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Swedish Methodology for Environmental Data

Methodology for calculating emissions from ships: 1. Update of emission factors

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SMED är en förkortning för Svenska MiljöEmissionsData, och är ett samarbete mellan IVL Svenska Miljöinstitutet, SCB och SMHI. Samarbetet inom SMED inleddes under 2001 med syftet att långsiktigt samla och utveckla kompetensen inom emissionsstatistik kopplat till åtgärdsarbete inom olika områden, bland annat som ett svar på Naturvårdsverkets behov av upprätta ett svenskt datavärdskap för utsläpp till luft. Målsättningen med SMED-samarbetet är att utveckla och driva nationella emissionsdatabaser och att tillhandahålla olika tjänster relaterade till dessa. Kundbasen är tänkt att omfatta både nationella, regionala och lokala myndigheter samt luft- och vattenvårdsförbund och näringsliv. Dessa kan genom samarbetet inom SMED erbjudas en attraktiv återföring av resultat inom ett större område än tidigare. Konsulttjänster kommer att utvecklas både för nationella och internationella uppdrag.

SMED is an abbreviation for Swedish Methodology for Environmental Data which is based on a collaboration between IVL Swedish Environmental Research Institute, SCB Statistics Sweden and SMHI Swedish Meteorological and Hydrological Institute. The work co-operation within SMED commenced during 2001 with the long-term aim of acquiring and developing expertise within emission statistics. SMED fulfils the Swedish Environmental Protection Agency's requirements for a Swedish air emission data centre. In particular, the work focuses on following the introduction of abatement measures for different sectors. A central objective of the SMED collaboration is thus to develop and maintain national emission databases and offer related services. Potential clients include national, regional and local governmental authorities, air and water quality associations, and industrial representatives. In work-coperation with SMED, an implementation of results in a wider perspective is achieved. Consultant services will be developed for both national and international assigments.

Acknowledgement

In compiling this report, a great amount of underlying measurement work has been undertaken on board several ships. Assistance and enthusiasm from shipowners and the ships' crews has been invaluable in this respect. The 100% response from the "Low-NO_x" shipowners regarding the questionnaire in this study is in particular commendable. In addition, the author would like to thank many experts working in the marine emission field for constructive and useful discussions.

Summary

SMED (Swedish Methodology for Environmental Data, a collaboration between the Swedish Environmental Research Institute, Statistics Sweden and the Swedish Meteorological and Hydrological Institute) has derived emission factors for ships (> 100 Gross Register Tonnage) to be applied in Sweden's international reporting duties. The basis for this type of reporting is that only emissions derived from Swedish sold marine fuels are accounted for.

The study has focused on 28 different air pollutants, where the emission factors have been proposed as a function of engine and fuel type. For year 2002, the factors cover three operational modes ("at sea", "manoeuvring" and "in port") and thereby take into account main engine and auxiliary engine emissions. A set of "at sea " emission factors has also been prepared from 1990 up to 2001 to allow an update of the marine emission time series.

In order to obtain representative and up-to-date emission factors for this application, "in-house" emission data and also published literature emission factor databases have been assessed. Thus emission factors were derived from a database consisting of exhaust measurements from ca. 62 ships involving ca.180 marine engines. The emission factors have been weighted to account for the proportion of the fleet using exhaust gas cleaning measures, age factors for fuel consumption and increased use of low-sulphur fuels.

Since the number of measurement data available for the different pollutant emission factors varies considerably, an attempt has been made to classify the factors after estimated uncertainty.

Swedish Summary

SMED (Svenska Miljö Emissions Data, ett konsortium bestående av IVL Svenska Miljöinstitutet, Statistiska Centralbyrån och Sveriges Meteorologiska och Hydrologiska Institut) har tagit fram emissionsfaktorer för fartyg (> 100 Brutto tonnage) som gäller för Sveriges internationella rapporteringsändamål. Grunden för denna typ av rapportering är att endast emissioner från i Sverige sålda marina bränslen ingår.

Studien har fokuserat på 28 olika luftföroreningar där emissionfaktorerna har angivits i samband med motor- och bränsletyp. För år 2002 har emissionsfaktorer för tre olika driftssätt presenterats (”till sjöss”, ”manövrering” och ”i hamn”) och därmed har utsläppen från både huvud- och hjälpmotorer ingått. Emissionsfaktorer “till sjöss” har även beräknats från år 1990 till 2001 så att tidserien för marina emissioner kan uppdateras.

För att erhålla representativa och uppdaterade emissionsfaktorer har data från egna mätserier och literaturstudier utvärderats. På så sätt bygger de framtagna emissionsfaktorerna på mätningar från 62 olika fartyg och ca. 180 motorer. Faktorerna har viktats för att ta hänsyn till andelen av fartygen som använder någon form av avgasreningsteknik, åldringsfaktorer för bränsleförbrukning samt en ökad användning av lågsvavelbränslen.

Eftersom antalet bakomliggande mätdata för de olika emissionsfaktorerna varierar kraftigt har resultaten presenterats med ett mått på mätosäkerheten.

Contents

1 Introduction

Reporting of air emissions from Swedish sea traffic is currently based on combining activity data (from marine fuel delivery statistics) with pollutant specific, emission factors (from guidebooks provided by EMEP (EMEP, 2002) and IPCC (IPCC, 1997)). This methodology and the results generated however, have raised several questions concerning the following:

- The emission factors used for ships in the guidebooks are mostly based on a relatively old and limited data set from the early 1990s (Lloyds Register Engineering Services, 1995). Furthermore some emission factors are lacking and they do not reflect Swedish developments regarding the introduction of NO_x emission reduction technologies, low sulphur fuel usage etc.

- For the Swedish privately-owned boat sector (so-called leisure craft), an even greater uncertainty exists in calculating these emissions; i.e. both in the activity data used and the lack of emission factor data.

- Since the emissions are generated from data on Swedish marine fuel sales only (according to international reporting requirements), fluctuations in fuel prices abroad will effect the reported emissions. In addition, many ships using fuel purchased abroad give rise to significant emissions around the Swedish coastline which will not be accounted for using the international reporting rules. Thus there is a need for a "more accurate and morally correct" methodology to determine actual "Swedish emissions" (see section 1.3).

In view of the above, (Swedish Methodology for Environmental Data (SMED) has initiated a multi-phase project with the aim to address these key issues and thereby improve the quality of Swedish marine emission reporting.

1.1 Aim of project

As part of the overall objective of improving Swedish marine emission reporting, this report focuses on the first of the topics above. Specifically, the aim of this work was to provide an updated and representative set of emission factors (in g/kWh, kg/ton fuel and kg/TJ supplied fuel) for ships (> 100 gross tonnage) to be used for present Swedish, international emission reporting duties. Applying these new emission factors for 2002 only will however create difficulties when comparing total marine emissions from previous years (where old emission factor methodology was used). Therefore, an additional aim was to modify the new set of 2002 emission factors so that they can be applied to previous years' activity data (i.e. from 1990 to 2001). A recalculation can thereby be made for each year and a relevant time series for Swedish marine emissions obtained.

1.2 International emission reporting requirements

On a yearly basis Sweden is obligated to report national air emissions of several pollutants to several international bodies:

- Directive 2001/81/EC on national emission ceilings for certain atmospheric pollutants which follows CORINAIR / EMEP guidelines.

- CLRTAP (United Nation's Convention on Long-Range Transboundary Air Pollution). which follows CORINAIR / EMEP guidelines.

- European Union's Mechanism for Monitoring Community greenhouse gas emissions and for implementing the Kyoto Protocol. Reporting follows revised 1996 IPCC (Intergovernmental Panel on Climate Change) Guidelines for National Greenhouse gas Inventories (IPCC Guidelines), IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse gas inventories (IPCC Good Practice Guidance), and UNFCCC Reporting Guidelines on annual inventories (FCCC/CP/2002/8).

- UNFCCC (United Nations Framework Convention on Climate Change): EUs climate gas directive ”Monitoring Mechanism”, which follows IPCC (Intergovernmental Panel on Climate Change) guidelines. Reporting follows revised 1996 IPCC (Intergovernmental Panel on Climate Change) Guidelines for National Greenhouse gas Inventories (IPCC Guidelines), IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse gas inventories (IPCC Good Practice Guidance), and UNFCCC Reporting Guidelines on annual inventories (FCCC/CP/2002/8).

Although some harmonisation exists between these bodies, different rules prescribe pollutants, quality requirements, reporting intervals, source categories, and geographical distribution. In general, common guidelines exist on choice of emission factors and calculation methodology (e.g. in EMEP, 2002; IPCC, 1997) but each nation is free to adopt a calculation methodology which is best suited to local conditions.

Regarding source categories covering marine navigational activities, Table I summarises the general divisions of the categories required and those where the emission factors presented in this study are applicable (bold text). The specific pollutants of concern for reporting are presented in Table II. In the past, definitions between national and international assignments have been a source of confusion. Improved definition criteria have however been added to the latest version (October 2003) of the web-based EMEP guidebook (EMEP, 2002) which offers some clarification.

Table I Source categories required for emission reporting of all shipping activities (bold text indicates categories relevant to the emission factors presented in this study).

"UNFCCC and IPCC guidelines"
Fuel Combustion Activities (Table 1A, 3d Transport – "National Navigation")
Small Combustion in Agriculture, Forestry, Fishing (Table 1A, 4ciii – "National Fishing")
Memo Item, "International Marine Bunkers" [b)]
"CLRTAP and CORINAIR guidelines"
"National sea traffic " [a)] (SNAP code 080402) – Table 1 A 3d
"National Fishing" [a)] (SNAP code 080403)
"International sea traffic" [a)] (SNAP code 080404) – Table 1 A 3d i
"Inland Waterways" - "Sailing Boats with auxiliary engines" (SNAP code 080301-01)
"Inland Waterways" - "Motorboats / Workboats" (SNAP code 080301-02)
"Inland Waterways" - "Personal watercraft / leisure craft" (SNAP code 080301-03)
"Inland Waterways" - "Inland Goods Carrying vessels" (SNAP code 080301-03)

[a)] Refers to ships > 100 gross tonnes, at sea, in port or on inland waterways irrespective of flag.
[b)] Equivalent to International sea traffic in CORINAIR reporting i.e. for ships > 100 gross tonnes.

One should note that the divisions and pollutants in Tables I and II are for the highest detail, if available. In reality however, the activity data of domestic marine fuel sales (and also emission factors) used by Sweden in past reporting exercises has not permitted this level of detail. The CLRTAP reporting with CORINAIR guidelines has been agglomerated to give the same level as required for IPCC guidelines. Only two categories have been reported; National and International sea traffic. Thus emission data for National Navigation are made at Table 1 A 3 d and International Navigation at Table 1 A 3 di (Memo Item). Since National Fishing (Table 1A, 4ciii) has been given the IE code (Included Elsewhere) in the previously submitted reports for all pollutants, these emissions have been included in National Navigation.

Concerning pollutants covered in the reporting duties, the scope of this work includes all pollutants which may be required for international reporting (Table II). Pollutants especially relevant to this work i.e. which can arise though combustion of marine diesel fuels on board ships are indicated in bold text.

Table II Pollutants where air emission factors are required for international reporting obligations (bold text indicates emissions relevant to combustion of marine diesel fuels on board ships).

"Main Pollutants"	
NO_x	Nitrogen oxides, refers to NO and NO_2 but calculated as NO_2
CO	Carbon monoxide
NMVOC	Non methane volatile organic compounds, organic compounds except methane, fluorocarbons and halons
SO_x	Sulphur oxides, refers to SO_2 and SO_3 but calculated as SO_2
NH_3	Ammonia
"Particulate Matter"	
TSP	Total Suspended Particulates
PM_{10}	Fine Particulates with diameter 10 mm or less
$PM_{2,5}$	Ultra-fine Particulates with diameter 2,5 mm or less
"Priority Metals"	
Pb	Lead
Cd	Cadmium
Hg	Mercury
"Other Metals"	
As	Arsenic
Cr	Chromium
Cu	Copper
Ni	Nickel
Se	Selenium
Zn	Zinc
"Persistent Organic Pollutants"	
"Pesticides"	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Hexabromo-biphenyl, Mirex, Toxaphene, HCH, DDT
PCB [a)]	PolyChlorinated Biphenyls
DIOX [a)]	Dioxins and Furans, given as TCDD equivalents
Benzo(a)pyrene	One of several PAH (poly aromatic hydrocarbons) compounds
Benzo(b)fluoranthene	"
Benzo(k)fluoranthene	"
Indeno(1,2,3-c,d)pyrene	"
Total PAH	Refers to sum of benzo(a)pyrene, benzo(b)fluoranthene, benzo(b)fluoranthene and indeno(1,2,3-c,d)pyrene
HCB	HexaChloroBenzene
PCP	PolyChloroPhenols
SCCP	Short-Chained Chlororinated Paraffins
"Greenhouse gas pollutants"	
CO_2	Carbon dioxide
CH_4	Methane
N_2O	Nitrous oxide
HFC	HydroFluoroCarbons
PFC	PerFluoroCarbons
SF_6	Suphur Hexafluoride

[a)] Note that unlike PAH (species defined), no specific definition of which PCB congeners should be included has been formulated (Dutchak, 2003). Similarly, for dioxins and furans, the TCDD equivalency factors are not unequivocally defined.

1.3 Other Swedish marine emission reporting

In addition to the international reporting duties outlined in section 1.2, "Swedish" marine emissions are periodically calculated as part of a contract for the Swedish Maritime Administration (Sjöbris et al., 2001; Mariterm 2003a, Mariterm 2003b). It is important to note that for this purpose both the boundaries and calculation methodology differ from those for the international reporting obligations. The main differences are that the emission boundaries are more "morally" representative of the Swedish emissions and the calculation methodology is based on the so-called "bottom-up approach" using a ship movement database. Specifically, fuel consumption data from fuel sales delivery data are not used in these calculations and instead the fuel consumption for an individual ship movement is calculated as an intricate function of engine type, ship type, route etc.[1] In addition, the emission factors used in the calculations (European Commission, 1999) are slightly more refined than those which have been previously used in the international reporting. A disadvantage with the "bottom-up approach" is that although well intended regarding improved accuracy and completeness, a substantial effort is necessary to fully complete such a model and thereafter maintain it.

Bearing in mind the obvious drawbacks with the regulations and boundaries governing the international reporting requirements however, other more "realistic" national marine emission inventories are indeed warranted. As a compliment to these efforts, it is hoped that the emission factors derived in this report will be of use.

[1] Recently, a bottom-up approach was carried out on global marine emissions and compared with previous top-down estimates from fuel sales. For fuel consumption (and NO_x emissions) the bottom-up calculation gave values twice those estimated by top-down estimates (Corbett and Koehler, 2003). This clearly highlights the potential uncertainty which can arise between the different calculation methodologies.

2 Factors influencing emissions from ships

A brief review of factors which affect pollutant emissions from ships are presented below[2]. A more in depth overview is presented elsewhere (European Commission; 2002a).

2.1 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. Generally, ship propulsion is provided by main engines while on board electricity is generated from auxiliary engines. In terms of number and emission magnitude, *main (ME)* and *auxiliary (AE) diesel engines* dominate by far, followed by turbine machinery (*steam (ST)* and *gas turbines (GT)*). 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 diesel engines are normally sub-divided according to their engine speed at the crankshaft as: *high speed (HSD), medium speed (MSD)* and *slow speed (SSD)*[3]. Slow and medium speed engines are far more abundant than high speed engines for main engines. For AEs, 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.

Since engine type will affect the prevailing combustion conditions (temperature, fuel mix, pressure, residence time), the level of emissions of some pollutants (e.g. NO_x, NMVOC and CO etc.) will also be influenced.

[2] Besides the factors mentioned here, meteorological factors will also have an influence on emissions. For NO_x, these are accounted for by directly correcting the emissions factors (in g/kWh) according to IMO Technical NO_x Code, 1997. Thus all the factors presented in the results refer to the IMO corrected emissions (in g/kWh_{corr}). In general, weather conditions will also affect the fuel consumption required for a ship to tavel a given distance. This is accounted for when combining the activity data with the emission factors.

[3] 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.

2.2 Fuel type

Ships consume a variety of fuels classed primarily by their viscosity, ranging from "*marine distillates (MD)*" through to heavier "*residual oils (RO)*". Within the distillate classification, a further division is normally made between marine gas oils and marine diesel oils. Marine gas oil is a light and clean distillate oil containing no residual fuel oil. Marine diesel oil is a heavier distillate and may contain some residual fuel oil. Marine distillate fuels are largely used by fishing vessels that have less space for equipment targeted to treat high viscosity fuels (RO) which require preheating. For the purposes of this study, RO fuels are classed as fuels with viscosity (measured at 50 ^{o}C) between 55 - 810 cst, and MD fuels between 1 - 50 cst.

Some pollutant emissions are predetermined solely by their fuel content irrespective of the engine combustion conditions. Examples are CO_2, SO_2 and metal emissions.

2.3 Ship operational mode

Some emission factors are dependent on how an engine is run, for example idling and rapid load changes give rise to more pollutants associated with incomplete combustion (CO, NMVOC, PM). Thus indirectly, the type of ship operation will affect the demands on the engine and thereby emissions. In general, one can identify three ship operational modes; *at sea* (where the ME are at ca. 80% of maximum load and AE emissions are relatively insignificant), *manoeuvring* (where ME emissions also dominate but at lower and varying loads), *in port* (where MEs are off and the emissions arise from AEs at ca. 50% of maximum load).

2.4 Engine age and use of emission reduction technologies

Some changes in emissions occur from a given engine with age but these are often difficult to quantify and are dependent on individual shipboard service and maintenance routines. For a larger fleet where older ships are continually being replaced however, the introduction of new engines with improved fuel consumption and following new emission legislation e.g. IMO Technical NO_x Code, 1997, will have an impact on the emissions. Similarly implementation of emission reduction technologies (e.g. Selective Catalytic Reduction, SCR, for reducing NO_x) will have a dramatic influence on the emissions. In this regard, the introduction and use of different fuels, for example, those containing lower sulphur contents, can also be seen as an emission reduction technology.

For the purposes of this study, the possible emission reduction categories taken into account and the magnitude of influence on the emission factors has been based largely on in-house experience and consultation with engine manufacturers. Note also that these technologies will affect only certain emission factors and they will be more evident when considering how the emission factors have changed over the time period 1990 – 2002. The following briefly summarises the central assumptions used. Further details are presented in section 3.6.

- Engines older than 10 years (engines manufactured before 1993) have been assigned specific fuel consumption values as being 7% greater (*sfcold*) than for newer engines (Hellén, 2003; Nielsen, 2003).

- All engines equipped with SCR for NO_x control (*SCR*) are assumed to achieve 91% reduction and gain an additional NH_3 emission factor (0,10 g/kWh). 45% of the SCR engines are assumed to have oxidation catalysts which provide a 70% and 80% reduction in CO and NMVOC emissions respectively. Engines using so-called low-NO_x techniques (e.g. slide valves and retarded injection) (*lowNOx*) are assumed to reach a 20% reduction, while Humid Air Motors (*HAM*) are assumed to reduce NO_x by 70%. Finally direct water injection systems (*DWI*) are expected to give NO_x reductions of 50%. New engines built from year 2000 onwards should conform to the IMO Technical NO_x Code (*NOxCode*) and therefore be tuned for lower NO_x emissions which correspond to a 6% decrease compared to the older engines[4]. It is assumed that new engines replace 4% of the older ones each year and 50% of the new engines will have one of the NO_x reduction technologies mentioned above. Note that for some of these NO_x emission reduction technologies, marginal changes in CO, PM and fuel consumption are conceivable but these have largely been judged as negligible in assigning the emission factors. An exception however, is for CO and NMVOC emissions from SCR engines (see above)

- Fuel usage, in terms of increased MD fuel is accounted for directly in the underlying activity data (fuel sales of each fuel type). The sulphur contents, (and thereby emission factor) can however differ within each fuel type for different years. For 2002, these have been assigned as 1,3 wt-% for RO fuel and 0,2 wt-% for MD fuel.

[4] It is assumed that old steam turbine driven ships will not be replaced by steam turbine machinery.

3 Methodology for evaluating emission factors

3.1 General overview

An outline for the central methodology used for calculating fuel based emissions from ships is presented in Figure 1.

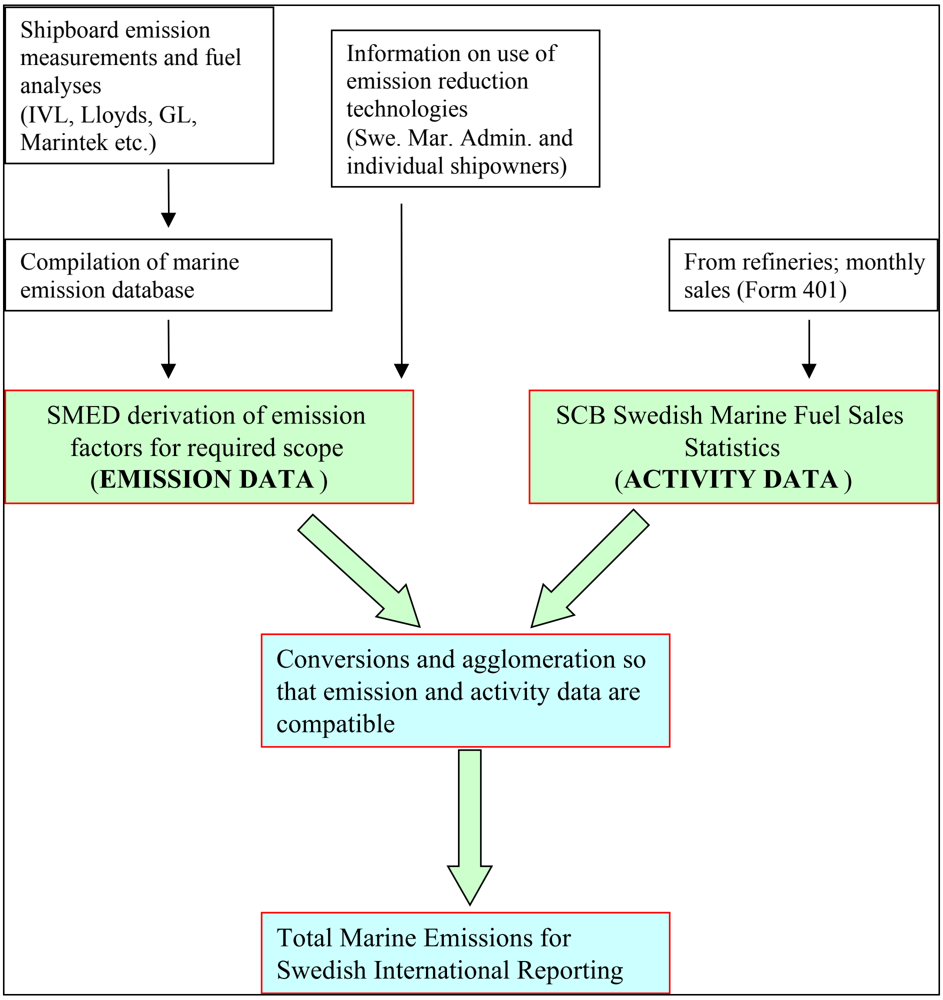

Figure 1. Overview for calculating fuel based marine emissions.

3.2 Scope

Bearing in mind the factors influencing emissions (section 2) and the aim of the project (section 1), Table III presents the potential scope of the required emission factors. Although detail in the set of emission factors is valuable for outlining general scientific understanding, subsequent accuracy and completeness, one should also consider whether the available activity data is at a corresponding level of detail. It is important to note that it is the product of the activity data and emission factors which give the required total emissions for reporting, and thus the data needs to be subsequently compatible (see section 5.1).

Table III Scope required for emission factors

No. of pollutants	28	NO_x, CO, NMVOC, SOx, NH_3, etc.
No. of engine types	5	High speed diesel (HSD), medium speed diesel (MSD), slow speed diesel (SSD), steam turbine (ST) and gas turbine (GT)
No. of fuel types	2	Marine distillate (MD) and residual oil (RO)
No. of operation modes	3	At sea (ME), manoeuvering (ME), in port (AE) only for year 2002
No. of years covered	13	From 1990 up to 2002
No. of Sulphur contents	26	Different fuel S value for RO and MD for each year
No. of NO_x red. techniques	5	SCR, lowNO_x, HAM, DWI, NO_xCode
No. of fuel cons./ age classifications	2	Engines built 1993-2003 and engines built before 1993

Thus each emission factor table as result output (Appendices 1 and 2) presents the pollutants (and fuel consumption) for all 10 engine / fuel combinations. Separate tables cover the three possible operational modes for year 2002 (Appendix 1). For previous years data (each with specifically assigned fuel sulphur for RO and MD) only the most significant operational mode regarding emission magnitude (at sea) has been considered (Appendix 2). Concerning NO_x reduction technologies, these are accounted for by weighting each emission factor accordingly using “reduction profiles” (see section 3.4).

It should be noted that of the 10 possible engine/fuel combinations given in the tables, several of them are of minor importance (and possibly will not even apply) for the current fleet using Swedish fuels. For example, steam turbines (with either RO or MD) are being gradually phased out and only a very few gas turbine ships are in operation. In addition slow speed engines (SSD) almost always operate using residual oil (RO) fuels which renders the emission factors for SSD/MD largely irrelevant. By far the most dominant combinations in use are SSD/RO, MSD/RO and MSD/MD[5]. In this regard, most of the available measurement data (from which the factors are assigned) fortunately reflect these populations, although the SSD/RO category could be considered slightly under represented. Few data exist for gas turbine ships and very little reliable data exists for steam turbines.

Initially, no difference in the emission factors was planned between ships operating on domestic and international routes. Since the use of SCR for controlling NO_x emissions is however significantly different for international and domestic routes relative to the fuel sold in these groups, an amendment for this has been included in the result tables. Thus different NO_x, CO, NMVOC and NH_3 emission factors are given for domestic and international traffic.

3.3 Database

The central database from where the appropriate emission factors have been derived consists largely of in-house emission measurement data and other sources (Lloyds Engineering Services, 1995; and various fuel oil analyses). The database consists of measurements from 62 different ships covering ca. 180 engines. This database is similar to that used to estimate European ship emissions and is presented in detail in European Commission 2002a. More pollutants have however been included in the current database, and new measurements have been added and old data (ships older than 23 years) removed. Since the number of measurements for a particular pollutant can vary considerably a range of uncertainty exists between the different emission factors. An attempt has been made to roughly quantify these uncertainties in the result tables using different colour codes.

3.4 Reduction profiles for engine/fuel categories

In order to account for NO_x reduction techniques in use, the base emission factors (i.e. without emission abatement) and those emission factors corresponding to the reduced emissions, have been weighted accordingly. Firstly data on the emission levels with the reduction techniques in use are required. These are relatively well represented in the database with a reasonable measurement uncertainty (see section 3.6.1).

[5] For the world fleet, it is estimated that 95% of all slow speed diesels and 70% of medium speed diesels operate using RO fuel (Corbett and Koehler, 2003).

Since the activity data is based on Swedish fuel sales, secondary information is also required concerning how much Swedish purchased fuel is consumed for a given reduction technique. Ideally this information should be quantified for each fuel / engine combination. To gather this data a questionnaire was sent out to cover 60 ships for 2002 (36 ships with "NO_x reduction certificates" identified by the Swedish Maritime Administration and an additional 24 ships using low-NO_x engines). Even data on the start year of the techniques has been collected. Since a 100% response was achieved, a good estimate of the relative use of the techniques and thereby emission factors is anticipated. Data on ships using low-NO_x engines may however be lacking since many of these ships are not certified with NO_x Reduction Certificates, thus a direct contact with the shipowner was the only apparent way of collecting data. In this regard, two of the larger shipowners, well known for their environmental progress (24 low-NO_x slide valve ships) were contacted within the project[6]. Since these ships are of the transoceanic type relatively small quantities of the ships' fuel are purchased in Sweden, but the impact for Swedish marine emissions from Swedish fuel is however considerable (i.e. ca. 18% of Swedish RO fuel in 2002 is operated by low NO_x slide valve engines).

The "reduction profiles" i.e. fractions of total fuel consumed for a given year used by a given reduction technique and engine / fuel combination are presented in Appendix 4. Data on the total fuel consumed (i.e. activity data) is presented in Appendix 3. Note that the reduction profiles have been largely derived from International ships only. For domestic ships however, the emission reduction technologies are confined to SCR on MSD and HSD engines using MD and RO fuels. Since there is a considerable difference between the fraction of SCR fuel for international and domestic traffic (e.g. for MSD/MD ships the fraction is 44% for domestic traffic compared to 3,3% for International ships[7]), these differences cannot easily be ignored. Consequently an "Amendment table" to treat the consequences of domestic SCR use is included in the result tables i.e. different emission factors for NO_x, CO, NMVOC and NH_3 for domestic traffic.

From Appendix 4, ca. 5,7% of the RO fuel sold in Sweden in 2002 was used for ships using SCR in international traffic. If all the SCR ships calling on Swedish ports had chosen to purchase only Swedish fuels then this percentage would increase to 11,8%. The emission reductions of the SCR ships using foreign fuels should be accounted for by the country selling the fuel.

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[6] There may be other ships using this low-NO_x technique which have not been registered in the present database. One of the larger engine manufacturers are now fitting low-NO_x slide valves on all newly built slow-speed engines giving emission reduction significantly greater that the IMO regulations (Motor Ship, 2002).

[7] It should be noted that International RO fuel is sold in much larger quantities i.e. 9 - 90 times the RO fuel sold for domestic traffic.

3.5 Evaluation and form of emission factors in result tables

Following standard international procedure for gaseous emissions from diesel engines, the base emission factors are presented in terms of a weight of a given pollutant (in grams) divided by the uncorrected power at the crankshaft (in kWh), i.e. g/kWh. The latter represents the net effect output from the engine as opposed to the supplied input effect from the fuel energy content (which is often used as convention for land-based power plants for example). By using the specific fuel combustion (gram fuel consumed per kWh) a simple calculation converts the power-based emission factors from g/kWh to g/ton fuel supplied which in turn is converted to Gg/supplied TJ using the heating value of the fuel in question. This latter unit is generally more useful when applying activity data (often expressed for reporting requirements as fuel consumed in TJ). In the emission factor tables supplied in Appendices 1 and 2 all these units are used.

Initially, the most appropriate emission factors (derived from the database) for a pollutant are given specifically for the 5 different engines types and each for the 2 alternative fuels. These “base” emission factors in g/kWh (which even include age corrections for the specific fuel consumption) have then been weighted according to the relative fuel used with the 5 different NO_x reduction technologies to obtain “corrected” factors in g/kWh (see reduction profiles in section 3.4). An example of this step from the base to corrected emission factors is provided in Appendix 5.

Finally, the “corrected” factors given in g/kWh are converted to g/ton fuel and Gg/TJ supplied energy.

3.6 Comments on derivation of specific emission factors

3.6.1 NO_x emissions

A detailed presentation of the base NO_x emission factors including comparisons with other sources is presented in European Commission, 2002a. An extension of this data for this study has focused on emission reduction technologies, most notably Selective Catalytic Reduction (SCR) systems.

From the database, SCR NO_x emission factors are based on 99 measurements (42 with RO fuel and 57 with MD fuel) on different MSD engines with 3 different manufacturers of SCR. The data includes certification measurements (at 75% engine load setting) and also so-called real-world measurements. An average NO_x emission of 1,26 g/kWh is obtained which can be compared with a weighted baseline 13.54 g/kWh. Thus a 91% reduction has been assumed.[8] Approximately 45% (international traffic) and 46% (domestic traffic) of the systems are equipped with oxidation catalysts in addition to the SCR. From the database, the oxidation catalysts result in emission reductions of CO and HC by 70% and 80% respectively. No significant change in PM or N_2O emissions has been observed with SCR systems.

3.6.2 CO_2 and heavy metal emissions

Fuel dependent emission factors of CO_2 and heavy metals have been assumed not to vary over the period 1990-2003. CO_2 emissions have been calculated from a carbon content of 86,7% for all fuels.

For heavy metals, fuel analysis data has been used where available to derive the emission factors (assumes that all the metals in the fuel are emitted in the exhaust). Some analysis certificates accompanying deliveries (especially residual oils) can include heavy metal contents. These however normally only include only lead, zinc and nickel of the metals to be reported. Vanadium and iron contents which can be appreciable are usually also included in the analyses[9] but these are not required for reporting purposes. A very limited amount of data is however available on the other 6 metals to be reported (Lloyds Register Engineering Services, 1995). In general however, measured values have been obtained for all metals although some are more certain than others and the RO data is slightly biased towards residual oils with higher viscosities (>300 cSt).

Table IV Assumed heavy metal contents (mg/kg) in the fuels.

	Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn	Fe	V
MD	0.15	0.005	0.0005	0.03	0.05	1.7	1	0.00005	1	4.2	1.7
RO	0.15	0.013	0.003	0.85	1.23	2.0	34	0.02	1.4	25	93

Several of the analysis data (Cd, Hg for MD fuel, As for MD fuel, Se for MD fuel) are less than values. In these cases a value of half of the detection value has been used in assigning the emission factors (as shown in Table IV). Note that although one can suspect that some metal contents decrease with lowering sulphur contents of fuels, this has not been taken into account in the present factors. This is due to the very limited data available in general for metals and no specific studies to our knowledge have correlated lower S with lower metal contents.

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[8] The few measurements on SSD engines with SCR indicate a similar reduction performance.

[9] One can anticipate that the Fe and V contents in fuels are about 2 –3 times more than the other reported metals combined.

3.6.3 SO_2 emissions

As for CO_2 and heavy metals, SO_2 emissions can be directly calculated from the sulphur content in the fuel. Thus the potential for a relatively accurate estimate for SO_2 emissions clearly exists. Unfortunately however, although sulphur content in marine fuels is relatively well tested (about 30% of all residual oils world-wide are tested) access to this data and the resulting averages for different fuel types is limited.

For the purposes of this project, a variety of information sources regarding sulphur content in marine fuels sold in Sweden was used (Table V). In addition, SCB have gathered data on the amounts of Swedish fuel sold with sulphur > 1 wt-%, but this data is at present confidential and not available to SMED (see section 5.1).The spread in the data of Table V and its applicability however casts some doubt on the general reliability and representativity of the material.

Table V Fuel sulphur contents regarding marine fuels.

Source	Reported data	Comments
DNV Petroleum (fuel testing agency) (Holmvang, 2003)	Data for 2002, Swedish average for RO 2,27 % (MD 0,72%)	Good agreement with refinery data
Bunker World (Vis, 2003)	Data for 2000, Swe. average for RO 2,73 % (MD not available) Data for 2001, Swe. average for RO 1,62 % (MD 0,32%) Data for 2002, Swe. average for RO 0,69 % (MD 0,19%) Data for 2003, Swe. average for RO 1,32 % (MD 0,15%)	Fuel S value for RO in 2002 appears to be anomalous. Otherwise RO data appear too low except for 2000.
National Swedish marine emission reporting (Mariterm, 2003a, 2003b)	For North and Baltic Sea [a)] Data for 2000, average for RO and MD 1,59% Data for 2001, average for RO and MD 1,59% Data for 2002, average for RO and MD 1,59% (Indicates RO 1,74→1,80 and MD 0,5 → 0,1) For "Swedish fraction" [a) b)] Data for 2000, average for RO and MD 1,01% (Indicates RO 1,13→1,23 and MD 0,5 → 0,1) Data for 2001, average for RO and MD 1,16% (Indicates RO 1,32→1,41 and MD 0,5 → 0,1) Data for 2002, average for RO and MD 1,25% (Indicates RO 1,43→1,52 and MD 0,5 → 0,1)	Note this study takes into account <u>fuel sold in all countries</u> (including low-S fuels from Eastern Europe) and all shipping in the region. It does however reportedly take into account "SO_x certificates" issued by Swe. Mar. Admin.
Refineries	<u>Swe. refinery A</u>: "For Sweden, ca. 1,0 milj. m^3 RO ca. 2,5 – 3,0 % S, ca. 0,3 milj. m3 lighter fuels < 0,5% S ca. 0,2 milj. ^{m3} MD < 0,2% often < 0,05%" <u>Swe. refinery B</u>: "For Sweden, ca. 1,5 milj. m^3 RO > 2,5% S, + gas oils < 0,05% S" <u>Swe. refinery C</u>: "own deliveries ca. 0,70 milj m3 RO 2,3 – 2,5 % S ca. 0,04 milj. m^3 gas oils < 0,2% + 0,04 milj m^3 MD < 1%S"	Good data source specific to Swedish fuels. Data for 2002.
IVL in-house emission database	Data for years 1990-2003, average for RO 1,91 % (MD 0,38%) (<u>fuel from all countries</u>)	Poor representativity of the whole fleet and biased to more recent years. Only 50 RO fuels tested and 54 MD
Swe. Mar. Admin. database	Data for 2002, for all the different ships (2514) which have visited Sweden and the number of separate calls (121 348 times). The ships with "SO_x certificates" i.e. using <1%S (832 ships and 11 535 calls) and <0,5% S (53 ships and 87 033 calls) are identified. Data for 2003 ships indicate that 1257 ships have SO_x certificates. Of these checks have been made on 512 samples where 66% were < 0,2% S and the average was 0,30 %.	Since the data does not include the fuel consumed for each ship and where the fuel was bunkered (i.e. <u>fuel from all countries</u>), no Swe. average fuel S can be calculated directly. The numbers do however indicate that low sulphur fuel usage is substantial.
EU Ship study (European Commission, 2002b)	Data for 2001 for samples (RO fuels) taken by DNV in different EU nations. For Sweden the average was given as 2,3% (Denmark 2,2 %, Finland 1,6%, Germany 2,1 %, Norway 2,0 %, Netherlands, 2,6% United Kingdom 1,9%)	Confirms data from refineries and data for DNV for year 2002.
EU Ship study (Davies et al., 2000)	Data for 1990 – 1996 on RO averages 2,8 and 2, 9 i.e. little variation 1990-1994. For 1995 & 1996 2,7%	Note <u>world averages</u> only

a) Data was derived by using the reported CO_2 emissions (tons) from each region and a carbon content of 86,7% to obtain a value for the total marine fuel consumed in each region. Using the reported SO_2 emissions (tons), assuming a RO/MD fraction of 7 (international) and 4,2 (International + domestic), fuel sulphur contents can be estimated.

[b] "Swedish fraction" refers to all domestic sea traffic and a "morally correct" fraction of international sea traffic (Sjöbris et al., 2001).

Bearing in mind the drawbacks of the information sources in Table V, it is unfortunate that only a very rough estimate of the fuel sulphur for the different fuels and years can be made for the purposes of this study. Generally, it is assumed that there has been little change in fuel sulphur values until the middle of the 1990s where the introduction of SO_x certificates by the Swe. Maritime Admin. has had an impact. It is suspected that an appreciable amount of these low sulphur RO fuels can originate from foreign sources. Consequently the values presented in Table VI have been estimated and assigned with priority given to data from Swedish refineries and DNV testing. Considerable uncertainty (± 40%) is assumed and thus caution should therefore be exercised in interpreting this data too rigidly.

Table VI Fuel sulphur content (wt-%) assignments roughly estimated in this study for Swedish sold marine fuels.

Year	Average fuel S in Residual Oil (RO)	Average fuel S in Marine Distillates (MD)
1990	2,7	1,0
1991	2,7	1,0
1992	2,7	1,0
1993	2,7	1,0
1994	2,7	0,9
1995	2,7	0,9
1996	2,5	0,9
1997	2,5	0,8
1998	2,4	0,7
1999	2,4	0,6
2000	2,3	0,5
2001	2,3	0,4
2002	2,3	0,4

In view of new regulations from IMO and the European Commission, member states and their national administrations (e.g. Swe. Maritime Administration) will need to compile fuel sulphur data in an effort to follow progress regarding new fuel sulphur caps which will be imposed. In future years, it is therefore anticipated that a much better basis for estimating national SO_2 emissions will be available than used in this study. An ideal solution would be to extend the database used by the Swe. Maritime Administration, by including questions on; sulphur content in ME and AE fuel, annual consumption of ME and AE fuel and % of ME and AE fuel bunkered in Swedish ports.

3.6.4 PAH, PCB, HCB and dioxin emissions

At present, data on PAH, PCB and dioxin emissions from ships are far too limited and have a far too large spread to enable separate engine specific factors. Instead, only emission factors classified after fuel type can be provided.

One should note that the 4 PAH species required for reporting in Table II represent only a very small fraction of the "total PAH" determined in studies[10] where other PAH species are identified, irrespective of the fuel used. Thus for these 4 PAHs there is little difference in emissions from engines using RO or MDO, neither as individual species nor the sum of the four i.e. "Total PAH-4".

Similarly, regarding HCB, PCB and PCDD/PCDF (dioxins and furans), the lack of measurement data has prevented assigned specific emission factors for different engine type, operation mode nor fuel type. For PCB there are currently no definitions as to which isomers (of the 209 available species) are summed and need to be reported (Dutchak, 2003). The PCB data for marine emissions used here refers to PCB totals of 7 – 15 species. Dioxin and furans are reported as a Toxicity Equivalent Quantity of 17 isomers using a set of Toxicity Equivalent Factors assigned in Lloyds Register Engineering Services, 1995

3.6.5 N_2O and CH_4 emissions

Data on CH_4 and N_2O emissions from ships are sparse but the emissions are considered as of minor importance. The CH_4 emission factors used here are based on 8 measured ratios of CH_4 : NMVOC from 4 ships (only HSD and MD fuels). To our knowledge no data exists on other engines and fuels but it is assumed that the same ratios are valid. Thus in all cases 2% [11] of NMVOC is assumed as CH_4.

For N_2O there are limited data (20 measurements) for so-called baseline conditions (i.e. without NO_x abatement) covering 7 ships and 12 different engines. None of the data cover however slow speed engines running on residual oil fuel. Since the results are fairly similar, one emission factor value (0,031 g/kWh) has been assigned for all fuels and engines [12]. For turbine machinery, only one measurement value (0,08 g/kWh) for a marine gas turbine has been found. This value has been assumed to be valid for all turbine machinery but carries a high uncertainty.

Regarding use of SCR systems with urea injection for NO_x abatement, measurements have shown no significant change in N_2O emissions. Thus trials on 5 different ships and 8 engines covering 2 types of SCR, show an average N_2O emission of 0,036 g/kWh. Thus bearing in mind measurement uncertainty and the relatively low number of data, no adjustment has been made for the N_2O emissions with use of SCR systems for NO_x control.

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[10] By including fluoranthene and benzo(ghi)perylene as extra PAH species however, as required for reporting in European Commission, 2000 (presumably required for stationary large combustion sources), then the "Total PAH-6" is 8 times greater than "Total PAH-4" due largely to the inclusion of fluoranthene. If the PAH list is further increased to include 29 species (including naphthalene) the "Total PAH-29" emission factor would be 0,0044 g/kWh for residual oil (ca. 730 times the reported PAH-4) and 0,0025 g/kWh for distillate fuel (ca. 420 times the reported PAH-4).

[11] In previous emission factor guidebooks, 12% of NMVOC has been assumed as CH_4 without any citation regarding measurement data (IPCC, 1997; EMEP, 2002).

[12] The value 0,031 g/kWh is about twice that recommended in IPCC 1997 (no measurement citation).

3.6.6 TSP, PM_{10} and $PM_{2.5}$ emissions

Very few studies have been conducted on particle size distributions from operating marine diesel engines. The general consensus however is that as for other diesel engines the emissions are dominated by particles with diameters less than 1 μm (i.e. TSP = PM_{10} = $PM_{2,5}$). This approach has been used in this study [13].

3.6.7 NH_3 emissions

For so-called baseline cases (i.e. engines without SCR systems for NO_x abatement), NH_3 emissions are very small and have been determined as an average of 0,003 g/kWh (ca. 0,5 ppm) for 7 engines on 5 ships. For a gas turbine only one value has been measured < 0,0008 g/kWh [14].

For SCR systems with urea injection for NO_x abatement (3 different SCR manufacturing companies considered), measurements for all engine and fuel types have been grouped together. The data includes measurements at steady-state (mostly at 75% for certification purposes) but also some real-world data where other operating loads and conditions are considered. In all, the data comprises 66 engines on 17 ships and indicates an average "NH_3 slip" of 15 ppm at 15% O_2 (0,10 g/kWh). Most engines have slip < 10 ppm but a few have considerably higher slip emissions which influence the average. These high NH_3 engines are a result of poorly trimmed systems and also cases where changing engine loads occur, both of these factors reflect the so-called "real-world". Note that the NH_3 slip from SCR systems is considered not to be dependent on engine type or fuel used.

3.7 Emissions from in port and manoeuvring operations

[13] Preliminary tests on two operating diesel engines (AE with MDO and ME with RO) indicate however that about 50 - 70% of the TSP could be as $PM_{2,5}$ and the remainder as PM_{10} (Cooper, 2003). One can anticipate that particle size distribution will be dependent on fuel type (due to ash and sulphur in the fuel).

[14] Note in the emission factor tables, for measurement data reported as less than a detection value, half of the detection limits has been used (i.e. 0,0004 g/kWh in this case).

Although "in port" and "manoeuvring" emissions account for a relative small fraction of the total emissions when compared to those generated "at sea" for propulsion of the ship, they are of importance due to their proximity to populated areas. Strictly speaking, a division of the activity data (marine fuel sales) into fuel consumed for the three operational modes ("at sea", "in port" and "manoeuvring") would ideally be required to fully utilise "in port" and "manoeuvring" emission factors and thereby improve the accuracy of the total emission estimate. Since one can assume that the relative fractions of fuel consumed for these modes are considerably smaller than for "at sea" operation, it is a reasonable simplification to use only the "at sea" emission factors when determining the total emissions. Nevertheless on the ground of completeness and outlining current scientific understanding an insight into in port and manoeuvring emissions has been provided for the year 2002 (Appendix 2).

Some fundamental assumptions used in assigning these emission factors are:

- The SCR reduction profiles for the auxiliary engines (AEs) used in port are assumed to be the same as those evaluated for MEs "at sea". This will however probably lead to an underprediction of the NO_x emission factor since in several cases AEs are operated in the real-world with relatively low engine loads which keep the exhaust temperature below the minimum for urea injection in the SCR to function correctly.

- No AEs are operated with low-NO_x, HAM or DWI.

- AEs are assumed to be either medium or high speed diesels (i.e. no slow-speed diesels or turbine machinery are used as AEs).

- For certain pollutants (e.g. PCB, dioxin and furans), measurement data from AEs are lacking. In these cases data from ME measurements have been used.

- For "manoeuvring" (MEs assumed to be operating at 20% MCR) the factors carry a high uncertainty and are based largely on professional judgement due to a lack of data. Consideration has however been given to in-house so-called real-world studies which cover whole journeys (e.g. Cooper, 2001) and the transient/passage and steady state/passage ratios reported in Lloyds Register Engineering Services, 1995. The approach adopted was to multiply "at sea" ME emission factors (derived from steady state loads 70 - 100%) by 0,8 for NO_x, 2,0 for HC, CO and PM for all diesel engines and steam turbines. For gas turbines the corresponding factors were taken as 0,5 for NO_x, 5,0 for HC, CO and PM. In addition, the specific fuel consumption (and thereby specific SO_2 and CO_2 emissions) has been assumed to increase by 10% for all engines at these low and varying loads. Clearly this approach unfortunately introduces significant uncertainty and provides an area to be targeted for future emission factors studies.

- The reduction profiles for "manoeuvring" are assumed to be the same as for "at sea". With regard to SCR operation which usually require a 30 minute warm-up period, this will probably give an underprediction of the NO_x emission factors.

- One should note that for manoeuvring emissions some ME operation can be either from starts with a cold engine, which will give significantly different emissions (especially CO, HC and PM), compared to starts with relatively warm engines. Secondly since engine loads can change rapidly during manoeuvring operations, the variability in emissions is increased.

In view of the differences in the emission factors between the three modes and the uncertainty level anticipated, it is difficult to specify exactly how biased the total emissions may be when relying solely on the "at sea" emission factors. With a reservation for the lack of measurement data, one can anticipate however that PM emissions in particular are likely to be underestimated.

4 Emission factors for ships

The results generated are presented in Appendices 1 and 2 for year 2002 and years 1990 –2001 respectively.

5 Discussion

5.1 Available activity data

The current level of detail for the activity data (Swedish marine fuel sales) provided by Statistics Sweden (SCB) for calculating ship emissions is, relative to the emission factors, quite limited (Table VII). Since diesel fuel oil, and fuel oil Eo1, are all essentially covered as “marine distillate fuel” and fuel oil Eo2 – Eo6 can be equated with “residual marine fuel”, these 3 SCB fuel groups can be agglomerated to the nomenclature of the 2 marine fuel types without any loss of pertinent information. The Swedish marine fuel sales data for 1990 – 2002 is presented in Appendix 3.

The data presented in Appendix 3 is considered to cover 100 % of all Swedish marine fuel sales. This even includes bunkering at sea made just outside of port areas. Some caution should be exercised however regarding the fraction of domestic and international fuels. Since some ships operate between several Swedish port (by definition domestic traffic) before going on to an international port (by definition international traffic), the fuel consumed for these voyages should ideally be split as domestic/international in the accounting procedure. Clearly, in practice this is very difficult and it is suspected that the fuel is classed as international traffic only. If this is the case, then the activity data (and thereby emissions) for domestic traffic is underestimated.

An additional factor to consider is that a fraction of the fuel included by the sales statistics is used by smaller sea vessels i.e. pleasure craft, fishing boats with < 100 gross tonnage. This will be particular so for distillate fuels. Since the activity data has no division for vessel size and a set of emission factors for the smaller vessels is outside of the scope of this work, then some uncertainty is introduced. In view of previous emission factors estimates for these types of vessel (Swedish Environmental Protection Agency,1992) one can expect a slight overestimate in NO_x emissions and underestimate in CO and HC emissions.

Table VII Scope of activity data (in m^3 delivered) concerning marine emissions reported by SCB

No. of fuel types	3	Diesel fuel oil, Fuel oil Eo1 (“Marine Distillate fuel”) and Fuel oil Eo2 – Eo6 (“Residual Oil”)
No. of uses for fuel	2	International and Domestic sea traffic

It should be borne in mind that from years 1997 onwards, some data on the amount of fuel sold with sulphur greater than or equal to 1 wt-% has been acquired by SCB. Since this data is supplied by only one company however, the data has been classed as confidential and thus has not been made available for use in this study.

The available activity data will dictate the form and units required for the "usable emission factors" (i.e. those directly used to give the total emissions as the product of activity data and emission factors). Although the fuel sales data is reported in m^3 delivered, convention is to convert this data directly to TJ supplied energy using heating value and density data (since UNFCC and IPCC guidelines require even fuel consumption data in TJ supplied energy).

The "usable emission factors" will therefore have to correspond to the same detail i.e. 2 different sets of emission factors one for RO and one for MD fuel. A further division of emission factors for international and domestic traffic is only required for NO_x, CO, NMVOC and NH_3 due to the different use of SCR between international and domestic traffic. It is important to note that additional emission factors covering for example different operational modes ("manoeuvring", "in port") and engine types will be largely superfluous and need to be agglomerated and weighted to suit the final two fuel divisions in order to obtain the total emissions (see section 5.2).

5.2 "Usable" emission factors

To calculate the total emissions, the emission factors in Appendices 1 and 2 need to be combined so that for each pollutant only two emission factors (one for MD fuel and one for RO fuel) are obtained in a way which is representative of the ships operating on Swedish fuel. An exception however is for NO_x, CO, NMVOC and NH_3 where both International and Domestic traffic emission factors will be required. In order to weight the original engine specific emission factors correctly, data on the fleet's (i.e. ships using Swedish fuel) machinery and fuel use is necessary. Such data is as yet unfortunately not been made available. Some data on ship machinery for the entire fleet making calls in Sweden forms however part of a central database kept by the Swedish Maritime Administration. Although the machinery of the ships is not linked to the amount of Swedish purchased fuel consumed, the data can be weighted by using installed engine effect. Fuel type (RO or MD) information can also most probably be deduced. Thus it is hoped that this database can be used in the future to obtain a best estimate of the total Swedish emissions.

If access to the above database proves not possible, an alternative using a more simplified approximation can be made by using data publicly available on the number and type of ships identified by the Swedish Institute for Transport and Communications Analysis (SIKA) for 2001 (Table VIII).

Table VIII. Swedish and foreign vessels (gross tonnage > 100 tons) in Swedish service 2001 according to SIKA. The corresponding identification following the LMIU code presented in European Commission, 2002a, is also given.

Ship type	**No.**	**Gross Register tonnage Kton**	**LMIU codes**
Tankers	148	3 252	A11, A12, A13, A14
Bulk carriers	8	41	A21, A22, A23, A24
Refrigerated cargo ships	130	1 260	A34
Dry cargo ships	188	2 184	A31, A33 and A35
Passenger ferries	43	726	A37
Other passenger ships	136	31	A36 and A32
TOTAL [a)]	653	7 493	-

[a)] Note the total number of ships in the SIKA register (653) can be compared to 2514 registered by the Swe. Mar. Admin. for 2002.

Using the engine/fuel profiles generated for each ship type (26 different ship types) as European averages from the LMIS database (European Commission (2002a), a further calculation gives the engine / fuel profile for the 6 SIKA ship types of the Swedish fleet (assuming that they all use Swedish fuel and that Swedish ships are similar to the European fleet). In this step, several ship types from the LMIS data are averaged (without weighting) to give the profile of a single ship type in the Swedish fleet (using Swedish fuel).

The second step involves weighting the 6 engine /fuel profiles for the SIKA ship types to give a single engine / fuel profile corresponding to the "average Swedish ship". To do this the average installed ME power for each of the SIKA ship type is derived using data from European Commission, 2002a (and assuming the Swedish fleet to has a similar build to the European ships).

In the third step, the Swedish average ship profile is used with the emissions factors tables (Appendices 1 and 2) to obtain average emission factors for each pollutant (and fuel type) corresponding to this profile.

With a reservation for the very rough approximations in this alternative methodology, the NO_x emissions for 2002 can be calculated as 83,5 and 6,6 ktons for international and domestic traffic respectively. This can be compared with the preliminary reported values of 85,6 and 10,4 kton from SCB statistics using the old emission factor methodology.

5.3 Conclusion

This study has presented an up to date and "best possible" estimate of emission factors for ships using Swedish sold fuel. Potential work areas which would improve the quality of the factors can however be outlined as follows:

- Availability of representative measurement data for the sulphur contents used in Swedish sold fuels (extended questionnaire for refineries, increased testing by Swe. Maritime Admin,. or extended questionnaire in Swe. Maritime Admin,. database).

- More measurement data for heavy metals, persistent organic pollutants (PCB, HCB, PCDD, PCDF) and PM (in particular particle size distributions).

- Finally combining this work with information on the machinery/fuel profile for the Swedish fleet using Swedish fuel (e.g. by use of Swe. Maritime Admin,. database), the total emissions can be evaluated with an improved accuracy and completeness covering the requirements for Sweden's international reporting obligations. In addition this would highlight areas for priority (if necessary) regarding engine / fuel types (e.g. steam turbines).

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Appendices

Appendix 1: Emission factors for ships, year 2002

Appendix 2: Emission factors for ships, year 2001

Appendix 3: Swedish marine fuel sales data for 1990-2002

Appendix 4: Reduction profiles for NO_x reduction techniques

Appendix 5: Example of calculation of NO_x emission factor.

2002 | ***at sea (MEs)***

"Equiv. Yr" IMO NOx--> **2002**

MD Fuel S wt% =	0.4	RO Fuel S wt% =	2.3
MD Fuel S wt% =	above	RO Fuel S wt% =	above

Base Factors in g/kWh from data base

Engine	Fuel	*Fuel cons.*	*Main Pollutants*					*Particulate Matter*			*Priority Metals*			*Other Metals*						*Persistent Organic Pollutants*								*Greenhouse gas pollutants*		
type	**type**	**sfc**	**NOx**	**CO**	**NMVOC**	**SOx**	**NH3**	**TSP**	**PM10**	**PM2.5**	**Pb**	**Cd**	**Hg**	**As**	**Cr**	**Cu**	**Ni**	**Se**	**Zn**	**PCB**	**Diox/Fur**	**Ben(a)pyr**	**Ben(b)flu**	**Ben(k)flu**	**Indenopyr**	**PAH-4**	**HCB**	**CO2**	**CH4**	**N2O**
SSD	MD	185	17.0	0.5	0.3	1.5	0.003	0.2	0.2	0.2	3E-05	9.25E-07	9E-09	6E-06	9E-06	0.000315	0.0002	9.25E-09	0.0002	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	588	0.006	0.031
SSD	RO	195	18.1	0.5	0.3	9.0	0.003	1.3	1.3	1.3	3E-05	2.54E-06	6E-07	0.0002	0.0002	0.00039	0.0066	3.9E-06	0.0003	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	620	0.006	0.031
MSD	MD	205	13.2	1.1	0.2	1.6	0.003	0.2	0.2	0.2	3E-05	1.03E-06	1E-08	6E-06	1E-05	0.000349	0.0002	1.03E-08	0.0002	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	652	0.004	0.031
MSD	RO	215	14.0	1.1	0.2	9.9	0.003	0.5	0.5	0.5	3E-05	2.8E-06	6E-07	0.0002	0.0003	0.00043	0.0073	4.3E-06	0.0003	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	683	0.004	0.031
HSD	MD	205	12.0	1.1	0.2	1.6	0.003	0.2	0.2	0.2	3E-05	1.03E-06	1E-08	6E-06	1E-05	0.000349	0.0002	1.03E-08	0.0002	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	652	0.004	0.031
HSD	RO	215	12.7	1.1	0.2	9.9	0.003	0.5	0.5	0.5	3E-05	2.8E-06	6E-07	0.0002	0.0003	0.00043	0.0073	4.3E-06	0.0003	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	683	0.004	0.031
GT	MD	300	5.9	0.1	0.1	2.4	0.0004	0.01	0.01	0.01	5E-05	1.5E-06	2E-08	9E-06	2E-05	0.00051	0.0003	1.5E-08	0.0003	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	954	0.002	0.08
GT	RO	305	6.1	0.1	0.1	14.0	0.0004	0.05	0.05	0.05	5E-05	3.97E-06	9E-07	0.0003	0.0004	0.00061	0.0104	6.1E-06	0.0004	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	970	0.002	0.08
ST	MD	300	2.0	0.2	0.1	2.4	0.0004	0.3	0.3	0.3	5E-05	1.5E-06	2E-08	9E-06	2E-05	0.00051	0.0003	1.5E-08	0.0003	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	954	0.002	0.08
ST	RO	305	2.1	0.2	0.1	14.0	0.0004	0.8	0.8	0.8	5E-05	3.97E-06	9E-07	0.0003	0.0004	0.00061	0.0104	6.1E-06	0.0004	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	970	0.002	0.08

Corrected Factors in g/kWh for introduction of NOx reduction technologies (fuel S and sfc age corrections made in base factors above)

Engine	Fuel	*Fuel cons.*	*Main Pollutants*					*Particulate Matter*			*Priority Metals*			*Other Metals*						*Persistent Organic Pollutants*								*Greenhouse gas pollutants*		
type	**type**	**sfc**	**NOx**	**CO**	**NMVOC**	**SOx**	**NH3**	**TSP**	**PM10**	**PM2.5**	**Pb**	**Cd**	**Hg**	**As**	**Cr**	**Cu**	**Ni**	**Se**	**Zn**	**PCB**	**Diox/Fur**	**Ben(a)pyr**	**Ben(b)flu**	**Ben(k)flu**	**Indenopyr**	**PAH-4**	**HCB**	**CO2**	**CH4**	**N2O**
SSD	MD	185	16.9	0.5	0.3	1.5	0.003	0.2	0.2	0.2	3E-05	9.25E-07	9E-09	6E-06	9E-06	0.000315	0.0002	9.25E-09	0.0002	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	588	0.006	0.031
SSD	RO	195	16.9916	0.4962	0.2974	9.0	0.00532	1.3	1.3	1.3	3E-05	2.54E-06	6E-07	0.0002	0.0002	0.00039	0.0066	3.9E-06	0.0003	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	620	0.006	0.031
MSD	MD	205	13.0	1.1	0.2	1.6	0.005	0.2	0.2	0.2	3E-05	1.03E-06	1E-08	6E-06	1E-05	0.000349	0.0002	1.03E-08	0.0002	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	652	0.004	0.031
MSD	RO	215	13.3	1.1	0.2	9.9	0.006	0.5	0.5	0.5	3E-05	2.8E-06	6E-07	0.0002	0.0003	0.00043	0.0073	4.3E-06	0.0003	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	683	0.004	0.031
HSD	MD	205	12.0	1.1	0.2	1.6	0.003	0.2	0.2	0.2	3E-05	1.03E-06	1E-08	6E-06	1E-05	0.000349	0.0002	1.03E-08	0.0002	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	652	0.004	0.031
HSD	RO	215	12.7	1.1	0.2	9.9	0.003	0.5	0.5	0.5	3E-05	2.8E-06	6E-07	0.0002	0.0003	0.00043	0.0073	4.3E-06	0.0003	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	683	0.004	0.031
GT	MD	300	5.5	0.1	0.1	2.4	0.0004	0.01	0.01	0.01	5E-05	1.5E-06	2E-08	9E-06	2E-05	0.00051	0.0003	1.5E-08	0.0003	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	954	0.002	0.08
GT	RO	305	5.7	0.1	0.1	14.0	0.0004	0.05	0.05	0.05	5E-05	3.97E-06	9E-07	0.0003	0.0004	0.00061	0.0104	6.1E-06	0.0004	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	970	0.002	0.08
ST	MD	300	2.0	0.2	0.1	2.4	0.0004	0.3	0.3	0.3	5E-05	1.5E-06	2E-08	9E-06	2E-05	0.00051	0.0003	1.5E-08	0.0003	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	954	0.002	0.08
ST	RO	305	2.1	0.2	0.1	14.0	0.0004	0.8	0.8	0.8	5E-05	3.97E-06	9E-07	0.0003	0.0004	0.00061	0.0104	6.1E-06	0.0004	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	970	0.002	0.08

Emission Factors in g/ton fuel

Engine	Fuel	*Fuel cons.*	*Main Pollutants*					*Particulate Matter*			*Priority Metals*			*Other Metals*						*Persistent Organic Pollutants*								*Greenhouse gas pollutants*		
type	**type**	**sfc**	**NOx**	**CO**	**NMVOC**	**SOx**	**NH3**	**TSP**	**PM10**	**PM2.5**	**Pb**	**Cd**	**Hg**	**As**	**Cr**	**Cu**	**Ni**	**Se**	**Zn**	**PCB**	**Diox/Fur**	**Ben(a)pyr**	**Ben(b)flu**	**Ben(k)flu**	**Indenopyr**	**PAH-4**	**HCB**	**CO2**	**CH4**	**N2O**
SSD	MD	-	91561	2703	1622	8000	16	1081	1081	1081	0.15	0.005	5E-05	0.03	0.05	1.7	1	0.00005	1	0.00054	5.4E-06	0.0054	0.0108	0.0054	0.0108	0.032	4.3E-05	3179000	32.4	168
SSD	RO	-	87136	2545	1525	46000	27	6667	6667	6667	0.15	0.013	0.003	0.85	1.23	2	34	0.02	1.4	0.00051	5.1E-06	0.0051	0.0103	0.0051	0.0103	0.031	4.1E-05	3179000	30.8	159
MSD	MD	-	63221	5339	970	8000	22	976	976	976	0.15	0.005	5E-05	0.03	0.05	1.7	1	0.00005	1	0.00049	4.9E-06	0.0049	0.0098	0.0049	0.0098	0.029	3.9E-05	3179000	19.5	151
MSD	RO	-	61657	5063	919	46000	29	2326	2326	2326	0.15	0.013	0.003	0.85	1.23	2	34	0.02	1.4	0.00047	4.7E-06	0.0047	0.0093	0.0047	0.0093	0.028	3.7E-05	3179000	18.6	144
HSD	MD	-	58326	5366	976	8000	15	976	976	976	0.15	0.005	5E-05	0.03	0.05	1.7	1	0.00005	1	0.00049	4.9E-06	0.0049	0.0098	0.0049	0.0098	0.029	3.9E-05	3179000	19.5	151
HSD	RO	-	58857	5116	930	46000	14	2326	2326	2326	0.15	0.013	0.003	0.85	1.23	2	34	0.02	1.4	0.00047	4.7E-06	0.0047	0.0093	0.0047	0.0093	0.028	3.7E-05	3179000	18.6	144
GT	MD	-	18487	333	333	8000	1	33	33	33	0.15	0.005	5E-05	0.03	0.05	1.7	1	0.00005	1	0.00033	3.3E-06	0.0033	0.0067	0.0033	0.0067	0.020	2.7E-05	3179000	6.7	267
GT	RO	-	18800	328	328	46000	1	164	164	164	0.15	0.013	0.003	0.85	1.23	2	34	0.02	1.4	0.00033	3.3E-06	0.0033	0.0066	0.0033	0.0066	0.020	2.6E-05	3179000	6.6	262
ST	MD	-	6667	667	333	8000	1	1000	1000	1000	0.15	0.005	5E-05	0.03	0.05	1.7	1	0.00005	1	0.00033	3.3E-06	0.0033	0.0067	0.0033	0.0067	0.020	2.7E-05	3179000	6.7	267
ST	RO	-	6885	656	328	46000	1	2623	2623	2623	0.15	0.013	0.003	0.85	1.23	2	34	0.02	1.4	0.00033	3.3E-06	0.0033	0.0066	0.0033	0.0066	0.020	2.6E-05	3179000	6.6	262

Emission Factors in Gg/TJ as fuel supplied energy (<--- this unit most suitable for multiplying with activity data in "reporting spreadsheets")

Engine	Fuel	*Fuel cons.*	*Main Pollutants*					*Particulate Matter*			*Priority Metals*			*Other Metals*						*Persistent Organic Pollutants*								*Greenhouse gas pollutants*		
type	**type**	**sfc**	**NOx**	**CO**	**NMVOC**	**SOx**	**NH3**	**TSP**	**PM10**	**PM2.5**	**Pb**	**Cd**	**Hg**	**As**	**Cr**	**Cu**	**Ni**	**Se**	**Zn**	**PCB**	**Diox/Fur**	**Ben(a)pyr**	**Ben(b)flu**	**Ben(k)flu**	**Indenopyr**	**PAH-4**	**HCB**	**CO2**	**CH4**	**N2O**
SSD	MD	-	0.00214	6.3E-05	3.8E-05	1.9E-04	3.8E-07	2.5E-05	2.5E-05	2.5E-05	4E-09	1E-10	1E-12	7E-10	1E-09	4E-08	2E-08	1E-12	2E-08	1.3E-11	1.3E-13	1E-10	3E-10	1E-10	3E-10	8E-10	1E-12	0.074	7.6E-07	4E-06
SSD	RO	-	0.00213	6.2E-05	3.7E-05	1.1E-03	6.7E-07	1.6E-04	1.6E-04	1.6E-04	4E-09	3E-10	7E-11	2E-08	3E-08	5E-08	8E-07	5E-10	3E-08	1.3E-11	1.3E-13	1E-10	3E-10	1E-10	3E-10	8E-10	1E-12	0.078	7.5E-07	4E-06
MSD	MD	-	0.00148	1.3E-04	2.3E-05	1.9E-04	5.2E-07	2.3E-05	2.3E-05	2.3E-05	4E-09	1E-10	1E-12	7E-10	1E-09	4E-08	2E-08	1E-12	2E-08	1.1E-11	1.1E-13	1E-10	2E-10	1E-10	2E-10	7E-10	9.1E-13	0.074	4.6E-07	4E-06
MSD	RO	-	0.00151	1.2E-04	2.2E-05	1.1E-03	7.0E-07	5.7E-05	5.7E-05	5.7E-05	4E-09	3E-10	7E-11	2E-08	3E-08	5E-08	8E-07	5E-10	3E-08	1.1E-11	1.1E-13	1E-10	2E-10	1E-10	2E-10	7E-10	9.1E-13	0.078	4.5E-07	4E-06
HSD	MD	-	0.00137	1.3E-04	2.3E-05	1.9E-04	3.4E-07	2.3E-05	2.3E-05	2.3E-05	4E-09	1E-10	1E-12	7E-10	1E-09	4E-08	2E-08	1E-12	2E-08	1.1E-11	1.1E-13	1E-10	2E-10	1E-10	2E-10	7E-10	9.1E-13	0.074	4.6E-07	4E-06
HSD	RO	-	0.00144	1.2E-04	2.3E-05	1.1E-03	3.4E-07	5.7E-05	5.7E-05	5.7E-05	4E-09	3E-10	7E-11	2E-08	3E-08	5E-08	8E-07	5E-10	3E-08	1.1E-11	1.1E-13	1E-10	2E-10	1E-10	2E-10	7E-10	9.1E-13	0.078	4.5E-07	4E-06
GT	MD	-	0.00043	7.8E-06	7.8E-06	1.9E-04	3.1E-08	7.8E-07	7.8E-07	7.8E-07	4E-09	1E-10	1E-12	7E-10	1E-09	4E-08	2E-08	1E-12	2E-08	7.8E-12	7.8E-14	8E-11	2E-10	8E-11	2E-10	5E-10	6.2E-13	0.074	1.6E-07	6E-06
GT	RO	-	0.00046	8.0E-06	8.0E-06	1.1E-03	3.2E-08	4.0E-06	4.0E-06	4.0E-06	4E-09	3E-10	7E-11	2E-08	3E-08	5E-08	8E-07	5E-10	3E-08	8E-12	8.0E-14	8E-11	2E-10	8E-11	2E-10	5E-10	6.4E-13	0.078	1.6E-07	6E-06
ST	MD	-	0.00016	1.6E-05	7.8E-06	1.9E-04	3.1E-08	2.3E-05	2.3E-05	2.3E-05	4E-09	1E-10	1E-12	7E-10	1E-09	4E-08	2E-08	1E-12	2E-08	7.8E-12	7.8E-14	8E-11	2E-10	8E-11	2E-10	5E-10	6.2E-13	0.074	1.6E-07	6E-06
ST	RO	-	0.00017	1.6E-05	8.0E-06	1.1E-03	3.2E-08	6.4E-05	6.4E-05	6.4E-05	4E-09	3E-10	7E-11	2E-08	3E-08	5E-08	8E-07	5E-10	3E-08	8E-12	8.0E-14	8E-11	2E-10	8E-11	2E-10	5E-10	6.4E-13	0.078	1.6E-07	6E-06

NOx, NH3, CO and NMVOC Amendment for fuels sold for DOMESTIC TRAFFIC only (due to greater fraction of SCR in use)

Engine	Fuel	*Corrected Factors in g/kWh*			
type	**type**	**NOx**	**CO**	**NMVOC**	**NH3**
MSD	MD	12.3	1.1	0.2	0.010
MSD	RO	8.4	0.9	0.2	0.045
HSD	MD	10.9	1.1	0.2	0.012

Engine	Fuel	*Emission Factors in g/ton fuel*			
type	**type**	**NOx**	**CO**	**NMVOC**	**NH3**
MSD	MD	60174	5251	952	47
MSD	RO	38928	4410	784	211
HSD	MD	53372	5209	943	59

Engine	Fuel	*Emission Factors in Gg/TJ as fuel supplied energy*			
type	**type**	**NOx**	**CO**	**NMVOC**	**NH3**
MSD	MD	0.00141	0.0001	2.23E-05	1E-06
MSD	RO	0.00095	0.0001	1.91E-05	5E-06
HSD	MD	0.00125	0.0001	2.21E-05	1E-06

NOTES:-

Approximate levels of uncertainty with emission factors at 95% confidence level (for whole fleet).

[white] = uncertainty ca 5-10% [green] = uncertainty ca 10-20% [orange] = uncertainty ca 20-50% [pink] = uncertainty > 50%

If some emission factors have been derived as "less than" values, then half of this value has been used in calculating the emission factors above.

For conversion of units, note that 1 Gg = 1 kton (i.e. 1g x 10^9) and 1 TJ = 10^6 x 1 MJ (i.e 1 J x 10^12) and 1 MWh = 3.6 GJ

Heating values and densities used are: MD - 0,84 ton/m3, 0,0427 TJ/ton (=9,633 MWh/m3) RO - 0,965 ton/m3, 0,04096 TJ/ton (=10,979 MWh/m3) (SCB used 0,91 and 10,583 previously which is same as 0.0418668 TJ/ton)

2002 **manoeuvring (MEs)** "Equiv. Yr" IMO NOx--> **2002**

MD Fuel S wt% =	0.4	RO Fuel S wt% =	2.3
MD Fuel S wt% =	above	RO Fuel S wt% =	above

Base Factors in g/kWh from data base

Engine	Fuel	*Fuel cons.*	*Main Pollutants*					*Particulate Matter*			*Priority Metals*			*Other Metals*						*Persistent Organic Pollutants*								*Greenhouse gas pollutants*		
type	type	sfc	NOx	CO	NMVOC	SOx	NH3	TSP	PM10	PM2,5	Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn	PCB	Diox/Fur	Ben(a)pyr	Ben(b)flu	Ben(k)flu	Indenopyr	PAH-4	HCB	CO2	CH4	N2O
SSD	MD	204	13.6	1	0.6	1.6	0.003	0.4	0.4	0.4	3E-05	1.02E-06	1E-08	6E-06	1E-05	0.00035	0.0002	1.02E-08	0.0002	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	647	0.012	0.031
SSD	RO	215	14.5	1.0	0.6	9.9	0.003	2.6	2.6	2.6	3E-05	2.79E-06	6E-07	0.0002	0.0003	0.00043	0.0073	4.29E-06	0.0003	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	682	0.012	0.031
MSD	MD	226	10.6	2.2	0.4	1.8	0.003	0.4	0.4	0.4	3E-05	1.13E-06	1E-08	7E-06	1E-05	0.00038	0.0002	1.13E-08	0.0002	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	717	0.008	0.031
MSD	RO	237	11.2	2.2	0.4	10.9	0.003	1	1	1	4E-05	3.07E-06	7E-07	0.0002	0.0003	0.00047	0.008	4.73E-06	0.0003	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	752	0.008	0.031
HSD	MD	226	9.6	2.2	0.4	1.8	0.003	0.4	0.4	0.4	3E-05	1.13E-06	1E-08	7E-06	1E-05	0.00038	0.0002	1.13E-08	0.0002	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	717	0.008	0.031
HSD	RO	237	10.2	2.2	0.4	10.9	0.003	1	1	1	4E-05	3.07E-06	7E-07	0.0002	0.0003	0.00047	0.008	4.73E-06	0.0003	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	752	0.008	0.031
GT	MD	330	3.0	0.5	0.5	2.6	0.0004	0.05	0.05	0.05	5E-05	1.65E-06	2E-08	1E-05	2E-05	0.00056	0.0003	1.65E-08	0.0003	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	1049	0.01	0.08
GT	RO	336	3.1	0.5	0.5	15.4	0.0004	0.25	0.25	0.25	5E-05	4.36E-06	1E-06	0.0003	0.0004	0.00067	0.0114	6.71E-06	0.0005	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	1067	0.01	0.08
ST	MD	330	1.6	0.4	0.2	2.6	0.0004	0.6	0.6	0.6	5E-05	1.65E-06	2E-08	1E-05	2E-05	0.00056	0.0003	1.65E-08	0.0003	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	1049	0.004	0.08
ST	RO	336	1.7	0.4	0.2	15.4	0.0004	1.6	1.6	1.6	5E-05	4.36E-06	1E-06	0.0003	0.0004	0.00067	0.0114	6.71E-06	0.0005	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	1067	0.004	0.08

Corrected Factors in g/kWh for introduction of NOx reduction technologies (fuel S and sfc age corrections made in base factors above)

Engine	Fuel	*Fuel cons.*	*Main Pollutants*					*Particulate Matter*			*Priority Metals*			*Other Metals*						*Persistent Organic Pollutants*								*Greenhouse gas pollutants*		
type	type	sfc	NOx	CO	NMVOC	SOx	NH3	TSP	PM10	PM2,5	Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn	PCB	Diox/Fur	Ben(a)pyr	Ben(b)flu	Ben(k)flu	Indenopyr	PAH-4	HCB	CO2	CH4	N2O
SSD	MD	204	13.6	1.0	0.6	1.6	0.003	0.4	0.4	0.4	3E-05	1.02E-06	1E-08	6E-06	1E-05	0.00035	0.0002	1.02E-08	0.0002	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	647	0.012	0.031
SSD	RO	215	13.5932	0.9924	0.5948	9.9	0.00532	2.6	2.6	2.6	3E-05	2.79E-06	6E-07	0.0002	0.0003	0.00043	0.0073	4.29E-06	0.0003	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	682	0.012	0.031
MSD	MD	226	10.4	2.2	0.4	1.8	0.005	0.4	0.4	0.4	3E-05	1.13E-06	1E-08	7E-06	1E-05	0.00038	0.0002	1.13E-08	0.0002	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	717	0.008	0.031
MSD	RO	237	10.6	2.2	0.4	10.9	0.006	1	1	1	4E-05	3.07E-06	7E-07	0.0002	0.0003	0.00047	0.008	4.73E-06	0.0003	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	752	0.008	0.031
HSD	MD	226	9.6	2.2	0.4	1.8	0.003	0.4	0.4	0.4	3E-05	1.13E-06	1E-08	7E-06	1E-05	0.00038	0.0002	1.13E-08	0.0002	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	717	0.008	0.031
HSD	RO	237	10.1	2.2	0.4	10.9	0.003	1	1	1	4E-05	3.07E-06	7E-07	0.0002	0.0003	0.00047	0.008	4.73E-06	0.0003	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	752	0.008	0.031
GT	MD	330	2.8	0.5	0.5	2.6	0.0004	0.05	0.05	0.05	5E-05	1.65E-06	2E-08	1E-05	2E-05	0.00056	0.0003	1.65E-08	0.0003	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	1049	0.01	0.08
GT	RO	336	2.9	0.5	0.5	15.4	0.0004	0.25	0.25	0.25	5E-05	4.36E-06	1E-06	0.0003	0.0004	0.00067	0.0114	6.71E-06	0.0005	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	1067	0.01	0.08
ST	MD	330	1.6	0.4	0.2	2.6	0.0004	0.6	0.6	0.6	5E-05	1.65E-06	2E-08	1E-05	2E-05	0.00056	0.0003	1.65E-08	0.0003	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	1049	0.004	0.08
ST	RO	336	1.7	0.4	0.2	15.4	0.0004	1.6	1.6	1.6	5E-05	4.36E-06	1E-06	0.0003	0.0004	0.00067	0.0114	6.71E-06	0.0005	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	1067	0.004	0.08

Emission Factors in g/ton fuel

Engine	Fuel	*Fuel cons.*	*Main Pollutants*					*Particulate Matter*			*Priority Metals*			*Other Metals*						*Persistent Organic Pollutants*								*Greenhouse gas pollutants*		
type	type	sfc	NOx	CO	NMVOC	SOx	NH3	TSP	PM10	PM2,5	Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn	PCB	Diox/Fur	Ben(a)pyr	Ben(b)flu	Ben(k)flu	Indenopyr	PAH-4	HCB	CO2	CH4	N2O
SSD	MD	-	66590	4914	2948	8000	15	1966	1966	1966	0.15	0.005	5E-05	0.03	0.05	1.7	1	0.00005	1	0.00049	4.9E-06	0.0049	0.0098	0.0049	0.0098	0.029	3.9E-05	3179000	59.0	152
SSD	RO	-	63372	4627	2773	46000	25	12121	12121	12121	0.15	0.013	0.003	0.85	1.23	2	34	0.02	1.4	0.00047	4.7E-06	0.0047	0.0093	0.0047	0.0093	0.028	3.7E-05	3179000	55.9	145
MSD	MD	-	45979	9707	1764	8000	20	1774	1774	1774	0.15	0.005	5E-05	0.03	0.05	1.7	1	0.00005	1	0.00044	4.4E-06	0.0044	0.0089	0.0044	0.0089	0.027	3.5E-05	3179000	35.5	137
MSD	RO	-	44841	9206	1671	46000	26	4228	4228	4228	0.15	0.013	0.003	0.85	1.23	2	34	0.02	1.4	0.00042	4.2E-06	0.0042	0.0085	0.0042	0.0085	0.025	3.4E-05	3179000	33.8	131
HSD	MD	-	42419	9756	1774	8000	13	1774	1774	1774	0.15	0.005	5E-05	0.03	0.05	1.7	1	0.00005	1	0.00044	4.4E-06	0.0044	0.0089	0.0044	0.0089	0.027	3.5E-05	3179000	35.5	137
HSD	RO	-	42805	9302	1691	46000	13	4228	4228	4228	0.15	0.013	0.003	0.85	1.23	2	34	0.02	1.4	0.00042	4.2E-06	0.0042	0.0085	0.0042	0.0085	0.025	3.4E-05	3179000	33.8	131
GT	MD	-	8403	1515	1515	8000	1	152	152	152	0.15	0.005	5E-05	0.03	0.05	1.7	1	0.00005	1	0.0003	3.0E-06	0.0030	0.0061	0.0030	0.0061	0.018	2.4E-05	3179000	30.3	242
GT	RO	-	8545	1490	1490	46000	1	745	745	745	0.15	0.013	0.003	0.85	1.23	2	34	0.02	1.4	0.0003	3.0E-06	0.0030	0.0060	0.0030	0.0060	0.018	2.4E-05	3179000	29.8	238
ST	MD	-	4848	1212	606	8000	1	1818	1818	1818	0.15	0.005	5E-05	0.03	0.05	1.7	1	0.00005	1	0.0003	3.0E-06	0.0030	0.0061	0.0030	0.0061	0.018	2.4E-05	3179000	12.1	242
ST	RO	-	5007	1192	596	46000	1	4769	4769	4769	0.15	0.013	0.003	0.85	1.23	2	34	0.02	1.4	0.0003	3.0E-06	0.0030	0.0060	0.0030	0.0060	0.018	2.4E-05	3179000	11.9	238

NOx, NH3, CO and NMVOC Amendment for fuels sold for DOMESTIC TRAFFIC only (due to greater fraction of SCR in use)

Engine	Fuel	***Corrected Factors in g/kWh***			
type	type	NOx	CO	NMVOC	NH3
MSD	MD	9.9	2.2	0.4	0.010
MSD	RO	6.7	1.9	0.3	0.045
HSD	MD	8.8	2.1	0.4	0.012

Engine	Fuel	***Emission Factors in g/ton fuel***			
type	type	NOx	CO	NMVOC	NH3
MSD	MD	43763	9547	1730	42
MSD	RO	28311	8019	1425	192
HSD	MD	38816	9470	1714	53

Engine	Fuel	***Emission Factors in Gg/TJ as fuel supplied energy***			
type	type	NOx	CO	NMVOC	NH3
MSD	MD	0.00102	0.0002	4.05E-05	1E-06
MSD	RO	0.00069	0.0002	3.48E-05	5E-06
HSD	MD	0.00091	0.0002	4.02E-05	1E-06

NOTES:-

Approximate levels of uncertainty with emission factors at 95% confidence level (for whole fleet).

[white] = uncertainty ca 5-10% [green] = uncertainty ca 10-20% [orange] = uncertainty ca 20-50% [pink] = uncertainty > 50%

If some emission factors have been derived as "less than" values, then half of this value has been used in calculating the emission factors above.

For conversion of units, note that 1 Gg = 1 kton (i.e. 1g x 10^9) and 1 TJ = 10^6 x 1 MJ (i.e 1 J x 10^12) and 1 MWh = 3.6 GJ

Heating values and densities used are: MD - 0,84 ton/m3, 0,0427 TJ/ton (=9,633 MWh/m3) RO - 0,965 ton/m3, 0,04096 TJ/ton (=10,979 MWh/m3) (SCB used 0,91 and 10,583 previously which is same as 0.0418668 TJ/ton)

2002 | **in port (AEs)**

"Equiv. Yr" IMO NOx--> **2002**

MD Fuel S wt% =	0.4	RO Fuel S wt% =	2.3
MD Fuel S wt% =	above	RO Fuel S wt% =	above

Base Factors in g/kWh from data base

Engine	Fuel	Fuel cons.	Main Pollutants					Particulate Matter			Priority Metals			Other Metals						Persistent Organic Pollutants								Greenhouse gas pollutants		
type	type	sfc	NOx	CO	NMVOC	SOx	NH3	TSP	PM10	PM2,5	Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn	PCB	Diox/Fur	Ben(a)pyr	Ben(b)flu	Ben(k)flu	Indenopyr	PAH-4	HCB	CO2	CH4	N2O
MSD	MD	217	13.8	0.9	0.2	1.7	0.003	0.2	0.2	0.2	3E-05	1.09E-06	1E-08	7E-06	1E-05	0.00037	0.0002	1.09E-08	0.0002	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	690	0.004	0.031
MSD	RO	227	14.5	0.9	0.2	10.4	0.003	0.5	0.5	0.5	3E-05	2.95E-06	7E-07	0.0002	0.0003	0.00045	0.0077	4.54E-06	0.0003	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	722	0.004	0.031
HSD	MD	217	11.8	0.8	0.5	1.7	0.003	0.4	0.4	0.4	3E-05	1.09E-06	1E-08	7E-06	1E-05	0.00037	0.0002	1.09E-08	0.0002	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	690	0.01	0.031
HSD	RO	227	12.0	1.3	0.5	10.4	0.003	0.5	0.5	0.5	3E-05	2.95E-06	7E-07	0.0002	0.0003	0.00045	0.0077	4.54E-06	0.0003	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	722	0.01	0.031

Corrected Factors in g/kWh for introduction of NOx reduction technologies (fuel S and sfc age corrections made in base factors above)

Engine	Fuel	Fuel cons.	Main Pollutants					Particulate Matter			Priority Metals			Other Metals						Persistent Organic Pollutants								Greenhouse gas pollutants		
type	type	sfc	NOx	CO	NMVOC	SOx	NH3	TSP	PM10	PM2,5	Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn	PCB	Diox/Fur	Ben(a)pyr	Ben(b)flu	Ben(k)flu	Indenopyr	PAH-4	HCB	CO2	CH4	N2O
MSD	MD	217	13.5	0.9	0.2	1.7	0.005	0.2	0.2	0.2	3E-05	1.09E-06	1E-08	7E-06	1E-05	0.00037	0.0002	1.09E-08	0.0002	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	690	0.004	0.031
MSD	RO	227	14.0	0.9	0.2	10.4	0.006	0.5	0.5	0.5	3E-05	2.95E-06	7E-07	0.0002	0.0003	0.00045	0.0077	4.54E-06	0.0003	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	722	0.004	0.031
HSD	MD	217	11.8	0.8	0.5	1.7	0.003	0.4	0.4	0.4	3E-05	1.09E-06	1E-08	7E-06	1E-05	0.00037	0.0002	1.09E-08	0.0002	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	690	0.01	0.031
HSD	RO	227	12.0	1.3	0.5	10.4	0.003	0.5	0.5	0.5	3E-05	2.95E-06	7E-07	0.0002	0.0003	0.00045	0.0077	4.54E-06	0.0003	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	722	0.01	0.031

Emission Factors in g/ton fuel

Engine	Fuel	Fuel cons.	Main Pollutants					Particulate Matter			Priority Metals			Other Metals						Persistent Organic Pollutants								Greenhouse gas pollutants		
type	type	sfc	NOx	CO	NMVOC	SOx	NH3	TSP	PM10	PM2,5	Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn	PCB	Diox/Fur	Ben(a)pyr	Ben(b)flu	Ben(k)flu	Indenopyr	PAH-4	HCB	CO2	CH4	N2O
MSD	MD	-	62440	4127	916	8000	21	922	922	922	0.15	0.005	5E-05	0.03	0.05	1.7	1	0.00005	1	0.00046	4.6E-06	0.0046	0.0092	0.0046	0.0092	0.028	3.7E-05	3179000	18.4	143
MSD	RO	-	61728	3924	871	46000	27	2203	2203	2203	0.15	0.013	0.003	0.85	1.23	2	34	0.02	1.4	0.00044	4.4E-06	0.0044	0.0088	0.0044	0.0088	0.026	3.5E-05	3179000	17.6	137
HSD	MD	-	54182	3687	2304	8000	14	1843	1843	1843	0.15	0.005	5E-05	0.03	0.05	1.7	1	0.00005	1	0.00046	4.6E-06	0.0046	0.0092	0.0046	0.0092	0.028	3.7E-05	3179000	46.1	143
HSD	RO	-	52673	5727	2203	46000	13	2203	2203	2203	0.15	0.013	0.003	0.85	1.23	2	34	0.02	1.4	0.00044	4.4E-06	0.0044	0.0088	0.0044	0.0088	0.026	3.5E-05	3179000	44.1	137

NOx, NH3, CO and NMVOC Amendment for fuels sold for DOMESTIC TRAFFIC only (due to greater fraction of SCR in use)

Engine	Fuel	Corrected Factors in g/kWh			
type	type	NOx	CO	NMVOC	NH3
MSD	MD	12.9	0.9	0.2	0.010
MSD	RO	8.7	0.8	0.2	0.045
HSD	MD	10.8	0.8	0.5	0.012

Engine	Fuel	Emission Factors in g/ton fuel			
type	type	NOx	CO	NMVOC	NH3
MSD	MD	59430	4059	899	44
MSD	RO	38187	3418	742	200
HSD	MD	49580	3579	2227	55

Engine	Fuel	Emission Factors in Gg/TJ as fuel supplied energy			
type	type	NOx	CO	NMVOC	NH3
MSD	MD	0.00139	1E-04	2.11E-05	1E-06
MSD	RO	0.00093	8E-05	1.81E-05	5E-06
HSD	MD	0.00116	8E-05	5.22E-05	1E-06

NOTES:-

Approximate levels of uncertainty with emission factors at 95% confidence level (for whole fleet).

(white) = uncertainty ca 5-10% (green) = uncertainty ca 10-20% (orange) = uncertainty ca 20-50% (pink) = uncertainty > 50%

If some emission factors have been derived as "less than" values, then half of this value has been used in calculating the emission factors above.

For conversion of units, note that 1 Gg = 1 kton (i.e. 1g x 10^9) and 1 TJ = 10^6 x 1 MJ (i.e 1 J x 10^12) and 1 MWh = 3.6 GJ

Heating values and densities used are: MD - 0,84 ton/m3, 0,0427 TJ/ton (=9,633 MWh/m3) RO - 0,965 ton/m3, 0,04096 TJ/ton (=10,979 MWh/m3) (SCB used 0,91 and 10,583 previously which is same as 0.0418668 TJ/ton)

2001	at sea (MEs)

"Equiv. Yr" IMO NOx--> **2001**

MD Fuel S wt% =	0.4	RO Fuel S wt% =	2.3
MD Fuel S wt% =	above	RO Fuel S wt% =	above

Base Factors in g/kWh from data base

Engine	Fuel	Fuel cons.	Main Pollutants					Particulate Matter			Priority Metals			Other Metals						Persistent Organic Pollutants								Greenhouse gas pollutants		
type	type	sfc	NOx	CO	NMVOC	SOx	NH3	TSP	PM10	PM2,5	Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn	PCB	Diox/Fur	Ben(a)pyr	Ben(b)flu	Ben(k)flu	Indenopyr	PAH-4	HCB	CO2	CH4	N2O
SSD	MD	185	17.0	0.5	0.3	1.5	0.003	0.2	0.2	0.2	3E-05	9.25E-07	9E-09	6E-06	9E-06	0.000315	0.0002	9.25E-09	0.0002	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	588	0.006	0.031
SSD	RO	195	18.1	0.5	0.3	9.0	0.003	1.3	1.3	1.3	3E-05	2.54E-06	6E-07	0.0002	0.0002	0.00039	0.0066	3.9E-06	0.0003	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	620	0.006	0.031
MSD	MD	205	13.2	1.1	0.2	1.6	0.003	0.2	0.2	0.2	3E-05	1.03E-06	1E-08	6E-06	1E-05	0.000349	0.0002	1.03E-08	0.0002	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	652	0.004	0.031
MSD	RO	215	14.0	1.1	0.2	9.9	0.003	0.5	0.5	0.5	3E-05	2.8E-06	6E-07	0.0002	0.0003	0.00043	0.0073	4.3E-06	0.0003	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	683	0.004	0.031
HSD	MD	205	12.0	1.1	0.2	1.6	0.003	0.2	0.2	0.2	3E-05	1.03E-06	1E-08	6E-06	1E-05	0.000349	0.0002	1.03E-08	0.0002	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	652	0.004	0.031
HSD	RO	215	12.7	1.1	0.2	9.9	0.003	0.5	0.5	0.5	3E-05	2.8E-06	6E-07	0.0002	0.0003	0.00043	0.0073	4.3E-06	0.0003	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	683	0.004	0.031
GT	MD	300	5.9	0.1	0.1	2.4	0.0004	0.01	0.01	0.01	5E-05	1.5E-06	2E-08	9E-06	2E-05	0.00051	0.0003	1.5E-08	0.0003	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	954	0.002	0.08
GT	RO	305	6.1	0.1	0.1	14.0	0.0004	0.05	0.05	0.05	5E-05	3.97E-06	9E-07	0.0003	0.0004	0.00061	0.0104	6.1E-06	0.0004	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	970	0.002	0.08
ST	MD	300	2.0	0.2	0.1	2.4	0.0004	0.3	0.3	0.3	5E-05	1.5E-06	2E-08	9E-06	2E-05	0.00051	0.0003	1.5E-08	0.0003	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	954	0.002	0.08
ST	RO	305	2.1	0.2	0.1	14.0	0.0004	0.8	0.8	0.8	5E-05	3.97E-06	9E-07	0.0003	0.0004	0.00061	0.0104	6.1E-06	0.0004	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	970	0.002	0.08

Corrected Factors in g/kWh for introduction of NOx reduction technologies (fuel S and sfc age corrections made in base factors above)

Engine	Fuel	Fuel cons.	Main Pollutants					Particulate Matter			Priority Metals			Other Metals						Persistent Organic Pollutants								Greenhouse gas pollutants		
type	type	sfc	NOx	CO	NMVOC	SOx	NH3	TSP	PM10	PM2,5	Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn	PCB	Diox/Fur	Ben(a)pyr	Ben(b)flu	Ben(k)flu	Indenopyr	PAH-4	HCB	CO2	CH4	N2O
SSD	MD	185	17.0	0.5	0.3	1.5	0.003	0.2	0.2	0.2	3E-05	9.25E-07	9E-09	6E-06	9E-06	0.000315	0.0002	9.25E-09	0.0002	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	588	0.006	0.031
SSD	RO	195	17.1624	0.4969	0.2978	9.0	0.00494	1.3	1.3	1.3	3E-05	2.54E-06	6E-07	0.0002	0.0002	0.00039	0.0066	3.9E-06	0.0003	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	620	0.006	0.031
MSD	MD	205	13.0	1.1	0.2	1.6	0.005	0.2	0.2	0.2	3E-05	1.03E-06	1E-08	6E-06	1E-05	0.000349	0.0002	1.03E-08	0.0002	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	652	0.004	0.031
MSD	RO	215	13.4	1.1	0.2	9.9	0.006	0.5	0.5	0.5	3E-05	2.8E-06	6E-07	0.0002	0.0003	0.00043	0.0073	4.3E-06	0.0003	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	683	0.004	0.031
HSD	MD	205	12.0	1.1	0.2	1.6	0.003	0.2	0.2	0.2	3E-05	1.03E-06	1E-08	6E-06	1E-05	0.000349	0.0002	1.03E-08	0.0002	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	652	0.004	0.031
HSD	RO	215	12.7	1.1	0.2	9.9	0.003	0.5	0.5	0.5	3E-05	2.8E-06	6E-07	0.0002	0.0003	0.00043	0.0073	4.3E-06	0.0003	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	683	0.004	0.031
GT	MD	300	5.7	0.1	0.1	2.4	0.0004	0.01	0.01	0.01	5E-05	1.5E-06	2E-08	9E-06	2E-05	0.00051	0.0003	1.5E-08	0.0003	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	954	0.002	0.08
GT	RO	305	5.9	0.1	0.1	14.0	0.0004	0.05	0.05	0.05	5E-05	3.97E-06	9E-07	0.0003	0.0004	0.00061	0.0104	6.1E-06	0.0004	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	970	0.002	0.08
ST	MD	300	2.0	0.2	0.1	2.4	0.0004	0.3	0.3	0.3	5E-05	1.5E-06	2E-08	9E-06	2E-05	0.00051	0.0003	1.5E-08	0.0003	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	954	0.002	0.08
ST	RO	305	2.1	0.2	0.1	14.0	0.0004	0.8	0.8	0.8	5E-05	3.97E-06	9E-07	0.0003	0.0004	0.00061	0.0104	6.1E-06	0.0004	1E-07	1E-09	0.000001	0.000002	0.000001	0.000002	0.000006	8E-09	970	0.002	0.08

Emission Factors in g/ton fuel

Engine	Fuel	Fuel cons.	Main Pollutants					Particulate Matter			Priority Metals			Other Metals						Persistent Organic Pollutants								Greenhouse gas pollutants		
type	type	sfc	NOx	CO	NMVOC	SOx	NH3	TSP	PM10	PM2,5	Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn	PCB	Diox/Fur	Ben(a)pyr	Ben(b)flu	Ben(k)flu	Indenopyr	PAH-4	HCB	CO2	CH4	N2O
SSD	MD	-	91671	2703	1622	8000	16	1081	1081	1081	0.15	0.005	5E-05	0.03	0.05	1.7	1	0.00005	1	0.00054	5.4E-06	0.0054	0.0108	0.0054	0.0108	0.032	4.3E-05	3179000	32.4	168
SSD	RO	-	88012	2548	1527	46000	25	6667	6667	6667	0.15	0.013	0.003	0.85	1.23	2	34	0.02	1.4	0.00051	5.1E-06	0.0051	0.0103	0.0051	0.0103	0.031	4.1E-05	3179000	30.8	159
MSD	MD	-	63298	5339	970	8000	22	976	976	976	0.15	0.005	5E-05	0.03	0.05	1.7	1	0.00005	1	0.00049	4.9E-06	0.0049	0.0098	0.0049	0.0098	0.029	3.9E-05	3179000	19.5	151
MSD	RO	-	62187	5071	921	46000	27	2326	2326	2326	0.15	0.013	0.003	0.85	1.23	2	34	0.02	1.4	0.00047	4.7E-06	0.0047	0.0093	0.0047	0.0093	0.028	3.7E-05	3179000	18.6	144
HSD	MD	-	58396	5366	976	8000	15	976	976	976	0.15	0.005	5E-05	0.03	0.05	1.7	1	0.00005	1	0.00049	4.9E-06	0.0049	0.0098	0.0049	0.0098	0.029	3.9E-05	3179000	19.5	151
HSD	RO	-	58928	5116	930	46000	14	2326	2326	2326	0.15	0.013	0.003	0.85	1.23	2	34	0.02	1.4	0.00047	4.7E-06	0.0047	0.0093	0.0047	0.0093	0.028	3.7E-05	3179000	18.6	144
GT	MD	-	18880	333	333	8000	1	33	33	33	0.15	0.005	5E-05	0.03	0.05	1.7	1	0.00005	1	0.00033	3.3E-06	0.0033	0.0067	0.0033	0.0067	0.020	2.7E-05	3179000	6.7	267
GT	RO	-	19200	328	328	46000	1	164	164	164	0.15	0.013	0.003	0.85	1.23	2	34	0.02	1.4	0.00033	3.3E-06	0.0033	0.0066	0.0033	0.0066	0.020	2.6E-05	3179000	6.6	262
ST	MD	-	6667	667	333	8000	1	1000	1000	1000	0.15	0.005	5E-05	0.03	0.05	1.7	1	0.00005	1	0.00033	3.3E-06	0.0033	0.0067	0.0033	0.0067	0.020	2.7E-05	3179000	6.7	267
ST	RO	-	6885	656	328	46000	1	2623	2623	2623	0.15	0.013	0.003	0.85	1.23	2	34	0.02	1.4	0.00033	3.3E-06	0.0033	0.0066	0.0033	0.0066	0.020	2.6E-05	3179000	6.6	262

Emission Factors in Gg/TJ as fuel supplied energy (<--- this unit most suitable for multiplying with activity data in "reporting spreadsheets")

Engine	Fuel	Fuel cons.	Main Pollutants					Particulate Matter			Priority Metals			Other Metals						Persistent Organic Pollutants								Greenhouse gas pollutants		
type	type	sfc	NOx	CO	NMVOC	SOx	NH3	TSP	PM10	PM2,5	Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn	PCB	Diox/Fur	Ben(a)pyr	Ben(b)flu	Ben(k)flu	Indenopyr	PAH-4	HCB	CO2	CH4	N2O
SSD	MD	-	0.00215	6.3E-05	3.8E-05	1.9E-04	3.8E-07	2.5E-05	2.5E-05	2.5E-05	4E-09	1E-10	1E-12	7E-10	1E-09	4E-08	2E-08	1E-12	2E-08	1.3E-11	1.3E-13	1E-10	3E-10	1E-10	3E-10	8E-10	1E-12	0.074	7.6E-07	4E-06
SSD	RO	-	0.00215	6.2E-05	3.7E-05	1.1E-03	6.2E-07	1.6E-04	1.6E-04	1.6E-04	4E-09	3E-10	7E-11	2E-08	3E-08	5E-08	8E-07	5E-10	3E-08	1.3E-11	1.3E-13	1E-10	3E-10	1E-10	3E-10	8E-10	1E-12	0.078	7.5E-07	4E-06
MSD	MD	-	0.00148	1.3E-04	2.3E-05	1.9E-04	5.2E-07	2.3E-05	2.3E-05	2.3E-05	4E-09	1E-10	1E-12	7E-10	1E-09	4E-08	2E-08	1E-12	2E-08	1.1E-11	1.1E-13	1E-10	2E-10	1E-10	2E-10	7E-10	9.1E-13	0.074	4.6E-07	4E-06
MSD	RO	-	0.00152	1.2E-04	2.2E-05	1.1E-03	6.5E-07	5.7E-05	5.7E-05	5.7E-05	4E-09	3E-10	7E-11	2E-08	3E-08	5E-08	8E-07	5E-10	3E-08	1.1E-11	1.1E-13	1E-10	2E-10	1E-10	2E-10	7E-10	9.1E-13	0.078	4.5E-07	4E-06
HSD	MD	-	0.00137	1.3E-04	2.3E-05	1.9E-04	3.4E-07	2.3E-05	2.3E-05	2.3E-05	4E-09	1E-10	1E-12	7E-10	1E-09	4E-08	2E-08	1E-12	2E-08	1.1E-11	1.1E-13	1E-10	2E-10	1E-10	2E-10	7E-10	9.1E-13	0.074	4.6E-07	4E-06
HSD	RO	-	0.00144	1.2E-04	2.3E-05	1.1E-03	3.4E-07	5.7E-05	5.7E-05	5.7E-05	4E-09	3E-10	7E-11	2E-08	3E-08	5E-08	8E-07	5E-10	3E-08	1.1E-11	1.1E-13	1E-10	2E-10	1E-10	2E-10	7E-10	9.1E-13	0.078	4.5E-07	4E-06
GT	MD	-	0.00044	7.8E-06	7.8E-06	1.9E-04	3.1E-08	7.8E-07	7.8E-07	7.8E-07	4E-09	1E-10	1E-12	7E-10	1E-09	4E-08	2E-08	1E-12	2E-08	7.8E-12	7.8E-14	8E-11	2E-10	8E-11	2E-10	5E-10	6.2E-13	0.074	1.6E-07	6E-06
GT	RO	-	0.00047	8.0E-06	8.0E-06	1.1E-03	3.2E-08	4.0E-06	4.0E-06	4.0E-06	4E-09	3E-10	7E-11	2E-08	3E-08	5E-08	8E-07	5E-10	3E-08	8E-12	8.0E-14	8E-11	2E-10	8E-11	2E-10	5E-10	6.4E-13	0.078	1.6E-07	6E-06
ST	MD	-	0.00016	1.6E-05	7.8E-06	1.9E-04	3.1E-08	2.3E-05	2.3E-05	2.3E-05	4E-09	1E-10	1E-12	7E-10	1E-09	4E-08	2E-08	1E-12	2E-08	7.8E-12	7.8E-14	8E-11	2E-10	8E-11	2E-10	5E-10	6.2E-13	0.074	1.6E-07	6E-06
ST	RO	-	0.00017	1.6E-05	8.0E-06	1.1E-03	3.2E-08	6.4E-05	6.4E-05	6.4E-05	4E-09	3E-10	7E-11	2E-08	3E-08	5E-08	8E-07	5E-10	3E-08	8E-12	8.0E-14	8E-11	2E-10	8E-11	2E-10	5E-10	6.4E-13	0.078	1.6E-07	6E-06

NOx, NH3, CO and NMVOC Amendment for fuels sold for DOMESTIC TRAFFIC only (due to greater fraction of SCR in use)

Engine	Fuel	Corrected Factors in g/kWh			
type	type	NOx	CO	NMVOC	NH3
MSD	MD	12.4	1.1	0.2	0.009
MSD	RO	8.0	0.9	0.2	0.048
HSD	MD	11.0	1.1	0.2	0.011

Engine	Fuel	Emission Factors in g/ton fuel			
type	type	NOx	CO	NMVOC	NH3
MSD	MD	60544	5259	953	44
MSD	RO	37288	4364	774	224
HSD	MD	53762	5219	945	56

Engine	Fuel	Emission Factors in Gg/TJ as fuel supplied energy			
type	type	NOx	CO	NMVOC	NH3
MSD	MD	0.00142	0.0001	2.23E-05	1E-06
MSD	RO	0.00091	0.0001	1.89E-05	5E-06
HSD	MD	0.001259	0.0001	2.21E-05	1E-06

NOTES:-

Approximate levels of uncertainty with emission factors at 95% confidence level (for whole fleet).

[white] = uncertainty ca 5-10% [green] = uncertainty ca 10-20% [orange] = uncertainty ca 20-50% [pink] = uncertainty > 50%

If some emission factors have been derived as "less than" values, then half of this value has been used in calculating the emission factors above.

For conversion of units, note that 1 Gg = 1 kton (i.e. 1g x 10^9) and 1 TJ = 10^6 x 1 MJ (i.e 1 J x 10^12) and 1 MWh = 3.6 GJ

Heating values and densities used are: MD - 0,84 ton/m3, 0,0427 TJ/ton (=9,633 MWh/m3) RO - 0,965 ton/m3, 0,04096 TJ/ton (=10,979 MWh/m3) (SCB used 0,91 and 10,583 previously which is same as 0.0418668 TJ/ton)

Swedish Marine Fuel Sales data for 1990-2002 (OBS Data for 2002 preliminary)

provided by Tomas Gustafsson, Statistics Sweden (SCB) - November 2003.

Supplied fuel from SCB protocol 401 Source: Fuel for transport from EN consumption report, form 401. Also published in EN 31 SM Table 2b.

m3	**2002**	2001	2000	1999	1998	1997	1996	1995	1994	1993	1992	1991	1990
Diesel, Nat. sea traffic	15 014	14 647	25 373	20 279	19 093	13 983	14 321	23 449	12 593	15 117	15 973	12 992	15 698
Eo 1, Nat. sea traffic	108 879	115 016	110 885	110 206	87 877	68 132	65 792	52 075	41 109	37 163	48 473	50 878	83 166
Eo 2-6, Nat. sea traffic	48 777	45 678	40 832	40 829	38 935	32 453	11 222	18 189	20 089	26 716	44 903	51 467	63 319
Diesel, Int. sea traffic	45 958	41 367	49 479	52 419	86 699	56 679	55 955	40 929	38 901	28 470	22 892	9 205	7 405
Eo 1, Int. sea traffic	128 809	135 129	158 840	204 275	249 005	234 594	191 123	170 997	189 998	176 314	187 405	167 470	171 935
Eo 2-6, Int. sea traffic	1 182 267	1 360 241	1 369 696	1 371 792	1 336 874	1 158 359	988 964	952 533	956 780	803 050	793 851	703 317	566 704

Note IPCC corrections for diesel, national sea traffic applied in above data
Conversions assuming "Diesel" + "Fuel oil Eo1" = "Marine Distillates (MD)" and "Fuel Oil Eo2 - Eo6" = "Residual Oil (RO)"
Heating values taken as 0.04096 TJ/ton (RO) and 0.04256 TJ/ton (MD)*
Densities taken as 0.965 ton/m3 (RO) and 0.861 ton/m3 (MD)

0.04096	0.04256
0.965	0.861

	International, m3		Domestic, m3	
Year	**RO**	**MD**	**RO**	**MD**
1990	566704	179340	63319	98864
1991	703317	176675	51467	63870
1992	793851	210297	44903	64446
1993	803050	204784	26716	52280
1994	956780	228899	20089	53702
1995	952533	211926	18189	75524
1996	988964	247078	11222	80113
1997	1158359	291273	32453	82115
1998	1336874	335704	38935	106970
1999	1371792	256694	40829	130485
2000	1369696	208319	40832	136258
2001	1360241	176496	45678	129663
2002	1182267	174767	48777	123893

	International, TJ		Domestic, TJ	
Year	**RO**	**MD**	**RO**	**MD**
1990	22400	6572	2503	3623
1991	27800	6474	2034	2340
1992	31378	7706	1775	2362
1993	31742	7504	1056	1916
1994	37818	8388	794	1968
1995	37650	7766	719	2768
1996	39090	9054	444	2936
1997	45786	10673	1283	3009
1998	52842	12302	1539	3920
1999	54222	9406	1614	4782
2000	54139	7634	1614	4993
2001	53765	6468	1805	4751
2002	46731	6404	1928	4540

* These values were averages determined from analyses from 50 RO fuels and 54 MD fuels
Previous heating values used by SCB up to 2003 were 0.04187 TJ/ton (RO) and 0.04270 TJ/ton (MD)
Previous density values used by SCB up to 2003 were 0.91 ton/m3 (RO) and 0.84 ton/m3 (MD)

Setting for assumptions regarding emissions reduction technologies, age factors etc.

NOTE that this will be different for each year - i.e red italicised values in the blue fields correspond to the year in question as indicated to the right

NOTE all underlined values are defined and used in emission factor tables

SCR (International ships)

% of SCRs with Oxi-cat = **45**

Engine/Fuel type	Assumed fraction of installed power using this red. tech.			Assumed fractions for each year 2002	2001	2000	1999	1998	1997	1996	1995	1994	1993	1992	1991	1990
		Default NOx emission red., %														
SSDMDO	*0.00*	*91*	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SSDRO	***0.024***			**0.024**	**0.020**	**0.020**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MSDMDO	***0.016***			**0.016**	**0.016**	**0.014**	**0.008**	**0.005**	**0.005**	**0.005**	**0.005**	**0.005**	**0.005**	**0.005**	0.00	0.00
MSDRO	***0.033***	Default NH3 slip, ppm		**0.033**	**0.028**	**0.026**	**0.026**	**0.014**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HSDMDO	*0.00*	*15*	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HSDRO	*0.00*			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GTMDO	*0.00*	OxiSCR CO emiss. red.,%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GTRO	*0.00*	*70*	0.685	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
STMDO	*0.00*	OxiSCR NMVOC emiss. red.,%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
STRO	*0.00*	*80*	0.640	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

SCR (Domestic ships)

% of SCRs with Oxi-cat = **45**

Engine/Fuel type	Assumed fraction of installed power using this red. tech.			Assumed fractions for each year 2002	2001	2000	1999	1998	1997	1996	1995	1994	1993	1992	1991	1990
		Default NOx emission red., %														
SSDMDO	0.00	*91*	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SSDRO	0.00			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MSDMDO	**0.068**			**0.068**	**0.063**	**0.060**	**0.063**	**0.077**	**0.011**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MSDRO	**0.438**	Default NH3 slip, ppm		**0.438**	**0.467**	**0.523**	**0.523**	**0.548**	**0.038**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HSDMDO	**0.093**	*15*	0.10	**0.093**	**0.087**	**0.082**	**0.086**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HSDRO	0.00			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GTMDO	0.00	OxiSCR CO emiss. red.,%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GTRO	0.00	*70*	0.685	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
STMDO	0.00	OxiSCR NMVOC emiss. red.,%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
STRO	0.00	*80*	0.640	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Setting for assumptions regarding emissions reduction technologies, age factors etc. - continued

NOTE that this will be different for each year - i.e red italicised values in the blue fields correspond to the year in question as indicated to the right

NOTE all underlined values are defined and used in emission factor tables

low NOx-slide valves

Engine/Fuel type	Assumed fraction of installed power using this red. tech.			Assumed fractions for each year 2002	2001	2000	1999	1998	1997	1996	1995	1994	1993	1992	1991	1990
		Default NOx emission red., %														
SSDMDO	*0.00*	*20*	0.8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

SSDRO	***0.179***	**0.179**	**0.156**	**0.098**	**0.006**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MSDMDO	*0.00*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MSDRO	*0.00*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HSDMDO	*0.00*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HSDRO	*0.00*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GTMDO	*0.00*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GTRO	*0.00*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
STMDO	*0.00*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
STRO	*0.00*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Humid Air Motor (HAM)

Engine/Fuel type	Assumed fraction of installed power using this red. tech.	Default NOx emission red., %		Assumed fractions for each year												
				2002	2001	2000	1999	1998	1997	1996	1995	1994	1993	1992	1991	1990
SSDMDO	*0.00*	*70*	0.3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SSDRO	*0.00*			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MSDMDO	*0.00*			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MSDRO	***0.015***			**0.015**	**0.013**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HSDMDO	*0.00*			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HSDRO	*0.00*			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GTMDO	*0.00*			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GTRO	*0.00*			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
STMDO	*0.00*			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
STRO	*0.00*			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Setting for assumptions regarding emissions reduction technologies, age factors etc. - continued

NOTE that this will be different for each year - i.e red italicised values in the blue fields correspond to the year in question as indicated to the right

NOTE all underlined values are defined and used in emission factor tables

Direct Water Injection (DWI)

Engine/Fuel type	Assumed fraction of installed power using this red. tech.	Default NOx emission red., %		Assumed fractions for each year												
				2002	2001	2000	1999	1998	1997	1996	1995	1994	1993	1992	1991	1990
SSDMDO	*0.00*	*50*	0.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SSDRO	*0.00*			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MSDMDO	*0.00*			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MSDRO	***0.018***			**0.018**	**0.016**	**0.016**	**0.016**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HSDMDO	*0.00*			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HSDRO	*0.00*			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GTMDO	*0.00*			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GTRO	*0.00*			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
STMDO	*0.00*			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
STRO	*0.00*			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

New diesel engines following IMO Tech. NOx Code

Default NOx emission reduction, %		Assume same replacement for all engines
6	**0.94**	except GT and ST
% Replacement of old engines with new WITHOUT SCR etc. from 2000		
2	**0.02**	

Age effect on fuel consumption for engines older than 10 years

Default increase in sfc, % compared to 2003	
7	**1.07**

EXAMPLE for 2002 emission factors "at sea" - regarding corrections on NOx, CO, NMVOC and NH3 factors for SCR use.

Consider NOx emission factor

Correction for IMO NOx Code engines

Year 2002 which means "Eqv Yr" (i.e. if after 1999 which it is) so also 2002
This means **3** years with IMO NOx Code(I.e. 2002 - 1999) and so **2%** x 3 yrs (**6**%) of all engines from base yr (1999)
have been replaced by new engines (but not having other NOx controls eg SCR etc.)
We assume and expect the reduction with the new IMO engines to be 6% from the orginal baseline NOx factor (i.e. 18.1 and 14.2 for SSD and MSD with RO)
So in our group of all engines, the NOx emission factor has to be weighted assuming that 6% of them (applies only to the diesels, i.e. HSD, SSD and MSD)
will have a reduction of 5% in their emissions.

Correction for SCR engines

Based on data from IVL questionairre (60 "clean" ships) and SCB fuel statistics. A "reduction profile" for SCR use has been assigned. This is where we assume for all the total Swedish fuel being used what percentage is being used by "exhaust cleaning ships". For 2002 we have:-

2.4% of Swe. sold RO fuel is used by SSD with SCR on International routes
3.3% of Swe. sold RO fuel is used by MSD with SCR on International routes
1.6% of Swe. sold MD fuel is used by MSD with SCR on International routes
For all other engine / fuel types none are equipped with SCR.
Regarding NOx reduction for weighting the NOx emission factor, we assume a **91**% reduction of NOx and an increase in NH3 emissions by a factor of **0,105** g/kWh

Correction for low-NOx slide valves, HAM, DWI engines

As above the same approach has been taken by considering the other NOx reduction techniques.
So for year 2002 the following "reduction profiles" for the other 3 NOx control technolgies are:
17,9% of all power from SSD/RO have low-NOx slide valves
1.5% of all RO fuel is used by MSD with HAM. No other types are equipped with HAM.
1,8% of MSD/RO have DWI for all other types we assume that none are equipped with DWI
Regarding NOx reduction for weighting the NOx emission factor, we assume an **20**% reduction for low-NOx slide valves, **70**% reduction for HAM and **50**% reduction for DWI

Weighting NOx emission factor to correct for reduction technologies

In view of the above and **considering correction of the base emission factor for SSD/RO** I.e. 18,1 g/kWh. The corrected factor will be:-
The corrected factor takes into account the proportion of engines with a certain reduction together with its reduction efficiency. Thus:-

= 18.1*(1-SCRSSDRO-lowNOxSSDRO-HAMSSDRO-DWISSDRO-((Eqyr-1999)*IMOreplace))	<-- the base factor x fraction of engines without any reduction
+ (18.1*NOxSCR*SCRSSDRO)	<-- corrected factor for SCR x fraction of engines with SCR (obs NOxSCR = 0,09)
+ (18.1*NOxlow*lowNOxSSDRO)	<-- corrected factor for slide valves x fraction of engines with slide valves (NOxlow = 0,80)
+ (18.1*NOxHAM*HAMSSDRO)	<-- corrected factor for HAM x fraction of engines with HAM (NOxHAM = 0,30)
+ (18.1*NOxDWI*DWISSDRO)	<-- corrected factor for DWI x fraction of engines with DWI (NOxDWI = 0,50)
+ (18.1*NOxIMO*((Eqyr-1999)*IMOreplace))	<-- corrected factor for new IMO engines x fraction of new engines

= 18.1*(1-0.024-0.179-0-0-((2002-1999)*0.02)) + 18.1*(0.09*0.024) + 18.1*(0.80*0.179) + 0 + 0 + 18.1*(0.94*3*0.02) (NOxIMO = 0,94, Eqyr = 2002, IMOreplace=0.02)

= 18.1*0.737 + 18.1*0.00216 + 18.1*0.1432 + 18.1*0.0564 = 13.3397 + 0.039096 + 2.59192 + 1.02084 **= 16.9916 g/kWh** **for International SSD/RO NOx**

Consider NH3 emission factor

Correction for SCR engines

Since SCR give elevated levels of NH3, the baseline emission factor (0.003 g/kWh) is corrected for as follows

= 0.003*(1-SCRSSDRO) <-- the base factor x fraction of engines without any SCR reduction

+ (NH3SCR*SCRSSDRO) <-- corrected factor for SCR x fraction of engines with SCR (obs NH3SCR = 0,100)

= 0.003*(1-0.024) + (0.100*0.024) **= 0.00532 g/kWh** **for International SSD/RO NH3**

Consider CO emission factor

Correction for SCR engines

Since some SCR have oxidation catalysts CO emissions are also reduced and corrected for as below. It is assumed that **45**% of the SCRs have oxicatalysts which reduce by **70**%

= 0.5*(1-SCRSSDRO) <-- the base factor (0,5 g/kWh) x fraction of engines without any SCR reduction

+ (COSCR*SCRSSDRO) <-- corrected factor for SCR x fraction of engines with SCR (obs COSCR = 0,685 i.e. 1 - (0.70 x 0.45)

= 0.5*(1-0.024) + (0.5*0.685*0.024) **= 0.4962 g/kWh** **for International SSD/RO CO**

Consider NMVOC emission factor

Correction for SCR engines

Since some SCR have oxidation catalysts, NMVOC emissions are also reduced and corrected for as below. It is assumed that **45**% of the SCRs have oxicatalysts which reduce by **80**%

= 0.3*(1-SCRSSDRO) <-- the base factor (0.3 g/kWh) x fraction of engines without any SCR reduction

+ (NMVOCSCR*SCRSSDRO) <-- corrected factor for SCR x fraction of engines with SCR (obs NMVOCSCR = 0,640)

= 0.3*(1-0.024) + (0.3*0.640*0.024) **= 0.2974 g/kWh** **for International SSD/RO NMVOC**