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Greenhouse Gas Emissions for Shipping and Implementation Guidance for the Marine Fuel Sulphur Directive

Report

Delft, December, 2006

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Preface

This report has been written for the European Commission, DG Environment, under contract 070501/2005/420196/MAR/C1 by a consortium comprising of CE Delft, Germanischer Lloyd, MARINTEK and Det Norske Veritas. Additional support has been given by the Netherlands Institute for the Law Of the Sea (NILOS).

The authors would like to thank all the organisations and individuals who have provided information, commented on drafts, or participated in stakeholder meetings. We especially would like to acknowledge the European Community of Shipowners Associations (ECSA) for inviting us to one of their Air Emissions Working Group meetings, Terje Gloersen of Norges Rederiforbund for commenting on task 4, and several shipowners for kindly providing data on CO_2 indexes for task 2.

Apart from this report, the deliverables of this project comprise an electronic version of a tool to calculate the IMO CO_2 index, suited for on-board use, and a database of CO_2 index trial results.

The authors

Contents

1 Introduction

Maritime transport is an important mode of transport for the European Union, with over 90% of its external trade and some 43% of its internal trade going by sea. The maritime sector is also important from an economic point of view. Maritime companies belonging to European Union nationals control one third of the world fleet and some 40% of EU trade is carried on vessels controlled by EU interests.

The environmental record of maritime transport is mixed. On the one hand, sea shipping is relatively climate friendly. Emissions of greenhouse gases per amount of transport work are low compared to other modes. In absolute terms, greenhouse emissions from shipping are significant. Emissions of greenhouse gases from sea shipping are rising due to the increase in the global trading of goods. Currently, fuel originating greenhouse gases from shipping are not subject to any policy measures.

On the other hand, sea shipping is an important source of air pollutants. Especially in coastal areas and harbours with heavy traffic, the contribution of shipping emissions to air pollution is substantial.

In November 2002 the European Commission presented an EU strategy to reduce atmospheric emissions from seagoing ships. The atmospheric emissions include both air pollutants such as sulphur dioxide and greenhouse gases like carbon dioxide. Among other things, the strategy has resulted in an amended Directive on the sulphur content of marine fuel (Directive 2005/33 amending Directive 1999/32). This Directive came into force in August 2005. Its first provisions, for the Baltic Sea, are due to be implemented on 11 August 2006, and provisions for the North Sea within a year of that date.

In order to reduce greenhouse gas emissions from shipping, the Commission will work with the IMO to ensure that its greenhouse gas strategy is concrete and ambitious. However, since the IMO has not yet adopted a concrete, ambitious strategy, the Commission is considering taking action at EU level to reduce ships' unitary emissions of greenhouse gases.

At this stage, the Commission believes it would be helpful to produce guidance on the implementation of Directive 2005/33 for both the shipping industry and Member States. Furthermore, the Commission will encourage the development of the CO_2 index by the IMO and assess policy options to reduce greenhouse gas emissions from sea shipping. The Commission has therefore asked a consortium of CE Delft (leading contract partner), MARINTEK, Det Norske Veritas (DNV) and Germanischer Lloyd (GL) to:

1 Develop implementation guidance for the Marine fuel sulphur directive 2005/33.
2 Contribute to further development of the IMO CO_2 index.

3 Inform the committee process on abatement technologies for Directive 2005/33 by providing a detailed technical report.
4 Provide a report that identifies effective and feasible climate policies for international shipping.

1.1 Project organisation

The project has been executed from December 2005 until December 2006. Four organisations contributed to it.

CE Delft has been the leading contract partner and played the leading role in Task 4 (climate policy for ships). CE Delft has also contributed to other tasks and has assumed responsibility for the overall quality of the work.

Germanischer Lloyd has played the leading role in Task 1 (implementation guidance for the sulphur directive). It has also contributed to Task 2 (the IMO CO_2 index) by bringing in its in-depth knowledge gained from preparing the calculations and papers on the CO_2 index trials for the German government.

MARINTEK has led Task 2 (CO_2 index). Furthermore, MARINTEK has closely collaborated with CE Delft on Task 4.

Det Norske Veritas (DNV) has played a leading role in Task 3 (information on abatement technologies). In addition, it has contributed to Task 1 (implementation guidance for the sulphur directive).

Table 1 summarises the project organisation.

Table 1 Project organisation

Task		CE Delft	Germanischer Lloyd	MARINTEK	DNV
1	Implementation guidance for 2005/33/EC	Associate contributor	Lead partner	Associate contributor	Main contributor
2	IMO CO_2 index	Associate contributor	Main contributor	Lead partner	
3	Inform committee process on abatement technologies		Associate contributor		Lead partner
4	Develop and assess climate policies for shipping	Lead partner		Main contributor	

1.2 Outline

This draft final report comprises four sections that can be read independently. The first and third sections focus on sulphur emissions of shipping, more specifically on the Marine Fuel Sulphur Directive (2005/33/EC), whereas the second and fourth section focus on greenhouse gas emissions of maritime transport.

Section A contains guidance for the implementation of the directive. Section B describes the current experiences with the IMO CO_2 index and provides recommendations for its use. Section C is a technical report on sulphur abatement technologies. Section D develops and assesses policy options for the reduction of greenhouse gas emissions of shipping.

All the individual sections contain executive summaries and conclusions.

PART A

Germanischer Lloyd

Client: European Commission Directorate General Environment	**Client's ref.:** Service Contract N° 070501/2005/420196/MAR/C1 Tender ENV.C.1/SER/2005/0077

Title:

Greenhouse Gas Policy for Shipping, and
Implementation Guidance for Marine Sulphur Directive
Task 1: Implementation Guidance for Directive 2005/33 (Interim Report)

Abstract:

With regard to the enforcement of EU Directive 2005/33/EC the report describes different compliance options, their design and construction as well as resulting operational procedures. A short overview of estimated capital and operational costs is given. As a guidance for Administrations, the shipping industry and other parties involved, inspection and enforcement messures are described.
Finally some ideas on additional enforcement action are presented.

Germanischer Lloyd, department „ Combustion Engines“ (NPC)

Performance	Released by
Dr.-Ing. Reinhard Krapp, Head of Department ERD Dipl.-Ing. Hans-Joachim Götze, Head of Department Responsible expert(s) in charge	Dipl.-Ing. Claus Hadler, Head of Competence Center Ship propulsion and electrical systems

Revision No.: Interim Report	**Date of latest revision:** 2006-07-10	
Keyword(s)	**No. of pages**	**Status**
Exhaust Gas Emissions Diesel Engine Fuel Sulphur Content	in main body : 48 in attached tables : - in attached figures : - in other appendices : 28	☐ Preliminary ☒ Final ☐ GL internal
	Report No.: NPC 2006.145 **GL Order No.:** 7620 05 62279 43 **GL Reg. No.:** - **Ref. no.:** 06-21748	

2 General approach

2.1 Directive 2005/33EC

Referring to Directive 2005/33/EC with regard to the sulphur content of marine fuels enforcement of the obligations is necessary in order to achieve the aims set out in the Directive. This study aims to give Member States some guidance in establishing enforcement action with respect to vessels flying their flag as well as to vessels under any other flag while in their ports. Moreover, the study takes into consideration the requirements deriving from IMO MARPOL Annex VI, Regulation 14 (sulphur oxides) and Regulation 18 (fuel oil quality) in order to harmonize enforcement, inspection and control mechanisms. Member States should also be aware of the necessity to promote measures to ensure that local fuel oil suppliers make compliant fuel available in sufficient quantities to meet the demand. Recommendations concerning enforcement and inspection measures are given in section 3 of the study.

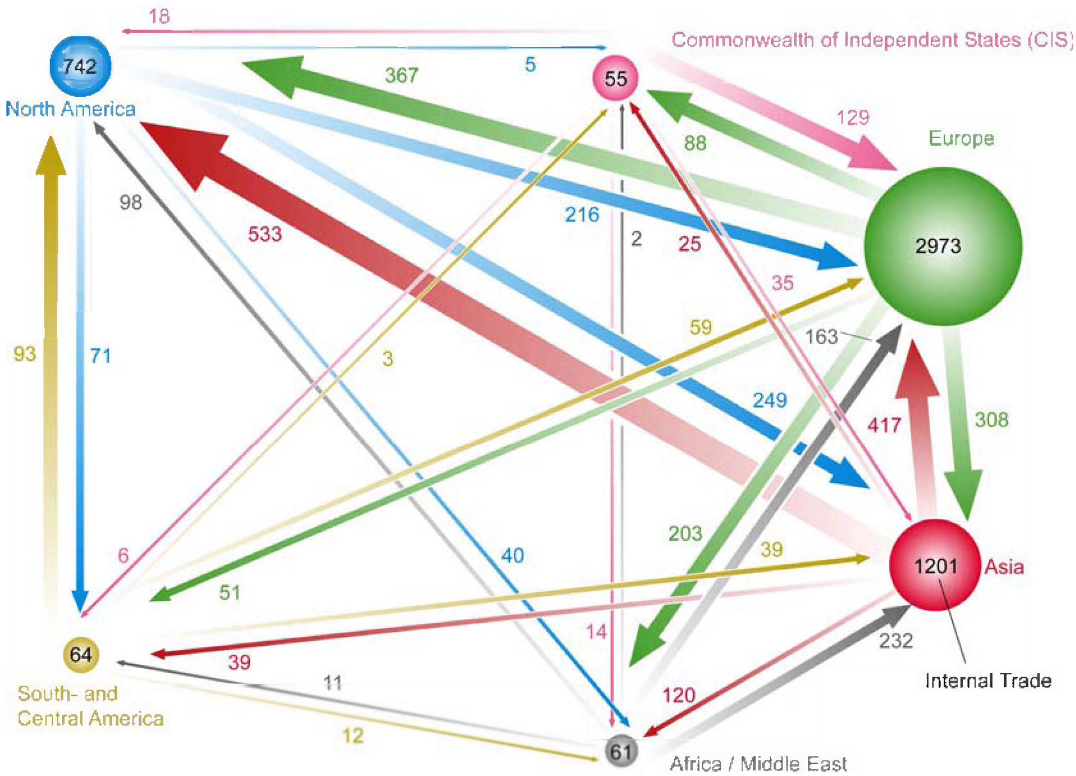
Within the Community it is intended to come to close cooperation between the Member States in taking additional enforcement action with respect to non-EU flagged vessels. This topic is addressed in more detail in section 4 of this report.

In order to present an overview, this report starts with specifying different compliance options including certain requirements concerning design, construction and operation of ship machinery, taking into account also available and possible future abatement technologies. With regard to the aim of prevention of air pollution from ships whilst at berth technical and commercial questions concerning the possibilities of using shore side electricity are highlighted. The study is intended as a guidance for ship operators to prepare for the forthcoming requirements and consider possible retrofit measures for ships.

2.2 Ship operation in European waters

Safe, reliable and environmentally as friendly as possible shipping is of vital interest for the European Union and the Member States. This is underlined by the international exchange of goods especially with North America and Asia as graphically represented in Figure 1. The inter-European trade with East and Central Europe is also significant, as well the trade within West Europe.

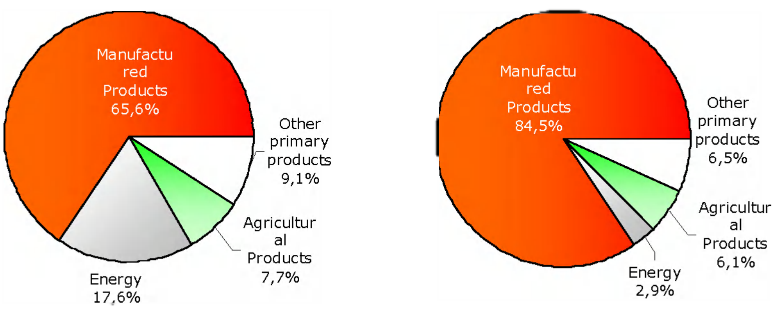
Figure 1 World trade of 2004, Flow of goods in billion US$



Source: WTO.

The following graph (Figure 2) shows a classification of goods that are imported or exported. EU internal trade is not included in these graphs. Biggest shares of import have Manufactured Products and Energy; the export is dominated by Manufactured Products.

Figure 2 Structure of EU-external trade



EU Imports of Goods 2004 EU Exports of Goods 2004

Source: DG Trade.

With regard to ships and maritime transportation the approach of number of port calls (Table 2) and transport volume expressed as sum of BRZ of ships (Table 3) approaching European ports is of interest.

Table 2 Number of European port calls

	Number of Ships 2004					
	Q1	Q2	Q3	Q4	2004	%
Total	448,583	535,439	724,582	582,051	2,290,655	100,00
Liquid bulk	24,525	24,873	30,454	29,479	109,331	4.77
Dry Bulk	9,010	9,497	14,402	14,872	47,781	2.09
Container	19,614	19,825	28,499	30,227	98,165	4.29
Cargo, specialized	5,855	6,537	11,640	11,556	35,588	1.55
Cargo, non-specialized	257,713	291,669	324,079	280,764	1,154,225	50.39
Passenger / Ferry	118,627	165,408	241,208	144,685	669,928	29.25

Source: EUROSTAT.

Table 3 Sum of BRZ of ships approaching European ports

	Sum of BRZ of Ships 2004					
	Q1	Q2	Q3	Q4	2004	%
Total	2,836,710	3,190,588	4,291,823	4,079,341	14,398,462	100.00
Liquid bulk	281,466	290,378	326,059	334,531	1,232,434	8.56
Dry Bulk	109,465	112,878	151,202	156,667	530,212	3.68
Container	348,243	350,920	424,523	488,762	1,612,448	11.20
Cargo, specialized	107,872	115,259	150,708	158,721	532,560	3.70
Cargo, non-specialized	1,741,889	1,919,860	2,202,220	1,997,921	7,861,890	54.60
Passenger / Ferry	202,258	290,733	520,384	424,980	1,438,355	9.99

Source: EUROSTAT.

2.3 Ship types and routes

Due to that data the frequency of ship approaches is dominated by non specialized cargo ships and passenger / ferry ships whereas to the amount of cargo again non specialized ships, but the container ships and liquid bulk carriers contribute most. The ship types listed in both tables cover approximately 92% both of numbers and sum of BRZ. Based on the restrictions from the budget the five ship types listed in Table 4) were selected.

Table 4 Selected ship types

Route	**Ship Type**	**European Ports**	**Ship Type EUROSTAT**
Channel-Hamburg-Channel	Large container ship	Several during approach and departure to far east	Container
Baltic Sea-North Sea and back or vice versa	Container Feeder ship, General Cargo	One port at end of each leg, to be decided	Cargo, non specialised
Baltic Sea	Passenger/RoRo-Ferry	2 Ports	Passenger/Ferry
Channel-Rotterdam-Channel	Large Tanker	Rotterdam	Liquid bulk
Channel-Gothenburg-Channel	Car Carrier	Gothenburg	Cargo Specialised

2.4 Selected ships

For the following investigations of fuel exchange detailed information about the fuel systems of the ship is necessary. This information is not publicly available. Therefore for the above ship types ships were selected with available information in the files of the Classification Society or by co-operation of the owner.

2.4.1 Large container ship

Maine Particulars

Dead weight	63,533 dwt
No. of 20 ft. containers	4,545 TEU
Length over all (LOA)	294.15 meter
Breadth	32.20 meter
Design draught	13.00 meter
Design speed	23.7 knots

Fuel consumer details

System	Type	Installed power	Specific consumption
Propulsion machinery	One set 2-stroke slow speed diesel engine	MCR: 41,040kW NCR: 34,900 kW	120 t/d[1]
Auxiliary machinery	Three sets 4-stroke medium speed diesel engine	2 sets à 1,650 kW 1 set à 1,470 kW	3.6 t/d[2]
Boiler			2.7 t/d

As to Fairplay data base the typical fuel consumption is given as 150.6 t/d.

Tank capacities

Tank	No of tanks	Capacity [m^3]	Tank arrangement
HFO settling	2	180 / 160	Figure 4
HFO service	1	120	

2.4.2 Container Feeder ship, General Garco

Main particulars

Dead weight	15,350 dwt
No. of 20 ft. containers	1,216 TEU
Length over all (LOA)	158.70 meter
Breadth	25.60 meter
Design draught	9.20 meter
Design speed	21.5 knots

[1] Onboard measurement.

[2] Onboard measurement.

Fuel consumer details

System	Type	Installed power	Specific consumption
Propulsion machinery	One set 2-stroke slow speed diesel engine	MCR: 17,760kW NCR: 15,105 kW	173 g/kWh
Auxiliary machinery	Three sets 4-stroke medium speed diesel engine	3 sets 1,118 kW each	190 g/kWh

As to Fairplay data base the typical fuel consumptions is given as 69 t/d.

Tank capacities

Tank	No of tanks	Capacity [m^3]	Tank arrangement
HFO settling	1	37	Figure 3
HFO service	1	42	

2.4.3 Passenger/RoRo-Ferry

Maine particulars

Dead weight	6,802 dwt
Passenger / Cargo capacity	2,613 lane m / 174 trailers 740 Passengers
Length over all (LOA)	190.77 meter
Breadth	29.50 meter
Design draught	6.20 meter
Design speed	23.0 knots

Fuel consumer details

System	Type	Installed power	Specific consumption
Propulsion	Electric Motors		
Diesel generators	Five sets 4-stroke medium speed diesel engine	2 sets à 7,200 kW 2 sets à 6,300 kW 1 set à 2,880 kW	17.9 t/d[3]
Boiler			8.5 t/d[4]

Tank capacities

Tank	No of tanks	Capacity [m^3]	Tank arrangement
HFO settling	2	95.9 / 95.9	Figure 5
HFO service	2	51.4 / 51.4	

[3] Onboard measurement.

[4] Onboard measurement.

2.4.4 Large Tanker

Main particulars

Dead weight	317,000 dwt
Cargo oil tanks capacity	352,000 m^3
Length over all (LOA)	330 meter
Breadth	60 meter
Design draught	21 meter
Design speed	15.5 knots

Fuel consumer details

System	Type	Installed power	Specific consumption
Propulsion machinery	One set 2-stroke slow speed diesel engine	MCR: 30,000 kW NCR: 25,000 kW	167 g/kWh
Auxiliary machinery	Three sets 4-stroke medium speed diesel engine	3 sets 1,300 kW each	184 g/kWh
Cargo boilers	Two sets oil fired boilers	Evaporation 50,000 kg/h, Steam pressure 16 kg/cm^2	min/max at low load 415/3,646 kg/h

Tank capacities

Tank	No of tanks	Capacity [m^3]	Tank arrangement
L.S. HFO settling	1	100	Figure 5
L.S. HFO service	1	150	
H.S. HFO settling	1	200	
H.S. HFO service	1	200	

2.4.5 Car Carrier

Main particulars

Dead weight	16,000 dwt
Gross tonnage	60,000 tonnes
Cargo hold capacity	6,500 RT43-units
Length over all (LOA)	200 meter
Breadth	32 meter
Design draught	9.5 meter
Design speed	20 knots

Fuel consumer details

System	Type	Installed power	Specific consumption
Propulsion machinery	One set 2-stroke slow speed diesel engine	MCR: 13,500kW NCR: 12,000kW	167 g/kWh
Auxiliary machinery	Three sets 4-stroke medium speed diesel engine	3 sets 1,300 kW each	184 g/kWh
Cargo boilers	One composite boiler, oil fired	Evaporation 1,600 kg/h, Steam pressure 0.69 MPa.	2.5 t/day

Tank capacities

Tank	No of tanks	Capacity [m^3]	Tank arrangement
L.S. HFO settling	1	30	Figure 5
L.S. HFO service	1	50	
H.S. HFO settling	1	50	
H.S. HFO service	1	70	

3 Compliance options

In the context of the task to discuss the consequences of SECAs, the term “Lead Time” as mentioned in terms of reference of this task needs to be defined in more detail. A survey with an internet translation tool (LEO) revealed the following possible meanings of the term ‘Lead Time’:

1 Cycle time, throughput time, running time.
2 Period of supply, delivery time.
3 Handling time, time to market.
4 Time for preparation.

Out of these meanings “Handling time” and “Time for preparation” seem to fit best, however, there are still different possibilities as to what or who is addressed. This could be:

1 The Fuel suppliers’ necessary time to build up an adequate infrastructure for bunkering. An example could be the supply of low sulphur fuel in Singapore for vessels in round the world trade.
2 The necessary time for guaranteed availability of sufficient low sulphur fuel.
3 The necessary time for the vessel to change fuel before entering the SECA, depending on design of the fuel system, current fuel consumption, etc.
4 The necessary time for installation of newly required equipment onboard ships (tanks, pumps, valves, etc.).
5 The necessary time for Administrations to establish a regime of survey, inspection and enforcement.
6 The time needed for the industry to develop new abatement technologies for market.

The above collection shows the complexity of the task. Since information necessary for items 1, 2, 4, 5 and 6 of the above list will be difficult and time consuming to establish and will vary significantly from case to case, in the context of the project main emphasis is laid on the operational lead time of the vessels. Here valuable input is expected that may assist in developing reasonable regimes for the Administrations, thus possibly reducing their necessary lead time.

3.1 Different approaches

Main fuel consumers onboard any type of ship are combustion engines for ship propulsion and for a ship type dependent amount of auxiliary energy, as there are electricity and heat. Oil burners are used in boiler plants for steam/heat production. Besides propulsion, typical energy consumers on board are, for instance:

- Bow and stern thrusters.
- Hydraulic systems.
- Heavy fuel oil storage tanks (heating).
- Processing and heating of fuel.

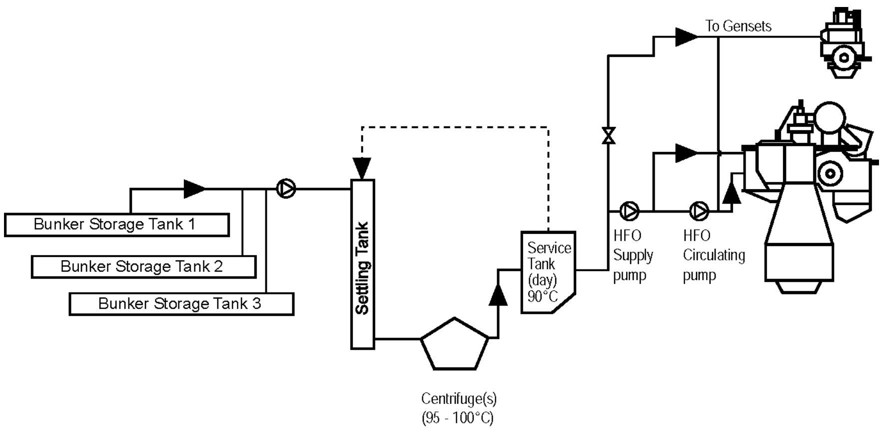
- Reefer containers.
- Navigational equipment.
- Electronic control of machinery.
- Air conditioning.
- Water production.
- Hotel (lifts, cooking, lighting, etc.).
- Cranes.
- Loading and unloading pumps onboard tankers.
- Production of inert gas for oil tanks.

For the necessary power supply auxiliary diesel generators, shaft generators driven by the main engine, boilers can be installed. On so called “all electric ships” the propeller is driven by an electric motor where the electric energy generally is produced by Diesel engine driven generators (diesel engines in these kind of machinery systems are considered to be propulsion engines, although they also provide electrical power to the ships accommodation, etc., even while at berth).

As a basis for this study, typical arrangements of fuel systems onboard ships shall be discussed ending up in the description and assessment of options which may be suitable to get in compliance with the Directive’s requirements.

As a result of the development ship machinery plants following the oil price crisis of the late 1970ties the fuel system of most seagoing ships is designed according Figure 3.

Figure 3 Fuel system of a one fuel ship

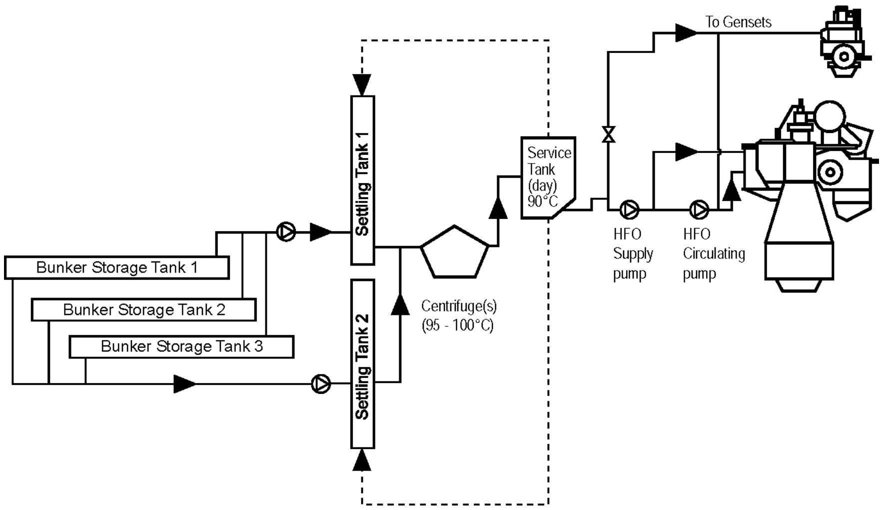


If no reconstruction of the fuel system is made, these ships would have to blend the existing fuel with low sulphur fuel before entering the SECA. This will also apply for future operation of auxiliary engine at berth with fuel of 0.1% sulphur content.

This operation has the danger of fuel incompatibility. When e.g. switching from HFO to a (distillate) fuel with a low aromatic hydrocarbon content, the

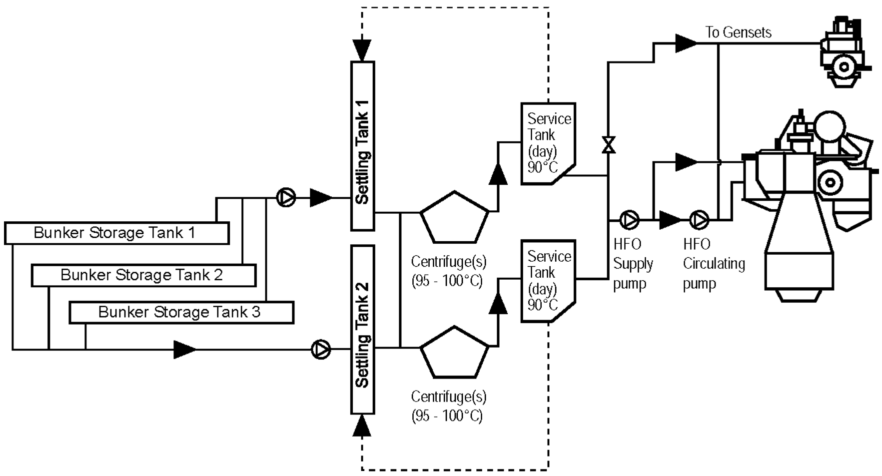
asphaltenes of the HFO are likely to precipitate as heavy sludge, with filter clogging as a possible result, and consequent lack of fuel at the engine. /1/.
Figure 4 shows a fuel system with 2 settling tanks. Here one settling tank could be totally emptied and filled with LSF. When blending both fuels in the service tank, any excess fuel could be returned to the HSF- settling tank, thus preventing to spoil the LSF. The results would be similar to the solution above with low level settling tank and adjusted purifier throughput. The advantage of this solution is that the control effort and the risk of malfunction would be lower.

Figure 4 Fuel system with 2 settling tanks



In Figure 5 also the service tank is doubled. This solution is the optimum from the operational point of view and minimises any incompatibility effects, however, it requires structural and space opportunities. Pay back could be realised by fuel savings during the blending periods of the other solutions.

Figure 5 Fuel system with 2 settling and 2 service tanks



3.1.1 Lubrication of engines operating on LSF

Acid corrosion in cylinder liners is basically the result of a condensation of the HFO sulphur compound. The corrosion is caused by the combination of water being present during the combustion process, and a thermodynamic condition where the temperature and pressure are below the dew point curve of the sulphur trioxide.

Even though the water mist catcher of the scavenge air cooler removes water droplets, the scavenge air is saturated with water vapour when entering the cylinder.
In order to neutralise the acid, the cylinder lube oil contains alkaline components – usually calcium salts. The Base Number (BN or TBN) is a measure of the cylinder lube oil's ability to neutralise acid. The higher the BN, the more acid can be neutralised. The BN is therefore an important parameter in controlling the corrosion on the cylinder liner surface. If the neutralisation of the acid is too efficient, the cylinder liner surface has a risk of being polished, i.e. the lube oil film is damaged and the risk of scuffing increases.

Therefore, running on low-sulphur fuel is considered more complex due to the relationship between liner corrosion and scuffing resistance, dry lubrication properties from the sulphur content (or lack of same), the interaction between the BN in the cylinder oil and the detergency level, possible surplus of alkaline additives, the piston ring pack, etc. /1/.

For 2-stroke engines, when the sulphur content in the fuel is above 1.5%, the use of approved 70BN cylinder oil is recommended by /1/. Where the sulphur content in the fuel is below 1.5%, approved 40BN cylinder oil is recommended. When following these target BN values, the recommended feed rate and all other operational settings can be applied irrespective of the fuel sulphur content.

If low sulphur heavy fuel oil (LSHFO) qualities have high ash content and if the lubricating oil consumption is on the higher side (e.g. no anti-polishing ring), there may be a risk for excessive ash deposit formation in the combustion chamber, exhaust valves and turbocharger for 4-stroke engines.
The recommendations are /2/:

- HFO engines starting to alternate between HFO and LSHFO or LFO can typically continue with the same lubricating oil as before.
- HFO engines starting to operate continuously on LSHFO can often start using lubricating oil with lower BN.
- HFO engines starting to operate continuously on LFO should start using lubricating oil with lower BN.
- Avoid operation with high-sulphur fuel and too low BN.
- Arrange lube oil systems with more flexibility.
- Establish lubricating oil BN monitoring equipment and routines.

3.1.2 Use of one type of fuel for any operation

One simple option to comply with the fuel sulphur requirements is to operate the combustion machinery on board a vessel with fuels only having a sulphur content in no case more than 1.5% S /m/m. This approach may be appropriate for ships sailing in SECAs only and for passenger ships engaged between resp. to and from ports of the Community on regular service from the date of enforcement of the Directive, as applicable. This option should also be considered by ship operators for vessels which leave a SECA only for short trips. Ships with a fuel oil system installed similar to that drawn in Figure 3 above could easily match the requirements.

However, it needs to be kept in mind that from 1 January 2010 also these ships are obliged to take measures to run its fuel burning machinery with a fuel not exceeding 0,1% S m/m whilst at berth in ports of the Community unless using shore side electricity is not foreseen.

3.1.3 Use of different types of fuel

In opposite to the option as described in 3.1.1 most vessels engaged in the overseas trade will head for the option to use High Sulphur Fuel Oil (HSFO) when sailing outside the designated areas and switching to Low Sulphur Fuel Oil (LSFO) when entering and operating in SECAs. Dependent on the arrangement of the fuel oil system installed on board, different fuel changeover procedures might apply. Technical issues are given in more detail in section 3.2.2.

3.1.4 Use of exhaust gas cleaning systems

The Directive expressively emphasizes the option to achieve reduction of the emissions of sulphur oxides from ships by using exhaust emission abatement technologies instead of burning low sulphur fuel. The current state of available technology and future possible developments is dealt with in Task 3 of the overall study in more detail.

Any abatement technology requires additional installations on board and results in transformation of one type of emission into another one that will be dealt with easier. Currently seawater scrubbing seems to be the most appropriate solution. Some more details are given in section 3.2.3. The topic is covered by Task 3.

3.1.5 Use of shore side electricity

Whilst at berth ships operation requires auxiliary energy for various purposes, for instance:

- Drive of hydraulic pumps.
- Heating of fuel oil storage tanks.
- Pre-heating of cooling water for combustion engines.
- Power supply for reefer containers.
- Communication/nautical equipment.
- Deck machinery/cranes.

- Air conditioning.
- Hotelling (lifts, cooking, lighting, etc.).
- Loading/unloading pumps onboard tankers.
- Production of inert gas for oil tanks.

The power demand of the various ship types, especially container ships provided for the carriage of a great number of reefer containers, cruise ships and oil tankers can be several Megawatt. Ports operating big container terminals may clear ten or even more large carriers at a time. Necessary electrical capacities need to be established by the port utility companies in order to serve the demand.

It may be considered to provide electrical energy to ships at berth from the local shore side grid. Shore side energy supply might be advantageous compared to the use of marine gas oil with a sulphur content equal or below 0.1% S m/m, especially for large bore auxiliary diesel engines, or compared to the use of exhaust gas cleaning devices.

In recent years several pilot projects have been established for using shore-side electricity on board, however, these systems are suitable only for certain ships docking at the same berths always. The basic problem today is that no international standards exist which define the technical requirements in detail for systems to satisfy high power demands. Furthermore, also questions of responsibility and liability need to be addressed.

Existing rules from classification societies concerning shore-side electricity connection address certain safety aspects already, but do not cover the necessary standardisation for a global introduction of ‘High Power’ connections.

Safety requirements for port personnel as well as for ship’s crew need to be regulated as far as not yet not regulated by respective accident prevention rules established by the port Administration and the ship’s flag state’s manning rules. Shore side requirements for mains quality, installation, license for switching by certified personnel are defined in Standards as the German DIN, VDE, by utilities, port authorities and fire protection rules of the port states, for instance.

However, according to present view the responsibilities for safety of personnel and the liability for establishing and operation of such connections are undefined or at least not clear. Quality requirements for the supplying mains are not defined and the requirements by the port’s utility company with respect to the ship’s mains need to be specified. It seems to be obvious that in every single case contractual agreements are necessary concerning mutual liability for personal injury of crew and port staff in case of accident, in case of damages onshore due to onboard mains or in case of damages onboard due to onshore mains failure.

For information: Germany and Sweden have submitted a joint paper to the IMO Marine Environment Protection Committee (MEPC) calling upon the Committee to consider and, if deemed appropriate, to invite the International Standards

Organization (ISO) to initiate a process of international standardization for shore connection systems that may be used for connecting ships to the shore power supplies (paper MEPC 54/4/3). This document is supported by a submission by Friends of the Earth International (FOEI) who urge MEPC further to set a timeline for installing shore power capabilities in ships and at ports. The papers will be considered at the 54th session of MEPC end of March, 2006.

Technical aspects and cost estimations are given in section 3.2.4 below.

3.2 Design, Construction and operation

3.2.1 One fuel operation – overall Low Sulphur operation

One fuel operation is required for ships:

- Only operating within the SECA.
- Operation of passenger ships on a regular basis between ports of the European Union;

and may be an economical solution for ships that operate only for a short time outside of SECAs.

The operation itself is not different form one fuel operation with high sulphur fuels as today. However the engine manufacturer may require different lubrication oils for safe operation of the engines.

3.2.2 Use of different types of fuel – Fuel switching

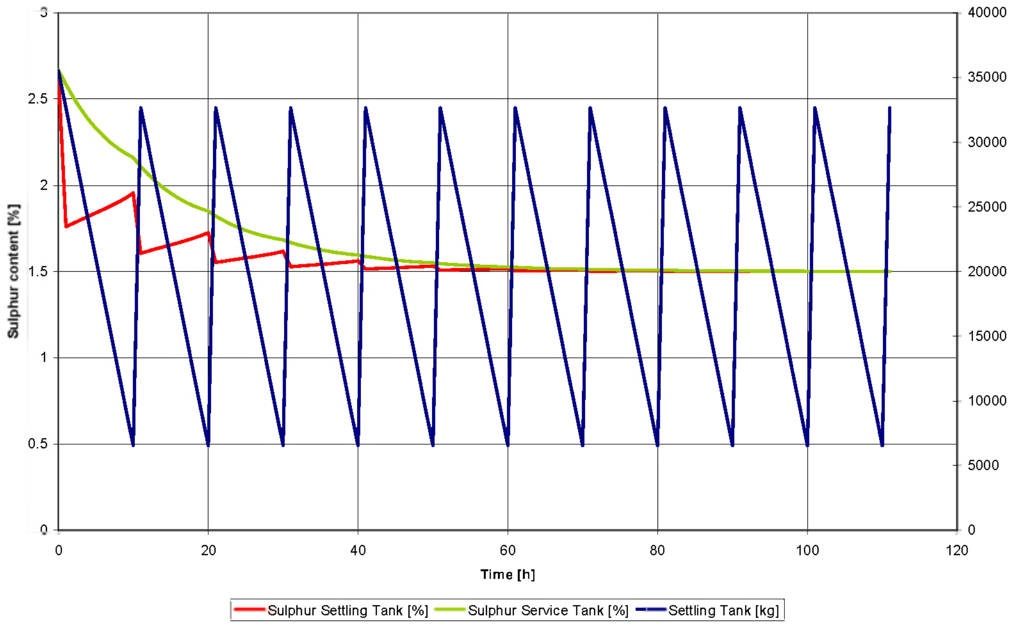
The feeder ship (Section 2.4.2) was taken as reference for the following investigation of various situations of switching from HSF to LSF for a one fuel ship with a fuel system according Figure 3.

For the calculation a simplified procedure was developed, assuming that both purifiers and fuel delivery to the engines operate at nominal volume flow. Excess fuel is returned to the service tank and from there to the settling tank. The fuel consumption of all engines is also taken as constant. High sulphur (HSF) and low sulphur fuel (LSF) are blending ideally in both tanks with no incompatibility. The calculation is based on time intervals of 1 hour.

Both tanks are filled up to 98%. The level of the service tank is taken as constant. The settling tank is emptied to 20% and then filled also up to 98%. For simplicity reasons in calculation it was assumed that the filling can take place in one hour. At the start of calculations the service tank is full of high sulphur fuel, the settling tank contains a mixture of 20% of high sulphur fuel and 78% of low sulphur fuel.

The first calculation considers a fuel consumption of 69 t/d and the blending of fuels with 2.67 and 1.5% sulphur respectively. The calculation was stopped, after the sulphur content in the settling tank reached a value below 1.501% (Figure 6). Simultaneously to filling of the settling tank the service tank is fed with purified fuel. In this simplified calculation with the large time steps therefore the maximum filling can not be seen in the graphs.

Figure 6 Blending of fuels with 2.67% and 1.5% sulphur



As a result of the blending of both fuels in the settling tank its sulphur content is reduced to 1.75%. The fuel in the service tank at the beginning still has 2.67% sulphur content. The purification plant feeds the maximum required file flow to the service tank. Fuel not consumed by the engines is returned to the settling tank. As a result its sulphur is rising again. The calculation stopped after 111 h with a sulphur content of 1.5009%. The deviation is probably not any more measurable, however formally the requirement is not yet fulfilled. To reach this result, the settling tank was filled 11 times with more than 310 tons of low sulphur fuel that was burnt before entering the SECA. With a service speed of 20 kts the fuel changeover should have started approximately 1,879 nm before the border of the SECA.

This result leads to the consequence that when blending is necessary the sulphur content of the low sulphur fuel should be below 1.5% to fulfil the requirement. The influence of this value on the necessary time and the amount of low sulphur fuel needed before entering the SECA is shown in Table 5) and Figure 7. The amount of LSFO was calculated from the number of filling operations of the settling tank and does not reflect the actual fuel consumption.

Table 5 Variation of sulphur contents (SH – Sulphur content high [%], SL – low [%])

Necessary lead time [h] before entering of SECA

SH\SL	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4
1.75	4	4	4	5	6	7	8	11	14	21
2.00	7	7	8	10	11	12	14	16	21	29
2.25	10	11	12	12	14	15	17	21	25	34
2.50	12	13	14	15	16	18	21	24	29	38
2.75	14	14	15	17	19	21	23	26	32	42
3.00	15	16	17	19	21	23	25	29	34	44
3.25	17	18	19	21	22	24	27	31	36	46
3.50	18	20	21	22	24	26	29	33	38	48
3.75	20	21	22	23	25	27	31	34	41	51
4.00	21	22	23	25	26	29	32	36	42	52
4.25	22	23	24	26	28	31	33	37	43	53
4.50	23	24	25	27	29	32	34	38	44	54

Fuel consumption [t] before entering of SECA

SH\SL	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4
1.75	1.89	1.89	1.89	2.73	3.68	4.73	5.86	9.72	14.53	28.13
2	4.73	4.73	5.86	8.33	9.72	11.23	14.53	18.15	28.13	46.62
2.25	8.33	9.72	11.23	11.23	14.53	16.31	20.05	28.13	37.08	59.16
2.5	11.23	12.83	14.53	16.31	18.15	22.00	28.13	34.77	46.62	69.62
2.75	14.53	14.53	16.31	20.05	24.00	28.13	32.51	39.42	54.06	80.31
3	16.31	18.15	20.05	24.00	28.13	32.51	37.08	46.62	59.16	85.74
3.25	20.05	22.00	24.00	28.13	30.29	34.77	41.79	51.54	64.36	91.22
3.5	22.00	26.03	28.13	30.29	34.77	39.42	46.62	56.60	69.62	96.74
3.75	26.03	28.13	30.29	32.51	37.08	41.79	51.54	59.16	77.61	105.06
4	28.13	30.29	32.51	37.08	39.42	46.62	54.06	64.36	80.31	107.86
4.25	30.29	32.51	34.77	39.42	44.20	51.54	56.60	66.98	83.02	110.66
4.5	32.51	34.77	37.08	41.79	46.62	54.06	59.16	69.62	85.74	113.46

From both tables and the figure the influence of the sulphur content can be taken. Within the variation of data that were investigated, a factor of 10 occurs between shortest and longest lead time.

Table 6 shows the corresponding variation of fuel consumption between 30% and maximum with similar differences between lead times on the one hand and low sulphur fuel consumption on the other before entering the SECA. The lower the fuel consumption of the machinery is the higher lead time and low sulphur fuel consumption are (Figure 8). For the calculations the high sulphur content was assumed as 2.67%.

Figure 7 Lead time as function of sulphur content of fuels

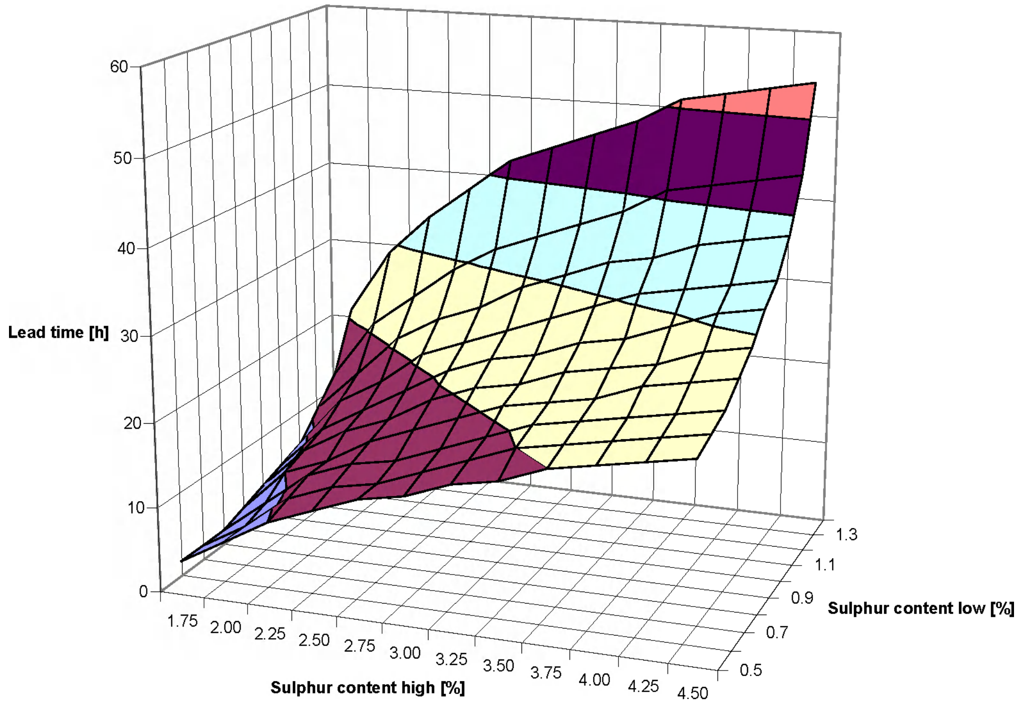


Table 6 Variation of fuel consumption and low sulphur content (Mcons- fuel consumption [t/d]. SL – Sulphur content low [%])

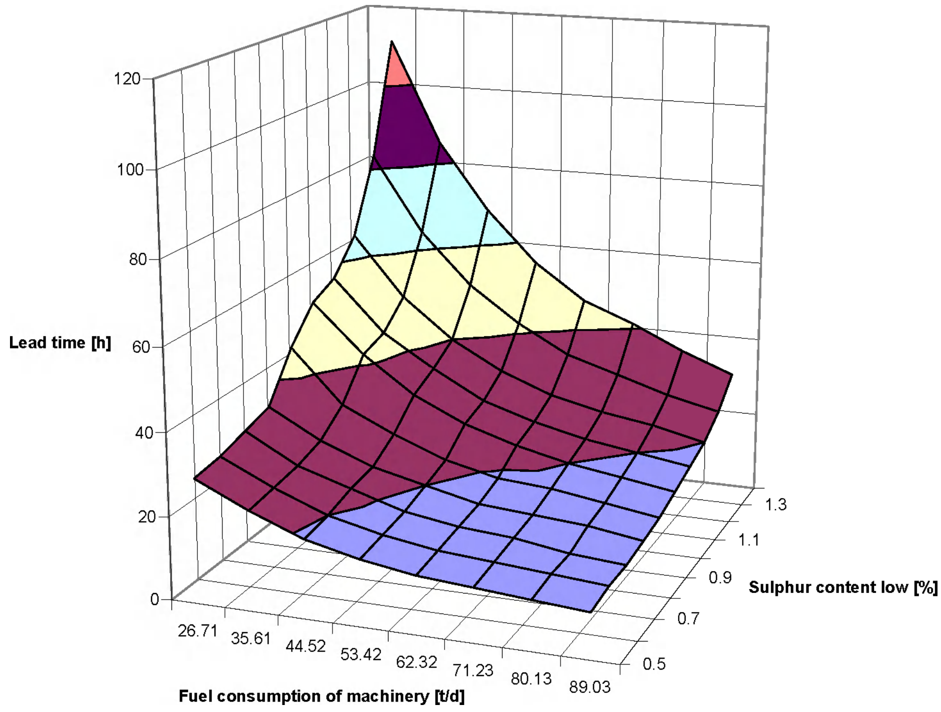
Necessary lead time [h] before entering of SECA

Mcons\SL	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4
26.71	30	31	33	35	46	54	57	65	83	111
35.61	24	25	26	28	33	42	44	50	64	85
44.52	19	20	22	23	27	33	36	40	51	68
53.42	16	17	18	20	22	27	29	33	42	55
62.32	14	15	16	17	19	23	25	28	35	46
71.23	13	14	15	16	18	20	22	25	31	41
80.13	12	13	13	15	16	18	20	23	27	35
89.03	11	12	12	13	14	16	18	20	24	30

Fuel consumption [t] before entering of SECA

Mcons\SL	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4
26.71	12.42	13.06	14.39	15.77	23.75	29.73	32.20	39.17	55.45	83.14
35.61	13.14	14.00	14.89	16.74	21.57	30.64	32.84	39.80	56.82	84.62
44.52	12.51	13.57	15.80	16.96	21.81	29.41	33.54	39.37	56.18	84.41
53.42	12.40	13.68	15.01	17.81	20.73	28.39	31.70	38.68	55.34	81.37
62.32	12.45	13.95	15.53	17.16	20.55	27.76	31.65	37.78	52.92	78.63
71.23	13.22	14.97	16.79	18.69	22.66	26.81	31.20	38.19	53.07	79.85
80.13	13.66	15.65	15.65	19.91	22.16	26.86	31.86	39.82	51.06	75.11
89.03	13.73	15.94	15.94	18.29	20.74	25.94	31.51	37.39	49.88	69.92

Figure 8 Lead time as function of machinery fuel consumption and sulphur content of low sulphur fuel



Another possibility to influence the blending process would be to empty the settling tank as far as possible. This would require special attention during the blending process. In the calculation a value of 5% was used for the minimum filling level of the settling tank. Sulphur concentrations are 2.67% and 1.4% respectively. The results are shown in Figure 9. In comparison to a calculation with 20% minimum level the necessary lead time is reduced from 41 to 38 h, the LSF consumption before entering the SECA is reduced from 141 t to 135 t. The sulphur content in the settling tank is characterised by an increase near the low filling level, depending on the current concentration in the service tank.

If as further improvement the fuel flow through the purifier is adjusted to the current fuel consumption, then the necessary lead time and LSF are reduced again to 69 h and 113 t (Figure 10). Combination with a low level in the settling tank of 5% leads to 36 h and 101 t of LSF (Figure 11). In this case the sulphur content could be closer to 1.5% but still has to be below that value.

Figure 9 Blending procedure with low minimum filling level in settling tank

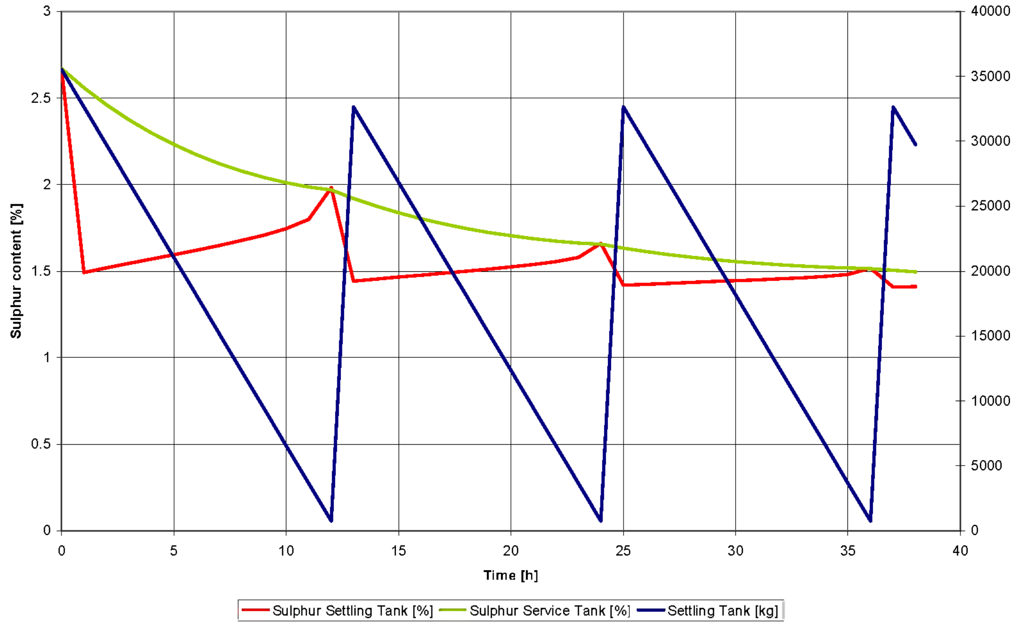


Figure 10 Fuel blending with adjustment of purifier flow to fuel consumption of machinery, low level of settling tank 20%

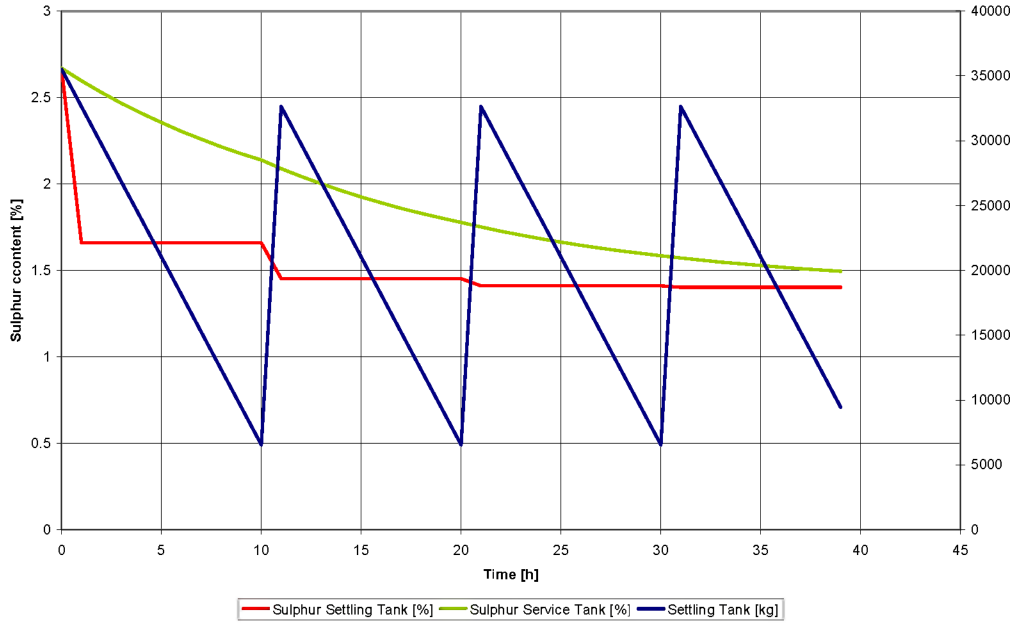
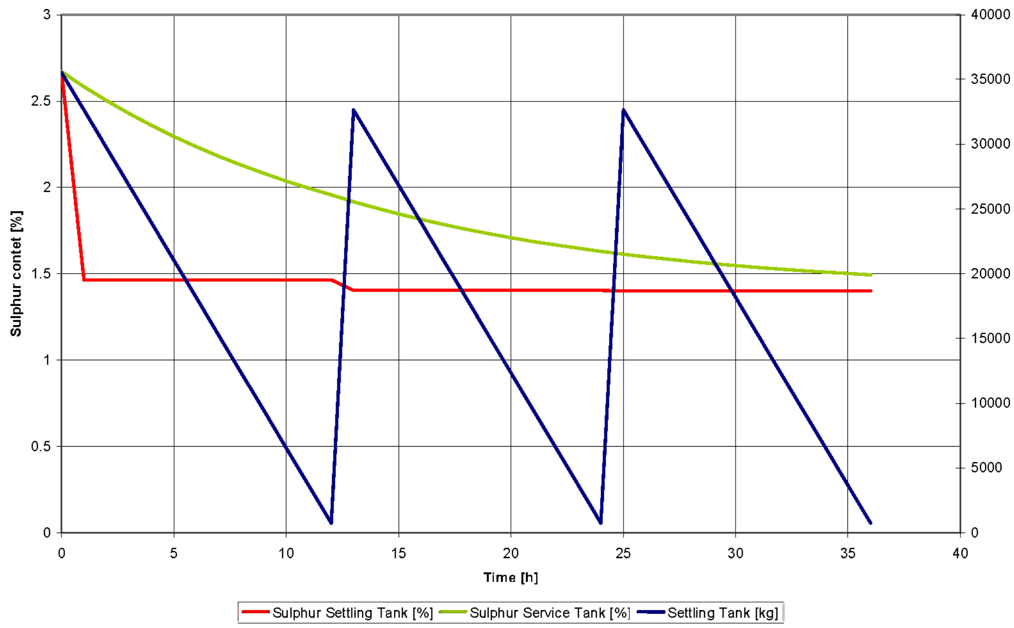


Figure 11 Fuel blending with adjustment of purifier flow to fuel consumption of machinery, low level of settling tank 5%



The results of the investigations so far are that when blending is necessary the lead time and the consumption of low sulphur fuel depend strongly on:

- Tank sizes in relation to nominal fuel consumption.
- Sulphur content of both fuels.
- Actual fuel consumption.
- Low level in the settling tank before filling with LSF.
- Adjustment of purifier flow to fuel consumption.

In any case there is a significant amount of LSF that has to be spent before entering the SECA that could be saved if for LSF operation special settling and service tanks could be installed. If the possibilities are given, the money saved for “unnecessary” combustion of LSF could be used for pay back of the investment.

As shown in the series of calculations above there are savings possible with adjustment of the operation of the fuels system during changeover. However, the requirements with regard to control of the changeover and the risk of malfunction increase with LSF savings.

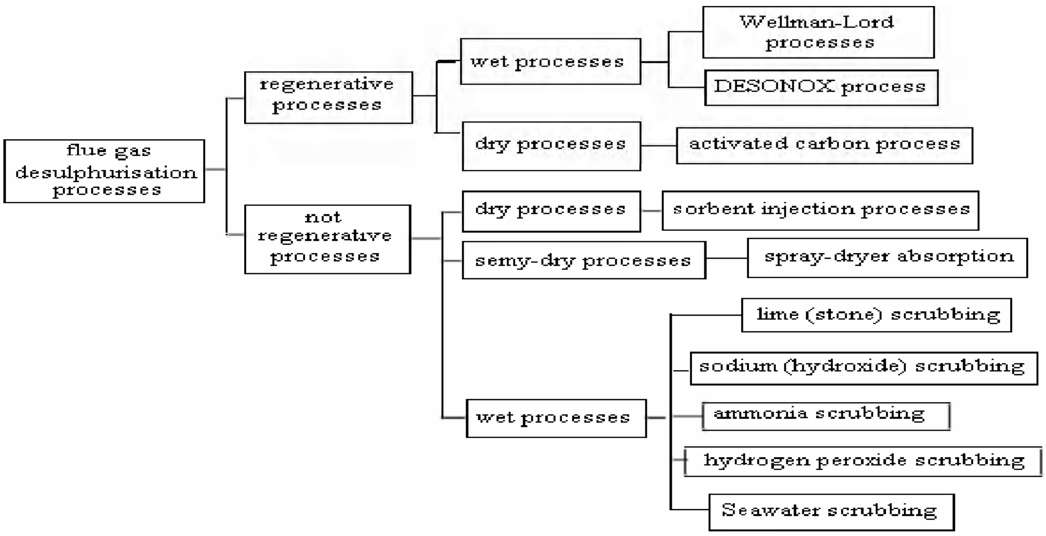
Figure 4 shows a fuel system with 2 settling tanks. Here one settling tank could be totally emptied and filled with LSF. When blending both fuels in the service tank, any excess fuel could be returned to the HSF settling tank, thus preventing to spoil the LSF. The results would be similar to the solution above with low level settling tank and adjusted purifier throughput. The advantage of this solution is that the control effort and the risk of malfunction would be lower.

In Figure 5 also the service tank is doubled. This solution is the optimum from the operational point of view and minimises any incompatibility effects, however, it requires structural and space opportunities. Pay back could be realised by fuel savings during the blending periods of the other solutions. This solution requires more investment but gives highest safety of operation.

3.2.3 Exhaust gas cleaning systems

The following graph (Figure 12) shows a wide variety of possible option for exhaust gas desulphurisation, however, the option to be most feasible for shipboard application seems to be the seawater scrubbing.

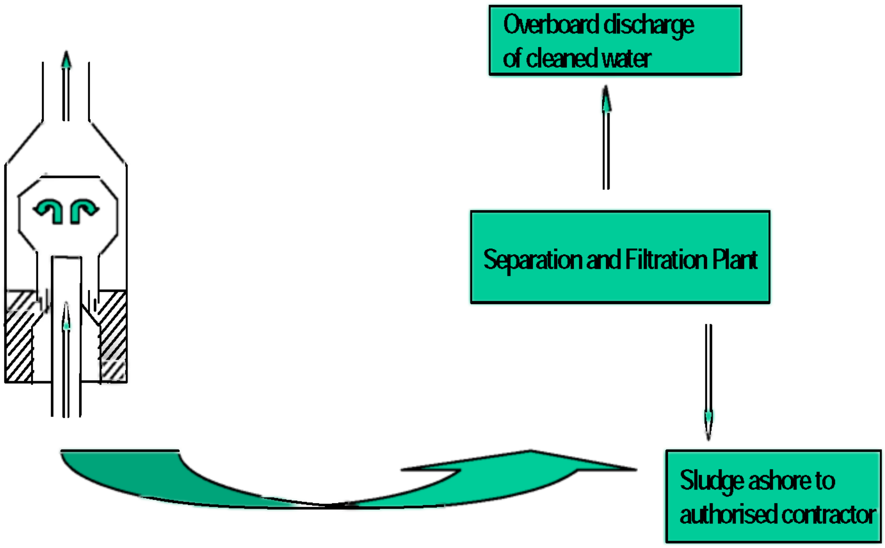
Figure 12 Exhaust gas desulphurisation options /4/



When SO_x comes into contact with seawater there is a fast and efficient reaction between the SO_x and Calcium Carbonate ($CaCO_3$) in the seawater, to form Calcium Sulphate (gypsum) and CO_2. The reaction neutralises the acidity of SO_x, and consumes some of the buffering capacity of the seawater. The reaction is complete in a very short time, so the equipment to bring the exhaust gas with SO_x and the seawater into contact can be compact and still achieve high reduction efficiencies (~95%).

However, it must be clear that this reaction depends on the $CaCO_3$-content of the available water and therefore the performance will be difficult in brackish and fresh water. Moreover one source of emissions is transformed into another type that will have to be treated on board. The humidity of the exhaust gas leaving the scrubber will be laden with sulphuric acid not converted in the scrubber.

Figure 13 Basic principle of seawater scrubber /5/



Considering the operation of an auxiliary engine with an output of 1 MW, running on HFO with 3% S and near 100% abatement this would require 82 tons of seawater per hour and produce 460 kg $NaHSO_3$ or similar salts per day. The use of brackish water alone could easily **triple** the water need for full Sulfur cleaning. For a main engine with 20 MW the corresponding values are 1.640 tons of sea water per hour and 9.2 tons $NaHSO_3$ or similar salts per day, burning HFO with 3% S. Near 100% abatement.

More details will be found in the report that covers Task 3 about the following technical solutions:

- *Krystallon sea water scrubber*, on board trials for half a year. Assumed ready for market in 2007.
- *Advanced Vortex Chamber*, testbed investigations in summer 2006. Onboard trials remain to be done. Assumed available for market late 2007 or 2008.
- *Wärtsilä Marine Scrubber*, testbed investigations in summer 2006. Onboard trials remain to be done. Assumed available for market late 2007 or 2008.
- *EcoSilencer*, ready for market, although only tested on smaller engines (1 MW).
- *Hamworthy sea water scrubber*, currently in feasibility study phase, however first test in 1995. If they decide to go for a product it can be available in 2007/2008.

All technologies use sea water as scrubbing media, although Vortex and Wärtsilä also consider chemicals (e.g. NaOH or lime).

Investment and operating costs are only to a little extent available. Only the Ecosilencer has been commercially introduced on the market. The other four are in a testing/trial phase and want to keep their information confidential. However they indicate that their technologies will cost less than this.

In general I believe that technologies will not be finally introduced on the market until the wash water discharge criteria are established. This will be addressed at MEPC in October, hence it is reason to believe that this will be in place some time during 2007.

3.2.4 Shore side electricity

It is not in the scope of this study to describe in detail all technical issues to be taken into account. However, the main topics taken from /6/ shall be addressed to give an idea on which technical installations need to be foreseen on both sides, the shipboard mains and the local port mains.

Technical Requirements
Additionally required ship-board installations:
- Power supply line.
- Switchgear.
- Power supply transformer.
- Additional switchboard.
- Communication system.
- Cables, foundation.
- Possible modifications on voltage controllers and speed governors of onboard gensets.

Of course for existing ships sufficient space in a suitable location regarding operational and safety requirements must be available for the additional installations.

The number and diameters of connecting cables depend on the voltage used onboard and the power demand. Vessel power demand is widely variable between 1 – 10 MW and an estimated average of 4MW depending of the type of vessel, number of reefer containers loading and unloading power requirement (tankers), etc.

With increasing voltage onboard the number of cables will be reduced. For example:
- A power demand of 2 Megawatt at 6.6 k V requires 1 cable
- A power demand of 2 Megawatt at 440 V requires 9 cables

Figure 14 Installing a 440 V connection on board

For the required shore-side installations the requirements for the berth (the port) and the supplying utility are different.

For the berth it is important that all ships calling the port and requiring shore side power can be served without difficulties. That implies the availability of:

- Different connecting devices to suit different ship connections (unless worldwide standard for the plugs is available).
- Special transformers to suit different onboard voltages (440 V, 6,600 V and up to 11,000 V).
- Alternating current converters for 60 Hz and 50 Hz onboard systems.
- Connecting cables for different power and voltage requirements.
- Lifting devices for the handling of cables.

Provisions must be taken for situations in which a ship has to disconnect cables swiftly because of security or safety reasons.

For the supplying utility depending on the port requirements:

- Extension and/ or expansion of their high voltage power supply mains.
- Additional power generation plants, presumably peak load plants.
- Improvement of control to prevent negative influence on grid stability when connecting and disconnecting high power demands of ships.

Safety

All the necessary operation for the connection and disconnection of the ship to the shore side power supply should not influence the safe operation of the ship. Therefore the concept of protection needs to be defined and assessed for the installations onboard:

- Parallel running of shore supply and onboard generators is not allowed according to current rules of classification societies.
- Sufficient de-coupling of mains systems.
- At least one transformer per ship.
- Mains form at shore and onboard need to be of identical design.
- Defined load signal from shore side required for means of control and protection.

- Switching of transformers and high consumer load must be allowed.
- Protection against lightning as well as against overvoltage.
- Protection of cargo from power disruption (reefer containers, etc.).

As can be seen in Figure 14 the connection is established manually. The operators have to be protected from any harm as far as possible therefore:
- Connecting and disconnecting operations should be protected by an interlocking concept.
- Only approved components should be used in the construction of connecting devices including the handing over of cables.
- The operations should be defined in a quality assured approved manual.

Cost
There are different influences on the cost of shore side power supply:
- Investment for the ship depending on voltage, power demand, local possibilities.
- Investment for the port for the facilities at the berths.
- Investment for the utilities to improve their possibilities for power supply.
- Operational cost for the ship.

The investment costs for the *shipboard application* range from $ 320,000 to $1,800,000 with an estimated average of $ 900,000 /7/. Another source predicts that it would cost shipping lines anywhere from $ 200,000 to $1.1 million to retrofit their vessels /9/.

It would cost the *port* anywhere from $ 560,000 to $ 3.3 million per berth to build dockside transformers to connect to power lines, depending on what type of ship docks there /9/.

The investment for the utilities can not be quantified in this context, because they depend on the actual conditions prevailing, that is *inter alia*:
- Capacity of the mains leading to the port in relation to the power demand.
- Capacity of available power stations.
- Composition of prime movers in the existing power stations and their properties (base load, intermediate load, peak load).

Operational cost will be presumably rather high because of uncertainties and high variations in power demand that force the utilities to always have sufficient power stations working on their grid to satisfy the varying power demand of the port. This will result in part load operation of plants and / or additional peak load power stations. All that resulting in an increase of power production cost. In the beginning the cost may be moderate, if currently available surplus power of the utility could be used to satisfy the port power demand and no additional investment is necessary.

3.3 Calculation and compilation of costs

The following information on fuel prices per 2006-07-07 form the basis for the cost estimations in Table 7. Since all vessels are required to use LSF when operating in the SECA only additional cost for operation outside SECA are given.

Station	Grade	Price (US-$) HSFO/LSFO
Store Baelt	IFO 380	321/+ (35 to 40)
	IFO 180	351/+ (35 to 40)
Rotterdam	IFO 380	305/+ (30 to 40)
	IFO 180	323/+ 30
	IFO 500	299 (no LSF available)

Table 7 Compliance options and their costs and lead times

	Compliance options	Capital costs	Additional operating costs outside SECA	Lead times	Paperwork (administrative costs)
1	Using low-sulphur fuel at all times	Close to zero	Fuel consumption times premium for LSF	Close to zero	Close to zero
2	Fuel-switching	Depending on procedure (ref. to Chapter 3.1.2) and existing fuel supply system 0 to some 100 k$	Depending on trade pattern and switchover procedure Additional fuel for lead time operation times premium for LSF	Depending on operational conditions and fuel system up to several days (ref. to Chapter 3.2.2)	Depending on fuel system, minimum Log Book (ref. 3.2.2) to special individual fuel change over documentation
3	Using abatement technologies - Only ecosilencer	Newbuild: € 168/ kW installed. -exist. ship: € 168/ kW installed estimated future cost: € 120/kW. Plus cost for monitoring equipment Cost for approval process (Administration, maker, yard, owner)	1-3% of capital cost depending on size per kWh and additional amount for calibration and monitoring	Dependent on development and operational experiences, solutions for waste treatment	Comparable to fuel switching Additional effort for systems approval for Administration and manufacturer
4	Using shore-side electricity	Ship $ 320,000 to $ 1,800,000, Estimated average $ 900,000 Port $ 560,000 to $ 3.3 million per berth Utility: unknown	Only applicable at berth. Power consumption rates of power supplier (utility), savings for onboard power generation	Not to be specified, standardisation necessary (years). Technical development (years) Market acceptance (years)	Can not yet be estimated

4 Evaluation of inspection and enforcement measures

4.1 Scope of inspection

Applicable enforcement dates set out in Directive 2005/33/EC for the use of marine fuel with a sulphur content not exceeding **1.5% S** by mass (m/m) are as follows:

- **11 August, 2006**
  The fuel sulphur limit applies to **all ships** operating in the **Baltic Sea** as designated SO_x Emission Control Area (SECA):
  - To be observed: this is approximately 3 months later than the 19 May, 2006, enforcement date under the IMO Convention, MARPOL Annex VI.

  All passenger vessels on regular services to and from Community ports.

- **11 August, 2007**
  In addition to the implementation criteria of 2006, the fuel limit applies for all ships in the North Sea SECA, which includes the Channel:
  - To be observed: this is approximately 3 moths earlier than the expected enforcement date under the IMO Convention MARPOL Annex VI.

Use of marine fuels not exceeding **0.1% S** m/m.

- **1 January, 2010**
  The limit applies to ships at berth in Community ports.
  To be observed: Several Greek vessels operating exclusively within the territory of the Hellenic Republic are exempted from these requirements until 1 January 2012.

Inspection and survey regimes should in principle be harmonised in accordance of MARPOL Annex VI.

According to MARPOL Annex VI /10/, every ship of 400 gross tonnage (gt) or above shall be subject to certain types of surveys in order to ensure that the ship complies with the applicable requirements of Annex VI. In the case of ships of less than 400 gt, the (flag state) Administration may establish appropriate measures to ensure that the applicable provisions are complied with.

According to Regulation 18 of Annex VI it is required that each ship needs to keep a bunker delivery note (BDN) in their records for any fuel oil intended and used for combustion purposes on board. The bunker delivery note shall contain information at least as specified (see section 4.2.1).

The bunker delivery note shall be retained on board the ship for a period of three years after the fuel has been delivered on board. The competent authority (of a Port State, for instance) may inspect the bunker delivery notes on board any ship t which Annex VI applies. Since Directive 2005/33/EC does not distinguish between ships but only sets general requirements for marine fuel, inspections in principle apply to all ships. The competent authority further may be enforced to make a copy of the BDN and require the master or person in charge of the ship to certify that each copy made is a true copy of the BDN. The competent authority may also verify the contents of each note through consultations with the port where the note was issued.

The bunker delivery note shall be accompanied by a representative sample of the fuel. Requirements, IMO Resolution MEPC.96 (47) 'Guidelines for the sampling of fuel oil'. The main topics of these guidelines are given in 4.2.1 below.

According to the Directive Article 4a, section 5 Member States shall require the correct completion of ships' log-book, including fuel-changeover procedures. MARPOL Annex VI Regulation 14 (6) does require a log-book as prescribed by the Administration. In 3.2.2 of this study a proposal is presented on the possible content and layout of such a log-book specifically adapted to the ships' fuel operation concept. It is recommended to keep such a log-book separate from other ships' log-books in order to make inspections as easy as possible and the handling not too much bothering.

4.2 Shipboard documentation

4.2.1 Fuel Sampling

The primary objective of the fuel sampling Guidelines /11/ is to establish an agreed method to obtain a representative sample of the fuel oil for combustion purposes delivered for use on board ships. The basis for the Guidelines is regulation 18(3) of Annex VI to MARPOL 73/78, which provides that details of fuel oil for combustion purposes delivered to, and used on board the ship, shall be recorded by means of a bunker delivery note which shall contain at least the information specified in appendix V to that Annex. In accordance with regulation 18(6) of Annex VI, the bunker delivery note shall be accompanied by a representative sample of the fuel oil delivered. This sample is to be used solely for determination of compliance with Annex VI of MARPOL 73/78.

Information which at least should be recorded in the BDN:
- Name and IMO number of the receiving ship.
- Port (of bunkering).
- Date and commencement of delivery.
- Name, address and contact information of marine fuel oil supplier.
- Product names.
- Quantity in metric tons.
- Density at 15 °C (kg/m^3).
- Sulphur content in percent by mass (% m/m).
- A declaration signed and certified by the fuel oil supplier's representative that the fuel oil supplied is in conformity with regulation 14(1) or (4)(a) and regulation 18(1) of MARPOL Annex VI.

Since Directive 2005/33/EC in respect of the fuel sulphur limit is harmonised with MARPOL Annex VI a BDN referring as stated should be acceptable for Member States' Administration for inspection purposes.

According to the guidelines the fuel sample should be obtained by one of the following methods:
- Manual valve-setting continuous-drip sampler; or
- Time-proportional automatic sampler; or
- Flow-proportional automatic sampler.

It is recommended in this study to allow any other method provided equivalency has been proven and approved on an international basis.

Sampling equipment should be used in accordance with the manufacturer's instructions, or guidelines, as appropriate.

According to the Guidelines the sample of the fuel delivered to the ship should be obtained at the receiving ship's inlet bunker manifold and should be drawn continuously throughout the bunker delivery period. This study, however, would give to consider whether this requirement would be practicable in any case. Thus, it is proposed to at least accept other sampling locations where equivalency for the sampling of fuel under certain circumstances might be granted. Such circumstances may result from extraordinary risks for persons during the bunker process, or risks of environmental pollution. However, the ship's Master's right to require the sample to be taken at the ship's inlet manifold as required according to IMO's fuel sampling Guidelines /11/.

Immediately following collection of the retained sample, a tamper proof security seal with a unique means of identification should be installed by the supplier's representative in the presence of the ship's representative. A label containing the following information should be secured to the retained sample container:
- Location at which, and the method by which, the sample was drawn.
- Date of commencement of delivery.
- Name of bunker tanker/bunker installation.
- Name and IMO number of the receiving ship.
- Signatures and names of the supplier's representative and the ship's representative.
- Details of seal identification.
- Bunker grade.

To facilitate cross-reference details of the seal, identification may also be recorded on the bunker delivery note.

The retained sample should be kept in a safe storage location, outside the ship's accommodation, where personnel would not be exposed to vapours which may be released from the sample. Care should be exercised when entering a sample storage location.

The retained sample should be stored in a sheltered location where it will not be subject to elevated temperatures, preferably at a cool/ambient temperature, and where it will not be exposed to direct sunlight.

Pursuant to regulation 18(6) of Annex VI of MARPOL 73/78, the retained sample should be retained under the ship's control until the fuel oil is substantially consumed, but in any case for a period of not less than 12 months from the time of delivery.

The ship's master should develop and maintain a system to keep track of the retained samples.

It is suggested (see IMO paper BLG 10/14/16) that rigorous application of the bunker delivery note requirement may be unpractical and not providing benefit in certain cases, as illustrated by the short distance ferry between Elsinore in Denmark and Helsingborg in Sweden. It is suggested that flexibility to give good solutions to this type of cases is introduced in practice for example as follows:

For every ship of 400 GT and above not sailing in domestic waters on scheduled services with frequent and regular port calls, the Contracting Party may decide after application and consultation of relevant foreign authorities that the fulfillment of regulation MARPOL Annex VI Regulation 18(6) may be documented in an alternative way, which gives the similar certainty of compliance with regulation 14 and regulation 18. This might be appropriate also for the storage requirements of fuel samples.

According to the Directive Article 4a, section 3, the requirements apply to ships flying the flag of EU member State and to vessels of all other flags. The latter, however, applies when non-EU Member State flagged vessels operate to and from or within a SECA.

4.2.2 Bunker Sample and SECA fuel changeover log-book

In this context the SECA requirements are to be applied in line for passenger ships on regular service to and from Community ports.

Article 4a(5) of Directive 2005/33/EC as well as Regulation 14 of Annex VI of MARPOL requires a log book to the satisfaction of the Administration. Administration means the Administration of the Flag state of the ship in question. This may lead to different solutions for the log book and to difficulties for the person to check on behalf of the Port state the ship was operating on LSF when entering the SECA. A proposal for the possible content of such a 'MARPOL Annex VI Fuel Oil Logbook' is given below in order to provide a basis for a 'Harmonised Log-book'. A more detailed proposal appended in Appendix 1 to Task 1 of this study.

The fuel switch-over should be documented in such a logbook that has to be adjusted in a way that the requirements of MARPOL Annex VI, regulation 14 are also met.

Proposed contents of a Log-book in question:
- Ship´s compliance strategy with MARPOL Annex VI Reg. 14.
- Plan view bunker tank arrangement.
- Bunker sample data.
- Custody transfer.
- Information to be included in the Bunker Delivery Note.
- Sample Note of Protest.
- Bunker Delivery Note and Bunker Sample.
- Notes and record guidelines.
- Changeover time and date at entry and leaving a SECA.
- Extract from regulation 14, 18 and Appendix V of MARPOL Annex VI.
- Resolution MEPC.96 (47).
- Envelope for plans.
- Chart and limiting coordinates of SECAs.

As shown in section 3.2.2 the procedure that will be applied for fuel switching will vary depending on the design of the fuel system of the ship in question. Improvements in lead time can be achieved by means of additional operational measures, e.g. returning of purifier overproduction to a storage tank. The actual lead times and the low sulphur fuel burnt before entry into the SECA depend on fuel consumption of the machinery and the sulphur contents of both fuels.

4.2.3 Ships with one service tank

In order to highlight the increased complexity of the procedures on ships with a fuel system with only one service tank like that of Figures 3 and 4 documentation requirements are given separately in this section again. The details could be included in the log-book's section 'Ship's Compliance Strategy' where not given in other sections, as below proposed. However, it may be considered to enter the procedure also in the ship quality documentation:
- Bunker delivery notes for fuels.
- Simplified description of the fuel system by means of graphs and comments:
  - No. and specification of tanks.
  - Nominal fuel consumption of machinery.
  - Nominal fuel throughput of purifiers.
  - Any other necessary information.
- Description of fuel switch over procedure (as part of ship quality documentation):
  - Detailed instructions with clear identification of responsibilities.
- Date and time and position of start of switchover:
  - Fillings of tanks and sulphur content of fuel (LSF- storage tank, settling tank, service tank) at that moment.

- Date and time at entry of SECA:
  - Fillings of tanks at that moment.
  - Mean fuel consumption between start of switchover and entry into SECA.
- Date and time when arriving in port:
  - Fillings of tanks and sulphur content of fuel at that time.
  - Mean fuel consumption during that period.
- Date and time and position when starting fuel switchover back to HSF when leaving SECA:
  - Fillings of tanks and sulphur content of fuel (LSF- storage tank, settling tank, service tank) at that moment.

Lead time for port state Administrations
As could be seen from paragraph 2 the assessment of the compliance with the SECA requirements may be quite complicated because of the many influencing parameters and additional operational possibilities, e.g. to start fuel switching with a service tank that is only partly filled. Therefore an accurate description of the fuel switching procedure is necessary. There will be no difficulty for an experienced Port state officer to check the fuel consumption between SECA border and port. However, the shipboard lead time and LSF consumption before entry into a SECA may vary significantly from ship to ship and even for the same ship at a second call of port because of different operational and weather conditions.
This would require significant training of the officers and perhaps the development of a versatile calculation program for independent calculations in case of doubt. One practical means of verification could be a certified ship specific fuel changeover manual with tables describing lead time and low sulphur fuel consumption before entry into a SECA as function of HSF and LSF sulphur contents and machinery fuel oil consumption.

4.2.4 Ships with two service tanks

For a ship with a fuel system with two service tanks like that of Figures 5 the situation is very much easier. Only the fuel in the piping to and from the engines has to be exchanged. No mixing in tanks will occur. For these ships the documentation has to include:

- Bunker delivery notes for fuels.
- Simplified description of the fuel system by means of graphs and comments:
  - No. and specification of tanks.
  - Nominal fuel consumption of machinery.
  - Nominal fuel throughput of purifiers.
  - Any other necessary information.
- Description of fuel switch over procedure (as part of ship quality documentation):
  - Detailed instructions with clear identification of responsibilities.
- Date and time and position of start of switchover when entering SECA:
  - Fillings of tanks and sulphur content of fuel (LSF storage tank, settling tanks, service tanks) at that moment.

- Date and time and position of start of switchover when leaving SECA:
  - Fillings of tanks and sulphur content of fuel (LSF storage tank, settling tanks, service tanks) at that moment.

Lead time for port state Administrations
The assessment of fulfilling the requirements of Annex VI will be by check of the time the LSF service tank was first used to supply the engines and the reasonability of fuel consumption between border of SECA and port. There will be no significant time necessary to train experienced Port state officers to fulfil that task.

4.2.5 Use of exhaust gas-SO_x Cleaning Systems – EGCS

For ships using EGCS besides the on-board documentation with respect to surveys and inspections it is to be observed that according to Directive 2005/33/EC Emission Abatement Technologies for ships flying the flag of a Member State need to be approved according to certain provisions. Similar requirements are also set out in MARPOL Annex VI regulation 14(4)(b). Waste streams from the use of such equipment shall not be discharged into enclosed ports, harbours and estuaries unless it can be thoroughly documented by the ship that such waste streams do not have any adverse impact on the ecosystems of such enclosed ports, harbours and estuaries, based upon criteria communicated by the authorities of the port State. IMO Resolution MEPC.130(53) /12/ represents Guidelines for Exhaust Gas-SO_x Cleaning systems which contain guidance on both the approval of such units and the in service verification at survey intervals. Main topics of these Guidelines are summarized in the following.

The Guidelines in question provide two approval, certification and survey regimes:

- Scheme A: Unit Type Approval and Certification.
- Scheme B: Continuous Monitoring of SO_x-Emissions.

Scheme A – EGCS-SO_X Unit Type Approval and Certification
This part provides procedures concerning unit certification of Exhaust Gas-SO_x Cleaning Systems by the Administration with subsequent in service verification at survey intervals by indirect means together with unit use monitoring. The purpose of the Guidelines is to specify the requirements for the design, testing, survey and certification of exhaust gas cleaning-SO_x systems to ensure that they comply with the requirements of regulation 14(4)(b) of Annex VI of MARPOL 73/78.

Prior to use within a SECA, each EGCS-SO_x unit should be issued with a SECA Compliance Certificate (SCC) by the Administration.

The EGCS-SO_x unit should be subject to survey on installation and at Initial, Annual/Intermediate and Renewals Surveys by the Administration, irrespective of whether or not the ship is in a SECA at the time of Survey.

In accordance with Regulation 10 of MARPOL Annex VI, EGCS-SO_x units may also be subject to inspection by PSC when operating within a SECA.

Either prior to, or after installation onboard, each EGCS-SO_x unit should be certified as meeting the emission limit of 6.0 g SO_x/kWh under the operating conditions and restrictions as given by the EGCS-SO_x Technical Manual (ETM) as approved by the Administration. The ETM is a manual to be prepared by the unit maker and to be approved by the Administration as well as amendments to the ETM should be approved. The ETM needs to be kept on board.

The ETM should, as a minimum, contain the following information:

a The identification of the unit (manufacturer, model/type, serial number and other details as necessary) including a description of the unit and any required ancillary systems.

b The operating limits, or range of operating values, for which the unit is certified. These should, as a minimum, include:
   - Maximum and, if applicable, minimum mass flow rate of exhaust gas.
   - The power, type and other relevant parameters of the fuel oil combustion unit for which the EGCS-SO_x unit is to be fitted. In the cases of boilers, the maximum air/fuel ratio at 100% load should also be given. In the cases of diesel engines whether the engine is of 2 or 4 stroke cycle.
   - Maximum and minimum wash water flow rate, inlet pressures and minimum inlet water alkalinity (pH).
   - Exhaust gas inlet temperature ranges and maximum exhaust gas outlet temperature with the EGCS-SO_x unit in operation.
   - Exhaust gas differential pressure range and the maximum exhaust gas inlet pressure with the fuel oil combustion unit operating at MCR or 80% of power rating whichever is appropriate.
   - Salinity levels or fresh water elements necessary to provide adequate neutralizing agents.
   - Other factors concerning the design and operation of the EGCS-SO_x unit relevant to achieving a maximum emission value no higher than 6.0 g SO_x/kWh.

c Any requirements or restrictions applicable to the EGCS-SO_x unit or associated equipment necessary to enable the unit to achieve a maximum emission value no higher than 6.0 g SO_x/kWh.

d Maintenance, service or adjustment requirements in order that the EGCS-SO_x unit can continue to achieve a maximum emission value no higher than 6.0 g SO_x/kWh.

e The means by which the EGCS-SO_x unit is to be surveyed to ensure that its performance is maintained and that the unit is used as required (see section 6).

f Through range performance variation in wash water characteristics.

g Design requirements of the wash water system.

h The SCC.

Each EGCS-SO_x unit should be capable of reducing emissions to no more than 6.0 g SO_x/kWh at any applicable load point when operated.

Determination of the emission value should be in accordance with the provisions of the Guidelines.

For technical details of the EGCS unit approval process IMO Resolution MEPC.130(53) should be referred to.

With regard to on-board verification of compliance with the emission limit, the ETM should contain a description of an adequate survey procedure for use as required. This verification procedure should not require specialized equipment or an in depth knowledge of the system. Where particular devices are required they should be provided and maintained as part of the system. The EGCS-SO_x unit should be designed in such a way as to facilitate inspection as required. The basis of this verification procedure is that if all relevant components and operating values or settings are within those as approved, then the performance of the EGCS-SO_x system is within that required without the need for actual exhaust emission measurements.

Included in the verification procedure should be all components and operating values or settings which may affect the operation of the EGCS-SO_x unit and its ability to meet the required emission limit. The verification procedure should be submitted by the EGCS-SO_x manufacturer and approved by the Administration. The verification procedure should cover both a documentation check and a physical check of the EGCS-SO_x unit. The Surveyor should verify that each EGCS-SO_x unit is installed in accordance with the ETM and has a SCC as required. The EGCS-SO_x unit should include means to automatically record when the system is in use. This should automatically record, as a minimum, wash water pressure and flow rate at the EGCS-SO_x unit's inlet connection, pH of wash water at the EGCS-SO_x unit's inlet and outlet connections, exhaust gas pressure before and pressure drop across the EGCS-SO_x unit, fuel oil combustion equipment load, and exhaust gas temperature before and after the EGCS-SO_x unit.

The data recording system should comply with the requirements of Scheme B.

If a continuous exhaust gas monitoring system is not fitted, it is recommended that a daily spot check of the exhaust gas quality in terms of SO_2 (ppm) / CO_2 (%) ratio, is used to verify compliance in conjunction with parameter checks. If a continuous exhaust gas monitoring system is fitted, only daily spot checks of the parameters would be needed to verify proper operation of the EGCS-SO_x unit.

The clean seawater supply to the EGCS-SO_x unit and the wash water being discharged should also be monitored, at a defined frequency appropriate to the sensors used, for pH and oil content together with other parameters which may have an adverse impact on ecosystems in the area in which the ship operates. The data provided by this monitoring should be used by the ship in assessing the acceptability of water discharge against criteria which may be developed by individual port State authorities.

The wash water monitor and data recording system should comply with the requirements of Scheme B.

An EGCS-SO_x Record Book should be maintained by the ship owner recording maintenance and service of the unit. The form of this record should be submitted by the EGCS-SO_x manufacturer an approved by the Administration. This record book should be available at surveys as required and may be read in conjunction with engine room log-books and other data as necessary to confirm the correction operation of the EGCS-SO_x unit. Alternatively, this information is to be recorded in the vessel's planned maintenance record system as approved by the Administration.

Scheme B – Continuous monitoring of SO_x emissions
This Scheme describes the process how to provide evidence that an approved EGCS is operated in compliance with the limits. Compliance can only be demonstrated in service by continuous exhaust gas monitoring. A monitoring system should be approved by the Administration and the results of that monitoring available to the Administration as necessary to demonstrate compliance as required.

Additionally for all ships which are to use an EGCS-SO_x unit, in part or in total, in order to comply with the requirements of Regulation 14(4) there should be a SECA Compliance Plan (SCP) for the ship, approved by the Administration, detailing how:
a Compliance is to be achieved.
b That compliance is to be demonstrated.

This Scheme should be used to demonstrate that the emissions from an item of fuel oil combustion equipment fitted with an EGCS will, with that system in operation, result in an emission value of SO_2 (ppm) / CO_2 (%) ratio of 65 or below at any load point, including during transient operation and thus compliance with the requirements of regulation 14(4)(b) of MARPOL Annex VI.

An Exhaust gas composition, (SO_2 plus CO_2) measurement should be at an appropriate position after the EGCS-SO_x unit.

The clean seawater to the EGCS-SO_x unit and the wash water being discharged should also be monitored. The data provided by this monitoring should be used by the ship in assessing the acceptability of water discharge against criteria which may be developed by individual port State authorities.

A data recording and processing device should be provided and be capable of preparing reports over specified time periods. Data should be retained for a period of not less than 18 months from the date of recording. If the unit is changed over that period, the ship owner should ensure that the required data is retained onboard and available as required.

The device should be capable of downloading a copy of the recorded data and reports in a readily useable format. Such copy of the date and reports should be available to the Administration or port State authority as requested.

An On-board Monitoring Manual (OMM) should be prepared to cover each item of fuel oil combustion equipment, which should be identified, for which compliance is to be demonstrated by this Scheme.

The OMM should, as a minimum, include:

- a The sensors to be used in evaluating EGCS performance and discharge water, their service, maintenance and calibration requirements.
- b The positions from which exhaust emission measurements are to be taken together with details of any necessary ancillary services such as sample transfer lines and sample treatment units and any related service or maintenance requirements.
- c The analysers to be used, their service, maintenance, and calibration requirements.
- d Analyser zero and span check procedures.
- e Other information or data relevant to the correct functioning of the monitoring system or its use in demonstrating compliance.
- f A specification how the monitoring is to be surveyed.

The OMM should be approved by the Administration.
For all ships which are to use an EGCS-SO_x unit, in part or in total, in order to comply with the requirements of regulation 14(4) there should be a SECA Compliance Plan (SCP) for the ship, approved by the Administration. The SCP should list each item of fuel oil combustion equipment which is to meet the requirements for operating in a SECA by means of an approved EGCS-SO_x unit. Under Scheme A, the SCP should present continuous monitoring data demonstrating that the applicable parameters are maintained within the manufacturer's recommended specifications. Under Scheme B, this would be demonstrated using daily recordings. Under Scheme B, the SCP should present continuous monitoring demonstrating that the SO_2 (ppm) / CO_2 (%) ratio is 65 or below. Under Scheme A, this would be demonstrated using daily recordings.

There may be some equipment such as small engines and boilers to which the fitting of EGCS-SO_x units would not be practical, particularly where such equipment is located in a position remote from the main machinery spaces. All such fuel oil combustion units should be listed in the SCP. For these fuel oil combustion units which are not to be fitted with EGCS-SO_x units, compliance may be achieved by means of regulation 14(4)(a) of MARPOL Annex VI (use of LSF) while operating within a SECA. Ship construction requirements generally require that each fuel oil combustion unit should have its own exhaust gas system venting to the atmosphere. Therefore compliance by the ship may be demonstrated by each item of fuel oil combustion equipment meeting the requirements of either Scheme A or Scheme B. Alternatively, compliance may be demonstrated on the basis of total emissions generated by the ship

Recognizing that the limit given in regulation 14(4)(b) of MARPOL Annex VI is for the ship, not each individual item of combustion equipment, the ship owner should have the opportunity to balance performance which considerably exceeds the requirements of 6.0 g SO_x/kWh or SO_2 (ppm) / CO_2 (%) ratio of 65 or below against that of equipment, potentially not fitted with EGCS-SO_x units, which does not meet that requirement. These cases should be subject to special consideration by the administration. In particular the SCP should detail how the actual emissions from each fuel oil combustion unit are to be aggregated together to obtain an overall, real time, emission value for the ship which does not exceed 6.0 g SO_x/kWh or SO_2 (ppm) / CO_2 (%) ratio of 65 or below.

At no time during operation in a SECA should the total ship emissions exceed the requirement of 6.0 g SO_x/kWh or exceed the SO_2 (ppm) / CO_2 (%) ratio of 65 or below. Ship owners are advised to consider worst case operating scenarios, such as manoeuvring or high power operation, in their SO_x control strategies.

The SCP should refer to, not reproduce, the ETM and Record Book as specified under that Scheme. Alternatively, this information is to be recorded in the ship's planned Maintenance Record System, as allowed by the Administration.

For all fuel oil combustion equipment listed under 15.1, details should be provided demonstrating that the rating and restrictions for the EGCS-SO_x unit as approved, 2.3.1(b), are complied with.

The wash water flow rate and pressure at the EGCS-SO_x unit inlet connections, pH of the wash water at the EGCS-SO_x unit's inlet and outlet connections, exhaust gas pressure before and pressure drop across the EGCS-SO_x unit, fuel oil equipment load, and other parameters as considered necessary, should be monitored and recorded continuously while within a SECA in order to demonstrate compliance.

The SCP should refer to the On-board Monitoring Manual as approved by the Administration and the input data and resulting reports.

EGCS-SO_x unit's wash water systems should:

a Eliminate, or reduce to a level at which they are not harmful, hydrocarbons, carbon residue, ash, vanadium, other heavy metals, and other substances contained within EGCS-SO_x unit's wash that may have an adverse impact on ecosystems if discharged overboard.
b Ensure that the approach adopted, to control wash water quality and residual waste is not achieved in a way that causes pollution in other areas or environmental media.
c Also taking into account guidelines, if applicable.

Residues generated by the EGCS-SO_x unit should be land disposed. Such residues should not be discharged to the sea or incinerated on board. The record keeping requirements in respect of the disposal of wash water residues needs further to be developed.

Lead time for Administrations

Since only little experience with EGCS is available for the time being there is expected further lead time to fully implement all necessary documentation, reporting and control measures. That is due to the fact that:

- The industry will need some time to develop such systems to market.
- The shipping industry will accept the provided solutions, or not (due to costs and practicability, safe ship operation).
- As mentioned in 3.2.5.above further regard needs to be laid on wash water and waste streams.
- Probably additional guidelines need to be developed especially with regard to the aforementioned subject.
- Adequate training of port state officers will be required.

4.3 Fuel oil suppliers

Since the Member States according to Article 4a(6), 4a(7), and 4b(3) are obliged to ensure that from the applicable effective dates on no marine diesel oils or marine gas oils are placed on the market in their territory which does not meet the specifications and that they further need to provide an annual report on the sulphur content and supplementary information about the fuels in question to the Commission, it is necessary to implement procedures to collect the requested data from the fuel oil suppliers.

Again referring to MARPOL Annex VI, here Regulation 18 (7) and 18(8) have put some obligation on the Administrations' shoulders:

- Maintain a register of local suppliers of fuel oil.
- Require local suppliers to provide BDN and fuel sample, certified by the supplier.
- Require local suppliers to retain a copy of the BDN.
- Take action against suppliers that have been found to deliver non-compliant fuel oil.
- Inform the Administration of any ship receiving non-compliant fuel.
- Inform IMO of all cases where fuel oil suppliers failed to meet the requirements.
- In connection with Port State Control.
- Inform Administrations under whose jurisdiction a BDN was issued of cases of non-compliant fuel.
- Ensure measures are taken to bring non-compliant fuel discovered into compliance.

The Member States' Administrations need to inform the suppliers of marine fuel accordingly.

4.4 New abatement technologies

Basic guidance for the use of new SO_x Emission abatement technologies are already set out in IMO Resolution MEPC.130(53) Guidelines for 'On-board exhaust gas SO_x cleaning systems'.

Where new system prototypes need to be tested in practice the provisions of Article 4c of Directive 2005/33/EC should be observed. In any case, whenever on-board trials are to be performed monitoring and reporting schemes according the SECA requirements need to be implemented. These trials should be applied for at the Flag state and approved accordingly.

The test period should not exceed a limited time period. After that agreed period possibly a short extension period may be granted. If, after the testing or trial period the system does not match the requirements to be approved, it must be switched off, removed, or replaced by an approved system. In any case, the limiting requirements should be complied with.

Where a ship flying a flag of a State other than a Member State, even those ships are requested to inform the ports of call accordingly in due time (6 months for example) before the scheduled visit and apply for exemption from the requirements. Also in this respect harmonisation with IMO needs to be achieved.

Emphasis should not only be laid on the emissions of SO_x in these cases, but also on possible waste streams which leave or could leave the ship and potentially could cause other environmental problems.

4.5 Member State reporting system

According to Directive 2005/33/EC the Member States are obliged to report to the Commission by 30 June every year on certain data (see above section 4.3).

These reports inter alia may form the basis for the Commission to consider a second stage of sulphur limit values and thus amending the Directive.

4.6 Penalties

Since the adoption of MARPOL Annex VI in 1997, up to now more than 35 Parties to the Protocol have ratified MARPOL Annex VI and have implemented their relevant national legislation. In many cases in this context regulations concerning non-compliance have been established, including penalties. MARPOL Annex VI is in force since 19 May, 2005.

This study shall not propose the amount of possible penalties expressed in Euro or even imprisonment, however, some guidance could be given on what could lead to penalties. Under focus are persons who act improperly: Master or other officer/persons in charge, fuel oil supplier or his representative.

Improper actions:

- Any deliberate or negligent contravention to the appropriate regulation concerning documentation and custody of BDN and fuel sample.
- Use of marine fuel oil which exceeds the set limit of fuel sulphur content.
- Where installed, improper or even no operation of an EGCS.
- Delivery of non-compliant fuel oil.
- Improper fuel sampling.

5 Additional enforcement actions

This section examines additional enforcement actions available to Member States in accordance with current international maritime law (law of the sea, UNCLOS). Details can be found in Appendix 3.

The phrase 'additional enforcement actions' relates to the enforcement of the maximum limit of sulphur (1.5% by mass) in fuels laid down in Article 4a(1) or the use of emission abatement technologies pursuant to Article 4c of the Marine Fuel Sulphur Directive for ships sailing under foreign flags that are within those parts of the maritime zones of Member States that fall within a SECA, whether or not the ships are proceeding to or from a Community port. Member States are not required to take these actions.

While the Sulphur Directive does not distinguish between vessels flying the flag of States that are parties or non-parties to the 1997 Protocol to MARPOL 73/78, if they so wish Member States could opt for such a distinction for the purpose of taking additional enforcement measures.

Coastal State enforcement powers in the territorial sea, whether for vessels in transit or proceeding to or from a port, are extensive as they include the right to physically inspect the ship and institute proceedings, including detention of the vessel. However, the "clear grounds" that a violation has taken place may be difficult to establish. The only exception is a request for relevant information, which is not subject to the need for clear grounds. In relation to internal waters that are not subject to the right of innocent passage, the enforcement powers are potentially even broader. Conversely, there are no available enforcement powers in straits used for international navigation and all that coastal States can do in Exclusive Economic Zones (EEZ) is, again subject to "clear grounds", to require that a range of information be provided.

In addition to the scenario of vessels navigating in internal waters or territorial seas, vessels heading for a Member State's port can also be required to provide relevant information, prior even to entry into a SECA. In both these scenarios as well as in situations where clear grounds of non-compliance have been established, Member States can inform the master of the ship about the SECA and its requirements and, where the vessel is present in the SECA, to ask the master to confirm the vessel's compliance with the requirements. In case the information provided by the master eventually turns out to be false, some Member States may have the ability under their national legal framework to also prosecute the master for providing false information.

Under the law of the sea, States should in all cases refrain from enforcement measures that are unlawful or exceed those reasonably required in the light of available information. In this light, account should also be paid to the obligation to avoid undue detentions or delays. Otherwise they are liable and required to pay compensation.

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/10/ IMO: MARPOL 73/78, Annex VI

/11/ IMO Resolution MEPC.96(47) Guidelines for the sampling of fuel oil for determination of compliance with Annex VI of MARPOL 73/78

/12/ IMO Resolution MEPC.130(539): Guidelines for on-board exhaust gas-SO_X cleaning systems

Appendix 1: Bunker Sample- and SECA fuel change over Log-Book

Bunker Sample- and SECA*
fuel change over Log-Book

for the control of the emissions of sulphur oxides from ships

acc. Annex VI of MARPOL 73/78 and EU Directive 2005/33/EC

Name of Vessel ____

IMO No. __________________________

Date from: __________________________ to: _______________________

*) SECA = SO_x Emission Control Areas

Ship´s compliance strategy with Annex VI Reg. 14 and ISM Code of practice and operational manual

valid: ____________________ from: ____________________

☐ The ship is not intended to operate in a SECA.

Option 1 All fuel on board does not exceed the global Sulphur Maximum of 4.5% m/m

☐ All fuel oil carried on board is less than 1.5% m/m sulphur content

Option 2

☐ Dual Fuel operations < 1.5% & < 4.5% m/m fuel – change over procedures apply.

Option 3 Refer to ship/company ISM machinery operation manual.

☐ Exhaust Gas Cleaning System (EGCS) installed. Refer to EGCS-SO_x technical manual.

Option 4

☐ Alternative technological method – please specify:

Option 5 Refer to ship/company ISM machinery operation manual.

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☐ Strategy for handling national boundary emission regulations, such as those imposed by the EU and USA – please specify:

Option 6 Refer to ship/company ISM machinery operation manual.

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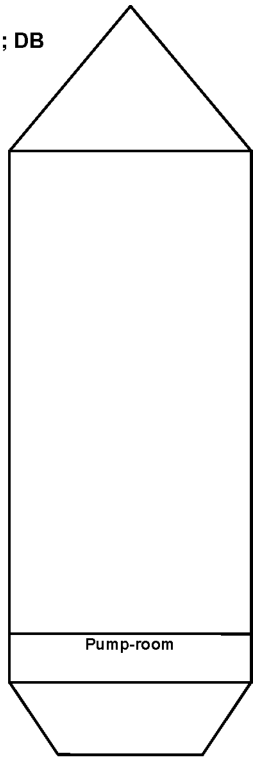
Name of ship: ____________________________________

IMO-No.: ______________________________

Plan view bunker tank arrangement
(to be completed on board)

Deck; DB



Identification of the tanks	Capacity

(State the capacity of each tank)

Deck; DB

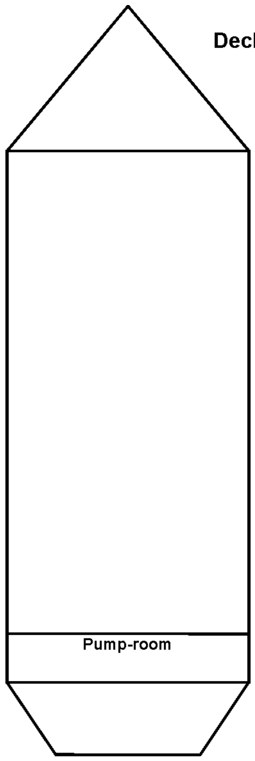


Table 8 Bunker sample data

BDN Reference No.	Date of bunkering time of start and stop	Bunker Port	Bunker Grade (s) Quantity (MT)	Name of Supplier	Bunker barge (s)/ terminal(s) name IMO No.	Supplier Registration with Port State Authority	BDN in compliance with Annex VI requirements	Supplier´s MARPOL Annex VI sample taken at ship´s manifold	Additional sample taken by continous drip sampler	MARPOL seal number(s)	Sample sent for fuel quality testing	Sulphur level (% m/m)	Tank (s) used for received bunker	Note of Protest (NOP) issued	Date which received bunkers has been consumed	Sample disposal date	Date BDN destroyed	Sample given Authorities	Comments
													Signature	Signature	Signature	Signature	Signature	Signature	Signature

Table 9 Custody transfer of Annex VI

BDN Ref. No.	Annex VI Reg. 18 – 1(6) Sample Seal No.	Port of Custody	PSA Custody Transfer Form Transfer	Date & Time of Custody Ref. No.	Address & Contact Details of receiver	Name, Signature and Stamp of Transfer	Remarks Signature of officer in charge
						◯	
						◯	

Annex VI Appendix V MARPOL 73/78
Information to be included in the
Bunker Delivery Note
(Regulation 18(3))

- Name and IMO Number of receiving ship
- Port
- Date of commencement of delivery
- Name, address and telephone number of marine fuel oil supplier
- Product name(s)
- Quantity in (metric tons)
- Density at 15°C (kg/m^3)
- Sulphur content (% m/m)
- A declaration signed and certified by the fuel oil supplier's representative that the fuel oil supplied is in conformity with regulation 14(1) or (4)(a) and regulation 18(1) of this Annex.

SAMPLE "NOTE OF PROTEST"

To: ____

(Name, address, telephone number, fax number, e-mail address of supplier)

____

____

Dear Sirs,

NOTE OF PROTEST FOR BUNKERING OPERATION ON ______________________

(Date)

This is to record that the a. m. stated Supplier failed to comply with the MARPOL Annex VI requirement as follows:

____

____

____

____

____

The bunkers were supplied by Bunker Barge / Tanker ______________________

(Name of Bunker Barge / Tanker)

on ______________ at ______________________

(Date) (Location)

I hereby lodge a protest to reserve rights for any future consequences on this matter.

Yours faithfully,

______________________	______________	______________________
(Name of Master of Vessel)	(Date)	(Signature of Master of Vessel and Vessel Stamp)

original: bunkersupplier copy: port authority copy: flag state authority copy: vessel

---

ACKNOWLEDGEMENT RECEIPT

____

(Name of Master/Cargo Officer of Bunker Barge/Tanker)

____ ______________

(Signature of Master/Cargo Officer of Bunker Barge/Tanker) (Date)

Bunker Delivery Note and Bunker Sample

according to MARPOL ANNEX VI

Notes and record Guidelines for table 1 + 2

(We thank the company DNV Petroleum Services who granted an excerpt from their “bunker sample record guidelines” to quote here.)

BDN Reference No:
Number of bunker delivery note

Date of Bunkering
Indicate date bunkering was performed (start and completion).

Port of Bunkering
Indicate the Port where the bunkering operation was performed.

Bunker Grade (s) and Quantity (MT)
Indicate Product’s name/Grade as per Bunker Delivery Note (BDN) or specification. ISO grades preferably to be used. Indicate quantity received
in Metric Tons. Low sulphur fuel consumption within SECAs is a statutory requirement (from 19 May 2006 onwards) and may therefore be subject
to third party verification/control. Accordingly, it is recommended that increased focus is put on bunker quantity measurements and testing of
density to ascertain that the quantity received is in accordance with BDN value.

Name of Supplier
Indicate Name of supplier.

Bunker barge(s)/Terminal(s) Name, IMO No:
Indicate Name of bunker barge(s) or bunker terminal(s) and if available IMO No.

Supplier Registration with Port State Authorities
Answer with Yes, No or Unknown with respect to whether the Supplier is registered with Port State Authorities or not. Note that MARPOL Annex VI does require Port States to maintain such a register. Although not a requirement, it is recommended that only registered suppliers are used.

BDN in compliance with MARPOL Annex VI
Answer with Yes or No. It is a requirement for every barge delivery/fuel grade supplied to the ship to be accompanied by a BDN. If the BDN does
not contain the required information and supplier’s declaration a letter of protest should be issued. The BDN is to be retained onboard for min. 3
years.

Supplier’s MARPOL sample taken with continuous drip sampler
Answer with Yes or No. The guidelines to Annex VI [MEPC.96 (47)] specify that the representative MARPOL sample is to be continuously drawn throughout the bunkering period and is to be obtained either by a manual valvesetting continuous drip sampler or an automatic sampler. The sampling equipment and the attached receiving container are to be sealed throughout the bunker delivery period. If the supplier’s sample is not taken using a continuous drip or auto-sampler, a letter of protest should be issued an the separate MARPOL sample taken by the ship’s crew should be maintained onboard together with the supplier’s sample. The BDN sample is to be retained onboard for min. 12 months. The sample is to be min. 400 ml and provided with a label with information regarding location where sample was taken (ship’s manifold), sampling method, bunker date, name of bunker barge/pier, receiving ship’s name and IMO No., sample seal number and bunker grade. Every sample is to be sealed by supplier and label is to be signed by the Officer in charge of the bunkering and the supplier’s rep. It is the supplier’s responsibility to provide such a sample. See however below requirements. If the supplier does not provide a MARPOL sample, a letter of protest should be issued and the separate MARPOL sample taken by the ship’s crew should be maintained onboard together with the supplier’s sample.

Supplier's MARPOL sample taken at ship's manifold
Answer with Yes or No. The guidelines to Annex VI [MEPC.96 (47)] specify that the MARPOL sample is to be continuously drawn at the receiving ship's manifold. In case the supplier does not take the MARPOL sample at the ship's manifold, a letter of protest should be issued and the separate MARPOL sample taken by the ship's crew should be maintained onboard together with the supplier's sample. If there are operational constraints such as vacuum problems that prohibit samples to be taken at the ship's manifold, this should be recorded separately and the sample taken e.g. at barge manifold.

MARPOL sample seal Nos.
MARPOL sample bottle seal number(s) are to be specified. Note that it is recommended that all seal number(s) related to bunker samples taken are recorded in the BDN (CP 60 requirement in Singapore).

Other sample sent for fuel quality testing
Answer with Yes or No. Applicable if the vessel sends other fuel samples for fuel quality testing. The MARPOL sample is to be retained onboard and not be used for commercial disputes i.e. the sample is only handed over to a Port or Flag state authority upon request.

Sulphur level (%m/m)
Indicate the sulphur content as stated on the BDN.

Tank(s) used for received bunker and quantity
Indicate in which tank(s) the received fuel was stored, and specify quantity in each tank.

Note of Protest (NOP) issued
Answer with "date or no" and "signature". The letter of protest should be referred to the BDN.

Date when received bunkers has been consumed and signature
Indicate the date that the quantity of the fuel bunkered was substantially consumed. Please sign.

Sample disposal date and signature
The disposal date should be indicated. All samples should be stored onboard for a minimum of 12 months or until the fuel was substantially
consumed – whichever is sooner. Please sign.

Date BDN destroyed and signature
Indicate the date of destroying the bunker delivery note. The BDN is to be retained onboard for minimum 3 years.

Sample given to Authorities
The date on which the sample was given to an Authority for verification should be indicated with port and name of authority, if applicable. A
receipt should always be obtained. In case the supplier's sample has not been taken as per Annex VI requirements, both the supplier's sample and the MARPOL sample taken at ship's manifold, and a copy of the letter of protest should be handed over.

Port of Custody
Name of port of custody.

PSA Custody transfer form transfer
State transfer form of Port State Authority where transfer took place.

Date and time of Custody Ref. No.
State date and time of custody reference number to enable verification and tracing when contacting the port where the fuel sample was delivered or taken.

Address & contact Details of receiver
Please state address, phone number, fax number and email (if available) of receiver.

Name, Signature and stamp of transfer
State name of person who signed the transfer, request stamp (if available) of port state authority.

Table 10 SECA entry changeover data / SECA leaving changeover data

Change Over Completion Date / Time Position	Time used for change over procedure	LSF Fuel consumed during change over procedure Tk name / Qty (MT)	LSF in storage tks at the end of change over procedure Tk name / Qty (MT)	Status fuel quantities of non LSF at completion of change over procedure Tk name / Qty (MT)	Fuel Type Sulphur Content % m/m From to	Remarks	Start of change over procedure Date / Time / Position	LSF in storage tanks at start of change over procedure Tk name / Qty (MT)	Status fuel quantities of non LSF at start of change over procedure Tk name / Qty (MT)	Remarks
						Signature of officer in charge				Signature of officer in charge

Appendix 2: Checklists for Port State Control

Distinction should be made between first port after entering of SECA and following ports.

A First port after entering of SECA

1. Check fuel log book with regard to availability of LSF.
2. Check availability of bunker delivery notes and fuel samples.
3. Check design of fuel system.
4. Ask for description of fuel switchover procedure.
5. Ask for logbook with data as required by Annex VI and additional data to verify correct performance of fuel switchover procedure.
6. Ask for LSF consumption since start of switchover.
7. Estimate reasonability of fuel consumption since start of switchover (Depending on design of fuel supply system fuel consumption must exceed that between borderline of SECA and port in question).
8. If available check Pos.7 with fuel changeover manual.
9. If vessel is equipped with exhaust gas treatment ask for manual of equipment supplier and check the amount of residuals for reasonability.

B Following ports in SECA

1. Check fuel log book with regard to availability of LSF.
2. Check availability of bunker delivery notes and fuel samples.
3. Ask for logbook with data as required by Annex VI.
4. Ask for LSF consumption since last port.
5. Estimate reasonability of fuel consumption.
6. If vessel is equipped with exhaust gas treatment ask for manual of equipment supplier and check the amount of residuals for reasonability.

C First port at second and following entries into SECA

1. Check fuel log book with regard to availability of LSF.
2. Check availability of bunker delivery notes and fuel samples.
3. Check design of fuel system.
4. Ask for description of fuel switchover procedure.
5. Ask for logbook with data as required by Annex VI and additional data to verify correct performance of fuel switchover procedure.
6. Ask for LSF consumption since start of switchover.
7. Estimate reasonability of fuel consumption since start of switchover (Depending on design of fuel supply system fuel consumption must exceed that between borderline of SECA and port in question).
8. If available check Pos.7 with fuel changeover manual.
9. Ask for LSF consumption after departure of last port before last time leaving SECA (Depending on design of fuel supply system fuel consumption must exceed that between last port and borderline of SECA by volume of service tank).

10 If vessel is equipped with exhaust gas treatment ask for manual of equipment supplier and check the amount of residuals for reasonability.

D Remote sensing of sulphur content in fuel used

The following chapter investigates the possibility to assess the sulphur content of the fuel used for combustion by means of remote sensing. First the possibility to calculate the sulphur content from a measured exhaust gas composition is investigated.

The measured composition of the exhaust will deliver the concentration of the components listed in the table below. On the other hand, with a given composition of the fuel the exhaust gas composition can be calculated. However, these equations give as result concentrations only in relation to the fuel consumption. A measurement of exhaust gas SO_2-concentration then only leads to direct results if the fuel consumption would be known.

These considerations lead to the following:

Composition of exhaust gases:

L_{min}: minimum air required for complete combustion

λ: excess air in relation to L_{min}

Exhaust gas concentrations, example Sulphur dioxide:

X_{SO2}= 1,998s m_{fuel} /(m_{fuel} + λ * L_{min}*[1+ x_D])

Component	**Measured concentration**	**kg/kg fuel**	**remarks**
SO_2	X_{SO2}	1,998s	s= sulphur content of fuel
CO_2	X_{CO2}	3,664c + 0,0005 * λ * L_{min}	c= carbon content of fuel
H_2O	X_{H2O}	8,937h + w+ λ * L_{min}*x_D	h= hydrogen content of fuel x_D= humidity of combustion air
O_2	X_{O2}	0,2319*(λ -1)* L_{min}	
N_2	X_{N2}	n + 0,7548 * λ * L_{min}	n= nitrogen content of fuel
Ar	X_{Ar}	0,0128 * λ * L_{min}	a= argon content of fuel
	x_D		Humidity of ambient air
L_{min}		(2,664c +7,937h +0,998s) / 0,2319	Minimum air required
		s + c + h + n + w = 1,0	Fuel composition
		X_{SO2} + X_{CO2} + X_{H2O} + X_{O2} + X_{N2} + X_{Ar}=1,0	Exhaust composition

To conclude on the sulphur content of the fuel therefore the above system of equations has to be solved.

The above equations postulate that the humidity of the air actually used for combustion is not changed from ambient conditions. This is not true for marine diesel engines. Usually the air is cooled down after leaving of the charge air compressor, potentially leading to condensation of humidity with the condensate being extracted from the process. On the other hand several engine manufacturers use water for the reduction of NO_x-formation during combustion either by humidifying the air, as fuel-water-emulsion or direct injection. This leads to additional difficulties in concluding from measured exhaust gas compositions to the sulphur contents of the fuels used.

Even in the simple case that n=0 , w=0 and CO_2 content of the fuel equal 0 as well as neglecting of argon content of the air (a=0) we find the following nonlinear system of equations:

Component	**Measured concentration**	**kg/kg fuel**	**Remarks**
SO_2	X_{SO2}	1,998s	s= sulphur content of fuel
CO_2	X_{CO2}	3,664c	c= carbon content of fuel
H_2O	X_{H2O}	8,937h + λ * L_{min}*x_D	h= hydrogen content of fuel x_D= humidity of combustion air
O_2	X_{O2}	0,2319*(λ -1)* L_{min}	
	x_D		Humidity of ambient air
L_{min}		(2,664c +7,937h +0,998s) / 0,2319	Minimum air required
		s + c + h = 1,0	Fuel composition
		X_{SO2} + X_{CO2} + X_{H2O} + X_{O2} =1,0	Exhaust composition

This set of equations may be solvable, however, there is reason for doubt that the required accuracy could be reached, that should be comparable to the accuracy.

Irrespective of the technical realisation of remote sensing with the required accuracy there seems not possible to use this kind of measurement as basis for additional enforcement actions. Even if the exhaust gas composition could be measured onboard the accuracy difficulty is still existent and increased significantly when water is used for NO_x reduction.

Regulation14 of Annex VI to MARPOL within SECAs requires that:

“(4),(a) the sulphur content of fuel oil used on board ships in a SO_x emission control area does not exceed 1.5% m/m”

With regard to the required accuracy that means that the maximum allowed value is 1.5%. The accuracy of an estimation of sulphur content by means of exhaust gas measurement should be comparable to the standard accuracy of fuel analysis. In ISO 8217 “Petroleum Products – Fuels (Class F) – Specifications of Marine Fuels” regarding fuel analysis reference is made to ISO 8754 “Petroleum Products – Determination of Sulphur Content – Energy Dispersive X-Ray Fluorescence Spectrometry”. There the required accuracy is given as ± 0.1% for a measurement range from 0.01% to 5%. The lower value given indicates that the achievable accuracy should be better.

Without attempting to find an analytical solution for the above set of equations that would enable the calculation of the error in determining the sulphur content from the exhaust gas composition it is obvious that the accuracy will not be sufficient to establish “clear ground” for additional enforcement measures. This would even apply if the exhaust would be measured directly in the exhaust gas duct of the engine. This is also underlined by the chemical reactions the fuel oil sulphur undergoes during combustions and exhaust.

The fuel oil sulphur content is oxidised into different oxides of sulphur (SO_X), mainly SO_2 and SO_3.

In two stroke diesel engines itself typically 2% of the SO_2 is oxidised to SO_3. The SO_3 reacts with H_2O and forms H_2SO_4, sulphuric acid – first as vapour in the exhaust piping and outside the funnel as condensed droplets and aerosols.
A small fraction of the SO_X is neutralised in the engine by the use of alkaline lubricants to form neutral compounds of calcium. This is done to protect the engine from corrosion by SO_2 and SO_3 which condense as sulphuric acid.

During the LIFETIME Project [1] the sulphur emission calculated by the sulphur content of the fuel oil was compared to the sulphur emission measured in the exhaust gas. The resulting conversion factor was calculated using the fuel oil consumption, the sulphur content of the fuel oil (HFO with 4% m/m Sulphur), the sulphur dioxide emission in the exhaust gas and the sulphate content of the particulate emission. Approximately between 85 and 90% of the fuel oil sulphur content was converted to SO_2 and emitted to the atmosphere. A small unknown proportion was oxidised to SO_3 and another unknown proportion was neutralised in the engine by the use of alkaline lubricants. Additional a small amount is deposited on the particulate matter.

These difficulties would be increased with remote sensing. Here the system has to be correctly focused on the exhaust gas exit and additionally the influence of the ambient air composition between exhaust exit and measuring device must be eliminated. Therefore it seems to be improbable that this technology would give results to establish the required clear grounds.

Reference

/1/ Lifetime, Deliverable D2b, Onboard Measurements Results, Contract No. G3RD-CT-2000-00245, 2001-04-12

Appendix 3: Additional enforcement actions

Author: Dr. Erik-Jaap Molenaar (Netherlands Institute for the Law of the Sea)

Introduction

This section examines additional enforcement actions available to Member States in accordance with current international maritime law (law of the sea). It is structured as follows: first, the remainder of this subsection examines the meaning of the phrase ‘additional enforcement actions’. The next subsection discusses which ships should be targeted for enforcement. The third subsection examines the relevant provisions on coastal State enforcement in the international law of the sea, with separate attention for the various relevant maritime zones. Fourth, and finally, guidance is given to Member States on the implementation of three enforcement phases. The results of the analysis are summarised in the conclusion.

The term ‘additional enforcement actions’ is used in the Marine Fuel Sulphur Directive (1999/32/EC, amended by 2005/33/EC). Article 4a(3) of this Directive stipulates that “Member States may also take additional enforcement action in respect of other vessels in accordance with international maritime law”. The reference to paragraph (1) in Article 4a(3) means that passenger ships operating on regular services - which are dealt with in Article 4a(4) - are not included among “other vessels”. Furthermore, as the remainder of Article 4a(3) relates to enforcement by flag States and port States, it can be presumed that the words “other vessels” relate to foreign vessels that are within those parts of the maritime zones of Member States that fall within a SO_x Emission Control Area (SECA). As so far only the Baltic and North Seas have been designated as SECAs, the issue of additional enforcement measures applies in principle only to Member States that border the Baltic and North Seas. Furthermore, within the context of this study, we assume that additional enforcement actions designate actions in addition to the ones discussed in the previous section[5].

The use of “may” in Article 4a(3) in the amended Directive 1999/32 indicates that Member States are not required to take such additional enforcement measures. This use of “may” therefore appears to take precedence over the obligation for Members States “to take the necessary measures” etc. pursuant to Article 6(a) of the same Directive. This is consistent with Article 4(2) of MARPOL 73/78, which requires port and coastal States to ensure that violations of MARPOL 73/78 are prohibited and subject to penalties, but without requiring them to actually take

[5] These are: sampling fuel being delivered, in accordance with IMO guidelines; sampling and analysing fuel in tanks and in sealed samples; Inspecting ships’ log books and bunker delivery notes; remote sensing ships’ exhaust from fixed or mobile monitoring stations; ensuring representative sampling of fuels used by ships in relevant sea areas (in combination with any of the first two measures); ensuring that local suppliers provide compliant fuels and bunker delivery notes; setting penalties at a level that is both proportionate and dissuasive; structuring Member States’ short annual reports to the Commission.

enforcement measures at sea. Coastal States are also not required to do this under the LOS Convention[6].

In sum, the phrase 'additional enforcement actions' is aimed at enforcing certain provisions of the Marine Fuel Sulphur Directive for ships sailing under foreign flag that are within those parts of the maritime zones of Member States that fall within a SECA, whether or not the ships are proceeding to or from a Community port. Member States are not required to take these actions.

1 Ships flying the flag of States parties or non-parties to the 1997 Protocol

This section examines which ships should be targeted for enforcement.

While implementation guidance is only requested in the sphere of enforcement, the legality of coastal State enforcement action under international law is strongly linked to the scope and extent of coastal State prescriptive jurisdiction under international law. As regards the "other vessels" under consideration, amended Directive 1999/32 contains in fact only one standard. Ships present in SECAs must either observe the maximum limit of sulphur (1,5% by mass) in fuels laid down in Article 4a(1) or use emission abatement technologies pursuant to Article 4c. This standard does not appear to be more stringent than that required by Regulation 14(4) of Annex VI to MARPOL 73/78.

At this juncture, reference should be made to Regulation 11 of the 1997 Protocol to MARPOL 73/78 (which contains its Annex VI). This Regulation is entitled 'Detection of Violations and Enforcement' and is virtually identical to Article 6 of MARPOL 73/78, except that the former uses the term "emissions" whereas the latter uses "discharges". Moreover, a paragraph (6) has been added to Regulation 11, which reads:

> "The international law concerning the prevention, reduction and control of pollution of the marine environment from ships, including that law relating to enforcement and safeguards, in force at the time of application or interpretation of this Annex, applies, *mutatis mutandis*, to the rules and standards set forth in this Annex."

Through this provision, the States that negotiated the 1997 Protocol to MARPOL 73/78 agreed that the relevant international law relating to prescription and enforcement (including safeguards) over vessel-source pollution would also be applicable *mutatis mutandis* to the regulation of vessel-source air pollution as laid down in Annex VI. Those States thereby agreed that, at least as between States Parties to the 1997 Protocol to MARPOL 73/78, the relevant international law as laid down *inter alia* in Articles 21(2), 42(1)(b), 54, 211, 217, 218, 220, 233 and 234 of the LOS Convention (pollution from vessels) would apply instead of Articles 212 and 222 (pollution from or through the atmosphere)[7].

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6 United Nations Convention on the Law of the Sea, Montego Bay, 10 December 1982. In force 16 November 1994, 1833 *United Nations Treaty Series* 396; <www.un.org/Depts/los>. See in particular paras. (1), (2), (3), (5) and (6) of Art. 220.

7 For a more comprehensive discussion see E.J. Molenaar, *Coastal State Jurisdiction over Vessel-Source Pollution* (The Hague/Boston/London, Kluwer Law International: 1998), at pp. 499-513.

Important for the current report is that the sulphur standard contained in amended Directive 1999/32 can be regarded as *not* more stringent than a 'generally accepted international rules and standard' (GAIRAS) as meant within several provisions of the LOS Convention[8]. Accordingly, recourse can be had to the usual enforcement powers to which coastal States are entitled in their own maritime zones. Worth noting is that amended Directive 1999/32 does not distinguish between vessels flying the flag of States parties or non-parties to the 1997 Protocol to MARPOL 73/78. In our opinion, this is not problematic[9].

It is nevertheless recognized that not all Member States may agree with this view[10]. As the 'additional enforcement measures' are optional instead of mandatory, Member States may themselves choose to distinguish between ships flying the flag of States parties or non-parties to the 1997 Protocol. Reference should also be made to the importance of the qualification/characterization of the fuel standard in the context of the jurisdictional framework of the LOS Convention. In case the standard can *not* be qualified as a construction, design, equipment and manning (CDEM) standard, Article 21(2) of the LOS Convention provides that coastal States (acting alone or in concert) are *not* bound to the level of GAIRAS but are entitled to prescribe national standards for the territorial sea (but not in straits used for international navigation). This right would not only exist as between States parties to the LOS Convention but also under international customary law. Whether or not the fuel standard qualifies as a CDEM standard depends on whether or not the prescription of national standards in the territorial sea endangers the objective of global uniformity in the regulation of international shipping, which is the rationale behind the exception in Article 21(2) of the LOS Convention. That objective may be endangered if compliance requires substantial and costly adjustments[11].

In summary, while amended Directive 1999/32 does not distinguish between vessels flying the flag of States parties or non-parties to the 1997 Protocol to MARPOL 73/78, if they so wish Member States could opt for such a distinction for the purpose of taking additional enforcement measures.

2 Coastal State enforcement over vessel-source pollution under the LOS Convention

2.1 Introduction

The following subsections deal with coastal State enforcement jurisdiction over vessel-source pollution within internal waters, the territorial sea, straits used for international navigation and the EEZ.

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8 See in particular Arts 21(2), 42(1)(b) and 211(5).

9 See *inter alia* Molenaar, note 7 above, at p. 507.

10 Note for instance that the *Study on the Economic, Legal, Environmental and Practical Implications of a European Union System to Reduce Ship Emissions of SO_2 and NO_x* (Study for DG Environment of the EC Commission: August 2000; text at <europa.eu.int/comm/environment/enveco>), Appendix 4: Legal Analysis: Prescription, Enforcement and Observance", at p. A4.34 observes that "The better view is that MARPOL Reg. VI/11(6) will be binding only (...) on Parties to Annex VI when it comes into force".

11 See also Appendix 4 of the EC Emissions Study, note 10 above, at Section 2.2.3.1.

Of the various maritime zones recognized by the LOS Convention, only the following are relevant: internal waters, territorial seas, straits used for international navigation and exclusive economic zones (EEZs). (The Baltic and North Seas do not contain areas that have the status of archipelagic waters pursuant to Article 49 of the LOS Convention. Moreover, coastal States do not have relevant jurisdiction within the contiguous zone pursuant to Article 33 of the LOS Convention). It is worth noting that of the EU Member States that are coastal States to the Baltic and North Seas, all except the United Kingdom have established EEZs[12]. The rights claimed by the United Kingdom in the so-called 'controlled waters' established by its 1996 Pollution Regulations[13] do not go beyond those that coastal States are entitled to within EEZs under the LOS Convention.

2.2 Internal waters

Under the international law of the sea, internal waters are waters landward of the territorial sea baselines established in accordance with the LOS Convention. Foreign ships do not have a right of innocent passage in internal waters, except where the internal waters were created through straight baselines[14]. In the absence of a right of innocent passage, the coastal State has in principle full enforcement jurisdiction (but see the safeguards examined in subsection 2.6). Where a right of innocent passage *does* exist in internal waters, the observations of subsection 2.3 apply *mutatis mutandis*.

2.3 Territorial sea

As the territorial sea is part of a State's territory, enforcement is in principle full and unrestricted unless international law imposes restrictions. An important restriction is the right of innocent passage through the territorial sea recognized in Article 17 of the LOS Convention and defined in Articles 18 and 19. Among other things, passage includes continuous and expeditious navigation through the territorial sea by vessels in transit (traversing) or those proceeding to or from a port. Passage loses its innocent character if a ship engages in one of the activities listed in Article 19(2), such as "wilful and serious pollution contrary to this Convention". However, a violation of the fuel standard in amended Directive 1999/32 cannot be regarded as such. This does not mean that coastal States are not entitled to take enforcement measures at all. Article 220(2) clearly indicates that any violation of laws and regulations relating to the prevention, reduction and control of pollution from vessels entitles a coastal State to physically inspect a ship during its passage through the territorial sea, whether in transit or proceeding to or from a port, when there are "clear grounds" that a violation has taken place. And "where the evidence so warrants" by the physical inspection, the coastal State can institute proceedings, including detention of the vessel. The enforcement powers of the coastal State discussed in subsection 2.5 on the EEZ are also available for vessels navigating in the territorial sea, but are less onerous than those available under Article 220(2).

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[12] Source: 'Table of Claims to Maritime Jurisdiction (as at 26 August 2005)', available at: <www.un.org/Depts/los>.

[13] Merchant Shipping (Prevention of Oil Pollution) Regulations, of 19 August 1996, *Statutory Instruments*, No. 2154 (1996).

[14] Cf. Art. 8(2) of the LOS Convention.

2.4 *Straits used for international navigation*

In geographical areas where the regime of transit passage of Part III, Section 2 of the LOS Convention applies, foreign ships have a right of transit passage pursuant to Article 38. The regime of transit passage is very complicated and subject to a number of important exceptions. As regards those areas of the Baltic and North Seas that are part of SECAs, the Strait of Dover would certainly be subject to the regime of transit passage. Accordingly, in implementing amended Directive 1999/32, France and the United Kingdom must take account of the right of transit passage in the relevant geographical areas, both as regards enforcement and prescription. Pursuant to Article 233 of the LOS Convention, enforcement action against vessels that remain within the bounds of the right of transit passage is only possible in relation to violations that cause or threaten "major damage to the marine environment of the straits". In the sphere of vessel-source air pollution, this is not likely to happen. It should also be noted that enforcement is linked to the prescriptive bases in paragraphs (1)(a) and (1)(b) of Article 42. As paragraph (1)(b) - the only relevant basis - relates exclusively to "discharges", strait States may not be entitled to prescribe at all. However, the effect of Regulation 11(6) of Annex VI may acknowledge such a right as between States parties to the 1997 Protocol to MARPOL 73/78. Finally, while the Danish Straits are generally regarded as falling under the exception of Article 35(c), the claim by Finland and Sweden that this also applies to the Ahvenanrauma Strait is more controversial. This notwithstanding, the practical implications of those exceptions vis-à-vis the prescription and enforcement of the fuel standard in amended Directive 1999/32 are not clear.

2.5 *EEZ*

Coastal State enforcement jurisdiction over vessel-source pollution in the EEZ is set out in paragraphs (3), (5) and (6) of Article 220 of the LOS Convention. They relate to enforcement of violations (by foreign vessels) of laws or regulations on vessel-source pollution committed in the EEZ while the vessel is navigating in the territorial sea or EEZ. Paragraph (3) gives coastal States a right to "require the vessel to give information regarding its identity and port of registry, its last and its next port of call and other relevant information required to establish whether a violation has occurred", provided the coastal State has "clear grounds" that a violation has been committed. The more onerous enforcement measures under paragraphs (5) and (6) - physical inspection and institution of proceedings, including detention - are linked to specified environmental impacts and these are not likely to occur in the case of a violation of the fuel standard.

2.6 *Conclusions*

The four subsections above indicate that coastal State enforcement powers in the territorial sea, whether for vessels in transit or proceeding to or from a port, are extensive but subject to the need for 'clear grounds' that a violation has taken place. The only enforcement action that does not require clear grounds is a request for relevant information. In relation to internal waters that are not subject to the right of innocent passage, the enforcement powers are potentially even broader. Conversely, there are no available enforcement powers in straits used for international navigation and all that coastal States can do in EEZs is, again subject to ‘clear grounds’, to require that a range of information be provided.

It should also be noted that the safeguards contained in Section 7 of Part XII of the LOS Convention would in principle apply to all these situations, including those where no right of innocent passage exists. Of particular importance is the obligation under Article 225 to avoid adverse consequences in the exercise of the powers of enforcement as well as Article 232, which provides that States shall be liable in case enforcement measures are unlawful or exceed those reasonably required in the light of available information. Account should also be paid to the obligation to avoid undue detentions or delays pursuant to Article 7 of MARPOL 73/78, which is explicitly linked to entitlements to compensation[15]. Thus, even enforcement powers over ships navigating in internal waters are subject to restrictions.

3 Which additional enforcement actions are in accordance with the international law of the sea?

The examination in the subsections above has revealed that there are three separate enforcement phases: (1) requiring the vessel to provide certain information, (2) physical inspection of the vessel and (3) institution of proceedings against the owner or operator of the vessel, including the detention of the vessel. These three phases are now examined in turn.

3.1 Requiring the vessel to provide certain information

As described in subsection 2.5, coastal States are entitled to require the vessel to provide the following information: (a) the vessel’s identity and port of registry, (b) its last and next port of call and (c) other relevant information required to establish whether a violation has occurred. Categories (a) and (b) would seem to be mainly relevant for ships in transit that are not proceeding to or from a Community port. With regard to ships proceeding to or from a Community port, such information is probably already required through other EC enactments.[16] The last category indicates that the list is non-exhaustive and gives coastal States a margin of discretion as to which information is “relevant”.

In relation to vessels navigating in the EEZ, paragraph (3) of Article 220 stipulates that as a prerequisite for resorting to this phase of enforcement, coastal States need to have ‘clear grounds’ that a violation has been committed. Information obtained through remote sensing from fixed or mobile monitoring stations[17] would be one way of satisfying this requirement. More accurate information on the sulphur content of fuel could be obtained through on-board sensors capable of measuring sulphur content in emissions. Data collected from

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[15] Even though this obligation has not been incorporated in the 1997 Protocol, according to Art. 3(1) of the 1997 Protocol “The Convention and the present Protocol shall, as between Parties to the present Protocol, be read and interpreted together as one single instrument“

[16] For example, Directive 2002/59/EC of the European Parliament and of the Council of 27 June 2002 establishing a Community vessel traffic monitoring and information system and repealing Council Directive 93/75/EEC.

[17] This is one of the inspection and enforcement measures listed under Task 1(2) of the Technical Annex to the Service Contract.

these sensors could then be examined during physical inspections, whether in port or at sea. In order for this data to serve as 'clear grounds' for at-sea inspection, however, the coastal State must have prior access to it, for instance through satellite systems. But at the moment Annex VI to MARPOL 73/78 does not contain a requirement to have such sensors installed or to ensure that the data are transmitted to coastal States.

In relation to the territorial sea, even though paragraph (2) of Article 220 also contains the need for clear grounds, this is not specifically linked to the current enforcement-phase, namely requiring the vessel to provide relevant information. Arguably, all ships in internal waters or the territorial sea, whether in transit or proceeding to or from port, can be required to provide the relevant information referred.

Two suggestions are finally offered for consideration. First, port Member States could stipulate along the usual requirements and procedures[18] that the operator, agent or master of a ship bound for its port gives prior notification that the ship will be navigating through a SECA, provides relevant information and that it is aware of, and in compliance with, the fuel standards therein. Second, in the course of enforcement while the foreign vessel is navigating within the SECA, whether in the territorial sea or the EEZ, the coastal State could draw the attention of the master of the ship to the ship's presence in the SECA and ask confirmation that the ship is in compliance with the fuel standards therein. In case the information provided by the master in this scenario and the previous one eventually turns out to be false, some Member States may have the ability under their national legal framework to also prosecute the master for providing false information.

3.2 Physical inspection of the vessel

Provided the coastal State has clear grounds that the fuel standard has been violated or that it is still being violated, it can physically inspect the ship in its territorial sea. Even though the prerequisite of clear grounds is not strictly applicable in internal waters that are not subject to the right of innocent passage, in view of the risk of liability and claims for compensation for undue delays, coastal States are well advised to observe that prerequisite as well.

Article 220(2) of the LOS Convention stipulates that the purpose and extent of the physical inspection of the ship (as well as the implicit right to board the ship) has to be related to the violation. This would include sampling and analysing fuel in tanks and sealed samples as well as inspecting ships' log books and bunker delivery notes[19]. In addition, the physical inspection could extend to checking the presence and functioning of emission abatement technologies and related waste management systems as well as inspecting the relevant documents thereto.

Finally, for essentially similar reasons as those set out at the end of subsection 3.1, during the physical inspection the coastal State may choose to ask the

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[18] For instance those used pursuant to Art. 4 of Directive 2002/59, note 12 above.

[19] These are listed under Task 1(2) of the Technical Annex to the Service Contract.

master of the ship to confirm verbally or in writing that the ship has been in compliance with the fuel standard and/or that the relevant documentation is in order. In case these verbal or written statements eventually turn out to be false, some Member States may have the ability under their national legal framework to prosecute the master for providing false information.

3.3 Institution of proceedings

Article 220(2) of the LOS Convention entitles the coastal State to institute proceedings if the evidence generated by the physical inspection warrants this. This latter qualification is once again linked to the risk of liability and claims to compensation for undue delays and detention. Coastal States are well advised to observe that qualification also for internal waters that are not subject to the right of innocent passage.

The right to institute proceedings explicitly includes the right to detain a vessel and, implicitly, to bring it to port. However, reference is also made to the "provisions of section 7", which contain the safeguards. Relevant here is Article 226(1)(b) which requires the coastal State to release the vessel promptly "subject to reasonable procedures such as bonding or other appropriate financial security". Furthermore, as the violation of the fuel standard cannot amount to a "wilful and serious act of pollution", Article 230(2) only allows coastal States to impose monetary penalties. It is finally worth noting that as the violation has occurred in the territorial sea, flag States do not have the right to pre-empt the coastal State's proceedings pursuant to Article 228.

4 Conclusion

Member States can take various additional actions to enforce the Sulphur directive. However, most of the available enforcement actions - such as physical inspection and the institution of proceedings, including detention of the vessel - require 'clear grounds' that a vessel is not in compliance with the Sulphur directive. These may be hard to establish.

However, no clear grounds are needed if Member States want to require vessels navigating in their internal waters or territorial seas to provide relevant information. Also, vessels heading for a Member State's port can be required to provide such information, prior even to entry into a SECA. In both these scenarios as well as in situations where clear grounds of non-compliance have been established, Member States can inform the master of the ship about the SECA and its requirements and, where the vessel is present in the SECA, to ask the master to confirm the vessel's compliance with the requirements. In case the information provided by the master eventually turns out to be false, some Member States may have the ability under their national legal framework to also prosecute the master for providing false information.

Executive summary

This section examines additional enforcement actions available to Member States in accordance with current international maritime law (law of the sea). The phrase 'additional enforcement actions' relates to the enforcement of the maximum limit of sulphur (1.5% by mass) in fuels laid down in Article 4a(1) or the use emission abatement technologies pursuant to Article 4c of the Marine Fuel Sulphur Directive for ships sailing under foreign flag that are within those parts of the maritime zones of Member States that fall within a SECA, whether or not the ships are proceeding to or from a Community port. Member States are not required to take these actions.

While the Sulphur Directive does not distinguish between vessels flying the flag of States parties or non-parties to the 1997 Protocol to MARPOL 73/78, if they so wish Member States could opt for such a distinction for the purpose of taking additional enforcement measures.

Coastal State enforcement powers in the territorial sea, whether for vessels in transit or proceeding to or from a port, are extensive as they include the right to physically inspect the ship and institute proceedings, including detention of the vessel. However, the ‘clear grounds’ that a violation has taken place may be difficult to establish. The only exception is a request for relevant information, which is not subject to the need for clear grounds. In relation to internal waters that are not subject to the right of innocent passage, the enforcement powers are potentially even broader. Conversely, there are no available enforcement powers in straits used for international navigation and all that coastal States can do in EEZs is, again subject to ‘clear grounds’, to require that a range of information be provided.

In addition to the scenario of vessels navigating in internal waters or territorial seas, vessels heading for a Member State’s port can also be required to provide relevant information, prior even to entry into a SECA. In both these scenarios as well as in situations where clear grounds of non-compliance have been established, Member States can inform the master of the ship about the SECA and its requirements and, where the vessel is present in the SECA, to ask the master to confirm the vessel’s compliance with the requirements. In case the information provided by the master eventually turns out to be false, some Member States may have the ability under their national legal framework to also prosecute the master for providing false information.

Under the law of the sea, States should in all cases refrain from enforcement measures that are unlawful or exceed those reasonably required in the light of available information. In this light, account should also be paid to the obligation to avoid undue detentions or delays. Otherwise they are liable and required to pay compensation for damage.

Part B

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ABSTRACT

This report covers the elements set out in chapter 2.6 in Tender No. ENV.C.1/SER/2005/0077. Together with an electronic version of the calculation tool and a database of trial results (available on the attached CD) this report completes Task 2 set out by EU and MARINTEKs deliverables.

KEYWORDS	ENGLISH	NORWEGIAN
GROUP 1	Shipping	Skipsfart
GROUP 2	Environment	Miljø
SELECTED BY AUTHOR	IMO	IMO
	CO_2	CO_2

7 Executive summary

Introduction

Reducing CO_2 emissions from ships is an important but difficult task. An important contribution to this effort has been the development by the IMO of an interim CO_2 emission index which enables ships to calculate their emissions of CO_2 in relation to transport work.

The aim of the work described in this report is to assist in the further development of the IMO CO_2 emission index by:

- Collecting and organizing all the available information on IMO CO_2 index trials using the new guidelines.
- Liaising with the European Community Ship owners Associations and selected ship-owners to collect trial data and feedback on the guidelines from end users.
- Identifying remaining gaps in knowledge, extent of trials or methodology, and propose further improvements and potential use of the guidelines.

The IMO CO_2 index

The IMO CO_2 index was developed to assess the CO_2 emissions of a ship in relation to the transport work that has been performed. Consequently, the IMO index is defined as:

$$IMO_{INDEX} = \frac{Emitted\_Mass\_CO_2}{Transport\_Work}$$

The emitted mass of CO_2 is calculated based on the total fuel consumption of the ship including when the ship is in harbour and ballast voyages. Transport work is calculated by multiplying a suitable cargo unit (mass in tons, number of containers, cars etc.) by the distance transported.

The IMO has suggested that the index can be used by ship-owners as part of an environmental management system, however the index could potentially also be used in a policy to reduce or regulate CO_2 emission.

Collection of IMO index trial data

Data has been collected from 364 ships covering 8 of 18 ship categories as defined by Lloyds Fairplay. Of these, 294 are original data collected in conjunction with this study while data from 70 trials has been compiled from existing sources. A summary of the data collected is shown in Table 11.

Table 11 Summary of data collected

Ship Type	Index unit	Average Value	Average size (GT)	Number of ships
LNG Tanker	g CO_2 / ton n.mile	66.5	79,652	3
LPG Tanker				0
Chemical Tanker	g CO_2 / ton n.mile	23.5	20,311	49
Crude Oil Tanker	g CO_2 / ton n.mile	8.0	57,703	46
Product Tanker				0
Other Liquids				0
Bulk Dry	g CO_2 / ton n.mile	7.6	81,519	4
Bulk Dry / Oil				0
Self Discharging Bulk Dry				0
Other Bulk Dry				0
General Cargo				0
Passenger / General Cargo				0
Container	g CO_2 / ton n.mile	24.4	40,021	23
Refrigerated Cargo	g CO_2 / ton n.mile	124.3	9,850	11
RoRo Cargo	g CO_2 / ton n.mile	94.9	49,294	29
Passenger / RoRo Cargo	g CO_2 / car unit n.mile	9379	2,894	199
Passenger Ship				0
Other Dry Cargo				0

Remaining gaps in the data

Some large ship categories in terms of number of ships such as general cargo and product tankers are not represented. Bulk dry is represented by a very small number of ships. Moreover, since the data which has been collected originates from a limited number of ship-owners, this data is should not be considered representative for the ship category in general. Hence, in order to get an overall picture of the index values for the world fleet, more data would be needed in all categories. Since the index value depends on ship size one should also ensure that the distribution in size of the trial ships is representative for the actual distribution in size within each category. Finally, since variations in demand for transport services may affect the index, index values should preferably be collected over a number of years.

Causes for variation in the index

The index value obtained by a ship is strongly correlated with ship size, larger ships being more efficient. Differences in cargo requirements may also cause index levels to vary significantly between ship categories. Ferries demonstrate particularly high emission indexes which are believed related to special requirements posed by human cargo such as shops, restaurants, and regular sailing schedules.

Operational effects may also cause considerable variation in index between virtually identical ships. The difference between the best and worst performer in a set of fifteen sister ship was observed to be 33% in one particular case.

In general, operational variations in index are mainly caused by:
1 Variation in utilization cargo space.
2 Variation in fuel consumption on ballast voyages (related to the length of ballast voyages).
3 Variation in ship efficiency (engine condition, hull and propeller fouling, etc.).
4 Variations in speed between voyages.
5 Weather and currents.
6 Errors in measurement and registration.

Application of the IMO CO_2 index

The IMO index is well suited to report efficiency and calculate specific emissions related to the transport of goods.

Use of the IMO index for environmental management purposes is challenging because the index typically varies significantly from one voyage to the next. Identification of the specific causes for variation may also be difficult since the index measures the aggregate effect of many contributing factors. While the IMO index is a useful indicator of overall performance, it is advisable that it is supplemented by other indexes so that the cause of variations can be more readily identified and actions taken as appropriate.

The use of the IMO index in a voluntary or mandatory scheme would require the establishment of a baseline. A baseline common for all ships in one category could result in effortless compliance of the larger ships while smaller ships would be unable to reach the target even under optimal conditions. This distinction is desired if these ships are in the same trade and serving the same marked, however it may be considered unfair if the ships are serving different markets, i.e. the smaller ships are visiting harbors inaccessible to larger ships or delivering smaller parcels that could not be served by the large tanker in an economical or environmentally friendly manner. From this perspective, assigning baselines to specific trades rather than ship types could be equally relevant.

The average IMO index performance of a ship segment could change from year to year according to variations in demand for transport. Such variation could cause a static baseline to lose its effectiveness as a control parameter as 'compliance' could become alternately too easy or too difficult to achieve. In order to stay relevant, a baseline may need to account for variation in demand for transport.

Experience using the index onboard ships

The CO_2 index spreadsheet was distributed to participating ships and returned by electronic mail. Instructions apart from those given in the spreadsheet were not initially submitted. Some issues had to be clarified, but in general the ship crew had few problems understanding how to use the spreadsheet and to find data to enter.

Recommendation for improvement of the index
Experience using the index has resulted in the following recommendations towards the further development of the IMO index:

Ferries currently report transport work either as passenger miles or car unit miles. Passengers and cars transported by a ferry could preferably be converted to a singular unit (such as mass) in order to get a better expression for transport work.

The IMO guideline could preferably clarify that it is not necessary to measure the fuel consumption for individual voyage legs in order to get a correct overall index, it is only the transport work that must be recorded for each leg. This simplification is particularly for ships making many short legs to collect or deliver goods in conjunction with long voyage.

Also, ships operating back and forth in a regular single leg schedule (such as a ferry) can calculate the IMO index for any given period using aggregated data to calculate transport work. This approach is beneficial since aggregated data are typically more readily available and could be mentioned in the guideline.

LNG boil-off is used as fuel for LNG carriers, however a carbon factor for boil-off is not provided in the guideline. It is suggested that the guideline should either state specifically that that the carbon factor for natural gas given in the circular can be applied to LNG boil-off, or derive an applicable factor for LNG boil off.

8 Background

One of the most important environmental challenges for international shipping is to limit or reduce the emissions of greenhouse gases (GHG), first of all CO_2. IMO has initiated this process and as a first step developed a policy which was adopted as a Resolution by the Assembly in December 2003 as A.963(23) – *IMO Policies and practices related to the reduction of greenhouse gas emissions from ships.*

An important element in this process has been the development of *Interim Guidelines for Voluntary Ship CO_2 Emission Indexing for Use in Trials*, which was adopted by IMOs Marine Environment Protection Committee, MEPC 53 in July 2005 as MEPC/Circ.471. The IMO CO_2 index is defined as:

$$IMO_{INDEX} = \frac{Emitted\_Mass\_CO_2}{Transport\_Work}$$

Adoption of the draft guidelines was achieved on the premise that these be adopted for use in further trials and urging interested parties to facilitate and report back from such trials. The interim guidelines will later be updated, taking into account experience from new trials as reported by industry, organizations and Administrations. IMO has suggested that the IMO index can be used by ship owners or operators as part of an environmental management system.

The CO_2 emission indexing, expressing the ships CO_2-efficiency in terms of CO_2-emissions per unit transport work in tonne-km, offers a potential tool for rating ships, which could be required in both voluntary and mandatory schemes for emissions reduction. Application of the indexing guidelines related to a market based option is still an issue requiring further discussion within IMO and few proposals have as yet been made on this issue.

The main purpose of the work in this report is to assist in the further development of the IMO CO_2 emission index by encouraging European ship-owners to use the IMO index, by collecting IMO index data from all available sources, analyzing the data, and suggesting possible improvements and applications of the index.

9 Ship trails and collection of CO_2 index data from other sources

The European Ship-Owners association (ECSA) circulated a letter on behalf of this project asking their member ship-owner organizations to ask their members to participate in this study. Participating ship-owners would ask one or more ships to calculate their CO_2 efficiency index using a spreadsheet that was developed as part of this project.

A spreadsheet tool was developed for ships' crew to input fuel consumption, distance and cargo data. The tool automatically calculates the CO_2 index per voyage and year to date. The input tool is based upon Microsoft Excel. A copy of this spreadsheet has been delivered along with the index database.

Only two ship owners volunteered as a result from this initial effort by communicating through ECSA. When approached directly, some ship-owners questioned the usefulness of this exercise; a few indicated reluctance to part with what was considered sensitive data; however the reluctance of most was typically related to high work pressure, not lack of interest.

Typically, the more interested ship-owners have the data needed to calculate the index available on shore, but typically not in a readily usable format. In the end, only 8 ships from 5 ship owners submitted data using the spreadsheet while a substantial amount of data was obtained in various formats from shipping companies. While this clearly is acceptable with respect to gathering data for analysis of index properties, this is a setback in terms of introducing the index to the industry and gaining practical experience from the use of the index onboard ships.

In total, index data was collected from 364 ships. Of these, 294 are original data collected in conjunction with this study, while data from 70 trials has been compiled from previous trials.

Most data from previous trials originates in submissions to the IMO workshop on GHG indexing of ships or to the MEPC. Not all the information submitted was suitable for inclusion in the database principally due to uncertainties regarding duration of the trial and/ or how the index was calculated.

10 Experience using the index onboard ships

The CO_2 index spreadsheet was distributed to participating ships and returned by electronic mail. Instructions apart from those given in the spreadsheet were not initially submitted. The ship crew generally had few problems understanding how to use the spreadsheet and to find data to enter. In order to record a voyage data must be submitted on

- Distance sailed.
- Fuel consumption.
- Cargo carried.

Distance sailed
This is correctly interpreted as the actual distance travelled over earth, i.e. not necessarily the shortest route from A to B, nor the distance logged through water. Finding this information proved to be unproblematic.

Fuel consumption
Fuel consumption includes all fuel consumed by engines, boilers and incinerators at sea and in port. Not all respondents included fuel consumed in port or by auxiliary engines at sea in their first replies as this information were not readily available. When challenged, these ships provided the data.

In case of LNG carriers, cargo boil-off is frequently used to generate extra propulsion power. This gas must also be included in the calculation; otherwise the result will be misleading, however this appeared to be overlooked by some.

Regarding the use of fuel oil in port, one ship reported that this was not recorded on a port by port basis; hence consumption in each port had to be estimated by dividing the total auxiliary engine fuel consumption over a month by port calls. While this could have some minor influence on the voyage by voyage index value, it does no affect the long term average.

Cargo
Not surprisingly, determining type of cargo was troublesome in case of Ro-Pax ferries where both number of passengers and number of cars is relevant, and selecting either will results in overlooking one aspect of the transport work.

In case of other ship types, deciding whether to use cargo mass or another measure (such as TEU or car units) may also be difficult as the implications of using one over the other are unclear. It is our impression that this choice was mainly done on convenience, i.e. which ever relevant information that is more easily available is chosen.

Reporting period
The IMO guidelines do not specify or place any requirement on the reporting period, but suggests that a voyage or day may be used. The corresponding

column heading in the IMO CO_2 index reporting sheet (IMO Circ 471) reads 'Voyage or day'. The IMO CO_2 index reporting sheet format was used in the spreadsheet in this project. One ship operator misinterpreted this as 'Voyage or day, whichever is shorter' and subsequently made a split in fuel consumption at midnight, in port or at sea. This approach was not wrong as it does not affect the overall index, however the associated extra work does not provide any appreciable benefit. In the worst case, it may actually increase the difficulty of interpreting individual index results.

Other experiences
Consider the following example: A ship picks up cargo in three or four comparatively closely situated harbors then proceeds with an intercontinental voyage followed by unloading of the cargo in three or four closely situated harbors. The ship owner will typically consider this to be a single voyage. A single voyage number will be assigned for the entire operation and existing reports will treat this as one event, however accurate calculation of the IMO index requires that each short leg is treated as a single voyage since the amount of cargo varies.

Finding the correct data can be laborious since data for the 'sub voyages' are not necessarily readily available. Fuel consumption is of particular concern since fuel consumption is not necessarily measured on each short leg. A compromise solution could be to accurately record the transport work for the whole voyage including all sub voyages without determining the fuel consumption for each sub-voyage. This data could then be used to calculate an index for the complete voyage.

Some ship crews noted that the information entered into this spreadsheet is recorded and reported elsewhere already, hence the use of spreadsheets as done in this project was not a particularly efficient as a long term solution.

Some ship-owners have already implemented the IMO or similar ship CO_2 indexing proving the practical feasibility of implementing this type of index. Once a suitable reporting system is in place, the extra work load on the ship crew is small. As of now, CO_2 index data is used typically and environmental accounting and reporting purposes. Analysis of ship performance with the aim of improved operation has not been implemented by any of the participants in this project.

11 Index levels for different ship categories

The index obtainable for any given ship on a single voyage ranges from infinity (fuel is consumed while no transport work is done) to a minimum level determined by the design of the ship. The minimum level is strongly correlated with ship size, larger ships being more efficient. Differences in cargo requirements may also cause minimum index levels to vary significantly between ship categories. Finally, the ability of a ship to find return cargo will affect the average index when calculated over a number of voyages.

As previously mentioned, IMO index data has been collected from 364 ships. In order to analyze this data and to estimate index levels, it is first necessary to decide how ship types should be categorized. A categorization of the world fleet can be done in many different ways but will inevitably entail some element of compromise between the desire to differentiate and the need to limit the number categories.

After some deliberation it was decided to use Lloyd's Registers ship categorization in this project because it is well established and statistical data is available for these ship categories. Since CO_2 indexing is applicable only to ships performing transport work, ship categories that are not primarily designed to performing transport work are disregarded. This will include research ships, naval ships, mobile oil rigs, floating production units, dredgers, cable layers, fishing vessels, cruise ships and more. Arguably, some of these ships do perform transport work to some extent however transporting goods is not the main purpose of their missions. Apart from ship type, the IMO index is also strongly affected by ship size (gross tonnage, deadweight, length, etc.).

Table 12 lists a breakdown of the part of the world fleet that performs transport work and shows the number of ships in each category (according to Fairplay 2004 /1/) and the number of ships within each of these categories in this study. It is clear from this table that data is available for only eight of eighteen ship categories, and that the fraction of the world fleet that is covered is very small. Some large ship categories in terms of number of ships such as general cargo and product tankers are not represented at all. Bulk dry is represented by a very small number of ships Moreover, since the data which has been collected originates from a limited number of ship-owners, many of the ships are sister ships or otherwise similar. Ship owners providing data may also be considered to have a higher than average interest in environmental reporting. This data is thus biased and should not be considered representative for the ship group even for ship groups where the number of ships in this study seems comparatively high. *For the purpose of determining truly representative index levels for ship types a broader base with a higher number of ship owners should be involved.* Average index level has never the less been indicated as shown in Table 13 which also clearly indicates which ship types where no data is available.

Table 12 Ship categories used in this study

Ship Category	Total Number of ships	Ships in study
LNG Tanker	174	3
LPG Tanker	1,020	0
Chemical Tanker	2,970	49
Crude Oil Tanker	1,850	46
Product Tanker	5,047	0
Other Liquids	365	0
Bulk Dry	5,267	4
Bulk Dry / Oil	152	0
Self Discharging Bulk Dry	166	0
Other Bulk Dry	1,105	0
General Cargo	15,859	0
Passenger / General Cargo	339	0
Container	3,283	23
Refrigerated Cargo	1,242	11
RoRo Cargo	1,959	29
Passenger / RoRo Cargo	2,743	199
Passenger Ship	2,873	0
Other Dry Cargo	240	0
Total	**46,654**	**364**

Table 13 Average CO_2 index values observed in this study

Ship Type	Index unit	Average Index	Average GT	Number of ships
LNG Tanker	g CO_2 / ton n.mile	66.5	79,652	3
LPG Tanker				0
Chemical Tanker	g CO_2 / ton n.mile	23.5	20,311	49
Crude Oil Tanker	g CO_2 / ton n.mile	8.0	57,703	46
Product Tanker				0
Other Liquids				0
Bulk Dry	g CO_2 / ton n.mile	7.6	81,519	4
Bulk Dry / Oil				0
Self Discharging Bulk Dry				0
Other Bulk Dry				0
General Cargo				0
Passenger / General Cargo				0
Container	g CO_2 / ton n.mile	96.5	40,021	23
Refrigerated Cargo	g CO_2 / ton n.mile	124.3	9,850	11
RoRo Cargo	g CO_2 / ton n.mile	94.9	49,294	29
Passenger / RoRo Cargo	g CO_2 / car unit n.mile	9,379	2,894	199
Passenger Ship				0
Other Dry Cargo				0

The data in Table 13 is presented graphically in Figure 15. Interestingly, this figure seems to indicate an almost linear relationship between the average index value and average ship size for ships carrying dry or liquid bulk cargos (Chemical tanker, Crude oil tanker and Dry bulk) and a similar almost linear relationship for ships carrying volume intensive cargos. Container ships appear close to the weight intensive ships (wet and dry bulk), but their emissions are somewhat higher. If these indicated relationships were to hold true, two broad tonnage dependent baselines would be sufficient to cover broad segments of shipping.

Two such sample trend lines are shown in Figure 16 together with a background scatter of individual observations. The variation in index for the various ship groups is apparent. Although the use of common baselines for multiple ship groups may appear tempting at first glance, this may result in some ship sub-types finding it very difficult to perform at baseline level, while others will do so with very little effort.

Figure 17 shows the index value given in g CO_2 / car unit* nautical mile for RoRo passenger vessels. The large RoRo ferries with gross tonnage over 20,000 emit from 400 to 1,300 g CO_2 / car unit* nautical mile, the worst emitting more than four times more than the best. In case of the smallest ferries, the variation for a ship of the same size is by a factor of ten (from 1,600 to 16,000 or more), and the worst performers emit almost 80,000 g CO_2 / car unit* nautical mile (i.e. outside the chart).

A car unit corresponds to a volume, not weight. However, if we were to assume that a car unit represents a mass of 1,000 kg, an emission of 1 g CO_2 / car unit* nautical mile would correspond to 1 g CO_2 / ton* nautical mile. The passenger ferries could then be plotted in the same chart as other ships as is done in Figure 18.

A split has been made between large and small ferries for clarity. Note also the logarithmic scale on the Y axis in this plot. The average index of the small ferries is approximately 50 times the index of comparable ships, while the index of the larger ferries is approximately 10 times larger. It should be admitted that the passenger ferries are disadvantaged since only the weight of the car has been considered. For fair comparison, the weight of the passengers should have been included; however inclusion of passenger weight would not change the overall picture. The reasons for this difference could be many and complex; however two factors spring to mind:

- Passengers resent waiting and will demand a thigh schedule with more frequent departures than could be optimal in order to optimize energy efficiency. This effect is particularly strong for smaller ferries which often operate day an night in rural areas (subsidized and with politically controlled schedules), and are sized to cope with rush hour needs. The constraints placed on these ferries thus forces energy inefficient operation in terms of g CO_2 / car unit* nautical mile.
- Passengers demand comfort. Passengers want room to move around, places to sit and sleep, and facilities like shops, restaurants and more depending on the length of the journey. This result in passenger ships needing significantly more space and weight to cater for these needs compared to traditional cargos.

While it could be feasible to convert car units and or passengers to weight, comparing the energy efficiency of these ships with other ship types puts ferries at significant disadvantage given the principal difference between human and other cargo. Such combination could, perhaps, be useful to compare ferries with each other.

In general, variations in index performance within a ship category is very significant and size dependent as can be appreciated by looking at Figure 16 and Figure 17.

Figure 15 Average index levels and gross tonnage

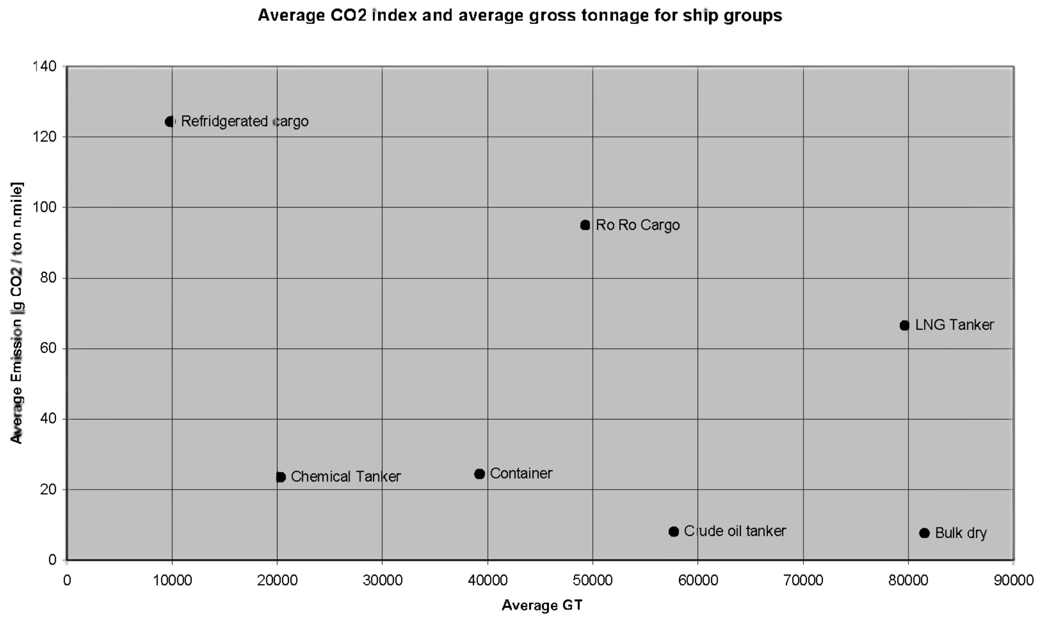


Figure 16 Scatter showing individual ship performance and trend lines for bulk (dry and liquid) and volume intensive cargo

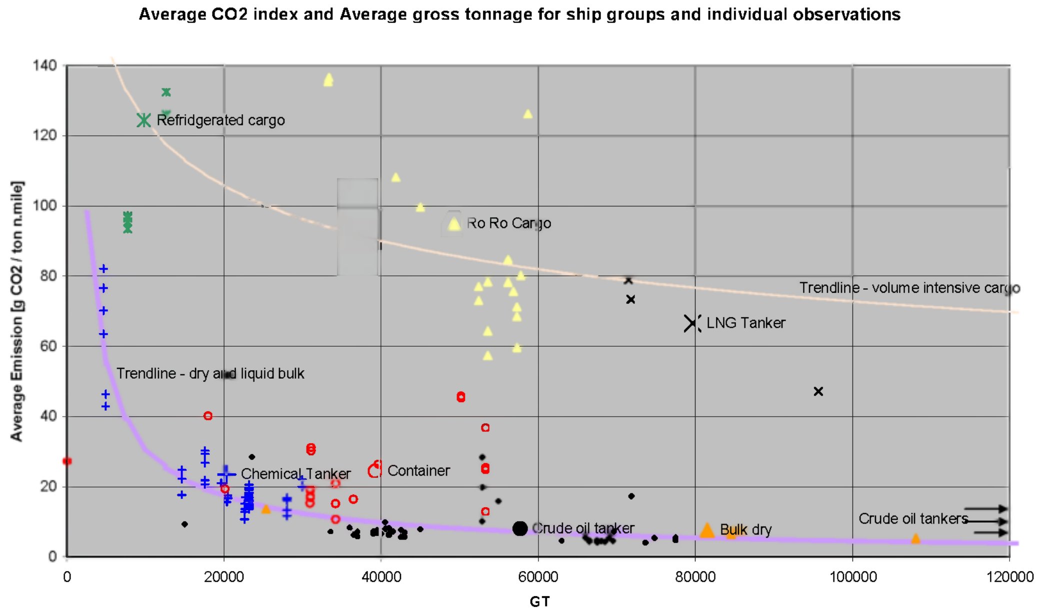


Figure 17 IMO index for RoRo / passenger vessels

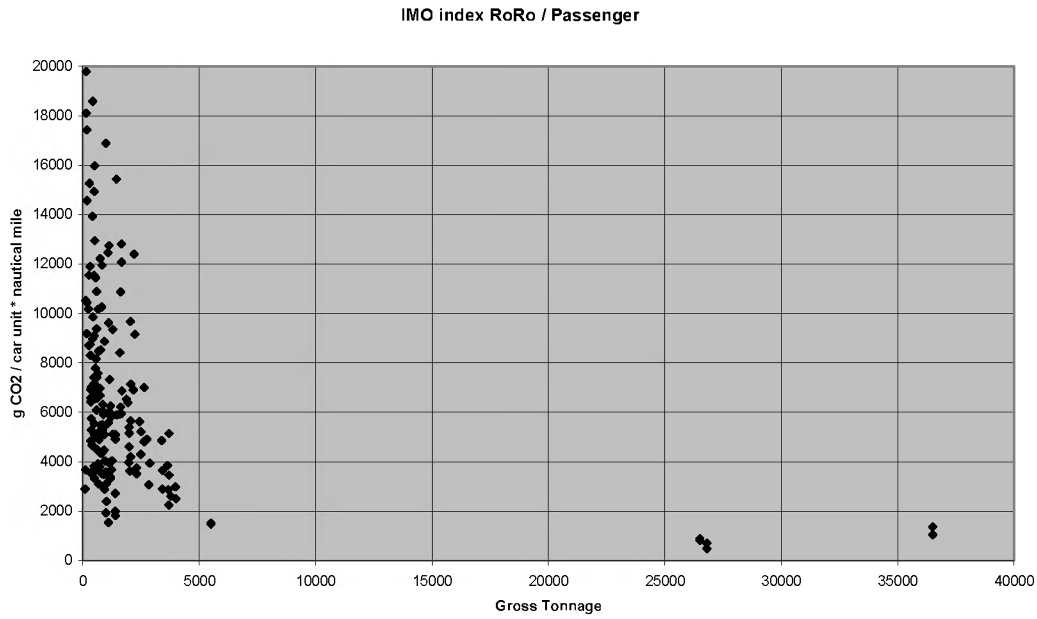
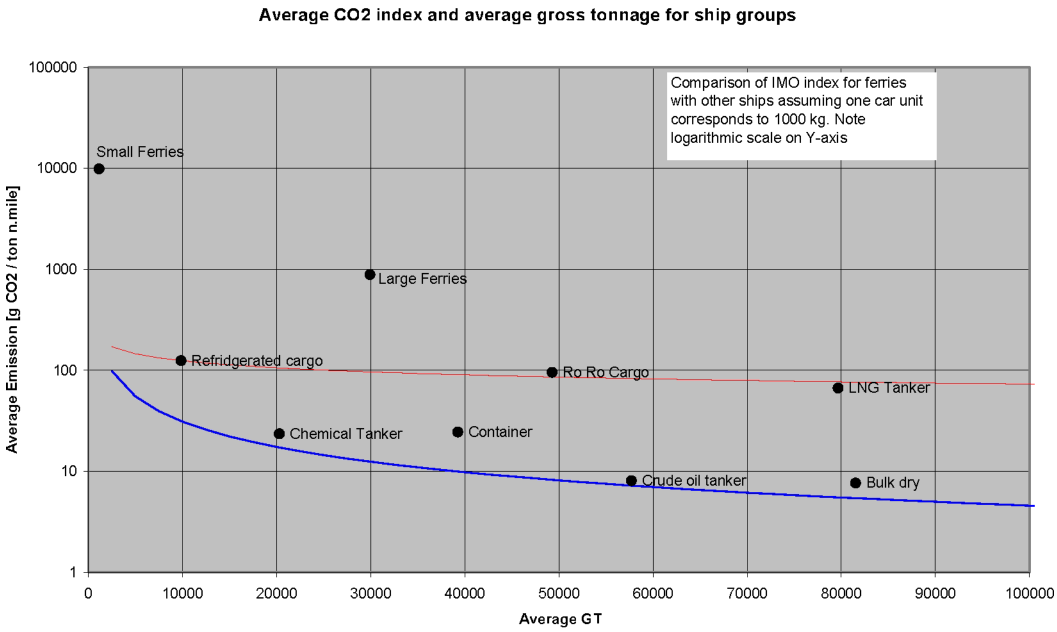


Figure 18 IMO index for RoRo passenger ships compared to other ships assuming a car unit weight of 1,000 kg



12 Index variations between sister ships

Sister ships are identical in design. Comparing the variation in index between sister ships is of particular interest because the differences observed would be related to the operation of the ship only, not design factors.

The variation in index calculated over a period of one year for 15 sister chemical tankers is shown in Figure 19. The emissions from the worst performers are 33% higher than the emissions from the best performers. These ships are built at the same yard, have identical hull and tonnage, the main machinery features are identical and they are operated by the same company. They are, however, 8 years age difference between the oldest and the newest vessel during which some minor alterations have been made to engine design and system solutions.

Figure 19 Index value calculated over a period of one year for 15 sister ships

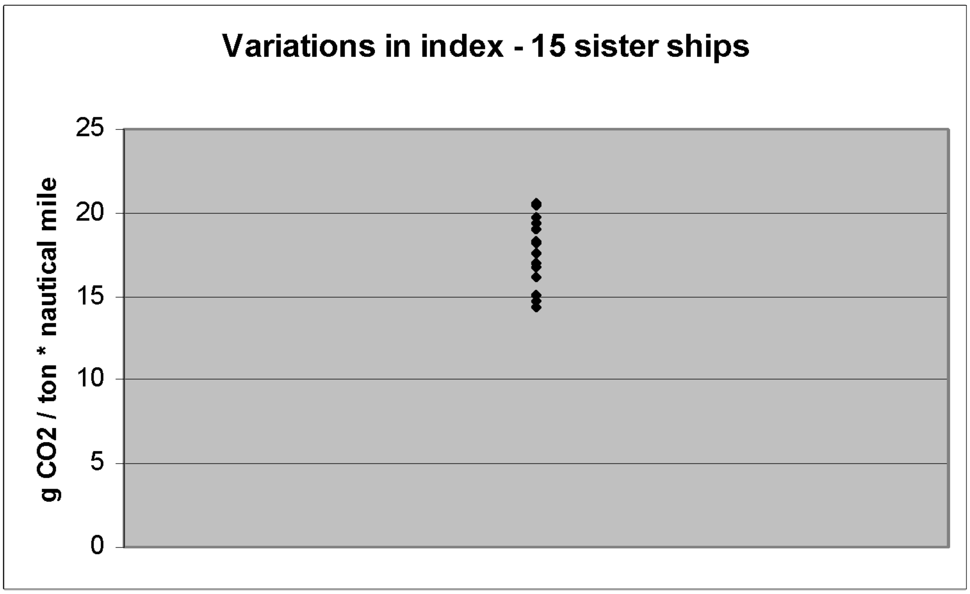
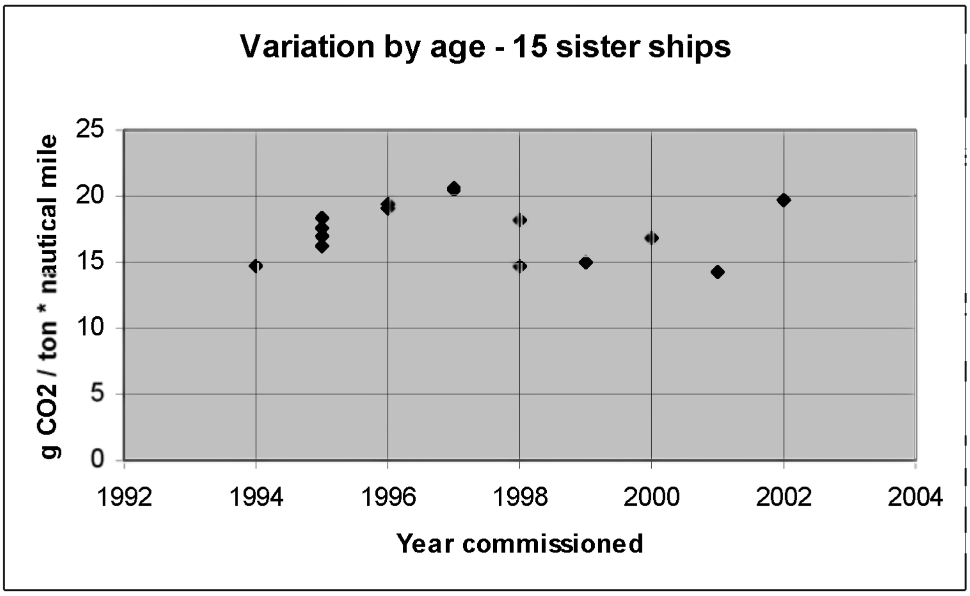


Figure 20 shows the CO_2 index depending on the age of the ship expressed as the year which the ship was commissioned for service. As shown in Figure 20, newer ships are not necessarily better than older. Figure 20 does, however, indicate some degree of autocorrelation – meaning that ships commissioned in 1995 have indexes between those commissioned in 1994 and 1996, that the index observed for the ship commissioned in 1996 is between the values of the ships of 1995 and 1997 and so forth (with some exceptions). This is an indication that age in fact could play a role on the index. This could for instance be related to periodic hull and propeller maintenance.

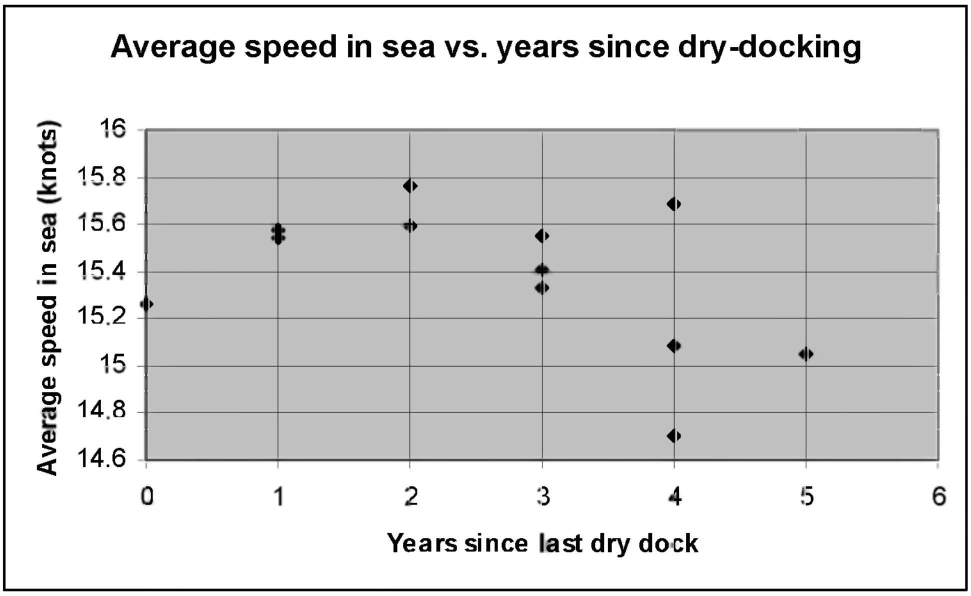
Figure 20 Distribution by ship age of index value for 15 sister ships



MARINTEK has monitored the fuel consumption and hull performance of more than one hundred ships over a period of 10 - 20 years. It has been observed that speed reductions of 5-10% are typical between hull renewals when the hull renewal period is three to five years. A speed reduction of 10% due to fouling would roughly correspond to an increase in fuel consumption of 30%.

The operator of these fifteen sister ships kindly provided data showing the speed in sea compared to time since last dry docking as shown in Figure 21. The average speed in sea shown in this figure is calculated over a period of one year. The data point 0 years since dry-docking thus includes both speed data logged before and after hull cleaning.

Figure 21 Average speed obtained in sea compared with years since last dry dock

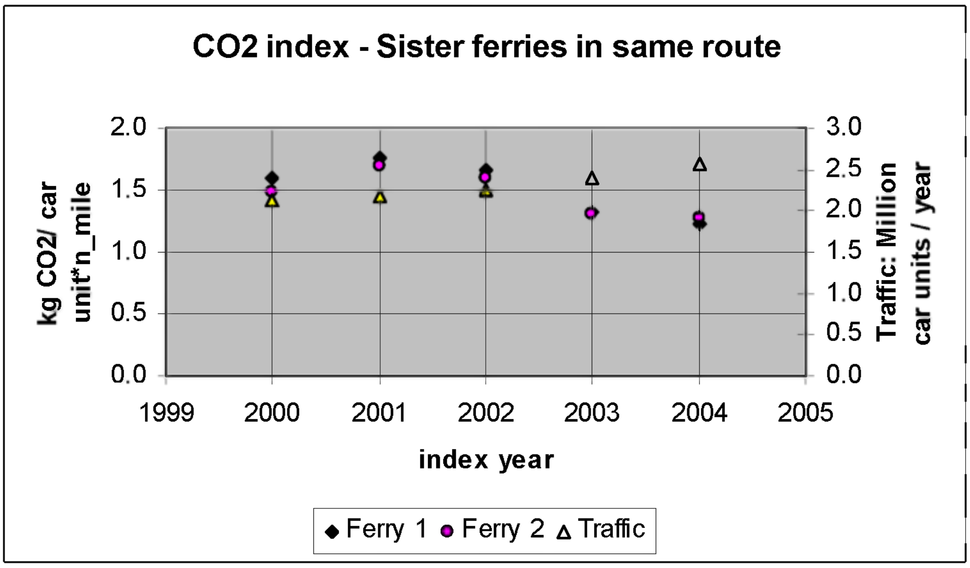


The data in Figure 21 substantiates the notion from Figure 20, that hull fouling is playing a role. The speed drop is roughly 5% which roughly corresponds to a 15% increase in fuel consumption. It seems reasonable to assume that a significant part, but not all of the variation in the index observed in this example is caused by hull fouling. This example thus highlights both the ability of the index to identify long term differences in performance between identical ships and also the considerable influence hull fouling can have on fuel consumption and hence emissions.

The decrease in speed and increase in power demand due to fouling accelerates non-linearly. Precise information on hull performance is desirable to monitor the effect of fouling and to find the right time to dry dock the ship and clean the hull. While the IMO index may be a useful as a general indicator, indicators utilizing ship specific resistance curves, draught, speed and consumption are more suitable to monitor and trend hull performance and detect variations at an early stage.

Another example that illustrates variation between sister ships is shown in Figure 22 which shows the index for two identical ferries in the same route calculated on a yearly basis over a period of five years. Unlike the previous case, the performance the ships are nearly identical in this case. The variation from one year to the next is, however, significant. This variation is driven by an increase in traffic in this particular ferry connection. Any hull fouling that has occurred in this period will tend to be masked by steadily improving index.

Figure 22 Index value for identical ferries in same route



In this case, the worst index observed in 2001 value is 40% higher than the best which was observed in 2004. The ferry operator is a government subcontractor and has very little influence on both the amount of traffic and on the sailing schedule. In terms of improving the ferry operation, comparing the ships with each other is more meaningful for the ship operator than comparing their performance with a fixed baseline for ferries or to last years performance.

In summary, the variation between sister ships has been observed to be more than 33% within the same year, i.e. the effect of operational issues (not design) can amount at least to this figure. Theoretically, the variation can be much greater. The question is, however, what lies behind the variation – how should the differences in index be interpreted?

13 Interpretation of IMO index results

A better understanding of how the index behaves in 'real life' can be obtained from a case study. The indexes observed for a Crude Oil Tanker transporting crude oil from oil fields in the North Sea is shown in Figure 23. The individual index is plotted for cargo voyages. Ballast voyages, (i.e. voyages where no cargo is carried) are not plotted since the transport work is zero and the index value cannot be determined (division by zero). The combined overall average indicated by a red line and a 5 voyage moving average plotted in yellow includes ballast voyages.

The average is comparatively stable in the first fourteen voyages, (256 to 270); however it then raises significantly for eight voyages (271 to 279) before falling back to a slightly elevated level the next 15 voyages. The variation in voyage index increases after the ten first voyages.

It appears that something has happened in the intermediate period that caused the index of the ship to increase significantly and for and extended period of time. This is, of course, helpful information for a ship operator, however in order to take action it is necessary to understand the underlying cause. In general, the reasons for variations in the index can be attributed to a combination of the following factors:

1 Relative utilization cargo space.
2 Relative fuel consumption on ballast voyages (related to the length of ballast voyages).
3 Efficiency of ship (engine condition, hull and propeller fouling, etc.).
4 Variations in speed.
5 Weather and currents.
6 Errors in measurement and registration.

Only the two first can be independently analyzed on basis of the index input data. These factors are plotted together with the IMO index in Figure 24 in order to see to what degree high indexes correspond to low cargo utilization and high consumption in ballast voyages.

In this figure, it appears that the utilization of cargo space shows a greater variation and has a lower average value after the first 14 voyages. This will contribute to the increase in the emission index. The relative amount of fuel consumed in ballast seems slightly lower during the last 15 voyages (279-295) than in the intermediate period where the index was on the highest level (271 to 279). This will cause the index to drop somewhat as is also seen in Figure 24. Looking at this chart, however, it is difficult by eye to assess the magnitude of the effects mentioned.

Figure 23 CO_2 index for individual voyages for crude oil tanker

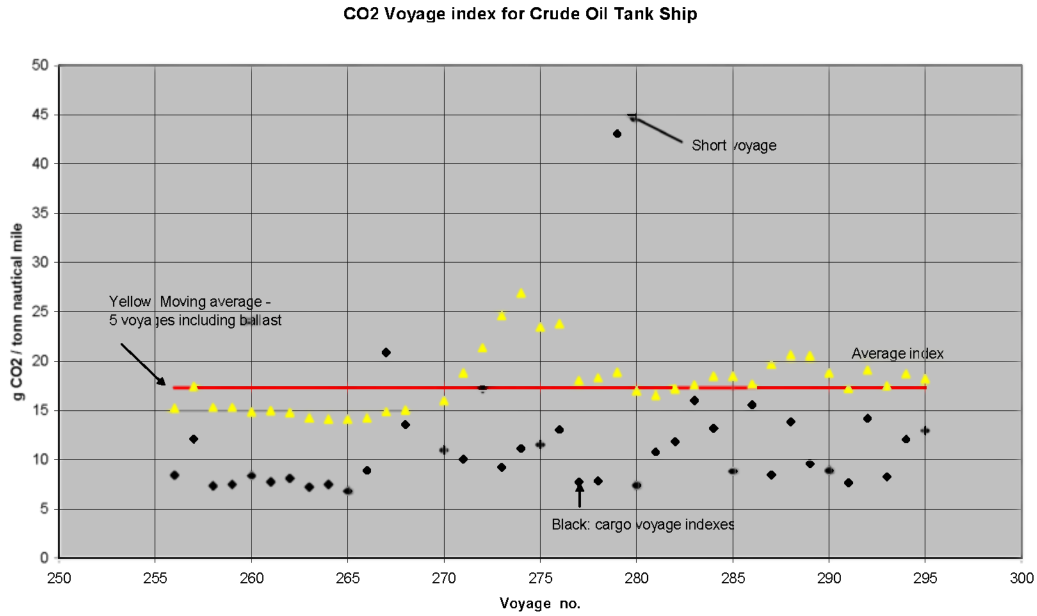
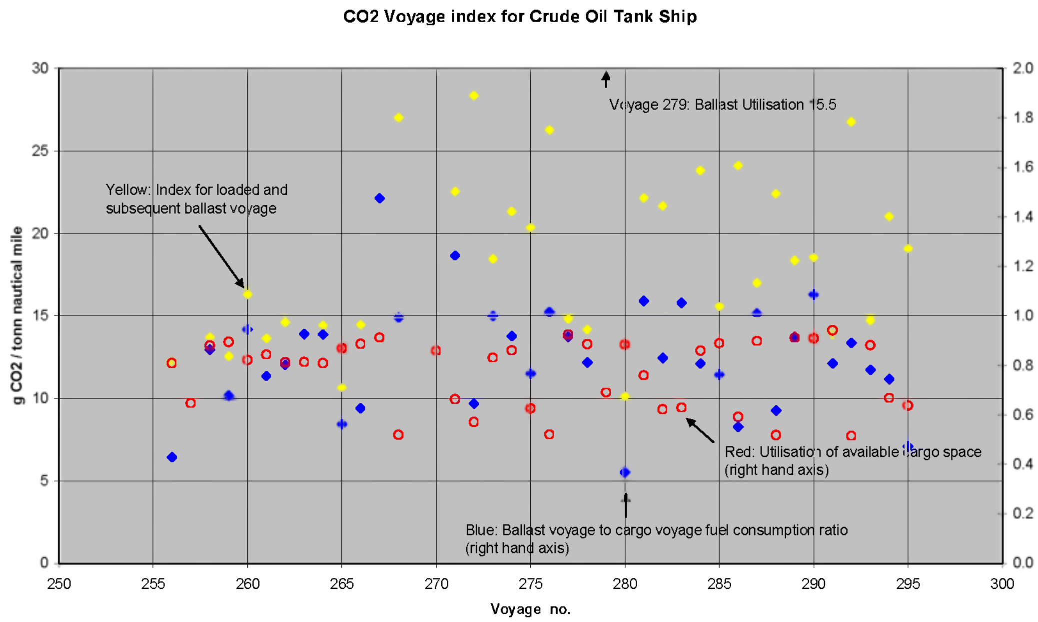


Figure 24 Comparison of index result to relative length of ballast voyage and cargo utilization



The contribution to the variation on the index that can be assigned to cargo load and ballast voyage fuel consumption can be estimated as shown in Annex 1 to this report. This calculation shows that in the current example, 68% of the variation in index is caused by cargo loading and fuel consumption in the ballast voyage.

The remaining 32% of the variation is interpreted as the combined effect of all other factors including propulsion efficiency, hull fouling, fuel consumption in harbor, errors in measurement and registration as well as the influence loading has on prolusion resistance and hence fuel consumption per nautical mile. Since the latter effect is not included in the simple prediction model, the actual influence of cargo loading and consumption in ballast is likely to be larger than 68%.

Using the IMO index, it will be very difficult to detect even a moderate increase in fuel consumption. Perhaps, over a number of years one would be able to see a clear difference; however other indexes could detect such deficiencies at an early stage.

14 Comparison of the IMO index with other CO_2 emissions indexes

Apart from the IMO index, two other indexes for CO_2 emission performance have been developed. These indexes have been developed by the industry organization Business for Social Responsibility (BSR) and the tank ship organization INTERTANKO. These indexes are referred to as the BSR and the INTERTANKO index in the following:

14.1 The BSR index

The BSR index has been developed in order to enable companies who have goods transported by containers at sea to calculate the CO_2 emission related to the transportation of their cargo. These companies know how many containers they have sent on a specific route via a known shipping company, but not necessarily by which ship. The BSR index is intended as an index for the emissions and transport work done by all ships operated by any given company on any given route. The index expresses CO_2 emissions in g/TEU-km. The ship owner calculates the BSR index for his route and sends it to interested customers who calculate the emission related to their activity. Monitoring the performance of individual ships has never been an objective with the BSR index.

The BSR index differs from the IMO index on these points:

- The index has been developed for container ships only.
- The index is calculated assuming the ship is fully loaded at all times.
- Fuel consumption used to cool containers is not included in the figure.
- The index is calculated for a group of ships on the same route.

14.2 The INTERTANKO index

The INTERTANKO index has been developed in parallel with the IMO index with the same principal objective. Both indexes are defined as CO_2 emitted divided by transport work. The difference between the IMO index and the INTERTANKO index is the definition of transport work. According to the INTERTANKO transport work is defined as follows:

> Transport work = Cargo mass * (distance sailed with cargo + distance sailed in ballast)

Distance sailed in ballast is not included in the IMO definition of transport work, hence according to the IMO definition:

> Transport work = Cargo mass * distance sailed with cargo

14.3 Example calculation

An example using fictitious numbers has been constructed in order to illustrate the difference between these indexes. Fictitious data has been chosen over real numbers because numbers can be selected to highlight the differences between the indexes. The example is based on a ship with a capacity for transporting 10,000 units of cargo (TEU, tons, etc.). In case A, this ship carries goods both on the outward and return leg. In case B, the ship does not carry cargo on the return leg. Since no cargo is carried, the fuel consumption is slightly lower.

Table 14 Emission Indexes calculated on fictitious data

		Outward			**Return**			**Index**		
	Capacity [units]	Fuel [tons]	Cargo [units]	Distance [n_miles]	Fuel [tons]	Cargo [units]	Distance [n_miles]	IMO	BSR	INT
A	10,000	100	9,000	1,000	100	9,000	1,000	35.6	32.1	35.6
B	10,000	100	9,000	1,000	90	0	1,000	67.7	30.5	33.8

Obviously, case A represents the more environmentally friendly operation of this ship. The IMO index clearly indicates this difference. The BSR index does not reflect this important difference in this example because it does not take the actual amount of cargo transported into account. The INTERTANKO index also misses out in this example because it credits the distance sailed in ballast. In fact, both the BSR and the INTERTANKO index falsely indicate that case B is better because less fuel is consumed. Clearly, both indexes have disadvantages when they are used to assess the performance of a ship and may result in qualitative errors.

An interesting aspect of the BSR index is the way it is used to distribute emissions to transport customers. The IMO index could be used for the same purpose as the BSR index while providing significantly more robust and reliable emission data.

15 Recommendations for improvement and application

The trials with the IMO index have clearly demonstrated the feasibility of employing this index and using it for monitoring ship performance. Nevertheless, a number of issues have surfaced during the practical testing and analysis of the IMO index. Some of these issues are related to the IMO guidelines and index definition while others relate to interpretation and use of results.

15.1 Recommendations relating to IMO guidelines and index definition

Transport work for ferries

Passenger ferries carry cars, trucks and passengers and are faced with a dilemma when calculating their transport work. As the IMO index is defined today, the operator can choose between passengers, car units, occupied lane-meters or another singular unit expressing amount of cargo transported. Selecting one (e.g. car units), the operator looses the other (e.g. passengers).
Ideally, both these should be included in the transport work.
One possible solution to this problem is to convert both cars and passengers to mass and adding them together. This way, the ship operator would be credited for transporting both. In this case, ferries would express their transport efficiency in g CO_2/ ton nautical mile.

Fuel consumption on short voyages

Ships making many short legs to collect or deliver goods in conjunction with long voyage have questioned the necessity of recording the actual fuel consumption on each short leg in stead of just pooling all fuel consumed for the long and short legs together divide by actual transport work figure. The latter may be convenient because the actual fuel consumption is not necessarily measured on each short leg. In many ships, the fuel consumption is determined by sounding tanks; hence it is not just a matter of reading a display.
In fact, it is not necessary to determine the fuel consumption on each leg in order to get the right overall index. What is required is the correct transport work on each leg; however this is not obvious when reading the IMO guideline and looking at the reporting sheet. The IMO guideline could preferably clarify this particular point. Naturally, this point applies both to fuel used in sea as well as in port.

Ships in regular single leg schedule

Ships operating back and forth in a regular single leg schedule (such as a ferry) can calculate the IMO index for any given period using the following definition of transport work:

$$Transport\_work = D * \sum_i m_{CARGO}$$

Since the distance is the same, it is thus not necessary to have cargo data for each voyage and aggregated data can be used to calculate transport work. This approach is beneficial since aggregated data are typically more readily available.

Carbon factor for LNG boil-off
LNG boil-off is used as fuel for LNG carriers. Is suggested that the guideline should either state specifically that that the carbon factor for natural gas given in the circular can be applied to LNG boil-off, or derive an applicable factor for LNG boil off (the carbon content in LNG boil-off can be expected to be slightly lower than in natural gas).

Misinterpretations
Some issues that are well defined in the IMO guideline have nevertheless been misinterpreted. IMO could consider whether these issues should be states more clearly:

1 The IMO guideline suggests that operators to record index data either per voyage or per day. The corresponding column heading in the IMO CO_2 index reporting sheet (IMO Circ 471) reads 'Voyage or day'. This has been misinterpreted as 'Voyage or day, whichever is shorter'.

2 Some operators have failed to include LNG boil off in their fuel consumption figures, reporting only the consumption of fuel purchased.

15.2 Recommendations relating to application of the IMO index

Use of the IMO index to calculate cargo specific emissions
Some companies who buy transport services from ships have requested specific emission figures in order to calculate the emissions caused by the transportation of their goods. This need has been addressed by the BSR index. However as previously argued, the BSR index underestimates emissions and can give misleading indications in some cases regarding which service is more environmentally friendly. In principle, the IMO index could also be used for the same purpose as the BSR index while providing significantly more robust and reliable emission data. To do this, the IMO index should preferably be calculated for the individual routes used by each customer as done by BSR. A suitable guideline for this application of the IMO index could be developed by IMO.

Use of the IMO index to monitor ship performance
The intent of the IMO index is presently use as a parameter of an environmental management system. The purpose of measuring and indexing the CO_2 emission within an environmental management system is not just to monitor the emission but also to identify poor performance and make improvements. To do so, one must be able to understand the cause of the variations observed.

The total CO_2 emission performance of a ship depends on the technical condition of the ship but also on the transport market. Market related factors (loading and fuel consumed in ballast) accounted for at least 68% of the variation observed in one example. Identifying the different causes for variation in the index is difficult.

A package of ship specific indexes more apt at monitoring the specific aspects of ship efficiency could be derived and included in an environmental management system. This way, it would be much easier to identify where improvements are needed.

Evaluation of ship performance in relation to voluntary or mandatory schemes
Applying the IMO index in a voluntary or mandatory incentive or regulatory scheme will result in a need to evaluate whether the performance of a ship qualifies for some sort of benefit or penalty. This necessitates the use of some sort of reference level or baseline with which the ship's index is compared. Establishing baselines is not straight forward. As previously discussed, the potential minimum index value will amongst other depend on:

- Ship size.
- Type of cargo.
- Speed.
- Special capabilities (self discharge, ice breaking, etc.).

For instance, a baseline common for all crude oil tankers would probably allow effortless compliance of the larger tankers while smaller tankers would be unable to reach the target even under optimal conditions. This effect is fair and desired if these ships are in the same trade and serving the same marked, however it could be considered unfair if the tankers are serving different markets, i.e. the smaller tankers are visiting harbors inaccessible to larger tankers or delivering smaller parcels that could not be served by the large tanker in an economical or environmentally friendly manner. From this perspective, assigning baselines to specific trades rather than ship types could be equally relevant.

This is a fundamental problem which applies to all ship types. If the baseline is adjusted for ship size, the distinction between an efficient bigger ship and a smaller less efficient ship is eliminated, hence the incentive to improve operation by using the larger ship is also eliminated. If corrections are made for speed, the incentive for speed reduction is removed and so forth.

Any voluntary or mandatory scheme based on the IMO CO_2 index will pass judgment on the combined effect of technical condition of the ship and utilization of the cargo carrying capacity of a ship. The latter is affected by the constantly changing 'business climate'. The influence a ship-owner can have on cargo utilization is debatable. Some gains can probably be achieved by improving business structure, logistics, marketing and more. How much this can amount to will depend on the trade, but such gains cannot on a general basis be expected to counteract general drops in demand. Hence the average index for a ship category may vary from one year to the next.

Such variation could cause a static baseline to lose its effectiveness as a control parameter as 'compliance' could become alternately too easy or too difficult. In order to stay relevant, the baseline may need to account for variation in demand for transport.

Obtaining data suitable as a basis for a possible baseline

The CO_2 index data this study covered only 364 ships. Furthermore, only data for 8 out of 18 ship categories have been collected. In order to have reliable and representative CO_2 index data for different ship types, a larger number of ships reflecting the size distribution should be included within each category of the dataset. To account for variations in trade, data for more than one would probably be needed.

More data could be obtained by approaching selected ship owners. Getting more data by this approach could be useful, however approaching a limited number of ship-owners will result in data that is biased, and hence not ideally suited to determine truly representative averages. If a trade flow approach to baselines is to be evaluated, this would introduce new requirements to the data collection.

In terms of data quality, the best way forward would be some sort of compulsory reporting scheme since this would give more representative average.

15.3 References

/1/ Lloyds Fairplay World Fleet Statistics

/2/ Study of Greenhouse Gas Emissions from Ships. Report for the IMO. MARINTEK Trondheim, Norway, March 2000

Annex 1: Contribution of loading and consumption in ballast to index variation

The purpose of this annex is to assess how much of the variation in the index in the shuttle tanker example in chapter 13 can be attributed to variation in loading and fuel consumption during ballast voyages. If we calculate the index for a cargo voyage and the subsequent ballast voyage together as one index we observe find the following average values in the dataset:

Average index (combined ballast and loaded)	20.76
Average cargo load on loaded leg	0.77
Average relative fuel consumption in ballast leg	0.93

Slightly simplified, the index value for one loaded voyage and one subsequent ballast leg consists of the following

$$Index = C_{Carbon} \frac{Fuel\_loaded + Fuel\_ballast}{m_{cargo} * distance\_travelled}$$

C_{carbon} is the conversion factor used to calculate CO_2 emission from fuel consumption. Introducing *r* as the relative fuel consumption in ballast voyage and *l* as the load factor, the formula reads

$$Index = C_{Carbon} * \frac{Fuel\_loaded}{distance\_travelled * m_{cargo\_max}} * \frac{1+r}{l}$$

All else equal, if the cargo load *l* was to increase on one voyage, we would assume the index to decrease. For instance: if the ship was full (loading factor 1.0) the index would decrease approximately from the average 20.76 to 15.99 (calculated as (1/1)/ (1/0.77)*20.76). On the other hand, if the ship is only half full (loading factor 0.5), the index would be expected to increase to approximately 31.97 (calculated as (1/0.5)/ (1/0.77)*20.76).

In the same manner, if the relative fuel consumption in the ballast voyage was to increase we would expect the index to increase as well. For instance, should it increase from the average 0.93 to 1, we would expect the index to increase to approximately 21.5 ((1/0.93+1)/2)*20.76) while a decrease to 0.8 would result in an increase in the index to 19.3 ((0.8/0.93+1)/2)*20.76.

Note that no attempt has been made to analyze the ratio of fuel consumed to distance traveled. The reason is that this relationship is strongly interrelated with ship loading, ship efficiency and the amount of fuel consumed in port which cannot be distinguished in the input data.

This simple prediction model is applied the dataset for this ship in Table 15.

Some very extreme indexes believed related to errors in registration were removed from the dataset prior to this analysis. The table should be read as follows. The ship reported than on voyage 256 the index was 12.6, the cargo utilization was 0.81 and the fuel consumption on the ballast leg was 43% of fuel consumption on the loaded voyage.

Table 15 Comparison between observed index and predictions based on cargo volume and fuel consumption in ballast leg (table abridged to fit page)

	Data reported from ship			Prediction from			Deviation		Square error	
Voyage	Index	Cargo	Ballast	Cargo	Ballast	Combined	Prediction	Total	Res- error	total
	18.75	**0.77**	**0.80**							
256	12.06	0.81	0.43	17.78	14.37	13.63	1.57	6.69	2.46	44.73
258	13.70	0.88	0.86	16.34	19.45	16.95	3.25	5.05	10.58	25.53
259	12.55	0.89	0.68	16.07	17.27	14.80	2.25	6.20	5.07	38.39
260	16.29	0.82	0.95	17.50	20.39	19.03	2.74	2.46	7.51	6.03
261	13.63	0.84	0.76	17.04	18.19	16.54	2.90	5.12	8.43	26.17
262	14.60	0.81	0.80	17.68	18.73	17.66	3.06	4.15	9.36	17.20
263	13.92	0.81	0.93	17.67	20.18	19.01	5.09	4.83	25.94	23.31
264	14.42	0.81	0.92	17.78	20.15	19.11	4.69	4.32	21.99	18.70
265	10.65	0.87	0.56	16.54	15.93	14.06	3.41	8.10	11.62	65.63
266	14.47	0.89	0.63	16.22	16.68	14.43	-0.03	4.28	0.00	18.35
268	27.02	0.52	0.99	27.69	20.96	30.95	3.93	-8.27	15.47	68.41
271	22.54	0.66	0.65	21.69	16.91	19.55	-2.99	-3.79	8.93	14.39
272	28.34	0.57	1.00	25.17	21.03	28.24	-0.11	-9.60	0.01	92.07
273	18.46	0.83	0.92	17.31	20.08	18.54	0.08	0.29	0.01	0.08
274	21.32	0.86	0.77	16.71	18.31	16.32	-5.00	-2.57	25.03	6.61
275	20.35	0.63	1.02	22.96	21.21	25.97	5.62	-1.61	31.57	2.58
276	26.26	0.52	0.92	27.63	20.05	29.55	3.30	-7.51	10.86	56.35
277	14.82	0.93	0.81	15.53	18.84	15.61	0.79	3.93	0.62	15.44
280	10.13	0.88	0.37	16.27	13.66	11.86	1.73	8.62	2.98	74.29
281	22.15	0.76	1.06	18.93	21.73	21.94	-0.21	-3.40	0.04	11.58
282	21.66	0.62	0.83	23.10	19.05	23.48	1.82	-2.91	3.31	8.48
283	32.86	0.63	1.05	22.86	21.64	26.39	-6.47	-14.11	41.91	199.12
284	23.81	0.86	0.81	16.73	18.78	16.76	-7.06	-5.07	49.80	25.67

Total sum of squares total	1,024
Sum of squares residual error	327
Difference	697

Contribution by cargo and ballast to variation in index 68% (697/1024).

On basis of the reported cargo utilization we would predict that the index would be 17.78 (slightly lower than the average). On basis of the reported fuel consumption in ballast we would predict that the index would be 14.37 (much lower than the average). Combined, we predict the index to 13.63. The actual index is 12.06 hence the predicted value deviates from the true index by 1.57. The actual index deviates from the average by 6.69. The square of these deviations (square error) is shown in the right hand columns.

The total sum of squares amounts to 1,024. The sum of squares of the residual error (difference between observed and predicted value) is 327. The difference between these two numbers, 697 or 68% of the total variation is an expression of the contribution by cargo and ballast to the variation in index.

Part C

Date of first issue: 2006-09-15	Project No.: 31200231
Approved by: Espen Kiær, Principal Consultant	Organisational unit: DNV Maritime Solutions
Client: European Commission, Directorate – General Environment	Client ref.: Ian Hodgson

Summary:

Directive 2005/33 came into force in August 2005. The Commission will produce guidance in the implementation of the Directive for both the shipping industry and the Member States.

The objective of this report is to provide information that will be used to; 1) Facilitate a committee process to approve the use of emission abatement technologies for ships sailing the flag of a Member State. 2) Propose criteria to the EU on selecting emission abatement technologies according to Directive 2005/33.

The main elements of the report is a summary of IMO Guidelines for Exhaust Gas SO_x Cleaning Systems, an evaluation of the divergences between the EU and IMO approval regimes for EGCS and recommend adjustments and specifications to the EU regime, a literature study on EGCS emission efficiency and verification of emissions by monitoring, literature study on the impacts and handling of effluents from EGCS, an assessment of sulphuric mist, and finally recommended EGCS use criteria in ports and harbours and enclosed waters.

Report No.: 2006-1127	Client Doc. No.:	Client Rev.No.
Report title: Greenhouse gas policy for shipping, and implementation guidance for marine fuel sulphur directive Task 3: Inform Committee Process		
Work carried out by: Tommy Johnsen, Michael Lorange, Sofia Fürstenberg		
Work verified by: Hanna L. Behrens		
Date of this revision: 2006-10-09	Rev. No.: 02	Number of pages:

Indexing terms

Ships
Exhaust gas cleaning
Sulphur emission
Criteria

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16 Summary

1 Practical information about SO_x-EGCS is scarce. No SO_x-EGCS are commercially in use today, or has been up until today. Technology owners that have performed tests are to a large extent reluctant to share detailed information because they are in a development phase and do not want to share technical information that can be exploited by competing companies.

2 The main area of divergence between the EU and IMO SO_x-EGCS approval schemes is that continuous monitoring is mandatory in the EU while the IMO opens for type approval as an alternative to continuous monitoring. It is recommended that EU also opens for a scheme similar to the IMO Scheme A (type approval) and in general refers to the IMO guideline to the degree possible when it comes to specifying approval requirements. Within Scheme A, it is in theory possible to turn the scrubber off without the authorities being able to control this. This can however be compensated by monitoring other more simple parameters, like water flow.

3 Since 1990, 6 scrubber development projects have been identified where tests/trials have been conducted or are planned for. Tests and trials are performed on 1 MW units and are reporting SO_x cleaning efficiencies above 90%.

4 Information on the EGCS SO_x cleaning efficiency sensitivity to operational variables is to a little extent available. The efficiency seems not very sensitive to operational variations as long as the operational parameters are kept within the ranges that the system is designed for. Due to the laws of nature, sea water alkalinity is an important sensitivity parameter. Low alkalinity may give low cleaning efficiency if an alkaline material is not mixed with the scrubbing water. At low engine loads (idling) scrubbers might reduce the engine backpressure below what is required. The IMO guideline allows a SO_x concentration of 50 ppm at idling conditions to overcome this challenge.

5 Continuous monitoring equipment onboard ships presently have an investment cost in the range € 65,000 – 125,000 plus installation costs. Also maintenance costs must be added.

6 The environmental impact of scrubber waste water discharge depends on the ship traffic, water exchange and the receiving waters sensitivity to the pollution. Waste water dispersion modelling shows that discharges are rapidly diluted when ships are in movement. The most critical situation is when the ship is at quay. Then an average plume dilution of 1:150 is calculated within 20 metre from the point of discharge.

7 Taking the worst case discharge into account and allowing PEC/PNEC to exceed 1 within the near field (20 m at quay and 50 m while sailing), no compounds or properties exceed 1. I.e. only accumulative substances discharged to waters with unsatisfactory water exchange relative to the ship traffic are critical. As an example discharges without any water treatment are not problematic in the Port of Oslo according to performed modelling.

8 If waste water treatment is necessary hydro cyclones removing particles and adhered pollutants seems like the most viable option. Practical experience

onboard the Pride of Kent shows a particle removal efficiency of 95%. Also filters are possible, but no practical experience is available.

9 Waste water treatment residues can be further handled by the separator sludge tanks. Amounts of residues produced are of the same order of magnitude as sludge.

10 Scrubber manufacturers are aware of the acid mist challenge (H_2SO_4 droplets) and design their equipment to avoid the formation of acid mist. This is secured by high SO_x cleaning efficiency, demisting the exhaust gas after the scrubber and by reheating the exhaust gas. If the mitigating measures should fail (e.g. demisting) acid mist can be formed. Although, due to dilution it does not represent any health risk to humans beyond the ship. Nor corrosion is regarded is a severe problem given the fact that acid mist formation would be an accidental situation and not a continuous exposure. However, for extended periods damage to property and vegetation can occur. Thus, in situations where acid mist formation is detected (visually) the scrubbers should be shut down.

11 The following wash water discharge criteria are recommended:

Substance/property	**Discharge criteria**
HC*	1 ppm (increase of background concentration)
pH	2 pH units (decrease from background level) can be considered. Preferably the outcome from the IMO wash water criteria correspondence group should be applied.
Deposits washout	During dry operations of the scrubber there might be build up of deposits within the scrubber. This will inevitably lead to a significant increase in components in the wash water and the possible overload of the wash water treatment plant and discharge criteria. Short term deviation allowance is needed for such periods. However, these washout situations should not be allowed in enclosed waters, harbours and ports.

* To avoid that the criteria is met by dilution only, the concentration must be adjusted according to the water flow rate. The 1 ppm level is for a nominal wash water rate of 44 ton/hour for a 1 MW engine.

12 The discharge criteria recommendations are based on a limited amount of information from a few tests and trials. It is therefore important to not have a static baseline, but to improve criteria and their robustness over time as more extensive information becomes available.

17 Introduction

17.1 Background and purpose

Directive 2005/33 came into force in August 2005. At this stage, the Commission believes it would be helpful to produce guidance in the implementation of the Directive for both the shipping industry and the Member States.

The objective of this report is to provide information that will be used to:

- Facilitate a committee process to approve the use of emission abatement technologies for ships sailing the flag of a Member State.
- Propose criteria to the EU on selecting emission abatement technologies according to Directive 2005/33.

17.2 Comments to the availability of information

Regarding the quality of waste water from the scrubber process discharged to sea Directive 2005/33/EC requires that the "*….discharge has no impact on ecosystems, based on criteria to be communicated by the authorities of Port States to the IMO*".

A similar wording is given in by MARPOL, Annex VI, Regulation 14: "*….waste streams have no adverse impact on the ecosystem of such enclosed ports, harbours and estuaries, based upon criteria communicated by the authorities of the Port State to the Organization*".

Both requirements refer to criteria to be developed. As per today no such criteria are in place, although proposals are developed, or are about to be, in some Port States. As long as no criteria are established the scrubber manufacturers do not know what type of waste water treatment to apply and ship owners are reluctant to invest in SO_x-EGCS with water treatment plants that might be non-compliance once the criteria are established. Also, ship owners are not willing to pay any extra cost for expensive water treatment plant that might not be necessary.

This leads to a situation where:

- No SO_x-EGCS are commercially in use today, or has been up until today. This leads to very little practical experience and few sources of information that can be applied in this project.
- The tests that are performed have to a little extent had their focus on waste water treatment. Hence, even less information is available within this field.

In addition, technology owners that have performed tests are to a large extent reluctant to share information. This, because they are in a development phase and do not want to share technical information that can be exploited by competing companies.

As a conclusion, practical information about SO_x-EGCS is scarce. Hence, some of the issues that are dealt with in this report cannot be described to the extent that initially was intended.

17.3 Report structure

This report is divided into 8 chapters. The chapters are addressing the following issues:

1 **Introduction**. Background purpose and report structure.
2 **Summary of IMO Guidelines for Exhaust Gas SO_x Cleaning Systems**. The GUIDELINE was adopted by the Marine Environment Protection Committee (MEPC) 53rd session the 21 July 2005. The chapter summarises the contents of the Guideline.
3 **EU ECGS approval requirements**. The chapter evaluates the divergences between the EU and IMO approval regimes for EGCS and recommend adjustments and specifications to the EU regime.
4 **Literature study on EGCS emission efficiency and verification**. The chapter includes the results from a literature study on the cleaning efficiency of EGCS and how the emission reductions are verified by measurements and monitoring. Also the costs of continuous monitoring are addressed.
5 **Literature study on effluents from EGCS**. The chapter includes the results of a literature study of the environmental impacts of EGCS effluents. Alternative ways of handling such effluents are described and recommendations will be made taking into account the environmental aspects, practicalities and cost of the handling options.
6 **EGCS efficiency variables**. The chapter evaluates the cleaning efficiency of EGCS as a function of EGCS operational variables with an influence on the cleaning performance.
7 **Assessment of potential sulphuric mist impacts**. The chapter evaluates the possibility of acid mist formation and emission from scrubbers, and to what extent such emissions can cause local acidification problems. Mitigation options are also discussed.
8 **Recommended EGCS use criteria**. The chapter gives recommendations on minimum criteria for using EGCS in ports and harbours and enclosed waters.

18 Summary of IMO guidelines for exhaust gas SO_x cleaning systems

The IMO GUIDELINES FOR EXHAUST GAS SO_X CLEANING SYSTEMS was adopted by the Marine Environment Protection Committee (MEPC) 53rd session the 21 July 2005. This chapter summarises the contents of the Guideline /1/.

There are two alternative ways of demonstrating compliance to the guideline:
- **Scheme A**: Type approval and certification of exhaust gas cleaning system (EGCS).
- **Scheme B**: Continuous monitoring of SO_x emissions.

For both schemes, one of the two alternative emission limits should be met:
- 6.0 g SO_x/kWh.
- 65 SO_2 (ppm) / CO_2 (%).

It is possible to treat only a part of the exhaust gas flow with the EGCS and by-pass the rest. The overall emission value must however not exceed the limit values at any point in time.

18.1 Scheme A – type approval

Prior to use within a sulphur emission control area (SECA), an EGCS must obtain a SECA Compliance Certificate (SCC).

An SCC can be issued for a single product (specific design and rating) or for a product range (same design, but different ratings). Additional tests must be performed for product range approval compared to single product approval.

Subsequent similar products with same design and rating as the approved single product or the product range do not need testing (serially manufactured units). SCC is then provided by the Administration (i.e. class societies) following conformity of production arrangement submitted by the manufacturer to the Administration.

18.1.1 Single product approval requirements

To receive a SCC the EGCS product must:
- Be supplied with a EGCS Technical Manual (ETM).
- Perform emission measurements according to the guideline to prove compliance with the emission limit.
- Perform wash water measurements to prove compliance with criteria to be developed by Port States.

ETM content

The ETM must contain unit identification information and the operational parameters for which the unit is certified, including, but not limited to:

- Max. and min. exhaust gas mass flow rate.
- The power and type of engine/boiler and other relevant machinery parameters.
- Exhaust gas inlet temperature ranges and max. outlet with EGCS in operation.
- Exhaust gas differential pressure range.
- Max. exhaust gas inlet pressure with machinery operating at max continuous rating (MCR) and 80% engine load.
- Max. and min. wash water flow rate, inlet pressure and min. inlet water alkalinity.
- Effect on wash water quality.
- Wash water system design requirements.
- Salinity levels or fresh water elements necessary to provide adequate neutralizing agents.
- Other factors or restrictions relevant to perform below the emission limit.
- Maintenance requirements in order to perform below the emission limit over time.
- Survey means and the SCC.

Emission measurements

Emission limits must be met at the following load ranges:

- At machinery loads falling within the ETM operating parameters and at the load levels specified in the bullets below.
- Main propulsion diesel engines: 100-25% of the load range of the engines.
- Auxiliary diesel engines: 100-10% of the load range of the engines.
- Diesel engines for both main propulsion and auxiliary purposes: 100-10% of the load range of the engines.
- Boilers: 100-10% of the load range (steaming rates) of the boiler(s).
- At load points below the minimum load points given above, the EGCS should continue in operation. During fuel oil combustion under idling conditions the exhaust gas concentration of SO_2 should not exceed 50 ppm (at 15% O_2 concentration for diesel engines and 3% for boilers).

Emission measurements must be performed to demonstrate compliance with the emission limit at minimum four load points for the exhaust gas mass flow rate:

1. 100-95% of the maximum rate for which the unit is certified.
2. Within ±5% of the minimum rate for which the unit is certified.
3. At 1/3 and 2/3 of the range between the max. and min. level above.

Measurements must be performed at additional load points if:

- There are discontinuities in the operation.
- There is evidence of emission peaks below the max. exhaust gas mass flow.

The emission limit must be met with a fuel sulphur content of 4.5%. Alternatively, lower sulphur content fuels can be used if compliance with a 4.5% sulphur level can be justified through two series of tests with fuel sulphur content of:

- $\geq$2% sulphur.
- 1% sulphur above the fuel with the lowest sulphur content.

The effect of variations in parameters defined in the ETM, and combinations of these are to be assessed by testing or otherwise where appropriate. No variations should lead to an excess of the emission limit value.

The emission testing should follow the requirements of the NO_x Technical Code, chapter 5 and associated appendices, except as provided by the SO_x Guideline, the most important requirements being:

- CO_2, O_2 and SO_2 should be measured. Also water content if cross duct sampling[20] system is used.
- SO_2 should be measured using analysers operating on NDIR[21] or NDUV[22] principles.
- SO_2 should be monitored online.
- Samples should be maintained at temperatures that avoid water condensing.
- Sample drying must not result in loss of SO_2.
- Fuel oil used in tests should be sampled and analysed.
- Two adjustments to make the NO_x Technical Code applicable to SO_2 including specification of how exhaust mass flow is to be calculated and how to convert concentrations from a wet to a dry basis.
- If the SO_2 (ppm)/CO_2(%) ratio method is used some additional requirements are given including: 1) SO_2 and CO_2 from the same sampling point; 2) measurements above dew point or on a fully dry basis; 3) Method for calculating the SO_2 (ppm)/CO_2(%) value.

Wash water and wash water residues requirements

The wash water system should eliminate or reduce to a non-harmful level; hydrocarbons, carbon residue, ash, vanadium, other heavy metals and other substances contained within the EGCS unit.

Control of wash water quality and residual waste should not lead to pollution in other areas or to other environmental media.

Additional guidelines will be developed by IMO.
Residues should be land disposed. Requirements on record keeping of disposal are to be developed by IMO.

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[20] Cross duct sampling is a method for taking samples from the exhaust gas. The samples is taken via a multipoint probe over the whole exhaust gas channel (in opposite to a single “representative” sampling point.

[21] NDIR (Non-dispersive infrared) is a gas analysis principle. The exhaust gas sample is exposed to IR light. Different molecules absorb the light at different wavelengths. The degree of absorbance at a given wavelength is used to measure concentration of a particular substance. The term non-dispersive refers to the fact that all the light passes through the gas sample (no prism to pre-select desired wavelengths).

[22] NDUV (Non-dispersive ultraviolet) is a gas analysis principle. The principle is the same as for NDIR, but UV light is used instead of IR light.

18.1.2 Product range approval

Tests according to the unit approval requirements must be performed for three different capacities (highest, lowest and intermediate capacity) and an EGCS Technical Manual (ETM) must be provided for each capacity unit.

Additional information must also be given on the different capacities sensitivity to variation in parameters documented in the ETM.

18.1.3 Demonstrating compliance during operation

Verification procedure
The ETM (including SCC) must be retained onboard and be available for surveys. Changes in the ETM must be approved.

The ETM should contain a verification procedure for use at surveys as required. The basis for the verification procedure is that if all components, values and settings are within those as approved, the emissions will be within the limit and no measurements are needed.

EGCS in use documentation
When the system is in use it should be automatically recorded, minimum by wash water pressure and flow rate, pH, combustion unit load and exhaust gas pressure and temperature at given locations.

Emission monitoring
Daily spot checks of the SO_2(ppm)/CO_2(%) ratio in conjunction with in-use recordings (recordings listed under the heading *EGCS in use documentation* above) are recommended if a continuous monitoring system is not installed. In case of continuous monitoring only daily spot checks of the in-use recordings are needed.

Continuous monitoring is recommended if the EGCS manufacturer is unable to provide assurance that the limit value will be met between surveys by means of the verification procedure.

Record book
The shipowner should record service and maintenance. Record book format is to be provided by EGCS manufacturer. Alternatively, service and maintenance should be a part of the vessel's approved maintenance system.

18.2 Scheme B

Requirements particularly for scheme B are:

- The monitoring system should be approved by the administration and the results of monitoring should be available to demonstrate compliance.
- SO_2 and CO_2 should be measured and measurement guidelines specific for the SO_2(ppm) / CO_2 (%) ratio method should be followed.

- The continuous monitoring and recording frequency should not be less than 0,005 Hz (every 200 second). The limits value for the total emissions from the ship must be met at all measurements.
- If more than one analyser is used to determine the SO_2/CO_2 ratio, these should be tuned in time so that the calculated value is fully representative.

The Guideline does not address how to deal with a breakdown of continuous monitoring equipment.

18.3 Common Scheme A and B requirements

The following requirements are quite similar for Scheme A and B:
- Wash water monitoring.
- Data recordings and processing.
- Onboard Monitoring Manual (OMM).
- SECA Compliance Plan (SCP).

The table below summarises the requirements.

Table 16 Common Scheme A and B requirements

Requirement area	Requirements
Wash water monitoring	Wash water in and out of the EGCS should be monitored with respect to pH, oil content and other parameters harmful to the ship operating area. Recording requirements are as for the EGCS in-use documentation recordings. Wash water data provided should be used to ensure compliance with criteria to be developed by Port State Authorities.
Data recordings and processing	Robust, tamper proof and with read only capability. Data should be recorded against UTC and position. Be able to prepare reports over specified time periods. Data should be retained for not less than 18 months It should be possible to do download of a copy of recorded data and reports in a readily useable format.
Onboard Monitoring Manual (OMM)	An Onboard Monitoring Manual (OMM) should cover monitoring equipment and include description of use, maintenance and calibration.
SECA Compliance Plan (SCP)	The SCP should be approved by the Administration and details on how compliance is to be achieved and demonstrated is to be given. It should contain: • List of combustion units to meet SECA requirements. • Recording data to document that equipment specifications and emission limits are followed. • Aggregation method for single emission sources if the sources are balanced with each other to obtain compliance for the total emissions. • Demonstrate compliance with emission limits during worst case operating scenarios.

19 EU ECGS approval requirements

This chapter describes the divergences between the EU and IMO approval regimes for EGCS and recommend adjustments and specifications to the EU regime.

19.1 Comparison of EU and IMO EGCS approval requirements

The EU procedures on approval of Emission Gas Cleaning Systems (EGCS) trials are given by Directive 2005/33/EC, article 4c /2/. There are requirements for both trial approvals and final approval of EGCS.

The EU trial approval requirements are as follows:

- The Commission and any Port State concerned must be notified in writing at least 6 months before trials.
- Permit trials shall not exceed 18 months duration.
- All ships must install tamper proof equipment for the continuous monitoring of funnel gas emissions and use it throughout the trial period.
- All ships involved must achieve emission reductions which are at least equivalent to those which would be achieved through the limits on sulphur in fuel.
- There must be proper waste management systems in place for any waste generated by the emission abatement technologies throughout the trial period.
- Impacts on the marine environment must be assessed, particularly ecosystems in enclosed ports, harbours and estuaries throughout the trial period.
- It must be documented thoroughly that any waste streams discharged into enclosed ports, harbours and estuaries have no impact on ecosystems, based on criteria communicated by the authorities of Port States to the IMO.
- Full results are provided to the commission, and made publicly available, within six months of the end of the trials.

The IMO Guideline /1/ does not have any requirements specifically for the test-phase, although the IMO requirements must be met also during trials. One significant difference between the EU and IMO requirements is that EU requires that the full trail results are made publicly available. In case of a publicly funded development project this can be perceived as a reasonable requirement. However, in the case where a SO_x-EGCS technology is developed by private companies this requirement may be in conflict with commercial interests.

The EU procedure for EGCS approval is yet to be established /3, 4/, although issues to be taken into account by the Committee on safe seas and the prevention of Pollution from Ships (COSS) are /2/:

- The IMO guidelines.
- Results of trials.

- Achievable emission reductions.
- Impacts on eco-systems in enclosed ports, harbours and estuaries.

Although the COSS procedures are not finalised, the Directive 2005/33/EC defines some approval criteria. These are given in the table below and compared to similar requirements in the IMO Guideline.

Table 17 Comparison of EU and IMO procedures and requirements on EGCS approval

2005/33/EC requirements	**IMO Guidelines**
Approval by COSS, consisting of member states representatives and chaired by commission representative.	Approval by the Administration, i.e. certification by class societies.
Continuously achieve emission reductions which are at least equivalent to those which would be achieved through the limits on sulphur in fuel.	Emission limits equivalent to 1.5% sulphur in fuel are defined as 6 g SO_x / kWh. This limit value must be met at defined engine load ranges (ref. section 19.1.1 - emission measurements). Alternatively the limit of 65 SO_2 (ppm) / CO_2 (%) must be met at any load point.
Fitted with continuous emission monitoring equipment.	Scheme A: Type approved SO_x -EGCS subject to periodic parameter and emission checks. Scheme B: Approved tamper proof continuous monitoring system for SO_x -EGCS.
Document thoroughly that any waste streams discharged into enclosed ports, harbours and estuaries have *no impact* on ecosystems, based on criteria communicated by the authorities of Port States to the IMO.	Waste streams shall not be discharged in enclosed ports, harbours and estuaries unless it can be documented that such waste streams have *no adverse impact* on the ecosystem in which waste streams are discharged, based on criteria communicated by the authorities of the Port State to the organisation.
Criteria shall be established for the use of emission abatement technologies by ships of all flags in enclosed ports, harbours and estuaries. The commission shall communicate these criteria to the IMO.	

19.2 Recommendations for an EU approval scheme

IMO and EU approval requirements should be harmonised so that scrubber manufacturers only have one set of requirements to relate to. To completely avoid any divergence EU can refer to the IMO Guideline for detailed information on how to perform the approval process. To the extent possible this solution is recommended.

However, there are some differences in the legislation that can make a direct reference to the IMO Guideline inappropriate. These differences are discussed below and recommendations are given on how to deal with these differences.

Approval
In Europe there is already a system for equipment approval in place which is well coordinated with the approval under IMO which is the approval regime under the Marine Equipment Directive (MED). For simplification and to treat scrubbers in

the same manner as all other marine equipment it is recommended the COSS delegates the approval to the MED regime.

Continuous monitoring
The main area of divergence is that continuous monitoring is mandatory in EU. This accounts both for the trial phase and the final approval. IMO opens for type approval as an alternative to continuous monitoring.

Ships sailing with a SECA Compliance Certificate (SCC) based on type approval (Scheme A) will additionally need continuous monitoring if they sail in EU waters or have a member state flag. The type approval is from an IMO perspective meant as an *alternative* to continuous monitoring with the same level of reliability regarding emission limit compliance. It is recommended that EU also opens for a scheme similar to the IMO Scheme A. An argument for allowing Scheme A is that once a system is commercialised and the operational variables are established there is a low risk of significant fluctuations in the SO_x cleaning efficiency. The Krystallon trial results support this hypothesis (six months trials better than 98%) /24/.

Within Scheme A, it is in theory possible to turn the scrubber off without the authorities being able to control this. This can however be compensated by monitoring other more simple parameters, like water flow.

Availability of trials results
As discussed in section 19.1, the EU requirement of making full results of trials publicly available is likely to be in conflict with commercial interests. It is recommended to specify what is meant by “full results” and to ensure that this specification allows business sensitive information to be kept secret.

Environmental impact
EU requires that *no ecosystem impact* is to be documented from waste water discharges, while MARPOL requires *no **adverse** impacts*. To document no impact is regarded as much stricter than documenting no adverse impacts. This might only be a technicality as long as it is up to the Port States to define criteria. However, it might influence the criteria level selected by Port States. To document no ecological impact can be very difficult. Hence, it is recommended to specify what is meant by no impact or add *adverse* as used by MARPOL.

Engine load limits
EU requires that emission reductions which are at least equivalent to those which would be achieved through the limits on sulphur in fuel are continuously achieved. This is not expressed in the same explicit manner in MARPOL. The IMO Guideline opens, within Scheme A, for a lower engine load where the emission requirements must be met (<25% for main engines and <10% for auxiliary engines and boilers). Below these loads a SO_2 criteria of 50 ppm is used (e.g. idling conditions).

It should be considered to allow higher emission rates at load levels below 10-25% to ensure that the necessary engine backpressure is maintained. If SO_x-EGCS is used at very low engine loads the engine might not work properly due to insufficient backpressure. An approach as described by the IMO Guideline is preferable.

20 Literature study on EGCS emission efficiency and verification

This chapter includes the results from a literature study on the cleaning efficiency of EGCS and how the emission reductions are verified by measurements and monitoring. Also the costs of continuous monitoring are addressed.

20.1 Literature study description

Literature and information on emission gas cleaning systems (EGCS) have mainly been gathered through the following two sources of information:

1 Library databases.
2 DNV participation in the Norwegian Maritime Sulphur Forum.

Searches in library databases have been performed using the following search criteria:

Ship + SO_2 + abatement
Ship + SO_x + abatement
Ship + sulphur emission + abatement
Ship + SO_2 + cleaning
Ship + SO_x + cleaning
Ship + sulphur emission + cleaning
Ship + sea water scrubber

By participating in the Norwegian Maritime Sulphur Forum access has been given to information about the status of SO_x-EGCS development projects.

The literature study can be summarised by the following two findings:

- Published scientific literature does not contain information beyond what is already given in the ENTEC report on SO_2 abatement /5/. I.e. no new testing results have been published. This finding is in line with a literature search performed by Statoil /6/.
- Producers developing new EGCS technologies are reluctant to publish results from their test. Hence, it is difficult to obtain information about new technologies beyond what is presented at conferences, seminars and other forums where technologies are presented on a coarse level.

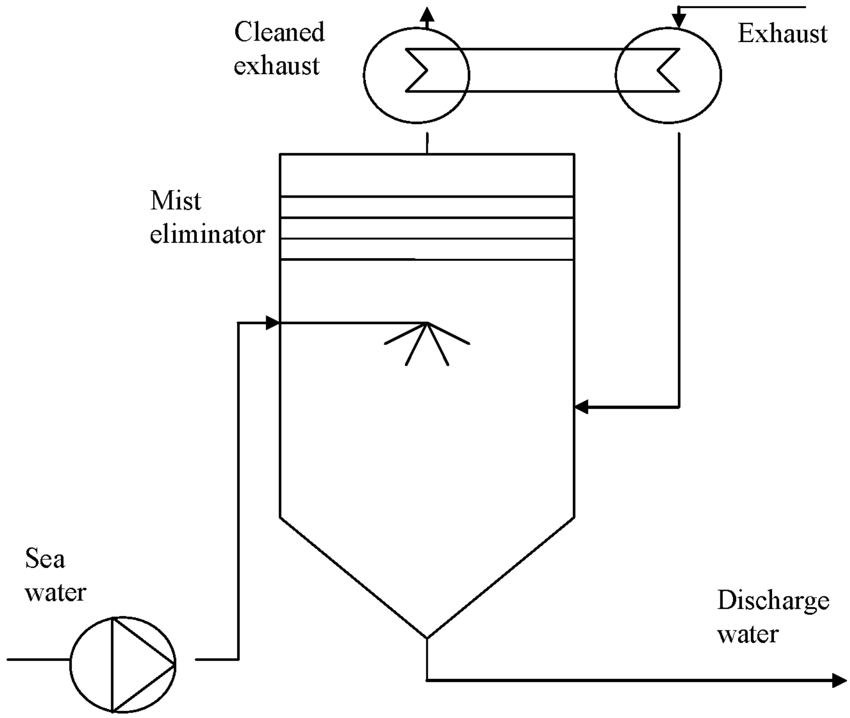
20.2 General description of scrubbers

To give a common understanding of what is meant by scrubbers brief description is given in this section.

The principle is to bring sea water (or any other fluid with the capacity to absorb SO_x and neutralise the effluent) in contact with the exhaust gas. Once the SO_2 is absorbed into the seawater, the SO_2 is converted by reaction with alkali material in the liquid to SO_4. The sulphur containing compound produced leaves the scrubber with the effluent and the desulphurised exhaust gas is demisted and reheated before exiting the stack. Figure 25 illustrated the principle.

During the scrubbing process, also particles can be removed from the exhaust gas quite efficiently.

Figure 25 Principal arrangement of a sea water scrubber unit



20.3 Identified technologies and their emission reductions

Based on the literature study, identified technologies are given in the table below together with an indication of the maturity of the abatement technology.

Table 18 Identified SO_x emission abatement technologies and their maturity

Technology	Technology owner/sponsor	Maturity description
EcoSilencer	Marine Exhaust Gas Solutions (MES)	Onboard testing performed 2003/2004. New test to be initiated
Hamworthy sea water scrubber	Hamworthy	Onboard testing performed 1993. Project laid on ice. Re-launch is considered
Krystallon	Kittywake and BP Marine	Onboard testing performed 2005/2006. Results are presently confidential
Advanced Vortex Chamber (AVC)	Vortex Ecological Technologies ltd., Klaveness, MAN and Barber	Testbed testing performed 2006 Results are presently confidential
Wärtsila sea water scrubber	Wärtsila, Kvaerner Power, Neste Oil	Purchase and building in 2006 Testing to be performed early 2007
Mecmar sea water scrubber	Mecmar AS	Has existing scrubber product for high speed engines. Feasibility study phase for low speed engines
ProPure Mixer	ProPure	Feasibility study phase Presently used for H_2S removal from natural gas. Considered developed for SO_2 removal from exhaust gas
Liqui-Cel	Liqui-Cel Membrane Contactors	Desktop/feasibility study phase. The project has haltered due to lack of financing /7/

Based on the maturity description in the table above, verifiable emission reductions are only available for technologies previously reported by ENTEC; EcoSilencer and Hamworthy onboard tests. Cleaning efficiency results for other technologies are based on performance stated by the technology owner without documentation. Efficiency information is summarised in Table 19.

Table 19 Cleaning efficiency of SO_x-EGCS

Technology	SO_x emission reduction efficiency	Comment
EcoSilencer	Typically 74% - 80%. Max. 94%. Min. 68%	Ref. /8/. 14 months testing period with four units on four 1.2 MW auxiliary engines. A new third version of the product has been released after the trials. Reduction efficiency of new version is claimed to be >90% (no onboard testing yet).
Hamworthy sea water scrubber	90% during transport load 89% during Port Load.	Ref. /9/. Trial for 1 unit treating ~10% of the exhaust volume of a 10,800 kW main engine for 4 days.
Krystallon	Above 99%. SO_x not detectable in exhaust gas using 2% sulphur fuel Target: 98%	Based on news articles from Kittiwake and conversation with Krystallon. Figures are derived after several months testing of a scrubber on a 1 MW engine.
Advanced Vortex Chamber (AVC)	No data available	Testbed measurements are presently confidential.
Wärtsila sea water scrubber	No data available	Trials are planned for.
Mecmar sea water scrubber	Up to 97% (0.54 g/kWh)	Based on presentation held at the Norwegian Sulphur Forum February 2006.
ProPure Mixer	No data available	
Liqui-Cel	No data available	
Sea water scrubbers in land based industries	Above 94%	DNV survey at 7 plants /20/.

Regarding other scrubber parameters like costs and size, information is difficult to obtain except for those systems that have been thoroughly tested. With respect to size, the scrubbers are designed to fit within the upper funnel area. Both Krystallon and MES says that their scrubbers can replace the silencer and is hence of a comparable size. At present there is no market for scrubbers, hence the investment, installation and operational costs are very uncertain. Figures from the EcoSilencer trials are given below /5/. According to the manufacturers both the EcoSilencer and Krystallon can now provide scrubbers at lower costs, although exact costs cannot be specified.

- Investment costs (including waste water plant and ancillary systems):
  - Newbuild: €168/ kW installed.
  - Exist. ship: €168/ kW installed; estimated future cost: € 120/kW.
- Operational costs:
  - 1-3% of Newb. investment depending on size.

Benchmarking the various EGCS is not possible due to lack of comprehensive data. Also, it is important to note that the scrubbers may be designed for different purposes. Some scrubbers are designed to meet the 1.5% sulphur content equivalency. This requires a certain cleaning efficiency. Others aim to also meet the port 0.2% or 0.1% sulphur content equivalency. Thus, a higher cleaning efficiency is required.

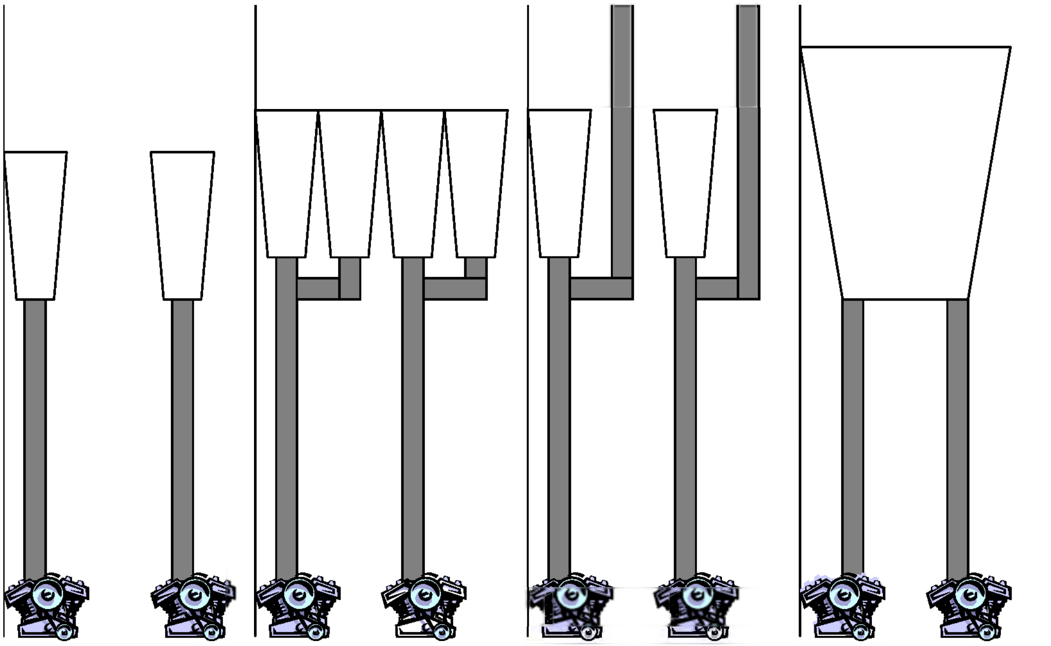
20.4 Efficiency for single engines and all engines combined

The IMO Guideline /1/ requires that the average emission level of all combustion units summarised is below the emission limit. This means that the emission limit applies to the total exhaust gas flow from the ship, not the individual combustion units or scrubbers. Hence, it is possible to clean some exhaust gas lines to a level lower than the level corresponding to 1.5% S, while others are above, given that the average is below. Due to this there is no reason to differentiate between EGCS efficiencies for individual engines and all engines combined.

Different alternatives for arranging scrubbers to funnels are described in the figure below. No literature reporting on practical experience with various arrangements has been identified.

Compliance with cleaning requirements (6 g/kWh or 65 ppmSO_2/%CO_2) is documented through continuous monitoring or the scrubber SECA Compliance Certificate (SCC). The cleaning performance of the ship where the arrangements illustrated in the figure below are applied is documented by the approved SECA Compliance Plan (SCP). The SCP should detail how the actual emissions from each combustion unit are to be aggregated together to obtain an overall, real time, emission value for the ship which does not exceed the limit value. The SCP should further refer to the approved On-board Monitoring Manual (OMM) for compliance verification methodology.

Figure 26 Alternative arrangements of scrubbers to the funnels



A ship is normally equipped with several engines (main and auxiliary) and boilers which all may use heavy fuel oil. A scrubber is fitted to each of the funnels related to each of the combustion units.

Engines may be so large that it is unpractical to treat the exhaust gas from one funnel with only one ECGS unit. Generally smaller scrubbers which handle smaller gas volumes give better scrubbing efficiency. In order to handle the produced gas volume, several scrubbers can operate in parallel. This also offers the advantage of availability to maintain efficiency at reduced gas load by taking units off-stream, provided that both inlets and outlets are effectively isolated.

Engines may be so large that it is unpractical to treat the all the exhaust gas from one funnel with one ECGS unit. It is then a solution to treat a share of the total funnel gas flow and by-pass the rest. The treated flow must then be of such a volume and SO_x reduced to a level that give a mass weighted average below the SO_x emission limit.

One single scrubber treating all exhaust gas flows is not practically relevant due to the dimensions of the scrubber, retrofitting costs, vulnerability to scrubber failure and sensitivity to operational variations

20.5 Monitoring

20.5.1 General principles

The ships environment is a demanding one with changing ambient temperatures, tilts, vibration, dust, electromagnetic interference, dripping and spaying of fluids and, not least, fluctuations in voltage supply. Thus shipboard emission monitoring needs to be robust and able to withstand all these potential difficulties.

There are two types of measurement strategies:

1. Periodic measurements: Short term measurements at a specific engine load. Usually carried out by external measurement consultant.
2. Continuous measurements: Emission monitoring system used continuously during all times of engine operation.

The emission can be sampled and analysed in many ways as summarised in Table 20.

Table 20 Gas sampling principles

Principle	Description
Extractive	Sample is extracted via a multi probe port over the channel cross section and then transported via a heated gas line for analysis. Prior to concentration measurement in gas analysers, the gas is dried (cooled) and filtered (gas conditioning system).
Extractive dilution	As above, but the sampled gas is diluted with air at the sample probe thus eliminating the need for gas conditioning.
Path in-situ	Gas analysis occurs directly over the entire cross section of the exhaust channel.
Point in-situ	Gas analysis occurs in the exhaust channel at a fixed representative point.
Remote sensing	Gas analysis occurs by optical analysis of the exhaust gas at a fixed point.

Table 21 Gas analysis principles

Principle	NO_x	SO_2	O_2	CO_2
Chemiliminiscence	X			
Electrochemical sensors	X	X	X	
Non-dispersive ultraviolet (NDUV)	X	X		
Non-dispersive infrared (NDIR)	X	X		X
Pulsed UV fluorescence		X		
Paramagnetic			X	

20.5.2 Monitoring in trails

How the SO_2 emissions are monitored for the various technologies with a stated cleaning efficiency are given in the table below. Table 22 also shows practicalities reported in relation to the measurements. None of the projects have reported cost figures related to monitoring. Such information must be derived from companies providing monitoring equipment.

Table 22 Type monitoring applied in scrubber tests to measure EGCS cleaning efficiency

Technology	Measurement type	Practicalities
EcoSilencer /11/	Continuous monitoring Extractive NDIR Horiba PG 250 analyser	No practical issues reported.
Hamworthy sea water scrubber //9/	NDIR	No information on practicalities are given.
Krystallon /10/	Continuous monitoring Remote sensing – optical Cascade Technologies	Measures SO_2, CO_2, NO_2 and NO simultaneously. Capable of serving up to 8 stacks simultaneously. Insensitive to turbulence and vibration. Excellent immunity to cross interference.
Wärtsila sea water scrubber /11/ *Note that this information is only for plans for measurements*	SO_2 (ppm) / CO_2 (%) method preferred Unit approval versus continuous monitoring decision depends on the project. Extractive sampling preferred in multi-scrubber installations. With extractive sampling: • Common NDIR analyser for SO_2 and CO_2. With in-situ sampling: • NDUV analyser for SO_2 and NDIR for CO_2	Reliability of measurement equipment not always satisfactory for continuous monitoring. Impact of vibrations and gas pulsation is unknown during in-situ sampling.

Regarding practicalities related to continuous monitoring this is not found reported in the literature. The only trial identified having experience with continuous monitoring is the ongoing Krystallon trials. They report no practical problems with their continuous monitoring equipment.

Continuous monitoring equipment will need type approval. IACS and class societies require that tests are performed to demonstrate that electrical equipment function as intended under specified testing conditions. Test are performed with respect to power supply failure, power supply variations, heat impacts, vibration, inclination, cold, salt mist, electrostatic discharge and more /28/.

Hence, equipment that is not functioning properly onboard a ship will preferably be identified during the approval process and practical problems will be mitigated. Thus, it is reason to believe that type approved monitoring equipment will not suffer from many practical challenges given that it is maintained according to the manufacturer manual. Lack of specified maintenance requirements could lead to unreliable monitoring results.

Another obvious challenge is if the monitoring equipment breaks down. No documentation will then be available to demonstrate compliance (unless the

EGCS has a type approval). A clear guidance on what to do in such a situation should be given.

Some of the challenges and solutions provided by available technologies are discussed below:

- Documentation of emission levels within a SECA: In addition to the continuous recording of SO_2 / CO_2 measurement results, position in UTM coordinates is recorded in the same system. This way it can easily be controlled whether the emission limit is met at all geographical points within a SECA area.
- Tampering of results: Monitoring equipment is logging values in a tamper proof manner. Monitoring systems with a type approval are certified to be tamper proof.
- Vibration: Continuous monitoring equipment is usually provided with shock absorbers. Hence, vibration is really not a problem for the reliability and accuracy of the monitoring equipment.

The IMO Guideline provides two alternatives for measuring SO_2 emissions:

- The g/kWh approach.
- SO_2 (ppm) / CO_2 (%) approach.

According to measurements planned for and those recently performed it seems like the latter approach is preferable, mainly due to the fact that this method is less complicated and thus less expensive. It is especially challenging to monitor directly the engine load continuously if the g/kWh approach is applied.

It is reason to believe that most monitoring systems will select the SO_2 / CO_2 approach and that the cost of necessary measurements for this approach should be the main area of focus regarding monitoring costs.

20.5.3 Continuous monitoring costs

An estimate is made for an example of continuous monitoring system with an expected lifetime of 10 years. The results are given in the table below and are based on experience from continuous monitoring for NO_x in land-based industry /13/ and on coarse figures from two ship emission continuous monitoring equipment providers (confidential information sources). The monitoring equipment that the costs are based on is available for measuring SO_2 / CO_2, or can be adjusted to do so. Note that also other emission compounds can be monitored with the same equipment, hence not all of the cost can be allocated to SO_2 monitoring. The cost figures from monitoring equipment providers are regarded as the most reliable of the two sets of cost figures, although there is little experience with maintenance of the equipment in the third column. Thus, the actual maintenance costs may be higher than indicated in the third column.

Table 23 Cost estimates for continuous monitoring

Cost element	**Cost figures (US $) for NO_x monitoring in land-based industry**	**Cost figures (€) for NO_x/CO_2 or SO_2/CO_2 monitoring onboard ships**
Capital cost (10 years lifetime)	(US $)	(€)
Investment cost of equipment including sampling lines	70,000 – 235,000	65,000 – 125,000
Installation costs	8,300 – 62,000	Unknown
Operating cost (annual cost)	(US $ per year)	(€ per year)
Internal maintenance, calibration tubes, spare parts, data	7,800 -23,600	1,250 (little experience)
External consultants	6,200 – 30,500	Unknown
Annualised total costs	(US $ per year)	
Estimated annualised total cost (10 years) for mid-range figures (4% discount rate)	66,000	7,000 – 14,000 (+ unknown costs)

21 Literature study on effluents from EGCS

This chapter includes the results of a literature study of the environmental impacts of EGCS effluents. Alternative ways of handling such effluents will be described and recommendations will be made taking into account the environmental aspects, practicalities and cost of the handling options.

21.1 Literature study description

Literature and information the environmental impacts of effluents from Emission Gas Cleaning Systems (EGCS) have mainly been gathered through the following two sources of information:

1 The following literature sources:
   - Literature listed at the EU web portal http://ec.europa.eu/environment/air/transport.htm.
   - The TRESHIP Thematic Network.
   - MARTOB.
   - SEAat.
   - Norwegian Research programmes MARMIL and MAREN.
   - ENTEC studies.
   - MARINTEK studies.
   - Studies undertaken in relation to scrubber development projects.

2 DNV participation in the Norwegian Maritime Sulphur Forum.

It should be noted that one ongoing project related to the impacts of EGCS effluent undertaken by VTT in Finland (Baltic Sea focus) aims to be completed during autumn 2006. Hence, its results are not included in this report. The report will probably contribute with new findings that a specific for the Baltic Sea.

It should be noted that the Norwegian project on wash water criteria /22/ has performed a literature study on scrubber wash water treatment recommendations. This includes contacting all HELCOM[23] states. No directly applicable studies have been identified.

[23] The Helsinki Commission, or HELCOM, works to protect the marine environment of the Baltic Sea from all sources of pollution through intergovernmental co-operation between Denmark, Estonia, the European Community, Finland, Germany, Latvia, Lithuania, Poland, Russia and Sweden. HELCOM is the governing body of the "Convention on the Protection of the Marine Environment of the Baltic Sea Area" - more usually known as the Helsinki Convention.

21.2 Waste water effluents and their impacts

21.2.1 Overview of substances and properties

It should be noted that the environmental impacts of sulphur discharges are generally regarded as insignificant. This is due to the fact that the exhaust gas sulphur reacts into sulphate and the sulphate levels of the sea are in general so high that the contribution from ship scrubbers will not make a difference.

Table 24 shows discharge properties addressed for environmental impact evaluation in various studies.

Table 24 EGCS effluent discharge properties

Discharge properties	Norwegian study on wash water criteria /22/	Hamworthy scrubber project /9/	EcoSilencer scrubber project /8/
Heavy metals			
Cd	X	X	X
Cu	X	X	X
Ni	X	X	X
Pb	X	X	X
Zn	X	X	X
As	X	X	
Cr	X	X	X
Hg	X	X	X
V	X	X	
Other properties			
pH	X	X	X
Chemical Oxygen demand (COD)	X	X	
Hydrocarbons (HC)	X		X
Temperature	X	X	
SO_4		X	
AOX		X	
Particles/Suspended Solids		X	X

Evaluation results from the various parameters are given in the table below. Note that the various studies are based on evaluation of effluents from different EGCS technologies. The result of one technology may not be valid for another.

21.2.2 Limit values for substances and properties

A collection of limit values for most of the substances and properties given by various authorities are shown in the following. Data are gathered from the Norwegian study on wash water criteria /22/ the UK submission to the IMO on wash water criteria /21/ and limit values given by HELCOM.

Metals

Table 25 summarises the identified sea water limit values for relevant metals.

Table 25 Limit values for metals

Discharge properties	EU PNEC* (µg/l)	US EPA CCC[#] (µg/l)	UK EQS[¤] (µg/l)	HELCOM[!] (µg/l)
Cd	-	9.3	2.5	50
Cu	-	3.1	5	500
Ni	-	8.2	30	500
Pb	14.5	8.1	25	200
Zn	6.1	81	40	1,500
As	-	36	25	150
Cr	-	50	15	500
Hg	0.11	0.94	0.3	30
V	-	-	100	-

* PNEC – Predicted No Effect Concentration according to the EU risk assessment program.

[#] CCC – Criterion Continuous Concentration. Highest chronic concentration of a pollutant not resulting in unacceptable effect.

[¤] EQS – Environmental Quality Standard.

[!] Discharged water limits. Based on more than 20 samples, not more than 5% of the measurements shall be exceeded. Note that the reason for the large difference between the HELCOM values and the other values is that HELCOM limit values are based on land based best Available Technology, while the others are based on toxicological impact evaluations.

Hydrocarbons (HC)

As a basis for comparison oil discharge rates from scrubbers are estimated based on HC content limit values used in other areas. A scrubber water discharge rate of 60 – 2,825 t/hr is applied.

According to MARPOL the limit for oil discharge from merchant ship bilge water is 15 ppm. Calculations made for Cruise liners and an aircraft carrier show that this equals a discharge of 0.03 – 2.8 kg/day.

If 15 ppm is applied for scrubbers this equals 13 – 593 kg/day. This is considered unacceptably high compared to the bilge water discharges. The Canadian Environment Protection Agency has introduced a 5 ppm limit for bilge water discharges (HC discharge: 4 - 198 kg/day).

For oil tankers Russian regulations limit the oil content in ballast water to 0.05 ppm. This equals 0.7 – 9.9 kg HC per complete ballast change. Application of this limit to the scrubber effluent compares to a HC discharge of 0.2 – 9 kg/day.

The large wealth of toxicity data on hydrocarbons makes it difficult to settle for a limit value. There is some consensus that chronic environmental impact of oil is observed when the HC concentration is above 50 µg/l. A value of 40 µg/l is adopted by the Norwegian Oil operators association (OLF) for risk assessment of offshore produced water. If 40 µg/l is applied to scrubbers this would equal a HC discharge rate of 0.06 – 2.7 kg/day, i.e. quite similar discharge rates as from a bilge water systems, although in a much more diluted form.

PAH
OSPAR has developed Ecotoxicological Assessment Criteria (EAC) for a large range of chemicals, also the various PAH groups. The values are to facilitate evaluation of monitoring data on toxic substances in the marine environment.

The only total PAH marine water quality criteria identified is Australian Guidelines setting a limit of 3 ppb.

Particles
Particles (soot –carbon) is considered to be if minor importance. However, as many other pollutants are adhered to the particles, the solids are the most efficient compound to focus on with respect to possible effluent treatment.

HELCOM sets a limit for total suspended solids of 30 mg/l (for BAT land based plants).

COD
HELCOM regard BAT as being fulfilled when land based plants with COD challenges has a COD concentration of 250 mg/l or the concentration of total organic carbon (TOC) is below 80 mg/l. National legislation operates with COD limits in the range 150 – 350 mg/l.

A concentration that should safeguard most marine temperate-coldwater organisms are proposed to be 5 mgO_2/l /22/.

pH
Review of the literature on pH tolerance indicates that there is little evidence of harm to marine organisms from a decrease of 0.5 – 1 pH units from ambient conditions 722/. The list below shows some Environmental Quality Standard values for pH.

- US EPA 6.5 – 8.5 (but not more than 0.2 units outside normally occurring range)
- Australia 6.5 – 8.5
- China 7.5 – 8.3
- Japan 7.8 – 8.3
- UK 6.0 – 8.5 (from UK Water Research Centre)
- HELCOM Above 7.0

21.2.3 Discharge levels

Waste water discharge concentrations are available from the Fjordshell project in 1991 /9/ and the EcoSilencer project, taking place during 2004-2005 /8/. The water discharge concentrations at the two trial events are given in Table 26 and Table 27 respectively. It should be noted that The EcoSilencer had waste water treatment in the form of hydro cyclones (removal of particles and hydrocarbons), while Fjordshell had none.

Table 26 Fjordshell water discharge concentrations

	Transit load[1] µg/L	**Port load[2] µg/L**
TOC	2,700	1,500
COD	33,300	10,000
Particles	680	880
HC	81.00	45.00
AOX	25.30	33.20
PAH	<0.1	<0.1
PCDD/PCDF	0.00001	
V	35.00	23.00
Ni	32.80	10.40
Zn	6.00	15.00
Cr	<1	<1
Pb	5.00	0.60
Cu	41.60	15.30
Hg	<0.1	<0.1
As	<0.1	<0.1
Cd	0.05	0.08

1 Transit load: Average engine load during transit (70-80%).
2 Port load: Average engine load while operating in port (20-30%).

Table 27 EcoSilencer water discharge concentrations

Components	**July 01 2004 µg/L**	**Jan 14 2005 µg/L**
Particles	790	450
Ni	140	5
Zn	180	150
Cr	58	3
Pb	66	79
Cu	48	5
Hg	0.08	0.08
Cd	2	2

21.2.4 Environmental impacts of scrubber discharges

Few environmental impact assessments of scrubber discharges have been made. Those identified are summarised in Table 28.

In general most of the compounds and properties in the scrubber discharge water are well below the discharge limits previously discussed.

pH is the property that is closest to the limits. Taking the immediate high dilution into account, pH seems not to cause any environmental harm. Although this should be evaluated for the waters in question due to high variability in alkalinity.

Enclosed waters have huge variations in the number of vessels per sea area (potential number of emission sources within an area), water exchange (affect potential for accumulative effects) and sensitivity to pollutants. Because of this, it is not possible to make any general conclusions on whether a discharge component or property is harmful or not. Conclusions for more specific areas for which scrubber discharge water impact assessments have been carried out are given in Table 28. A coarse evaluation of the alkalinity consumption for the North Sea is described in section 21.2.5.

Table 28 Summary of discharge environmental impact evaluations

Study	Conclusions on environmental impact of EGCS effluents
Pride of Kent Environmental Impact Assessment /21/	The average pH at the point of discharge was 6.2 – 6.5. Although samples taken from the receiving waters near the ship showed no change in pH. Most metals were present in particulate form. Thus they were filtered out of the scrubber wash water and retained in the residue handling system. As fuel related metals will currently enter the environment from unscrubbed exhaust systems, it was considered that the scrubber can have a beneficial impact on reducing metals entering the marine ecosystem, given that a filtration system is applied. The typical PAH-concentration was 3-4 ppb and the typical dissolved PAH (not removed by filtering) was around 2 ppb. Immediately next to the shipside discharge pipes no increased PAH concentration could be detected.
Norwegian study on wash water criteria /22/	Waste water dispersion modelling shows that discharges are rapidly diluted when ships are in movement. The most critical situation is when the ship is at quay. Then an average plume dilution of 1:150 is calculated within 20 metre from the point of discharge. The dilution takes 6-7 minutes. Taking the worst case discharge into account, applying dispersion modelling in the near field and allowing PEC/PNEC to be exceeded within the near field, no compounds or properties exceed 1. A PEC/PNEC less than one was also obtained with a pH=0 and DO=0 at the point of discharge (DO = Dissolved Oxygen). Temperature of effluents is not regarded as a problem as the effluent temperature is approximately 1°C above the ambient temperature. This is far less than the seasonal variations. The environmental impact in enclosed ports, harbours and estuaries depends on the traffic with scrubbers and the water exchange. As an example discharges without any water treatment are not problematic in the Port of Oslo according to the performed modelling.
Hamworthy scrubber project /9/	Discharges of process water from a single vessel equipped with EGCS will have no significant environmental effects on marine organisms – neither when the vessel is moving with cruise speed, with reduced speed, or when the vessel is manoeuvring practically at rest in a harbour (HC was not evaluated). Based on the traffic (all using EGCS) and water exchange of the inner Oslo Fjord and the Baltic Sea it is concluded that no significant reduction in the pH value in the fjord and the sea can be caused by discharges from the vessels equipped with EGCS.
EcoSilencer scrubber project /8/. Note that the EcoSilencer is equipped with a water treatment system continuously filtering the water.	At the discharge point the parameters with values close to or above the EPA water quality criteria was pH, Cu and Zn. Cu was the only parameter significantly above the criteria. Sampled Cu quantities were believed to be coming from the Ship's pipe cathodeic protection system. HC was compared to the 15 ppm MARPOL criteria.

Scrubbers using other neutralising agents than sea water (e.g. lime) has not been tested, or openly documented with respect to wash water impacts. Even though the neutralising agent does not have an ecological impact there might be esthetical issues related to the visibility of the effluent.

21.2.5 Scrubber discharge amounts

To be able to evaluate the collective implications of the discharges from a fleet of scrubbers with discharge concentrations as given in chapter 21.2.3 the total amounts discharged to the North Sea estimated. The estimate is based on:

- Standard factors between the discharge rates and the SO_x emission rate (at 90% SO_x cleaning efficiency). The calculated factors are given in Table 29. The calculations are based on the Fjordshell emission and discharge data.
- 100% of the North Sea SO_x emissions from ship traffic to be cleaned with scrubbers. This is regarded as unrealistically high. For lower shares the results can be adjusted accordingly.
- The total North Sea SO_x emissions from ship traffic are given by a coarse estimate based on an assumed share of each of the North Sea countries' emissions /29/. This results in a total North Sea SO_2 emission of 500 kt/year.

Table 29 Discharge rate factors relative to SOx emission rate and estimated total discharge to the North Sea

Discharge substance	**Discharge factor (g/kg SO_X)**	**Total discharge to the North Sea (ton/year)**	**Comparison with European Environment Agency (EEA) indicators (www.eea.europe.eu).**
Particles	1,46	728	-
HC	0,28	140	Offshore installation in Denmark, the Netherlands and UK emitted approximately 10,000 tonnes of oil in 1999.
PAH	0,0006	0,28	-
V	0,2	98	-
Ni	0,18	92	The sum of urban and industry sources in Switzerland, Germany, Denmark, Netherlands, Norway, Sweden was approximately 200 tonnes in 1999.
Cu	0,24	118	-
SO_4	1120	560 000	-

The total discharges are based on discharge factors valid for scrubbers without any waste water treatment, also it is assumed that all ships use scrubbers. Applying a realistic 20% of ships using scrubbers and a wash water treatment HC cleaning efficiency of 80%, the results for HC must be reduced by a factor 0.04.

Note that the estimates should be regarded as indicative as they have very high uncertainties. It must also be taken into account that the figures are not a net increase. A lot of the emissions to air will also eventually end up in the sea. As a indication approximately 70% of all ship traffic can be categorised as "coastal". If it is assumed a portion of at least 50% of these emissions will reach land some 60-70% of ship emission will directly end up in the sea globally and less than 50% in an area like the North Sea with relative short distances to shore.

Consumption of sea water alkalinity

Depending on the wash water rate relative to the fuel sulphur content and the fuel consumption there might be large variations in the discharge water pH. According to modelling and discharge measurements and ship side measurements the pH is however rapidly increased to the background level. Hence, the acidity is not regarded as a local problem. However, in an ocean perspective the alkalinity consumed can result in ocean acidification.

Sea water contains approximately 35‰ (wt) materials contributing to salinity. Alkalinity can be estimated from the following equation /22/:

$$\text{Alkalinity (mmol/l)} = 0.0697 * \text{Salinity (psu} \approx \text{‰)} = \mathit{2.44\ mmol/l}$$

If it conservatively is assumed that all sulphur is trapped in the water, a sulphur concentration of 0.16 mmol/l can be calculated (based on Fjordshell SO_2 emissions and water flow rate /9/).

It takes one carbonate molecule to neutralise one sulphuric molecule. Hence, the sulphur alkalinity consumption also becomes 0.16 mmol/l.

With the water flow used in these calculations, the alkalinity of the sea water consumed is reduced by 7%. If the water alkalinity is lower than the average of 35‰, this share will be increased.

By recirculation of the scrubber water higher alkalinity consumption can be obtained, although this will reduce the water consumption.

If the North Sea example in Table 29 is used, a water consumption in this ocean is estimated to 2.8 km^3. As a comparison the water volume of the North Sea is 94,000 km^3. A 7% alkalinity reduction in a very small portion of the water masses is regarded as insignificant.

21.3 Waste water treatment options

In principle there are three solutions for handling effluents from EGCS:

1. Discharge to sea without treatment.
2. Interim onboard storage of effluents and delivery to land.
3. Waste water treatment, discharge cleaned water and interim storage of treatment residues onboard before delivery to land.

Whether the first solution (discharge to sea without treatment) is an option should be decided based in the scrubber-specific discharge profile and the criteria of the relevant waters that the ship will sail in.

The second solution (interim onboard storage of effluents and delivery to land) requires a dry or semi dry cleaning agent. For sea water scrubbers this is not a relevant option due to the high water flow rates (e.g. the Hamworthy and EcoSilencer scrubbers have water discharge rates in the range 30-40 m^3/h per

MW engine, including cooling water). No information is presently available on the flow rates of a dry or semi dry EGCS.

The third solution (waste water treatment, discharge cleaned water and interim storage of treatment residues onboard before delivery to land) requires a waste water treatment system with associated capital costs and operational costs associated with delivering residues to shore.

The performed SO_x-EGCS trails and tests have to a little extent included waste water treatment. Either the technologies are in a too early phase of their development or the technology owner considers waste water treatment as a separate technology which must be fitted when needed. The only technologies known to have used waste water treatment in trials are the EcoSilencer and the Krystallon scrubber, both equipped with hydro cyclones.

There are several waste water treatment options that in theory can be applied, based on experience with e.g. offshore produced water treatment or land based scrubbers /25, 20/. The ones regarded as relevant for sea water scrubbers are discussed with respect to environmental impacts, practicalities and costs in the following:

- Filters.
- Hydro cyclones (centrifugal separators).
- Oxidation to reduce discharged amount of COD.

Other types of water treatment exist, but are here laid aside due to very large installations that are needed (e.g. gravity based separation and shut-off methods). This conflicts with the confined space available onboard a ship.

Filters

Many filters exist for land based and maritime application. Several maritime suppliers have been contacted. Duplex filters exist which consist of two filter units where one can be cleaned or act as stand by while the other filter is in operation.

Filters remove only pollutants in the form of particles and pollutants adhered to particles. Particles as small as 1 µm can be removed. Pollutants dissolved in the discharge water will not be affected. The particles in the exhaust gas is generally very fine ones, thus also the particles in the discharge water. Analyses show that it is mainly carbon (soot) particles that are of this size /22/. Filters will therefore mainly reduce the emission of carbon, which generally is more of an aesthetical rather than an ecological problem. However, also about 25% of the vanadium and 30% of the nickel is related to the larger particles.

Presently available filters can handle flow rates up to 180 m^3/h. At least one filter supplier is identified to provide such a capacity. This is in the same order of magnitude of water flow as a scrubber fitted to a 1-2 MW engine. Hence, sufficient filter capacity can be a practical challenge as larger scrubbers are developed. At least further product development is needed.

A back washed filter produces polluted water that must be handled. Due to the relatively low concentrations of pollutants in the effluent and thus small amount of residues, it might be sufficient to further process it through the bilge water treatment system.

The filters themselves do not require much space. However, a ship engine room do not have a lot of available space. Thus space restrictions still might be a problem, especially in a retrofitting situation, and even more if discharge water quality criteria are so strict that more than one type of discharge water cleaning equipment is needed (e.g. filters and cyclones).

Commercially available filters are not expensive compared other type of ship equipment. Filters are also usually well known onboard (fuel oil filters and lub oil filters). Thus they can be serviced and maintained at sea by the crew. It is uncertain whether the pressure due to height from the scrubber bottom to the filter is enough to overcome the pressure drop or if pumps are needed. The main running costs can then be associated with the need for pumps to overcome energy loss (head loss) across the filter.

Hydro cyclones

Hydro cyclones are already in use in maritime applications, for example in Optimarin's ballast water treatment system. The MicroKill Separator module removes organisms and particles from seawater taken aboard for ballast (http://www.optimarin.com/). Both the Ecosilencer and the Krystallon scrubber use hydro cyclones to clean the effluent /8, 24/.

The scrubber effluent most likely contains very low concentrations of solids, less than 1 g/l. Still, Krystallon reports a removal efficiency of 95% for pollutants that are heavier than water (solid particles – soot, and adhered pollutants). Also hydrocarbons (HC) are removed. Up to 10% of the residue is HC, although removal efficiency is not known.

Hydro cyclones have many benefits; they require a very limited amount of space, it is gravity based (no need for pumps), high reliability and low maintenance (no moving parts). Due to its benefits, the hydro cyclone has been the most commonly applied treatment option for produced water offshore since about 1990 /25/.

The residue can be sent to separator sludge tanks if the quantities generated allows for it. If not there can be a problem related to storage space for the residue. According to the residue amounts reported to be generated in section 21.4 it seems feasible to use the existing sludge tanks for storage.

Due to its simplicity hydro cyclones are not expensive compared to other ship equipment. However no specific cost information has been obtained.

Oxidation of COD
Oxidation of COD in the effluent is usually achieved by the use of chemicals in the case of high COD, or aeration of the effluent in the case of lower COD. The COD content of the scrubber effluent is regarded as a lower COD content.
The use of aeration tanks onboard a marine vessel, considering the potential flow rates, is not considered viable. The reaction times required may be of the scale of many hours, thus tanks of the size of thousands of tonnes are needed.

Chemicals used for oxidation may include ozone, chlorine or hydrogen peroxide, all of which are highly corrosive. They require specialist equipment, training and safety measures. Onboard oxidation by the use of chemicals is therefore considered undesirable. In addition, the capital and running costs of chemical treatment systems will most likely make this option too expensive.

21.4 Waste water treatment residues

Waste water treatment in the form of filters and separators will produce waste. According to the IMO Guideline on EGCS wash water residues should be disposed on land (no discharge or incineration allowed). It should be noted that port reception facilities may not necessarily in place, thus sufficient onboard residue storage capacities must be planned for according the specific vessels trading routes.

The amount of waste water treatment residues (kg/kWh) on a dry basis will be a function of the type of treatment technology and its cleaning efficiency. Residues cannot be discharged to sea or incinerated onboard (according to the IMO Guideline). This requires a residue onboard storage capability allowing residues to the stored onboard until it can be delivered at a port waste reception facility. Information on the amount of waste water treatment residues generated is available from the Krystallon tests. In addition a theoretical example is derived from the Hamworthy tests. Information is given in Table 30.

Table 30 Waste water treatment residues information

Project	Treatment type	Engine size and load	Residue amount	Calculated residue generation rate
Hamworthy	Not specified*	1 MW, 90%	0.35 kg/h (dry)	0.4 g/kWh (dry)
Krystallon	Hydro cyclone	1 MW, -	-	0.8 g/kWh (sludge)

* Based on average waste water outlet particulates content of 0.88 mg/l, a cleaning efficiency of 90% and a water discharge rate of 440 m^3/h. Other pollutants are minor amounts compared to particulates. Particles are the main mass components in the residue.

The Hamworthy residue generation rate gives an indication of the theoretical lowest residue generation level obtained by dewatering the sludge.

To give an idea of the amount of waste that must be delivered ashore and associated costs three typical sailing routes for three typical ships are used as a basis. It is assumed treatment and storage of residues throughout the whole sailing route. The cases and calculated data are shown in the table below.

Table 31 Example cases of generated waste from scrubber waste water treatment and associated costs

Case description	Background data for calculating waste generation	Quantity of waste generated	Waste reception fee*	Waste costs (sludge)#
Container ship sailing Channel-Hamburg 64,000 dwt	Installed power: 40,000 kW Average engine load: 75% Sailing time: 30 h	Sludge: 0.8 ton Dry: 0.4 ton	€ 0.12/litre	€ 86
Container feeder sailing Hamburg-Helsinki 15,000 dwt	Installed power: 15,000 kW Average engine load: 75% Sailing time: 40 h	Sludge: 0.4 ton Dry: 0.2 ton	€ 0.12/litre	€ 43
Car carrier sailing Channel-Gothenburg 16,000 dwt	Installed power: 13,000 kW Average engine load: 75% Sailing time: 40 h	Sludge: 0.32 ton Dry: 0.16 ton	€ 0.12/litre	€ 38

* The fee factor is collected from the Port of Oslo, oily waste.
# It is assumed 1 litre sludge = 0,001 ton.

The waste reception fee in the port of call will vary from port to port. According to Directive 2000/59/EC Member States shall ensure that the costs of port reception facilities for ship generated waste shall be covered through a reception fee from ships. This can be arranged through a standard waste fee, in can be included in the port dues or the fee can be based on the actual type and quantity of waste delivered. If a fee system incorporated port dues is applied, the waste generated might not lead to any increased costs for the ship owner if the quantity delivered is kept below the port due waste amount roof level.

To keep the calculations in the table simple, a fee system based on the actual waste quantity delivered is applied for all three cases. It is also assumed that the sludge will receive the same fee as oily waste.

The estimated waste costs in the table above are on the same level compared to the waste fees experienced from other ship sources. As an example the Port of Helsinki has a maximum fee per ship for oily waste at € 1,060. The Port of Rotterdam allows delivery of 1-20 m^3 oily waste within their fixed fee system, corresponding to a fee of € 20-400 (depending on ship size).

The costs estimated in Table 31 are based on waste water treatment throughout the whole journey in a SECA area. If treatment is performed only in ports, harbours and enclosed waters the generated waste quantities will be 10-100 times less.

21.5 Waste water treatment recommendations

The requirement for waste water treatment will depend on whether the discharge water quality criteria established by the Port States are stricter than the content of pollutants in the effluent without any water treatment. If a ship is sailing in waters where discharged water quality criteria is met without any treatment there should be no requirement.

However, if effluent treatment is necessary two treatment alternatives seem feasible to use onboard ships; filters and hydro cyclones. The two alternatives affect approximately the same pollutants (soot and adhered pollutants). In a typical land based set up the cyclones would be used before filters. This because the concentration of pollutants are very high and that the hydro cyclones are constructed to handle the coarse fractions, while the filters are effective on the finer elements.

Onboard a ship this set up is not recommended due to the following:

- Space restrictions make it difficult to use several treatment levels.
- The hydro cyclones seem sufficiently efficient as the only treatment unit (according to Krystallon experience).
- The concentration of pollutants in the effluent are so low before treatment that the efficiency of the second treatment step (if the first is efficient) will be low.

Hence, it is recommended to use either hydro cyclones or filters as scrubber effluent treatment, if the discharge water criteria require treatment. Of these two there is practical experience only with hydro cyclones. Hydro cyclones are also without moving part, making it reliable and low maintenance. Hence, it seems like the preferred option.

22 EGCS efficiency variables

This chapter evaluates the cleaning efficiency of EGCS as a function of EGCS operational variables with an influence on the cleaning performance.

Operational variables identified that may affect the efficiency of an EGCS of a specific design are:

- Fuel sulphur content.
- Alkalinity of inlet water.
- Wash water flow rate (or other neutralising agents).
- Exhaust gas mass flow rate/engine load.

Due to lack of trials being executed with different sulphur contents limited experience is available on how sensitive the scrubbers are to these operational variables.

Fuel sulphur content
For scrubber to obtain a type approval according to the IMO guideline a scrubber must prove that its claimed efficiency level can be met using a 4.5% sulphur fuel. Alternatively test must show that the claimed efficiency level is met with two different sulphur levels, minimum with 2% and 3% sulphur content. It is then taken for granted that the scrubber will be as efficient or better with fuels with lower sulphur contents.

As most EGCS technologies claim and document efficiency levels better than 90%, the system's ability to meet the 1.5% sulphur content quality requirement are not sensitive to the content of sulphur of fuel, given that the fuel sulphur content must be below 4.5% (4.5% * 0.1 = 0.45%).

However, if EGCS are to be used to meet the 0.1% sulphur content in port, an efficiency of 98% is required if the EGCS shall be capable of handling any fuel quality. Only the Krystallon trial project has so far reported such an efficiency level, although it has not been tested with 4.5 sulphur fuel.

For other scrubbers reporting a guaranteed efficiency level of 90% a 1% sulphur content is needed to meet the 0.1 sulphur content equivalency.

Alkalinity /22/
Sulphur oxide gases (SO_x) are readily soluble in sea water, where they form sulphuric acid. The natural alkalinity within sea water is used to neutralize the acids formed during scrubbing. In marine situations the salinity of the sea water is the prime indicator of the neutralisation capability. In non-marine situations, or situations where the marine environment is dominated by a fresh water source, the indicator of alkalinity reserve is the content of carbonates.

In non-marine or freshwater dominated waters with lack of carbonates (e.g. ice melting water dominated waters) there might be an insufficient alkaline reserve to neutralise acid compounds by sea water scrubbing.

Exhaust gas scrubbing is a process where the exhaust gas is contacted with a liquid (most often sea water) for selective absorption of SO_2. Once the SO_2 is absorbed into the sea water, the SO_2 is converted to SO_4 by reaction with alkaline material in the liquid. The conversion makes the sulphur stay in the water.

It is not possible to foresee to what extent the scrubber efficiency will be affected by variations in inlet water alkalinity. However, scrubbers are designed for a certain maximum inlet flow. If a ship is sailing in waters with so low alkalinity that the maximum inlet flow does not convert SO_2 to SO_4 to the necessary degree, emission limit values might not be met.

The Krystallon trials are performed in waters (Dover – Calais) ranging from fully marine alkalinity (Dover) to very high alkalinity (Calais). Within this variation range the scrubbing efficiency is quite insensitive to the alkalinity.

It is necessary to have a system that secures that scrubbers are not sailed into areas with alkalinity lower than what the inlet water flow rate is designed for. In general, all European marine waters have normal marine alkalinity of higher (alkalinity is proportional to salinity), except for the Baltic Sea. Hence, a scrubber tested in one area is likely to be insensitive to alkalinity variations due to geographical area, except for the Baltic Sea. Hence, for scrubbers to be used in the Baltic Sea, scrubber manufacturers should document that their scrubbers have a sufficient cleaning efficiency using these waters as a scrubber media. This also accounts for any other waters (e.g. rivers) with alkalinity levels below what is regarded as a normal marine situation.

Wash water flow rate /22/
The amount of water needed to clean the exhaust gas will depend on a number of factors including system design, fuel sulphur content, SO_x emission target, alkalinity of the water and use of chemicals. Some field testing experience indicates that pure sea water consumption needed for ~90% SO_x removal will be in the range of 30-100 kg/kWh. This water requirement can be:

- Approximately halved if the system designed according to current minimum requirements (equivalent to 1.5% sulphur fuel).
- Significantly increased in fresh and brackish water.
- Significantly reduced if alkaline chemicals are added to the sea water.

Exhaust gas flow rate/engine load
As long as the wash water inlet flow is regulated according to the exhaust gas flow (engine load) the scrubber efficiency or the efficiency is not affected.

It should be noted that according to the Krystallon trials the efficiency is above 98% at all operational conditions of the Pride of Kent. Thus, this scrubber, sailing in the relevant waters (Dover – Calais), seem to be quite insensitive to the operational variables it is exposed to (i.e. engine load).

Also the test onboard Fjordshell /9/ differentiates the cleaning efficiency by engine loads (90% and 25% MCR). The cleaning efficiency was reported to be approximately the same for both engine loads.

23 Assessment of potential sulphuric mist impacts

This chapter evaluates the possibility of acid mist formation and emission from scrubbers, and to what extent such emissions can cause local acidification problems. Mitigation options are also discussed.

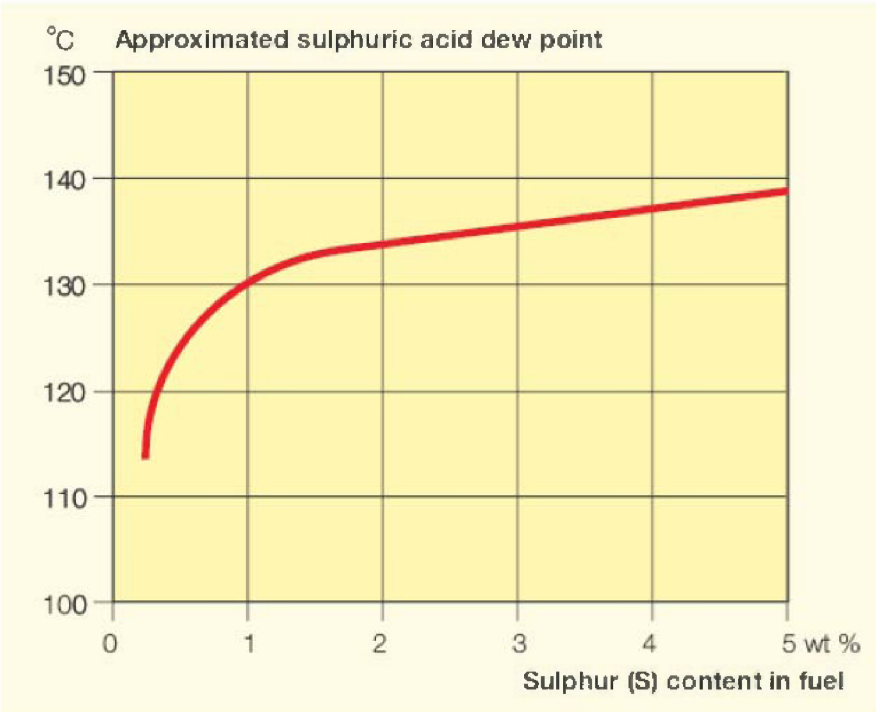
23.1 Formation of acid mist

During the combustion of HFO in an engine or boiler most of the sulphur in the fuel is oxidised to SO_2, but a small and variable percentage is further oxidised to SO_3. There are numerous design and operating parameters which influence the amount of SO_3 formation. Among these are exhaust gas sulphur content and excess air level. Typical SO_3 concentrations exhaust gas from combustion of high sulphur containing fossil fuels are less than 5% of the total SO_x emissions /15, 16/.

It should be noted that scrubber designers are aware of the problem and precautions are taken to avoid acid mist formation in the scrubber (see list of potential measures in section 23.3). Hence, the acid mist formation is not perceived as a significant challenge for the scrubber manufacturers. There is one practical experience with acid mist formation in the exhaust gas from ships from the EcoSilencer trials /8/. However, this was the result of a suboptimal design resulting in a water carry over and an overload of demisting capacity. The EcoSilencer design is now corrected for this issue.

Any SO_3 formed will rapidly react with water vapour to form H_2SO_4 (sulphuric acid) vapour. H_2SO_4 mist, which is acidic, will be formed if the temperature falls below the dew point for the acid. The dew point for H_2SO_4 as a function of fuel sulphur content is shown in Figure 27 /17/.

Figure 27 Sulphuric acid dew point curve

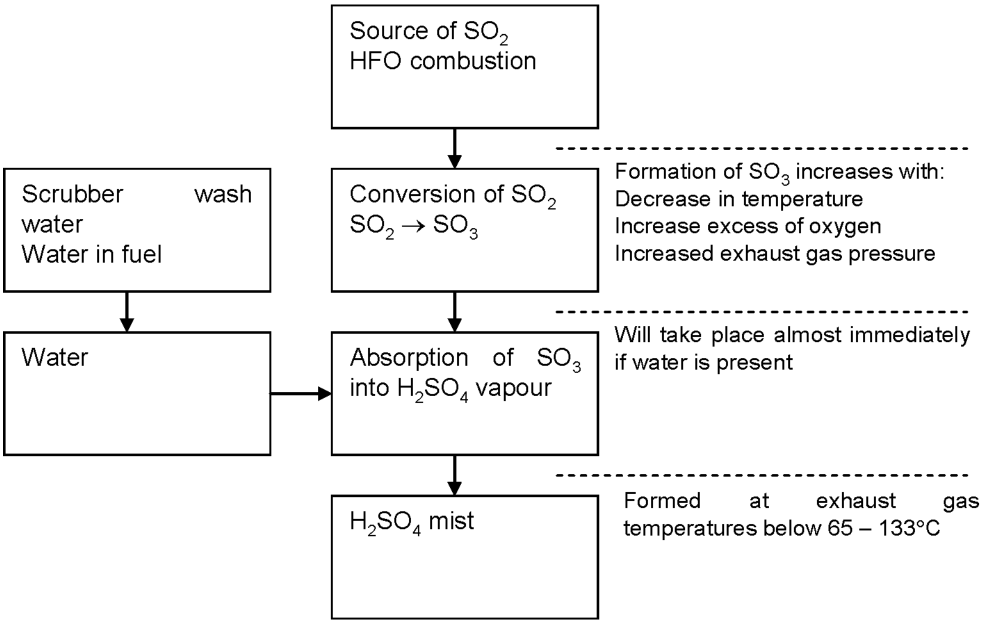


An EGCS will reduce the sulphur content in the exhaust gas to a level below the equivalent of 1.5% sulphur. The dew point temperature is then 133°C. With a cleaning efficiency of 90% and a worst case sulphur content of 4.5% the equivalent sulphur level is 0.45%. This corresponds to a dew point temperature of approximately 125°C. Below 65°C all H_2SO_4 will condensate /15/.

A scrubber media, wet or dry, can reduce the temperature of the exhaust gas rapidly below the acid dew point. Any SO_3 not washed out with the scrubber media will rapidly react to H_2SO_4.

If the SO_x cleaning efficiency is low (high SO_x concentrations), acid mist can be formed in an amount that may cause corrosion and impact human health. Generally, larger droplets in the mist can be removed in the scrubber, but the sub-micron droplets are not removed and are emitted from the stack. Hence, acid mist can potentially be formed in all scrubbers if they are operated with low SO_x cleaning efficiency and designed without taking the problem into account.

Figure 28 H_2SO_4 formation chart



It should be noted that the formation of acid mist is not unique for ships with sea water scrubbers. SO_x-emission from ships with no EGCS will also form H_2SO_4 from the SO_3-fraction in the SO_x, Probably at even higher concentrations due to much higher SO_x emissions. The exhaust gas temperature is however high above the dew point and it will only exist as vapour. Once the gases leave the stack, the rate of cooling and subsequent H_2SO_4 condensation competes with the plume dilution by entrainment of ambient air into the plume. If the dilution is limited e.g. due to very stable ambient air, a visible detached plume may form downwind as temperatures drop below the dew point. The plume will be visible due to the influence of acid mist on opacity.

Hence, what separates the acid mist exposure from a stack with a scrubber from a stack with no EGCS is that acid mist formed in the stack (if not necessary design precautions are taken) and consequently the potential for higher concentrations and deposition in the immediate surroundings of the ship. Also, the low gas stack exit temperature after a scrubber can contribute to higher concentrations in the areas impacted by the exhaust gas plume.

23.2 Impacts of acid mist

Precautions can be taken to avoid acid mist formation. If the right mitigating measures are implemented there will be no formation and no impacts. The evaluations made in the chapter presume that acid mist is formed.

Acid mist may have impacts both in the exhaust gas stack and after leaving the stack. Here, only consequences for the local environment surrounding the stack will be addressed.

H_2SO_4 may impact the surrounding environment by corrosion and impacts on human health. The impacts on regional acidification (ecosystem impact) is not evaluated due to the fact that the impact would be much higher if the scrubber was not in use as the sulphur emissions contributing to acidification would be an order of magnitude higher (i.e. scrubbers reduce ecosystem acidification).

Example of H_2SO_4 emission concentration and rate formation
Using a heavy fuel oil (HFO) with a S-content of 3%, the SO_x exhaust gas concentration measured for a 6,400 kW medium speed main engine is 2100 mg/Nm^3 /14/. Assuming that scrubbers have a cleaning efficiency of 90%, the post scrubbing SO_x-concentration would be less than 210 mg/Nm^3. Assuming (conservatively) that the SO_3 fraction of SO_x is 10%, and taking into account molar weight differences between SO_3 and H_2SO_4 (1:1,53), the H_2SO_4 concentration in the exhaust gas is estimated to ~30 mg/Nm^3. As a conservative worst case scenario a H_2SO_4-concentration of 60 mg/Nm^3 is assumed.

This H_2SO_4 concentration will be separated in a vapour fraction and a condensed fraction. For the acid mist to be formed the gas temperature must be in the range 65 – 133°C.

The example ship engine used in the above estimates has an exhaust gas flow of 27,000 Nm^3/h, giving a worst case H_2SO_4 emission rate of approximately 0.75 kg/hour (per main engine on a typical large passenger ship). The passenger ship in question has four main engines, and if they all are in operation 3 kg H_2SO_4 per hour is emitted. The main engines are operated close to shore (quay side manoeuvring) for maximum 0.5 hours. Hence, a total amount of max. 1.5 kg H_2SO_4 can be emitted from one large ship main machinery during port arrival or departure.

For ships using scrubbers on auxiliary engines to meet the post 0.2% sulphur content the emitted amount would be at least one order of magnitude lower per time unit.

Dispersion of H_2SO_4 aerosols
When emitted to the ambient air the gas temperature will quickly drop below 65°C and the H_2SO_4 will condensate within a certain distance from the stack. Hence, it is the dispersion that decides the acid mist concentrations and deposition rates the surrounding environment will be exposed to.

The dispersion is given by specific stack information, and meteorological and topographical information at the specific location. Hence it is not possible to generally model dispersion and assess impacts. However, simple examples can be used to indicate the order of magnitude of the exposure and as such indicate whether this is a problem or not.

DNV has performed dispersion modelling using the DNV tool Phast 6.51 /26/. Modelling has been performed using the following input data:

- Worst case meteorological conditions (stability class D and 1.5 – 5 m/s wind velocity).
- Stack height 40 m above sea level.
- Exhaust gas exit velocity 20 m/s.
- Emission temperature of 100°C.
- Flat surroundings.

The results show a minimum exhaust gas plume dilution factor of at least 1:300 for distances above 100 m from the stack. At ground level or at the ship deck the dilution factor would normally be even higher.

The potential for local entrapment of the plume due to ship design, harbour buildings and topography is not taken into account. A conservative assumption is that the concentrations on deck and at ground level at shore can be as high as in the plume.

A fallout of acid mist (H_2SO_4 rain) is regarded as unlikely as the droplets need only about 0.01 m/s lift to stay aloft or would fall with a terminal velocity of 0.01 m/s without uplift /13/.

Figure 29 and Figure 30 illustrates the dispersion of H_2SO_4 concentration after the exhaust gas plume has left the stack (ship is laying still).

Figure 29 H_2SO_4 dispersion at wind velocity 1.5 m/s

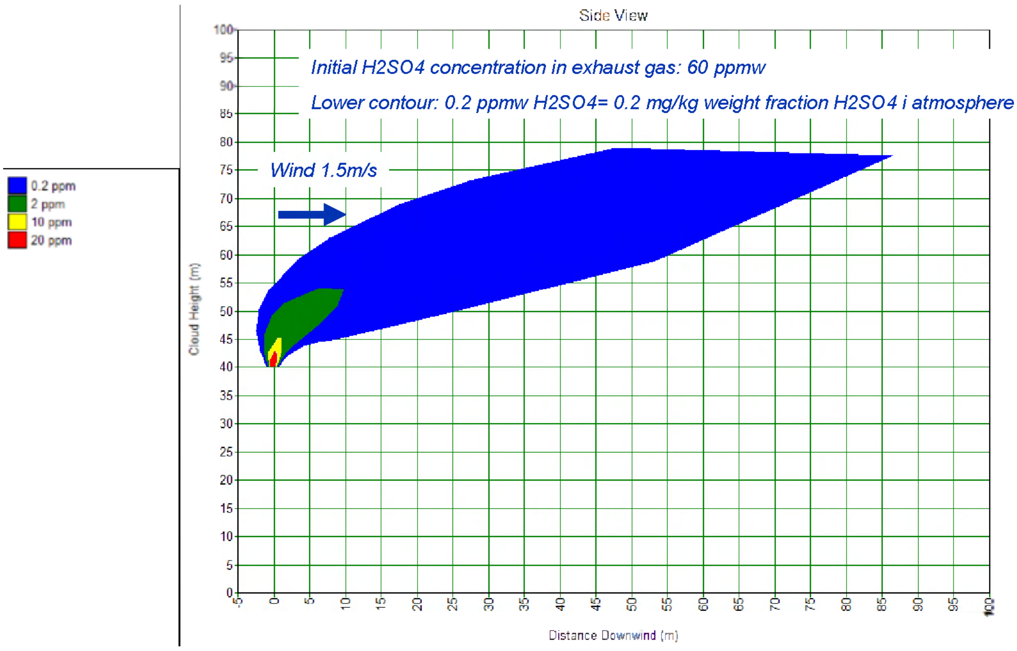
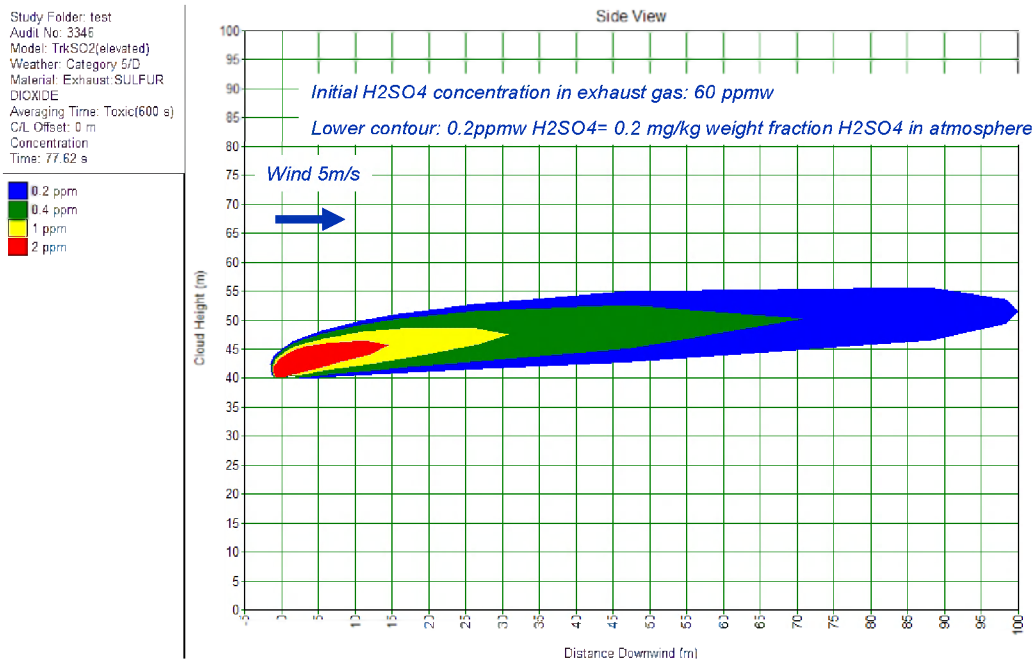


Figure 30 H_2SO_4 dispersion at wind velocity 5 m/s



Impacts on human health

Data on direct adverse effects on human health are inconsistent, but in general studies indicate that aqueous acidic aerosols at typical and even elevated ambient concentration have minimal effects on symptoms and mechanical lung function in young healthy adults. However, there are studies that have shown reactions in asthmatics exposed to elevated levels of 0.4 mg/m^3 or more /16/. The Norwegian occupational environment exposure limit is 0.2 mg/m^3 /18/. I.e. the worst case emission concentration must be diluted by a factor of 300 to meet the exposure criteria.

According to the worst case dispersion modelling it is a chance that the exposure limit of 0.2 mg/m^3 will be exceeded within 100 m from the stack. Taking into account all the conservative presumptions used in the modelling (overestimation of the in stack H_2SO_4 concentration), it is regarded as unlikely that the exposure limit will be exceeded outside the ship.

Even if several ships laying quay side emit acid mist simultaneously the combined air concentrations is unlikely to exceed the exposure limit because of the distance between the emission sources (ships).

The dispersion modelling uses a relatively large main engine as an emission source. While lying quay side the main engines will only be operated during arrival and departure. For longer stays in port smaller auxiliary engines will be used. The 6,400 kW main engine used as an example is likely to emit more exhaust gas (and H_2SO_4) than the auxiliary engines for any ship type and size. Thus, the example is regarded to also cover a worst case long term exposure.

It is concluded that human exposure to acid mist in the exhaust gas is unlikely to cause health impacts. However, in a worst case situation concentration above the occupational exposure limit of 0.2 mg/m^3 can occur onboard the ship.

Corrosion
For the surrounding environment it is expected that a scrubber, even if unplanned emissions of H_2SO_4 occurs, will contribute to less corrosion compared to emissions from ship without scrubbers.

There are several reasons why this is the case:

- Approximately 10 times more SO_2 is emitted from ships without scrubbers compared to ships with scrubbers. It is SO_2 and humidity that forms the basis for H_2SO_4 formation.
- Due to water condensing in scrubbers the water content in the exhaust gas from scrubbers is not significantly higher than the water content exhaust gas not passing through scrubbers. Hence, the basis for H_2SO_4 formation is approximately the same.
- Exhaust gases that have passed through scrubbers can have a higher content of condensed H_2SO_4 (acid mist) due to a lower temperature. Although by the time the exhaust gas from ships both with and without scrubbers has reached a deposition surface, the gas temperature will be below the dew point and H_2SO_4 will be in a liquid phase. Hence, exposure of surfaces to acid mist will be a function of the total amount of H_2SO_4 formed from the total SO_2 emissions rather than the acid mist emission rate.

Corrosion onboard the ship's outer surfaces and onshore quay side buildings is a complex matter as atmospheric corrosion is a product of several impacts, e.g /19/:

- Chlorides from sea water exposure.
- SO_2 exposure from other sources.
- Acid rain.
- Air humidity.

Acid mist depositing onto materials will only be one element in this picture and it is not possible to foresee the relative importance of this exposure.

It is reason to believe that ships being exposed to sea water will be more corrosive to the ship deck and exposed equipment than exposure to acid mist (based on expert judgement made by DNV Maritime Material Technology section). This is because the exposure to H_2SO_4 would be rare and in low concentrations (unless acute emissions occur), while sea water exposure is continuous.

Sea water will also contribute to a corrosive environment in harbour areas due to direct sea water exposure, higher air humidity and the air content of chlorides contributing to corrosion. Hence, any discontinuous exposure to H_2SO_4 will only give a marginal contribution to the corrosion in harbour areas.

To get an idea about the quantitative relative importance of H_2SO_4 exposure a calculation example is made:

- A H_2SO_4 emission rate of 0.75 kg/hour is assumed to expose a radius of 100 m around the emission point 10% of the time. 10% of the H_2SO_4 is deposited. This gives an S-deposition rate of approximately 2,000 mg/m^2*year.
- As a comparison the average sulphur deposition in southern parts of Norway the last 20 years has been in the range 500 – 1,000 mg/m^2*year /27/.
- By comparing the two exposure figures it is seen that H_2SO_4 from scrubbers on a long term basis contributes to local sulphur deposition in the same order of magnitude as long distance transboundary airborne pollution in Norway (although the H_2SO_4 exposure is at least 20 times higher when the exposure takes place). The main concern of the Norwegian exposure is acidification of lakes and not corrosion. Also this is a regional problem while the H_2SO_4 exposure would definitely be a local challenge.

Experience on whether H_2SO_4 is deposited and causes corrosion problems can also be gathered from the land based industry. DNV has conducted a survey on 7 industrial plants using sea water scrubbers. They have emission temperatures in the range 4 - 60°C and stack heights 25 - 60 meters. No plants report local down wash of the emission plume, local deposition or corrosion problems outside the stack /20/.

However, under meteorological conditions with a sinking exhaust gas plume containing acid mist damage to property and vegetation can occur if the conditions are sustained for an extended period /15/.

It is concluded that corrosion due to acid mist from scrubbers is of very little importance for corrosion of constructions surrounding the ship's emission point. More corrosion due to the use of scrubbers compared to no scrubbers is not expected, unless there is an accidental situation. This may give corrosions on surrounding constructions, but will be more of an aesthetical challenge than a human health, environmental or safety issue as long as the scrubber is shut down once acid mist is detected and the situation is not sustained for a long time period.

23.3 Mitigation options

To obtain an acid mist emission level not causing any harm several mitigating measures are or can be applied.

Possible options to mitigate the formation of acid mist are gathered from scrubber developers:

- Ensure sufficiently low SO_x-concentrations in the exhaust gas exiting the scrubber (90% cleaning efficiency claimed). This will result in H_2SO_4 levels so low that it will not cause noticeable impacts.
- Condense and collect the exhaust water content and H_2SO_4 vapour/mist. It is likely that only the larger acid mist particles will be collected. However, less water will contribute to less H_2SO_4 formation.

- Reheat exhaust gas to a level that keeps the temperature above the H_2SO_4 dew point at least to the stack exit point. Reheating can also be required to avoid a visible steam plume. The acid gas is also less likely to condense after leaving the stack, compared to ships without scrubbers, as there will be lower particulate concentration for the H_2SO_4 to condense upon.
- If possible, reduce the level of excess air supplied to burn the heavy fuel oil. The combustion gases will contain less SO_3 and thus less H_2SO_4 is formed.
- Inject alkali material into the exhaust gas to reduce SO_x. This is likely to be performed by introducing compounds such as hydrated lime –$CA(OH)_2$, limestone –$CaCO_3$, MgO and sodium carbonate -$NaHCO_3$ into the wash water. At least two scrubber manufacturers are today considering this as an option. However, then mainly due to other reasons than the acid mist problem. A dry injection subsequently to the washing process would probably require some sort of particulate removal (e.g. electrostatic precipitators). This is not used onboard ships today and is considered as an unlikely alternative.
- Acid mist can be detected visually. In cases from shipping and land based industry where acid mist has caused problems the situation is detected by observing the exhaust gas opacity or by complaints from those affected /15/. In such situations the scrubber should be shut down.

The principal arrangement of a sea water scrubber unit shown in Figure 25 shows that it is common to have both the second and third mitigating measure in the list above as a part of the design. With scrubbers having SO_x cleaning efficiencies generally above 90%, all the three first measures are in principle implemented.

24 Recommended SO_x-EGCS use criteria

This chapter gives recommendations on minimum criteria for using EGCS in ports and harbours and enclosed waters.

24.1 Requirements for SO_x-EGCS in use today

Even though they are few there are some pioneers investing in the development of cleaning technologies. At least one system is in use today and according to progress plans for other technologies it is likely to be more within a year.

The costs of being in the front in this area are high, and whatever use requirements that are implemented, it is important that they are not so stringent that the pioneering installations must be taken out of service immediately for even further investment. This would put an unreasonable amount of costs on the pioneering companies contributing to the development of SO_x-EGCS and use criteria.

To reduce this potential burden, it is recommended that SO_x-EGCS that are in use at the moment use criteria are introduced can continue to use the existing technology, even though it is non-compliant, until the ship's next docking or for a certain time period not exceeding e.g. 3-5 years.

The use requirements might make it necessary to take the ship out of service to install equipments that makes the cleaning technology compliant. By following the recommendation in the previous paragraph, at least off-hire and docking costs will be saved.

The consequence of the recommendations is that there will be ship sailing with non-compliant SO_x-EGCS for the exemption period. Taking into account the very few ships this is relevant for the environmental impact is regarded to be negligible compared to the knowledge and experience gained. In any case the few ships sailing with scrubbers will have conducted an environmental impact assessment for the trial phase according to the Directive 2005/33/EC requirements.

24.2 Areas in which SO_x-EGCS can be operated

SO_x-EGCS should not be operated in waters where there is insufficient ability to absorb SO_x and transform it to SO_4 as this could lead to reduced cleaning efficiency and non-compliance with sulphur emission requirements. This can be enforced by requiring that any ship using SO_x-EGCS must include in the SECA compliance plan (SCP) that they have a control system securing that the scrubber is not used in areas with alkalinity levels that the scrubber is not designed for.

24.3 Water discharge criteria

24.3.1 The criteria development process

Criteria for discharges of waste water from the EGCS are to be developed by the Port State authorities. This section aims to provide some baseline criteria that can be applied within the EU as a part of the SO_x-EGCS use criteria.

It is recommended that the EU criteria take into account the input provided by Port States as a part of the IMO process. If IMO is to propose baseline discharge criteria it is highly recommended that EU also uses the same baseline. The possibility for stricter Port State requirements will still be possible. National input to the waste water criteria and probably a decision for criteria will be given at the 55th MEPC meeting to be held 9-13 October 2006.

Port States will have to consider both the extent of ship traffic, and natural dilution effects such as provided by wind, current and rivers when defining their local criteria. Also the cleaning technology available can form basis for criteria.

While setting criteria it is also essential to avoid parameters and level that cannot be monitored. Due to the high water flow rates concentrations become very low. This can make e.g. monitoring of heavy metals difficult.

An Environmental Impact Assessment (EIA) performed by the authorities would be needed to decide which category a marine area belongs to. The EIA would consist of the following main steps:

1 Identify harmful substances and properties.
2 Identify the maximum permissible concentration that could be sustained over time, the Predicted No Effect concentration (PNEC). A similar limit value is needed for properties not described by PNEC, e.g. pH. For accumulative substances the PNEC value must take this effect into account.
3 Evaluate the expected environmental concentration of each discharge compound and property, designated as Predicted Environmental Concentration (PEC).
4 Evaluate the risk to the marine environment by the PEC/PNEC value. GESAMP has interpreted pollution in a way that allows local concentrations higher than PNEC in the immediate vicinity of the discharge point if the discharge is rapidly diluted. The immediate surrounding must then be defined. E.g. 50 m during normal sailing and 20 m during quay side manoeuvring/laying still. Dispersion modelling could be a useful tool in this context.

24.3.2 Recommended criteria

Recommendations given here are based on the pollutant discharge levels reported from sea water scrubbers, available cleaning technologies, what is possible to monitor, results from dispersion modelling and the lowest PNEC values identified in section 21.2.2. The minimum criteria are given by Table 32.

The criteria are based on a situation where the waters in question have a water exchange sufficient to avoid local accumulation of pollution. I.e. the water volume required to dilute the amount of pollutants below the criteria must not exceed the local water exchange rate.

Table 32 Recommended discharge water criteria in enclosed waters, harbours and ports

Substance/property	Discharge criteria
HC*	1 ppm (increase of background concentration)
pH	2 pH units (decrease from background level) can be considered. Preferably the outcome from the IMO wash water criteria correspondence group should be applied.
Deposits washout	During dry operations of the scrubber there might be build up of deposits within the scrubber. This will inevitably lead to a significant increase in components in the wash water and the possible overload of the wash water treatment plant and discharge criteria. Short term deviation allowance is needed for such periods. However, these washout situations should not be allowed in enclosed waters, harbours and ports.

* To avoid that the criteria is met by dilution only, the concentration must be adjusted according to the water flow rate. The 1 ppm level is for a nominal wash water rate of 44 ton/hour for a 1 MW engine.

According to the proposed HC criteria, the scrubbers would probably need waste water treatment. To remove HC by hydro cyclones is the most feasible option. This will also remove particles and heavy metals associated with HC and particles. Thus, no criteria are set for particles. This also is a part of the explanation why heavy metals are left out from the criteria. Three additional explanations for leaving heavy metals out are:

- Criteria levels will be very difficult (maybe impossible) to monitor due to very high water flow rates and low concentrations.
- Particulate and heavy metal criteria can be met by designing scrubbers with low trapping efficiency for particulates in the exhaust gas. Hence, the additional positive effect of scrubbers, the removal of particulates from the exhaust, can be lost.
- The main concern with heavy metals are long tem effects and that over a long time period the metals emitted to air will to a large extent end up in the sea. Hence, as long as acute effect levels are avoided, discharges of heavy metals from scrubbers to the sea will not result in any additional long term impacts (as long as water exchange is sufficient).

These recommendations does not address how monitoring shall be performed to prove compliance with the wash water criteria.

Finally, it is emphasised that ideally the robustness of the recommendations could have been better. The recommendations are based on a limited amount of information for a few tests and trials. It is therefore important to not have a static baseline, but to improve this over time as more extensive information becomes available.

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26 List of abbreviations

BAT	Best Available Technology
CCC	Criterion Continuous Concentration
COSS	Committee on Safe Seas and the Prevention of Pollution from Ships
EAC	Ecotoxicological Assessment Criteria
EGCS	Emission Gas Cleaning System
EIA	Environmental Impact Assessment
ETM	EGCS Technical Manual
EQS	Environmental Quality Standard
HFO	Heavy Fuel Oil
IACS	International Association of Classification Societies
MCR	Maximum Continuous Rating
NDIR	Non-Dispersive Infrared
NDUV	Non-Dispersive Ultraviolet
OLF	Oljeindustriens Landsforening (Norwegian Oil Industry Association)
OMM	Onboard Monitoring Manual
PEC	Predicted Environmental Concentration
PNEC	Predicted No Effect Concentration
SCC	SECA Compliance Certificate
SCP	SECA Compliance Plan
SECA	Sulphur Emission Control Area
UTC	Coordinated Universal Time

Part D

CE Delft

Brief summary

The EU strategy to reduce atmospheric emissions from seagoing ships specifies that policies could be introduced to reduce the climate impacts of shipping. This report designs and evaluates seven possible policies:

1 Voluntary commitments.
2 Requirement for all EU-based ship operators and/or EU-flagged ships to use the IMO CO_2 index and report results annually to Member State Administrations and/or the European Commission.
3 Requirement for EU-based ship operators and/or EU-flagged ships and/or EU-based shippers to meet a unitary CO_2 index limit or target.
4 Future inclusion of refrigerant gases from shipping in the EU regulation and/or an indexing system parallel to the CO_2 index.
5 Inclusion of a mandatory CO_2 element in an EU-wide regime for port infrastructure charging.
6 Inclusion of CO_2 emission from shipping in the EU ETS.
7 Allocation of ship emissions to Member States.

All policy options are assessed on four main criteria:

1 Operational effectiveness.
2 Legal implications.
3 Feasibility of monitoring and enforcement.
4 Feasibility of implementation.

The assessment shows that the most promising option is the **inclusion of CO_2 emissions from shipping in ETS**. Under this policy, ship operators would have to surrender EU allowances for CO_2 emissions on their voyage to EU ports. This policy would have a large environmental effectiveness, would be feasible to enforce and feasible to implement, provided that a number of design issues can be solved. The legal basis for implementation would also require further study.

Two other options have an equally large environmental effectiveness. Both a **requirement to meet a unitary CO_2 index value** and a **differentiation of harbour dues** could be effective ways to address the climate impact of shipping. However, it is not clear at this stage that a limit value of the CO_2 index can be assigned to vessels that would present an incentive to all vessels to reduce emissions, and would do so in all phases of the business cycle. Likewise, it is not clear at this stage that a basis for differentiation of harbour dues can be found that would not distort the competitive market between ports and would incentivise vessels to reduce emissions.

Three options have limited environmental effectiveness, but are still recommended to implement. The **inclusion of refrigerant gases in EU regulation** would open up very cost effective options to reduce emissions. The **allocation of ship emissions to Member States**, if agreed upon in the UNFCCC, would pave the way for a global solution to reduce the climate impacts

of shipping. And a **requirement to report the IMO CO_2 index** would provide data that could be used to assess the effectiveness of various policy options, while imposing only a small burden on ship operators.

Executive summary

Maritime transport is an important mode of transport for the European Union, with over 90% (in volume) of its external trade and some 43% of its internal trade going by sea. The maritime sector is also important from an economic point of view. Maritime companies belonging to European Union nationals control one third of the world fleet and some 40% of EU trade is carried on vessels controlled by EU interests.

The climate impact of shipping

Shipping emits various greenhouse gases, the most important being CO_2. Estimates show CO_2 emissions from maritime transport to account for 1.8% to 3.5% of global emissions, depending on the method of calculating emissions. Furthermore, greenhouse gas emissions from sea shipping are rising and there exist currently no policies that effectively control this development.

Apart from greenhouse gas emissions, ships emit other substances that have direct or indirect climate effects. NO_x emissions from ship engines cause the formation of ozone, which contributes to global warming. NO_x also induces the decay of methane, thus reducing global warming. Sulphur emissions have direct and indirect cooling effects. Overall, the impact of shipping on the global average temperature is probably negative (cooling).

However, the cooling effects are highly localised, whereas most warming effects are not. This uneven distribution may contribute to climate change, e.g. by changing winds and precipitation patterns. Furthermore, cooling effects are expected to become smaller as policies to reduce sulphur emissions are introduced. Thus in the near future the balance may shift and shipping may start to have a net warming effect.

A coherent climate policy must address the climate impacts of shipping in order to be effective. Therefore, the European Commission has presented an EU strategy to reduce atmospheric emissions from seagoing ships. It states that in order to reduce greenhouse gas emissions from shipping, the Commission will work with the IMO to ensure that its greenhouse gas strategy is concrete and ambitious. However, if progress within the IMO is slow, the Commission will consider taking action at EU level to reduce emissions.

Policy instruments to reduce the climate impact of shipping

This study designs seven policy options addressing greenhouse gas emissions of maritime transport. They are:

1 Voluntary commitments.
2 Requirement for all EU-based ship operators and/or EU-flagged ships to use the IMO CO_2 index and report results annually to Member State Administrations and/or the European Commission.
3 Requirement for EU-based ship operators and/or EU-flagged ships and/or EU-based shippers to meet a unitary CO_2 index limit or target.

4 Future inclusion of refrigerant gases from shipping in the EU regulation and/or an indexing system parallel to the CO_2 index.
5 Inclusion of a mandatory CO_2 element in an EU-wide regime for port infrastructure charging.
6 Inclusion of CO_2 emission from shipping in the EU ETS.
7 Allocation of ship emissions to Member States.

Assessment of policy options
All policy options are assessed on four main criteria:
1 Operational effectiveness: what is the amount of carbon emissions covered by the policy and how strong is the incentive to reduce emissions?
2 Legal implications: is the policy option and the enforcement possible under current EU and international law, and if not, will implementation require changing EU law or international treaties?
3 Feasibility of monitoring and enforcement: do current business practices enable monitoring and enforcing the policy aim, or would it require new administrative systems or other changes in business practices?
4 Feasibility of implementation: are there issues that require further study before the policy can be formulated and legal text can be drafted, and if so, which?

On the basis of this assessment, the report concludes that one policy option has severe drawbacks. Three options have a very limited effect on greenhouse gas emissions, but could be pursued for other reasons. Three options seem promising, but current understanding of how these policies would work in maritime transport is not mature enough to give a final assessment.

Policy option with severe disadvantages
There currently is no organisation that would be willing to enter into a **voluntary commitment**. Furthermore, a voluntary agreement is not expected to have a significant impact on greenhouse gas emissions. Neither can there be high expectations of its efficiency. Voluntary agreements may serve a purpose as ancillary to other instruments, but not as a main instrument in climate policy for maritime transport.

Policy options with limited effects, but still worthwhile
A **requirement to report the CO_2 index value** is feasible and within the realm of EU policy. The requirement can be limited to EU flagged ships, without fear for evasion. The effectiveness of this option per se is limited, but it could serve as a basis for more effective policies. It would generate representative data on the CO_2 index of the fleet, and could be used to increase knowledge and understanding of the CO_2 index, regarding how it depends on technical, operational and economic factors. This understanding seems to be a prerequisite to decide on using the index for regulation (option 3) or market based policy instruments based on this index, such as described in option 5. In addition, in order to calculate the CO_2 index, ship operators will have to collect data that could be used to evaluate other policy options as well (data on absolute emissions on voyages could be used for the evaluation of ETS).

Furthermore, ship owners or operators may use the data, once available, as a management tool to critically monitor and analyse their ships fuel consumption performance.

An **inclusion of refrigerant gases in EU regulation** would possibly require additional EU legislation, since it is not clear that the current regulation of refrigerant gases extends to ships outside the territorial waters. Furthermore, the climate impact of reducing emissions of refrigerants would be small. Nevertheless, because ship operators can take many cost effective measures to reduce refrigerant leakage and for this reason, the policy option should be explored further.

Allocation of emissions from maritime transport to states is not by itself a policy to reduce greenhouse gas emissions from shipping. States would have to introduce policies and measures in order to control the emissions that have been allocated to them. In the international maritime transport sector national and unilateral policies and measures are unlikely to be effective and may give rise to evasion and competitive distortions.

Partly for this reason, it can be expected that countries will be particularly unwilling to agree on an allocation method without a perspective on potential policies and measures to address these emissions, and without knowing the commitments/reduction obligations associated with these emissions. An integrated approach, addressing at once allocation, commitments and policies and measures may thus be required to achieve progress in the allocation discussions.

Most promising policy options

The first promising option is the **inclusion of maritime transport in ETS**. Under this option, ship operators calling at EU ports would have to surrender allowances for their CO_2 emissions on their voyage to an EU port. Such a policy would be in line with current developments in the EU, directed at the inclusion aviation in ETS. Furthermore, it would allow ship operators considerable flexibility in taking measures to reduce emissions (or buying emission allowances). And it would be the only policy instrument studied in this report that would cap the net climate impact of shipping.

Inclusion of maritime transport in ETS would need some further study, though. The wide variety of business models in the shipping sector makes it hardly possible to apply current methods of distributing allowances to the sector. New methods, suitable for the shipping sector, would need to be designed. Furthermore, the scope for evasion needs to be studies alongside ways to limit it. And the desirability to treat different segments of maritime transport in a different way warrants more attention than was possible in this study.

The second promising option is a **differentiation of harbour dues**, although this instrument would probably be an incentive to increase transport efficiency, not to cap absolute emissions. Under this policy, ports would have to give a rebate on their harbour dues to ships that emit less than a certain limit value, and should charge ships with higher emissions more. This instrument could be designed to give operators flexibility in the measures required to reduce emissions. It would be an economic, market based instrument for which most institutions are currently in place. This means that the additional overhead costs could be kept to a minimum. It could also be implemented in a budgetary neutral way.

The main obstacle that would have to be overcome before this option could be implemented would be the identification of a base for the differentiation that would be environmentally effective and technically attainable. The IMO CO_2 index could prove to be a suitable base, but the current understanding of the index is still immature. Other bases would be conceivable, but they would require more study.

Furthermore, the possible impact on the competitive market between ports needs further study. The instrument could discriminate against ports for which the price elasticity of demand is relatively high.

The third promising option is a **requirement of ships calling at EU ports to meet a unitary CO_2 index limit value**. The CO_2 index is a ship-specific indicator of the amount of CO_2 emitted per amount of transport work. Ship operators can reduce their index by operational measures (such as slow steaming or full loading) or by technical measures (such as increased hull maintenance).

A requirement to meet an index limit value would still allow ship operators to choose measures from a wide array of technical and operational options. Because of this flexibility, the cost effectiveness of this option could be good. However, it would need to be demonstrated that it is indeed possible to calculate a CO_2 index limit value that would not be dominated by external factors such as transport demand, and would take the large variety of ships into account.

27 Climate policies for international shipping

27.1 Introduction

Maritime transport is an important mode of transport for the European Union, with over 90% (in volume) of its external trade and some 43% of its internal trade going by sea. The maritime sector is also important from an economic point of view. Maritime companies belonging to European Union nationals control one third of the world fleet and some 40% of EU trade is carried on vessels controlled by EU interests.

The environmental record of maritime transport is mixed. Shipping has the lowest emissions of all transport modes relative to transport performance. Still, in absolute terms, emissions from shipping are not negligible. Estimates show CO_2 emissions from maritime transport to account for 1.8% to 3.5% of global emissions. Furthermore, greenhouse gas emissions from sea shipping are rising and not currently subject to any policy measures.

In November 2002 the European Commission presented an EU strategy to reduce atmospheric emissions from seagoing ships (COM(2002)595 final). It states that in order to reduce greenhouse gas emissions from shipping, the Commission will work with the IMO to ensure that its greenhouse gas strategy is concrete and ambitious. However, 'if the IMO has not adopted a concrete, ambitious strategy by 2003, the Commission will consider taking action at EU level to reduce ships' unitary emissions of greenhouse gases[24].

This study designs and assesses seven policy options addressing greenhouse gas emissions of maritime transport. It was performed under contract 070501/2005/420196/MAR/C1 by a consortium consisting of CE Delft (leading contract partner), MARINTEK, Det Norske Veritas (DNV) and Germanischer Lloyd (GL). This report has been drafted by CE Delft.

27.1.1 Outline

The next chapter presents stylised facts on the climate impact of shipping. Chapter 29 estimates CO_2 emissions in various geographical scopes. A sector analysis of maritime transport is presented in chapter 30, and chapter 31 assesses the possibilities to monitor, report and verify CO_2 emissions. Chapter 32 designs the policy instruments, which are assessed in chapter 33. Chapter 34 concludes this report.

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[24] COM(2002)595 final p. 17.

28 Stylised facts on the climate impact of shipping

Maritime transport emits several greenhouse gases (CE Delft, 2006b; Boon, 2006). The most important is CO_2. At a global level, shipping is estimated to have emitted between 428 and 913 Mtonnes of CO_2 in 2001, the most recent year for which figures are available. (The considerable uncertainty is due to different calculation methods; the lower figure is based on bunker fuel statistics, whereas the higher estimates are based on activity data). This means that shipping accounts for 1.8% to 3.5% of global CO_2 emissions. Chapter 3 estimates emissions in Europe.

Apart from CO_2, maritime transport emits small amounts of F-gases (refrigerated ships) and methane (CH_4 from LNG tankers), which are also greenhouse gases. Other emissions of shipping, notably nitrogen oxides (NO_x), sulphur dioxide (SO_2) and soot, have either direct or indirect climate effects.

NO_x has two indirect climate impacts. It causes the formation of ozone through intricate atmospheric chemistry. Ozone is a greenhouse gas which contributes to global warming. On the other hand, NO_x also causes decay of CH_4, thereby reducing global warming.

SO_2 also has a dual impact. It forms aerosols which reflect sunlight and have a direct cooling effect. Furthermore, these aerosols may serve as nuclei for the condensation of water vapour. This can cause the formation of 'ship tracks', low clouds that can be observed in busy sea lanes. These ship tracks also reflect sunlight and reduce global warming.

Soot has a very small warming effect.

When all the effects are quantified and added up, shipping seems to have an overall cooling effect. The cooling of the ship tracks outweighs all the positive contributions to global warming.

Does this mean that shipping is unproblematic or even good for climate change? The answer is no, for two reasons. First, some impacts are global (CO_2), whereas others (sulphur aerosols and ship tracks) are local. The total contribution of shipping to climate change may be cooling, but most scientists do not believe that local cooling and global warming effects actually cancel out in terms of climate. On the contrary, they can cause change of winds, changes in precipitation, et cetera, even though they may not contribute to a change in the mean global temperature. Second, because of concerns over air pollution, both international, regional and national policy aims to reduce the sulphur content of bunker fuel and therefore SO_2 emissions. It is likely that the cooling effects of shipping may decrease in the future, as these policies generate effect. At some point, they may even cease to offset the warming effects of greenhouse gas emissions of shipping.

29 Greenhouse gas emissions in geographical regions

This chapter discusses the different potential scopes of climate policy options and provide an indication of the amount of emissions that would be covered under these scopes.

We first discuss several options for the scope of policy instruments. At this stage, we do not select a scope, but merely provide insights that will be used in the design process and the assessment. Next, we briefly discuss the available information sources that could be used to derive a preliminary estimate of the amount of emissions under each scope. Based on this discussion, a choice will be made for a particular model or combination of models, and the amounts under each scope will be estimated.

29.1 Discussion of potential scopes

Any policy option needs to define the scope of the emissions that the option addresses. Since vessels engaged in international transport and fishing by definition pass through several jurisdictions, and since different boundaries exist on the seas, the definition of the scope is even more pressing in maritime policies than in policies that address land based emission sources.

Scopes can have various dimensions, such as geographical area, operators, operations and vessel age.

The geographical scope can be defined in a number of ways, such as:
- Activities in ports.
- Activities in the territorial waters (12 mile zone).
- Activities in the exclusive economic zone (200 mile zones).
- Activities on the continental shelf.
- Activities within the European Monitoring and Evaluation Programme (EMEP) region.
- Et cetera.

Apart from the geographical scope, policy instruments can, at least in theory, apply to different maritime operations and operators.

Operators that could be addressed by policy instruments include:
- All operators, ships and shippers, irrespective of base or flag.
- EU-based operators.
- EU-flagged ships.
- EU-based shippers.

Policy instruments could in principle apply to operations such as:
- All operations of a vessel.
- Operations on certain routes:
  - All operations between EU ports.
  - All operations departing from EU ports.
  - All operations arriving at EU ports.
  - All operations to and from EU ports.

Application of policy instruments could distinguish with respect to:
- Age of the vessel:
  - E.g. all new vessels.
- Use of the vessel:
  - E.g. oil tanker, bulk carrier, container ship, fishing, off shore supply, navy vessel, research, passenger ferry.
- Size of vessel:
  - In terms of TEU, DWT, GCT, engine capacity, etc.

Combining the dimensions of the scope described above, a large number of potential scopes is possible for greenhouse gas policies in maritime transport. Different scopes have different economic impacts and legal implications.

29.2 Discussion of available models to analyse emissions under each scope

There are various sources that could be used to indicate the amount of emissions falling under different scopes. Appendix A describes them in detail. Here, the main conclusions that have led to the selection of the Entec (2005) database will be repeated.

Appendix A considers the following data sources that could be used:
- Eurostat.
- Entec (2002).
- Tremove.
- EDGAR.
- Entec (2005).
- Eyring (2005).
- Corbett and Koehler (2003).

It should be noted that some of these sources are especially directed at the EU, whereas other studies / sources provide insight on a global level and may not even be restricted to emissions from maritime transport, such as EDGAR.

An overview of some of the characteristics of the different sources is presented in Table 33. The table describes the base year of the data bases, the geographical scope and whether or not a distinction of operators, operations and vessels is possible. Furthermore, it gives the estimate of total emissions in the database and, in the last column, whether the data are immediately available to the consultant. This is important, since the project does not allow for the acquisition of data or the development of new databases.

Table 33 Comparison of different data sources

	Base year	Scope	Data source distinguishes between:			Estimate of emissions	Data availability
			Types of operators	Types of operations	Types of vessels		
Entec (2002)	2000	EMEP region	EU/ACC/ non EU Flag	Yes	Vessels, ferries and fishing	157 Mt CO_2	Yes
Entec (2005)	2000	EMEP region, rough estimate for other emissions	EU	Yes	Vessels and ferries	153 Mt CO_2 (EMEP region); 757 Mt CO_2 (global)	Yes
Tremove	2000	EMEP region	EU/ACC/ non EU flag	Yes	Vessels and ferries	-	No
Eurostat (2006)	2004	EU	No	No	-	-	Yes
Eyring (2005)	2000	Global, grid data available	No	No	-*	813 Mt CO_2	No
Corbett & Koehler (2003)	2001	Global, grid data may be available	No	No	-*	912 Mt CO_2	No
EDGAR	2000	Global, grid data available	No	No	-*	428 Mt CO_2	Yes

Note: *: No results for specific types of vessels are presented, but based on the underlying model, such information should be available.

We selected Entec (2005) as the source for calculating CO_2 emissions under different scopes because of the immediate availability of the data and because it allows in principle to distinguish between different scopes.

29.3 CO_2 emissions under different scopes

Based on the above analysis we decided to make use of the datasets developed by Entec. However, the database which was available to us doesn't allow to estimate the emissions for specific geographical scopes (departing from EU ports, arriving at EU ports and between EU ports) nor to differentiate on the basis of the size of ships. Below we present information for the categories that we can distinguish.

In Table 34 an indication is given of the amount of CO_2 emissions in 2000 that can be assigned to various operators and operations. These figures are taken from the Entec database. A distinction is made between total CO_2 emissions and CO_2 emissions in the EMEP region. Since necessary data with regard to EU-based shippers and EU-based operators is not available (neither from the Entec database nor from other sources), it was not possible to estimate CO_2 emissions for EU-based operators or shippers.

Table 34 Indication of CO_2 emissions (2000) (excluding fishing, including ferries)

	Global CO_2 emissions of maritime transport (Mt)	CO_2 emissions in EMEP region (Mt)
Operators		
All operators	756.7	153.3
EU-based operators		
EU-flagged ships	196,6	71,4
EU-based shippers		
Operations		
All operations	756.7	153.3
All operations to and from EU ports	152,4	
In ports	30.2	10.2
territorial waters	-	38,3
exclusive economic zones	-	120,6

Sources: Entec, 2005.
Note: Table 2 covers EU15 + Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia, Slovenia.

The indication of CO_2 emissions in Table 34 does not include most CO_2 emissions of fishing vessels, since these types of vessels are not covered by Entec (2005). However, the emissions of fishing vessels are allocated to the countries where they buy their fuel, and consequently do fall under the climate policies of these countries (VROM, 2005). Furthermore, the CO_2 emissions of fishing vessels account for a relatively small proportion (ca. 2.5%) of total CO_2 emissions of shipping (Entec, 2002). For this two reasons we decided not to include CO_2 emissions of fishing vessels into this project.

By means of results from Entec (2002) (see Table 35) it is possible to make an estimation of the CO_2 emissions of trips from EU ports (118.3 Mt), to EU ports (115 Mt) and between EU ports (90.3 Mt). However, these estimations are not completely comparable to the estimations from Entec (2005), because both studies do not cover the same countries. Unlike Entec (2005), Entec (2002) does contain estimations of CO_2 emissions for ships with an Islandic or Norwegian flag. On the other hand, Entec (2002) does not contain estimations for ships with a Croatian flag, where Entec (2005) does. These differences in geographical coverage of both sources is also responsible for some incongruous estimations in Table 34 and Table 35.

Table 35 Distribution of CO_2 emissions (2000) within the EMEP region (excluding fishing, including ferries)

From	To	EU 15 + Accession flag	Other flag	Total
EU 15 + Acc	EU 15 + Acc	53.0	37.3	90.3
EU 15 + Acc	Other	11.3	16.7	28.0
Other	EU 15 + Acc	9.8	14.9	24.7
Other	Other	3.1	7.1	10.2
All	All	77.2	76.0	153.2

Source: Entec, 2002.
Note: The accession countries are: Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Iceland, Latvia, Lithuania, Malta, Norway, Poland, Romania, Slovakia, Slovenia.

For the purpose of getting an idea about the relevance of policy measures that only relate to new ships, an indication of the emissions by different age classes may be of interest. Unctad (2005) provides an average age distribution of the global fleet in 2005. In addition, age distributions are presented for the fleets of country groupings. Based on this information, in combination with the information deducted from the Entec database, the amount of CO_2 emissions that can be assigned to different age classes is estimated, both for all operators and EU-flagged operators. The results are presented in Table 3. Note that these figures should be considered rough estimates. They are only correct if (i) age does not deteriorate fuel efficiency, (ii) size and class distribution remains constant over time and (iii) old and young ships are operated similarly. These assumptions are known to be invalid. Still, the impression that young ships (less than 5 years old) account for about one fifth to one quarter of global CO_2 emissions seems credible.

Table 36 Indication of CO_2 emissions (Mton CO_2) in 2000 assigned to different age classes

		0 – 4 years	5 – 9 years	10 – 14 years	15 – 19 years	20 years and over
All operators	Total	174.0	165.7	124.9	85.5	206.5
	Percentage	23.0%	21.9%	16.5%	11.3%	27.3%
EU-flagged operators	Total	48.3	45.7	32.2	22.4	44.4
	Percentage	25.0%	23.7%	16.7%	11.6%	23.0%

Source: Entec, 2005; Unctad, 2005.

Finally, an estimation is made for CO_2 emissions that can be assigned to different use of ships. The shares of different use of ships in both the global fleet and fleets for groups of countries can be deducted from Unctad (2005). In combination with the results from the Entec database, it can be used to estimate the amount of CO_2 emissions that can be assigned to the various classes of ship applications, both for all operators and EU-flagged operators. Again, note that the results, as presented in Table 4, are rough estimates of the emissions of different vessel types[25].

Table 37 Indication of CO_2 emissions (Mton) in 2000 assigned to different classes of ship use

		Oil tankers	Bulk carriers	General cargo	Container ships	Other ships
All operators	Total	283.7	270.9	77.9	82.5	41.6
	Percentage	37.5%	35.8%	10.3%	10.9%	5.5%
EU-flagged operators	Total	80.2	55.6	20.7	23.2	13.3
	Percentage	41.6%	28.8%	10.7%	12.0%	6.9%

Source: Entec (2005), Unctad (2005).

[25] Again, the assignment of CO_2 emissions to different use of ships is (partly) based on data for groups of countries also including non-European countries. In addition, it is assumed that the distance travelled is independent of ship use.

30 Sector analysis

Maritime transport involves many stakeholders, and each group of stakeholders can in principle take different measures to reduce greenhouse gas emissions. These measures can be classified as either technical (involving physical changes in ship design, propulsion, et cetera) or operational (involving changes in the ways in which ships are operated).

This section first analyses which direct and indirect control various stakeholders have over emissions (section 30.1). Direct control implies that a stakeholder can reduce emissions without having to rely on the market to induce another stakeholder to act. Second, it analyses which stakeholders can be made responsible for which share of emissions (section 30.2). This analysis starts from the assumption that stakeholders can only be made responsible for emissions they can control, preferably directly, or otherwise indirectly.

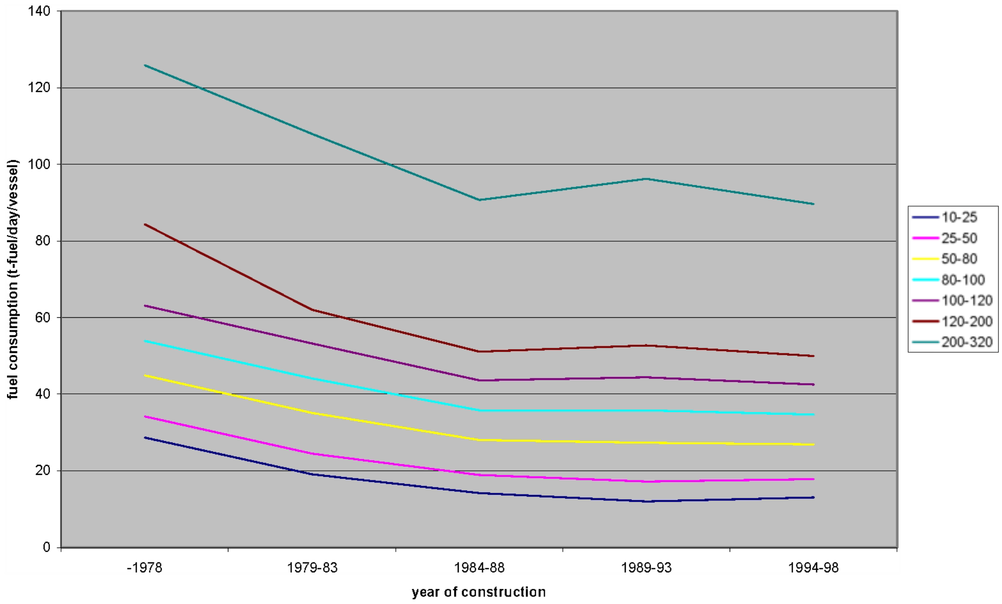
30.1 Which entities have control over fuel use and greenhouse gas emissions?

Ship builders have traditionally built unique ships designed to answer the a specifications made by the ship owner. If a ship owner commissions the ship builder to design a fast ship, it will build a fast ship. If the ship owner demands fuel efficiency, the ship builder will build a fuel efficient ships. Faster vessels use more fuel to cover the same distance than slower vessels. This business model still exists today, but there is a trend towards large ship yards which are increasingly focusing on developing their own ship concepts which are sold to ship owners with as few modifications as possible. Of course, the ship builder is bound by the technological frontier. Ship builders may decide to push the technological frontier by engaging in R&D activities. They will do so if they are convinced that a business opportunity exists for building fuel efficient ships (see box 1).

Clearly, ship builders have no influence on the absolute emission levels and on operational emission reduction measures. They can influence fuel efficiency, but will do so only if the market demands so.

Box 1 Oil prices and fuel efficiency of ships
After the first (1973) and second (1979) oil crises, ship builders improved the fuel efficiency of their ships considerably. However, as real oil prices started to decline in the 1980s and 1990s, the rate of improvement of fuel efficiency declined and even reversed in some cases. Figure 31 illustrates this. It shows the average fuel efficiency of newly built tankers in several size classes from 1978 to 1998.

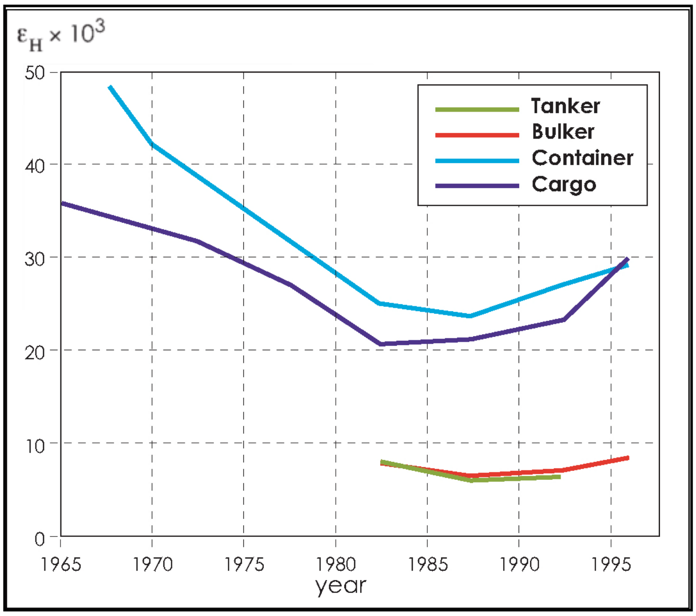
Figure 31 The average fuel consumption of newly built tankers decreased until 1990



Source: Ship and Ocean Foundation, 2000: A report on research concerning the reduction of CO_2 emissions from vessels, Tokyo.

The fuel efficiency of a ship is composed of the efficiency of the engine, the propeller and the hull. Estimates show that the hull and propeller efficiencies showed even more clearly that from the 1960s through the 1980s the trend was clearly towards more efficient ships, and that this trend has reversed since the mid-1980s (see Figure 32). Clearly, other design requirements have prevailed in the last decades. In the late 1980s and the 199s, there seems to have been a growing demand for wider and faster ships. These ships are generally cheaper to build, so they require lower initial investments.

Figure 32 Hull and propeller efficiency increased from the mid-1980s



Source: Ship and Ocean Foundation, 2000: A report on research concerning the reduction of CO_2 emissions from vessels, Tokyo.

These examples show that fuel price has a clear influence on fuel efficiency of new ships. Furthermore, it seems that in the past decades fuel efficiency has not been among the prime design requirements, probably due to the low fuel prices. This trend is likely to been reversed in recent years, although we have no data to corroborate this hypothesis.

Source: Ship and Ocean Foundation, 2000: *A report on research concerning the reduction of CO_2 emissions from vessels*, Tokyo.

Engine manufacturers build fairly standardised engines. The characteristics of the engines they offer to their clients are determined by the engine manufacturers' perception of their clients demands and by the technological frontier. Generally, there is a trade-off between engine efficiency and reliability. The engine buyer may typically choose between a smaller engine with a high rating (i.e. pushing the engine hard) or a larger engine which will have a lower efficiency at the same power but lower expected maintenance costs. The energy efficiency of large diesel engines can also be increased by the use of steam turbines driven by exhaust gas heat, unless this heat is already put to use for other purposes. This solution is currently not cost effective, however this may change for larger engines with increasing fuel prices. Hence the propulsion efficiency of ships delivered today depends both on the technology of the engine builder and on customer demand. The potential for increasing the efficiency of the base engines should not be overlooked, but is believed to be small compared with other measures to increase fuel efficiency.
Engine manufacturers have no impact on operational measures to reduce emissions, nor on the absolute amount of emissions.

Ship owners and ship operators own and/or operate ships[26]. Commonly, they offer either charter services or liner shipping services. Liner shipping is growing at a higher rate than charter shipping.

In charter services, ships are rented out to charterers, usually to transport a specific cargo from one port to another. Many different charter arrangements exist[27], each with different implications on who bears the costs of fuel use and harbour charges.

Typically, in voyage charters, voyage dependent costs such as fuel use and port costs are not included in the lease, but invoiced separately to the shipper. In the case of voyage charters, this means that owners and/or operators which provide charter services usually have no direct incentive to reduce fuel consumption, although there may be an indirect incentive because demand for fuel efficient ships may be higher than for less efficient ships. Operational measures will however hardly be incentivised under this business model. Ship owners do not pay the fuel bill, and charterers cannot influence the crew. The exception may be

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26 We adhere to the common definition that a ship owner is the legal owner of a vessel officially registered as such in the certificate of registry of the vessel, and the ship operator is the (legal) person making decisions about the daily operation and employment of the ship and crew.

27 The most common charter arrangements are: time charter, voyage charter, bare boat charter and contract of affreightment.

the trade-off between speed and fuel consumption which is typically made by the charterer, who may or may not give bonuses for fast steaming.

In traditional Contracts of Affreightment (CoA) and spot shipping, the charterer pays a lump sum per parcel/lot, or a fixed sum per ton cargo. This includes all costs including time charter costs, port costs, fuel costs etc. These ship owners and operators have an incentive to increase fuel efficiency. Slow steaming to reduce fuel consumption is common in all spot/CoA trades.

In liner services, ship owners or operators maintain a regular scheduled shipping service on certain routes. They rent out space on their ships, usually for cargo in containers. One ship typically transport containers for a large number of shippers or cargo owners, and freight rates cover all expenses including fuel costs. Therefore, these ship owners and operators have a direct incentive to reduce fuel consumption, although some of the increases in fuel prices may be passed on to the client in the form of fuel surcharges.

Ship crew determine to some extent the operation of a ship which may have an impact on fuel consumption. For example, the crew may decide to sail faster and avoid delay or slow down in order not to arrive early for harbour or pilot service. Furthermore, they may adjust the actual route of the ship depending upon weather conditions (weather routing). They may respond to incentives given to them by the ship operators.

Shippers[28] **and cargo-owners** may pay for the fuel a ship consumes when chartering a ship, depending on the charter arrangements. If they pay separately for the fuel costs, they would have an interest to reduce fuel consumption (even though other incentives may be larger). However, their direct control over fuel consumption is limited: they can require slow steaming or charter a fuel efficient ship. When shippers and cargo owners use liner shipping services, they have no incentive to reduce fuel consumption, neither do they have any control over fuel consumption.

Some large cargo transporters control their own vessel fleets, e.g. ChevronTexaco (product tankers), ExxonMobile (crude oil tankers). For these companies, the analysis is slightly different. They have both the incentive to reduce fuel consumption and the control over operational and technical measures to do so.

A typical type of cargo-owners are commodity traders. They may buy and sell cargo while it is still onboard ships. Crude oil is an example of a commodity that may change hands many times between loading and discharge. Change of

[28] A shipper is the merchant (person) by whom, in whose name or on whose behalf a contract of carriage of goods has been concluded with a carrier or any party by whom, in whose name or on whose behalf the goods are actually delivered to the carrier in relation to the contract of carriage:

1 One who transports goods for a charge, in normal usage, such a person would be called a carrier, but carriers are also called 'shippers'.
2 One who tenders goods to a carrier for transportation.
3 The sender of goods to be transported as distinct from the receiver or the consignee.

owner may lead to a change of destination for the cargo, hence the cargo may in some instances make significant detours. In these cases, the costs of extra fuel consumption can apparently be compensated by higher product prices.

Fuel suppliers have no control over fuel consumption by ships. This is a globally competitive industry, where individual suppliers have very limited market power. Fuel suppliers, of course, have no incentive to reduce fuel consumption, nor have they any direct control over emission reduction measures.

Port authorities have some control over emissions in and around ports. For the purpose of reducing local air pollutants, they may for example offer shore side electricity to reduce emissions from engines running in ports or impose speed limits. Moreover, they may be able to reduce manoeuvring and waiting operations in port. Some of these measures are also likely to reduce CO_2 emissions. Port authorities have no influence over operational measures taken at sea. Furthermore, port authorities have no direct incentive to reduce fuel consumption or greenhouse gas emissions in ports: they are not in a position to reap the benefits of a reduction in fuel consumption. Port authorities are currently not in a position to report the emissions from vessels since they do not have access to this information.

30.2 Policy implications

Table 38 summarises the control that entities have over greenhouse gas emissions and the incentive they have to reduce fuel consumption.

Table 38 Control over fuel consumption by different entities

Entity		Control over fuel consumption	Incentive to reduce fuel consumption
Ship builders		Efficiency of new ships	Only indirectly through market demand
Engine manufacturers		Efficiency of new engines	Only indirectly through market demand
Ship owners and operators	Chartered services	Technical and operational measures	Depending on charter contract either directly or indirectly
	Liner services	Technical and operational measures	Yes
Ship crew		Operational measures	Yes (only when ordered by operator)
Shippers and cargo owners	Chartered services	Indirectly, either by choosing for fuel efficient ships, or by giving incentives to ship crew	Yes, because shippers pay for the fuel costs
	Liner services	No	No, unless price increases are passed on
Commodity traders		Yes, but only over detours	No
Fuel suppliers		Not in practice	No
Port authorities		Only in and around ports	No

This sector analysis shows that the shipping sector has split incentives when it comes to fuel efficiency and reducing greenhouse gas emissions. Especially for chartered services, the entities that pay for the fuel often have no direct control over fuel consumption. They can only control fuel use indirectly be expressing their preference for fuel efficient vessels through the price they are willing to pay for the charter service. In that case, ship owners that invest in fuel efficient ships may be able to recoup their investments. For liner services, control and incentives are better aligned.

By making ship owners or operators responsible for the emissions their ships generate, it is possible to align the control over emissions with incentives to reduce emissions. Of course, ship owners and operators do not have total control over emissions, but they can make use of existing markets to extend their control and reduce emissions beyond their direct control. They can invest in more fuel efficient designs of ships and engines. They can incentivise ship crew to minimise emissions during a trip through training and through labour contracts[29].

When ship owners and operators would be made responsible for emissions in a non-discriminatory way, i.e. regardless of the flag of the ship or the nationality of the company, at least some the costs associated with increasing fuel efficiency could be passed on to shippers and cargo owners. However, if the responsibility would discriminate between flags, this would provide an incentive for ship owners and operators to flag their ships out, and the climate impact would be negligible.

Other parties are not in a good position to reduce emissions directly. Ship builders and engine manufacturers can only influence the efficiency of new ships. If they were nevertheless made responsible, and measures to reduce emissions would result in higher operating costs of new ships, leakage might occur: the economic life of existing ships would be prolonged, which would result in a slower reduction of emissions. Furthermore, ship builders and engine manufacturers cannot take operational measures to reduce emissions. Shippers and cargo owners may have difficulties calculating emissions unequivocally. It would be difficult to contribute the emissions of liner shipping services to particular shippers and cargo owners. This would also require ship operators to make fuel use data public, to which they may object.

30.3 Conclusion

Ship owners and operators are the first best entity to be made responsible for greenhouse gas emissions of shipping. They have direct control over operational measures to reduce emissions and both direct and indirect control over technical measures. Furthermore, they can reduce emissions not under their direct control through established and functioning markets, such as the labour market for ship crew and the market for new ships. In addition, or as a second best solution, other parties may be made responsible or partly responsible. Ship builders and

[29] DNV has reported that they can reduce fuel costs by 10% for many shipping companies by implementing adequate management standards and training of crew. DNV Press Statement 6 June 2006, http://www.dnv.com/press/Reducedemissionsandimprovedbottomline.asp.

engine manufacturers may be made responsible for the fuel efficiency of the ships and engines they make. This can be done additionally to the responsibility of ship owners or operators for the emissions of ships they control. As a third best option, cargo owners may be made responsible for the emissions they produce by transferring their cargo. However, they have little control over emissions. Moreover, this would require transfer of emission data from ship operators to cargo owners, as well as allocating emissions to pieces of cargo.

31 Monitoring and reporting emissions

In order for any climate policy to be effective, the greenhouse gas emissions should be measured or estimated with an acceptable accuracy. This requires monitoring, reporting and verification of emissions. The current section describes feasible ways to do this.

This section builds on the conclusion of the previous section, i.e. that ship owners or operators should be made responsible for emissions. In addition, it takes the following assumptions:

- The emissions of carbon dioxide are directly related to fuel consumption, and can be calculated on that basis, possibly in combination with an analysis of the carbon content of the fuel used. Note that this assumption does not imply that accurately measuring fuel consumption is possible on a trip basis or in a certain geographical area. This issue will be discussed later.
- The policies considered in this report are assumed to be regional policies (EU or EEA). Therefore, the emissions to be covered by the policy are not the total emissions of a ship, but rather emissions within a certain geographical boundary, or emissions on trips to and/or from a region, or some other geographically based subset of total emissions. In practice, this means that emissions must either be assigned to specific voyages in a systematic way, or that emissions, position and time must be monitored simultaneously.

Ships currently measure fuel consumption in a number of ways. These range from regularly measuring the level of the fuel in tanks by manually lowering a so-called 'gauging tape' in a tank until it reaches either the bottom of the tank of the surface of the fuel and reading the level, to automatically measuring the level of the tank by sonar 'sounding' equipment. Many ships register the level of their tanks on a daily basis, together with the position of the ship. Other ships record the level of the fuel at the beginning and end of a trip only.

Several studies have explored ways to monitor, report and verify emissions of air pollutants, such as NO_x and SO_2. The latter may have relevance to the issue of greenhouse gas emissions, since SO_2 emissions are the direct result of fuel combustion (there is a difference, though: SO_2 emissions can be abated by exhaust gas cleaning systems, whereas CO_2 emissions can not, or to a much lesser extent). Here, we review two recent studies into the monitoring and verification of SO_2 emissions: NERA (2005)[30] and PWC (2005)[31].

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30 NERA 2005. Harrison, David, Jr., Daniel Radov, James Patchett, Per Klevnas, Alex Lenkoski, Paul Reschke, and Andrew Foss, 2005: Economic Instruments for Reducing Ship Emissions in the European Union, London.

31 PWC 2005. Hansén, Ola, Johan Jacomsson, Joachim Jämttjärn, David Cooper and Eje Flodström, 2005: Demo Project: Final Report, Stockholm: PWC, IVL.

The NERA (2005) study is an analysis of four economic instruments to reduce emissions of air pollutants from maritime sources. One of the design elements studied in this report is emissions monitoring and reporting.

NERA (2005) differentiates between periodic fuel consumption monitoring and continuous fuel consumption monitoring[32]. Periodic fuel consumption monitoring 'involve(s) periodically compiling fuel delivery receipts to obtain data on total fuel consumption by individual ships during each period … This strategy would require no costly monitoring equipment, and would allow for relatively simple data verification' (NERA, 2005, p. 7). The administrative burden of a monitoring scheme based on fuel receipts would be low, but it would be hard to assign fuel consumption or emissions to a specific geographical area. This could only be done in a very general way, e.g. by calculating the average emissions per mile (or per tonne-mile) and multiplying this average value by the distance sailed (or the cargo transported and the distance sailed) within the relevant geographical scope.

Continuous fuel consumption monitoring 'would require continual on-board measurements of fuel consumption'. Records of this measurement could be combined with records of geographical location (e.g. based on continuous GPS measurements) to produce accurate figures for emissions in specific geographical areas. However, as NERA states, fuel consumption is difficult to measure directly on many vessels, so it may require additional investments on ships. According to NERA, data verification would be relatively straightforward (since total fuel consumption figures are readily available).

The analysis of NERA is corroborated by information from other sources. From interviews with industry stakeholders it has become clear than many ships prepare daily bunker reports, which are sent to the ship operator and/or the charterer. The daily bunker reports typically indicate the level of the fuel tanks and the position of the ship. The level of the fuel tanks can be determined with great accuracy in most ships, using various techniques, such as ultrasonic measurements.

PWC (2005) reports on a demonstration project that establishes the feasibility of monitoring and verification of NO_x and SO_2 emission reductions at sea. One of the tests described in the report concerns SO_2 monitoring onboard a ship using low sulphur fuel. In the test, fuel consumption was calculated directly from a fuel flow meter and indirectly from a signal that varies with engine load (viz. turbo charger speed). The reasoning behind this test procedure is that whereas few ships have a fuel flow meter, most ships are able to measure engine load. If the two measurements correlate well, it would be possible to measure continuous fuel consumption and record it jointly with time and position of a ship. The report concludes that both measurements of fuel consumption differ by 5-15%. Highly

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32 NERA uses slightly different terms (e.g. 'periodic fuel-based estimates') which are relevant to SO_2 emissions but not to CO_2 emissions.

accurate monitoring[33] of fuel consumption is hence not possible from measuring engine load (at least not in the way it has been done in this test).

PWC (2005) concludes that ‘monitoring of sulphur dioxide emission reductions by ships using low sulphur fuel is feasible (with the technology and knowledge existing today)’. This implies that continuous monitoring of fuel consumption is feasible. Furthermore, PWC concludes that verification of emissions is feasible.

31.1 Conclusion

It is possible to monitor, report and verify total fuel consumption and implicitly total CO_2 emissions. It is also possible to assign these emissions in a crude way to voyages. Better results could be obtained by continuous monitoring of fuel use, and simultaneous reporting of position and time. This can be done in a verifiable way, but would require additional investments for some ships.

[33] It should be held in mind that monitoring from fixed installations under the ETS is not entirely accurate either. In fact, most installations have uncertainties in the order of 5% - 15% in emission measurements.

32 Policy options

This section considers the design choices for the policy options. Based on the terms of reference, seven options are designed:

1 Voluntary commitments (section 32.1).
2 A requirement to report the IMO CO_2 index (section 32.2).
3 A requirement to meet a unitary CO_2 index limit value (section 32.3).
4 Inclusion of refrigerant gases in regulation or the CO_2 index (section 32.4).
5 Mandatory differentiation of harbour dues (section 32.5).
6 Inclusion of maritime transport in ETS (section 32.6).
7 Allocation of emissions from maritime transport to countries (section 32.7).

In designing the policy options, this chapter builds on the analyses in previous chapters.

32.1 Option 1: Voluntary commitments

Voluntary commitments are agreements between economic actors and governments to reach a certain environmental goal. In the context of this study, voluntary commitments would aim to reduce climate impacts from shipping, and the economic actors involved would be active in maritime transport. The design of a voluntary commitment involves the following choices, which are dealt with in this section:

- The economic actor(s) involved in the commitment.
- The basic parameter of the commitment.
- The carrot and stick involved.

Economic actors involved

In principle, the economic actors involved in a voluntary agreement could be the same as the actors described in section 30.1. There, many actors were considered. The conclusion was that ship operators are in the best position to reduce greenhouse gas emissions, since they have direct control over operational measures and both direct and indirect control over technical measures to reduce emissions. As a second best alternative, ship builders can influence the fuel efficiency of new ships. These two actors are also best suited to enter into a voluntary agreement. Agreements with other actors will be less effective than agreements with these actors, although other actors may be engaged in an agreement in order to facilitate its implementation[34].

Alternatively, governments may enter into an agreement with ports, for example to differentiate their harbour dues according to CO_2 index, or to give a rebate to ships with an index below a certain limit value.

[34] Consider, for example, an agreement with ship owners and operators to reduce the average CO_2 index of their fleet. Such an agreement may be more effective when a shippers agree simultaneously to require that their cargo is transported in ships that have calculated their CO_2 index or that have an index below a certain limit value.

Basic parameter of the commitment

A large number of basic parameters are conceivable. The most commitments would involve parameters that are directly related to climate impacts, greenhouse gas emissions or fuel consumption[35]. The goals can either be absolute or relative. This leads to the following taxonomy of basic parameters (see Table 39).

Table 39 Taxonomy of basic parameters for voluntary agreements

	Absolute	Relative
Climate impacts	Cap on climate impacts	Climate index
GHG emissions	Cap on GHG emissions	CO_2-equivalent index
Fuel consumption	Cap on CO_2 emissions	CO_2 index

Absolute reductions are in general very hard to achieve in voluntary agreements[36]. In the case of an absolute cap on CO_2 emissions, ship operators would have to pledge to reduce their total fuel consumption. In the case of strong demand for maritime transport, this would be an impossible pledge, since it would imply that a ship operator would voluntarily reduce his profits. The fact that voluntary agreements have by nature a limited means of enforcement would make this disadvantage even larger.

This leaves open the option of relative parameters. Of the three possible relative parameters in Table 39, only the CO_2 index has a well developed calculation method that has been agreed upon internationally. All the other options would imply amending or replacing the CO_2 index, something which might take a long time. Therefore, we conclude that the only possible basic parameter would be the IMO CO_2 index. However, Marintek (2006) shows that the CO_2 index can only be partly controlled by shipowners and operators: they have no control over the business cycle, which is the major determinant for the load factor of a ship.

Apart from these basic parameters, which are directly related to GHG emissions, other basic parameters are conceivable, such as monitoring and reporting, or R&D. Voluntary agreements on these basic parameters will only influence GHG emissions indirectly and are therefore not considered here in detail.

Carrot and stick

The carrot in voluntary agreements are often subsidies. However, apart from R&D subsidies, there are no apparent subsidies for shipping that are connected to GHG emissions.

[35] Other basic parameters may include operational practices such as weather routing, or infrastructure supply and use such as shore electricity. All these parameters would cover only a small fraction of the climate impacts of maritime transport. Therefore, unless large reductions are foreseeable, these are not first best choices as basic parameters.

[36] Examples exist of voluntary agreements to reduce absolute emissions, such as the UK greenhouse gas trading system. However, in this system, companies pledged to reduce their emissions by a certain amount that was more or less foreseen in their business as usual scenarios. Actual reductions have been larger than pledged reductions in some cases, due to increased attention for fuel or energy efficiency. However, the environmental effectiveness of such voluntary agreements is likely to be very limited.

The stick that may be used to engage parties to voluntary commitments is often the threat of regulation. In shipping, however, several stakeholders have argued that they prefer regulation over voluntary agreements, since regulation leaves less room for free riding.

Box: empirical analysis of voluntary commitments
In a thorough survey of voluntary commitments, the OECD concluded that voluntary approaches may have the advantage that they can be introduced relatively easily and rapidly, that they do not put a large burden on the economic actors involved and that they may in some cases be the only achievable form of environmental policy for some sectors.
However, the OECD also concludes that voluntary agreements have several important disadvantages over both command-and-control policies and economic instruments: • The environmental effectiveness of voluntary agreements is 'questionable'. • The economic efficiency is 'generally low'. • In order to improve the effectiveness, the administrative burden may need to be high.
Therefore, the OECD recommends to use voluntary commitments only after establishing a business as usual scenario and by setting goals that go beyond this scenario. It is also recommended that voluntary agreements are underpinned by 'well prepared alternative policy instruments', that serve as credible threats in case the goals of the agreement are not met.
OECD, 2003: Voluntary Approaches for Environmental Policy: Effectiveness, Efficiency and Usage in Policy Mixes, Paris.

Scope for voluntary agreements in the shipping sector

As part of this project, CE Delft consulted various organisations on the prospect of a voluntary commitment. These organisations included the European Community of Shipowners' Associations, the BSR Clean Cargo Group, and the European Shippers Council[37]. From these meetings, it became clear that most of these organisations supported the goal to reduce greenhouse gas emissions. Several organisations stated that they or their members continuously worked towards reducing greenhouse gas emissions, since this implies reducing fuel consumption for which a clear business rationale exists.

Some organisations argued that their effort to reduce fuel consumption was sometimes hampered by legislation. Examples brought forward included legislation on single hull tankers and ballast water. These organisations called upon legislators to assess the climate impacts of new legislation more thoroughly.

Some organisations questioned the need for greenhouse gas policy for shipping. These organisations argued that shipping emits less greenhouse gas per tonne kilometre than most other modes of transport. So if a greenhouse gas policy would result in a modal shift away from shipping, this would have negative environmental effects.

[37] Alas, the BSR Clean Cargo Group did not respond to CE Delfts questionnaire or engage in a dialogue.

On the basis of the discussions, it is CE Delfts judgement that none of these organisations can be expected to enter into a voluntary agreement to reduce greenhouse gas emissions. Shippers do not always have control over the mode of transport, and shipowners' organisations cannot enter into commitments on behalf of their members. Furthermore, in any voluntary commitment in shipping, free riding may be a problem, and this may cause a distortion of the market and evasion. Therefore, from a regulatory point of view, legislation or regulation may be preferable to voluntary agreements.

Box: existing voluntary agreements in shipping

BSR Clean Cargo Working Group
The Clean Cargo Working Group develops voluntary environmental management guidelines and metrics to help evaluate and improve the performance of freight transport. The aim is to integrate product transport into corporate supply chain management.

Members are leading multinational manufacturers and retailers (shippers), carriers and freight forwarders (carriers). Shippers increasingly include environmental performance of product transport into their corporate footprint, environmental management systems and supplier codes of conduct. Carriers realized their responsibilities as well as opportunities to improve environmental performance of freight transport as an industry. Offering responsible transportation becomes a competitive advantage.

The BSR Clean Cargo Working group has developed a simple benchmark for CO_2 emissions of transport. From their website, it is not clear whether or not members of the Group have committed themselves to reaching a certain limit value or lowering the value of the benchmark.

There is no government incentive to join the BSR Clean Cargo Group. Participation is entirely market-driven.

Source: http://www.bsr.org/CSRResources/WGO/CC-GF/index.cfm, accessed 5 September 2006.

Green Award
The Green Award flag is flown by ships, which have a crew and management who devote extra attention to quality, safety and environmental protection. More and more shipping companies and managers are recognising that extra-safe and extra-clean shipping is an asset for all involved, and that the costs involved in the Green Award certification are earned back quickly and easily.

Ships can earn a green award by demonstrating compliance with international and regional legislation, and meeting requirements for crew, management and technical equipment of the vessel.

Ships with a Green Award receive a discount in a number of ports, including ports in the EU Member States The Netherlands, Belgium, Lithuania, Spain, and Portugal. There is no government incentive for ships to apply for a green award.

Green Award has no criteria for greenhouse gas emissions.

Source: http://www.greenaward.org/, accessed 5 September 2006.

Conclusion

A voluntary agreement is not expected to be effective, neither can there be high expectations of its efficiency. Voluntary agreements may serve a purpose as ancillary to other instruments, but not as a main instrument in climate policy for maritime transport. Furthermore, in shipping there seems to be no obvious partner for a voluntary commitment.

32.2 Option 2: Requirement for all EU-based ship operators and/or EU-flagged ships to use the IMO CO_2 index and report results annually to Member State Administrations and/or the European Commission

In this option, ship operators (or other entities) are required to determine the CO_2 index of their ship, and report the results annually to Member State Administrations and/or the European Commission. Unlike the other options discussed in this report, this option is not aimed directly at achieving greenhouse gas emission reductions, since there will be no explicit incentives to improve the index, and the index will not be regulated. This option would raise awareness in the sector and improve data availability and understanding of the CO_2 index. Furthermore, the CO_2 index may serve as a management information tool for ship operators who would be able to compare CO_2 indexes of their ships, possibly compare them with the industry average, and take action to improve the index of their ships. This would have to be done on a voluntary basis. Finally, when a CO_2 index would be recorded and reported regularly for all ships, this could be the basis for more effective policy measures, as was intended when the CO_2 index was developed[38].

In 2005, the IMO has agreed on Interim Guidelines on GHG Emission Indexing, for use on trials on a voluntary basis (MEPC 53, July 2005). This policy option could thus generate a significant impetus to the further development and implementation of this index, since:

- It would lead to widespread experience with the CO_2 indexing methodology, including reporting procedure and monitoring, for shipping companies as well as for the European Commission and/or Member State Administrations.
- It would provide an extensive database of information on the CO_2 index of a large range of vessels, which can then be analysed and used to either further improve the methodology or develop policy measures aligned with this index.
- It could speed up IMO discussions on this topic, as it would promote the use of an indexing method deemed promising by the IMO.

Design of the option

When designing this option, the following choices have to be made:

a Who will be required to report the index (i.e. the ship owner, the operator, EU-flagged ships only, all ships entering EU waters or ports, ...)?

b How often (i.e. when) should the index be reported?

c Who will be responsible for the collection of the reports, enforcement and compliance?

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38 IMO Assembly resolution A.963(23) on IMO Policies and Practices Related to Reduction of Greenhouse Gas Emissions from Ships was adopted by the twenty-third session of the Assembly in 2004. It urged the MEPC to identify and develop the mechanism or mechanisms needed to achieve the limitation or reduction of GHG emissions from international shipping. Specifically, it requested, among other things, the development of a CO_2 index and the 'evaluation of technical, operational and market based solutions', which could be based on a CO_2 index. It has not been the intention of resolution A.963(23) that the GHG policy should stop when a CO_2 index would have been in place.

Furthermore, it is advisable to implement the recommendations of Marintek regarding the CO_2 index guidelines and definition, that result from the experience gained in carrying out Task 2 of this project (Marintek, 2006).

Reporting entity, scope of the scheme
A requirement to calculate the CO_2 index and report annually could be implemented for all ships within the jurisdiction of certain states. EU-flagged ships would therefore be a logical and legally relatively unproblematic scope of this option. The drawback would be the discriminatory nature of the measure, but since this option only covers a reporting requirement, this would not lead to a competitive disadvantage of EU-flagged ships. Extending the option to all ships entering EU waters or all ships entering EU ports would probably raise legal issues, since this would require ship operators to calculate and report the CO_2 index also for operations outside EU jurisdictions. These legal issues will be discussed further below.

From a practical point of view, extending the scope to all ships entering EU waters or EU ports would mean that all these ships, even those that visit the EU rarely, will have to report their CO_2 index (and the data behind it) when they enter EU waters or ports. This implies that they have had to record their fuel consumption and transport work in the previous year, on a continuous basis. It might be reasonable to ask this of ships that regularly enter EU waters or ports (as it will also be asked of EU-flagged ships). However, it would be out of proportion for ships that rarely travel to or from the EU. It can also be argued that the CO_2 index of these (non-EU flagged) ships would then be based mostly on trips outside of the EU waters, resulting in an extension of the scope of the measure to an almost global scale.

Under the current IMO guidelines, the CO_2 index is determined using fuel consumption and transport data of one year. A geographical limitation of the scope will then prove to be difficult: all trips in the past year will have to be included in the calculation of the index, irrespective of where these trips were made. Note that monitoring and verification of the reported data would thus have to be done on a global scale.

Regarding types of vessel that can be included in this system, the CO_2 index interim guidelines (MEPC 52/4/2) included calculation methodologies for the following types of ships and cargos:
- Bulk:
  - Tankers and bulk carriers.
  - All liquid and solid bulk cargo.
- General cargo:
  - Container ships, reefers, general cargo, car carriers and specialized ships.
  - General cargo (incl. return of empty ships), including CTUs, break bulk, heavy lifts, frozen and chilled goods, timber and forest products, cargo carried on freight vehicles, cars and freight vehicles on RoRo ferries.

- Passenger:
  - Passenger ships, RoRo passenger ships.

No application of the index for other types of vessels has currently been foreseen (e.g., for fishing vessels, naval or research ships, dredgers, etc.).

To determine the CO_2 index of a ship, a range of data need to be reported for each trip, including details about departure and arrival ports and dates, distances sailed, fuel consumption and cargo or passengers on board. Ship operators or owners are the only party that currently monitor these data. As discussed in section 30.1, ship operators or owners also have, to some extent, control over emissions since they can take both operational and technical measures to reduce them. Reporting the index data might encourage these parties to analyse the index data of the ships they own or operate, and use the results as a management tool.

We therefore conclude that both the shipping companies and the ship owners could be feasible reporting entities.

During the recent trials with the index (task 2 of this project), Marintek received most of the CO_2 index data from EU based shipping companies. These typically had the data available, but in different formats. The ship owners that were approached also typically had the required data available, but were reluctant to provide them. The result was that index data of only 8 of the total of 364 ships was gathered directly from the ships, via the ship owners. The main reason for this low response from ship owners was reported to be high work pressure, not lack of data.

Reporting frequency
The IMO guidelines for the CO_2 index state that the CO_2 index should represent an average value of the energy efficiency of the ship operation over a period of one year. For newly built ships, the measurement period should not be less than six month.

We recommend that the EU should follow that guideline, and require annual reporting (for example, per calendar year). This would minimize the administrative burden and cost imposed on the reporting entity.

Effectiveness
As mentioned above, this option may not affect CO_2 emissions from international shipping. In the long term, though, it may facilitate implementation of other, more effective measures. It can therefore be argued that it would not be fair to judge this option on its operational effectiveness in the short and medium term. Instead, we suggest judging this option on its own merits, i.e. we shall discuss whether and how its implementation could form a basis for further actions/applications.

Obviously, the results of Task 2 provide important input for further analysis of this option. In that task, practical experience with the trials to date as well as actual data have been compiled and evaluated. In general, the experiences with data gathering were moderately positive, once ship owners were approached directly and agreed to cooperate. The data needed to calculate the index were available in management systems on shore, but typically not in a readily usable format. Clearly, the ship owners or operators would have to do some effort to provide the necessary data for CO_2 index reporting, but we expect that these efforts should be mainly adaptations to existing management and administration software. The Marintek report provides a number of recommendations for improvement of the index that can be expected to further improve the application of the index.

As stated earlier, the operational effectiveness of this measure depends on the willingness of shippers and ship owners to use these data as a management tool, since the policy itself does not provide an incentive to reduce GHG emissions.

Marintek reports that until now, none of the participants in the project has analysed and used the data in order to improve operations. However, one can expect that this will happen in the future, once the people and companies involved will become more aware of the index, since index improvements may provide direct business benefits. The EU may enhance awareness (and thus, perhaps, effectiveness), for example with clear communication of the purpose and possibilities of the reporting requirement, and by carrying out an analysis of the results.

Lack of data on fuel efficiency in shipping is currently a significant bottleneck in the development of policy measures aimed at CO_2 reduction in shipping. As mentioned in the previous chapter, this policy option can therefore be a precursor to more stringent policy measures. In the future, the CO_2 index might provide the possibility to implement market based policy instruments in shipping, or perhaps even to set fuel efficiency standards (see options 3 and 5).

Monitoring, enforcement and compliance

This policy options requires ship owners or shippers to provide data about fuel type and consumption and transport work per voyage. These data are typically readily available, and provide the basis for the calculation of the index.

The IMO guidelines state that the data sources could be the ship log book (bridge log book, engine log book, deck log book and other official records. Bunker delivery notes provide information about the fuel types used.

Scope for evasion

Since the measure only involves a reporting requirement, the effect on the reporting entity is limited to an administrative task. Since this has no further consequences, we do not expect evasion (e.g., by changing flag state) to be a problem, even if only EU flagged ships are required to report the CO_2 index.

Conclusion
This option is feasible and within the realm of EU policy. The effectiveness of this option per se is limited, but it could serve as a basis for more effective policies. It would generate representative data on the CO_2 index of the fleet, and could be used to increase knowledge and understanding of the CO_2 index, regarding how it depends on technical, operational and economic factors. This understanding seems to be a prerequisite to decide on using the index for regulation (option 3) or market based policy instruments based on this index, such as described in option 5.
Furthermore, ship owners or operators may use the data, once available, as a management tool to critically monitor and analyse their ships fuel consumption performance.

32.3 Option 3: Requirement for EU-based ship operators and/or EU-flagged ships and/or EU-based shippers to meet a unitary CO_2 index limit or target

The discussion on scope and reporting entity of option 2 also applies here, since reporting of the CO_2 index is ain integral part (and, as we will argue, a prerequisite) for this policy option. However, this option goes one (significant) step further, in requiring ship operators or owners to achieve a CO_2 index limit or target.

Design of the option
The main bottleneck of designing this option is the difficulty of setting a fair and efficient limit or target. So far, only a limited number of index data has been gathered and analysed (see the report by Marintek of Task 2). This analysis revealed that, on the one hand, the CO_2 index is indeed influenced by operational and technical parameters that can, to some extent, be influenced by the ship owner or operator. On the other hand, however, the index was also found to depend strongly on factors out of control of these parties, such as transport demand and market conditions. Furthermore, when comparing different ships, factors such as ship size and type, and type of cargo strongly determine the value of the ships CO_2 index. The CO_2 index thus varies strongly between different types of ships.

Marintek therefore concludes the following:
a There are fundamental problems with setting a baseline for the CO_2 index of ships. For example:
   - Smaller ships will always be at a disadvantage, compared with larger ships.
   - In times of lower market demand (either globally, or on specific routes or return voyages), the CO_2 index will increase since the cargo will be transported. Ship owners or shippers have only very limited possibilities to influence these developments.
b In order to further analyse the possibilities of a baseline, more data are needed, that properly represent the different ship types, sizes and trade variations.

Making reporting of the CO_2 index mandatory (policy option 2), as discussed above, could be an attractive option to provide the necessary data for further analysis of the index, and further development of a potential baseline.

Only after more insight is gained in the factors that influence the index, can it be decided whether setting a limit or target for the index is a feasible option. Based on the data results to date, it can be concluded that the limit or target should at least be dependent on ship size and on the type of cargo. However, the impact of different operational and technical variables on the CO_2 index must be better understood. This might be feasible once more data are available. In addition, however, market conditions (e.g., of a specific good or region) are also a determining factor in the CO_2 index. For example, the load factor may be all-important. Although vessel operators can influence this to some extent, given the low price elasticity of demand for maritime transport it cannot be expected that they can significantly impact the current imbalances in global maritime trade. Due to the high demand for goods from China, many vessels return empty to pick up a new load in China. Such empty trips in particular, and world trade in general, may to a large extent determine the value of the CO_2 index.

This might pose a more difficult and fundamental problem, since we do not expect it to be practically feasible to vary the limit with these developments at well. The result will be that in 'good' years, shippers will have no problem meeting the CO_2 index limit or target, whereas in 'bad' years, they may have no means to achieve them (unless they do not operate at all, or lower their transport price to uneconomic levels). They will thus be punished for developments out of their control. This might be a fundamental hurdle for this policy option, that can not yet be investigate further with the limited data set currently available. We therefore recommend further investigation of this effect.

The index should thus be thoroughly understood to be able to design an index and determine a limit or target level that is fair, i.e. indeed represents the efforts made to reduce CO_2 emissions, and ambitious, i.e. defined such that CO_2 emissions will indeed be significantly reduced when the target is met. The report of Task 2 of this project, and a preliminary investigation into CO_2 indexing of container ships by the German delegation to the IMO[39] illustrates that this will not be an easy task.

Another, smaller problem remains. The CO_2 index is calculated over a year. This means that a ship operator with a high CO_2 index would have to sail outside the EU for a year, taking operational and/or technical measures to reduce his index, before he can call at an EU port. This would limit competition on the market for maritime transport to the EU.

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[39] 'Statistical investigation of containership design with regard to emission indexing', submission of Germany to the 51st Marine Environment Protection Committee, MEPC 51/INF.2, 2003.

Scope
Only when a requirement to meet an unitary CO_2 index limit could be introduced on a non-discriminatory basis, i.e. applying to all ships regardless of their flag, the option would have a significant environmental effect. If this would not be possible, it could have repercussions for the environmental effectiveness, since a requirement to meet a CO_2 index limit for EU-flagged ships is likely to distort the competitive market and lead to flagging out of ships. Clearly, if the flagging out would occur on a large scale, the environmental effectiveness of this policy option would be limited.

Effectiveness
Both the feasibility as well as the operational effectiveness of this option will depend on the following issues, each of which will need to be carefully addressed in designing this option:

a The consequences of not meeting the limit or target.
b The level of the limit or target (in gram CO_2/tonne mile).
c The number of ship classes distinguished:
  - One limit or target could apply to all vessels, but we expect it would be far more feasible and effective to set different limits or targets for a relatively limited number of ship categories[40], for a more detailed subdivision of ships, or even per ship.

d Whether the requirement would apply to EU-flagged ships or to EU-based operators only, or to all ships to/from EU ports irrespective of their nationality in order to avoid discrimination and economic distortions (see above).
e How to deal with the cyclical nature of the maritime sector. At the top of the cycle, ships sail with full loads (which reduces the CO_2 index) at high speeds (which increases the CO_2 index). At the bottom of the business cycle, the load and speed decrease. It remains to be studied which effect this would have on the CO_2 index. One would expect it to have a cyclical nature as well. That means that a requirement to meet a unitary CO_2 index would have to be averaged over a number of years in order to be feasible.

Furthermore, this option could be made more flexible, for example by allowing (credit) trading among ship operators or by looking at the average CO_2 index of an operator's fleet. In both cases, ships with a relatively high CO_2 index could be compensated by ships with a lower index. This could increase the flexibility for ship operators and thus reduce the cost of meeting the targets, but would need further study.

As mentioned above, the main technical hurdle to this option in our opinion relates to points b, c and e above. There is currently insufficient knowledge on the CO_2 index of the different types of ships, and on the effects of economic developments. Such knowledge is required to determine a) the feasibility and desirability of setting a CO_2 index limit or target, b) to what extent different targets are required for different vessel types, and c), ultimately, to decide on a limit or target system.

[40] Such as the 19 main categories used in Lloyd's Register, distinguished by LMIU Code. It may be expected that ship size and ship age influence its performance.

Box: Comparison with index for cars
An alternative to a CO_2 index as developed under the IMO, would be a CO_2 index for new vessels. Such an arrangement ('ACEA agreement') exists in the passenger car markets. The CO_2 agreement with passenger car manufacturers is based on the car's fuel efficiency (or, to be precise, its CO_2 emission per kilometre) during a very well-defined test cycle. Every new passenger car introduced on the EU market is required to undergo this test. Three car manufacturer associations voluntary agreed with the EU on a target for the average emissions of all new passenger cars sold by the members of the three car manufacturer associations involved.
It is however not straightforward how to implement such a measure in the shipping sector. Many vessels are custom built and there is no agreed test cycle to measure its performance.
It should be noted that regulation of CO_2 emissions under controlled test cycle conditions has only a limited impact. The main reason is that it no account of operational issues is taken, such as actual driving habits or load factor.

Once a CO_2 index limit or target is set, this policy option might be an effective means to reduce CO_2 emissions. In order to meet the target, ship operators can reduce the index of a ship by various operational means, such as increasing load factor, improving transport efficiency, reducing speed, etc. This will have a direct impact on CO_2 emissions. Furthermore, when a new ship or engine is bought, it will give owners an incentive to pay attention to the fuel efficiency (in addition to fuel cost).

Typically, a limit or target will only affect those operators or ship owners that fail to meet the limit. Once the limit is met, there is no incentive to further improve the performance.

The measure will thus be effective if the limit or target (and the non-compliance penalty) is set at a level at which the ships with relative low fuel efficiency are encouraged to improve their performance. It is currently too early to estimate the potential effect[41].

Note that there is a risk that the effectiveness of this option will be reduced due to evasion (discussed below) of the policy by flagging out, in case it is limited to ships with EU-flags or operators.

Monitoring, enforcement and compliance
Monitoring and checking of compliance will be in line with the previous option. Since in this option, a penalty is imposed on ships that do not comply with the limit or target, there will be a stronger need for enforcement and compliance.

Scope for evasion
In case the scope of this option is limited to ships or operators with EU-flags, ships or operators might evade this policy by flagging out. Obviously, only ships or operators that do not meet the target will consider this.

Evasion will thus mainly depend on how stringent the limit or target is. More specifically, it depends on how many ships will have to take dedicated action to meet the limit, and what the costs of the measures are that have to be taken. The

[41] NB. The total CO_2 emissions of EU-flagged operators are currently 184.2 Mton.

potential to reduce evasion with (cost effective) flanking instruments appears to be small, since it will be difficult to limit flanking instruments to only those vessels that are prone to evasion.

Legal analysis

In view of the wide discretion that port States have under general international law, it would in principle be possible to require all ships, irrespective of flag, to comply with a certain CO_2 emission target as a condition for entry into port. It must be noted, however, that there are currently no generally accepted CO_2 emission targets. Or, in other words, the international community of States has so far not been able to agree on the regulation of CO_2 emissions in international shipping. Most importantly, such targets were not laid down in the 1997 Protocol to MARPOL 73/78[42]. All there is at the moment are the Interim Guidelines for Voluntary CO_2 Emission Indexing for Use in Trials adopted by IMO's Marine Environment Protection Committee in July 2005. The choice for 'voluntary' indicates that these guidelines are not meant to be applied to foreign ships.

However, the absence of generally accepted CO_2 emission targets does not mean that port States do not have any discretion left, but only that this discretion is more limited. At various instances, the EU has already imposed unilateral standards as conditions for entry into port[43]. The problem nevertheless remains with the consequences of non-compliance with these conditions. As there is no right of access to ports under general international law, the port State can decide to allow certain foreign ships access but not others – at least under general international law. However, once a ship has entered into port but appears to be in non-compliance with the (unilateral) CO_2 emission target, the port State may not be able to do more than expel the ship. It is nevertheless possible that this is a sufficiently onerous enforcement tool. In case the port State wants to impose other onerous enforcement powers, for instance a monetary penalty, it needs a treaty provision that explicitly authorizes this[44]. An alternative would be to rely on the so-called territorial principle, but this would only be possible if non-compliance (also) occurs within port. Non-compliance with a double hull requirement would for example occur throughout a ship's voyage, but also in port. That latter aspect is arguably sufficient if the port State wants to impose such more onerous penalties. The way in which the EU's CO_2 emission target would be formulated has therefore consequences for the types of enforcement powers a port State can choose from.

[42] Conference Resolution No. 8.

[43] E.g. Art. 1 of Regulation (EC) No 417/2002 of 18 February 2002 'on the accelerated phasing-in of double hull or equivalent design requirements for single hull oil tankers, as amended by Regulation (EC) No 1726/2003 of 22 July 2003' (consolidated version, available at <europe.eu.int/eur-lex>).

[44] An example of such a treaty provision is Art. 218 of the United Nations Convention on the Law of the Sea (LOS Convention), which gives port States the right to impose monetary penalties on foreign ships for illegal discharges beyond its own maritime zones. The *a contrario* argument is that such a power would not exist without such a treaty provision.

Conclusion
It is too early to determine the feasibility of this policy measure. Task 2 has provided some insight into the potential of the index, but it is too early to properly assess the feasibility of using the CO_2 index to benchmark ships. The limit or target should at least be differentiated to ship size and load type, but further data gathering and analyses is required before a definite conclusion can be drawn. Furthermore, it is not yet clear how global market developments affect the index. If the impact of these developments is significant, it may be easy to achieve a limit in a 'good' year, whereas it may be very hard (i.e. expensive) or even impossible to achieve it in a 'bad' year. And finally, questions remain with regard to the legality of the option itself and the necessary enforcement actions.

The effectiveness of this policy option is strongly dependent on the limit or target, and the details of the system. Furthermore, the effectiveness may be reduced if evasion occurs, in case the system is limited to EU-flagged ships or EU-based operators. Such a limitation may also lead to economic distortions.

However, provided that the policy measure could be introduced on a non-discriminatory basis and that a sensible target can be set, this option could be an effective means to reduce CO_2 emissions, since it promotes both technical and can.

32.4 Option 4: Future inclusion of refrigerant gases from shipping in the EU regulation and/or an indexing system parallel to the CO_2 index

Refrigerant gases have a considerable global warming potential (up to several thousands of times the global warming potential of CO_2), although their total contribution to global warming seems to be decreasing rapidly as a consequence of the Montreal Protocol (IPCC, 2005[45]).

Emissions of these gases from shipping are significant, though there is quite some uncertainty regarding their magnitude. The IPCC guidelines suggest using an annual emission factor for leakages of 17% of on-board refrigerant gases[46]. However, the results of inspections by the Dutch government between 1996 and 2001 have shown much higher refrigerant leaks and thus emissions: on average, 50% annual refrigerant leakage for trawlers and merchant ships, and 80% for cutters[47]. The UNEP estimates that emissions from refrigerated containers and reefers amount to approximately 10%/y[48]. For comparison, the average annual emission rate of refrigerant gases from land-based installations is taken to be 4.5% in the Netherlands. Shipping may thus contribute significantly to total emissions of these gases.

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45 IPCC, 2005: Special Report on Safeguarding the Ozone Layer and the Global Climate System: Issues Related to Hydrofluorocarbons and Perfluorocarbons.

46 Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories.

47 'Enforcement of chlorofluorocarbons regulations on maritime vessels', A. Klingenberg, VROM Inspectorate, Seventh International Conference on Environmental Compliance and Enforcement, 2005.

48 2002 Report of the refrigeration, air conditioning and heat pumps technical options committee, UNEP, 2003.

The relatively high leakage rates of refrigeration equipment in marine vessels are partly attributed to the harsh environmental conditions at sea, such as the corrosive salt-laden and wet atmosphere, vibrations and torque. Furthermore, poor maintenance, the failure to detect leaks, the age and complexity of equipment, the technology used and lack of enforcement also contribute to these high leak rates (Klinkenberg, 2005).

Climate impact of refrigerants in maritime shipping
A recent inventory of global refrigerant gas emissions (IPCC, 2005) estimates that about 8.3 ktonne of refrigerants were used in maritime transport and fishing vessels (0.78% of the total global use), with an annual leakage rate estimated to be about 2.8 ktonne (1.1% of the total emissions). Expressed in Mtonne CO_2 eq, global refrigerant emissions of the maritime transport sector are about 9.5-10.6 Mtonne CO_2 eq (CE Delft, 2006a).

European data are not available. However, some member states have estimated refrigerant emissions of ships registered in their state. When analysing the data from ships under Dutch flag, annual emissions are about 350 tonnes. Based on German data, ships with German flag emit approximately 37 ktonne CO_2 eq per year. These emissions are very small compared to CO_2 emissions of maritime transport and land based GHG emissions.

Therefore, we conclude that even though the relative refrigerant emissions are high in the maritime sector, these emissions are only minor in terms of CO_2 eq.

Feasibility of policy options
An inclusion of refrigerant gases in the CO_2 index would in principle be possible. The leakage of refrigerant gases would have to be recorded, multiplied with the global warming potential and added to the CO_2 emissions. It makes some sense to include refrigerant gases in the CO_2 index, since like fuel consumption, emissions of refrigerant gases are likely to increase with the amount of cargo on board and the distance sailed. For fishing vessels, the inclusion may require a workable definition of the amount of cargo, since this obviously varies during as trip of a fishing vessel.

Irrespective of the exact reporting requirements, we expect potential problems with quality control of the data (and evasion), because the ships involved in international trade will be able to buy their refrigerant gases in countries where monitoring and reporting of these sales are less stringent than in the EU.

The other option would be to include shipping refrigerant emissions in the EU regulations on refrigerant gases. This option would be in line with refrigerant policies in other sectors.

In 2000, the EU has issued Regulation No 2037/2000, which regulates the phase out of production and use of substances that deplete the ozone layer. It is not completely clear, though, whether this regulation also applies to maritime shipping, since the geographical scope of the EC Treaty is in principle limited to the territories of EC Member States (pursuant to Article 299 of the EC Treaty).

Accordingly, the general rule is that secondary EC law is limited to the territories of the Member States, except where provided otherwise. Apart from an arrangement on the use of halons in fire-fighting systems, Regulation No 2037/2000 does not contain explicit provisions on its geographical scope or its applicability to sea-going ships in its entirety. Also, the object and purpose of the Regulation do not give reason to assume that its scope logically extends beyond the territories and to sea-going ships. It therefore follows that the general rule applies according to which the scope is limited to the territories of the Member States and not to sea-going ships. There are some arguments that contradict this view but also important arguments that support it. On balance, the argument that Regulation 2037/2000 is not applicable to sea-going ships seems the better one[49].

In 2005, the EU has agreed on a directive for stationary applications and vehicle air conditioning. The use of refrigerants in maritime shipping is not regulated in these proposals. However, the proposal does include the statement that the Commission shall publish a report by 2007 on, among other topics, refrigeration systems contained in transport modes other than motor vehicles. Research by the Dutch Environmental Inspection (Klinkenberg, 2005) suggests that operational measures and improved maintenance of equipment might reduce emissions considerably. For example formal maintenance systems can be introduced, crew members can be trained and made aware of the problem, leak detection systems may be improved. Furthermore, newly constructed ships could be required to install indirect rather than direct refrigeration systems, to replace synthetic refrigerants with natural alternatives, and to apply the principles of Life Cycle Engineering within the design of refrigeration installations.

Conclusion
The climate impact of leakage of refrigerant gases is probably small. However, there are probably many cost-effective options for reducing this leakage. We suggest that a reduction of leakage should be pursued, but not as a main or major element of GHG policy for maritime transport.

32.5 Option 5: Inclusion of a mandatory CO_2 element in an EU-wide regime for port infrastructure charging

This section analyses the pros and cons of differentiated harbour dues as a policy instrument to reduce greenhouse gas emissions of maritime transport. First, the section describes harbour dues and the mechanism by which differentiation could in theory reduce greenhouse gas emissions. Second, some key design elements are discussed. Third, the main advantages and disadvantages of differentiated harbour dues are identified.

Harbour dues
Ship operators pay harbour dues to port authorities for the use of the harbour (although under some charter contracts they may pass on the costs to the charterer). Harbour dues are one of the few charges paid by ship operators to

[49] Personal communication with Mr. E.J. Molenaar, University Utrecht Faculty of Law.

authorities and possibly the only charge that is paid by all ships visiting certain ports, regardless of their flag. Harbours have a large autonomy in establishing their dues. As a result, dues differ both in level and in basis. Most harbours levy harbour dues on the basis of gross tonnage of a ship. In addition, some harbours levy dues on the basis of the amount of cargo loaded or discharged. Other harbours charge vessels on the basis of their volume. Table 40 shows the basis for the calculation of harbour dues in five of the largest European ports. The table also shows the harbour dues for a crude oil tanker of 40,000 gross tonnes. It is clear that even among these ports harbour dues differ by more than 250%.

Table 40 Harbour dues in selected EU ports

Port	Charge basis	Dues for an Aframax oil tanker (80,000 GT (47,000 m^3)) discharging 80,000 tonnes of crude (2006)
Rotterdam	Gross tonnage and cargo loaded and discharged	€ 93,280
Hamburg	Gross tonnage	€ 33,600
London	Vessel volume and cargo loaded and discharged	£ 28,936 (Approximately € 41,995)
Le Havre	Vessel volume and cargo loaded and discharged	€ 80,129
Marseille	Gross tonnage and cargo loaded and discharged	€ 68,779

Source: Port authorities.

In principle, harbour dues could be differentiated in order to provide incentives to reduce CO_2 emissions. The incentive could either be targeted at increasing the fuel efficiency of a vessel through improved performance or though implementing technical measures. In all cases, the differentiation of harbour dues would increase the return on the investment in fuel-efficiency measures.

The main advantage of using differentiated harbour dues as a policy instrument would be that the institutional arrangements for the payment of harbour dues and enforcement are already in place.
Differentiated harbour dues have proven to be an effective policy measure in Sweden to reduce NO_x emissions of ships (NERA, 2005). An immediate extension to CO_2 emissions is not straightforward, however. Whereas NO_x emissions may be reduced by end of pipe technologies that can be easily monitored, this is not possible for the technical and operational measures to reduce CO_2 emissions.

A disadvantage of a differentiation of harbour dues is that it could distort the competitive market of ports. There are indications that the price elasticity of demand varies greatly between ports (see Table 41). Differentiated tariffs could have a larger impact on some ports than on others.

Table 41 Estimated price elasticity of demand for container traffic with respect to harbour dues

Port	Price elasticity of demand
Hamburg	3.1
Bremen Ports	4.4
Rotterdam	1.5
Antwerp	4.1
Le Havre	1.1

Note: Price elasticities for other cargoes may be lower than for container traffic. Source: Atenco, 2001.

Setting the level of harbour dues is currently the prerogative of port authorities. When dues would be differentiated, this section assumes that the differentiation is mandatory for all EU ports, and that EU legislation prescribes both the level of differentiation and the basis of the differentiation. This would reduce the autonomy of port authorities in setting their dues.

Design of differentiated harbour dues

Differentiated harbour dues have two main design elements: the basis for the differentiation and the level of differentiation. Both will be discussed subsequently.

The **basis** for the differentiation could be a technical standard, a performance indicator or a management system. Most of the current differentiation schemes are based either on performance indicators (Swedish harbour and fairway dues) or on management systems (Green Award) (NERA, 2005). A performance indicator would show that a ship is sailing efficiently, emitting less CO_2 than average. The main advantage of a performance indicator would be that it would allow ship operators to meet the standard by both operational and technical measures. Ship operators could, for example choose to bring down their emissions by sailing slower or by installing better propulsion systems, and make the trade-off that suits their company best.

One performance standard that comes to mind is the IMO CO_2 index (IMO, 2005). It shows a yearly average of CO_2 emissions per amount of transport work performed. However, the analysis of Marintek (2006) shows that the index is mainly dependent on ship type and ship size. Differentiation according to the CO_2 index per se would imply that large ships would pay lower dues than smaller ships, which does not necessarily lead to a reduction of climate impacts. It would therefore be necessary to differentiate harbour dues on the basis of the CO_2 index per ship type and size class. For example, a 80,000 GT oil tanker would have to meet a much lower index in order to qualify for reduced harbour dues than a 10,000 GT chemical tanker (see also section 32.3). Furthermore, the index is heavily dependent on the business cycle. In good years, ships sail full and the index is low. In bad years, ships will find it difficult to fill their hold and will show a high index. The choice of an index baseline would therefore need to be taken with good care.

Alternatives to the IMO CO_2 index are also conceivable. A CO_2 index for the last trip, for example, would have the advantage that it would give a very direct incentive to increase the load factor or sail efficiently on the trip to an EU harbour. Furthermore, it would directly penalise a ship operator or charterer or shipper who decides to sail with a ship that is not fully loaded or who sails at maximum speed. A disadvantage would be, however, that the index may be unpredictable due to external circumstances such as weather.

Another possible performance standard could be an environmental management standard, such as ISO 14000 or the Green Award Certificate. However, these standards are not (or not primarily) aimed at increasing fuel efficiency. At most, they aim to provide management tools to increase their fuel efficiency. Therefore, such standards would not necessarily result in lower emissions.

The **level** of the differentiation could either be relative or absolute. A relative differentiation would have the effect that in some ports the financial incentive would be much smaller than in other ports. This could incentivise ship operators to send the most efficient ships to the harbours with the highest rebate, and thus maximise profits by a simple rerouting of vessels without taking measures that would reduce greenhouse gas emissions. Table 40 shows that a charge that is differentiated by a percentage of the harbour dues will provide a different incentive in different ports. The incentive will be much smaller in London and Hamburg than in Rotterdam and Le Havre.

An absolute differentiation (e.g. a reduction of € 1,000 for the cleanest ships within a certain type/size class) would have the advantage that the financial incentive for ship-owners and operators to improve their efficiency would not differ from port to port. Since many ships do not sail regular routes, their operators do not know in advance how many times they will visit a certain port in the near future. They may, however, make a more reliable calculation with regard to how often their vessels will visit EU ports. This would allow them to make a more accurate business case for an investment in fuel efficient technology.

Apart from the question whether the differentiation would need to be absolute or relative, there is the question how large the financial incentive would have to be to provide an effective incentive to ship owners and operators. Ideally, the financial incentive would be just enough to give ship operators an acceptable return on their investment in those fuel efficient technologies, management and operational practices that are cost efficient from a wider economic perspective. If certain technologies would have large upfront investments and low operating costs, it would make sense to supplement the differentiation of dues with a subsidy. This is exactly what was done in Sweden with respect to the installation of scrubbers to reduce NO_x and SO_2 emissions (NERA, 2005).

For CO_2 emissions, one of the obstacles that would have to be overcome would be that currently hardly any reliable cost estimates exist of measures that reduce emissions. Moreover, some measures may effectively reduce emissions on some ships, while they would not have an impact on ships with different designs.

In general, many technical measures (such as improved propulsion systems or propeller design) would require up-front investments but have negative operational costs: ships would use less fuel. In these cases, investment subsidies would probably be more efficient than differentiated harbour dues. Operational measures, such as slow steaming of crew training, would have low investments but positive operating costs. These measures could in principle be used to calculate the level of the differentiation.

To indicate the incentive needed to induce slow steaming, which is just one measure that could be taken to reduce CO_2 emissions, an exemplary calculation is presented below[50]. Slow steaming would reduce fuel consumption and CO_2 emissions. However, it comes at a considerable cost, since ships have to sail longer and have high operating costs per day. For example, daily charter rates for very large crude carriers in 2005 were up to US$ 90,000 and for the smaller (but still large) Aframax carriers up to US$ 31,000 (RMT, 2005). An Aframax carrier can consume 60 tonnes of oil per day (Maritime reporter, 2005). At US$300 per tonne, the fuel consumption per day amounts to US$ 18,000. For a charterer, it would only be financially attractive to sail slower if the reduction in harbour dues plus the reduction in fuel costs matched the extra expenses on chartering. The business case depends on a large range of variables, and can therefore not be estimated for a representative selection of vessels. Table 42 shows one example, for an Aframax oil tanker carrying oil from Curacao to Hamburg.

Table 42 Business case for slow steaming (5% speed reduction; 9% increase in fuel efficiency)

	Costs ($)		Benefits ($)
Charter	36,000	Fuel	38,800
Cargo financing	8,400	Harbour due discount (13%)	5,600
Insurance	p.m.		
TOTAL	44,400		44,400

Note: Figures based on Aframax, sailing from Curacao to Hamburg in 24 days (25.2 at reduced speed); charter rate US$ 30,000 per day; fuel consumption at regular speed 60 tonnes per day at US$ 300 per tonne; value of cargo 80,000 tonnes * US$ 400 = US$ 32 million; interest rate 8%.

In this case, the discount in harbour dues would have to be at least US$ 5,600 (€ 4,480 ar a rate of 0.8 €/$), or 13% of the harbour dues, in order to pose no net cost to the ship charterer. Please note that this is just an example intended to give an impression of the order of magnitude of the differentiation of harbour dues needed to provide an incentive to slow steaming. Many parameters are highly volatile. Freight rates can increase by 400% within a year[51]. Fuel prices are highly volatile, interest rates are variable, as are insurance fees. Under different assumptions, slow steaming may be cost-effective and under yet other

50 In Sweden, ferries and RoRo vessels were the first to respond to differentiated harbour dues by taking measures to reduce NO_x and SO_2 emissions. It is less likely that these vessels would be the first to introduce slow steaming, since their customers demand fast connections. Therefore, this example is based on an oil tanker, rather tan a ferry or RoRo vessel.

51 See, for example, BRS (www.brs-paris.com; 25-Jul-06).

assumptions, the same tanker would require a much larger discount in harbour dues to make up for opportunity costs of fast steaming.

In sum, the level of the differentiation would probably have to be in the order of several thousands of euros per vessel, at least for large vessels. It is likely that if the incentive could not be related to actual fuel use precisely, but to some other indicator such as the IMO CO_2 index. In that case, the required incentive would be even larger because the signal would be passed on distorted. Moreover, the actual incentive differentiated harbour dues would provide to ship owners and operators would vary with ship type, ship size, and voyage.

Conclusion
Differentiated harbour dues could in principle be introduced to reduce greenhouse gas emissions of maritime transport. The main advantages of this policy instrument are:
- The institutions for charging port dues are in place.
- The instrument is efficient, since it incentivises ship owners and operators to take measures to reduce emissions.

However, there are some disadvantages:
- The introduction of an EU-wide scheme of differentiated harbour dues would require limiting the autonomy that port authorities currently have in setting their charges. This could have implications for the economic viability of ports.
- A differentiation of harbour dues would most likely change the competitive market for ports.

When implementing a differentiation of harbour dues, the following challenges would have to be met:
- First, care should be taken to connect the differentiation in harbour dues closely to the environmental impact one wants to control. It is not yet clear how this could be done. The IMO CO_2 index would only be feasible if a large number of classes would be defined, and even then, the result could very well be a that fuel-efficient ships would visit EU harbours whereas less fuel efficient ships would be operated in other parts of the world. This would have no environmental benefit.
- Second, in designing the instrument of differentiated harbour dues, further attention should be paid to determining the optimal level of differentiation, taking the variety of harbours, ships and shipping business models into account.

32.6 Option 6: Inclusion of CO_2 emission from shipping in the EU ETS

Under this option, the possibilities for including CO_2 emissions from maritime transport in the EU ETS will be discussed. Several design variables are of crucial importance for this option. We will discuss:

- Scope of scheme.
- Trading entity.
- Climate unit.
- Allocation and distribution of allowances.
- Scope for evasion.

The issue of monitoring has already been discussed under building block 3 in Chapter 5.

Scope of the scheme

As discussed under building block 1, the scheme could in principle apply to many different combinations of operators, type of vessels and geographical scope.

In consultation with the client, we have decided to take a non-discriminatory approach with regard to the operators that are to be included. This means that whether emissions from a vessel are subject to the scheme does not depend on the country in which the operator is based, the country in which the shipper is based, or the flag under which the vessels is operated. At this stage of the project, such a non-discriminatory approach appears feasible from a legal perspective. The main advantage of this approach is that no competitive distortions will occur between operators when competing for the same shipment. Moreover, the emissions covered under the scheme will thus be maximized. In the next stage of the project, a more thorough legal assessment should make clear whether this approach is in fact feasible.

With regard to the type of vessels, we will assume that the scheme will hold for all vessels above a certain threshold, which would have to be further defined in a more elaborate design study. The threshold is intended to reduce the administrative burden for ships that emit a small amount of CO_2. An objective threshold based on the gross tonnage or deadweight tonnage may be best.

The geographical scope of the scheme can be determined in two manners. First, it can relate to where (in a strict geographical sense) emissions take place. The 200 miles zone or the EMEP region could demarcate such a scope. Alternatively, the ‘geographical’ scope of the scheme could relate to the route of the vessel. Route groups that could be distinguished are for example routes between two EU ports, routes leaving from EU ports and routes arriving at EU ports.

Both types of schemes (route-based and one based on where emissions take place) have pros and cons. In general, a route-based scheme may give rise to evasive behaviour where vessels may prefer to go to non-EU 25 ports instead. A vessel could for example call at Kalingrad (Russia) instead of a Polish or Lithuanian port nearby. Freight could then further be transported by road or rail to its final destination. Other non-EU 25 countries where this might occur are

Norway, Turkey, Croatia, Bulgaria, Romania, Serbia and Montenegro and Albania. Only the latter two could pose significant problems, since the former are either EEA Member States, which have to implement EU ETS directives, or candidate or accession countries, which in time will need to implement the Acquis Communautaire.

Potentially, a second type of evasive behaviour may take place in a route-based scheme. This depends on how routes are defined precisely. If only the last and next port are of importance for the definition of a route, ships from e.g. the East coast of South America may decide to call at a North African port before calling at an EU port. In a scheme in which all routes to EU ports are included, a large part of the trip will no longer fall under the scheme by the extra call in North Africa. How best to define a route will be discussed below.

Alternatively, a scheme based on geographical area may also give rise to evasive behaviour. Depending on the costs associated with emissions, ships may decide to make a detour around the area included. This may give rise to additional emissions. The impact will depend on the precise definition of the geographical area.

There is one more argument to may have to be taken into account in the choice between a geographically defined area and a route-based scheme. This argument relates to monitoring. If the scope depends on where exactly emissions take place, monitoring of fuel use needs to be related to the location of a vessel. Instead, if the scope is route-based, data is only required on the total amount of fuel during the trip. This may be less complicated.

We now go over the options for both a geographically defined scheme and a route-based scheme. A geographically based scheme could be based on:
- In ports only.
- 12 miles zone (territorial waters).
- 200 miles zone (exclusive economic zone).
- EMEP area.

Under the first two options, only a very limited amount of emissions would be included. Also, all these options might cause legal problems since they might violate the right of innocent passage. After all, these scopes would require ships sailing in e.g. the exclusive economic zone to surrender allowances, regardless of whether they are bound for an EU port or not. Without further study we discard these options.

A route-based scheme could be based on:
- All voyages between EU ports.
- All voyages from EU ports.
- All voyages arriving at EU ports.
- All voyages to and from EU ports.

Geographical scopes including emissions on voyages from EU port may not be feasible, since ships may change their destination while at sea. The same ship may not visit an EU port again while owned or operated by the same person or company. But can the new owner or operator be held responsible for possible excess emissions due to a change in destination? Probably not. Therefore, we propose to study only options

From the quantification of CO_2 emissions in section 29.3, it is possible to estimate CO_2 emissions under different scopes within the EMEP region. It is not possible to estimate global emissions under different scopes from the Entec database.

Table 43 CO_2 emissions in EMEP region under different geographical scopes

Scope	CO_2 emissions (Mt, share of global maritime emissions)
Voyages between EU ports	90.3 (11.9%)
Voyages ending at EU ports	115.0 (15.2%)

Bron: Entec, 2002.

A route-base scheme would probably be less problematic from a legal point of view; it would at least not violate the right of innocent passage.

It may, however, be difficult to define a voyage under a route based scheme including all voyages ending at EU ports. For example, assume a vessel departing from a non-EU port and calling at another non-EU before arriving at an EU port. Clearly, the emissions of the second stage of the trip would be included. But how should the emissions during the first stage of the trip be treated? That is, should only the emissions from the trip from the last non-EU port to the EU port be included? This would limit the scope of the scheme and therefore its environmental effectiveness. However, the inclusion of all emissions from the first port of departure may be possible in this example, but not in case of a liner service sailing in circles and visiting a number of ports.

Trading entity

A second design element relates to who would be the most appropriate entity to assign responsibility for surrendering allowances to. Important considerations with respect for a choice for an entity are:

- Who has the most control over abatement measures?
- Who is best equipped to report emission data?
- Is enforcement of compliance possible?

As discussed under building block 2, the access to operational emission abatement measures is very important if the policy is to be effective within, say, 10 years. The reason is the long lifetime of vessels and engines.

Based on the analysis in section 30.1, we conclude that the operator of the ship is the most logical choice for the trading entity. First, because it would guarantee emission reduction is achieved effectively. Because the operator has direct control over most of the operational abatement options, he can decide with measures would most cost-effectively reduce emissions. If any other entity would be elected, it cannot be ensured that incentives for emission reductions would be passed on efficiently.

Moreover, the operator is most suited to monitor and report emissions from the vessel. After all, the ship operator keeps records of his fuel consumption for his own administration and in many cases to bill his clients. If any other entity would be selected, more parties would be involved in monitoring and reporting emissions, increasing the administrative costs.

The data reported by the ship operators could be verified by making use of average emission factors and combining these with information on the trips made by a particular vessel. This data is collected by Lloyds. Enforcement by Member States could be based on the same procedure as enforcement of payments of harbour dues by harbour authorities. In both cases, the ultimate penalty could be detention of a ship.

Climate unit

The third design element to be discussed is the climate unit that may be used. In the current EU ETS allowances for the emissions of CO_2 are traded. However, the Directive leaves room for the inclusion of other gases. Annex II specifically refers to:

- Methane.
- Nitrous oxide.
- Hydrofluorocarbons.
- Perfluorocarbons.
- Sulphur hexafluoride.

Apart from greenhouse gases, ships also emit local pollutants. There is ample scientific literature on the potential impact of emission of local pollutants by vessels on climate change[52]. Emissions of nitrogen oxides (NO_x) enhance ozone formation, which has a positive climate forcing. However, they also reduce the lifetime of methane in the atmosphere, leading to negative climate forcing. Emissions of sulphur oxides leads to aerosol sulfates, which both directly (back shattering of sunlight) and indirectly (through enhanced cloud formation) has a cooling effect. The chemical processes underlying these climatic impacts are fairly complicated and not yet fully understood.

[52] See for example Capaldo (1999), Corbett & Fishbeck (1997) and Endresen (2003).

Allocation and distribution of allowances

In order to be able to participate in ETS, the sector would have to be allocated emission allowances and these would have to be distributed amongst ship owners or operators[53]. Currently, allocation in ETS is often based on a historical baseline or a business as usual baseline, possibly combined with a target. Distribution is based on grandfathering (a historical baseline), benchmarking, or auctioning. This section discusses the feasibility of these methods for shipping.

Allocation in shipping can be based on a historical or business as usual baseline, at least if the geographical scope would be intra-EU routes. Data on the amount of emissions in a historical year can be calculated from the Entec database or an update, although it would be advisable to calibrate the database by requiring a representative number of vessels to report emissions in a specific year. After all, the Entec database uses activity data, and this method for calculating emissions generally provides a much higher figure than calculations based on fuel sales (see Table 44). A business as usual scenario for shipping can be based on an analysis of historical data on imports and exports and passenger transport by ferries.

The distribution of allowances cannot be based on grandfathering, at least not for operators engaged in tramp shipping. The reason is that ships from tramp operators may not visit EU ports regularly. If they would happen to make only a few calls at EU ports in the year used for grandfathering, and many calls in a later year, they would need to buy many allowances. On the other hand, a competitor who happened to make many calls at EU ports in the baseline year but only very few thereafter, would receive a large windfall profit. Thus grandfathering allowances would distort the competitive market in the sense that it would penalise growth of transport to the EU by ship operators and reward a decrease of transport, and much more so than ETS does in the current trading sectors, because of the volatility of transport of some firms.

For operators engaged in liner shipping, the situation may be different, since their share of business in the EU may be more predictable. However, in order not to distort the competitive market, it would not be advisable to design a different allocation and distribution method for liner shipping.

Distribution of allowances on the basis of a benchmark (CO_2 emissions per tonne mile, say) would share some of the disadvantages of grandfathering. Furthermore, as Marintek (2006) has shown, it may be hard to design a benchmark that does not discriminate against certain ship classes or sizes.

Auctioning allowances would not suffer from the same drawbacks. It would, however, place a considerable extra burden on shipping companies. This could

[53] In ETS, both the calculation of the total amount of allowances for a Member State and sectors in that Member State, and the distribution of these allowances amongst trading entities ('installations') are called 'allocation'. Since these are two different processes, we adhere to the term 'allocation' for the calculation of the total amount for the maritime sector and the term 'distribution' for the distribution of these allowances amongst trading entities. These definitions were coined by the Aviation Working Group under ECCP2.

even distort the competitive market for transport if other modes would not face similar burdens.

Scope for evasion
The scope for evasion depends on the geographical scope of the scheme. If only emissions of voyages between EU ports would be included in the scheme, evasion could take place by making an extra call at a port outside the EU. This could be profitable in the Mediterranean, where an extra stop in an Albanian, North African or Middle Eastern port can be made with little extra delay on some voyages. Also in the Baltic Sea, an extra call at a Russian port would be conceivable.

If all emissions on voyages to EU ports would be included in the scheme, other possibilities for evasion would be opened. There could be an incentive to make an extra stop at a port just outside the EU. For example, a ship departing from Asia, may be inclined to call at a North African port so to substantially reduce the amount of emissions for which it can be made responsible.

Evasion would reduce the environmental effectiveness of the policy measure. Measures to reduce the scope for evasion should be studied further.

Legal aspects
In view of the wide discretion that port States have under general international law, it would in principle be possible to require all ships, irrespective of flag, to surrender certain amounts of CO_2 emission allowances as a condition for entry into port. The observations made in relation to requiring foreign ships to meet a unilateral CO_2 emission target as a condition for entry into port - for instance as regards the available enforcement powers - are applicable in this scenario as well (see section 32.3).

Even more so than this other proposal, however, it must be emphasized that the abovementioned general rule relates to the situation under general international law. That situation may be fundamentally changed by the impact of international trade law. As the envisaged system for the allocation and trading of CO_2 emission allowances would not be a global system, but one that would be designed and operated unilaterally by the EU, it may not be consistent with international trade law. Further thorough study on the implications of international trade law and the relationship with the international law of the sea is therefore desirable.

Conclusion
Based on the brief analysis above, an inclusion of shipping in ETS seems possible under a design that would have a route based scope, either for intra EU routes or all arriving vessels. The trading entity would have to be the ship operator and the climate unit could be CO_2 only.

An inclusion of shipping in ETS could be effective if evasion can be limited. It would clearly be in the realm of EU policy to include EU flagged ships on intra EU routes. Whether or not more extensive scopes are indeed possible would need further legal analysis.

32.7 Option 7: Allocation of ship emissions to Member States

Under this option the feasibility of allocating emissions from ships to Member States is studied. Currently, emissions from bunker fuels sold to international aviation and maritime transport are not included in the national totals. Therefore, these emissions are not part of the emission targets set by the Kyoto Protocol for Annex I countries. When emissions of shipping would be allocated to countries, these emissions would become part of the national effort to limit emissions. The target, of course, may need to be recalculated, as some countries would face much higher additions to their national totals than others (in fact, under most allocation options, landlocked countries would not face higher totals at all). Making states responsible for these emissions, could provide them with an additional incentive to introduce policies and measures aimed at reducing emissions from maritime transport.

It has to be noted that allocation is not a policy option in itself (CE Delft, 2006b). When maritime emissions are included in national totals, Annex I countries will in most cases need to introduce policies and measures in order to reduce these emissions. These policies could be some of the policies designed above, or other policies, such as emission charges.

This section first describes briefly the historical discussions on allocation of emissions of shipping to Member States. The allocation options currently discussed internationally will be presented. For each of these options, we will discuss feasibility in light of data availability and reliability. Subsequently we further discussion the issue of allocation in relation to international coordination of policy measures and make recommendations on how to proceed with this option.

Short history of allocation discussion

At the Conference of the Parties (COP) 1 in 1995 the UNFCCC Subsidiary Body for Scientific and Technological Advice (SBSTA) was requested to address the issue of allocation and control of emissions from international bunker fuels[54]. The UNFCCC secretariat presented a paper at SBSTA 4 (1996), including eight allocation options for consideration. These were:

1 No allocation.
2 Allocation of global bunker sales and associated emissions to parties in proportion to their national emissions.
3 Allocation according to the country where the bunker fuel is sold.
4 Allocation according to the nationality of the transporting company, or to the country where an aircraft of ship is registered, or to the country of the operator.

[54] For a more elaborate background on the process within the UNFCCC, consult its website at: http://unfccc.int/adaptation/methodologies_for/vulnerability_and_adaptation/items/3416.php (consulted January 19th, 2006).

5 Allocation according to the country of departure or destination of an aircraft or vessel; alternatively, emissions related to the journey of an aircraft or vessel shared by the country of departure and the country of arrival.
6 Allocation according to the country of departure or destination of passengers or cargo: alternatively, emissions related to the journey of passengers or cargo shared by the country of departure and the country of arrival.
7 Allocation according to the country of origin of passengers or owner of cargo.
8 Allocation to a party of all emissions generated in its national space.

At SBSTA 4, Parties noted that there are three separate issues related to international bunker fuels:
- Adequate and consistent inventories.
- Allocation of emissions; and
- Control options.

In 1997, the Conference of the Parties (COP 3) recalled that 'emissions based upon fuel sold so ships or aircraft engaged in international transport should not be included in national totals, but reported separately'. Parties included in Annex I of the Kyoto Protocol should pursue limitation or reduction of emissions of greenhouse gas emissions from international aviation and marine bunker fuels working through the International Civil Aviation Organization (ICAO) and the International Maritime Organization (IMO), respectively. The Conference urged 'SBSTA to further elaborate on the inclusion of these emissions in the overall greenhouse gas inventories of Parties' (FCCC/CP/1997/7/Add.1). In reviewing the allocation options, SBSTA recommended in 1997 that allocation options 1, 3, 4, 5 and 6 should form the basis of further work (UNFCCC, 1997). The three discarded allocation options have several important disadvantages. To name a few: allocation option 2 would not be equitable and would lead to practical problems, such as assigning maritime emissions to land locked countries that have no control over them; allocation option 7 would suffer from heavy data requirements; and allocation option 8 would leave emissions on and over the high seas outside the responsibility of any party.

In this section we will focus on the allocation options that are still under discussion. We therefore exclude allocation options 2, 7 and 8. Allocation option 1 (no allocation) is discarded for obvious reasons in this section.

Feasibility of current options
In this section we briefly describe the feasibility of the different allocation options in the context of data availability and reliability. It should be possible to guarantee the availability and sufficient accuracy of the data required for the allocation option in question. The assessment is based on CE Delft (2004) and CE Delft (2006b). Where possible, we furthermore include an indication of the amount of emissions that would be allocated to the EU-25 for each allocation method.

Allocation option 3: Allocation to the country where the bunker fuel is sold.
This allocation option is often regarded as feasible from the perspective of data availability. Annex I countries are required to report separately on the amount of bunker fuel sold. Data is therefore available for all EU-25 countries. However,

there are some inconsistencies in current bunker fuel statistics. Moreover, there is some doubt about the reliability of bunker fuel sold as an indicator of the actual fuel used.

Inconsistencies in current bunker fuel statistics are discussed extensively in CE Delft (2004, section 7.5). In short, both IEA and UNFCCC acknowledge that national practices for distinguishing between energy use for domestic and international transport do not always follow reporting guidelines fully. Countries may also apply different Tier methodologies. However, correction or modification of the data collection of bunker fuel statistics is feasible.

There is doubt about the reliability of bunker fuel statistics as an indicator of actual fuel use by maritime transport. Estimates for global CO_2 emissions from maritime transport derived from energy statistics differ substantially from activity-based estimates. The latter methods combine data on fleet and fleet activity with specific emission factors. One of the reasons for this discrepancy may be the practice of offshore[55] tankering. Furthermore, it is possible that bunker fuel statistics of some countries are unreliable. Table 44 provides an overview of different estimates of global fuel use and CO_2 emissions.

Table 44 Estimates of CO_2 emissions from international maritime transport

Source	Year	Method	Fuel (million metric tones)	CO_2 (Tg[56] CO_2)[57]
Marintek et al. (2000)[58]	1996	Energy statistics	138	438
EDGAR (2005)	2000	Extrapolation of 1995 energy statistics	-	428
Endresen et al.(2003)[59]	2000	Energy statistics	166	526
Olivier & Peters (2004)	2002	Energy statistics	-	463
Corbett & Koehler (2003)[60]	2001	Activity-based	289	912
Eyring et al. (2005a)	2001	Activity-based	280	813

According to Olivier & Peters (2004) that made use of IEA data, the emissions related to the bunker fuels in the EU-25 amounted to 145 Mt, compared to 463 Mt

55 Taking in fuel at sea outside of ports.
56 One Teragram (Tg) corresponds to 1 Megaton.
57 It should be mentioned that these figures cannot directly be compared. They are based on different demarcations of domestic and international shipping. Furthermore the studies differ somewhat in their exact scope, regarding military and fishing fleet, passenger fleet, fuel use of auxiliary engines and cut off value of vessels included.
58 Mid-estimates based on Corinair emission factor presented.
59 Including a correction factor of 5% for emissions related to port operations, as indicated in Endresen et al. (2003).
60 Note that estimates in the original paper for CO_2, NO_x and SO_2 are presented in Tg of C, N and S respectively.

CO_2 globally. They also provide an overview of bunker fuel totals for each EU-25 country in 2002 (reprinted as Table 4 in CE Delft, 2004).

Allocation option 4: Allocation according to the nationality of the transporting company, or to the country where an aircraft of ship is registered, or to the country of the operator.
For this allocation option, data on actual fuel consumption of vessels is required from which CO_2 emissions can easily be calculated. As discussed before, ship operators have data on fuel consumption. For this option, it needs to be reported, verified and registered by the country which hosts the transporting company or where the ship is registered or operated from. Verification could be done on the base of bunker fuel notes.

In general, information on where the ship is registered is available. However, some ships change flags regularly and may do so even while at sea. In that case, ships would need to register fuel consumption on a daily basis in order to report to the flag state. Defining the nationality of the transporting company or operator may be even more complicated, certainly in the case of companies that are listed on stock markets.

The major disadvantage of this allocation option is that the nationality of a transporting company, an operator or the state where a ship is registered is not stable. Ships can easily change flags, and companies can relocate their headquarters or their registration. This opens up the possibility of evasion. If operators would be faced with policies and measures that would be expensive to them, they can simply change their registration to a state with no commitment under a global climate policy agreement. This would reduce the environmental effectiveness of any policy.

Furthermore, if the possibility to change flag or registration would be limited, this allocation option and the policies based upon it would distort the competitive market. After all, it would imply that two identical ships, sailing identical routes with identical cargo could face two different policy regimes, according to their flag or the nationality of the owner or operator. Since most policies would put a burden on the ship operator, ships or operators from countries with commitments would be in a competitive disadvantage to ships or operators from countries with no commitments. One operator could then grow at the expense of the other, without any economic reason, and without any environmental effect.

Allocation option 5: Allocation according to the country of departure or destination of an aircraft or vessel; alternatively, emissions related to the journey of an aircraft or vessel shared by the country of departure and the country of arrival.
The requirements with respect to fuel consumption data for this option are very similar to that under option 4. The difference is that information on fuel use must now be available for every specific trip between two ports. Again, this data may not be centrally registered at this moment, but most operators have this data in their own accounts, and it could be reported at limited costs, as has been described in section Chapter 5. Verification may be slightly more difficult than

under option 4, since bunker notes cannot be used to estimate fuel use between ports.

This allocation option furthermore requires data on country or port of departure and / or destination. Such data is generally available. Information of arrival and destination is recorded in ship's logbooks and at shipping companies. Furthermore, Lloyds Marine Intelligence Unit (LMIU) keeps a database containing all daily movements by ships of more than 400 tonnes gross.

Evasion by flagging out is no longer an option. There may be some distortions between ports though. This could happen if ports from a certain country are included in policies and measures because the country is in Annex I, and ports in a neighbouring country are not. Shipping to the Annex I country may then become relatively expensive due to the introduced policies and measures. Freight may then be shipped to the neighbouring country from where it could be transported further over land.

An additional point that requires attention is the definition of the country of departure or destination. Liner services may call at several ports on route. It may be difficult to define the ports of departure / destination unequivocally. A pragmatic solution is required for such situations.

Allocation option 6: Allocation according to the country of departure or destination of passengers or cargo: alternatively, emissions related to the journey of passengers or cargo shared by the country of departure and the country of arrival.

The data requirements for this allocation option are more extensive than for the other options considered. Apart from information on the fuel use on specific trips between two ports, information is required on the freight carried on each trip. This information is only available from two different sources, who would have to be combined in order to allocate emissions to countries.

Data is required on the destination and / or departure of each separate cargo load. This information is available in so-called bills of lading, which vessels are required to keep on board for every item of cargo they carry. The bill of lading contains information on, among others, the country where the cargo has been loaded (often also the country of origin of the cargo). It should also be noted that more and more ports in the EU make use of electronic bills of lading. Despite the large amount of data needed, digitalization may limit the efforts for data collection[61].

Data from the bill of lading will need to be combined with data on ship emissions. Furthermore, when a ship carries several cargoes (such as a container vessel) the emissions on a specific voyage need to be allocated to all the containers on board before they can be allocated to either the countries of origin or destination of these containers.

[61] It should be studied how transshipments are reflected in the bill of lading and to what extent all EU ports make use of electronic bills of lading.

For bulk carriers, oil tankers and other segments things may be easier, because they call at less ports and in general carry relatively few different cargo loads.

At this stage, we are unable to assess whether the data requirements of this option would be too severe to make it a feasible allocation option.

Further discussion
Apart from the criteria of data availability and reliability, other criteria may also be of importance in discussion allocation options. Agreement of the allocation option with the 'polluter pays principle' and the potential for evasion under the allocation option are examples. Moreover, the allocation options cannot be assessed in separation from potential mitigation policies. We will briefly discuss these points below.

The analysis above has shown that various allocation options are practically feasible. It is more a question of political feasibility, with which allocation option would countries be willing to agree? This question is very much related to whether and how the emission reduction or limitation targets for countries would be adjusted after inclusion of emissions from international maritime transport in the national totals. Ideally, the new targets would account of:

- The share of emissions from maritime transport in countries' totals.
- The potential for and costs of emission reductions in the sector.
- The potential for countries to implement policies to reduce emissions for which they are made responsible.

In that case, there would remain little objective arguments for countries to prefer particular allocation options.

In practice, it is unsure to what extent the new targets will reflect these three points. It can be expected that countries will be particularly unwilling to agree on an allocation method without a perspective on potential policies and measures to address these emissions, and without knowing the commitments / reduction obligations associated with these emissions[62].

Unilateral policy measures could be introduced under all allocation options. Policy measures could furthermore be specified such to adhere closely to the emissions a country is held responsible for. For example, a fuel tax directly aims at reducing the amount of fuel sold in a country (option 3). Regulations for the shipping company, vessel or operator could target emissions under option 4. Regulations or emission charges on all ships calling at a country's port would affect the amount allocated under option 5. Only under option 6 it appears more difficult to design a policy instrument that only targets emissions a country is made responsible for.

However, unilateral policies have very important drawbacks. They can lead to strategic behaviour by entities to evade the scheme, the may induce economic

[62] For an elaboration of this argument and further reasons for the inability to reach agreement on an allocation option, see CE Delft et al., (in progress) Aviation and maritime transport in a post 2012 climate regime, Delft.

distortions, they not be effective and may even compromise the environmental integrity of climate policies[63]. To avoid this, international coordination of mitigation measures is required. For all allocation options assessed, international coordination of mitigation policies is required in order to be effective and to limit the possibility of strategic behaviour and significant economic distortions.

Allocation in itself is clearly not the solution to the rising emissions of the maritime transport sector. Moreover, it makes little sense to address allocation separately from regulation and commitments. Nordic Council (2004) makes this point for aviation. For shipping it holds even stronger because the potential for evasion is much larger. Ships can easily change flag and are able to tanker large amounts of fuel. An integrated approach, addressing at once allocation, commitments and policies and measures may thus be required to achieve progress in the allocation discussions.

For this reason, it makes also little sense to apply additional criteria to the allocation options such as agreement with the ‘polluter pays principle’ and the potential for evasion. The assessment on these criteria depends in part on the policy measure implemented.
In general, it can be argued that unilateral policy measures targeting a country’s fuel sales could increase the practice of tankering. Policy options related to country of registration or nationality of shipping company / country of operator could lead to flagging out and may cause economic distortions. Unilateral policy measures related to departure or destination (options 5 and 6) may lead ships to call at other ports thus evading the system.

Conclusion
Allocation of emissions is not by itself a policy to reduce greenhouse gas emissions from shipping. States would have to introduce policies and measures in order to control the emissions that have been allocated to them. In the international maritime transport sector national and unilateral policies and measures are unlikely to be effective and may give rise to evasion and competitive distortions.

Partly for this reason, it can be expected that countries will be particularly unwilling to agree on an allocation method without a perspective on potential policies and measures to address these emissions, and without knowing the commitments / reduction obligations associated with these emissions. An integrated approach, addressing at once allocation, commitments and policies and measures may thus be required to achieve progress in the allocation discussions (CE Delft, 2006b).

It is questionable whether allocation of emissions lies within the realm of EU policy. In general, allocation has been and is discussed within SBSTA, a

63 For example, suppose that emissions are allocated based on country of fuel sales. In that case, the Netherlands would be allocated a relatively large amount of emissions. A relatively low Dutch fuel tax may now lead to massive tankering in other countries. The potential reduction in the amount of emissions allocated to the Netherlands may contribute substantially to the Netherlands meeting their overall emission reduction target, without any actual emissions being avoided.

subsidiary body of the UNFCCC. Furthermore, allocation of emissions is a prerequisite for making countries legally responsible for emissions. However, when the EU considers itself to be responsible, it could assume responsibility by implementing policies and measures, such as the policy options discussed above. Regionally imposed policies and measures are likely to be more effective that unilateral national policies. By designing the policies such that do not differentiate between ships and nationalities, evasion may be avoided. For such policies and measures, allocation of emissions is not required.

33 Assessment of policy options

This chapter assesses the policy options designed in Chapter 32 on four criteria:
1. Operational effectiveness.
2. Legal implications.
3. Feasibility of monitoring and enforcement.
4. Feasibility of implementation.

The assessment builds on the analyses in Chapters 29, 30 and 31, and on the rationale of the design of the policy options as laid out in the previous chapter.

33.1 Operational effectiveness

The operational effectiveness of a policy option may be defined by:
1. The amount of emissions covered by the policy option
   The environmental effectiveness of a policy option depends largely on the feasible jurisdiction or geographical scope considered. In theory this scope can be defined uniformly for all options. In practice, though, the choice of entity as well as legal obstacles may lead to differences in (geographical) scopes and hence in the amount of emissions covered by the scheme.
2. Incentives for emission reduction
   This refers to the ability of a policy option to provide incentives for introduction of all available abatement measures, i.e. leaves ship operators or other entities maximum flexibility in the actions undertaken to reduce CO_2 emissions. Obviously, operational effectiveness is determined not only by the choice of policy option as such but also by the monitoring method employed. Furthermore, effectiveness may also depend on the scope for evasion, i.e. potential for free riding. This issue will be treated separately under this criterion.

33.1.1 Voluntary commitments

As explained in section 32.1, there does not seem to be a partner for a voluntary agreement at the moment. Therefore, the operational effectiveness of this policy currently seems to be nil. However, it is possible that an organisation would be willing in the future to enter into a voluntary agreement to reduce greenhouse gas emissions of shipping.

If an organisation would be found, it could be an organisation of shipowners and -operators, or an organisation of shippers. In the first case, the maximum amount of emissions covered by the policy option would be the emissions by the shipowners and -operators involved. Since it is most likely that this organisation would be European based, the fraction of global CO_2 emissions under such a scheme would at most equal the share of emissions by EU owned or operated vessels.

Section 32.1 shows that the abatement options likely to be covered by a voluntary agreement are likely to be the most cost-effective options in order not to distort the competitive market. Many of these measures would probably be taken in a business-as-usual scenario as well.

In sum, the operational effectiveness of voluntary commitments is likely to be very small.

33.1.2 IMO CO_2 index reporting requirement

A requirement to report the IMO CO_2 index to authorities can most easily be implemented for EU flagged ships. To extend the requirement to foreign ships would not be legally impossible, but it could meet resistance from foreign shipowners or -operators, who would be required to record their fuel use and cargo load on every voyage, anywhere in the world. Therefore, the amount of emissions under this policy would be the share of global emissions of EU-flagged ships. Section 29.3 estimates this to be 197 Mt CO_2 in 2000, or 26% of global CO_2 emissions from maritime transport.

As shown in section 32.2, a reporting requirement provides no incentive to improve the CO_2 index or to take measures to decrease the greenhouse gas emissions of the ship. Any environmental effect from this reporting requirement would be based on the use of the CO_2 index as a management tool by shipowners. They could for example choose to train crews to sail fuel efficiently, or take measures such as improved hull maintenance for vessels that show a deteriorating CO_2 index (see also Marintek, 2006). However, the IMO CO_2 index may not provide all the management information needed to take adequate measures.

The measures that shipowners would possibly take when the reporting requirement would provide them with new information, would most probably be measures that are economically rational, i.e. measures that are cost effective. By lack of a reliable marginal abatement cost curve, it is not possible to estimate the emission reduction that could result from these measures. However, with the current high fuel prices and the emphasis of shipowners and –operators at reducing fuel costs, probably only a small share of measures would be cost effective.

In sum, the operational effectiveness of a requirement to report the IMO CO_2 index is likely to be small.

33.1.3 A requirement to meet a unitary CO_2 index limit value

A requirement to meet a unitary CO_2 index limit value would have to be implemented for all ships calling at EU ports. Otherwise, it would distort the competitive market and cause evasion, because ships would change flag. This means that the amount of emissions under this policy would be all the emissions of ships visiting EU ports. It is currently not known which share of all ocean going vessels calls at EU ports at some stage. Moreover, if this policy would be implemented, shipowners would most likely direct their most fuel efficient ships to EU ports, leaving their less efficient ships outside the EU. Therefore, it is not possible to estimate the amount of emissions under this scheme. However, it would be fair to say that this policy would cover a very significant share of global maritime emissions.

An index limit value would incentivise shipowners and –operators to take measures to improve their CO_2 index. The IMO CO_2 index is affected by both operational and technical factors (Marintek, 2006). Therefore, a ship operator would have a large flexibility in taking measures to meet the index limit value. He could choose to maximise cargo load, sail slower, increase hull maintenance, train his crew, install new propellers, and a large number of other measures.

In sum, the operational effectiveness of a requirement to meet a unitary IMO CO_2 index limit value is likely to be large.

33.1.4 Inclusion of refrigerant gases in regulation or the CO_2 index

An inclusion of refrigerant gases in regulation or the CO_2 index would provide an incentive to reduce emissions of these gases. As section 32.4 has demonstrated, the amount of refrigerant gases emitted by maritime transport is very small compared to other greenhouse gas emissions. Therefore, the operational effectiveness of this policy is likely to be very small.

33.1.5 Mandatory differentiation of harbour dues

A mandatory differentiation of harbour dues would provide an incentive to reduce CO_2 emissions of ships calling at EU ports. Which emissions would be targeted, is still an open question. Section 32.5 explores a number of alternatives and selects two: all emissions of these ships (in case the IMO CO_2 index would be used as a base for the differentiation), or the emissions on voyages to EU ports. The first alternative would cover as many CO_2 emissions as the requirement to meet a unitary CO_2 index value (see section 33.1.3); the second would cover circa 152 Mt CO_2 (in 2000), representing circa 20% of global maritime CO_2 emissions (Table 34).

Both alternatives would provide incentives to take all the measures that would cost less than the reduction in harbour dues. Which measures these are, depends on the differentiation. When the base of the differentiation would be a performance standard, such as the CO_2 index, the operator would have maximum flexibility in his choice for measures.

In sum, the operational effectiveness of a mandatory differentiation of harbour dues is likely to be large.

33.1.6 Inclusion of maritime transport in ETS

The inclusion of maritime transport in ETS can be designed with a number of scopes, as laid out in section 32.6. The maximum scope would be the inclusion of all emissions of vessels on voyages to EU ports. This would amount to circa 115 Mt CO_2 emissions, or 15% of the global maritime emissions.

Of all the instruments assessed here, this is the only one that sets a cap for absolute emissions. All other instruments are at best capable of reducing emissions relative to transport performance, in other words, of increasing transport efficiency. However, if demand for transport would increase faster than transport efficiency, emissions would still continue to grow[64].

The policy would incentivise ship operators to take all the measures to reduce emissions that would cost less than the current price of allowances. Operators would have maximum flexibility to choose measures, and be incentivised to take the most cost effective measures first.

In sum, the operational effectiveness of the inclusion of maritime transport in ETS is likely to be large.

33.1.7 Allocation of emissions from maritime transport to Member States

There are four options for the allocation of emissions from maritime transport to Member States. Each option would result in a different share of global maritime emissions to be allocated to EU member states. However, under all these options, the amount of emissions allocated would probably be large.

As set out in section 32.7, allocation is not a policy instrument and thus allocation does not incentivise anyone to take measures to reduce emissions. Rather, states that are allocated maritime emissions would have to design and implement policy instruments to incentivise economic actors to reduce emissions. Therefore, it is not possible to assess the operational effectiveness of allocation of emissions per se, without an analysis of policy measures.

33.2 Legal implications

States have a considerable freedom to demand of ships calling at their ports to fulfil certain requirements. In general, foreign ships do not have a right of innocent passage in internal waters. In the absence of a right of innocent passage, the coastal State has in principle full enforcement jurisdiction. However, under the UN Laws of the Seas Convention, States have the obligation to avoid adverse consequences in the exercise of the powers of enforcement. What is more, States are liable in case enforcement measures are unlawful or exceed those reasonably required in the light of available information. This means that for all the mandatory policy options that extend to non-EU flagged ships,

[64] Other instruments, not discussed in this report, could also be capable of reducing transport demand. For example, emission charges would raise the price of transport and thus reduce demand.

enforcement could have a too thin legal basis. Voluntary policies and policies exclusively aimed at EU flagged ships may be on more solid ground.

As for allocation of maritime emissions to countries, it is clear that this would require an international agreement within the scope of the UNFCCC.

33.3 Monitoring and enforcement

Most policy options studied in this report either require the calculation of the CO_2 index or the CO_2 emissions on a certain trip. The only two exceptions are voluntary commitments and allocation of emissions to Member States.

Chapter 31 has argued that trip CO_2 emissions can be calculated from fuel consumption on a voyage. Ship operators generally have data on fuel emissions per voyage, either for their own bookkeeping or in order to bill the charterer. Probably, only ships that only sail under charter agreements in which the shipowner or operator bears the cost of fuel may not be able to calculate fuel consumption on all voyages from their books, and ferries that make many trips per day. However, even the operators of these ships would be able to calculate fuel use (and thus emissions) per trip with a slight modification of their operating procedures. It is therefore unlikely that shipowners and operators would not be able to monitor and report the CO_2 emissions on a specific voyage.

In order to calculate the CO_2 index, ships need to have data on fuel consumption per voyage, distance sailed and cargo loaded. The distance sailed can be calculated from the ships' log (and is currently being recorded at most vessels), and the amount of cargo loaded can be calculated from the cargo manifests that a ship operator is required to hold. In many cases, ship owners or operators are able to calculate the CO_2 index from their current information systems. It is therefore unlikely that shipowners and operators would not be able to monitor and report the CO_2 index of their vessels.

Data reports from shipowners and operators can be verified using a number of data sources, such as their business accounts, data on ship locations as registered by Lloyds or AMVER, and data on cargo as registered in the bills of lading.

Enforcement will need to be focussed at ports, where States have the ultimate enforcement measure to detain a ship. There may however be legal limitations with regard to the enforcement actions a State can take, which warrant further study (see also section 33.2).

In sum, the requirements for monitoring and reporting do not differ much for the policy instruments discussed here. Likewise, the possibilities for verification of reported data, as well as possible the enforcement actions, seem to be very similar.

33.4 Feasibility of implementation

The feasibility of the implementation of policy measures depends on a large number of factors. This section focuses on the technical feasibility and answers the following question for each policy option:
Are there issues that require further study before the policy can be formulated? And if so, which?

33.4.1 Voluntary commitments

There are two main obstacles that would have to be overcome before a voluntary agreement can be reached:
- The EU would need to have a credible carrot and stick which would incentivise organisations to reach a voluntary agreement.
- An organisation, or several organisations, would need to be willing to reach a voluntary agreement and they would need to have sufficient control over their members to enforce compliance.

It is not likely that these obstacles will be overcome in the near future. But even if they would, a large number of issues would remain to be solved before a voluntary agreement could be reached (see section 32.1).

In conclusion, the practical feasibility of the implementation of a voluntary commitment is low.

33.4.2 IMO CO_2 index reporting requirement

A requirement to report the CO_2 index of vessels to the flag state of a vessel seems to be feasible. From Marintek (2006) one gets the impression that many ship operators can calculate the CO_2 index for their vessels. All the data is available in the information systems of the company, and the only challenge is to link different databases to produce the index. The additional administrative burden required to calculate the index seems to be small.

When ships sailing under flags of EU Member States would report their CO_2 index on a yearly basis, the data could be analysed to assess the merits of this index. Currently, it is clear that the IMO index is well suited to report efficiency and calculate specific emissions related to the transport of goods (Marintek, 2006). However, use of the IMO index for environmental management purposes is challenging because the index typically varies significantly from one voyage to the next. Identification of the specific causes for variation may also be difficult since the index measures the aggregate effect of many contributing factors.

Marintek (2006) concludes that 'the use of the IMO index in a voluntary or mandatory scheme would require the establishment of a baseline. A baseline common for all ships in one category could result in effortless compliance of the larger ships while smaller ships would be unable to reach the target even under optimal conditions'.

Many of the outstanding issues could be solved if more data would be available. However, because this policy measure would not have any other purpose than collection of data in order to assess the merits of the index, it seems a blunt instrument to put a legal obligation on shipowners or operators to report the index of their vessels. The same result could probably be achieved with a voluntary agreement.

33.4.3 A requirement to meet a unitary CO_2 index limit value

The feasibility of a requirement to meet a unitary CO_2 index limit value depends on the possibility to define a limit value that would be both environmentally effective and technically attainable. This is not at all straightforward. There are a number of issues that need to be solved:

1. As Marintek (2006) shows, the index depends both on the ship class and on the ship size. As more data on the CO_2 index comes available, it may be possible to derive a formula for the variation of the index under these parameters. However, there may remain problems with some ships that have an index out of line with the rest of their class.
2. The index is very sensitive to the business cycle. Such variation could cause a static baseline to lose its effectiveness as a control parameter as 'compliance' could become alternately too easy or too difficult to achieve. In order to stay relevant, a baseline may need to account for variation in demand for transport. However, since different markets may be in a different phase of the business cycle, this would be very complicated to do.
3. The CO_2 index is calculated over a year. This means that a ship operator with a high CO_2 index would have to sail outside the EU for a year, taking operational and/or technical measures to reduce his index, before he can call at an EU port. This would limit competition on the market for maritime transport to the EU.

In sum, some obstacles need to be overcome before the requirement to meet a unitary CO_2 index value could become feasible.

33.4.4 Inclusion of refrigerant gases in regulation or the CO_2 index

Before refrigerant gases could be included in the CO_2 index, their consumption would need to be reported with verifiable data. Currently, verification of data does not seem possible (see section 32.4), which would undermine the effectiveness of such a policy. Furthermore, inclusion in the CO_2 index would share many of the advantages and disadvantages of the CO_2 index.

Inclusion of emissions of refrigerant gases in EU regulation would require new legislation, since the existing regulations do not seem to extend to vessels at sea. There do not seem to be legal or other obstacles to the adoption of new legislation aimed at limiting the emissions of refrigerants.

In sum, the feasibility of the implementation of legislation on emissions of refrigerant gases in EU regulation is high. New legislation would be needed, as it would for most of the other policies discussed in this report.

33.4.5 Mandatory differentiation of harbour dues

The feasibility of a mandatory differentiation of harbour dues depends first of all on the possibility of finding a base for the differentiation that would be environmentally effective and technically attainable. Section 32.5 suggested the CO_2 index or the CO_2 index of the last trip, but as set out above, the current understanding of the CO_2 index is insufficient to conclude that this would indeed be a good base for a differentiation of harbour dues.

Furthermore, the impact on the competitive market for ports would need to be studied in greater detail. Since the objective of the policy instrument would not be to favour some ports, and since doing so would meet resistance, any differentiation of harbour dues would have to minimise distortions of competition.

33.4.6 Inclusion of maritime transport in ETS

Based on the analysis in section 32.6, the inclusion of maritime transport in ETS seems feasible, although some issues need to be resolved. These include:

- The method of distributing allowances over ship operators. It is clear that the methods currently used under ETS cannot be applied in the shipping sector. Auctioning could be a solution, but could place a large financial burden on the sector. Ploughing back the proceeds of an auction in order to alleviate the financial burden needs a well designed method.
- The geographical scope of the system, which would have to be in compliance with international law, environmentally effective and possible to verify.
- The impact on the different segments of shipping (liner shipping, tramp shipping, container and bulk cargo) and the desirability to reduce possible differential impacts.
- In relation to the geographical scope, the possibilities for evasion would have to be studied in greater detail. If, for example, all voyages to EU ports would be brought under the scheme, would this create an effective incentive for ship operators to make an extra stop just outside EU jurisdiction?

33.4.7 Allocation of emissions from maritime transport to Member States

Allocation of emissions from maritime transport to Member States is feasible. Data on emissions are available from ship operators, but procedures need to be established to report the data to the authorities responsible for making the national inventories. This cannot be done without international agreement on the allocation options, which still does not seem within reach.

33.5 Conclusion

Table 45 summarises the assessment of the policy options. There are three options that stand out:

- A requirement to meet a unitary CO_2 index limit value.
- A mandatory inclusion of a CO_2 element in a differentiation of harbour dues.
- The inclusion of maritime transport in ETS.

These options have a high operational effectiveness and could be feasible to implement. Their feasibility warrants further study, however, the subjects of which have been indicated in sections 33.1.3, 33.4.5 and 33.4.6.

Two policy options have a high feasibility but a small or very small operational effectiveness:

- A requirement to report the IMO CO_2 index could be implemented in order to be able to assess other options better. However, it could probably be implemented as a voluntary agreement instead of a legal obligation.
- The inclusion of refrigerant gases in EU regulation would have a very small environmental effect, but this effect would probably be reached at a very low cost. Implementation of regulation would probably be feasible.

The allocation of emissions of maritime transport to states would encourage the development of policies and measures and be one of the best ways to address the climate impacts of maritime transport on a global scale. It is, however, not in the realm of EU policy to allocate emissions. There would need to be international agreement within the UNFCCC.

Voluntary agreements do not seem to be a promising policy instrument to reduce the climate impact of maritime transport.

Table 45 Assessment summary of policy options

	Operational effectiveness	Legal implications	Monitoring and enforcement	Feasibility of implementation
Voluntary commitments	Very small	No legal obstacles foreseen	Not applicable	Low
IMO CO_2 index reporting requirement	Small	No legal obstacles foreseen	Feasible	High
Requirement to meet a unitary CO_2 index limit value	Large	Enforcement could require additional international legislation	Feasible	Depends on the possibility to establish a limit value
Inclusion of refrigerant gases in regulation or the CO_2 index	Very small	Probably requires new EU legislation	Feasible	High
Mandatory differentiation of harbour dues	Large	Enforcement could require additional international legislation	Feasible	Depends on the possibility to establish a baseline and limit distortion of competition between ports
Inclusion of maritime transport in ETS	Large	Enforcement could require additional international legislation	Feasible	Depends on the possibility to solve a number of design issues
Allocation of emissions from maritime transport to Member States	Not applicable	Would require international agreement on allocation	Not applicable	Not applicable

34 Conclusions

This report concludes that there are at least three promising policy options to reduce the climate impact of maritime transport.

The first option is the inclusion of maritime transport in ETS. Such a policy would be in line with current developments in the EU, which aim to include aviation in ETS. Furthermore, it would allow ship operators considerable flexibility in taking measures to reduce emissions (or buying emission allowances). And it would be the only policy instrument studied in this report that would cap the net climate impact of shipping.

Inclusion of maritime transport in ETS would need some further study, though. The wide variety of business models in the shipping sector makes it hardly possible to apply current methods of distributing allowances to the sector. New methods, suitable for the shipping sector, would need to be designed. Furthermore, the scope for evasion needs to be studies alongside ways to limit it. And the desirability to treat different segments of maritime transport in a different way warrants more attention than was possible in this study.

The second promising option is a differentiation of harbour dues, although this instrument would probably be an incentive to increase transport efficiency, not to cap absolute emissions. This instrument would give operators flexibility in the measures required to reduce emissions. It would be an economic, market based instrument for which most institutions are currently in place. This means that the additional bureaucracy could be kept to a minimum. It could also be implemented in a budgetary neutral way.

The main obstacle that would have to be overcome before this option could be implemented would be the identification of a base for the differentiation that would be environmentally effective and technically attainable. The IMO CO_2 index could prove to be a suitable base, but the current understanding of the index is still immature. Other bases would be conceivable, but they would need even more study.

Furthermore, the possible impact on the competitive market between ports needs further study. The instrument could discriminate against ports with a high price elasticity of demand.

The third promising option is a requirement of ships calling at EU ports to meet a unitary CO_2 index limit value. This would still allow ship operators to choose measures from a wide array of technical and operational options. Because of this flexibility, the cost effectiveness of this option could be good. However, it would need to be demonstrated that it is indeed possible to calculate a CO_2 index limit value that would not be dominated by external factors such as transport demand, and would take the large variety of ships into account.

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Annex A: Sources of estimates of CO_2 emissions from shipping

There are various sources that could be used to indicate the amount of emissions falling under different scopes. This appendix describes seven sources that have recent information on CO_2 emissions from shipping and that allow for definition of different scopes.

In general, estimates of global fuel use in maritime transport vary considerably. In an overview presented in Entec (2005, Task1, table 6.1), estimates vary from 121 to 289 million tonnes of yearly fuel consumption. In general, estimates based on bunker fuel sales for international maritime transport are relatively low, whereas estimates based primarily on vessel activity are relatively high.

Despite these differences with respect to absolute amounts of emissions, we expect that different models will reasonably well agree with respect to the relative amount of emissions covered under each of the policy scopes. The reason is that both bunker fuel based models and activity based models apply traffic data and engine characteristics to allocate emissions to geographical locations. Some differences may remain, however, because not all models make use of the same traffic data.

We now turn to a brief discussion of the different models available and discuss their pros and cons with respect to the particular requirements of this study. The following data sources could be used:
- Eurostat.
- Entec (2002).
- Tremove.
- EDGAR.
- Entec (2005).
- Eyring (2005).
- Corbett and Koehler (2003).

It should be noted that some of these studies / models / databases are especially directed at the EU, whereas other studies provide insight on a global level and may not even be restricted to emissions from maritime transport, such as EDGAR.

Eurostat
The website from Eurostat contains information on fuel sales and fuel consumption. Neither of these sources will provide information on the fuel used by vessels of specific flag or on a particular route.

Entec (2002)
This study for DG ENV is directed especially at emissions from operations of vessels in the EU. It quantifies the CO_2 emissions of vessels in the EMEP region, including the North Sea, Irish Sea, English Channel, Baltic Sea, Black Sea and Mediterranean. In-port emissions were also quantified. Emissions were presented for:

- All vessels movements.
- Starting and destination port both in the EU.
- Starting port in the EU, destination not.
- Destination port in the EU, starting port not.
- Vessels with no stops in EU ports.

The underlying database used was provided by Lloyds Marine Intelligence Unit (LMIU), including all movements of ships (greater that 500 gross tonnes) world-wide. The data include information with respect to vessel type, vessel size, and flag. The base year was 2000. Vessels were assumed to take the shortest straight line between ports (if not prohibited by land). Emissions were calculated based on vessel specific emission factors. Since many fishing vessels may not be covered by the LMIU database, another approach was used to calculate the emissions of these types of vessels. Based on data of annual fish catches and the locations of fishing grounds for the different nations and the fuel consumption by fishing vessels in the UK, total fuel consumption of fishing vessels for different countries was estimated. Emissions were calculated by multiplying these consumption figures by emission factors. All results were presented separately for EU flagged ships, ships under a flag of an accession country and for ships under any other flag.

Tremove
Although the original TREMOVE model only included surface transport, an update does take account of emissions from shipping. The approach adopted for maritime transport in Tremove is to a large extent based on Entec (2002). So, the emissions were presented for the same scopes as in this study. Also the base year was the same, namely 2000. However, in contrast to Entec (2002), fishing vessels are not included in Tremove. Additionally, a different forecasting method of vessel activities up to 2020 was used.

EDGAR
EDGAR (Emission Database for Global Atmospheric Research) has information on emissions from maritime transport for the year 2000. Emissions from international shipping are primarily based on bunker fuel statistics from the International Energy Agency (IEA). In general, not included in international bunkers are emissions from ships engaged in coastal waters (cruise ships, ferries, offshore supply, fishing and research). An estimate of the geographical spread of these emissions has been made making use of traffic data from Eyring (2005). No direct relation with type of operator or type of operation is available.

Entec (2005)
In this study, several different methods for assignment of emissions to European countries are discussed. Although assignment does not directly underlie this study, the models used may provide an indication of emissions covered under different types of policy scopes.
Assignment methods taken into account are:
a Geographical region.
b Flag of ship.
c Country of fuel sales.
d Reported fuel consumption.
e Freight tonnes loaded.
f In proportion to national emissions.
g Country of departure / destination.

In principle, calculations were based on the same database underlying Entec (2002), although the emissions of fishing vessels were not included.The results include emissions at sea, emissions in ports and at inland waterways. For emissions on inland waterways, use was made of results from TREMOVE.
Table 46 provides an overview of some relevant characteristics of the outcomes of these methods. Both bottom up and top-down methods are used. By applying a bottom up approach, emissions are calculated for individual vessels and aggregated to estimate the total emissions for the different scopes. In contrast, if a top-down method is used aggregate numbers for the total EU are divided over the different countries, ships or locations.

Table 46 Overview of available data from Entec study

	Method	Emissions outside EMEP region	Disaggregate by vessel type	Disaggregate by operation type
A Location	Bottom up	No	Yes	Yes
B Flag	Bottom up	Yes	Yes	Yes
C Fuel sales	Top-down	Yes	No	No
D Fuel consumption	Top-down	Yes	No	No
E Freight tonnes	Top-down	No*	No	No
F National emissions	Top-down	No*	No	No
G Departure/destination	Bottom up	Yes	Yes	Yes

* These methods make use of results of method (a). Can make use of results from other method and can include emissions outside EMEP regions in that case.

For illustrative purposes, emission estimates outside of the EMEP region were calculated. This was done making use of average distances between continents. This could be further refined in the future.

Methods (e) and (f) are not directly relevant in relation to this study. The results from methods (a), (b) and (g) may prove useful.

Eyring (2005)
Eyring (2005a) estimate emissions from all ships over 100 gross tonnes[65], using a bottom-up approach based on ship data from LMIU and vessel location data from AMVER (Automated Mutual-assistance Vessel Rescue system). Military vessels of over 300 GT are also included. The method is independent of fuel sales statistics. It makes use information on vessels, engines, fuel consumption and emissions factors. Information for vessels for different use (tanker, bulk, container etc.) is likely to be available in their database, but not presented in the paper. It appears that no direct relation with type of operator or type of operation is available.

Corbett & Koehler (2003)
Eyring (2005) estimate emissions from all ships over 100 gross tonnes, making use of data from LMIU. All military vessels are included. Their method is independent of fuel sales statistics and very similar to the method used by Eyring (2005a).

An overview of some of the characteristics of the different methods is presented in Table 47. It is clear that no available data set makes any distinction regarding the base of the shipper or operator.

[65] A vessel of 100 grt measures about 20 to 30 meters.

Table 47 Comparison of different data sources

	Base year	Scope	Data source distinguishes between:			Estimate of emissions	Data availability
			Types of operators	Types of operations	Types of vessels		
Entec, (2002)	2000	EMEP region	EU/ACC/ non EU Flag	Yes	Vessels, ferries and fishing	157 Mt CO_2	Yes
Entec (2005)	2000	EMEP region, rough estimate for other emissions	EU	Yes	Vessels and ferries	153 Mt CO_2 (EMEP region); 757 Mt CO_2 (global)	Yes
Tremove	2000	EMEP region	EU/ACC/ non EU flag	Yes	Vessels and ferries	-	No
Eurostat (2006)	2004	EU	No	No	-	-	Yes
Eyring (2005)	2000	Global, grid data available	No	No	-*	813 Mt CO_2	No
Corbett & Koehler (2003)	2001	Global, grid data may be available	No	No	-*	912 Mt CO_2	No
EDGAR	2000	Global, grid data available	No	No	-*	428 Mt CO_2	Yes

* No results for specific types of vessels are presented, but based on the underlying model, such information should be available.

Annex B: Notes of meeting with ECSA's air emissions working group

As part of this project, CE Delft had a meeting with the European Community of Shipowners' association to discuss greenhouse gas policies for shipping in general and voluntary commitments in particular. The meeting was held in Brussels on 25. April 2006. The meeting notes are reproduced below.

The Chairman welcomed Mr Faber from CE Delft and explained that while ECSA had no firm view on a voluntary system, participants could share their knowledge of the industry and put forward their own views.

Mr Faber provided background to CE Delft's involvement, noting that they were project leaders for Commission contract, other partners being GL, DNV and Marintek who were responsible for the other tasks of the project. It was anticipated that the report would be delivered in November. While the seven options listed were for consideration, he wished to concentrate on the first relating to voluntary commitments by shipowners, who he felt were best placed to be made responsible for ship emissions as they had the most direct operational and technical control.

In discussion, ECSA participants made the following points:

- Shipowners were willing to examine all practical and feasible solutions for CO_2 reductions, especially as the issue was an ongoing one in IMO.
- Shipowners were continually striving to increase the fuel efficiency of their vessels, it being in their commercial interests to do so. For such essentially commercial reasons, shipowners would be placing increased emphasis on fuel efficiency in the future, higher fuel prices being a driver in that regard; customers would choose another ship if not satisfied with the fuel efficiency.
- Improvements had always been market driven, with voluntary measures being taken in that context. ECSA was consequently against a regulatory approach.
- Increased engine efficiency as a result of the introduction of new technology had been significant, after 1987 in particular; the industry fully supported increased R&D with that goal and there was an important role for the EU in that regard.
- There was a clear improvement over the last years, a tabled paper from the Port of Rotterdam demonstrating that significantly more cargo was carried with fewer ships today when compared with 30 years ago.
- ECSA consistently advocated international rather than regional rules in order to establish a level playing field for the global shipping industry. However, this did not mean that regional susceptibilities could not be taken into account, SECAs being a prime example. What was important was that such measures were taken within the international framework.

- Neither ECSA nor its member associations could enter into commitments on behalf of their members and while voluntary arrangements may be acceptable, distortions of competition should not result.
- It should be borne in mind that parties other than shipowners were often better placed to take initiatives to reduce emissions. In particular, there was scope for action by port authorities to increase the efficiency of ship handling and logistics generally.
- It was noted also that shipowners currently had little bargaining power or control when purchasing vessels and that the growth of world trade was a factor over which the industry also had no control. In the latter regard, tonne mile efficiency was the criteria to examine.
- The whole transport chain should be examined in the context of CO_2 reductions, including regulators where the negative impact on fuel efficiency of regulations, concerning single hulls and ballast water for example, should be assessed.
- While improving the CO_2 index year on year was important, it could be achieved without EU regulation.
- It was noted that speed reductions could result in a need for more ships to carry the cargo, with an overall negative consequence for the environment.
- Overall, CO_2 emissions from ships remained low, and solid reasons were needed to justify the cost increases of any measures taken.

Both Mr. Faber and ECSA **agreed** that the exchange of views had been useful and that contact should be maintained during the course of the project.