa has gained market shares over the last five years at the expense of South and North America.

Table 12 **Fuel Oil Tonnage Inbound to the EU-25**

	1995	2005
Africa	4,743,000	2,722,000
Japan	78,000	0
Middle East	810,000	245,000
Mediterranean	354,000	30,000
North America	1,781,000	308,000
Other Asia	878,000	15,000
South America	3,784,000	536,000

A.3.6 Dirty Petroleum Product: Gas & Diesel Oil

EU Inbound

Table 13 illustrates Asia and North America's dominance as a supplier of gas and diesel oil to the EU. Africa lost market shares between 1995 and 2005 while Asia and North America gained share. Norway is also a significant supplier, supplying 2 million tonnes in 2005.

Table 13 Gas & Diesel Oil Tonnage Inbound to the EU-25

	1995	2005
Africa	1,972,000	842,000
Japan	16,000	342,000
Middle East	582,000	797,000
Mediterranean	46,000	306,000
North America	345,000	1,794,000
Other Asia	2,000	2,954,000
South America	30,000	650,000

A.3.7 Liquefied Natural Gas (LNG)

EU Inbound

Table 14 illustrates that at the majority of LNG imports into the EU are concentrated in Africa and Australia. While other suppliers are expected to come online, Africa and Australia have and will continue to supply the majority of LNG tonnage to the EU. Inbound growth between 2005 and 2015 is expected to be slow with growth from Africa expected at 0.5%. Africa will continue to remain the dominant supplier to the EU by 2015 with over 27 million metric tonnes exported to the EU-25.

Table 14 LNG Tonnage Inbound to the EU-25

	1995	2005
Africa	10,456,121	26,379,322
Australia	288,778	63,993

A.3.8 LPG

EU Inbound

Table 15 illustrates Africa's dominance as a supplier of LPG to the EU. Africa is clearly the largest supplier in both 1995 and 2005, despite strong growth from the Middle East, North America and South America. Africa will continue to remain the dominant supplier to the EU by 2015 with over 38 million metric tonnes exported to the EU-25.

Table 15 LPG Tonnage Inbound to the EU-25

	1995	2005
Africa	1,387,306	3,759,377
Australia	0	1,562
Japan	16	0
Mediterranean	772	272,320
North America	49,079	480,644
Other Asia	608	3,771
South America	9,267	120,646

A.3.9 Ethylene

EU Inbound

Table 16 illustrates the emergence of new suppliers of ethylene to the EU. Africa is clearly the largest supplier in both 1995 and 2005, after growing at an annual rate of 3.6% over those 10 years. Inbound growth between 2005 and 2015 is expected to be slow with growth from Africa expected at 0.5%. Africa will continue to remain the dominant supplier to the EU by 2015 with 57,000 metric tonnes exported to the EU-25.

Table 16 Ethylene Tonnage Inbound to the EU-25

	1995	2005
Africa	37,882	53,940
Mediterranean	0	5,378
North America	2,855	7,436
Other Asia	0	3,306

A.3.10 Animal & Vegetable Oils (HS 1502-1516)

EU Inbound

Animal and vegetable oil tonnage inbound to the EU-25 has experienced more shifts between 1995 and 2005 than oil and natural gas. Table 17 illustrates these shifts. Other Asia[4] is clearly the largest supplier in both 1995 and 2005, and gains market shares throughout the ten-year period. Gains in Other Asia come at a 14% market share loss for North America and a 5% loss for Africa. Inbound growth[5] between 2005 and 2015 from Other Asia is expected to slow from 4.2% growth between 1995 and 2005 to only 1.0% between 2005 and 2015. North America's growth will turn positive in the forecast period, but only to 0.8% growth. Inbound growth will be fastest from Australia (albeit at smaller tonnage levels) with future expected annual growth of 4.4%.

4 Other Asia includes Asia less China, Japan and Australia.

5 Compound Annual Growth (CAGR).

Table 17 **Animal & Vegetable Oil Tonnage Inbound to the EU-25**

Africa	307,292	161,253
Australia	4,153	8,470
China	6,038	7,792
Japan	1,346	3,273
Mediterranean	31,662	35,442
North America	551,401	131,732
Other Asia	2,080,999	3,132,127
South America	343,953	445,915

A.3.11 Inorganic Chemicals, incl. Ammonia (HS 2801-2851)

EU Inbound

Table 18 illustrates the volatility found in inorganic chemicals inbound to the EU-25. Tonnage from Africa into the EU-25 declined steadily between 1995 and 2005, falling by a compound annual 4.4% over the ten-year stretch. With Africa's decline came the emergence of South America, China and the Mediterranean. Africa will continue to decline over the forecast period (2005-2015) at a CAGR of -2.1% while the fastest growth will come from China and Other Asia at 5.5% and 4.1% (CAGR), respectively.

Table 18 **Inorganic Chemical Tonnage Inbound into the EU-25**

	1995	2005
Africa	1,093,104	699,639
Australia	44,424	29,330
China	155,277	220,758
Japan	17,763	12,416
Mediterranean	331,941	495,430
North America	603,536	654,839
Other Asia	39,118	67,315
South America	149,109	353,468

A.3.12 Organic Chemicals (HS 2901-2942, 3507)

EU Inbound

Table 19 displays the modest shifts the origin regions supplying organic chemicals to the EU-25 between 1995 and 2005. North America's share of tonnage into the EU-25 declined steadily between 1995 and 2005, but grew at a compound annual rate of 2.8% over the 10-year stretch. Africa gained market share over the period with a growth rate of 10.6% over the last 10 years of history. Africa will only grow at 1.0% between 2005 and 2015, but faster compound annual growth (10.9%) will come from Other Asia.

Table 19 **Organic Chemical Tonnage Inbound to the EU-25**

	1995	2005
Africa	483,667	1,325,252
Australia	1,284	1,969
China	66,697	58,139
Japan	99,863	26,267
Mediterranean	144,497	319,199
North America	1,595,675	2,111,509
Other Asia	131,713	364,571
South America	179,422	268,354

A.4 Dry bulk demand analysis

A.4.1 Grain (HS 1001-1008)

HS codes 1001-1008 include wheat, rye, barley, oats, corn, rice, grain, buckwheat, millet, and cereals, with the major commodities being wheat, corn and rice.

EU Inbound

The majority of grain tonnage flowing into the EU-25 comes from North America6. However, Table 20 illustrates the origins of EU grain in both 1995 and 2005, where it becomes evident that North America's dominance as the supplier for EU demand is waning as South America becomes a larger supplier. The Africa and Other Asia exporters gained footing as exporters to the EU over the last 10 years. Even with annual growth (CAGR) of 1.8% between 2005 and 2015, North America will continue to be the largest supplier of grain tonnage to the EU-25 and with growth of 1.2% (CAGR); South America will maintain a convincing hold on the second place spot in 2015.

Table 20 **Grain Tonnage Inbound to the EU-25**

	1995	2005
Africa	46,320	10,037
Australia	109,759	260,777
China	36,694	47,138
Japan	101	283
Mediterranean	119,692	42,782
North America	8,105,939	3,611,109
Other Asia	379,214	682,485
South America	993,925	2,333,941

A.4.2 Sugar (HS 1701-1703, 0409)

EU Inbound & Outbound

Sugar tonnage flowing into the EU-25 comes from a stable and diverse set of origin regions. Other Asia, South America, and Africa maintain the first to third place spots in terms of total market share in both 1995 and 2005. South America's share is not surprising, considering that Brazil is the largest sugar exporter in the world. North America also maintains moderate market share, and will continue to do so with expected growth (CAGR) of 6.1% between 2005 and 2015. Though not representing significant tonnage in either 1995 or 2005,

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[6] Analysis does not include EU grain production for EU consumption.

Australia is expected to become a major supplier to the EU-25 over the next ten years. South America is expected to become the largest supplier to the EU-25 by 2015 with forecasted annual growth of 16.0% (CAGR).

Table 21 Sugar Tonnage Inbound from the EU-25

	1995	2005
Africa	1,237,367	1,047,714
Australia	70,144	3,719
China	43,611	12,416
Japan	106	187
Mediterranean	291,132	346,845
North America	473,903	243,558
Other Asia	1,669,872	1,452,333
South America	1,082,093	1,071,381

A.4.3 Oil Seeds & Soy Beans (HS 1201-1208)

EU Inbound

Oil Seed tonnage flowing into the EU-25 is concentrated in North and South America for 1995 though to 2005. As Table 22 indicates, the two regions switch places in terms of their dominance over the 10-year period, with South America holding 75% of the market in 2005. Although South America is only expected to grow at 0.7% annually (CAGR) between 2005 and 2015, it will continue to supply the highest level of oil seed tonnage to the EU-25 by 2015. While its levels will remain low, Other Asia will demonstrate the fastest growth over the forecast horizon with annual growth of 6.7% expected over the forecast horizon.

Table 22 Oil Seed Tonnage Inbound to the EU-25

	1995	2005
Africa	174,075	266,963
Australia	8,266	23,542
China	84,290	6,416
Japan	27	0
Mediterranean	28,596	35,759
North America	10,581,159	4,136,209
Other Asia	120,084	103,282
South America	6,194,390	13,373,062

A.4.4 Animal Feed (HS 1213-1214, 1802, 2302-2309)

EU Inbound

Animal feed tonnage inbounds to the EU-25 primarily originated from South America, North America and Other Asia in 1995. By 2005, however, Other Asia diminished in importance leaving South and North America as the primary suppliers of Animal Feed to the EU. While Other Asia will make up some ground by 2015, with annual growth of 2.7% (CAGR) expected between 2005 and 2015, South and North America will remain the largest suppliers. South America is expected to witness annual growth of 1.6% while North America will see -0.3% growth (CAGR) over the forecast horizon.

Table 23 Animal Feed Tonnage Inbound to the EU-25

	1995	2005
Africa	433,275	338,374
Australia	116,220	40,695
China	244,063	311
Japan	1,233	0
Mediterranean	61,823	131,231
North America	10,254,067	1,506,169
Other Asia	2,922,281	76,934
South America	16,116,317	25,078,052

A.4.5 Coal (HS 2701-2704)

Along with iron ore, coal is the largest (volume terms) commodity traded in the bulk shipping market. Chinese demand for coal will rise astronomically over the next 20 years, while demand from the United States and India will also witness strong growth[7]. Europe is a large importer of coal, with Germany spurring much of the demand[8]. The effects of the drought across Europe must soon raise the problem of lack of cooling water for many nuclear plants-with gas at high prices and no real constrain on carbon it must be expected that coal will meet the short-fall. It is considered that if there are short-term difficulties in supply then it is likely to arise as a result of operational infrastructural problems rather than a fundamental lack of capacity. Capacity expansion plans exist around the world such that, in theory, it is thought that there will be more than adequate capacity to meet future demand levels.

EU Inbound

As seen in Table 24, coal tonnage inbound to the EU-25 was dominated by North American supply in 1995, but became almost evenly distributed between North America, Africa, and Australia by 2005. In fact, North American coal tonnage into the EU fell by an annual 6.7% (CAGR) between 1995 and 2005 and is expected to continue falling (albeit more slowly) by an annual 4.1% (CAGR). Africa and Australia coal tonnage into the EU should fare slightly better over the forecast period with projected rates of 1.1% and 0.9% (CAGR), respectively.

Table 24 Coal Tonnage Inbound to the EU-25

	1995	2005
Africa	27,187,859	39,367,250
Australia	17,913,623	31,222,132
China	2,299,475	2,042,182
Japan	0	806
Mediterranean	0	34,819
North America	75,635,354	37,729,447
Other Asia	3,017,340	10,527,782
South America	2,797,454	3,273,308

7 Macqueen, Julian. 'Burning Questions.' Lloyd's Shipping Economist. December 2005. Pp 16-18.
8 Germany receives a large share of its imports from South Africa.

A.4.6 Briquettes, Lignite, Peat & Coke (HS 2701-2702, 2704)

EU Inbound

The majority of EU's briquettes, lignite, peat and coke tonnage imports were from China in 1995 and 2005. China import tonnage of this commodity grouping into the EU grew by 3.9% (CAGR) between 1995 and 2005 but will slow to 0.2% between 2005 and 2015. Despite this slowdown in growth, China will remain the largest supplier to the EU.

Table 25 Briquettes, Lignite, Peat, Coke Tonnage Inbound to the EU-25

	1995	2005
Africa	234,919	99,815
Australia	104,915	1,275,637
China	2,618,323	3,842,197
Japan	417,618	100,199
Mediterranean	311,227	201,369
North America	197,219	142,822
Other Asia	29,621	56,493
South America	38,814	110,601

A.4.7 Copper (HS 7401, 2603), Alumina (HS 2818), Bauxite (HS 2606), Zinc (HS 2608), Lead (HS 2607), Nickel (HS 2604, 7501) & Other Ores (HS 2601-2603, 2613-2615)

Global copper consumption growth remains sluggish due to high prices, but is beginning to grow faster primarily because of Chinese consumption growth. In part, the decline in consumption growth reflects a transfer of production to China, but high prices are forcing material substitutions. Piping markets are the most imperiled, although even in wiring applications and in other uses for copper (like radiators), other metals are starting to find an opening, even though prices for metals like aluminum are also quite high. Despite current weakness, the consumption growth forecast remains healthy, principally because of China.

Zinc fundamentals continue to be excellent from a producer perspective as supply is falling significantly below global demand levels. Global consumption growth has slowed since the middle of 2005, and is now barely positive; however, it is still exceeding production output, which to April 2006, was actually down slightly in year-over-year (y/y) terms. In a significant development for prices, China, a major exporter of refined zinc, became a large net importer in the fourth quarter of 2005. China, the United States and Japan are the world's largest consumers of Zinc, followed by Germany, South Korea, Italy, France, Taiwan, Belgium, India and the UK.

With rebounding stainless steel production, nickel has shifted back into deficit in 2006. Chinese stainless production has rebounded and is complemented by stronger production rates in Europe. Nickel mine production is seeing the signs of a long awaited expansion, with several large projects in development that will shift the market to surplus around 2008. Japan consumes 17% of the world's nickel followed in consumption by the United States, Taiwan, Germany, South Korea and China. Russia, Canada and France remain the world's largest suppliers.

EU Inbound

As seen in Table 26, ore tonnage inbound to the EU-25 was dominated by South American supply in both 1995 and 2005. Although Australia lost some market share to Africa over the aforementioned 10-year period, the key suppliers to the EU-25 remained constant. South America will continue to be the largest supplier of copper and ore tonnage to the EU in 2015, even with a projected compound annual growth rate of 1.2% (2005-2015). Other Asia will be the fastest growing supplier to the EU with an anticipated growth rate of 3.3% (CAGR) over the forecast period.

Table 26 Ores Tonnage Inbound to the EU-25

	1995	2005
Africa	27,903,521	28,936,906
Australia	26,513,924	16,782,263
China	571,636	389,960
Japan	1,921	2,223
Mediterranean	71,982	76,939
North America	17,064,335	13,004,983
Other Asia	2,688,819	1,498,129
South America	66,059,376	51,636,236

A.4.8 Fertilizers (HS 3102-3105)

EU Inbound

As is displayed in Table 27, fertilizer tonnage inbound to the EU-25 was primarily shipped from Africa in 1995, but was more evenly split between Africa and the Mediterranean by 2005. Africa will continue to be the largest supplier of fertilizer tonnage to the EU in 2015, closely followed by tonnage from the Mediterranean, despite negative compound annual growth rates of -0.9% and -1.1% expected between 2005 and 2015 for each region, respectively. EU imports of fertilizer from Australia will demonstrate the fastest growth with 2.4% (CAGR) projected. It is important to note, however, that this growth is on the back of low levels of tonnage.

Table 27 Fertilizer Tonnage Inbound to the EU-25

	1995	2005
Africa	2,277,127	1,755,391
Australia	559	2,240
China	3,107	3,709
Japan	3,357	94
Mediterranean	1,522,658	1,642,357
North America	344,475	156,731
Other Asia	6,622	5,446
South America	38,966	55,617

A.4.9 Phosphates & Crude Fertilizers (HS 2510, 3101, 3102, 3104)

EU Inbound

Phosphates and crude fertilizer tonnage inbound to the EU-25 was fairly stable in terms of origin between 1995 and 2005. Table 28 illustrates that while the Mediterranean lost market share over this 10-year period, Africa strengthened its position as the primary supplier of phosphates to the EU. Inbound growth[9] between 2005 and 2015 is expected to be weak for all regions supplying the commodity to the EU. In fact, no region is expected to change by greater or less than 1% per year between 2005 and 2015.

Table 28 Phosphate Tonnage Inbound to the EU-25

	1995	2005
Africa	3,496,318	2,598,813
China	0	0
Mediterranean	687,287	150,524
North America	77,671	4,862
Other Asia	15,333	1,541
South America	38,054	29,016

A.4.10 Cement (HS 2523, 3816) & Other Non-Metallic Products (HS 2522)

European demand for cement is not expected to experience strong future growth; rather, global demand will stem from Asia in the future. The fact that cement is an input to new construction implies that demand for cement follows developing economies.

EU Inbound

The majority of cement tonnage flowing into the EU-25 came from the Mediterranean in both 1995 and 2005. Table 29 illustrates the stability in the source of supply of cement tonnage between the Mediterranean and Africa, and hints at the growing importance of Other Asia as a supplier of EU cement. Other Asia will continue to gain steam as it is expected to be the fastest growing exporter of cement to the EU, with anticipated annual growth of 8.2% (CAGR) between 2005 and 2015.

Table 29 Cement Tonnage Inbound to the EU-25

	1995	2005
Africa	465,198	1,228,015
Australia	2	0
China	2,525	0
Japan	889	0
Mediterranean	832,350	2,648,016
North America	8,672	3,041
Other Asia	8,707	206,584
South America	204	272,160

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9 Compound Annual Growth (CAGR).

A.4.11 Aggregates, Sulphur & Salt (HS 2501-2530)

EU Inbound

Table 30 displays the shifts the origin regions supplying aggregates, sulphur & salt to the EU-25 between 1995 and 2005. North America's share of tonnage into the EU-25 declined between 1995 and 2005, while South America and the Mediterranean regions gained share over this period. These two regions are expected to see slower growth between 2005 and 2015 with projected compound annual rates of -0.1% and 0.6%, respectively. Other Asia, Australia and China are the regions to watch in the future with projected growth rates (of exports to the EU) of 4.3%, 3.6% and 3.1% (CAGR), respectively.

Table 30 Aggregates Tonnage Inbound to the EU-25

	1995	2005
Africa	2,596,561	2,679,887
Australia	197,070	254,987
China	929,069	1,460,328
Japan	38,519	27,655
Mediterranean	920,695	1,849,894
North America	2,229,362	1,311,863
Other Asia	1,111,498	1,441,936
South America	2,389,532	4,319,382

A.4.12 Non-Ferrous Metals (incl. Aluminium) (HS 7402-7406, 7106, 7110)[10]

The non-ferrous metals category is fairly broad and contains products that move dry bulk as well as neo-bulk/general cargo. The analysis presented below related to tonnage moving in dry bulk vessels. Paragraphs in the Neo-Bulk Demand Analysis section of this report will cover non-ferrous metals moving in general cargo vessels.

EU Inbound

The majority of EU's non-ferrous metals tonnage imports were from South America and Australia in 1995 and 2005. By 2005 Africa also grew to become a significant supplier to the EU, trailing closely behind Australia. Non-ferrous metals exports from these regions to the EU are expected to grow at compound annual growth rates of 2.6%, 3.0% and 1.3%, respectively, between 2005 and 2015. China's exports to the EU for this commodity grouping will grow at a strong CAGR of 5.9%, but tonnage levels will remain low throughout the forecast period.

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10 The non-ferrous metals category includes other commodities than the HS codes listed above. A complete list can be provided upon request.

Table 31 **Non-Ferrous Metals Tonnage Inbound to the EU-25**

	1995	2005
Africa	234,919	99,815
Australia	104,915	1,275,637
China	2,618,323	3,842,197
Japan	417,618	100,199
Mediterranean	311,227	201,369
North America	197,219	142,822
Other Asia	29,621	56,493
South America	38,814	110,601

A.4.13 Steel & Iron Ore (HS 7201-7217)

EU Inbound

As is evident in Table 32, significant shifts occurred in the origins of dry bulk steel and iron ore tonnage inbounds to the EU. North America lost 20% of its market share between 1995 and 2005 while China, the Mediterranean and Africa both gained share.

Table 32 **Dry Bulk Steel & Iron Ore Tonnage Inbound to the EU-25**

	1995	2005
Africa	1,604,105	3,439,918
Australia	12,001	72,416
China	431,122	2,978,236
Japan	174,338	319,228
Mediterranean	572,618	995,935
North America	1,451,243	545,032
Other Asia	402,026	1,233,080
South America	1,160,538	2,190,494

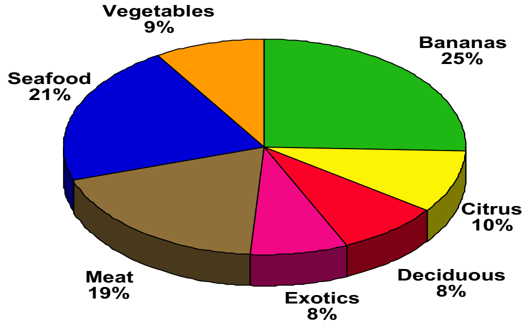
A.5 NEO-BULK DEMAND ANALYSIS

A.5.1 The Reefer Market

The reefer market is driven by the demand for meat, fruit, vegetable and seafood which is exported from regions with a comparative advantage in producing these products.

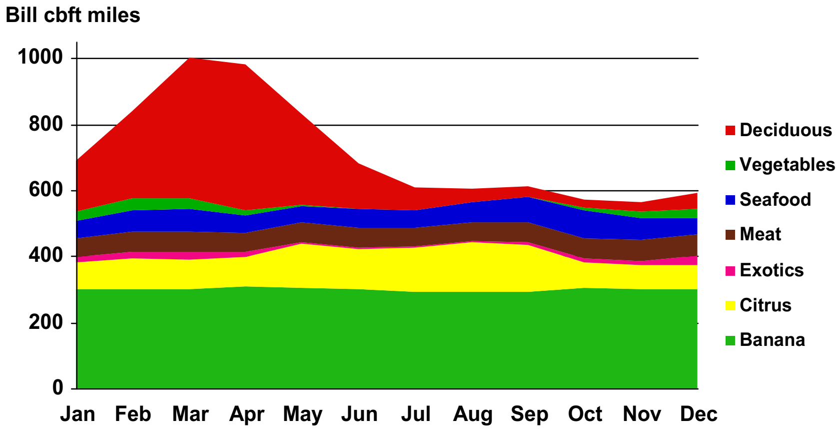
The specialised reefer market is composed of a wide variety of products, but about 60% of the products which was transported are fruit and vegetables, and the remaining commodities and/or goods are frozen seafood and meat. The cargo mix is illustrated in Figure 10.

Figure 10 Specialised reefer fleet commodities[11]



The reefer market is highly seasonal, and the seasonal fluctuations are illustrated in Figure 11:

Figure 11 Seasonality of demand for reefer commodities[12]



As can be seen from the graph above, the smallest fluctuation is seen for the trade in bananas, as the exports volumes are fairly stable. Deciduous fruit (which includes apples, pears, etc.) follows the opposite pattern, and the trade is most active in the first part of the year.

The major operators, like the big banana and deciduous fruit companies, cover their basic shipping needs by hiring a given number of vessels on a one year time charter basis, and then they cover seasonal changes in transportation needs by using vessels on a spot voyage charter basis, where the typical trip is in the range of 40 days. During the off season months (July-December), many vessels are usually laid up. However, this may change somewhat as Russia has appeared as a major growth market for fruit imports, especially for bananas and citrus from South Africa and Argentina, which are important trades during the off season months.

The alternative to hiring a ship on a time charter and spot basis is to hire space onboard vessels which operate on a seasonal liner basis based on export, where one can buy space on board the vessel which is filled with different commodities and/or goods. The cargo is typically palletized. These services

11 Source: http://www.sitrusfees.co.za/papers/TrevorPresentation.ppt.

12 Source: http://www.sitrusfees.co.za/papers/TrevorPresentation.ppt.

are offered both by specialized reefers and container lines. The commodities and/or goods which are covered on these services include bananas, vegetables, seafood, meat, exotics and deciduous fruit. Freight rates are paid in USD per cubic meter for specialized reefers and USD per container for container vessels, and specialized reefer vessels with container capacity. Availability of modern specialized reefer vessels is becoming ever more limited. This appears to be a response to dwindling demand from shippers for specialized transport, or at least recognition that container lines can offer an equivalent level of service in terms of technical quality, flexibility on timing and choice of routes. Modern containerships are all now fitted with large numbers of reefer plugs for transportation of perishable commodities. Consequently the ability of container ship operators to price competitively by filling available spare slot space at marginal prices has proved attractive to shippers and drastically changed demand patterns as well. One can expect the trend to be maintained and demand for specialized reefer vessels to remain static or even reduce, especially as the average fleet age becomes older.

A.5.2 Fruit & Vegetables, Refrigerated (HS 0702, 0703, 0710, 0711, 0803-0810, 2001-2005)

There continues to be a steady increase in the demand for fresh produce in the main import markets. In the main reefer trades, food requiring refrigeration is transported from the Southern hemisphere to the major import markets: Europe, USA, and Japan. Conventional reefers carry the majority of these commodities, but refrigerated containers continue to gain market share. Bananas, citrus fruits and deciduous fruits[13] are the major commodities in this category.

EU Inbound

Table 33 depict the fact that the source of refrigerated fruit and vegetable tonnage did not change substantially between 1995 and 2005. Points of interest include a reduction in imports from North America coupled with an increase in imports from Africa and Asia. Inbound compound annual growth between 2005 and 2015 is expected to be strongest from Asia, with imports from China growing at over 11% annually (11.8%) and imports from the rest of Asia (less Japan) posting an annual growth rate of 4.1% (CAGR).

Table 33 Refrigerated Fruit & Vegetable Tonnage Inbound to the EU-25

	1995	2005
Africa	534,368	1,123,336
Australia	9,857	5,151
China	23,183	896
Japan	112	0
Mediterranean	73,582	79,612
North America	84,743	13,888
Other Asia	191,528	468,242
South America	2,351,103	3,725,411

13 Deciduous fruits include apples, pears and table grapes (avocados and kiwi are typically considered exotic fruits).

A.5.3 Fruit & Vegetables, Non-Refrigerated (HS 0701-0710, 0713; 1210-1212, 0802)

Non-refrigerated fruit and vegetables include potatoes, peas, beans, onions, garlic, leeks, cauliflower, brussel sprouts, cabbage, broccoli, carrots, turnips, beets, cucumbers, artichokes, asparagus, eggplants, celery, mushrooms, corn, cassava, sweet potatoes, other roots and nuts.

EU Inbound

Unlike reefer trade of fruits and vegetables, Table 34 illustrates significant changes in the origins of the EU-25's inbound tonnage of non-reefer fruits and vegetables between 1995 and 2005. While Asia existed as the primary supplier in 1995, no country existed as a dominant supplier in 2005 with many regions representing significant shares. The share of tonnage inbound from South America increased substantially, as did the share of tonnage from Africa, the Mediterranean, and Australia. Inbound growth (CAGR) between 2005 and 2015 is expected to be strongest from Asia, with imports from China growing at 8.8% annually, imports from Australia growing at 5.5%, and imports from the rest of Asia (less Japan) posting annual growth rates of 3.3%.

Table 34 Non-Refrigerated Fruit & Vegetable Tonnage Inbound into the EU-25

	1995	2005
Africa	65,610	59,299
Australia	11,620	23,493
China	55,725	2,478
Japan	58	0
Mediterranean	100,991	70,563
North America	453,668	65,263
Other Asia	2,038,877	34,791
South America	32,942	52,486

A.5.4 Meat, Dairy, Fish, Refrigerated (HS 0201-0208, HS 0301-0307, HS 0401, HS 0403; HS 0405-0406, HS 0408, HS 1604, HS2105)

EU Inbound

Unlike reefer trade of fruits and vegetables, Table 35 illustrates notable shifts in the origins of the EU-25's inbound tonnage between 1995 and 2005. While Asia existed as the primary supplier in 1995, South America emerged as the largest supplier in 2005. While many producers maintain their 1995 status in 2005, Asia dropped from the n. 1 to the n.3 supplier by 2005 and South America moved from n. 3 (tied with Africa in 1995) to n.1 in 2005. Inbound growth (CAGR) between 2005 and 2015 is expected to be strongest from Asia, with imports from China growing at 5.4% annually, and imports from Australia and Other Asia each growing at 4.2%.

Table 35 **Meat, Dairy and Fish Tonnage Inbound to the EU-25**

	1995	2005
Africa	201,852	359,956
Australia	20,721	27,718
China	39,157	290
Japan	1,909	35
Mediterranean	7,504	9,196
North America	164,306	139,885
Other Asia	276,058	256,153
South America	206,404	528,753

A.5.5 Pulp (HS 4701-4706)

EU Inbound

Table 36 depict the relatively stable sources of inbound pulp tonnage to the EU. North America was clearly the largest supplier in both 1995 and 2005, though it relinquished 24% of its market share by 2005. Inbound growth between 2005 and 2015 is expected to be fairly weak, but strongest from South America at 2.1% (CAGR). North America will continue to lose its market share with growth of negative 1.6% expected between 2005 and 2015.

Table 36 **Pulp Tonnage Inbound to the EU-25**

	1995	2005
Africa	33,227	55,599
Australia	0	4
China	4	0
Japan	3	0
Mediterranean	412	611
North America	1,644,170	985,641
Other Asia	5,381	2,613
South America	342,540	704,087

A.5.6 Waste Paper (HS 4707)

EU Inbound

Waste Paper inbound to the EU arrived primarily via North America in 1995, but by 1996, Africa began supplying the largest amount to the EU and continued to do so up to and including 2005. With compound annual growth of 0.8% between 2005 and 2015, Africa will continue to be the primary supplier to the EU. The Mediterranean region maintained a third-place position (3rd to North America) over the 10-year horizon, and will demonstrate moderate growth of 2.9% (CAGR) over the forecast period. While North America will remain a significant supplier to Europe throughout the forecast period, its compound annual growth between 2005 and 2015 will be a negative 1.2%.

Table 37 Waste Paper Tonnage Inbound to the EU-25

	1995	2005
Africa	19,299	25,597
Australia	100	0
China	0	0
Mediterranean	593	169
North America	39,350	4,525
Other Asia	293	0
South America	38	0

A.5.7 Paperboard & Products (HS 4801-4814, HS 4816-4820, HS 4822-4823)

EU Inbound

Paperboard and products inbound to the EU arrived primarily via North America in both 1995 and 2005, though North America's share diminished from 78% in 1995 to 58% in 2005. Conversely, South America and Africa improve, growing in their paper tonnage inbound to the EU. At expected growth of 3.1% (CAGR) between 2005 and 2015, North America will continue to be the primary supplier of this commodity grouping to the EU. Significant growth will come from China, Australia and South America with expected growth rates (CAGR) of 7.5%, 6.6% and 4.8%, respectively over the forecast period.

Table 38 Paperboard and Products Tonnage Inbound to the EU-25

	1995	2005
Africa	38,713	167,876
Australia	330	14,162
China	10,035	1,058
Japan	6,726	1,710
Mediterranean	17,933	31,223
North America	1,267,813	910,082
Other Asia	21,128	11,608
South America	135,978	200,315

A.5.8 Cork & Wood (HS 4401-4403, HS 4406-4407, HS 4409, HS 4501-4502)

EU Inbound

Table 39 depict the shifts in the sources of inbound cork and wood tonnage to the EU. Africa was the largest supplier in both 1995 and 2005, gaining 15% market share over the 10-year period. North America and Asia diminished in importance as a supplier of cork and wood to the EU between 1995 and 2005. Inbound growth between 2005 and 2015 is expected to be strongest from China (though tonnage levels will remain low) with 4.9% growth and South America with 2.2% (CAGR) growth.

Table 39 **Cork & Wood Tonnage Inbound to the EU-25**

	1995	2005
Africa	2,870,378	3,321,590
Australia	14,315	11,113
China	8,945	100
Japan	1,122	2
Mediterranean	32,875	6,993
North America	1,253,918	703,468
Other Asia	498,089	4,977
South America	2,228,829	1,713,910

A.5.9 Agricultural Machinery (HS 8701)

EU Inbound

Agricultural Machinery inbound to the EU arrived primarily via North America in both 1995 and 2005, and no major shifts occurred among suppliers. North America increased its share of the EU's agricultural machinery imports from 83% in 1995 to 85% in 2005. Japan's share dropped from 7% to 2%, while the Mediterranean grew from 2 to 4% over the 10-year period. Even at slow growth of 0.6% (CAGR) between 2005 and 2015, North America will continue to be the primary supplier of this commodity grouping to the EU. Significant growth will come from Other Asia and China, with expected growth (CAGR) of 4.0% and 4.1%, respectively over the forecast period. However, it is important to note that tonnage from China is insignificant at only 14 tonnes in 2015.

Table 40 **Agricultural Machinery Tonnage Inbound to the EU-25**

	1995	2005
Africa	191	253
Australia	340	381
China	1,817	9
Japan	3,072	521
Mediterranean	744	1,128
North America	38,102	22,250
Other Asia	1,045	1,470
South America	62	110

A.5.10 Motor Vehicles

Year-to-May Western European new car demand posted just over 6.5 million units, up 2.3%. A move to more pricing restraint in Europe in the face of rising raw material manufacturing costs and low industry profitability will probably undermine any cyclical upswing in car sales over the next two years or so. This will open the door for Japanese and Korean importers to make extra sales gains at the expense of the European makers.

By 2011, Central Europe will house nearly 1 million units worth of new greenfield automotive plant. Meanwhile, Turkish output is being raised by Toyota, Hyundai, Ford, Fiat and PSA. Here Light Vehicle production will also reach over 1 million units by 2011. More caution is being exercised in Russia, underlining the risks of investment. Nevertheless, new capacity from foreign OEMs will amount to 450,000 units by 2011, but the majority of this output will remain in Russia for domestic consumption.

EU Inbound

As is evident in Table 41, significant shifts occurred in the origins of Motor Vehicle tonnage inbound to the EU. Japan dropped as the primary supplier in 1995 to the 3rd largest supplier in 2005. Japan's market share was replaced by shipments from North America, which became the primary supplier in 2005. On a smaller scale, Africa emerged as a supplier to the EU. At the steady growth rate of 4.4% (CAGR) between 2005 and 2015, North America will continue to be the primary supplier of this commodity grouping to the EU. Significant growth (CAGR) between 2005 and 2015 will come from China (9.2%), Africa (7.5%) and Asia (less Japan) (5.8%).

Table 41 Motor Vehicle Tonnage Inbound to the EU-25

	1995	2005
Africa	3,939	99,167
Australia	609	757
China	860	7,089
Japan	1,032,105	80,247
Mediterranean	12,932	59,716
North America	193,831	393,920
Other Asia	273,425	118,962
South America	34,378	18,139

A.5.11 Metal Products (HS 7415-7419)[14]

EU Inbound

The majority of EU's metal products tonnage imports were from Other Asia and China in 1995. However, by 2005 China lost market share as North America and the Mediterranean drew closer to levels set by Other Asia. Other Asia will continue to be the largest supplier in 2015 with expected annual growth of 7.8% (CAGR) between 2005 and 2015. Australia and China will also experience strong rates of growth- each posting rates of 4.9% and 4.6% (CAGR) over the forecast horizon.

Table 42 Metal Products Tonnage Inbound to the EU-25

	1995	2005
Africa	20,330	27,512
Australia	1,347	1,294
China	106,255	22,090
Japan	15,290	101
Mediterranean	20,295	31,013
North America	40,945	47,250
Other Asia	134,754	52,192
South America	1,364	1,690

[14] The metal products category also contains HS codes: 7308-7315, 7317, 7318, 7320, 7321, 7323, 7413-7419, 7508, 7610-7616, 8101-8109, 8112, 8201-8215, 8301-8311.

A.5.12 Petroleum Coke & Other Residual Petroleum Products (HS 2713 & 2708)

EU Inbound

The majority of EU's petroleum coke tonnage imports were from North America in 1995 and 2005. By 2005 South America also grew to become a significant supplier to the EU, but North American outbound tonnage to the EU in 2005 was still more than twice tonnage from South America. These two countries will continue to dominate in 2015, each growing at rates of 1.6% and 1.9% (CAGR) between 2005 and 2015.

Table 43 Petroleum Coke Tonnage Inbound to the EU-25

	1995	2005
Africa	6,916	3,428
Australia	1	7
China	595	1,476
Japan	769	960
Mediterranean	1,528	1,368
North America	156,324	123,509
Other Asia	563	13,059
South America	9,642	54,607

A.5.13 Steel (HS 7201-7217)

Global steel supply is relatively balanced. Low production in 2005 outside of China caused thin inventory early in the year, but excess production in China meant imports were available. Production is up sharply in almost every region as inventory is replenished and steel makers reap the benefits of current high prices. Demand continues to rise in the United States, China, and Central/Eastern Europe, with China acting as the main demand driver, with infrastructure, consumer durables, and fabrications for export. Central and Eastern Europe are benefiting from exports to Western Europe and growing internal demand. Steel supply has improved compared to the first half of 2006, and in general, higher global production has allowed supply to better meet demand.

EU Inbound

As is evident in Table 44, significant shifts occurred in the origins of neo-bulk steel tonnage inbound to the EU. North America lost 20% of its market share between 1995 and 2005 while China and Africa both gained share. With moderate growth rates of 2.3 and 3.9% (CAGR) between 2005 and 2015, Africa and China will continue to be the primary suppliers of this commodity grouping to the EU.

Table 44 Neo-bulk Steel Tonnage Inbound to the EU-25

	1995	2005
Africa	195,678	410,808
Australia	1,464	8,648
China	58,002	256,598
Japan	23,441	27,566
Mediterranean	69,851	118,938
North America	177,031	65,090
Other Asia	51,303	119,827
South America	141,569	261,597

A.5.14 Non-Ferrous Metals (HS 7402-7406, 7106, 7110)[15]

The non-ferrous metals category is fairly broad and contains products that move dry bulk as well as neo-bulk/general cargo. The analysis presented below related to neo-bulk/general cargo tonnage.

EU Inbound

The majority of EU's non-ferrous metals tonnage imports on neo-bulk/general cargo vessels were from South America and Australia in 1995 and 2005. Africa and Australia are both significant EU suppliers, though both countries suffered a decline in their tonnage sent to the EU market between 1995 and 2005.

Table 45 Non-Ferrous Metals Tonnage Inbound to the EU-25

	1995	2005
Africa	19,299	25,597
Australia	100	0
China	0	0
Japan	593	169
Mediterranean	39,350	4,525
North America	293	0
Other Asia	38	0
South America	0	0

A.5.15 Containers

The container market into EU can be divided into two sections; liner and tramp. The problem is to get proper information on the container origin and imports to EU.

EU Inbound

The majority of containers inbound to EU is from the category *Others*, follow by Asia and North America.

Table 46 Containers in TEU Inbound to the EU

	2001	2005
Asia	4,900,000	
North America	2,100,000	
Others		
Japan	593	169
Mediterranean	39,350	4,525
North America	293	0
Other Asia	38	0
South America	0	0

[15] The non-ferrous metals category includes commodities other than those listed above. A complete list is available upon request.

Annex B Legal comments on possibilities of evasion

The main concern with a route-based scheme is that the implementation of the scheme may lead to evasion in one of two ways:

- A route-based scheme may encourage ship operators to avoid European ports altogether. Or
- A route-based scheme may encourage operators to call at a port located near to but outside the EU prior to calling at an EU port thereby reducing the amount of the journey which will be subject to the emissions scheme.

As regards operators avoiding EU ports altogether, clearly, from a legal perspective, there is nothing that the EC could do to prevent operators from avoiding EU ports if they so choose. Given the regional basis of the scheme, it would be entirely open to operators to call instead at ports located near to but not in the EU in order to avoid incurring the costs of complying with emissions regulations.

One possible way in which such evasion could be reduced or restricted would be to enter into some form of agreement with non-EU ports (e.g. Ukraine, Gibraltar) whereby the non-EU ports would agree to enforce the emissions trading scheme in respect of those cargos which are ultimately destined for discharge in EU ports. Agreement to such a scheme would have to be obtained on a purely voluntary basis and it is not certain that non-EU countries would agree to participate in such a scheme, especially given that the introduction of any emissions scheme could have the effect of increasing port calls at non-EU ports, thereby raising revenue.

Another option would be to draft any route-based scheme in such a way as to include the entire journey of the vessel from the load port of the first cargo loaded onboard the vessel to be discharged in the EU port, rather than focusing on the emissions of the vessel from the last port of call to its EU port destination. Regulations could be made whereby port authorities examine the origin of the cargo or port of loading as identified on the bill of lading so as to determine the proper duration/length of the voyage into the EU. This would complicate the approach with regard to the responsible entity, but would effectively limit evasion for cargo carried in bulk, where often the port of loading can be clearly determined. For container ships, however, it may in most cases not be possible to establish a port of loading as they onload and offload at every port.

Annex I Ship-to-ship transfers

1 Introduction

A climate change policy with a limited geographical scope would be sceptible to evasion techniques, one of them being ship-to-ship transfer (STS). STS is the practice whereby cargo is transferred from one ship to another. For example, crude oil can in principle be transported from the Middle Eastern Gulf to seas near Europe in a VLCC (very large crude carrier) and then transferred to smaller ships that take the cargo to EU ports. Any policy enforced in EU ports could be partly evaded by increasing STS by ship to ship transfers outside the EU sovereign (or jurisdictional) waters.

This paper has three main goals:
1. To identify current STS operations in or around EU waters to the extent possible.
2. To identify possible barriers to STS.
3. To assess the economic incentives for STS created by climate policy.

The paper is organised as follows. Chapter 2 discusses development of STS operations, identifies the main geographical areas where STS is popular, assesses the volume of STS operations and lists possible barriers to STS. Chapter 3 identifies areas around Europe which could potentially be used for STS operations in order to evade a CO_2 reduction policy. Chapter 4 assesses the economic incentives for STS by comparing the costs of direct freights with the costs of the freights including STS. Chapter 5 presents summary and conclusions. In addition, Annex A presents legal comments on STS.

The paper is based on the assumption that for the ETS scheme in the EU to be evaded, the STS operation has to be done in international waters or within territorial waters of non-EU members.

Much of the information in this document is based on input, figures and facts from FenderCare Marine (FCM, 2009), the leading STS operator company.

2 STS today

In the 1970's, with the Suez Canal closed, the advent of the Supertanker arriving from the Middle East via the Cape of Good Hope gave birth to a burgeoning trade. The tankers were unable to enter European Ports fully laden and therefore all the Oil Majors designated specialist vessels to act as 'lightering ships'. The trade was probably at its peak during this decade with vessels queuing up in Lyme Bay, Liverpool Bay and Seine Bay which saw constant activity and benefitted from providing the support services ships and crews.

As deep water ports developed, the trade declined. By the 1990's fewer crude oil operations were taking place but an interest grew in product transshipment as traders realized the benefits STS could provide to their logistics. The geographic pattern spread with more interest focused on the Mediterranean, particularly Malta and Gibraltar Bay (Algeciras). At the same time a reverse trade was born with transshipment of North Sea Crude Oils from costly shuttle tankers to larger long haul vessels in the Orkney Islands.

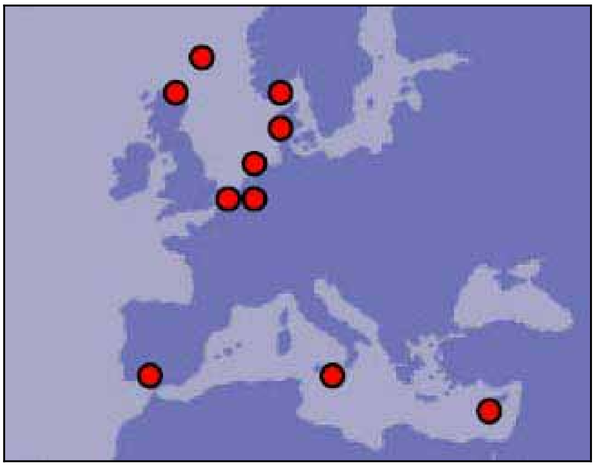
By this time the Oil Majors had reviewed their operating criteria and specialist service providers now conducted the majority of the transfer operations on their behalf and under the rules formulated by the Oil Companies International Marine Forum (OCIMF).

By the turn of the Millennium, the growth of exports from the former Soviet Union created a new demand for this 'reverse lightering'. Vessels loading in the shallow waters of the Baltic States started transshipping their cargos to larger vessels for delivery to long haul destinations particularly the Asia pacific region.

STS operations today are normally related to liquid or gas cargoes, but it is also sometimes done with dry bulk cargoes. However the dry bulk STS operations are mostly done in the Middle East with iron ore which is transhipped to get into shallow ports where the melters are located. STS are also used in river trades, barges to ships or ship to barges, in Asia and the US. STS operations with liquids are done for example by lightering smaller feeder vessels on to a large vessel, and then the large vessel transports the commodity to the market. Transportation on one big vessel is cheaper than using many smaller vessels. This is done in Northern Norway/Russia and also in the Baltic. The other way around is also done: reloading cargo from big vessels onto smaller vessels and bringing it to ports where there are size restrictions; this is done in the US and the EU.

2.1 The popular STS areas in or around Europe

Based on FenderCare information we can identify the following STS and lightering zones in or around EU:
- SKAW, Denmark.
- Kalundborg, Denmark.
- Rotterdam, Netherlands.
- Amsterdam, Netherlands.
- Southwold, UK.
- Sullom Voe, UK (Shetland Islands).
- Scapa Flow, UK (Orkney Islands).
- Gibraltar.
- Mauritania.
- Cyprus.
- Malta.
- Ukraine.
- Sevastopol, Black Sea.
- Kirkenes, Norway.



Source: FenderCare Marine.

It should be noted that Rotterdam and Amsterdam are 'In Port' Transshipment areas with STS taking place at designated jetties or dolphin facilities. But other remote areas might also be covered by mobilizing support craft and STS equipment from mentioned bases.

The location at Kirkenes and also Scapa Flow are used for STS operations with oil from northern Russia in the winter season when ice is a problem in this area. During the operational season the volumes are around 170,000 tonne per month.

2.2 Current STS volumes

We cannot be definitive regarding the total transshipment volumes, although FCM are without doubt the leading STS operator. The other significant STS service providers in the region are SPT Marine who offer their services in the same areas as FCM and Mariflex (largely confined to Rotterdam Port Operations).

The figures in Table 1 demonstrate FCM's operational levels and approximate transshipment volumes within the EU zone (including Cyprus) during the year 2008. The final column contains an estimate of the percentage of the total volumes that are transshipped by FCM. This information is drawn from the FCM database and the percentages are only indicative.

Table 1 **Transshipment volumes in 2008 reported by FCM**

STS Location	Number of Transhipments	Total Volume Transhipped (BBLS)	Average cargo Volume (BBLS)	Estimated percentage of total
Scapa Flow	8	3,455,282	431,910	70 %
Southwold	22	9,240,530	420,024	60 %
Sullom Voe	1	415,422	415,422	100 %
Amsterdam	14	956,109	68,294	30 %
Rotterdam	142	28,742,184	202,410	40 %
Kalundborg	35	6,264,019	178,972	60 %
Skaw	35	13,900,157	397,147	60 %
Copenhagen	4	402,065	100,516	80 %
Malta	38	7,702,339	202,693	60 %
Cyprus	80	15,202,244	190,028	60 %

Source: FenderCare Marine.

It should be noted that a large quantity of bunker fuels are transshipped in the EU waters. Gibraltar Bay and Malta are the notable bunkering areas. These are not normally handled by the STS service providers and may not conform to the same standards set by them and recommended by OCIMF. Information on bunker volumes are not available to FCM.

2.3 Possible barriers to STS

As for all operations where cargo is either being loaded or discharged into or onto a vessel, there is always a risk of spills. In normal operation the ship is moored to a quay, but in most STS operations the vessels are only moored to each other or with the lightering ship in-between, open for the forces of nature and movements of the seas. Naturally this will increase the potential risk for something going wrong, and therefore stricter regulations and guidelines are needed for performing STS operations.

Moving a loading and discharge operation from the berth and out to the seas increases the effect from the weather conditions to a very important factor. FenderCare Maritime reports the following weather limitations:

'The weather conditions under which the operations may be conducted depend on many factors and commencement or continuation of operations are largely dependent on the discretion and experience of the professional STS Superintendent (Mooring Master) employed by the Service Provider. However the following extract from the FCM STS Operations Manual gives a broad outline of the parameters and this is mirrored in part by the OCIMF Ship to Ship Transfer Guide.

The parameters for safe operation during STS operations depend mainly on the wind speed, height of seaway and swell period particularly with respect to the light ship.

Superintendents should be guided by local weather forecasts and relevant Harbor Authority regulations and the movement between the two ships and the limitations of the support craft.

The STS Superintendent should consider delaying the mooring operations when winds exceed 25 knots or swell/seas reach two to three meters. When alongside, consideration should be given to suspending the transfer when the wind consistently exceeds 35 knots, especially if weather forecasts indicate an approaching deep low pressure system or gusting winds.

Notwithstanding the above, the STS Superintendent may suspend or delay operations at any time at his own discretion if he believes weather or other extraneous circumstances dictate.

Note: The effect of Ice buildup between vessels needs to be considered whilst conducting the pre operation risk assessment. For example in Danish Territorial waters and Black sea operations.

Where it is considered that the ice buildup or potential ice buildup during the operation could have an adverse impact on the safety and the security of the fender moorings or vessel mooring arrangements no STS operations are to be conducted.'

From FCM information, the limits for STS operations are:
- Mooring operation: 25 knots wind, which equals around 13 meters per second.
- Transfer operation: 35 knots wind, which equals around 18 meters per second and swells/seas reaches two to three meters.
- The STS superintendent continues evaluation of the conditions.

3 Potential areas of policy evasion by using STS

Before we perform any calculations or analyses of the economic incentives for STS, we will discuss in which areas STS operations are most likely to be used.

The European Union is surrounded by the Mediterranean Sea, Northern Atlantic Ocean, North Sea and Baltic Sea. To use an STS operation to evade any of the EU emission reduction policies, the ship has to be outside the EU waters meaning in high seas or in none-EU waters.

Without doing any elaborate analyses with metocean data, we know that the Northern Atlantic Ocean and the North Sea are very rough ocean areas with strong winds and high swells. We believe therefore that STS operations on a regular basis in these high seas are very unlikely. Furthermore, all the places used today for STS operations, which are partly sheltered from natural forces, are within the EU waters. Still, if weather and waves allow, we cannot rule out the possibility for STS operations in these waters.

For the Baltic Sea area, only the waters outside Russia are not within the European territorial waters. This means either outside Kaliningrad or in the Russian waters of the Gulf of Finland. However, the Baltic region is an export area for petroleum products, only limited import. With this in mind, the evasion of EU's emission policy by STS in the Baltic Sea would mean that the cargo would have to be transported 'back' to for example the ARA area. There is a draught restriction on 15.4 meters for sailing through the Danish straights and ice is a problem during the winter season.

In the Mediterranean there are numerous possibilities with the coast of Northern Africa, Eastern Mediterranean and also the non-member states as Croatia, Albania and Montenegro. Also weather and ocean data show that it is highly possible to perform STS operations in high seas most of the time.

4 Economic incentives for STS

STS as a means to evade the CO_2 reduction policy scheme is likely to occur if the scope of the policy is restricted to the distance travelled from the last port call before arrival at the EU. This option is viable only if the additional costs linked to such evasion do not exceed savings related to lower costs of compliance with the policy scheme. The freight costs are voyage-related and cover bunker costs, port costs and time costs.

In our analysis we will make an estimate of STS costs based on two examples:
1. The first scenario will cover the northern part of the European continent, and the only place suitable for an STS operation unless gambling on the weather conditions is outside Kaliningrad. The cargo is transported in an medium range (MR) sized product tanker with diesel fuel from Houston in the US. The cargo is transferred onto another MR by an STS operation and then shipped to Rotterdam.
2. The second scenario is also diesel fuel on an MR from Houston but this time the final destination is Piraeus in Greece. On its way to the final destination, the cargo is reloaded using an STS operation to another MR in Albanian territorial waters.

Selection of these examples is based on the following criteria:
- Diesel fuel from US to Europe is an increasing trade.
- Both the northern and southern part of the continent are covered.
- The STS done from MR to MR and not from a smaller to a larger vessel is to lower the cost to a minimum to check the economic incentive.
- Any emission reduction policy chosen would have to take into account STS operations within the contingency zone, meaning that any evasion of the policy would have to occur outside the contingency zone (200 nm from shore).

Ship operators, while considering a possibility to evade the policy scheme, would compare the costs of a direct freight, unloading the cargo at an EU port, with the freight costs including unloading the cargo using STS technique. If the costs of a direct freight (including the costs of CO_2 emissions along the whole route) are higher than the costs of the freight including STS (but with reduced CO_2 costs), the operator will have a financial incentive to engage in this evasion possibility. Thus the relevant comparison is as follows:

$$\text{Freight-costs}_{\text{DIRECT}} + \text{Emission-cost}_{\text{DIRECT}} \geq \text{Freight-costs}_{\text{TO STS location}} + \text{STS costs}$$

The STS Operation cost includes fenders, hoses, moorings, STS Superintendent and support craft to assist with rigging and unrigging of STS equipment. The STS operation cost varies from area to area and volume that is transferred. In this paper we have estimated the STS operation cost to be US$ 20,000 in both scenarios.

Scenario 1
This scenario is chosen to cover the northern part of the European continent based on the previously listed criteria. The scenario is in principle the same as in the paper on potential for evasion (Faber et al., 2009), with diesel fuel transported from Houston to Rotterdam. This trade is normally performed by MR oil tankers or product vessels ranging from 30,000 to 55,000 dwt. We will use a state of the art MR tanker with the dwt of 47,128 tonnes and a cargo capacity of 46,500 tonnes of diesel. The fuel consumption is estimated to be 33 tonnes per day for heavy fuel oil and 0.5 tonnes per day of marine diesel oil.

The direct route is from Houston to Rotterdam, 5,062 nm, and the STS evasion route is Houston to Kaliningrad, 5,750 nm, and then from Kaliningrad back to Rotterdam, 1,031 nm.

To simplify the calculations we will assume that the freight rate for direct shipment is equal to the freight rate to the STS area.

First let us look at the CO_2 cost for a direct shipment.

The voyage time for a Houston to Rotterdam trip will then be:
- At sea: 14.55 days.
- Sea Margin 7.5 %: 1.09 days.
- In Port: 4.0 days.
- Extra: 1 day.
- Total: 20.64 days.

We adopt the following CO_2 emission factors based on Buhaug (2008):

Type of Fuel	Tonne CO_2/Tonne Fuel
Marine Diesel Oil (MDO)	3.09
Heavy Fuel Oil (HFO)	3.02

This gives us the following CO_2 emissions:

$(Consumption_{HFO} * CO_2\ factor_{HFO}) + (Consumption_{MDO} * CO_2\ factor_{MDO})$ * Travel days = Total emission of CO_2

This gives the following result:

(33 * 3.02 + 0.5 * 3.09) * 20.64 days = 2088.87 tonnes CO_2

Depending on the price of the CO_2, the fee will be:

CO_2 fee US$ per Tonne CO_2	CO_2 fee for Houston to Rotterdam	CO_2 fee US$ per tonne diesel
10	20,888.7	0.45
30	62,666.1	1.35
50	109,500	2.25

Looking at the evasion STS operation, the CO_2 cost for the route from Kaliningrad to Rotterdam will be:
- At sea: 2.96 days.
- Sea Margin 2.5 %: 0.07 days.
- In Port: 4.0 days.
- Extra: 2 day.
- Total: 9.04 days.

We have added one extra day in case of problems related to the weather and ocean conditions.

Taking the same CO_2 emission factors as before, we have calculated CO_2 emissions at the level of 914.85 tonnes.

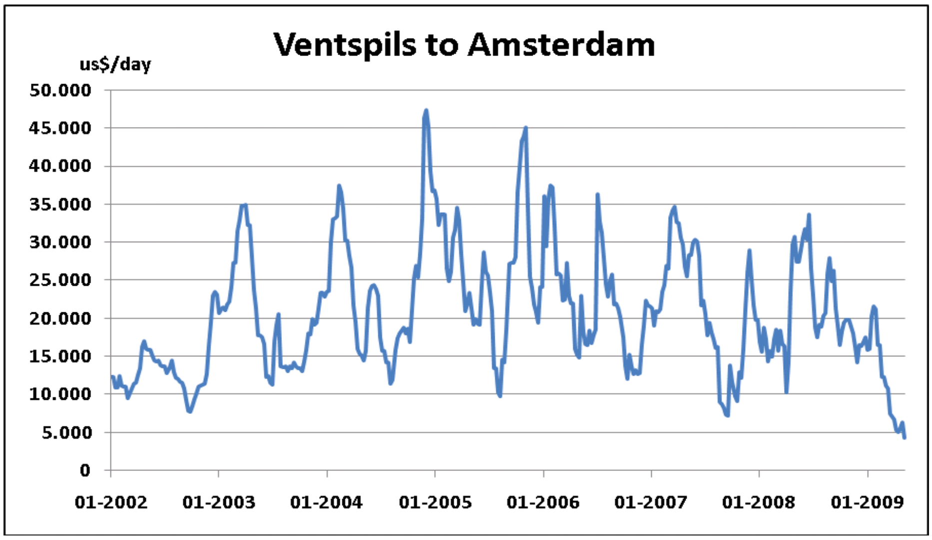
Depending on the price of the CO_2, the fee will be:

CO_2 fee US$ per Tonne CO_2	CO_2 fee for Kaliningrad to Rotterdam	CO_2 fee US$ per tonne diesel
10	9,149	0.20
30	27,447	0.59
50	45,745	0.98

The STS operation cost is estimated at US$ 20,000 covering the complete operation over two days, this gives us a cost of US$ 0.43 per tonne of diesel fuel transported.

For the freight cost from Kaliningrad to Rotterdam we have used the route Ventspils in Latvia to Amsterdam as a freight market indicator of Baltic to the Continent trade. The development of the freight rate for this route is as shown in Figure 1.

Figure 1 Freight rates from Ventspils to Amsterdam, 2002-2009



Source: Clarksons, 2009.

Historically, this route has a maximum value of US$ 47,419 per day, an average value of US$ 20,779 and a minimum value on US$ 4,336 per day.

Using these values and earlier calculations we get the following:

Freight Market	TC Equivalent US$ per day	Gross Freight	Freight US$ per tonne
Low	4,336	135,657	2.92
Average	20,779	288,058	6.19
High	47,419	534,968	11.50

Summarizing and comparing these costs we get the following estimates – see Table 2.

Table 2 Difference in costs with and without STS according to the Scenario 1

Market	Low			Average			High		
CO_2 fee	*10*	*30*	*50*	*10*	*30*	*50*	*10*	*30*	*50*
CO_2 fee Houston Rotterdam	0.45	1.35	2.25	0.45	1.35	2.25	0.45	1.35	2.25
CO_2 fee Kaliningrad-Rotterdam	0.20	0.59	0.98	0.20	0.59	0.98	0.20	0.59	0.98
STS operation Cost	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43
Freight Cost from Kaliningrad-Rotterdam	2.92	2.92	2.92	6.19	6.19	6.19	11.50	11.50	11.50
Difference	-3.10	-2.59	-2.08	-6.37	-5.86	-5.35	-11.68	-11.17	-10.66

From the calculations we can see that there is no economical incentive to perform an STS operation in our scenario (negative red numbers indicate loss in USD per tonne of cargo related to STS operation as compared to direct freight). We simplified our calculations by equaling the freight cost direct and to STS location, but the truth is that the freight cost to the STS location would actually be higher than the direct route, emphasizing this result even more.

Scenario 2

The second scenario is a more likely one, where the territorial waters of non-EU state are used. The route is again diesel fuel from Houston, the final destination is Piraeus in Greece, and the STS operation area is in the Albanian seas. The Vessel is a 47,000 dwt product vessels from the previous scenario.

New assumptions are:
- Distance from Houston to Piraeus is 6,279 nm.
- Distance from Houston to Albanian waters is approx. 6,100 nm.
- Distance from Albanian waters to Piraeus is approx. 400 nm.

The freight rate levels are based on a backhaul estimation of a Europe to US Gulf route, the same as used in the paper on potential for evasion (Faber et al., 2009).

The voyage time will then be:
- At sea: 18.04 days.
- Sea Margin 7.5 %: 1.35 days.
- In Port: 4.0 days.
- Extra: 1 day.
- **Total : 24.39 days.**

Based on these, we get the following rates for a trip from Houston to Piraeus:

Freight Market	TC Equivalent US$ per day	Gross Freight	Freight US$ per tonne
Low	2,831	291,246	6.26
Average	14,834	591,584	12.72
High	25,704	863,571.8	18.57

Next, we will calculate the CO_2 emissions and the costs related to them along this route. The vessel will be charged a CO_2 fee on the sailing leg from Houston to Piraeus and for the usage of generators in the Port of Piraeus. We adopt the same emission factors as in Scenario 1.

The vessel in this scenario consumes 33 tonne of HFO per day and 0.5 tonne of MDO per day. The MDO consumption estimation covers usage of MDO in maneuvering in and out of harbor, generator usage in harbor and also some generator usage when sailing. The trip from Houston to Piraeus takes 19.4 days. Based on these assumptions, we have calculated the CO_2 emissions at the level of 1,963.38 tonnes.

Depending on the price of the CO_2, the fee will be:

CO_2 fee US$ per Tonne CO_2	CO_2 fee for Houston to Piraeus	CO_2 fee US$ per tonne diesel
10	19,633.8	0.42
30	58,901.4	1.27
50	98,169.0	2.11

Under the EU trading scheme this route would imply the following total cost per tonne of diesel fuel shipped:

Market	Low			Average			High		
CO_2 fee	*10*	*30*	*50*	*10*	*30*	*50*	*10*	*30*	*50*
Houston-Piraeus freight cost	6.26	6.26	6.26	12.72	12.72	12.72	18.54	18.54	18.54
Houston-Piraeus CO_2 fee per Tonne	0.42	1.27	2.11	0.42	1.27	2.11	0.42	1.27	2.11
Total Shipping Cost from Houston-Piraeus	6.68	7.53	8.37	13.14	13.99	14.83	18.96	19.81	20.65

The TC equivalent freight levels for the Houston-Piraeus route and Houston-Albanian waters will be the same, but since the last route is shorter we would have to re-calculate the gross freight and freight in US$ per tonne.

The voyage time will then be:
- At sea: 17.53 days.
- Sea Margin 7.5 %: 1.31 days.
- In Port: 4.0 days.
- Extra: 2 day.
- **Total: 24.84 days.**

We have added one extra day in case of problems related to the weather and ocean conditions. Thus we get the following freight rates from Houston to the Albanian waters:

Freight Market	TC Equivalent US$ per day	Gross Freight	Freight US$ per tonne
Low	2,831	295,758	6.36
Average	14,834	593,954	12.77
High	25,704	864,001	18.58

Because of the extra day added in case of problems during the STS operations the freight levels are very similar to the Houston-Piraeus levels.

Freight levels from the Albanian waters will be a on the same levels as a cross Mediterranean trip, which we also used in the Faber et al. (2009) report. The freight rates adjusted for the Albanian waters to Piraeus are as follows:

Freight Market	TC Equivalent US$ per day	Gross Freight	Freight US$ per tonne
Low	3,981	60,446	1.30
Average	32,002	263,196	5.66
High	67,534	520,292	11.19

Finally, we have to calculate the emission fee from Albanian waters to Piraeus under the following assumptions.

- At sea: 1.15 days.
- Sea Margin 2.5 %: 0.03 days.
- In Port: 4.0 days.
- Extra: 2 day.
- **Total: 7.18 days.**

Using the same emission factor as before, we have calculated the emissions at the level of 119.4 tonnes of CO_2.

Depending on the price of the CO_2 fee will be:

CO_2 fee US$ per Tonne CO_2	CO_2 fee for Casablanca to Rotterdam	CO_2 fee US$ per tonne coal
10	1,194.0	0.03
30	3,582.0	0.08
50	5,970.0	0.13

Summarizing all the calculations, we get the following comparison of costs with and without STS along this route – see Table 3.

Table 3 Difference in costs with and without STS according to the Scenario 2

Market	Low			Average			High		
CO_2 fee	*10*	*30*	*50*	*10*	*30*	*50*	*10*	*30*	*50*
Total Shipping Cost from Houston- Piraeus	6.68	7.53	8.37	13.14	13.99	14.83	18.96	19.81	20.65
Freight Cost Houston-Albanian Waters	6.36	6.36	6.36	12.77	12.77	12.77	18.58	18.58	18.58
STS Operation Costs	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43
Freight Cost Albanian Waters-Piraeus	1.30	1.30	1.30	5.66	5.66	5.66	11.19	11.19	11.19
CO_2 Cost Albanian Waters-Piraeus	0.03	0.08	0.13	0.03	0.08	0.13	0.03	0.08	0.13
Total Shipping Cost Houston-Albania-Piraeus	8.12	8.17	8.22	18.89	18.94	18.99	30.23	30.28	30.33
Difference	-1.44	-0.64	0.15	-5.75	-4.95	-4.16	-11.27	-10.47	-9.68

On the contrary to what we thought before the calculations, there are no economic incentives for an STS operation like this except for the situation when the freight markets are low and the CO_2 emission price is high. We might have overestimated the weather risk by adding one extra day into our voyage calculations in the STS operation but still the economic loss related to using an STS option could be expected to be quite high.

5 Summary and conclusions

STS operations preformed outside the European contingency zone of 200 nm would be very difficult, as the vessels would then be at high seas, where weather and ocean conditions might not allow such operations. The only solution if a ship operator would like to use STS in order to evade the CO_2 reduction policy would be to seek such opportunities in non-EU members waters. However, according to calculations in our two scenarios, STS operations in non-EU members' waters do not seem to be profitable for ship operators, i.e. the additional costs related to STS outweigh the savings related to lower CO_2 fees. One should remember, however, that we have only looked at two scenarios and these are limited to our assumptions. There might be other trades and segments that could have better economic incentives for STS.

It should be noted that in an STS operation, the shipper can surrender his original Bills of Laden documents and the 'new' Bills of Laden can be issued by the agent with only the location of the STS operation as loading place, i.e. the tracing of the cargoes origin by the Bills of Laden is impossible.

The best way to avoid STS as an evasion technique might be to control all STS operations that happen in the EU contingency waters, and make sure that both the 'mother' ship and the feeder(s) are held liable for their emissions into EU waters. See also legal comments in Annex A.

Annex A Legal comments on STS

In designing any emissions scheme it is currently envisaged that one potential form of evasion would be ship to ship transfer (STS).

For current purposes we set out the English law position on STS transfers. In the UK, the customs authorities are not concerned with a cargo until it is imported into or exported out of the UK through a port or offshore terminal. This is the usual position outside the UK.

Consequently, an STS can take place in the UK's territorial waters (out to 12nm) or in the UK Continental shelf area (EEZ equivalent) without interference from the UK customs authorities, save for pollution and safety reasons when the activity may have to be reported to the coastguard as a precaution. Where an STS takes place in the port limits of a UK port or in UK internal waters such as Sullom Voe or Scapa Flow in the Orkney Islands, this may attract the attention of the authorities for customs purposes (but presently does not). However, it would not be difficult to extend regulations to deal with this.

Therefore, if a person wanted to avoid the emissions scheme in some way, a transhipment could take place inside or outside the territorial sea of the UK or another EU state. However, the current position is based on the premise that there is no reason why the UK or the EU would need to control STS in their territorial waters, save for the prevention of pollution.

Of course, if an emissions scheme were brought in, the regulation could, in theory, have provisions which prevent evasion by STS within territorial waters. Of course, policing this might be more difficult and thought would have to be given as to how evasion of this type would be monitored in practice as it would fall outside the scope of port authorities but it is not an insuperable problem. This would mean that any transhipment had to take place outside EU waters. Whilst this may be practicable in certain parts of the Mediterranean at certain times of the year, it seems unlikely that STS would be able to be practised on a wide scale basis outside the 12nm limit in North West Europe - the conditions prevailing in the Atlantic Ocean, North Sea and Baltic Sea would make this too risky for ship and cargo carriers.

While STS as it is currently practised may appear to pose a threat to the successful operation of an emissions reduction scheme, there is no reason why it should actually become an evasion risk under any scheme once implemented. The regulations would simply have to cover this type of evasion - for instance, where transhipment takes place within 12 nm of the EU coastline. Clearly the EU could not outlaw this practice - it is perfectly legitimate and in fact often necessary to allow parcels of cargo to be transferred from a large ship to a smaller ship to aid distribution and allow delivery to smaller ports. However, provisions could be put in place to deal with situations where transhipment has occurred so the responsible entity of the discharging ship would still have to account for the voyage into EU waters.

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Annex J

Ad-hoc paper on bunkers in possible US cap-and-trade schemes

Draft 26.10.2009
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Ad-hoc paper on bunkers in possible US cap-and-trade schemes

The **American Clean Energy and Security Act of 2009** (ACES) is an energy bill in the 111th United States Congress (H.R.2454) that would establish a cap-and-trade scheme for greenhouse gases. The bill was approved by the House of Representatives on June 26, 2009 by a vote of 219-212, and placed on calendar in the Senate on July 6. The bill is also known as the Waxman-Markey Bill, after its authors Representatives Henry Waxman and Edward Markey, of respectively California and Massachusetts, both Democrats. Waxman is the chairman of the Energy and Commerce Committee, and Markey chairs the committee's Energy and Environment Subcommittee.

The ACES consists of five titles:

• Title I, Clean Energy
• Title II, Energy Efficiency
• Title III, Reducing Global Warming Pollution
• Title IV, Transitioning to a Clean Energy Economy
• Title V, Agriculture and Forestry Related Offsets

Proposal for a cap-and-trade scheme

This ad-hoc paper will limit its scope to ACES' Title III, which includes the bill's proposal for a cap-and-trade system. What is described and analyzed below is the version adopted by the House of Representatives. The objective of the ad-hoc paper is to find out how the bill treats bunker fuels sold in the United States for use in international transport.

The scheme will cover carbon dioxide, methane, nitrous oxide, sulfur hexafluoride, hydrofluorocarbons (HFCs) from a chemical manufacturing process at an industrial stationary source, perfluorocarbons, and nitrogen trifluoride as GHGs and establishes a carbon dioxide equivalent value for each of these gases. It sets mandatory caps on 87 per cent of US greenhouse gas emissions.

The cap

The emissions covered by the scheme will be reduced from 4,627 million ton in 2012 to 1,035 in 2050 (Part C, Sec. 721e). The emission reduction cap targets are:

- 2012: 3% below 2005 emission levels (~12% above 1990 emission levels)
- 2020: 17% below 2005 (~4% below 1990)
- 2030: 42% below 2005 (~33% below 1990)
- 2050: 83% below 2005 (~80% below 1990)

The cap brings in covered sources in three phases from 2012 through 2016. Natural gas liquid-, petroleum-, and coal-based liquid fuel producers/importers will be covered from 2012 if their products when combusted emit over 25,000 tons annually.

Allocation and use of allowances

The scheme allocates 85 per cent of the allowances to industry for free, auctioning the remainder according to the discussion draft summary.

Auctions shall be held four times per year at regular intervals, with the first auction to be held no later than March 31, 2011, and follow a single-round, sealed-bid, uniform price format. They shall be open to any person but no person may, directly or in concert with another participant, purchase more than 5 per cent of the allowances offered for sale at any quarterly auction. The minimum auction price shall be $10 (in constant 2009 dollars) for auctions occurring in 2012. The minimum price for auctions occurring in years after 2012 shall be the minimum reserve auction price for the previous year increased by 5 percent plus the rate of inflation (sec. 791, pg 943-946).

The free allowances are distributed in a number of ways to support various federal and state programs (both existing and established under the Act) and benefit energy consumers. The amount of value directed to various purposes changes over time (Part H, Sec. 781-790, pg. 862-942). Because of the rules governing the distribution of allocations under the Act, industries reliant on liquid petroleum fuels will bear a greater share of the cost of the cap-and-trade program than industries like electric power producers.

Unlimited trading of allowances is permitted by any party (not restricted to owners and operators of covered entities). All allowances will be tracked in an allowance tracking system (Sec. 724, pg. 752). Banking of allowances and offsets is not limited (Sec. 725, pg. 754).

A covered entity's allowable emissions level for each calendar year is the number of emission allowances (or offset credits or other allowances) it holds as of 12:01 a.m. on April 1 (Sec. 222, pg 734).

Allowances can be used for compliance for emissions in the calendar year preceding the vintage year. There is no limit on this type of borrowing (Sec. 725, pg. 755) and no interest has to be paid. However, up to 15 per cent of an entity's compliance obligation can be met through submission of allowances with a vintage year 1-5 years later than that calendar year. For each allowance borrowed under this rule, the borrower needs to submit additional allowances to meet an 8 per cent annual interest fee (Sec. 725, pg. 756).

The strategic reserve

The bill proposes that a strategic reserve shall be established. Quarterly auctions will be held to auction strategic reserve allowances. Only covered entities will be eligible to purchase allowances from the auction (Sec. 726, pg. 757). The following percentage of allowances will be held annually by the Administrator for the auction:

- 2012-2019: 1% of allowances for that year
- 2020-2029: 2% of allowances for that year
- 2030-2050: 3% of allowances for that year

The reserve will also contain allowances not sold in previous auctions. There will be a minimum price on allowances auctioned from the strategic reserve. The 2012 minimum price will be $28, and the 2013 and 2014 price will be the price set for 2012, plus 5 per cent above the rate of inflation. From 2015 and onward the minimum price will be 60 per cent above a rolling 36-month average of the daily closing price for that year's allowance vintage.

Not more than 20 per cent of a covered entity's compliance obligation may be purchased from the strategic reserve annually. The Administrator shall establish a separate purchase limit for new entrants, starting at a minimum of 20 per cent.

The auction proceeds will be placed in a strategic reserve fund. The fund will be used to purchase international offset credits from reduced deforestation. The Administrator will retire those credits and establish emissions allowances equal to 80 per cent of the number of offset credits retired. These allowances will be placed back into the strategic reserve to fill it to its original size (Sec. 726, pg. 763).

Under certain circumstances (very high offset use and a full exhaustion of strategic reserve allowances at any given auction), entities may sell at auction additional forest offsets above and beyond allowances sold at strategic reserve auctions. These offsets are not subject to the purchase limits in place for strategic reserve allowances or use limits in place for international offsets (Sec. 726, pg. 765).

Offsets

Covered entities may offset part of their emissions. However, there will be a system-level offset limit. No more than 2 billion tons of offsets annually may be used for compliance (Sec. 722, pg. 740). Covered entities may satisfy a percentage of their compliance obligation with offsets each year. This number is divided pro rata among covered entities.

This percentage limit varies year to year and is determined by the Administrator by dividing the number 2 billion by the sum of 2 billion plus the number of emission allowances in the previous year's allowance budget and multiplying that number by 100 (for example, the 2013 limit will be 30% of an entity's compliance obligation and the 2050 limit will be 66%) (Sec. 722, pg. 741).

Of the total offsets allowed, not more than half can come from domestic offsets and not more than half can come from international offsets. However, if the Administrator determines that less than 0.9 billion tons of domestic offsets are available, the Administrator can increase the use of international offsets, and decrease by a corresponding amount the domestic offset limit up to a maximum of 1.5 billion international tons and a minimum of 0.5 billion domestic tons (Sec. 722, pg. 744).

The rules for offsetting include provisions for project approval, verification, verification accreditation, credit issuance, and auditing. The Administrator shall establish provisions to address additionality, leakage, uncertainty, permanence, and variances from methodologies (Sec. 734, pg. 785).

The Administrator, in consultation with the Secretary of State and Administrator of USAID, may issue international offset credits based on projects that avoid, reduce or sequester emissions in developing countries (Sec. 743, pg. 805). Such credits may be issued only if: 1) the US is a party to a bilateral or multilateral agreement that includes the country in which the project has occurred, 2) such a country is a developing country, 3) the agreement ensures all requirements of legislation apply and provides for appropriate disposition of offsets (Sec. 743, pg. 805). Beginning in 2018, a covered entity must surrender 1.25 offset credits in lieu of 1 allowance for any international offset credits (Sec. 722, pg. 743).

Offset credits may be issued for projects identified by the Administrator under Sec. 733, through an approved international body, sectoral crediting mechanisms, or international reduced deforestation as outlined in legislation (Sec. 743, pg. 805). The Administrator can issue credits in exchange for credits issued by an international body established by the UNFCCC, a protocol to such convention or a treaty that succeeds such a convention, as long as those credits were generated through a program that creates equal or greater assurance of the environmental integrity of the U.S.

The treatment of international bunker fuel

The entities covered by the Act include any stationary source that produces, and any entity that (or any group of two or more affiliated entities that, in the aggregate) imports, for sale or distribution in interstate commerce in 2008 or any subsequent year, petroleum-based or coal-based liquid fuel, petroleum coke, or natural gas liquid, the combustion of which would emit 25,000 or more tons of carbon dioxide equivalent, as determined by the Administrator (Sec. 700(13)(B). For a covered entity described in that section (pg 847), one emission allowance must be submitted for each ton of carbon dioxide equivalent of greenhouse gas that would be emitted from the combustion of any petroleum-based or coal-based liquid fuel, petroleum coke, or natural gas liquid, produced or imported by such covered entity (Sec. 722).

The meaning of interstate commerce

For understanding the geographical scope of the scheme, the key element of section 700(13) is "for sale or distribution in interstate commerce". Interstate commerce in US constitutional law concerns any commercial transactions or traffic that cross state boundaries or that involve more than one state (Encyclopedia Britannica). However, the official definition (49 CFR 390.5) is detailed and reads:

Interstate commerce means trade, traffic, or transportation in the United States:

(1) Between a place in a State and a place outside of such State (including a place outside of the United States);

(2) Between two places in a State through another State or a place outside of the United States;

or

(3) Between two places in a State as part of trade, traffic, or transportation originating or terminating outside the State or the United States.[1]

Interstate commerce is thus a broad term that does not necessarily apply to physical distribution and use of products but instead applies to the legal status of such products as they flow through the US economy. More importantly the use of the term interstate commerce applies to the point where the fuels subject to the ACES enter the US economy, not to when and where they are used. This means that bunker emissions from fuel sold in the US are under the cap. The Waxman-Markey bill, and so far the Kerry-Boxer bill (of the US Senate) contain the same language requiring refiners and importers of petroleum fuels that sell products into interstate commerce to hold allowances to cover the emissions attributable to those sales.

1 http://www.fmcsa.dot.gov/rules-regulations/administration/fmcsr/fmcsrruletext.aspx?section=390.5

The Kerry-Boxer bill

Action has now moved to the Senate, where the Environment and Public Works Committee has taken up its own climate legislation. Senators John Kerry (D-Mass.), Chairman of the Foreign Relations Committee, and Barbara Boxer (D-Calif.), Chairman of the Committee on Environment and Public Works, recently introduced the Kerry-Boxer bill, officially known as the **Clean Energy Jobs and American Power Act** to the US Congress, which more or less mirrors the American Clean Energy and Security Act of 2009. The definition of the liable entity is identical to that of the ACES, meaning that any entity that imports, for sale or distribution in interstate commerce in 2008 or any subsequent year, petroleum-based or coal-based liquid fuel, petroleum coke, or natural gas liquid, the combustion of which would emit 25,000 or more tons of carbon dioxide equivalent are subject to the Act.

Other Senate committees, including the Energy and Natural Resources Committee, Commerce Committee, Agricultural Committee, Finance Committee and the Senate Foreign Relations Committee, are likely to take actions on parts of the legislation that fall within their jurisdiction. Then, the Senate leadership will need to pull these various parts together for a vote on the Senate floor.

If the Senate does pass a bill, it will need to be reconciled with the American Clean Energy and Security Act. To become law, the joint legislation would then receive a final vote in both chambers, before being sent to the president for signing.

The European legislation

The EU ETS Directive of the EC covers CO_2 emissions from large stationary sources but no other greenhouse gases. Only about 40 per cent of all GHG are covered. For CO_2 the share is approximately 50 per cent. A decision has been taken to reduce the cap by 21 per cent between 2005 and 2020. In 2012 the EU ETS will be widened to include emissions from commercial aircraft, for journeys that start or end in EU airports.

No other transport modes are covered but the Community has decided to prepare itself for the eventual situation that the International Maritime Organization does not succeed in taking a decision on how to cut emissions of CO_2 from international shipping. A consortium comprising the authors of this paper has argued in a consultancy report to the European Commission that one of the policy instruments that could be used to address CO_2 emissions from maritime transport is a cap-and-trade scheme. In such a scheme, ships' emissions would be included from the port of loading to an EU port.

The EU ETS allocates responsibility and free allowances based on a down-stream approach. The end-user of fossil fuel is thus responsible for the submission of allowances (or credits).

Analysis

The American emissions trading system is based on a combination of up- and down-stream allocation of responsibility. The liability for emissions from transport fuels lies with the importer or producer, based on an up-stream approach.

Bunker fuel used in international transport is not part of the nation states greenhouse gas inventories under the Kyoto Protocol but are, nevertheless, covered by the proposed American cap. According to the UNFCCC[2], the United States for 2007 reported 170,661 million tons from domestic aviation and 45,022 tons from domestic navigation. The corresponding figures for international bunkers were respectively 52,740 and 56,016 tons.

When the ACES becomes law, US carriers that enter the EU will not have to purchase and surrender EU allowances for the outbound part of the trip, because aviation will be included in climate policy in the home country, as provided for in the EU ETS Directive. However, there may be some transition needed for 2012 and 2013 as US refineries specifically need allowances as of 2014.

As mentioned above, the report on regional climate policies for shipping proposes that the geographical scope of a European emissions trading scheme for ships should be limited to emissions from port of laden to EU port. With the current design of ACES, this means an obvious risk of double-counting. A problem in this context is that all fuel that a ship bound for Europe bunkered in an American port may not be used for that specific journey.

The adoption by the IMO and/or the ICAO of universal schemes for emissions trading will most likely require the American legislation (if based on the current proposals) to be changed with regard to emissions from internal bunker fuel.

Interestingly, the Bush-era predecessor of the Waxman bill, the Liebermann-Warner Bill, had an amendment introduced by Senator Boxer which exempted fuel for international flights where it was covered 'by the laws of another country'. This provision was made with a view to the EU ETS, in order to avoid double-counting, but could easily be amended to refer to a global deal for aviation. A similar amendment of the ACES would serve two purposes; to make it unambiguous that international bunkers are included in the scope of the bill, and show a way to avoid double-counting.

Linking with the EU ETS

According to the proposed ACES, the Administrator may by rule allow allowances from other trading programs that are at least as stringent as the US program. Entities may initially use an unlimited number of international allowances for compliance, though the Administrator has the authority to restrict their use (Sec. 728, pg. 774). As emissions subject to the EU ETS cap for 2020 must be reduced by at least 21 per cent, entities under the ACES should be free to import allowances issued under the EU ETS.

Whether the EC can accept American allowances to count under the EU ETS is a different matter but should in principle be possible as the ACES does not include a cap on the price of allowances, only a floor price. However, as noted above, from 2015 and onward the minimum price of allowances auctioned from the strategic reserve will be 60 per cent above a rolling 36-month average of the daily closing price for that year's allowance vintage. That means that the strategic reserve may act as a ceiling for the price in the American market. If Europe becomes a net-buyer in the allowance trade with the US, it will push the American price up-wards. However, the current ACES does not include any prohibition on American net-sales, and it would anyway, presumably be difficult to enforce as anyone is free to buy American allowances and can use them, scrap them or sell them to entities abroad.

2 http://unfccc.int/di/DetailedByParty/Event.do?event=go

Two systems, bunker fuels caught in the middle?

The different approaches taken by the US and the EU may result in overlapping or conflicting jurisdiction over emissions of movable sources that emit both in the US and in the EU. Bunker fuels used in international aviation and maritime transport may in some instances be covered by both schemes.

One way to avoid double counting could be to align the systems in their treatment of bunker fuels. The EU could decide, for example, to incorporate bunker fuels upstream. However, this would risk carbon leakage, especially for maritime bunkers.

Aircraft usually take enough fuel for the trip plus a certain amount for contingency. If there is a price difference in fuel at several locations, however, airlines may choose to tanker fuel, i.e. to take as much fuel on board as possible on the airport where fuel is cheap, so that they have to buy less at the airport where fuel is expensive. As taking off with a full aircraft costs more fuel, a complicated calculation has to be made to determine whether it's worthwhile to tanker and if so, how much. The US emissions trading scheme will rise fuel prices in the US and thus increase the incentive for tankering, but tankering will be contained by the fact that it costs fuel to lift fuel. Hence, carbon leakage of this sort is unlikely to occur on a large scale in aviation.

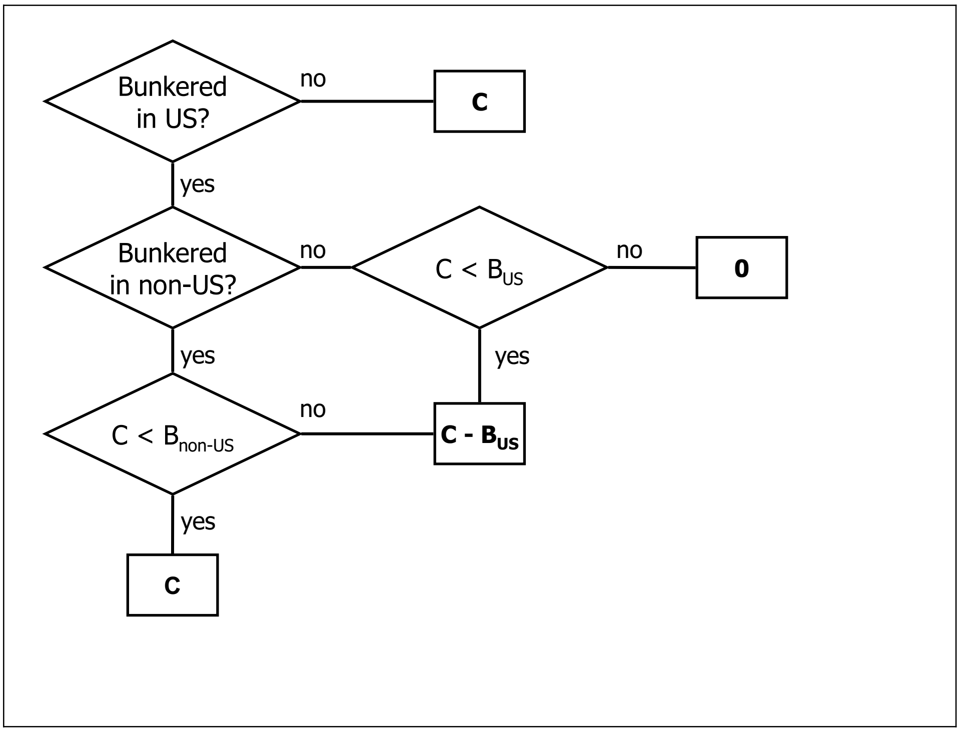
Ships usually bunker where bunker is cheap. As they can sail large distances on a full tank, they have several options to choose from. In contrast to airlines, ships do not pay a large penalty for sailing with full tanks. There is evidence that bunker sales are very sensitive to price differences (LOA, 2001, Michaelis, 1997). Therefore, it is to be expected that the inclusion of maritime bunker fuels in an upstream cap-and-trade scheme will significantly reduce bunker fuel sales in the US. Extending the upstream approach to the EU could exacerbate avoidance and is undesirable for that reason.

However, as stated above, if both systems exist in parallel, the opposite of carbon leakage could occur, viz. double counting. The same emissions could be subject to two systems, which would be economically inefficient.

The risk of double counting emissions would be largest for ships that bunkers in a US port and uses the fuel to sail to an EU port. To reduce this risk, fuel bunkered in the US and used on voyages to EU ports could be excluded from the EU scheme. It is feasible to do so, although it may require a good administrative system, because both bunker fuel purchases and bunker fuel consumption on voyages have to be monitored in a verifiable way.

The way in which fuel sold in the US and consumed on a voyage to the EU could be excluded from a European cap-and-trade scheme is as follows. If a ship has bunkered fuel in the US prior to sailing to an EU port, emissions from this fuel are excluded from the emissions under the scope of an EU cap-and-trade scheme. A special situation occurs when a ship has bunkered in the US and subsequently in a non-US location. In this case, the liability depends on the relative size of fuel consumption on the voyage in the scheme, and the amounts of fuel bunkered in different locations. Figure 1 shows a flow chart signifying the amount of emissions under the EU scheme in different situations.

Figure 1 Flow chart for excluding emissions from fuels bunkered in the US



Note: C – the amount of emissions in the geographical scope of the EU cap-and-trade scheme; B_{US} – the amount of emissions from fuels bunkered in the US; $B_{non\text{-}US}$ - the amount of emissions from fuels bunkered in the outside the US.

The flow chart of Figure 1 would have to be followed for every voyage of ships in the EU, except for ships that have not bunkered in the US in the reporting period. It is not possible to estimate the number of ships that would have to go through this administrative procedure. We think, however, that this will only be a small share of ships in the scope of the EU cap-and-trade scheme for the following reasons:

- DLR model results show that 6% of the emissions on voyages to EU ports are on ships that departed from a North American port. Likewise, 6% of the emissions of voyages from ships departing from EU ports are on routes to North America. While the number of ships that visit a North American port in a reporting period may be larger than this share, it is unlikely that a majority of ships visits North American ports in any year, let alone bunker there.

- The share of bunker fuels sold in North America ranged from 6% - 10% of the global sales in the years 2004-2006 (EIA, 2009). For comparison, Europe's share ranged from 29% - 31%. Taking into account the result from the DLR model that 21% of bunker fuel is consumed on voyages to the EU, even in the very unlikely case that all fuel bunkered in the US would be consumed on voyages to the EU, 29% - 48% of emissions on routes to the EU would be from fuels bunkered in the US. In reality, this share will be much smaller since much of the fuel bunkered in the US will be consumed on voyages to other destinations.

However, another way of avoiding the problem of double-counting would be for the EU and the US to jointly initiate a convention on CO_2 emissions from international bunker fuels, which means these emissions would neither be covered by the EU ETS nor by the American cap-and-trade scheme.

Conclusions

The current drafts of cap-and-trade schemes in the US would incorporate emissions of maritime transport through the emissions of fuels bunkered in the US. Such a system is different from a system where emissions of the ship would be incorporated directly. The different treatment of maritime transport emissions carries the risk that these emissions will be covered by two schemes, which is economically inefficient and can be considered inequitable to the maritime transport sector.

In order to avoid double coverage of emissions, bunkers sold in the US and consumed on voyages to the EU could be excluded from the coverage of the EU ETS when extended to international shipping emissions. Doing so would increase the administrative burden of the system for a limited number of ships.

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