3. Market Survey of Marine Distillates with 0.2% Sulphur Content

3.1 Background

Marine distillates can be broadly divided into two categories: marine gas oil (MGO) and marine diesel oil (MDO). MDO is classed as fuel with a viscosity (measured at 50 °C) between 5,5 - 50 cst and MGO 1 - 5,5 cst.[3] The majority of world-wide sales of marine distillates are produced and sold under quality standards categorised under ISO 8217 which places maximum limits on their chemical and physical properties, including sulphur content.

Table 3.1 – International Fuel Oil Standards (ISO 8217)

	Max % (m/m)			
	MGO		MDO	
ISO 8217	**DMX**	**DMA**	**DMB**	**DMC**
Sulphur content	1	1.5	2	2

Under Directive 1999/32/EC, relating to a reduction in the sulphur content of certain liquid fuels, shipping vessels using marine distillates must use a distillate with a sulphur content of no more than 0.2% by mass within the territory of every EU Member State. This limit was applicable from 1 July 2000 and tightens to 0.1% from 1 January 2008. Derogations allowing sulphur contents in excess of these limits apply to the Canary Islands, French Overseas Departments, Greece, Madeira and Azores.

Directive 1999/32/EC is enforceable upon fuel users. It does not apply directly to distillate suppliers meaning that distillates with higher sulphur grades can, and are, still made available at ports throughout the EU.

Within this report, low sulphur marine distillates are defined as those complying with the 0.2% limit set within Directive 1999/32/EC applicable from 1st July 2000 until 1st January 2008 when the limit decreases to 0.1% sulphur. This report provides an overview of the availability of low sulphur distillate fuels relative to the equivalent grades with higher sulphur contents that conform to the sulphur limits specified in ISO 8217. Four main areas are addressed:

1. The proportion of European ports which sell low sulphur (0.2%) grades;

2. The proportion of low sulphur marine distillates sold in the EU relative to the higher sulphur equivalents in ISO 8217;

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[3] IVL 2002

3. Typical price premiums in the EU between low and high sulphur distillate grades; and

4. The availability of low sulphur marine distillates outside the EU.

3.2 Data Gathering

Initial contact with key industry representatives from both the oil/bunker industry and the shipping industry revealed both that the data required was not readily available and that there is a high degree of interest in obtaining this information, especially amongst the various industry trade organisations.

This section outlines the difficulties faced in gathering the required data and describes the methodology adopted to effectively overcome these difficulties.

3.2.1 Supply Chain Complexity

There are principally three potential levels at which the required data could, in theory, be gathered:

1. Petroleum refineries;

2. Bunker suppliers/brokers/traders; and

3. Shipping operators.

Refinery representatives were unable to provide information as to the final destination of their fuel or actual sulphur contents once reaching this final destination. This is due largely to the complexity of the market. In particular, refineries were often unable to differentiate between distillates going to inland uses such as agriculture and distillates going to marine uses.

The complexity of the marine distillate market has been augmented by the increasingly large number of independent and state owned companies (around 500 worldwide[8]), operating on a regional basis, that have moved in to participate in the bunker business. In the past the major oil companies used to supply the majority of the bunker market (approx. 85%) this share has now decreased to around 40%. The market is further complicated by the activities of the large number of brokers and traders within the bunker industry.[4]

At the shipping operator level, the large number of operating companies at all levels, from tankers through to non-ship structures, makes obtaining the relevant data at this level an extremely resource intensive task. Sample data is available from large testing laboratories, however this is sold as commercial data at costs in excess of the capacity of this study. It is also difficult to determine the reliability of this data as it will come only from those shipping operators who deal with that particular laboratory and may therefore not provide a representative sample, especially in terms of geographical coverage.

3.2.2 Optimal Approach

As a result of exploring these three potential data gathering levels, as well as close dialogue with industry contacts, it was decided that the optimal way to obtain the required information

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[4] Figures taken from BEICIP-FRANLAB (2002)

was at the bunker supplier level. At this level, accessible information should be available in terms of what grade of distillate is being supplied to which port. This also ensures representative coverage through targeting bunker suppliers across the EU and the rest of the world.

A survey was constructed asking for information on the four key areas and sent electronically to listed bunker suppliers, traders and brokers within the November 2001 Bunker News Directory. 400 questionnaires were sent out in total and 56 responded. The resulting information was then analysed by country and region. The major oil companies were individually contacted independently from the survey.

It was hoped that this bottom up approach would be able to be verified by top down figures for marine distillate sales broken down by ISO 8217 grades. Unfortunately this data is not available in a form that differentiates between high and low sulphur, again due to current reporting requirement deficiencies.

3.3 Results

3.3.1 Response Rate

The response rate to the survey (14% of 400 bunker suppliers, traders and brokers) seems to confirm the concerns of the various industry organisations whose overriding opinion is that obtaining comprehensive information in this area is not possible under current information sharing requirements. This is largely due to the information often being of a commercially sensitive nature in terms of market share, relative pricing etc. as well as a lack of requirement to report on the differentiation between high and low sulphur distillate sales.

Three major oil companies, including the main marine fuel suppliers in Europe, were not forthcoming with any relevant information despite sustained dialogue over several months. Two were more helpful although did not supply all the information required in the format requested. No response was received from suppliers servicing two of the accession countries namely Lithuania and Bulgaria.

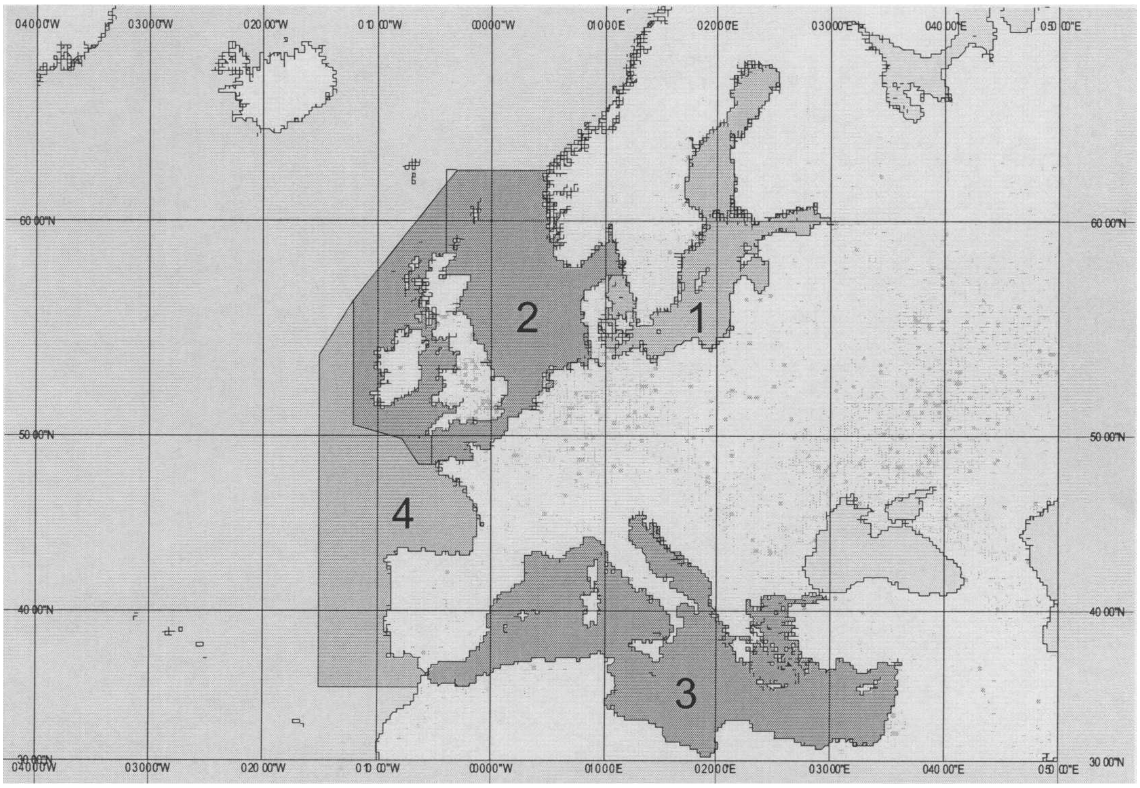
3.3.2 Proportion of European Ports Which Sell Low Sulphur (0.2%) Grades

In accordance with MARPOL definitions, with the exception of the arbitrarily defined N E Atlantic, European waters can be divided into four sea areas:

1. The Baltic
2. The North and Irish Sea
3. The Mediterranean
4. The N E Atlantic

These are illustrated in Figure 3.1.

Figure 3.1 Map of European Sea Areas



Source: BMT 2000

The general picture derived through this study, as a result of both the survey and extensive dialogue with industry contacts, is that low sulphur marine distillates are available at ports throughout Europe except certain areas of Greece, Spain and the Canary Islands. Most Scandinavian and Baltic States, as well as the UK and Ireland tend to sell only max 0.2% sulphur gasoil. Northwest Europe tends to be mixed with low sulphur available but some suppliers still supplying high sulphur gasoil at a discounted price. Portugal tends to be exclusively 0.05% sulphur with the same grade of distillate (all DMA) supplied for road and marine use. The Mediterranean and Aegean markets are also mixed with 0.2% available except in parts of Greece where it is only available by truck. However, according to correspondence with industry representatives and the results of the survey, in terms of quantities of distillates sold, despite the seemingly widespread availability of low sulphur distillates, outside the EU / Baltic this availability may be marginal. Responses to the survey imply that even outside of Greece, Spain, Gibraltar and the Canaries, the majority of distillates sold have a sulphur content of over 0.2%.

Notably, the survey suggested that the availability of low sulphur marine distillates is predominantly MGO. MDO tends not to be widely available at <0.2% sulphur.

From this study it is estimated that low sulphur (<0.2%) distillates are available at approximately 95-99% of ports within the EU. However, the quantities in which they are available may vary significantly between ports and regions.

3.3.3 Proportion of Low Sulphur Marine Distillates Sold in the EU Relative to Higher Sulphur Equivalents

It should be noted that DMA is the main grade of MGO supplied within the world market and DMB the main grade of MDO. The less extensive data for DMX and DMC grades within the survey results is considered to be a reflection of this. Over the last five years (1997-2001), the average price of DMA (0.2%S) was 186 USD per mt and the average price of DMB (2%S) over the same period was 156 USD per mt.[5] Price premiums given in this section are between high and low sulphur DMA.

Table 3.2 EU-15: Average Proportions of Low Sulphur Marine Distillate Sold and Price Premiums Between High and Low Sulphur Distillates

Country	% Distillate Sold That Is Low Sulphur				Price Premium USD per mt
	DMX	DMA	DMB	DMC	
Austria	-	-	-	-	-
Belgium	50	30	7	3	18
Denmark	-	100	-	-	10
Finland	-	100	100	-	12
France	-	95	-	-	8
Germany	70	70	40	35	23
Greece	28	2	3	0	24
Ireland	100	98	0	0	13
Italy	-	100	10	-	20
Luxembourg	-	-	-	-	-
Netherlands	50	35	7	5	19
Portugal	100	40	-	-	8
Spain	100	77	28	25	15
Sweden	-	100	0	0	25
UK	100	98	0	0	13

Table 3.2 outlines the proportions of low sulphur fuel sold in EU-15 countries as indicated by the survey results. It can be seen that in most EU-15 countries, the majority of MGO sold is low sulphur. Exceptions to this are Greece, Belgium and the Netherlands. This is of significance due to the location of the ports of Rotterdam, Amsterdam and Antwerp (ARA) within Belgium and the Netherlands. These ports account for one third of EU-15 sales[6]. The data suggests that the

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[5] BEICIP-FRANLAB (2002)

[6] Figures based on 1999 data taken from BEICIP-FRANLAB (2002)

majority of sales of MDO throughout EU-15 countries are high sulphur, with the exception of Finland.

Table 3.3 Accession Countries: Average Proportions of Low Sulphur Marine Distillate Sold and Price Premiums Between High and Low Sulphur Distillates

Country	% Distillate Sold That Is Low Sulphur					Price Premium USD per mt
	Unspecified Grade	DMX	DMA	DMB	DMC	
Estonia	-	100	80	0	-	10
Latvia	-	-	99	0	-	11
Lithuania	-	-	-	-	-	-
Slovenia	-	-	-	-	-	-
Romania	-	-	-	-	-	-
Bulgaria	-	-	-	-	-	-
Malta	50	-	-	-	-	-
Cyprus	-	-	6	-	-	7
Czech Rep	-	-	-	-	-	-
Hungary	-	-	-	-	-	-
Poland	-	-	100	0	-	9
Slovak Rep	-	-	-	-	-	-
Turkey	-	50	63	12	-	6

Table 3.3 provides the same data for accession countries where available. Here, a similar picture is observed with the majority of MGO sold being low sulphur except for Cyprus which sells only a very small proportion of low sulphur MGO. Virtually all sales of MDO (the only exception being Turkey) are high sulphur. In the case of Turkey, 80% of MDO sold in Istanbul is low sulphur, but with only 10% of MDO sold outside Istanbul being low sulphur.

It should be noted that sales of, and availability of, low sulphur distillates will often be as much due to the initial sulphur content of crude as it is to do with legislative requirements. For example, distillates supplied in the UK from North Sea crude are naturally very low in sulphur. This is also the case for some distillates produced from crude oil originating in Russia, although correspondence with industry contacts suggests that in Russia low sulphur contents are also a result of historical production of low sulphur distillates by Russian refineries due to government requirements.

3.3.4 Typical Price Premiums Between Low and High Sulphur Distillate Grades

Bunker prices constantly fluctuate due to market forces and the cost of crude oil and the bunker market is extremely price sensitive with ships often basing decisions on where to bunker on the relative price of fuel available in respective ports. These bunkering decisions would therefore also be impacted by relative price premiums arising as a result of different fiscal policy across countries and regions, especially in terms of fuel taxes. This is particularly significant in terms of using financial incentives to promote the use of low sulphur distillates.

Price information that distinguishes between low and high sulphur marine distillates is not readily available. The survey results are therefore based on estimates by the responding bunker suppliers based on their own recent observations of the market. The predominant view expressed by industry contacts during the course of this study is that where both low and high sulphur distillates are available, there is a premium of around $10-15 per metric tonne (mt) on the low sulphur fuel. The results of the survey (Tables 3.2, 3.3 and 3.4 for EU-15 Countries, Accession Countries and Rest of World respectively) show that this is a fairly representative estimate. Premiums seem to be highest in certain EU15 countries including Greece, Germany, and Sweden. The relatively low price premiums in Accession countries and the rest of the world are probably due to the availability of low sulphur distillates being incidental as opposed to a result of legislative requirements.

3.3.5 Availability of Low Sulphur Marine Distillates Outside the EU

Table 3.4 below provides an overview of average percentage sales of low sulphur marine distillates relative to high sulphur distillates outside the EU. Low sulphur MGO and MDO tend to be available in North America (US and Canada) and South America. There is also limited availability of both in Central America. Low sulphur MGO (DMA) is also available in Russia, where it is almost exclusively low sulphur. The low sulphur content of distillates originating in Russia is sometimes due to a low original crude sulphur content but correspondence with industry contacts suggests that it is more often due to the historical production of low sulphur products by Russian refineries (usually 0.2% content) due to government requirements. Low sulphur MGO (DMA) is also available in the Middle East in limited quantities. Middle East availability is likely to be incidental. Correspondence with industry contacts together with the results of the survey suggested that in Asia, including Singapore and Fujairah but with the exception of the Philippines, there is very limited availability of low sulphur MGO (DMA). This is significant because Singapore and Fujairah are major world bunker suppliers.

Table 3.4 Rest of World: Average Proportions of Low Sulphur Marine Distillate Sold and Price Premiums Between High and Low Sulphur Distillates

Country / Region	% Distillate Sold That Is Low Sulphur					Price Diff. USD per mt
	Unspecified Grade	DMX	DMA	DMB	DMC	
Asia	0	0	100*	0	0	8
Canada	-	0	10	45	45	8
Caribbean	0	0	0	0	0	-
Central America	45	0	10	10	0	10
Egypt	0	0	0	0	0	
Middle East	0	0	20	0	0	2
US	0	100	39	27	10	10
Russia	-	0	100	0	0	11
South America	100	95	53	33	0	-

*Philippines only

3.4 Data Quality

3.4.1 Data Sources

The data used to compile this market research consisted of a combination of dialogue/correspondence with industry contacts and an electronic survey.

3.4.2 Data Age, Geographical and Technical Coverage

The data is up to date as of April 2002. Geographical coverage is worldwide and technical coverage of the marine distillate market is comprehensive from all ends of the market.

3.4.3 Data Precision, Completeness and Representativeness

Due to the lack of available data on marine distillates that distinguishes explicitly between high and low sulphur, within the time scale and remit of this study it was not possible to undertake a totally comprehensive analysis of the marine distillate market. This is largely a result of the lack of requirements for comprehensive reporting within the industries involved.

Whilst the 14% response rate to the questionnaire is relatively low, it achieved representative coverage throughout EU-15 countries and most accession countries with ports as well as a good global response. The response rate could be argued to make the precision of the data questionable. However, the survey, combined with comprehensive dialogue with industry contacts undertaken in this study, provides an excellent overview of the marine distillate market which is as close as possible to approximating the current world-wide situation.

3.4.4 Consistency and Reproducibility

Data collection and analysis was carried out in a consistent and systematic manner through the use of a standardised questionnaire and constant internal review by the project team. The level of detail of data collection and interrogation is considered appropriate to meet the goal and scope of the study. The same level of review and interrogation was applied throughout the study.

3.4.5 Uncertainties

The principal uncertainties within this study arise from the lack of comprehensive reporting requirements within the marine distillate industry which make it difficult to obtain data that differentiates between high and low sulphur distillates. This is augmented by the highly dynamic nature of the marine distillate market that means pricing information is based on estimates only and is likely to fluctuate significantly with time.

There may also be some concern with regards to honest reporting where organisations feel they may be in breach of legislation, or that the way in which they answer might influence future legislation.

3.5 References

BEICIP-FRANLAB (2002) *Advice on the costs to fuel producers and price premia likely to result from a reduction in the level of sulphur in marine fuels marketed in the EU.* Study C.1/01/2002

BMT (2000) *Study on the economic, legal, environmental and practical implications of a European Union system to reduce ship emissions of* SO_2 *and* NO_x. EU B4-3040/98/000839/MAR/B1

IVL (2002) *Representative emission factors for use in "Quantification of emissions from ships associated with ship movements between ports in the European Community" (ENV.C.1/ETU/2001/0090).* Unpublished report for Entec UK.

4. Feasibility of Ships Storing Multiple Grades of Marine Distillates

As shown by the market survey, the majority of sales of marine distillates outside of the EU tend to be high sulphur. This has obvious implications in terms of ships bunkering with high sulphur distillates outside the EU before entering Community territorial seas. Burning these fuels then places them in breach of Directive 1999/32/EC which obliges them to burn low sulphur (<0.2%) grades within EU waters.

This section considers the feasibility of the idea of ships installing separate fuel tanks for high and low sulphur grades.

4.1 Vessel Type and Applicability

Most smaller vessels such as closed cross channel ferries and small coastal trade vessels will be burning distillates only. In this case the need to carry two grades of distillate would only arise if the vessels are operating across territories inside and outside of the EU. Larger ships spending significant periods outside of the EU region are likely to be more relevant in terms of installing dual-fuel capacity.

Historical shipping practice, for vessels entering port for manoeuvres, is to operate on a different fuel, often distillates. The advantage of this was more reliable engine control with the diesel fuel and less general degradation of the engine. More recently the trend has changed to maintaining use of the heavy fuel oils throughout the vessel operation. Advancements in engine manufacture and improved fuels have made this a more feasible option for shipping operators. This makes the issue of installing dual-fuel capacity on board for distillates somewhat redundant because ships would be running on heavy fuel oils at all times rather than switching to distillates. However, conversations with shipbuilders during the course of this study suggest that there are still a significant number of vessels built with the capacity to switch to distillates for the purposes of starting engines as well as manoeuvring in port.

As a result of contacting a wide cross-section of shipbuilders, repairers and marine engine specialists, the following sections have been compiled giving the best available overview of the issues and costs involved in installing dual-fuel capacity for purposes of running both low and high sulphur distillates.

4.2 Engine Specific Issues

The principal issue in terms of running an engine on low sulphur distillates is in terms of lubrication oils. Lubrication oils protect the engine from fuel emissions by acting to neutralise acidic emissions such as those from high-sulphur fuel grades. Ships running on heavy fuel oil will usually be using a two cylinder lubricant such as BN70 to neutralise the high sulphur content of the fuel oil. If a low sulphur distillate is switched to, the distillate will not neutralise the calcium content of the lube oil resulting in white calcious deposits on the cylinder rings. This in turn will cause scuffing of the cylinders and tearing of the cylinder liners. There would therefore be a need to install an extra cylinder oil tank. It is unlikely that this would be too great an issue in larger vessels but could be problematic depending on the available space in the engine room and its original design.

4.3 Fuel Tank Installation Issues

4.3.1 Cost Isolation

Ship building is costed on the basis of steel weight as opposed to individual component parts. It is therefore extremely difficult to isolate the cost of fuel tank installation. This is further complicated by the fact that 75% of the fuel tank is likely to consist of the hull of the tank. There are, however, a number of factors that would impact on costs and these are considered below.

4.3.2 Split Tank or Double Capacity?

The cost of installation will be different as to whether existing distillate tanks were to be split or whether new tanks were installed so as to double capacity.

Dividing the tanks would be feasible, however complex information would be required as to the relative requirements for quantities of low and high sulphur distillates. This information is needed to inform what proportions the tank would be split into and is unlikely to be easy to predict owing to changes in commercial emphasis in response to market pressures over the life of the vessel. The principal cost would be the installation of extra pipes and pumps. This is the same in terms of the installation of separate fuel tanks. Costs include installing extra vents, air pipes, filling pipes, gauges, manhole access, as well as the significant costs of testing the tanks.

Doubling the distillate capacity by installing extra tanks is significantly more problematic. Whilst building in the capacity at the design stage may not be such a large cost issue in terms of actual installation, it would cause significant problems in terms of dead weight and stability from carrying extra liquid on board. All shipbuilders consulted within this study stated that through life costs are very significant as increased fuel capacity is likely to require increased vessel size with knock on costs such as increased engine size requirements, increased fuel consumption and so on.

Installing extra tanks on an already operational vessel is also technically problematic. There are significant design issues involved as to where the tank would be fitted. Vessels are not allowed to carry fuel at the far and after ends (collision and watertight bulk heads) and a double bottom is forbidden under Marpol conventions. Without stretching the shape of the vessel, which is likely to be an excessively expensive exercise, the vessel would have to lose cargo space to make room for the extra fuel tank. On smaller vessels such as ferries this is not feasible because their cargo space is essentially limited. On larger vessels, such as oil tankers, whilst it may be feasible, the loss of cargo space is a significant cost issue for commercial vessels and has been described as the “cardinal sin” by several shipbuilders and operators consulted during this study. To give some indication of the implications, a vessel from the fleet of auxiliary tankers currently being built by one shipbuilder that was consulted had a bunkering capacity of 2,000m^3 (for which they now bunker distillates only) relative to a 16,000m^3 cargo capacity. Increasing the bunkering capacity could have a significant impact on cargo capacity and it is this loss over the life of the ship that could represent a significant economic cost to the ship operator. However, were the vessel is bunkering predominantly heavy fuel oil with small quantities of distillates for the purposes of starting the engines and manoeuvring in port, the increased capacity required to run two grades of distillate may be less significant in terms of less cargo capacity.

Estimates of capital costs for installing an extra fuel tank on an already operational vessel ranged from €25K for a 30m vessel to €80K for a 100m vessel. These costs include tank installation as well as the required pumps, gauges etc. However, shipbuilders unanimously stated that these costs could only be estimated with any degree of accuracy by completing a series of case studies involving the commissioning of this work across a range of vessel types. There would be no significant variation in cost across EU countries in terms of ship alterations.

From this analysis it is likely that splitting existing distillate fuel tanks would be less costly and problematic than installing extra tanks if dual fuel capacity was desired.

4.3.3 Major Conversion Issues

One important issue raised was that the installation of new tanks is likely to be considered a major conversion. When an existing vessel undergoes what is considered to be a major conversion it is reclassified as a new ship and must be upgraded throughout to the specifications required of new ships under all relevant international conventions such as MARPOL and SOLAS. Thus, unless an exemption was granted by the International Maritime Organisation, the costs of installing the extra fuel tank could be increased significantly.

4.3.4 Increased Fuel Consumption

Whether installing extra fuel tanks on an existing or new vessel, there will be issues arising in terms of increased fuel consumption. This may either be through loss of cargo capacity resulting in more journeys being required to transport the same cargo and/or increased vessel/engine sizes. Increased vessel and hence engine sizes were consistently quoted by industry representatives as being likely to be required if fuel capacity were increased to enable duel-fuel capacity. Loss of cargo capacity was the most highly cited cause of concern in response to the possibility of increasing fuel capacity to enable bunkering of high and low sulphur distillates, although there is some room for debate here as vessels may not always load to design capacity.

If fuel consumption were increased through increased capacity, it would be important to consider whether the increase in fuel consumption resulted in an aggregate increase in sulphur emissions despite the increased capacity to burn low sulphur distillates. However, it should be noted that marine gas oils have a higher specific energy implying lower specific fuel consumption when using them. This would be offset against any potential increases in fuel consumption discussed in this section.

4.3.5 Operational Issues

The bunkering of two grades of distillate would require different operational procedures than those currently pursued requiring personnel to ensure the correct distillate is bunkered in the correct tanks according to sulphur content (which is distinct from ISO 8217 grade) as opposed to all distillates being bunkered in the same tanks. This would require a degree of retraining on behalf of the personnel responsible for bunkering operations and raises the possibilities of human error in terms of ensuring that the correct distillates are bunkered in the appropriate tanks. Clear marking to distinguish between low and high sulphur distillates may be required.

4.4 Data Quality

Data Sources

Data sources consisted of a representative sample of shipbuilders and repairers as well as trade organisations. It is considered that those organisations consulted are in the best position to provide an overview of the feasibility of ships storing multiple grades of marine distillates.

Data Age, Geographical and Technical Coverage

The data is up to date as of April 2002. Technical coverage is comprehensive. Consultation was undertaken predominantly in the UK. UK costs and issues are considered representative of the European situation due to the international nature of the shipbuilding industry.

Data Precision, Completeness and Representativeness

The data is considered comprehensive and precise to the extent achievable within the time and budget limits of this study. The overview is representative of the situation across Europe.

Consistency and Reproducibility

Data collection and analysis were carried out in a consistent and systematic manner through the use of standardised questions to industry contacts and constant internal review by the project team. The level of detail of data collection and interrogation is considered appropriate to meet the goal and scope of the study.

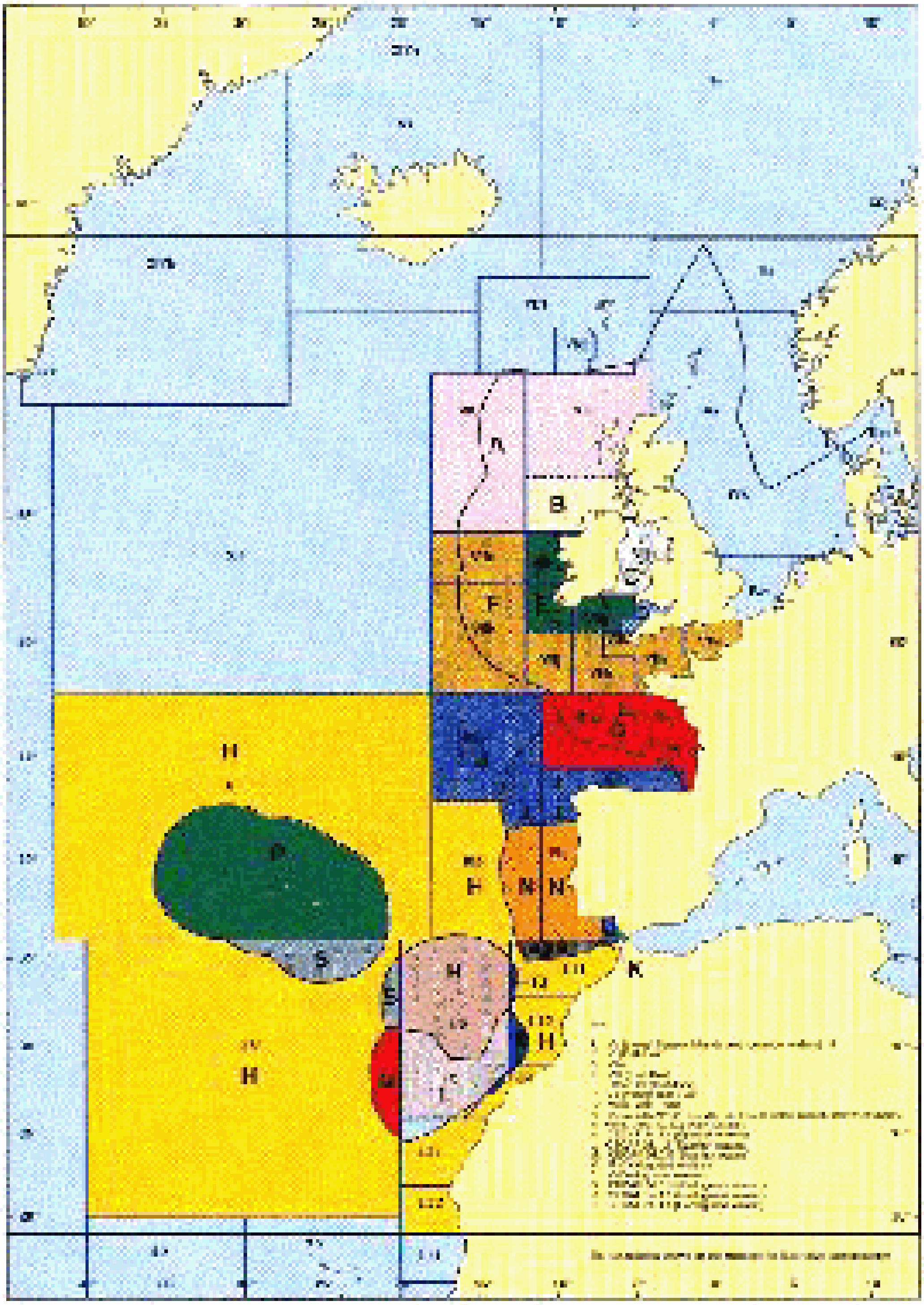
Uncertainties

Without a series of case studies commissioning the design and costing of the required alterations to various vessel types it is impossible to gain accurate information as to the actual cost of installing a dual fuel regime. However, it is unlikely that such an undertaking would raise any other significant issues than those provided within the general overview provided here.

Appendix A
Map of Fishing Effort Zones

1 Page

FISHING EFFORT ZONES



Reproduced from The European Area - Fishing Areas and Quotas. La Tene Maps, Ireland

Appendix B
Details of In-Port Times

2 Pages

SUMMARY SHEET of all port information received.

Main shipping type	Subcategories	Indicate length of time spent (in hours, per port visit)				
		Hotelling	Manoeuvring	Loading and unloading	Additional activity (please state)	Manoeuvring from one berth to another
Tankers	Liquefied gas	12	0.5 – 1.5	6 - 36		
	Chemical	10	0.5 - 1	6 - 12		
	Oil	10 – 48	0.5 - 2	8 - 24		
	Other liquids	24	0.3 – 1.3	12 – 48		1.13
Bulk carriers	Bulk dry	3 - 24	0.5 – 3	8 – 120		1.45
	Bulk dry/oil	0		72 – 96		
	Self discharging bulk dry (note 1)	0	1	6		
	Other bulk dry	9.5	0.2 – 0.5	3 - 6		
Dry cargo/passenger	General cargo	23 hours – 1 year	0.5 – 1.2	6 - 276		1.23
	Passenger/general (note 2)	0 – all year	0.2 – 0.4	Abt 1		
	Container	4 - 60	0.5 – 1	4 - 14		0.93
	Ro-ro cargo	4 - 12	0.5 – 1.3	3 - 76		1.18
	Passenger/ro-ro cargo	4	0.5 – 6	3 - 26		0.3
	Passenger	0	0.5 – 0.75	2 - 12		
	Other dry cargo	0	1 - 1.5	24 to 96		1.1

Main shipping type	Subcategories	Indicate length of time spent (in hours, per port visit)				
		Hotelling	Manoeuvring	Loading and unloading	Additional activity (please state)	Manoeuvring from one berth to another
Fishing	Fish catching	48	0.5 - 1	6 - 30		
	Other fishing	0 – all year	0,1	0.5		
Offshore	Offshore supply	24	2	22		
	Other offshore	24	0.5	0		
Miscellaneous	Research	3 - 10 / all year	0.5 to 1.3	non applicable / 0 / 2017 (almost non stop activities in the port)		
	Towing/pushing	3 – 96 / all year	0.5 – 1.3 - as much as they can abt 300Hr/year each	non applicable / 0 / 12 – 170	3 weeks to 3 months working	1.03
	Dredging	744	3 - 62	4 - 124		
	Other activities	0	1.5	1071 (almost non stop activities in the port)		0.78
Non-seagoing merchant ships	Tanker	0			10 – 12 hours (supply)	
	Dry cargo/passenger	0 / 6 - 48	0.5	0.5	1 –3 hours (crew change)	
	Other non-seagoing	0 / 3 - 10				
Non-merchant ships		72	1 – 1.4	0 - 49		0.58
Non-propelled		336	2	12 - 40		

Notes – 1) vessel does not have to go into port to unload; 2) general cargo vessel that also has capacity for passengers

Appendix C
Factors Influencing Ship Emissions

26 Pages

C.1.1 Engine type

Apart from a very few exceptions where power cables from land sources are connected and used on board vessels in port, ships are self sufficient regarding energy supply. A general overview of potential combustion (and emission) sources and their use on board ships is presented in Table C.1. In terms of number and emission magnitude, *Main (ME)* and *Auxiliary (AE) diesel engines* dominate by far, followed by turbine machinery (steam and gas turbines). Emissions from boilers, emergency diesel engines and waste incinerators are relatively very small and can be considered negligible (excluded hereafter). Rather than size, ME and AE engines are normally sub-divided according to their engine speed at the crankshaft as: *high speed, medium speed* and *slow speed*[7]. Slow and medium speed engines are more abundant than high speed engines for main engines. For auxiliary engines, high and medium speed engines dominate. Old steam turbine systems, which use steam to drive turbines geared to the propeller shaft, have a relatively low efficiency and consequently are being replaced by diesel engines.

For the world fleet in general, the total installed main engine power consists of 63% as slow speed diesel, 31% as medium speed diesel and 6% as others e.g. gas and steam turbines (IMO, 2000). Engine types by number for the world fleet (ship size > 100 GRT) are reported as 65,7% (slow speed diesel), 32,2% (medium speed diesel) and 2,1% (other) (Davies et al., 2000). In a 1990 emission study for the Mediterranean Sea including ca. 7300 vessels (Lloyds Register Engineering Services, 1999), the number of engines were reported as 47,3% (slow speed diesel), 50,6% (medium speed diesel), and 2,1% (steam turbine) while based on installed power, the proportions were 65,8% (slow speed diesel), 26,2% (medium speed diesel), and 8,0% (steam turbine).

In contrast to CO_2 and SO_2 emissions, which are fuel dependent emissions, emissions of NO_x are particularly dependent on the combustion process (engine type). For slow speed engines a longer period at higher temperatures occurs which gives improved of combustion efficiency but greater thermal fixation of nitrogen in the combustion air to NO_x. Thus the new maximum allowable NO_x emission limits for marine diesel engines (IMO Technical NO_x Code, 1997) are directly related to the rated speed of the engine.

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[7] Refers to engine speed at the crankshaft in terms of number of revolutions per minute (rpm). For the purposes of this study, slow speed has been assigned to engines with speeds between 60 - 300 rpm, medium speed as 300 - 1000 rpm and high speed as 1000 - 3000 rpm. In some cases, high and medium speed diesel engines are combined collectively and termed simply medium speed diesel engines.

Table C.1. Marine combustion sources

Combustion source [a]	Application / Types
Main Engine (ME)	Primarily ship propulsion. Modifications include addition of shaft generator (for providing electric power at sea instead of AEs) and addition of exhaust boiler (for providing steam for heating purposes). Normally MEs are shut down in port. [b] Almost entirely diesel engines [c]; mostly medium speed 4-stroke or slow speed 2-stroke. Generally, engine drives propeller axle with or without a gear system but in a few cases diesel-electric operation is used (generator used to drive an electric motor for propellers).
Auxiliary Engine (AE)	Electric power generation on board for lighting, ventilation, cranes, pumps etc. Normally shut down at sea when a shaft generator on the MEs is used or when diesel-electric operation is used on board. Diesel engines; either high speed 4-stroke or medium speed 4-stroke. Engines drive a generator unit.
Emergency Engine	For electric power generation during short-term operations (e.g. use of bow-thrusters during manoeuvring in port) or in emergency situations (AE failure). Diesel engines; either high speed 4-stroke or medium speed 4-stroke. Engines drive a generator unit.
Boiler	For heat production on board (can be used in conjunction with boilers installed on the exhaust channels of MEs). Small oil burners used normally periodically.
Incinerator	For burning ship waste on board (often for larger transoceanic ships). Incinerator usually based on a simple stove.

[a] For hydrocarbons, in addition to emissions from combustion sources, significant evaporative emissions of VOCs (Volatile Organic Compounds) occur during loading and unloading operations in port for tankers. These emissions fall outside the scope of this study but have been examined in a previous study for the European Commission by AEA Technology, available at http://www.europa.eu.int/comm/environment/air/vocloading.pdf.

[b] Exception is for some tankers which can use MEs for unloading and loading operations in port.

[c] Exceptions include gas and steam turbines.

C.1.2 Fuel type

Ships consume a variety of fuels classed primarily by their viscosity, ranging from "distillates" through to heavier "residual oils (RO)". Within the distillate classification, a further division is normally made between marine gas oils (MGO) and marine diesel oils (MDO). For the purposes of this study, RO are classed as fuels with viscosity (measured at 50 ^{o}C) between 55 - 810 cst, MDO between 5,5 - 50 cst and MGO 1 - 5,5 cst [8]. A further description of fuel types and their properties is presented in Table II where average elemental analyses are based on 50 (RO), 11 (MDO) and 43 (MGO) analyses (from IVL's in-house database, Lloyds Register Engineering Services, 1990a and Lloyds Register Engineering Services, 1990b). Since most of the fuel samples in Table C2 were obtained from ships operating in northern EU seas, it should be noted that the fuel data (e.g. sulphur content) may not be entirely representative of the EU shipping fleet as a whole. Subsequently, a value of 2,7% sulphur for RO recently reported to IMO for the year 2000 (IMO MEPC, 2001) was used in the proposed emission factors. This can be compared to 2,5% sulphur for RO which was the average value for the year 2001 sold by the EU states in a recent study examining sulphur content in ROs (Beicip-Franlab, 2002). It should be borne in mind that national or regional (EU) characteristics of fuels *sold* may not be the same as those fuels *used* by the fleet in that area. Thus it cannot be assumed that vessels operating in the EU have the same fuel sulphur content as the average sulphur value of sold fuels in the EU.

An estimate for 1996 reported the world consumption to consist of 28% distillates and 72% residuals (IMO, 2000). Although a similar profile is reported for the EU (24% distillates and 76% residuals), this can vary significantly between EU nations (Davies et al., 2000; Beicip-Franlab, 2002). For example, between 1990-1996 the percentage of distillate fuels of total fuel sales varied from 47,8 % (United Kingdom) to 13,8% (France) while the average for the EU was 23,6% (Davies et al., 2000).

For CO_2 and SO_2 emissions, the carbon and sulphur content of the fuel dictates the resulting emission since virtually all carbon and sulphur is completely burnt to their dioxides. The carbon contents can be compared with 86,5% which corresponds to that given for all fuels from the Lloyds Register CO_2 emission factor, 3170 kg CO_2/tonne fuel or 660 g/kWh, (Lloyds Register Engineering Services, 1995) used in most marine emission inventories to date. Previously assigned sulphur contents for the different fuel types have varied however; distillate 0,5% and residual 2,7% (Lloyds Register Engineering Services, 1995), distillate 2,0% and residual 3,3% (Corbett and Fischbeck, 1997), and distillate 0,3 – 1,0% and residual 2,5 – 3,5% (IMO, 2000). From data collected over 1990-1996, the global average sulphur contents in marine fuel oils have been reported as 2,75 – 2,95%. Some variation exists however between nations; thus for the same period, the average sulphur content for the Netherlands was 3,05%, USA 2,54% and for the UK 2,35% (Davies et al., 2000). In addition, a set of three SO_2 emission factors was used to account for different sulphur contents in bunker fuel oil, BFO, (3%), marine diesel oil, MDO, (1%) and marine gas oil, MGO, (0,2%) (Trozzi and Vaccaro, 1998a).

In addition, correlations between fuel type and NO_x (e.g. fuel nitrogen content), HC (cetane index or ignitability) and PM (sulphur and ash contents) emissions also exist.

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[8] A more in depth fuel classification, where divisions of 4 distillates and 15 residual oils are defined, is presented elsewhere (ISO, 1996b).

Table C.2. Marine fuel types and general properties. Data based on averages from 50 analyses of ROs, 11 analyses of MDOs and 43 analyses of MGOs from ships operating in northern EU seas.

Fuel type	Properties			
Residual Oil (RO)	Density at 15 ^{o}C (kg/m^{3}):	0,965	Viscosity at 50 ^{o}C (mm^{2}/s):	204
(Viscosity 50 - 810)	Effective heating value (MJ/kg):	40,96		
	Carbon (%):	86,61	Hydrogen (%):	11,34
	Sulphur (%):	1,91	Nitrogen (%):	0,33
	Oxygen (%):	<0,1		
Marine Diesel Oil (MDO)	Density at 15 ^{o}C (kg/m^{3}):	0,900	Viscosity at 50 ^{o}C (mm^{2}/s):	19,3
(Viscosity 5,5 - 50)	Effective heating value (MJ/kg):	42,19		
	Carbon (%):	86,68	Hydrogen (%):	12,62
	Sulphur (%):	0,93	Nitrogen (%):	<0,1
	Oxygen (%):	<0,1		
Marine Gas Oil (MGO)	Density at 15 ^{o}C (kg/m^{3}):	0,852	Viscosity at 50 ^{o}C (mm^{2}/s):	3,1
(Viscosity 1 - 5,5)	Effective heating value (MJ/kg):	42,65		
	Carbon (%):	86,74	Hydrogen (%):	13,23
	Sulphur (%):	0,23	Nitrogen (%):	<0,1
	Oxygen (%):	<0,1		

C.1.3 Engine size, age, condition and power output

In general, emission correlations with engine size (MCR kW) age, condition (service intervals) and power output are difficult to isolate from a limited dataset of measurements on board operating ships. Since considerable variation and spread can exist in the data, the significance of a suspected correlation can often prove questionable.

Some data show that with increasing engine MCR size, specific emissions[9] of CO and HC decrease slightly at a given % engine load (Lloyds Register Engineering Services, 1995). For NO_x a weak correlation is evident where specific emissions increase slightly with engine size (Figure C.1.). In view of the spread in data however, a differentiation of assigned emission factors based on engine size appears not to be warranted.

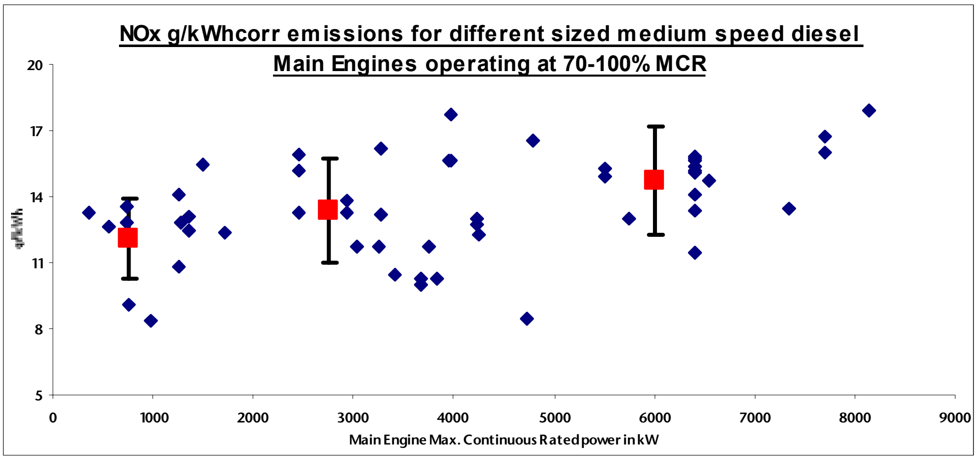

Figure C.1. Main Engine specific NO_x emissions for medium speed diesel engines operating at 70 - 100% MCR. Data from 53 measurements on 47 engines onboard 39 ships undertaken by IVL and Lloyds Register Engineering Services. Mean emission and standard deviations are shown in the diagram for three engine size groups (i) 350 - 1500 kW MCR, (ii) 1500 - 4000 kW, and (iii) 4000 - 8200.

The specific emission across the power output range of engines, irrespective of engine size, varies depending on the pollutant in question. SO_2 and CO_2 emissions follow the specific fuel consumption curve which normally remains fairly constant over the power range but tends to have a minimum at the designed operating load (usually ca. 80% of MCR). Specific HC, PM and CO emissions show increased levels at lower engines loads which is further accentuated for relatively cold engines at start-up. For NO_x no clear and universal trend is apparent, thus specific NO_x emissions have been observed to both increase and decrease with power for different engines. Emissions expressed as a mass flow rate, kg/hr, will generally always increase as the power of the engine increases.

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[9] Specific emission refers to the emission in g/kWh i.e. expressed on the basis of brake power at the crankshaft per unit time. This can be compared with emissions which can be loosely expressed as either a mass flow rate of a pollutant in kg/hr, or in kg/ tonne fuel burnt.

C.2 Marine emission data sources

Several studies involving marine emission factors are present in the literature. These can be subdivided into two categories; studies where emission measurements on marine engines have been carried out on board ships in operation, and, studies where data from other reports have been compiled and reused in different emission inventory applications.

C.2.1 IVL in-house emission database

IVL Swedish Environmental Research Institute has several years' experience of research and contract work involving marine emission measurements on board 35 different ships (as of 1st February 2002). Where available, measurement techniques have followed international standard procedures. Thus from 1994 onwards, measurements followed firstly the draft and then the final standard which subsequently became ISO 8178 (1996) and the "Simplified Measurement Method" in IMO's Technical NO_x Code (1997). Some of the data are presented in peer-reviewed, publicly available reports (Cooper and Andreasson, 1998; Cooper, 2001; Cooper and Peterson, 1993; Cooper and Peterson 1995; Cooper and Peterson, 1996; Cooper et al., 1996). A description of the IVL database is presented in Table C.3.

Table C.3. Details of the IVL in-house emission database.

Characteristic of database	No.	Comments
No. of vessels	35	ages: 1972 - 2000, GRT: 450 - 59000
Passenger ferries	12	
Roro	5	
HSC passenger ferries	3	
Container	3	
Roro / container	2	
General cargo	2	
Pure truck car carrier	2	
Storo paper carrier	2	
Ice breaker	1	
Ice breaker / tug / supply	1	
Tanker	1	
Buoy tender	1	

Characteristic of database	No.	Comments
Nationality of ships		
Swedish	17	
Dutch	7	
German	4	
Norwegian	3	
British	2	
Finnish	2	
No. of Engines included	114	17 engine manufacturers represented, includes 1 gas turbine
slow speed	11	for range 101 - 225 rpm and for range 5180 - 22580 kW
medium speed	75	for range 425 - 1000 rpm and for range 140 - 7350 kW
high speed	27	
No. of Main Engines	55	
No. Auxiliary Engines	59	includes 3 emergency engines
No. fuel analyses	54	25 Residual Oils, 9 Marine Diesel Oils and 20 Marine Gas Oils
No. of emission measurements at given engine load	180	76 measurements with NO_x emission control equipment
NO_x	180	mostly at 75% engine load, but also at max. and other partial loads
SO_2	180	“
CO_2	180	“
HC	76	“
PM	45	“
Listed ship details		Ship name, Ship type, Nationality, Dead weight tonnage, Gross Register tonnage, Length and breadth, Year of delivery, Ship service speed, Engine configuration,
Listed engine details		Engine manufacturer and model, Engine type, Cylinder number and alignment, Rate speed rpm, Rated power kW, Exhaust diameter, Abatement technology,
Listed measurement details		Engine load, fuel consumption, exhaust temperature, NO_x ambient correction factor, exhaust flow, location of measurement, date of measurement, emissions measured where applicable (NO_x, SO_2, CO_2, CO, HC, PM, NH_3, N_2O, PAH, CH_4, N_2O).
Listed fuel analysis details		Density, Viscosity, Heating value, C, H, N, O, S

Following a review and compilation of the data, several points concerning the IVL data are worth noting:

- Although the IVL database is relatively large, the choice of measurement ships and engines has been influenced by commercial factors rather than with the purpose of obtaining representative data of the shipping fleet in general.
- For campaigns prior to 1994, exhaust flow was measured by Pitot tube which is expected to increase uncertainty in these measurements. Some of this old data has however been corrected with exhaust flows calculated from fuel consumption data according to current standard procedure (IMO Technical NO_x Code, 1997).
- A significant fraction of the measurements has focused on evaluation of NO_x abatement technologies (e.g. Selective Catalytic Reduction systems). Such technologies will have a greater impact on the future emissions but at present cannot be considered as representative for the EU shipping fleet in general (it is estimated that in 2001 only 40 - 60 ships operate in the EU region with NO_x abatement technology).

C.2.2 Lloyds Register Engineering Services emission database

During 1990 - 1995 Lloyds Register Engineering Services (London, England) carried out a comprehensive emission study on board ca. 50 sea vessels (Lloyds Register Engineering Services, 1990a; Lloyds Register Engineering Services, 1990b; Lloyds Register Engineering Services, 1993a; Lloyds Register Engineering Services, 1993b; Lloyds Register Engineering Services, 1995). Consequently the results represent the most commonly used and largest marine emission database at present. Examples where the data has been used for further inventory work include; European Commission 1999a; IMO, 2000; IPCC, 1997; Corbett et al, 1999; EMEP, 2001; Holmegaard Kristensen, 2000; Davies et al. 2000. Measurement procedures were based on US EPA standard procedures. For most of the measurements, the presentation of raw data in the reports enable a check on emission calculations and permit incorporation of the data into other databases[10]. Unlike the IVL database, the choice of measurement ships, engines and operation was with the aim of obtaining a representative set of emissions for the shipping fleet in general. A summary of the Lloyds Register Engineering Services database is present in Table C.4 and the principal emission factors derived in Tables C.5 and C.6.

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[10] Where possible, raw data from Lloyds has been incorporated with the IVL database (in section 4 of this report). A direct incorporation of the specific emission data is not possible since the emissions for a given engine are presented only in diagrams as unlabelled curves, and with data from other engines. The engine specific data reported in table form including measured NO (ppm), CO_2 (%), engine effect (kW), fuel consumption (lit/min), fuel density (kg/lit), fuel carbon and hydrogen contents, ambient conditions allow however a calculation of the engine specific emissions in g/kWh using the carbon balance and standard procedure (IMO Technical NO_x Code). For NO_x, a correction to account for NO_2 can be made (x 1,075) for data based only on a NO measurement. Further one can assume that the temperature of the charge air during the trials was equal to the reference temperature given by the engine manufacturers to enable calculation of the ambient NO_x correction factor.

Table C.4. Details of the Lloyds Register Engineering Services database.

Characteristic of database	No.	Comments
No. of vessels	50	ages: 1963 – 1990, dead wt.: 80 - 172810
Roro ferries	14	
Tanker	11	
Container	3	
Dredger	6	
Bulk carrier	6	
Tug	8	
Rhine barge	1	
Naval unit	1	
No. of Engines included	62	
No. Of Main Engines	57	Including 1 gas turbine unit
Slow speed	15	for range 5296 – 21634 kW
Medium speed	41	for range 364 – 7700 kW
No. Auxiliary Engines	5	Including 1 gas turbine unit
Slow speed	0	
Medium speed	3	for range 960 – 3933 kW
High speed	1	for range 960 – 3933 kW
No. Fuel analyses	48	9 for HFO, 2 intermediate FO, 19 light FO, 18 GO
No. of emission measurements at steady state engine loads		All measurements for engines without emission control. In addition, numerous measurements were made for transient engine load changes (8 ships)
NO_x	ca. 280	at 5 – 9 partial steady-state load settings per ship
SO_2	ca. 280	SO_2 measurements using gas analyser and compared with fuel data
CO_2	ca. 280	at 5 – 9 partial steady-state load settings per ship
HC	ca. 280	at 5 – 9 partial steady-state load settings per ship
PM	ca. 24	Emission factors assigned for fuel type

Characteristic of database	No.	Comments
Listed ship details		Ship type, Dead weight tonnage, Length, Year of delivery, Ship speed,
Listed engine details		Engine type, Cylinder number, Rated power kW
Listed measurement details		Engine load, engine speed, fuel consumption (lit/min), exhaust temperature, ambient conditions, emissions measured where applicable (NO_x, SO_2, CO_2, CO, HC, PM, PAH, nitro-PAH, metals, dioxins, furans).
Listed fuel analysis details		Density, Viscosity (at 50 and 100 ^oC), C, H, N, S

Table C.5. Lloyds Register Engineering Services emission factors in g/kWh and kg/tonne fuel for diesel engines (Lloyds Register Engineering Services, 1995).

	NO_x	NO_x	CO	HC	CO_2	SO_2	PM	PM
	Slow speed	Medium speed					Fuel Oil	Gas Oil
Steady state								
kg/tonne fuel	87	57	7,4	2,4	3170	20 x S%	7.6	1,2
g/kWh	17	12	1,6	0,5	660	4,2 x S%	1,5	0,2

Table C.6. Lloyds Register Engineering Services emission factors in kg/hr. (Lloyds Register Engineering Services, 1995). P = engine power (kW) x engine load (85% MCR), N = No. of MEs, A = Total auxiliary power (kW), C = 1, 2, 3, 4 and 5 where vessel GRT is <1000, 1000-5000, 5000-10000, 10000-50000 and > 50000 respectively.

	ME medium speed	ME slow speed	AE (medium speed)
NO_x	$4{,}25 \times 10^{-3} \times P^{1{,}15} \times N$	$17{,}50 \times 10^{-3} \times P \times N$	$4{,}25 \times 10^{-3} \times A^{1{,}15}$
CO	$15{,}32 \times 10^{-3} \times P^{0{,}68} \times N$	$0{,}68 \times 10^{-3} \times P^{1{,}08} \times N$	$15{,}32 \times 10^{-3} \times A^{0{,}68}$
HC	$4{,}86 \times 10^{-3} \times P^{0{,}69} \times N$	$0{,}28 \times 10^{-3} \times P \times N$	$4{,}86 \times 10^{-3} \times A^{0{,}69}$
SO_2 [a]	$2{,}31 \times 10^{-3} \times P \times N$	-	-
SO_2 [b]	$12{,}47 \times 10^{-3} \times P \times N$	$11{,}34 \times 10^{-3} \times P \times N$	-
SO_2	-		$2{,}36 \times 10^{-3} \times A \times C$

[a] For engines < 2000 kW.

[b] For engines >= 2000 kW.

Following a critical review of the Lloyds reports, several points concerning the work are worth noting:

- According to the reports, NO_x emission factors presented at steady-state engine loads for medium and slow speed engines (Phase I of study i.e. Lloyds Register Engineering Services, 1990a; Lloyds Register Engineering Services, 1990b) refer to NO only (no correction for NO_2 was made). Since the NO_2:NO_x ratio can vary between 0,05 - 0,10, the derived NO_x emission factors are likely to be 5 - 10% too low. Later on in the programme for the transient load campaigns however (Phase II, Lloyds Register Engineering Services, 1993), measurements on NO_x (i.e. both NO and NO_2) were made. According to Lloyds Register Engineering Services, an adjustment was indeed made to take into account NO_2 in the early work and the data was reworked in the final summary report in 1995 (Reynolds, 2002).
- The reworking of early data in the final summary report also explains why the NO_x emission factor for medium speed diesel engines was reported as 59 kg/tonne (Lloyds Register Engineering Services, 1990a; Lloyds Register Engineering Services, 1993a; Lloyds Register Engineering Services, 1993b) and then changed to 57 kg/tonne (Lloyds Register Engineering Services, 1995). Similarly CO, HC, SO_2 and CO_2 emission factors were also slightly reduced in the final 1995 report.
- For the emission factors given in kg/hr (in Table VI above), the origin of the exponent for power (P) was obtained through a regression analysis to correlate engine size and emissions (Reynolds, 2002).
- Considerable effort was directed towards determining transient emissions where ratios of transient/passage and steady state/passage[11] are reported (Lloyds Register Engineering Services, 1993a). On average the transient emissions were not significantly different from steady state to warrant use of specific transient emissions factor (Reynolds, 2002). In the European MEET project (European Commission 1999a) undertaken by TECHNE srl however (section 3.3), emission factors for manoeuvring were assumed to correspond to steady state factors multiplied by the transient/passage ratios standardised for time and fuel consumption from the Lloyds report.
- Fuel consumption in the studies was measured using shipboard installed meters or engine manufacturers data (Reynolds, 2002). Some of the measured fuel consumption rates however appear quite high. For example, for 11 slow speed engines operating at 70 – 85% load, the fuel consumptions reported in the tables of Lloyds Register Engineering Services (1990b), correspond to an average of 223 g/kWh with a range 200 – 243 g/kWh. This is inconsistent with the data presented in Table VI where one can calculate 195 g/kWh for the consumption (from NO_x for

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[11] "Transient" refers to a period of engine operation where the load is changing (e.g. during manoeuvring) and "passage" a period where a ship passes through locks (Lloyds Register Engineering Services 1993a).

slow speed i.e. 17/0,087). (Normally fuel consumptions for slow speed diesels are estimated by manufacturers as lying between 170 - 220 g/kWh. In IMO, 2000 a value of 195 g/kWh was assigned.)

- In determining the NO_x correction factor for humidity, ambient data was generally measured on deck and not at the engine air intake the engine room (Reynolds, 2002).
- Some of the data show extremely large and abrupt emission variability over the power range for the steady state data (Lloyds Register Engineering Services 1990b). For example CO concentrations for ship CT2 which could possibly arise from a change in the fuel injection process (Reynolds, 2002).
- The raw data presented for the PM and micro-pollutant (PAH etc.) is lacking (especially ship and fuel consumption data). No emission factors in g/kWh can be derived for PAH in Lloyds Register Engineering Services (1995) as the data was considered far too few to formulate emission factors (Reynolds, 2002).
- For ship R2 the reported maximum rated engine load is less than the engine output measured during the trials in Lloyds Register Engineering Services 1990a. This error was however corrected when consolidating the data in the 1995 summary report (Reynolds, 2002).
- The gas turbine measurements in Lloyds Register Engineering Services 1993a were part of a separate naval research contract and only selected information released. Thus unfortunately neither fuel consumption nor CO_2 emission could be reported (Reynolds, 2002).
- Most of the NO_x data in the early measurements has been derived from a NDIR (non-dispersive infrared) analyser measuring only NO. As ISO measurement procedure work started and progressed during the course of Lloyds research program, Lloyds performed considerable comparison measurements between NDIR and chemiluminescence techniques to establish their equivalence (Reynolds, 2002). Later on in the Lloyds study, a NO_2 converter and NO_x chemiluminescence analyser was used. Subsequently, ISO 8178 (1996) and IMO's Technical NO_x Code (1997) procedure opted for the chemiluminescence technique to be used for NO_x measurements from marine engines.

C.2.3 TECHNE srl emission inventory work

TECHNE srl have reviewed marine emission factors and developed inventory methodology on behalf of the European Commission in the so-called MEET project (Methodologies for Estimating air pollutant Emissions from Transport) (European Commission 1999a; European Commission 1999b; Trozzi and Vaccaro 1998a, Trozzi and Vaccaro 1998b, Trozzi and Vaccaro, 1998c). Further studies thereafter include an Italian case study (Trozzi et al. 2001) and software development (Trozzi et al., 1999). In addition, other researchers have used their emission factors and methodology for inventory work e.g. in the Turkish Straits (Kesgin and Vardar, 2001).

The methodology calculates emissions for 10 different vessel types (> 100 GRT) using fuel consumption (in tonne/day from an algorithm with GRT as input) and emission factors (in kg/hr). Three sets of emission factors are proposed for 9 different engine/fuel types; for ships in cruise, during manoeuvring and while hotelling. Furthermore, three SO_2 emission factors were used to account for different sulphur contents in bunker fuel oil, BFO, (3% sulphur), marine diesel oil, MDO, (1% sulphur and marine gas oil, MGO, (0,2% sulphur).

A summary of the proposed emission factors and their origin is presented in Table C.7 and C.8. Other emission data sources which were included in the review for comparison purposes were: Alexandersson et al. (1993), Bouscaren (1990), Cooper et al. (1995), Cooper and Peterson (1996), Klokk (1997), Flodström, 1997; Rideout, 1997; and Melhus 1990.

Table C.7. TECHNE's proposed emission factors (in kg/tonne fuel) used for the European Commission's MEET project.

MODE Engine type	NO_x	CO	CO_2	VOC [b]	PM	SO_x [a]	Reference
IN CRUISE							
Steam turbines using BFO	6,98	0,431	3200	0,085	2,50	20s	EPA (1985)
Steam turbines using MDO	6,25	0,6	3200	0,5	2,08	20s	EPA (1985)
High speed diesel engines	70	9	3200	3	1,5	20s	NMTRI (1990)
Medium speed diesel engines	57	7,4	3200	2,4	1,2	20s	Lloyds Register (1995) [c]
Slow speed diesel engines	87	7,4	3200	2,4	1,2	20s	Lloyds Register (1995) [c]
Gas turbines	16	0,5	3200	0,3	1,1	20s	Sowman (1996), EMEP (1996), EPA (1995)
Inboard diesel (pleasure craft)	48	20	3200	26	negl.	20s	EPA (1995)
Inboard gasol. (pleasure craft)	21,2	201	3200	13,9	negl.	20s	EPA (1995)
Outboard gasol. (pleasure craft)	1,07	540	3000	176	negl.	20s	EPA (1995)
MANOEUVRING							
Steam turbines using BFO	6,11	0,19	3200	0,85	2,50	20s	EPA (1985); Scott Environmental Technology Inc. (1981)
Steam turbines using MDO	5,47	0,27	3200	5,0	2,08	20s	EPA (1985); Scott Environmental Technology Inc. (1981)
High speed diesel engines	63	34	3200	4,5	1,5	20s	NMTRI (1990); Lloyds Register (1995) [d]
Medium speed diesel engines	51	28	3200	3,6	1,2	20s	Lloyds Register (1995) [d]
Slow speed diesel engines	78	28	3200	3,6	1,2	20s	Lloyds Register (1995) [d]
Gas turbines	14	1,9	3200	0,3	1,1	20s	Sowman (1996), EMEP (1996), EPA (1995), Lloyds Register (1995) [d]
Inboard diesel (pleasure craft)	48	20	3200	26	negl.	20s	EPA (1995)
Inboard gasol. (pleasure craft)	21,2	201	3200	13,9	negl.	20s	EPA (1995)
Outboard gasol. (pleasure craft)	1,07	540	3000	176	negl.	20s	EPA (1995)

MODE	**NO_x**	**CO**	**CO_2**	**VOC** [b]	**PM**	**SO_x** [a]	**Reference**
Engine type							
HOTELLING							
Steam turbines using BFO	4,55	0	3200	0,4	1,25	20s	EPA (1995)
Steam turbines using MDO	3,11	0,6	3200	0,5	2,11	20s	EPA (1995)
High speed diesel engines	28	120	3200	28,9	1,5	20s	NMTRI (1990); EPA (1995)
Medium speed diesel engines	23	99	3200	23,1	1,2	20s	Lloyds Register (1995); EPA (1995)
Slow speed diesel engines	35	99	3200	23,1	1,2	20s	Lloyds Register (1995); EPA (1995)
Gas turbines	6	7	3200	1,9	1,1	20s	Sowman (1996), EMEP (1996), EPA (1995)
Inboard diesel (pleasure craft)	negl.	negl.	negl.	negl.	negl.	negl.	EPA (1995)
Inboard gasol. (pleasure craft)	negl.	negl.	negl.	negl.	negl.	negl.	EPA (1995)
Outboard gasol. (pleasure craft)	negl.	negl.	negl.	negl.	negl.	negl.	EPA (1995)
Tanker off- and onloading	12	1	3200	0,01	2,11	20s	Scott Environmental Technology Inc. (1981)

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[a] Sulphur content of fuel (% by weight) denoted as “s”.

[b] VOC (Volatile Organic Compounds) can be considered as being equivalent to HC (hydrocarbons) here.

[c] Lloyds Register Engineering Services (1995) uses 3170 kg/tonne for CO_2 and 1,2 kg/tonne for PM (gas oil).

[d] Using ratios between manoeuvring emissions / steady state load emissions as 0,9 (NO_x), 3,8 (CO), and 1,5 (VOC) (i.e. ratios for transient operation: “on passage” standardised for time and fuel consumption in Lloyds Register Engineering Services, 1995).

Table C.8. TECHNE's proposed emission factors (in kg/tonne fuel) for Auxiliary engines. Regression analysis from data provided in EPA, (1985). P = rated power output at generator in kW, L = Load in % of rated power, s = sulphur content of fuel.

	AE Emission factor in kg/tonne fuel
NO_x	$108{,}58 - [2{,}47 \times P] + [0{,}0136 \times P^2] - [0{,}000018 \times P^3] + [0{,}000684 \times P \times L]$
CO	$20{,}72 - [0{,}218 \times L] - [0{,}0231 \times P] + [0{,}000345 \times P \times L]$
CO_2	3200
VOC	$3{,}27 - [2{,}16 \times P] - [0{,}0144 \times P^2] + [0{,}0000203 \times P^3] - [0{,}719 \times L] + [0{,}00476 \times L^2]$
PM	1,1
SO_x	20s

In general, TECHNE's work provides useful marine emission source references and a "bottom-up" approach methodology for calculating ship emissions. Some points worth raising are however:

- Certain emission factors are based on relatively old sources which highlights the need of more up to date emission measurement data from different sources e.g. for high speed diesel engines, tankers off/on loading operations.
- The NO_x factors used for high speed diesel engines (70 kg/tonne in cruise) compared to that for medium speed (57 kg/tonne in cruise) and slow speed (87 kg/tonne in cruise) run against generally accepted trends among branch experts that higher engine speeds produce lower NO_x emissions (their combustion characteristics restrict thermal nitrogen fixation to NO_x) (IMO Technical NO_x Code, 1997). It should also be appreciated that, whilst there is an indirect correlation between engine speed and NO_x emissions, it is combustion temperature and pressure that is the prime determinant of NO_x emission levels.
- The PM factor for medium and slow speed diesel engines is taken from the value given in Lloyds Register Engineering Services (1995) for gas oil only. The value of 7,6 kg/tonne for fuel oil also in Lloyds Register Engineering Services (1995) would probably be a better choice especially for slow speed diesel engines, which normally run on heavier fuel oils (with higher quantities of sulphur and ash).
- The emission factors for hotelling are from ratios of hotelling : cruise reported in US EPA (1985), multiplied with cruise emission factors (i.e. from main engines). The amount of time ships use their main engines while stationary in port is difficult to quantify. For longer harbour stops (> 1 hour) main engines are however normally shut down completely (with the exception of some tankers, and diesel

electric main engine systems) and power for the ship is provided by auxiliary engines (EMEP 2001).

- Emissions from auxiliary engines during hotelling are calculated from formulae derived from a regression analysis of measurements from 4 auxiliary engines at 4 different engine loads (US EPA, 1985). The size of engines (20, 40, 200 and 500 kW) and spread of emission data (e.g. NO_x 19 - 60 kg/tonne, VOC 2,4 - 82 kg/tonne) in the original data casts some doubt on the representativity of the universal emission factors derived.

C.2.4 IPCC Greenhouse Gas Inventory guidebook

The Intergovernmental Panel on Climate Change (IPCC) provide guidelines for calculating marine emissions from ocean-going ships (diesel engines) of the greenhouse gases CO_2, CH_4, and N_2O (and also CO and NO_x). The default emission factors are taken directly from Lloyds Register Engineering Services (1995). Exceptions are however for N_2O and CH_4 where no cited references are given. Table C.9 summarises the emission factors presented by IPCC (IPCC, 1997). A CO_2 emission factor is given separately as 3212 g/kg fuel (which corresponds to a fuel with 87,6% carbon).

Table C.9. IPCC default emission factors for ocean-going ships.

	CH_4	N_2O [e]	NO_x	CO	NMVOC [a]
In g/MJ	0,007	0,002	1,8	0,18	0,052
In g/kg fuel [b]	0,3 [d]	0,08	72 [c]	7,4	2,1 [d]

[a] NMVOC (Non Methane Volatile Organic Compounds) can be considered as HC minus CH_4, or VOC minus CH_4.

[b] No heating value of the fuel given but assumed as 40,4 MJ/kg fuel.

[c] Average of 87 (slow speed diesel engine) and 57 (medium speed diesel engine) g/kg fuel from Lloyds Register Engineering Services (1995).

[d] From an uncited assumption that "12% of VOC (HC) is present as CH_4". HC emission factor given as 2,4 g/kg fuel in Lloyds Register Engineering Services (1995).

[e] No reference cited.

Some comments to note concerning the IPCC data are:

- The default factors are intended for simplified emission inventory methodologies.
- The value for CH_4 is probably too high. 6 measurements of VOC and CH_4 on 3 high speed diesel engines indicate that ca 2% of the total VOC consists of CH_4 (Cooper, 2001; IVL in-house database).
- The value for N_2O can be compared with results from 10 N_2O measurements on 10 medium/high speed diesel engines which indicate an average emission of 0,032 g/kWh or ca. 0,15 kg/tonne (Cooper, 2001; Cooper and Peterson, 1993; Cooper and Peterson, 1994; Cooper and Peterson, 1996; IVL in-house database).

C.2.5 EMEP / CORINAIR Emission Inventory Guidebook

Recently the 3rd edition of the Atmospheric Emission Inventory Guidebook was released by the EMEP Task Force on Emission Inventories (EMEP, 2001). The guidebook outlines two methodologies (simple and detailed) for reporting national marine emissions for EU nations. Suitable emission factors (Tables C.10 and C.11) are provided which are mostly taken directly from Lloyds Register Engineering Services (1995) and IPCC (1997). The emission factor for SO_2 is given as 20 x sulphur content of fuel in wt. % and default sulphur contents are given as 2,7 % for residual fuel and 0,5 % for distillate fuel.

Table C.10. EMEP/CORINAIR emission factors for ships using simplified "fuel consumption" methodology.

	NO_x	NO_x	NO_x	CO_2	CO	NMVOC [a]	CH_4	N_2O
	Slow speed	**Medium speed**	**Composite**					
kg/tonne fuel	87	57	72	3170	7,4	2,4	0,3	0,08

[a] NMVOC (Non Methane Volatile Organic Compounds) can be considered as HC minus CH_4, or VOC minus CH_4.

For the detailed methodology (NO_x, CO, HC and SO_2 emissions) which uses ship movement information (e.g. from LMIS), the emissions factors are given as rates in kg/hr and are directly from Lloyds Register Engineering Services (1995). These are the same as those used previously in emission inventories of the EMEP area and Mediterranean Seas (Lloyds Register Engineering Services, 1995; Lloyds Register Engineering Services, 1999).

Some comments to note concerning the EMEP / CORINAIR data are:

- Uncertainty in the emission estimates for the detailed methodology is given as ±20% for NO_x and HC, and ±5% for SO_2.
- The comments regarding the N_2O and CH_4 factors made for IPCC (1997) in section 3.4 apply equally so for the EMEP/CORINAIR guidebook.
- The Lloyds data pertaining to PM has been omitted, but PM_{10} data for steam and gas turbines are given (from TECHNE, 1997). Note that in the TECHNE report PM_{10} is in fact given as PM.
- The NO_x emission factor for steam turbine propulsion using distillate fuel (3,3 kg/tonne fuel) is ca. 2 times lower than that given in the cited reference TECHNE, 1997.
- The emission factor for NMVOC has been taken directly as the HC emission factor from Lloyds Register Engineering Services (1995) without any deduction for methane.
- Other micro-pollutant emission factors in g/tonne e.g. PAH, metals, HCB, dioxins, speciated VOCs are given but considered as highly uncertain due to lack of data.

C.2.6 EPA marine emission study

In a similar way that TECHNE srl reviewed emission data, the US Environmental Protection Agency has carried out a similar assessment (US Environmental Protection Agency, 2000) with the aim of deriving emission factors for use in developing EPA emission inventories for sea vessels. The review includes a critical discussion of emission data presented in four studies from; the Lloyds Register Engineering Services database (Lloyds Register Engineering Services, 1990a; Lloyds Register Engineering Services, 1990b; and Lloyds Register Engineering Services, 1995), Environment Canada (1998), Environment Canada (1997), and US Coastguard Headquarters Naval Engineering Division (1995). Of these, data from two studies (Environment Canada, 1998 and 1997) were rejected since the reports did not provide sufficient detail to support the fundamental analysis required.

Details of the Lloyds Register Engineering Services database are presented elsewhere in this report. The US Coastguard study was based on 6 ships with 8 medium speed and 4 high speed main engine diesels. In both cases the raw concentration and engine data of the studies were reworked to obtain emission factors. Thereafter a rather elaborate regression analysis was performed with Lloyds and US Coastguard data to give emission factor algorithms as a function of engine load (Table C.11). With some reservation, the algorithms are intended for all marine engines.

Table C.11. Emission factors derived by EPA from Lloyds Register Engineering Services and US Coastguard studies. In addition, specific fuel consumption can be calculated by sfc = 14,12/ (Fractional load) + 205,717. n/a refers to "not applicable" and "n/s" not significantly significant.

Emission factor g/kWh	**y**	**b**	**a**
= [a x (Fractional load)$^{-y}$] + b			
PM	1,5	0,2551	0,0059
NO_x	1,5	10,4496	0,1255
NO_2	1,5	15,5247	0,18865
SO_2	n/a	n/s	2,3735 [a]
CO	1	n/s	0,8378
HC	1,5	n/s	0,0667
CO_2	1	648,6	44,1

a) SO_2 emission in g/kWh = [a x (Fuel Sulphur flow in g/kWh)] + b

For comparison purposes, emission factors (in g/kWh) for a marine engine operating at 80% of maximum load (i.e. Fractional Load = 0,80) can be calculated as:

PM = 0,26, NO_x = 10,6; NO_2 = 15,8; CO = 1,05; HC = 0,09; CO_2 = 704; SO_2 = 14,3 (where specific fuel consumption = 223,4 g/kWh and an RO fuel of 2,7% is assumed).

Some comments concerning this EPA study are:

- Expression of the NO_x and NO_2 emission factors did not follow conventional reporting routines (where mass of NO_x is taken as NO_2) (Meszler, 2002). Instead the NO_x emission factor in the EPA report is based on a weighted mass of the NO:NO_2 ratio mix as it exists in the exhaust i.e. 95:5. The NO_2 emission factor given in the report is where all the NO_x is taken as NO_2 (i.e. as in the conventional reporting routine). Thus the NO_2 emission factor in the EPA study can be compared to the NO_x emission factors in this report.

- The data analysis in the report "showed no statistically significant differences in emission rates by engine size or output range, or by two-stroke/four stroke" (i.e. slow and medium speed). Most emission studies report however some significant differences e.g. NO_x emission factors are generally 20-30% higher for slow speed than medium speed diesel engines.

Generally, all US emission factor data are compiled and presented in the EPA emission factor guidebook known as AP-42 (currently 5th Edition) of which volume II specifically deals with mobile sources. Regarding marine emission factors however, only factors for small recreational craft are provided. Some other marine factors for larger engines (ships) were presented in the 4th Edition but these have now been removed from the guidebook (Janssen, 2002).

C.2.7 European Commission

BMT Murray Fenton Edon Liddiard Vince Ltd undertook a contract for the European Commission to assess economic, legal, environmental and practical implications of a European Union system to reduce ship emissions of SO_2 and NO_x (Davies et al., 2000). In addition to an in depth discussion of policy options and recommendations, the report presents an informative overview of marine fuel sulphur levels and emission inventories in the appendices. Although emission factors are not compiled directly, with the exception of data from Lloyds Register Engineering Services, several emission inventory studies are compared and a useful analysis presented.

C.2.8 International Maritime Organisation

The International Maritime Organisation (IMO) have in many earlier instances quoted marine emission factors as those derived form the Lloyds Register Engineering Services work. In a more recent IMO initiative undertaken by a Norwegian and an American collaboration examining greenhouse gas emissions (IMO, 2000) however, marine emission factors from Lloyds Register Engineering Services were compared to other data sources. These included emission measurement datasets from Marintek, (7 measurement series from medium speed engines), several undisclosed engine manufacturers (22 measurement series of which 11 were for slow speed diesel engines and 11 medium speed diesel engines), and partly from Germanischer Lloyd (35 measurement series). A summary of the data is presented in Table C.12 below. It should be noted that the engine manufacturer value for NO_x and slow speed engines is based on the combination of the specific NO_x emission (g/kWh) and fuel consumption. Since engine manufacturers tend to indicate relatively low fuel consumptions, the NO_x emission in kg/tonne fuel is considered high (Skjolsvik, 2002).

Table C.12. A comparison of marine emission factors in kg per tonne fuel and fuel consumption in g/kWh presented in IMO (2000).

Mean values	**Engine manufact. Slow Speed**	**Engine manufact. Med. Speed**	**Lloyds Slow Speed**	**Lloyds [a] Med. Speed**	**Marinteks Lolw Speed**	**Marintek Med. Speed**	**Ger. L Slow Speed**	**Ger. L Med. Speed**
NO_x [e]	105,4	61,2	80,4	57,5	-	63,8 [b]	-	
CO	3,3	2,8	8,7	7,9	-	6,1	-	
HC	7,7	1,8	7,0	6,6	-	2,1	-	
CO_2	-	-	3153	3165	-	3171	-	
NO_x g/kWh	17,9	11,2	18,2	13,8		14,2		12,6 [c]
sfc [d]	170	184	230	243	-	222	-	207
St. dev.	2,1	7,6	15,9	15,1	-	4,3	-	-

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[a] Note that only 28 data sets (9 slow speed and 19 medium speed) from Lloyds Register Engineering Services were analysed in IMO, 2000. Some Lloyds data (tugs, dredgers etc.) was discarded and the raw data reworked using ISO 8178 methodology (i.e. ISO (1996a).

[b] This can be compared with earlier Marintek measurements on board 15 ships in 1989-1990, which gave a mean emission of 63 kg/tonne fuel for NO_x.

[c] Based on 17 data sets for main engines.

[d] Sfc refers to specific fuel consumption. Note that these values are not necessarily those used to derive the NO_x emissions presented in g/kWh.

[e] According to the report all NO_x measurements were based on NO.

In contrast to most marine emission studies, the IMO (2000) report addresses and attempts to quantify the uncertainties in emission factor determinations. By examining the variability and the spread in the underlying data, which in some cases is significant, an estimate of the uncertainty at the 95% confidence level for the data was made (Table C.13).

Table C.13. Estimated uncertainties given as relative percent of average value at the 95% confidence interval.

	Engine Manufacts low speed	Engine manufact. med. speed	Lloyds slow speed	Lloyds medium speed	Marintek slow speed	Marintek medium speed
NO_x	11	24	29	16,3	-	10,5
CO	27	86	114	37	-	39
HC	16	100	109	38	-	43
CO_2	-	-	1,2	0,5	-	0,5

Based on the above assessment, marine emission factors in the form of a range were proposed for this report in addition to those used in recognised standards (EMEP, 1999; Lloyds Register Engineering Services, 1995).

The full listing of emission factors is contained in Tables in the main body of this report.

C.3 Acknowledgement

IVL express their gratitude to numerous experts in the field of marine emissions who have contributed with valuable comments during the course of this work. In particular, Jim Corbett (University of Delaware, USA) and Kjell-Olav Skjolsvik (Marintek, Norway) are thanked for peer-reviewing the report.

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Appendix D
Breakdown of Vessel Profiles

14 Pages

A11 Liquified Gas

Engine Speed / Fuel Class	% of Installed ME Power	% of Installed AE Power
SSD - MGO	0.00%	0.0%
SSD - MDO	0.00%	0.0%
SSD - RO	34.76%	0.0%
MSD - MGO	0.00%	5.6%
MSD - MDO	0.00%	0.0%
MSD - RO	7.00%	52.4%
HSD - MGO	0.00%	4.0%
HSD - MDO	0.00%	0.0%
HSD - RO	0.00%	38.0%
GT - MGO	0.00%	0.0%
GT - MDO	0.00%	0.0%
GT - RO	0.00%	0.0%
ST - MGO	10.74%	0.0%
ST - MDO	0.00%	0.0%
ST - RO	47.50%	0.0%
sum	**100.00%**	**100.00%**

A12 Chemical

Engine Speed / Fuel Class	% of Installed ME Power	% of Installed AE Power
SSD - MGO	0.00%	0.0%
SSD - MDO	0.00%	0.0%
SSD - RO	67.21%	0.0%
MSD - MGO	0.00%	0.0%
MSD - MDO	0.00%	0.0%
MSD - RO	30.97%	58.0%
HSD - MGO	0.00%	0.0%
HSD - MDO	0.00%	0.0%
HSD - RO	0.00%	42.0%
GT - MGO	0.00%	0.0%
GT - MDO	0.00%	0.0%
GT - RO	0.00%	0.0%
ST - MGO	0.00%	0.0%
ST - MDO	0.00%	0.0%
ST - RO	1.82%	0.0%
sum	**100.00%**	**100.00%**

A13 Oil

Engine Speed / Fuel Class	% of Installed ME Power	% of Installed AE Power
SSD - MGO	0.11%	0.0%
SSD - MDO	0.00%	0.0%
SSD - RO	75.89%	0.0%
MSD - MGO	0.02%	0.0%
MSD - MDO	0.00%	0.0%
MSD - RO	4.94%	58.0%
HSD - MGO	0.00%	0.0%
HSD - MDO	0.00%	0.0%
HSD - RO	0.16%	42.0%
GT - MGO	0.00%	0.0%
GT - MDO	0.00%	0.0%
GT - RO	0.20%	0.0%
ST - MGO	0.00%	0.0%
ST - MDO	0.00%	0.0%
ST - RO	18.67%	0.0%
sum	**100.00%**	**100.00%**

A14 Other Liquids

Engine Speed / Fuel Class	% of Installed ME Power	% of Installed AE Power
SSD - MGO	0.00%	0.0%
SSD - MDO	0.00%	0.0%
SSD - RO	63.72%	0.0%
MSD - MGO	0.00%	0.0%
MSD - MDO	0.00%	0.0%
MSD - RO	35.68%	58.0%
HSD - MGO	0.00%	0.0%
HSD - MDO	0.00%	0.0%
HSD - RO	0.60%	42.0%
GT - MGO	0.00%	0.0%
GT - MDO	0.00%	0.0%
GT - RO	0.00%	0.0%
ST - MGO	0.00%	0.0%
ST - MDO	0.00%	0.0%
ST - RO	0.00%	0.0%
sum	**100.00%**	**100.00%**

A21 Bulk Dry

Engine Speed / Fuel Class	% of Installed ME Power	% of Installed AE Power
SSD - MGO	0.00%	0.0%
SSD - MDO	0.00%	0.0%
SSD - RO	97.10%	0.0%
MSD - MGO	0.00%	0.0%
MSD - MDO	0.00%	0.0%
MSD - RO	2.29%	58.0%
HSD - MGO	0.00%	0.0%
HSD - MDO	0.00%	0.0%
HSD - RO	0.06%	42.0%
GT - MGO	0.00%	0.0%
GT - MDO	0.00%	0.0%
GT - RO	0.00%	0.0%
ST - MGO	0.00%	0.0%
ST - MDO	0.00%	0.0%
ST - RO	0.55%	0.0%
sum	**100.00%**	**100.00%**

A22 Bulk Dry/Oil

Engine Speed / Fuel Class	% of Installed ME Power	% of Installed AE Power
SSD - MGO	0.00%	0.0%
SSD - MDO	0.00%	0.0%
SSD - RO	87.56%	0.0%
MSD - MGO	0.00%	0.0%
MSD - MDO	0.00%	0.0%
MSD - RO	6.23%	58.0%
HSD - MGO	0.00%	0.0%
HSD - MDO	0.00%	0.0%
HSD - RO	0.00%	42.0%
GT - MGO	0.00%	0.0%
GT - MDO	0.00%	0.0%
GT - RO	0.00%	0.0%
ST - MGO	0.00%	0.0%
ST - MDO	6.21%	0.0%
ST - RO	0.00%	0.0%
sum	**100.00%**	**100.00%**

A23 Self-Discharging Bulk Dry

Engine Speed / Fuel Class	% of Installed ME Power	% of Installed AE Power
SSD - MGO	0.00%	0.0%
SSD - MDO	0.00%	0.0%
SSD - RO	59.19%	0.0%
MSD - MGO	0.00%	0.0%
MSD - MDO	0.00%	0.0%
MSD - RO	22.93%	58.0%
HSD - MGO	0.00%	0.0%
HSD - MDO	0.00%	0.0%
HSD - RO	0.00%	42.0%
GT - MGO	0.00%	0.0%
GT - MDO	0.00%	0.0%
GT - RO	0.00%	0.0%
ST - MGO	0.00%	0.0%
ST - MDO	2.92%	0.0%
ST - RO	14.84%	0.0%
sum	**99.88%**	**100.00%**

A24 Other Bulk Dry

Engine Speed / Fuel Class	% of Installed ME Power	% of Installed AE Power
SSD - MGO	0.00%	0.0%
SSD - MDO	0.00%	0.0%
SSD - RO	87.59%	0.0%
MSD - MGO	0.00%	0.0%
MSD - MDO	0.00%	0.0%
MSD - RO	9.44%	58.0%
HSD - MGO	1.65%	0.0%
HSD - MDO	0.00%	0.0%
HSD - RO	0.00%	42.0%
GT - MGO	0.00%	0.0%
GT - MDO	0.00%	0.0%
GT - RO	0.00%	0.0%
ST - MGO	0.00%	0.0%
ST - MDO	0.00%	0.0%
ST - RO	1.33%	0.0%
sum	**100.00%**	**100.00%**

A31 General Cargo

Engine Speed / Fuel Class	% of Installed ME Power	% of Installed AE Power
SSD - MGO	0.00%	0.0%
SSD - MDO	0.00%	0.0%
SSD - RO	59.53%	0.0%
MSD - MGO	0.67%	0.2%
MSD - MDO	0.00%	0.0%
MSD - RO	37.74%	57.8%
HSD - MGO	0.23%	0.1%
HSD - MDO	0.00%	0.0%
HSD - RO	1.42%	41.9%
GT - MGO	0.00%	0.0%
GT - MDO	0.00%	0.0%
GT - RO	0.00%	0.0%
ST - MGO	0.00%	0.0%
ST - MDO	0.00%	0.0%
ST - RO	0.41%	0.0%
sum	**100.00%**	**100.00%**

A32 Passenger/General Cargo

Engine Speed / Fuel Class	% of Installed ME Power	% of Installed AE Power
SSD - MGO	0.00%	0.0%
SSD - MDO	0.00%	0.0%
SSD - RO	44.25%	0.0%
MSD - MGO	0.00%	0.0%
MSD - MDO	0.00%	0.0%
MSD - RO	55.75%	58.0%
HSD - MGO	0.00%	0.0%
HSD - MDO	0.00%	0.0%
HSD - RO	0.00%	42.0%
GT - MGO	0.00%	0.0%
GT - MDO	0.00%	0.0%
GT - RO	0.00%	0.0%
ST - MGO	0.00%	0.0%
ST - MDO	0.00%	0.0%
ST - RO	0.00%	0.0%
sum	**100.00%**	**100.00%**

A33 Container

Engine Speed / Fuel Class	% of Installed ME Power	% of Installed AE Power
SSD - MGO	0.00%	0.0%
SSD - MDO	0.00%	0.0%
SSD - RO	92.11%	0.0%
MSD - MGO	0.00%	0.0%
MSD - MDO	0.00%	0.0%
MSD - RO	5.83%	58.0%
HSD - MGO	0.00%	0.0%
HSD - MDO	0.00%	0.0%
HSD - RO	0.00%	42.0%
GT - MGO	0.00%	0.0%
GT - MDO	0.00%	0.0%
GT - RO	0.00%	0.0%
ST - MGO	0.00%	0.0%
ST - MDO	0.00%	0.0%
ST - RO	2.06%	0.0%
sum	**100.00%**	**100.00%**

A34 Refrigerated Cargo

Engine Speed / Fuel Class	% of Installed ME Power	% of Installed AE Power
SSD - MGO	0.00%	0.0%
SSD - MDO	0.00%	0.0%
SSD - RO	83.29%	0.0%
MSD - MGO	0.00%	0.0%
MSD - MDO	0.00%	0.0%
MSD - RO	16.65%	58.0%
HSD - MGO	0.00%	0.0%
HSD - MDO	0.00%	0.0%
HSD - RO	0.00%	42.0%
GT - MGO	0.00%	0.0%
GT - MDO	0.00%	0.0%
GT - RO	0.00%	0.0%
ST - MGO	0.00%	0.0%
ST - MDO	0.00%	0.0%
ST - RO	0.00%	0.0%
sum	**99.95%**	**100.00%**

A35 Ro-Ro Cargo

Engine Speed / Fuel Class	% of Installed ME Power	% of Installed AE Power
SSD - MGO	0.00%	0.0%
SSD - MDO	0.00%	0.0%
SSD - RO	45.66%	0.0%
MSD - MGO	0.00%	0.0%
MSD - MDO	0.00%	0.0%
MSD - RO	49.70%	58.0%
HSD - MGO	0.00%	0.0%
HSD - MDO	0.00%	0.0%
HSD - RO	1.14%	42.0%
GT - MGO	0.00%	0.0%
GT - MDO	0.00%	0.0%
GT - RO	0.00%	0.0%
ST - MGO	0.00%	0.0%
ST - MDO	0.00%	0.0%
ST - RO	2.42%	0.0%
sum	**98.93%**	**100.00%**

A36 Passenger/Ro-Ro Cargo

Engine Speed / Fuel Class	% of Installed ME Power	% of Installed AE Power
SSD - MGO	0.00%	0.0%
SSD - MDO	0.00%	0.0%
SSD - RO	3.15%	0.0%
MSD - MGO	0.68%	0.0%
MSD - MDO	0.00%	0.0%
MSD - RO	70.87%	58.0%
HSD - MGO	9.56%	0.0%
HSD - MDO	0.00%	0.0%
HSD - RO	9.88%	42.0%
GT - MGO	5.86%	0.0%
GT - MDO	0.00%	0.0%
GT - RO	0.00%	0.0%
ST - MGO	0.00%	0.0%
ST - MDO	0.00%	0.0%
ST - RO	0.00%	0.0%
sum	**100.00%**	**100.00%**

A37 Passenger

Engine Speed / Fuel Class	% of Installed ME Power	% of Installed AE Power
SSD - MGO	0.06%	0.0%
SSD - MDO	0.00%	0.0%
SSD - RO	2.04%	0.0%
MSD - MGO	0.00%	0.4%
MSD - MDO	0.00%	0.0%
MSD - RO	87.15%	57.6%
HSD - MGO	0.00%	0.3%
HSD - MDO	0.00%	0.0%
HSD - RO	3.79%	41.7%
GT - MGO	0.60%	0.0%
GT - MDO	0.00%	0.0%
GT - RO	0.30%	0.0%
ST - MGO	0.00%	0.0%
ST - MDO	0.00%	0.0%
ST - RO	6.06%	0.0%
sum	**100.00%**	**100.00%**

A38 Other Dry Cargo

Engine Speed / Fuel Class	% of Installed ME Power	% of Installed AE Power
SSD - MGO	0.00%	0.0%
SSD - MDO	0.00%	0.0%
SSD - RO	19.39%	0.0%
MSD - MGO	0.00%	0.0%
MSD - MDO	0.00%	0.0%
MSD - RO	48.95%	58.0%
HSD - MGO	0.00%	0.0%
HSD - MDO	0.00%	0.0%
HSD - RO	0.59%	42.0%
GT - MGO	0.00%	0.0%
GT - MDO	0.00%	0.0%
GT - RO	0.00%	0.0%
ST - MGO	0.00%	0.0%
ST - MDO	0.00%	0.0%
ST - RO	31.07%	0.0%
sum	**100.00%**	**100.00%**

B11 Fish Catching

Engine Speed / Fuel Class	% of Installed ME Power	% of Installed AE Power
SSD - MGO	0.00%	0.0%
SSD - MDO	0.00%	0.0%
SSD - RO	5.16%	0.0%
MSD - MGO	1.46%	0.4%
MSD - MDO	0.00%	0.0%
MSD - RO	84.49%	57.6%
HSD - MGO	0.00%	0.3%
HSD - MDO	0.00%	0.0%
HSD - RO	8.90%	41.7%
GT - MGO	0.00%	0.0%
GT - MDO	0.00%	0.0%
GT - RO	0.00%	0.0%
ST - MGO	0.00%	0.0%
ST - MDO	0.00%	0.0%
ST - RO	0.00%	0.0%
sum	**100.00%**	**100.00%**

B12 Other Fishing

Engine Speed / Fuel Class	% of Installed ME Power	% of Installed AE Power
SSD - MGO	0.00%	0.0%
SSD - MDO	0.00%	0.0%
SSD - RO	62.13%	0.0%
MSD - MGO	0.00%	0.0%
MSD - MDO	0.00%	0.0%
MSD - RO	10.23%	58.0%
HSD - MGO	0.00%	0.0%
HSD - MDO	0.00%	0.0%
HSD - RO	0.00%	42.0%
GT - MGO	0.00%	0.0%
GT - MDO	0.00%	0.0%
GT - RO	0.00%	0.0%
ST - MGO	0.00%	0.0%
ST - MDO	0.00%	0.0%
ST - RO	27.42%	0.0%
sum	**99.78%**	**100.00%**

B21 Offshore Supply

Engine Speed / Fuel Class	% of Installed ME Power	% of Installed AE Power
SSD - MGO	0.00%	0.0%
SSD - MDO	0.00%	0.0%
SSD - RO	1.21%	0.0%
MSD - MGO	4.96%	2.7%
MSD - MDO	0.00%	0.0%
MSD - RO	90.08%	55.3%
HSD - MGO	0.00%	1.9%
HSD - MDO	0.00%	0.0%
HSD - RO	3.75%	40.1%
GT - MGO	0.00%	0.0%
GT - MDO	0.00%	0.0%
GT - RO	0.00%	0.0%
ST - MGO	0.00%	0.0%
ST - MDO	0.00%	0.0%
ST - RO	0.00%	0.0%
sum	**100.00%**	**100.00%**

B22 Other Offshore

Engine Speed / Fuel Class	% of Installed ME Power	% of Installed AE Power
SSD - MGO	0.00%	0.0%
SSD - MDO	0.00%	0.0%
SSD - RO	0.09%	0.0%
MSD - MGO	4.94%	0.0%
MSD - MDO	0.00%	0.0%
MSD - RO	74.90%	58.0%
HSD - MGO	0.00%	0.0%
HSD - MDO	0.00%	0.0%
HSD - RO	17.78%	42.0%
GT - MGO	0.00%	0.0%
GT - MDO	0.00%	0.0%
GT - RO	0.00%	0.0%
ST - MGO	0.00%	0.0%
ST - MDO	0.00%	0.0%
ST - RO	2.28%	0.0%
sum	**100.00%**	**100.00%**

B31 Research

Engine Speed / Fuel Class	% of Installed ME Power	% of Installed AE Power
SSD - MGO	0.00%	0.0%
SSD - MDO	0.00%	0.0%
SSD - RO	6.48%	0.0%
MSD - MGO	0.00%	0.0%
MSD - MDO	0.00%	0.0%
MSD - RO	86.59%	58.0%
HSD - MGO	0.00%	0.0%
HSD - MDO	0.00%	0.0%
HSD - RO	6.93%	42.0%
GT - MGO	0.00%	0.0%
GT - MDO	0.00%	0.0%
GT - RO	0.00%	0.0%
ST - MGO	0.00%	0.0%
ST - MDO	0.00%	0.0%
ST - RO	0.00%	0.0%
sum	**100.00%**	**100.00%**

B32 Towing / Pushing

Engine Speed / Fuel Class	% of Installed ME Power	% of Installed AE Power
SSD - MGO	0.00%	0.0%
SSD - MDO	0.00%	0.0%
SSD - RO	3.30%	0.0%
MSD - MGO	5.22%	0.0%
MSD - MDO	0.00%	0.0%
MSD - RO	63.46%	58.0%
HSD - MGO	1.55%	0.0%
HSD - MDO	0.00%	0.0%
HSD - RO	26.44%	42.0%
GT - MGO	0.00%	0.0%
GT - MDO	0.00%	0.0%
GT - RO	0.00%	0.0%
ST - MGO	0.00%	0.0%
ST - MDO	0.00%	0.0%
ST - RO	0.02%	0.0%
sum	**100.00%**	**100.00%**

B33 Dredging

Engine Speed / Fuel Class	% of Installed ME Power	% of Installed AE Power
SSD - MGO	0.00%	0.0%
SSD - MDO	0.00%	0.0%
SSD - RO	5.09%	0.0%
MSD - MGO	0.00%	0.0%
MSD - MDO	0.00%	0.0%
MSD - RO	89.82%	58.0%
HSD - MGO	0.85%	0.0%
HSD - MDO	0.00%	0.0%
HSD - RO	4.24%	42.0%
GT - MGO	0.00%	0.0%
GT - MDO	0.00%	0.0%
GT - RO	0.00%	0.0%
ST - MGO	0.00%	0.0%
ST - MDO	0.00%	0.0%
ST - RO	0.00%	0.0%
sum	**100.00%**	**100.00%**

B34 Other Activities

Engine Speed / Fuel Class	% of Installed ME Power	% of Installed AE Power
SSD - MGO	0.00%	0.0%
SSD - MDO	0.00%	0.0%
SSD - RO	1.06%	0.0%
MSD - MGO	11.53%	7.3%
MSD - MDO	0.00%	0.0%
MSD - RO	65.15%	50.7%
HSD - MGO	0.84%	5.3%
HSD - MDO	0.00%	0.0%
HSD - RO	10.31%	36.7%
GT - MGO	0.00%	0.0%
GT - MDO	0.00%	0.0%
GT - RO	0.00%	0.0%
ST - MGO	0.00%	0.0%
ST - MDO	0.00%	0.0%
ST - RO	11.11%	0.0%
sum	**100.00%**	**100.00%**

W11 Tanker

Engine Speed / Fuel Class	% of Installed ME Power	% of Installed AE Power
SSD - MGO	0.00%	0.0%
SSD - MDO	0.00%	0.0%
SSD - RO	0.00%	0.0%
MSD - MGO	0.00%	0.0%
MSD - MDO	0.00%	0.0%
MSD - RO	95.34%	58.0%
HSD - MGO	0.00%	0.0%
HSD - MDO	0.00%	0.0%
HSD - RO	0.00%	42.0%
GT - MGO	0.00%	0.0%
GT - MDO	0.00%	0.0%
GT - RO	0.00%	0.0%
ST - MGO	0.00%	0.0%
ST - MDO	0.00%	0.0%
ST - RO	0.00%	0.0%
sum	**95.34%**	**100.00%**

W12 Dry Cargo / Passenger

Engine Speed / Fuel Class	% of Installed ME Power	% of Installed AE Power
SSD - MGO	0.00%	0.0%
SSD - MDO	0.00%	0.0%
SSD - RO	0.00%	0.0%
MSD - MGO	0.00%	0.0%
MSD - MDO	0.00%	0.0%
MSD - RO	0.00%	58.0%
HSD - MGO	0.00%	0.0%
HSD - MDO	0.00%	0.0%
HSD - RO	100.00%	42.0%
GT - MGO	0.00%	0.0%
GT - MDO	0.00%	0.0%
GT - RO	0.00%	0.0%
ST - MGO	0.00%	0.0%
ST - MDO	0.00%	0.0%
ST - RO	0.00%	0.0%
sum	**100.00%**	**100.00%**

W13 Other Non-Seagoing

Engine Speed / Fuel Class	% of Installed ME Power	% of Installed AE Power
SSD - MGO	0.00%	0.0%
SSD - MDO	0.00%	0.0%
SSD - RO	0.00%	0.0%
MSD - MGO	0.00%	0.0%
MSD - MDO	0.00%	0.0%
MSD - RO	0.00%	0.0%
HSD - MGO	0.00%	0.0%
HSD - MDO	0.00%	0.0%
HSD - RO	0.00%	0.0%
GT - MGO	0.00%	0.0%
GT - MDO	0.00%	0.0%
GT - RO	0.00%	0.0%
ST - MGO	0.00%	0.0%
ST - MDO	0.00%	0.0%
ST - RO	0.00%	0.0%
sum	**0.00%**	**0.00%**

Appendix E
Emission Factors for Future Policy Scenarios

16 Pages

Emission factors for scenario "1. 2006"

Emission factors for scenario "1. 2006" are identical to those already presented.

Emission factors for scenario "2. 2006"

Emission factors for scenario "2. 2006" are presented in Tables E.1 – E.3 below. These factors are applied to ship movements in the North Sea/Baltic region only, while the other factors are applied to movements in "other territorial waters".

Table E.1. Emission factors for "at sea" operation (North Sea/Baltic region) regarding ship type (scenario "2. 2006").

AT SEA	NO_x	SO_2	CO_2	HC	sfc	NO_x	SO_2	CO_2	HC
	in g/kWh					in kg/tonne fuel			
A11 Liquefied Gas	8.5	7.0	822	0.3	258	41	27	3179	1.4
A12 Chemical	16.5	6.1	645	0.6	203	83	30	3179	2.8
A13 Oil	14.9	6.5	689	0.5	217	75	30	3179	2.5
A14 Other liquid	16.6	6.1	641	0.6	202	83	30	3179	2.8
A21 Bulk dry	17.9	5.9	624	0.6	196	92	30	3179	3.0
A22 Bulk dry/oil	16.8	5.9	643	0.6	202	86	29	3179	2.9
A23 Self-discharging bulk dry	14.3	6.5	695	0.5	218	71	30	3179	2.4
A24 Other bulk dry	17.4	5.9	631	0.6	198	88	30	3179	2.9
A31 General cargo	16.3	6.0	644	0.6	203	81	30	3179	2.7
A32 Passenger/general cargo	15.8	6.2	653	0.5	205	77	30	3179	2.7
A33 Container	17.5	6.0	631	0.6	199	89	30	3179	3.0
A34 Refrigerated cargo	17.4	6.0	631	0.6	198	88	30	3179	2.9
A35 Roro cargo	15.6	6.2	659	0.5	207	76	30	3179	2.6
A36 Passenger/Roro cargo	13.3	5.5	686	0.4	216	63	26	3179	2.0
A37 Passenger	13.2	6.5	696	0.5	219	62	30	3179	2.2
A38 Other dry cargo	11.1	7.1	757	0.4	238	53	30	3179	1.9
B11 Fish catching	13.9	6.4	685	0.5	215	65	30	3179	2.1
B12 Other fishing	13.3	6.8	722	0.5	227	66	30	3179	2.2
B21 Offshore supply	14.0	6.1	675	0.5	212	66	29	3179	2.3
B22 Other offshore	13.5	6.2	682	0.4	215	63	29	3179	2.1
B31 Research	14.2	6.4	673	0.5	212	67	30	3179	2.3
B32 Towing/Pushing	13.7	6.0	673	0.4	212	65	28	3179	2.0
B33 Dredging	14.1	6.3	674	0.5	212	67	30	3179	2.3
B34 other activities	12.5	6.0	705	0.4	222	59	27	3179	2.0
W11 Other activities	14.0	6.4	678	0.5	213	66	30	3179	2.3
W12 Other activities	12.7	6.4	677	0.2	213	60	30	3179	0.9

Table E.2. Emission factors for “in-port” operation (North Sea/Baltic region) regarding ship type (scenario “2. 2006”).

IN PORT	NO_x	SO_2	CO_2	HC	PM	sfc	NO_x	SO_2	CO_2	HC	PM
	in g/kWh						in kg/tonne fuel				
A11 Liquefied Gas	7.5	7.5	884	0.9	1.3	278	33	27	3179	3.7	5.0
A12 Chemical	13.3	6.7	710	1.5	1.3	223	60	30	3179	6.7	6.1
A13 Oil	12.1	7.1	754	1.4	1.4	237	55	30	3179	6.3	6.0
A14 Other liquid	13.3	6.7	707	1.5	1.4	222	60	30	3179	7.0	6.3
A21 Bulk dry	13.8	6.7	706	1.0	0.9	222	62	30	3179	4.5	4.2
A22 Bulk dry/oil	13.4	6.7	715	0.9	0.9	225	60	30	3179	4.3	4.1
A23 Self-discharging bulk dry	13.1	6.8	727	0.5	0.6	229	58	30	3179	2.4	2.7
A24 Other bulk dry	13.6	6.6	709	1.0	0.9	223	61	30	3179	4.6	4.3
A31 General cargo	13.3	6.7	716	0.9	0.9	225	59	30	3179	4.1	4.1
A32 Passenger/general cargo	13.2	6.8	721	0.6	0.7	227	59	30	3179	2.9	3.1
A33 Container	13.7	6.7	710	1.0	0.9	223	62	30	3179	4.4	4.2
A34 Refrigerated cargo	13.5	6.7	714	0.7	0.8	225	60	30	3179	3.4	3.4
A35 Roro cargo	13.0	6.8	723	0.9	0.9	227	58	30	3179	3.9	3.9
A36 Passenger/Roro cargo	11.3	6.3	746	1.0	1.1	235	49	27	3179	4.4	4.9
A37 Passenger	11.6	7.0	750	1.0	1.1	236	50	30	3179	4.4	4.8
A38 Other dry cargo	11.8	7.2	761	0.7	0.9	239	52	30	3179	2.9	3.5
B11 Fish catching	13.4	6.8	722	0.4	0.5	227	59	30	3179	1.8	2.3
B12 Other fishing	11.3	7.3	776	1.1	1.3	244	51	30	3179	5.1	5.2
B21 Offshore supply	12.0	6.7	734	1.1	1.1	231	52	29	3179	4.6	4.7
B22 Other offshore	12.0	6.8	737	0.9	1.0	232	52	29	3179	3.8	4.3
B31 Research	11.8	6.9	736	1.2	1.3	232	51	30	3179	5.2	5.4
B32 Towing/Pushing	11.8	6.7	734	1.0	1.1	231	51	29	3179	4.2	4.9
B33 Dredging	11.9	6.9	736	1.2	1.2	232	51	30	3179	5.1	5.3
B34 other activities	11.1	6.5	756	1.0	1.1	238	48	27	3179	4.2	4.6
W11 Other activities	12.7	6.9	729	0.8	0.8	229	55	30	3179	3.2	3.5
W12 Other activities	11.2	7.0	738	0.5	1.2	232	48	30	3179	2.3	5.1

Table E.3. Emission factors for “manoeuvring” operation (North Sea/Baltic region) regarding ship type (scenario “2. 2006”).

MANOEUVRING	NO_x	SO_2	CO_2	HC	PM	sfc	NO_x	SO_2	CO_2	HC	PM
			in g/kWh						in kg/tonne fuel		
A11 Liquefied Gas	7.4	7.5	887	0.9	1.3	279	32	27	3179	3.7	5.0
A12 Chemical	13.3	6.7	710	1.5	1.4	223	60	30	3179	6.9	6.2
A13 Oil	12.0	7.1	754	1.4	1.4	237	55	30	3179	6.4	6.1
A14 Other liquid	13.3	6.7	706	1.6	1.4	222	60	30	3179	7.1	6.4
A21 Bulk dry	14.3	6.5	688	1.7	1.4	217	66	30	3179	7.8	6.6
A22 Bulk dry/oil	13.5	6.5	708	1.6	1.4	223	62	29	3179	7.3	6.3
A23 Self-discharging bulk dry	12.0	7.0	751	1.1	1.2	236	54	30	3179	5.2	5.1
A24 Other bulk dry	13.9	6.5	695	1.6	1.4	219	64	30	3179	7.6	6.5
A31 General cargo	13.1	6.6	709	1.6	1.4	223	59	30	3179	7.0	6.4
A32 Passenger/general cargo	12.8	6.8	718	1.4	1.3	226	57	30	3179	6.2	5.8
A33 Container	14.0	6.6	696	1.6	1.4	219	65	30	3179	7.6	6.5
A34 Refrigerated cargo	13.9	6.6	697	1.5	1.3	219	63	30	3179	7.1	6.2
A35 Roro cargo	12.5	6.8	724	1.5	1.4	228	56	30	3179	6.7	6.2
A36 Passenger/Roro cargo	10.6	6.1	754	1.3	1.4	237	46	26	3179	5.4	5.8
A37 Passenger	10.7	7.2	764	1.4	1.5	240	46	30	3179	5.8	6.1
A38 Other dry cargo	9.3	7.8	821	1.1	1.4	258	40	30	3179	4.7	5.5
B11 Fish catching	13.0	6.8	725	0.6	0.7	228	57	30	3179	2.6	3.0
B12 Other fishing	10.7	7.5	792	1.3	1.5	249	49	30	3179	6.0	6.2
B21 Offshore supply	11.2	6.7	742	1.4	1.4	233	48	29	3179	6.1	6.1
B22 Other offshore	10.9	6.8	749	1.3	1.4	236	47	29	3179	5.4	6.0
B31 Research	11.4	7.0	740	1.4	1.5	233	49	30	3179	6.2	6.4
B32 Towing/Pushing	11.0	6.6	740	1.2	1.4	233	48	28	3179	5.3	6.1
B33 Dredging	11.4	6.9	741	1.4	1.5	233	49	30	3179	6.2	6.3
B34 other activities	10.1	6.6	774	1.2	1.4	243	43	27	3179	5.3	5.8
W11 Other activities	11.5	7.0	742	1.4	1.4	233	49	30	3179	5.9	5.9
W12 Other activities	10.2	7.0	744	0.6	1.5	234	44	30	3179	2.5	6.3

Emission factors for scenario “3. 2006”

Additional emission factors for use in scenario “3. 2006” are presented in Tables E.4 and E.5 below. Note that since some in port emissions are from MEs (which will not be affected by the in-port 0,2% MGO AE only legislation) there will be a slight difference for in-port emissions for ships in the North Sea/Baltic compared to “other territorial waters”. Table E.4 refers to the case for “other territorial waters” where ME operation occurs with no capped fuel sulphur limit (i.e. set to 2,7%) and Table E.5 for ships in the ports of the North Sea/Baltic region. Emission factors for at sea and manoeuvring for this scenario are presented in Tables E.1 and E.3 (North Sea/Baltic) and Tables 2.11 and 2.13 (“other territorial waters”) respectively.

Table E.4. Emission factors for “in-port” operation (in “other territorial waters”) regarding ship type (scenario “3. 2006”).

IN PORT	NO_x	SO_2	CO_2	HC	PM	sfc	NO_x	SO_2	CO_2	HC	PM
	in g/kWh						in kg/tonne fuel				
A11 Liquefied Gas	7.4	12.3	881	0.9	2.0	277	33	44	3179	3.7	7.6
A12 Chemical	13.1	10.3	706	1.5	2.1	222	60	46	3179	6.7	9.4
A13 Oil	12.0	11.6	750	1.4	2.2	236	55	49	3179	6.3	9.4
A14 Other liquid	13.2	10.8	703	1.5	2.2	221	60	49	3179	7.0	9.8
A21 Bulk dry	13.4	5.5	688	1.0	1.2	216	62	25	3179	4.6	5.5
A22 Bulk dry/oil	13.0	5.3	697	0.9	1.1	219	60	24	3179	4.4	5.3
A23 Self-discharging bulk dry	12.5	2.4	699	0.5	0.6	220	57	10	3179	2.5	2.5
A24 Other bulk dry	13.2	5.7	691	1.0	1.2	218	61	26	3179	4.6	5.7
A31 General cargo	12.8	5.5	698	0.9	1.2	219	59	25	3179	4.2	5.3
A32 Passenger/general cargo	12.6	3.1	695	0.6	0.7	219	58	14	3179	2.9	3.2
A33 Container	13.2	5.4	691	1.0	1.2	217	61	25	3179	4.5	5.4
A34 Refrigerated cargo	13.0	3.7	690	0.7	0.8	217	60	17	3179	3.4	3.9
A35 Roro cargo	12.6	5.3	703	0.9	1.1	221	57	24	3179	3.9	5.0
A36 Passenger/Roro cargo	11.1	8.0	737	1.0	1.6	232	49	34	3179	4.5	7.0
A37 Passenger	11.3	8.6	739	1.0	1.6	232	50	36	3179	4.5	6.9
A38 Other dry cargo	11.3	5.6	741	0.7	1.0	233	51	22	3179	3.0	4.3
B11 Fish catching	12.6	1.0	691	0.4	0.3	217	58	5	3179	1.9	1.5
B12 Other fishing	11.1	10.4	768	1.1	1.9	242	51	42	3179	5.1	7.9
B21 Offshore supply	11.7	7.9	723	1.1	1.6	227	52	34	3179	4.6	6.7
B22 Other offshore	11.7	6.8	722	0.9	1.4	227	52	29	3179	3.8	5.8
B31 Research	11.6	9.8	729	1.2	1.9	229	51	42	3179	5.2	8.2
B32 Towing/Pushing	11.5	8.1	723	1.0	1.6	228	51	35	3179	4.2	7.0
B33 Dredging	11.7	9.3	727	1.2	1.8	229	51	40	3179	5.1	7.8
B34 other activities	10.9	8.2	747	1.0	1.6	235	48	33	3179	4.2	6.6
W11 Other activities	12.2	4.6	707	0.8	1.0	223	55	20	3179	3.3	4.2
W12 Other activities	10.9	9.0	728	0.5	1.8	229	48	39	3179	2.3	7.5

Table E.5. Emission factors for "in-port" operation (in North Sea/Baltic region) regarding ship type (scenario "3. 2006").

IN PORT	NO_x	SO_2	CO_2	HC	PM	sfc	NO_x	SO_2	CO_2	HC	PM
	in g/kWh						in kg/tonne fuel				
A11 Liquefied Gas	7.4	6.9	881	0.9	1.3	277	33	25	3179	3.7	4.9
A12 Chemical	13.1	5.8	706	1.5	1.3	222	60	26	3179	6.7	5.9
A13 Oil	12.0	6.5	750	1.4	1.4	236	55	27	3179	6.3	5.9
A14 Other liquid	13.2	6.0	703	1.5	1.4	221	60	27	3179	7.0	6.2
A21 Bulk dry	13.4	3.2	688	1.0	0.8	216	62	15	3179	4.6	3.8
A22 Bulk dry/oil	13.0	3.2	697	0.9	0.8	219	60	15	3179	4.4	3.6
A23 Self-discharging bulk dry	12.5	1.7	699	0.5	0.5	220	57	7	3179	2.5	2.0
A24 Other bulk dry	13.2	3.4	691	1.0	0.8	218	61	16	3179	4.6	3.9
A31 General cargo	12.8	3.3	698	0.9	0.8	219	59	15	3179	4.2	3.6
A32 Passenger/general cargo	12.6	2.0	695	0.6	0.5	219	58	9	3179	2.9	2.4
A33 Container	13.2	3.2	691	1.0	0.8	217	61	15	3179	4.5	3.7
A34 Refrigerated cargo	13.0	2.3	690	0.7	0.6	217	60	11	3179	3.4	2.8
A35 Roro cargo	12.6	3.2	703	0.9	0.8	221	57	14	3179	3.9	3.4
A36 Passenger/Roro cargo	11.1	4.6	737	1.0	1.1	232	49	20	3179	4.5	4.6
A37 Passenger	11.3	4.9	739	1.0	1.1	232	50	21	3179	4.5	4.5
A38 Other dry cargo	11.3	3.4	741	0.7	0.7	233	51	13	3179	3.0	3.0
B11 Fish catching	12.6	1.0	691	0.4	0.3	217	58	4	3179	1.9	1.5
B12 Other fishing	11.1	5.9	768	1.1	1.2	242	51	24	3179	5.1	5.0
B21 Offshore supply	11.7	4.5	723	1.1	1.0	227	52	19	3179	4.6	4.5
B22 Other offshore	11.7	4.0	722	0.9	0.9	227	52	17	3179	3.8	3.9
B31 Research	11.6	5.6	729	1.2	1.2	229	51	24	3179	5.2	5.3
B32 Towing/Pushing	11.5	4.7	723	1.0	1.1	228	51	20	3179	4.2	4.6
B33 Dredging	11.7	5.3	727	1.2	1.2	229	51	23	3179	5.1	5.0
B34 other activities	10.9	4.7	747	1.0	1.1	235	48	19	3179	4.2	4.4
W11 Other activities	12.2	2.8	707	0.8	0.7	223	55	12	3179	3.3	3.0
W12 Other activities	10.9	5.1	728	0.5	1.1	229	48	22	3179	2.3	4.9

Emission factors for scenario "4.   2006"

Emission factors for use in scenario "4.   2006" are presented in Tables E.6 and E.7 below. Note that these will be valid for all territorial waters irrespective of other legislation enforcing regional sulphur capping of RO. Emission factors for at sea for this scenario are presented in Table E.1 (North Sea/Baltic) and Table 2.11 ("other territorial waters").

Table E.6. Emission factors for “in-port” operation regarding ship type (scenario “4. 2006”).

IN PORT	NO_x	SO_2	CO_2	HC	PM	sfc	NO_x	SO_2	CO_2	HC	PM
	in g/kWh						in kg/tonne fuel				
A11 Liquefied Gas	7.4	6.9	881	0.9	1.3	277	33	25	3179	3.7	4.9
A12 Chemical	13.1	5.8	706	1.5	1.3	222	60	26	3179	6.7	5.9
A13 Oil	12.0	6.5	750	1.4	1.4	236	55	27	3179	6.3	5.9
A14 Other liquid	13.2	6.0	703	1.5	1.4	221	60	27	3179	7.0	6.2
A21 Bulk dry	13.4	3.2	688	1.0	0.8	216	62	15	3179	4.6	3.8
A22 Bulk dry/oil	13.0	3.2	697	0.9	0.8	219	60	15	3179	4.4	3.6
A23 Self-discharging bulk dry	12.5	1.7	699	0.5	0.5	220	57	7	3179	2.5	2.0
A24 Other bulk dry	13.2	3.4	691	1.0	0.8	218	61	16	3179	4.6	3.9
A31 General cargo	12.8	3.3	698	0.9	0.8	219	59	15	3179	4.2	3.6
A32 Passenger/general cargo	12.6	2.0	695	0.6	0.5	219	58	9	3179	2.9	2.4
A33 Container	13.2	3.2	691	1.0	0.8	217	61	15	3179	4.5	3.7
A34 Refrigerated cargo	13.0	2.3	690	0.7	0.6	217	60	11	3179	3.4	2.8
A35 Roro cargo	12.6	3.2	703	0.9	0.8	221	57	14	3179	3.9	3.4
A36 Passenger/Roro cargo	11.1	4.6	737	1.0	1.1	232	49	20	3179	4.5	4.6
A37 Passenger	11.3	4.9	739	1.0	1.1	232	50	21	3179	4.5	4.5
A38 Other dry cargo	11.3	3.4	741	0.7	0.7	233	51	13	3179	3.0	3.0
B11 Fish catching	12.6	1.0	691	0.4	0.3	217	58	4	3179	1.9	1.5
B12 Other fishing	11.1	5.9	768	1.1	1.2	242	51	24	3179	5.1	5.0
B21 Offshore supply	11.7	4.5	723	1.1	1.0	227	52	19	3179	4.6	4.5
B22 Other offshore	11.7	4.0	722	0.9	0.9	227	52	17	3179	3.8	3.9
B31 Research	11.6	5.6	729	1.2	1.2	229	51	24	3179	5.2	5.3
B32 Towing/Pushing	11.5	4.7	723	1.0	1.1	228	51	20	3179	4.2	4.6
B33 Dredging	11.7	5.3	727	1.2	1.2	229	51	23	3179	5.1	5.0
B34 other activities	10.9	4.7	747	1.0	1.1	235	48	19	3179	4.2	4.4
W11 Other activities	12.2	2.8	707	0.8	0.7	223	55	12	3179	3.3	3.0
W12 Other activities	10.9	5.1	728	0.5	1.1	229	48	22	3179	2.3	4.9

Table E.7. Emission factors for “manoeuvring” operation regarding ship type (scenario “4. 2006”).

MANOEUVRING	NO_x	SO_2	CO_2	HC	PM	sfc	NO_x	SO_2	CO_2	HC	PM
	in g/kWh						in kg/tonne fuel				
A11 Liquefied Gas	7.0	1.1	849	0.9	0.8	267	32	4.0	3179	3.9	3.3
A12 Chemical	12.5	0.8	675	1.5	0.8	212	59	4.0	3179	7.2	3.9
A13 Oil	11.3	0.9	717	1.4	0.8	225	55	4.0	3179	6.7	3.9
A14 Other liquid	12.5	0.8	672	1.6	0.8	211	60	4.0	3179	7.5	4.0
A21 Bulk dry	13.4	0.8	653	1.7	0.9	206	65	4.0	3179	8.2	4.2
A22 Bulk dry/oil	12.7	0.8	675	1.6	0.9	212	61	4.0	3179	7.7	4.1
A23 Self-discharging bulk dry	11.3	0.9	716	1.1	0.7	225	53	4.0	3179	5.4	3.3
A24 Other bulk dry	13.1	0.8	661	1.6	0.9	208	63	4.0	3179	8.0	4.1
A31 General cargo	12.3	0.8	675	1.6	0.9	212	59	4.0	3179	7.4	4.0
A32 Passenger/general cargo	12.1	0.9	684	1.4	0.8	215	56	4.0	3179	6.5	3.6
A33 Container	13.1	0.8	661	1.6	0.9	208	64	4.0	3179	8.0	4.1
A34 Refrigerated cargo	13.0	0.8	662	1.5	0.8	208	63	4.0	3179	7.5	3.9
A35 Roro cargo	11.8	0.9	689	1.5	0.8	217	55	4.0	3179	7.0	3.9
A36 Passenger/Roro cargo	10.1	0.9	725	1.3	0.9	228	45	4.0	3179	5.6	3.8
A37 Passenger	10.1	0.9	728	1.4	0.9	229	45	4.0	3179	6.1	3.9
A38 Other dry cargo	8.8	1.0	782	1.1	0.8	246	40	4.0	3179	5.0	3.5
B11 Fish catching	12.2	0.9	693	0.6	0.4	218	56	4.0	3179	2.8	1.9
B12 Other fishing	10.1	0.9	753	1.3	0.9	237	48	4.0	3179	6.4	3.9
B21 Offshore supply	10.6	0.9	708	1.4	0.9	223	48	4.0	3179	6.4	3.9
B22 Other offshore	10.3	0.9	715	1.3	0.9	225	46	4.0	3179	5.7	3.9
B31 Research	10.7	0.9	705	1.4	0.9	222	48	4.0	3179	6.5	4.0
B32 Towing/Pushing	10.5	0.9	707	1.2	0.9	222	47	4.0	3179	5.5	4.0
B33 Dredging	10.7	0.9	706	1.4	0.9	222	48	4.0	3179	6.5	4.0
B34 other activities	9.6	0.9	741	1.2	0.9	233	43	4.0	3179	5.5	3.8
W11 Other activities	10.8	0.9	708	1.4	0.8	223	49	4.0	3179	6.1	3.7
W12 Other activities	9.7	0.9	709	0.6	0.9	223	43	4.0	3179	2.7	4.0

Emission factors for scenario "5. 2008"

Emission factors for scenario "5. 2008" are identical to those presented in section 2.5.

Emission factors for scenario "7. 2008"

For "other territorial waters" and activities at sea and manoeuvring, the appropriate emission factors are covered in Tables 2.11 and 2.13 respectively of section 2.5. In-port operations for "other territorial waters" are presented in Table E.8 below. Similarly for the North Sea/Baltic region and activities at sea and manoeuvring, the appropriate emission factor tables are covered in Tables E.1 and E.3 respectively. In-port operations for the North Sea/Baltic region are presented in Table E.9 below.

Table E.8. Emission factors for “in-port” operation (in “other territorial waters”) regarding ship type (scenario “7. 2008”).

IN PORT	NOx	SO$_2$	CO$_2$	HC	PM	sfc	NO$_x$	SO$_2$	CO2	HC	PM
	in g/kWh						in kg/tonne fuel				
A11 Liquefied Gas	7.4	12.1	881	0.9	2.0	277	33	43	3179	3.7	7.6
A12 Chemical	13.1	10.2	706	1.5	2.1	222	60	46	3179	6.7	9.4
A13 Oil	12.0	11.5	750	1.4	2.2	236	55	48	3179	6.3	9.4
A14 Other liquid	13.2	10.7	703	1.5	2.2	221	60	48	3179	7.0	9.8
A21 Bulk dry	13.4	5.2	688	1.0	1.2	216	62	24	3179	4.6	5.5
A22 Bulk dry/oil	13.0	5.0	697	0.9	1.1	219	60	23	3179	4.4	5.3
A23 Self-discharging bulk dry	12.5	2.0	699	0.5	0.6	220	57	9	3179	2.5	2.5
A24 Other bulk dry	13.2	5.5	691	1.0	1.2	218	61	25	3179	4.6	5.7
A31 General cargo	12.8	5.2	698	0.9	1.2	219	59	23	3179	4.2	5.3
A32 Passenger/general cargo	12.6	2.8	695	0.6	0.7	219	58	12	3179	2.9	3.2
A33 Container	13.2	5.2	691	1.0	1.2	217	61	24	3179	4.5	5.4
A34 Refrigerated cargo	13.0	3.4	690	0.7	0.8	217	60	15	3179	3.4	3.9
A35 Roro cargo	12.6	5.1	703	0.9	1.1	221	57	22	3179	3.9	5.0
A36 Passenger/Roro cargo	11.1	7.8	737	1.0	1.6	232	49	34	3179	4.5	7.0
A37 Passenger	11.3	8.5	739	1.0	1.6	232	50	35	3179	4.5	6.9
A38 Other dry cargo	11.3	5.3	741	0.7	1.0	233	51	21	3179	3.0	4.3
B11 Fish catching	12.6	0.6	691	0.4	0.3	217	58	3	3179	1.9	1.5
B12 Other fishing	11.1	10.3	768	1.1	1.9	242	51	41	3179	5.1	7.9
B21 Offshore supply	11.7	7.7	723	1.1	1.6	227	52	33	3179	4.6	6.7
B22 Other offshore	11.7	6.6	722	0.9	1.4	227	52	28	3179	3.8	5.8
B31 Research	11.6	9.7	729	1.2	1.9	229	51	42	3179	5.2	8.2
B32 Towing/Pushing	11.5	8.0	723	1.0	1.6	228	51	34	3179	4.2	7.0
B33 Dredging	11.7	9.2	727	1.2	1.8	229	51	39	3179	5.1	7.8
B34 other activities	10.9	8.0	747	1.0	1.6	235	48	33	3179	4.2	6.6
W11 Other activities	12.2	4.4	707	0.8	1.0	223	55	19	3179	3.3	4.2
W12 Other activities	10.9	8.9	728	0.5	1.8	229	48	38	3179	2.3	7.5

Table E.9. Emission factors for “in-port” operation (in North Sea/Baltic) regarding ship type (scenario “7. 2008”).

MANOEUVRING	NO_x	SO_2	CO_2	HC	PM	sfc	NO_x	SO_2	CO_2	HC	PM
	in g/kWh						in kg/tonne fuel				
A11 Liquefied Gas	7.4	6.8	881	0.9	1.3	277	33	24	3179	3.7	4.9
A12 Chemical	13.1	5.7	706	1.5	1.3	222	60	26	3179	6.7	5.9
A13 Oil	12.0	6.4	750	1.4	1.4	236	55	27	3179	6.3	5.9
A14 Other liquid	13.2	6.0	703	1.5	1.4	221	60	27	3179	7.0	6.2
A21 Bulk dry	13.4	3.0	688	1.0	0.8	216	62	14	3179	4.6	3.8
A22 Bulk dry/oil	13.0	3.0	697	0.9	0.8	219	60	14	3179	4.4	3.6
A23 Self-discharging bulk dry	12.5	1.3	699	0.5	0.5	220	57	6	3179	2.5	2.0
A24 Other bulk dry	13.2	3.2	691	1.0	0.8	218	61	14	3179	4.6	3.9
A31 General cargo	12.8	3.0	698	0.9	0.8	219	59	14	3179	4.2	3.6
A32 Passenger/general cargo	12.6	1.7	695	0.6	0.5	219	58	8	3179	2.9	2.4
A33 Container	13.2	3.0	691	1.0	0.8	217	61	14	3179	4.5	3.7
A34 Refrigerated cargo	13.0	2.0	690	0.7	0.6	217	60	9	3179	3.4	2.8
A35 Roro cargo	12.6	2.9	703	0.9	0.8	221	57	13	3179	3.9	3.4
A36 Passenger/Roro cargo	11.1	4.4	737	1.0	1.1	232	49	19	3179	4.5	4.6
A37 Passenger	11.3	4.8	739	1.0	1.1	232	50	20	3179	4.5	4.5
A38 Other dry cargo	11.3	3.1	741	0.7	0.7	233	51	12	3179	3.0	3.0
B11 Fish catching	12.6	0.5	691	0.4	0.3	217	58	2	3179	1.9	1.5
B12 Other fishing	11.1	5.8	768	1.1	1.2	242	51	23	3179	5.1	5.0
B21 Offshore supply	11.7	4.4	723	1.1	1.0	227	52	19	3179	4.6	4.5
B22 Other offshore	11.7	3.8	722	0.9	0.9	227	52	16	3179	3.8	3.9
B31 Research	11.6	5.5	729	1.2	1.2	229	51	23	3179	5.2	5.3
B32 Towing/Pushing	11.5	4.5	723	1.0	1.1	228	51	19	3179	4.2	4.6
B32 Towing/Pushing	11.5	4.5	723	1.0	1.1	228	51	19	3179	4.2	4.6
B33 Dredging	11.7	5.2	727	1.2	1.2	229	51	22	3179	5.1	5.0
B34 other activities	10.9	4.5	747	1.0	1.1	235	48	18	3179	4.2	4.4
W11 Other activities	12.2	2.5	707	0.8	0.7	223	55	11	3179	3.3	3.0
W12 Other activities	10.9	5.0	728	0.5	1.1	229	48	21	3179	2.3	4.9

Emission factors for scenario “8. 2008”

Additional emission factors for use in scenario “8. 2008” are presented in Tables E.10 and E.11 below. Note that these will be valid for all territorial waters irrespective of other legislation enforcing regional sulphur capping of RO.

Table E.10. Emission factors for “in-port” operation regarding ship type (scenario “8. 2008”).

IN PORT	NO_x	SO_2	CO_2	HC	PM	sfc	NO_x	SO_2	CO_2	HC	PM
	in g/kWh						in kg/tonne fuel				
A11 Liquefied Gas	7.1	0.5	846	0.9	0.8	266	33	2.0	3179	3.8	3.2
A12 Chemical	12.5	0.4	676	1.5	0.8	213	59	2.0	3179	7.1	3.8
A13 Oil	11.3	0.5	716	1.4	0.8	225	55	2.0	3179	6.7	3.8
A14 Other liquid	12.5	0.4	672	1.5	0.8	211	60	2.0	3179	7.4	4.0
A21 Bulk dry	13.0	0.4	673	1.0	0.6	212	62	2.0	3179	4.8	2.7
A22 Bulk dry/oil	12.7	0.4	683	0.9	0.6	215	60	2.0	3179	4.5	2.6
A23 Self-discharging bulk dry	12.4	0.4	695	0.5	0.4	218	57	2.0	3179	2.5	1.7
A24 Other bulk dry	12.8	0.4	676	1.0	0.6	213	61	2.0	3179	4.8	2.7
A31 General cargo	12.5	0.4	683	0.9	0.5	215	58	2.0	3179	4.4	2.6
A32 Passenger/general cargo	12.5	0.4	688	0.6	0.4	217	58	2.0	3179	3.0	1.9
A33 Container	12.9	0.4	677	1.0	0.5	213	61	2.0	3179	4.6	2.6
A34 Refrigerated cargo	12.8	0.4	681	0.7	0.5	214	60	2.0	3179	3.6	2.1
A35 Roro cargo	12.3	0.4	689	0.9	0.5	217	57	2.0	3179	4.1	2.5
A36 Passenger/Roro cargo	10.7	0.5	716	1.0	0.7	225	49	2.0	3179	4.6	3.2
A37 Passenger	10.9	0.5	716	1.0	0.7	225	49	2.0	3179	4.7	3.0
A38 Other dry cargo	11.1	0.5	726	0.7	0.5	228	51	2.0	3179	3.1	2.2
B11 Fish catching	12.6	0.4	690	0.4	0.3	217	58	2.0	3179	1.9	1.4
B12 Other fishing	10.6	0.5	738	1.1	0.8	232	50	2.0	3179	5.3	3.3
B21 Offshore supply	11.3	0.4	702	1.1	0.7	221	51	2.0	3179	4.8	3.0
B22 Other offshore	11.4	0.4	704	0.9	0.6	221	52	2.0	3179	4.0	2.8
B31 Research	11.1	0.4	702	1.2	0.8	221	51	2.0	3179	5.5	3.4
B32 Towing/Pushing	11.1	0.4	702	1.0	0.7	221	51	2.0	3179	4.4	3.1
B33 Dredging	11.2	0.4	702	1.2	0.7	221	51	2.0	3179	5.3	3.3
B34 other activities	10.5	0.5	725	1.0	0.7	228	48	2.0	3179	4.4	3.1
W11 Other activities	12.0	0.4	696	0.8	0.5	219	55	2.0	3179	3.4	2.2
W12 Other activities	10.5	0.4	704	0.5	0.7	221	48	2.0	3179	2.4	3.2

Table E.11. Emission factors for “manoeuvring” operation regarding ship type (scenario “8. 2008”).

MANOEUVRING	NO_x	SO_2	CO_2	HC	PM	sfc	NO_x	SO_2	CO_2	HC	PM
	in g/kWh						in kg/tonne fuel				
A11 Liquefied Gas	7.0	0.5	849	0.9	0.8	267	32	2.0	3179	3.9	3.3
A12 Chemical	12.5	0.4	675	1.5	0.8	212	59	2.0	3179	7.2	3.9
A13 Oil	11.3	0.5	717	1.4	0.8	225	55	2.0	3179	6.7	3.9
A14 Other liquid	12.5	0.4	672	1.6	0.8	211	60	2.0	3179	7.5	4.0
A21 Bulk dry	13.4	0.4	653	1.7	0.9	206	65	2.0	3179	8.2	4.2
A22 Bulk dry/oil	12.7	0.4	675	1.6	0.9	212	61	2.0	3179	7.7	4.1
A23 Self-discharging bulk dry	11.3	0.5	716	1.1	0.7	225	53	2.0	3179	5.4	3.3
A24 Other bulk dry	13.1	0.4	661	1.6	0.9	208	63	2.0	3179	8.0	4.1
A31 General cargo	12.3	0.4	675	1.6	0.9	212	59	2.0	3179	7.4	4.0
A32 Passenger/general cargo	12.1	0.4	684	1.4	0.8	215	56	2.0	3179	6.5	3.6
A33 Container	13.1	0.4	661	1.6	0.9	208	64	2.0	3179	8.0	4.1
A34 Refrigerated cargo	13.0	0.4	662	1.5	0.8	208	63	2.0	3179	7.5	3.9
A35 Roro cargo	11.8	0.4	689	1.5	0.8	217	55	2.0	3179	7.0	3.9
A36 Passenger/Roro cargo	10.1	0.5	725	1.3	0.9	228	45	2.0	3179	5.6	3.8
A37 Passenger	10.1	0.5	728	1.4	0.9	229	45	2.0	3179	6.1	3.9
A38 Other dry cargo	8.8	0.5	782	1.1	0.8	246	40	2.0	3179	5.0	3.5
B11 Fish catching	12.2	0.4	693	0.6	0.4	218	56	2.0	3179	2.8	1.9
B12 Other fishing	10.1	0.5	753	1.3	0.9	237	48	2.0	3179	6.4	3.9
B21 Offshore supply	10.6	0.4	708	1.4	0.9	223	48	2.0	3179	6.4	3.9
B22 Other offshore	10.3	0.5	715	1.3	0.9	225	46	2.0	3179	5.7	3.9
B31 Research	10.7	0.4	705	1.4	0.9	222	48	2.0	3179	6.5	4.0
B32 Towing/Pushing	10.5	0.4	707	1.2	0.9	222	47	2.0	3179	5.5	4.0
B33 Dredging	10.7	0.4	706	1.4	0.9	222	48	2.0	3179	6.5	4.0
B34 other activities	9.6	0.5	741	1.2	0.9	233	43	2.0	3179	5.5	3.8
W11 Other activities	10.8	0.4	708	1.4	0.8	223	49	2.0	3179	6.1	3.7
W12 Other activities	9.7	0.4	709	0.6	0.9	223	43	2.0	3179	2.7	4.0

Appendix F
Detailed Breakdown of Scenario Emission Calculations

13 Pages

Table F.1 TOTAL EMISSION PROJECTIONS (ALL SEA AREAS)

Note: For policies involving 1.5% S RO in North Sea & Baltic, the S in other areas is 2.7%. For the policy involving 1.5% S RO in North Sea, Baltic & Territorial Waters, the S in other areas is also 2.7%

Policy scenario	**Actual**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
	2000	**2006**	**2006**	**2006**	**2006**	**2008**	**2008**	**2008**	**2008**	**2008**	**2010**
	BaseLine	**Baseline**	**1.5%S RO in North Sea & Baltic / higher S RO elsewhere**	**1.5%S RO in North Sea & Baltic / higher S RO elsewhere**	**1.5%S RO in North Sea & Baltic / higher S RO elsewhere**	**Baseline**	**1.5%S RO in North Sea & Baltic / higher S RO elsewhere**	**1.5%S RO in North Sea & Baltic / higher S RO elsewhere**	**1.5%S RO in North Sea & Baltic / higher S RO elsewhere**	**1.5%S RO in North Sea, Baltic & territorial waters / higher S RO elsewhere**	**Baseline**
				0.2%S MGO in port for AEs	**0.2%S MGO in port & manoeuvring for AEs & MEs**			**0.1%S MGO in port for AEs**	**0.1%S MGO in port & manoeuvring for AEs & MEs**	**0.1%S MGO in port & manoeuvring for AEs & MEs**	
Emission projections in kt - 3% growth rate											
NO_X	3,617	4,186	4,186	4,183	4,179	4,411	4,411	4,408	4,403	4,403	4,649
SO_2	2,578	2,968	2,601	2,512	2,477	3,127	2,739	2,642	2,602	2,248	3,294
CO2	157,298	180,639	180,639	180,432	180,218	190,085	190,085	189,865	189,640	189,640	200,105
HC	134	153	153	153	153	162	162	162	162	162	171
PM (in port only)	21	25	22	13	10	26	24	14	11	11	28

Policy scenario	Actual	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
	2000	2006	2006	2006	2006	2008	2008	2008	2008	2008	2010
Reductions compared to baseline achieved by policies in kt - 3% growth rate											
NO_X		0	0	3	8	0	0	3	8	8	
SO_2		0	368	456	491	0	388	484	524	879	
CO2		0	0	207	421	0	0	220	446	446	
HC		0	0	0	0	0	0	0	0	0	
PM (in port only)		0	2	11	15	0	2	12	15	15	
Incremental reductions of tightening policies in kt - 3% growth rate											
NO_X		0	0	3	4	0	0	3	5	0	
SO_2		0	368	88	35	0	388	96	40	354	
CO_2		0	0	207	214	0	0	220	226	0	
HC		0	0	0	0	0	0	0	0	0	
PM (in port only)		0	2	9	3	0	2	9	3	0	

Policy scenario	**Actual**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
	2000	**2006**	**2006**	**2006**	**2006**	**2008**	**2008**	**2008**	**2008**	**2008**	**2010**
Emission projections in kt - 1.5% growth rate											
NO_X	3,617	3,833	3,833	3,831	3,826	3,922	3,922	3,919	3,915	3,915	4,015
SO_2	2,578	2,718	2,381	2,301	2,268	2,780	2,435	2,350	2,314	1,999	2,845
CO_2	157,298	165,412	165,412	165,222	165,026	169,024	169,024	168,828	168,628	168,628	172,791
HC	134	140	140	140	140	144	144	144	144	144	147
PM (in port only)	21	23	20	12	9	23	21	13	9	9	24
Reductions compared to baseline achieved by policies in kt - 1.5% growth rate											
NO_X		0	0	3	7	0	0	3	7	7	
SO_2		0	337	418	450	0	345	430	466	781	
CO_2		0	0	190	386	0	0	196	396	396	
HC		0	0	0	0	0	0	0	0	0	
PM (in port only)		0	2	10	13	0	2	11	14	14	

Policy scenario	Actual	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
	2000	**2006**	**2006**	**2006**	**2006**	**2008**	**2008**	**2008**	**2008**	**2008**	**2010**
Incremental reductions of tightening policies in kt - 1.5% growth rate											
NO_X		0	0	3	4	0	0	3	4	0	
SO_2		0	337	81	32	0	345	86	36	315	
CO_2		0	0	190	196	0	0	196	201	0	
HC		0	0	0	0	0	0	0	0	0	
PM (in port only)		0	2	8	3	0	2	8	3	0	

Table F.2 EMISSION PROJECTIONS FOR NORTH SEA AND BALTIC ONLY

Policy scenario	**Actual**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
	2000	**2006**	**2006**	**2006**	**2006**	**2008**	**2008**	**2008**	**2008**	**2008**	**2010**
	BaseLine	**Baseline**	**1.5%S RO in North Sea & Baltic / higher S RO elsewhere**	**1.5%S RO in North Sea & Baltic / higher S RO elsewhere**	**1.5%S RO in North Sea & Baltic / higher S RO elsewhere**	**Baseline**	**1.5%S RO in North Sea & Baltic / higher S RO elsewhere**	**1.5%S RO in North Sea & Baltic / higher S RO elsewhere**	**1.5%S RO in North Sea & Baltic / higher S RO elsewhere**	**1.5%S RO in North Sea, Baltic & territorial waters / higher S RO elsewhere**	**Baseline**
				0.2%S MGO in port for AEs	**0.2%S MGO in port & manoeuvring for AEs & MEs**			**0.1%S MGO in port for AEs**	**0.1%S MGO in port & manoeuvring for AEs & MEs**	**0.1%S MGO in port & manoeuvring for AEs & MEs**	
Emission projections in kt - 3% growth rate											
NO_X	1,074	1,243	1,243	1,242	1,241	1,306	1,306	1,305	1,304	1,304	1,373
SO_2	763	881	514	504	494	925	538	527	516	516	972
CO_2	40,849	46,761	46,761	46,711	46,648	48,976	48,976	48,922	48,857	48,857	51,325
HC	39	45	45	45	45	47	47	47	47	47	50
PM (in port only)	6	7	4	4	3	7	4	4	3	3	7

Policy scenario	Actual	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
	2000	2006	2006	2006	2006	2008	2008	2008	2008	2008	2010
Reductions compared to baseline achieved by policies in kt - 3% growth rate											
NO_X		0	0	1	2	0	0	1	2	2	
SO_2		0	368	377	387	0	387	398	410	410	
CO_2		0	0	51	113	0	0	54	119	119	
HC		0	0	0	0	0	0	0	0	0	
PM (in port only)		0	2	3	4	0	2	3	4	4	
Incremental reductions of tightening policies in kt - 3% growth rate											
NO_X			0	1	1		0	1	1	0	
SO_2			368	10	10		387	11	12	0	
CO_2			0	51	63		0	54	65	0	
HC			0	0	0		0	0	0	0	
PM (in port only)			2	1	1		2	1	1	0	

Policy scenario	**Actual**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
	2000	**2006**	**2006**	**2006**	**2006**	**2008**	**2008**	**2008**	**2008**	**2008**	**2010**
Emission projections in kt - 1.5% growth rate											
NO_X	1,074	1,138	1,138	1,137	1,136	1,161	1,161	1,160	1,159	1,159	1,186
SO_2	763	807	470	462	452	823	478	469	459	459	840
CO_2	40,849	42,819	42,819	42,773	42,716	43,549	43,549	43,502	43,443	43,443	44,319
HC	39	41	41	41	41	42	42	42	42	42	43
PM (in port only)	6	6	4	3	2	6	4	3	2	2	6
Reductions compared to baseline achieved by policies in kt - 1.5% growth rate											
NO_X		0	0	1	2	0	0	1	2	2	
SO_2		0	337	345	355	0	344	354	364	364	
CO_2		0	0	47	104	0	0	48	106	106	
HC		0	0	0	0	0	0	0	0	0	
PM (in port only)		0	2	3	4	0	2	3	4	4	

Policy scenario	Actual	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
	2000	2006	2006	2006	2006	2008	2008	2008	2008	2008	2010
Incremental reductions of tightening policies in kt - 1.5% growth rate											
NO_X			0	1	1		0	1	1	0	
SO_2			337	9	9		344	10	10	0	
CO_2			0	47	57		0	48	58	0	
HC			0	0	0		0	0	0	0	
PM (in port only)			2	1	1		2	1	1	0	

Note: For policies involving 1.5% S RO in North Sea & Baltic, the S in other areas is 2.7%. For the policy involving 1.5% S RO in North Sea, Baltic & Territorial Waters, the S in other areas is also 2.7%

Table F.3 EMISSION PROJECTIONS FOR OTHER SEA AREAS

Policy scenario	**Actual**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
	2000	**2006**	**2006**	**2006**	**2006**	**2008**	**2008**	**2008**	**2008**	**2008**	**2010**
	BaseLine	**Baseline**	**1.5%S RO in North Sea & Baltic / higher S RO elsewhere**	**1.5%S RO in North Sea & Baltic / higher S RO elsewhere**	**1.5%S RO in North Sea & Baltic / higher S RO elsewhere**	**Baseline**	**1.5%S RO in North Sea & Baltic / higher S RO elsewhere**	**1.5%S RO in North Sea & Baltic / higher S RO elsewhere**	**1.5%S RO in North Sea & Baltic / higher S RO elsewhere**	**1.5%S RO in North Sea, Baltic & territorial waters / higher S RO elsewhere**	**Baseline**
				0.2%S MGO in port for AEs	**0.2%S MGO in port & manoeuvring for AEs & MEs**			**0.1%S MGO in port for AEs**	**0.1%S MGO in port & manoeuvring for AEs & MEs**	**0.1%S MGO in port & manoeuvring for AEs & MEs**	
Emission projections in kt - 3% growth rate											
NO_X	2,544	2,944	2,944	2,941	2,938	3,105	3,105	3,103	3,099	3,099	3,276
SO_2	1,815	2,087	2,087	2,008	1,983	2,201	2,201	2,115	2,086	1,732	2,322
CO_2	116,449	133,878	133,878	133,721	133,570	141,109	141,109	140,943	140,783	140,783	148,780
HC	95	108	108	108	108	114	114	114	114	114	121
PM (in port only)	15	18	18	10	7	19	19	10	8	8	20

Policy scenario	**Actual**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
	2000	**2006**	**2006**	**2006**	**2006**	**2008**	**2008**	**2008**	**2008**	**2008**	**2010**
Reductions compared to baseline achieved by policies in kt - 3% growth rate											
NO_X		0	0	2	6	0	0	3	6	6	
SO_2		0	0	79	104	0	0	86	115	469	
CO_2		0	0	157	308	0	0	166	326	326	
HC		0	0	0	0	0	0	0	0	0	
PM (in port only)		0	0	8	11	0	0	9	11	11	
Incremental reductions of tightening policies in kt - 3% growth rate											
NO_X			0	2	3		0	3	3	0	
SO_2			0	79	25		0	86	29	354	
CO_2			0	157	151		0	166	160	0	
HC			0	0	0		0	0	0	0	
PM (in port only)			0	8	2		0	9	2	0	

Policy scenario	Actual	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
	2000	2006	2006	2006	2006	2008	2008	2008	2008	2008	2010
Emission projections in kt - 1.5% growth rate											
NO_X	2,544	2,696	2,696	2,693	2,690	2,761	2,761	2,759	2,756	2,756	2,829
SO_2	1,815	1,911	1,911	1,839	1,816	1,957	1,957	1,881	1,855	1,540	2,005
CO_2	116,449	122,592	122,592	122,449	122,310	125,475	125,475	125,327	125,184	125,184	128,472
HC	95	99	99	99	99	102	102	102	102	102	104
PM (in port only)	15	16	16	9	7	17	17	9	7	7	17
Reductions compared to baseline achieved by policies in kt - 1.5% growth rate											
NO_X		0	0	2	5	0	0	2	5	5	
SO_2		0	0	72	95	0	0	76	102	417	
CO_2		0	0	143	282	0	0	148	290	290	
HC		0	0	0	0	0	0	0	0	0	
PM (in port only)		0	0	8	10	0	0	8	10	10	

Policy scenario	**Actual**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
	2000	**2006**	**2006**	**2006**	**2006**	**2008**	**2008**	**2008**	**2008**	**2008**	**2010**
Incremental reductions of tightening policies in kt - 1.5% growth rate											
NO_X			0	2	3		0	2	3	0	
SO_2			0	72	23		0	76	26	315	
CO_2			0	143	138		0	148	143	0	
HC			0	0	0		0	0	0	0	
PM (in port only)			0	8	2		0	8	2	0	

Note: For policies involving 1.5% S RO in North Sea & Baltic, the S in other areas is 2.7%. For the policy involving 1.5% S RO in North Sea, Baltic & Territorial Waters, the S in other areas is also 2.7%

Table F.4 Emissions estimates for Future Scenarios – 3% per annum assumed growth rate

Scenario	NO_x Kte / annum	SO_2 Kte / annum	CO_2 Kte/ annum	HC Kte/annum	PM (in port) Kte/annum
2000 BAU	**3,617**	**2,578**	**157,298**	**134**	**21**
1 2006 BAU	**4,186**	**2,968**	**180,639**	**153**	**25**
2	**4,186**	**2,601**	**180,639**	**153**	**22**
3	**4,183**	**2,512**	**180,432**	**153**	**13**
4	**4,179**	**2,477**	**180,218**	**153**	**10**
5 2008 BAU	**4,411**	**3,127**	**190,085**	**162**	**26**
6	**4,411**	**2,739**	**190,085**	**162**	**24**
7	**4,408**	**2,642**	**189,865**	**162**	**14**
8	**4,403**	**2,602**	**189,640**	**162**	**11**
9	**4.403**	**2,248**	**189,640**	**162**	**11**
10 2010 BAU	**4,649**	**3,294**	**200,105**	**171**	**28**