Swedish Methodology for Environmental Data

Methodology for calculating emissions from ships: 2. Emission factors for 2004 reporting

David Cooper, IVL

Tomas Gustafsson, SCB

2004-09-13

On behalf of the Swedish Environmental Protection Agency

Report title: Methodology for calculating emissions from ships. 2. Emission factors for 2004 reporting
Authors: David Cooper IVL, Tomas Gustafsson, SCB
Year of publication: 2004
Publication at: www.smed.se
Title: Report series for SMED and SMED&SLU
Publisher: SMHI Swedish Meteorological and Hydrological Institute
Address: Folkborgsvägen 1, 601 76 Norrköping, Sweden
Start Year: 2004
ISSN: 1652-4179

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.

Summary

As part of an on-going project to improve the quality of Swedish marine emission reporting, 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). The basis for this type of reporting is that only emissions derived from Swedish sold marine fuels are accounted for. This work presents the agglomerated emissions factors to suit available activity data (i.e. Swedish marine fuel sales) enabling total emissions for the period 1990 – 2002 to be calculated.

When tentatively comparing the new emission totals with those reported earlier (using older emission factor data), a striking difference is that SO_2 emissions have been previously underestimated (ca. 5 times too small for International sea traffic). The new HC and CO emissions are however approximately half of those calculated earlier. For NO_x, the older estimates agree reasonably well with the new estimates.

Sammanfattning

Med syftet att förbättra den svenska rapporteringen av marina emissioner har SMED (Svenska Miljö Emissions Data, ett konsortium bestående av IVL Svenska Miljöinstitutet, Statistiska Centralbyrån och Sveriges Meteorologiska och Hydrologiska Institut) tagit fram emissionsfaktorer för fartyg (> 100 Brutto tonnage). Grunden för denna typ av rapportering är att endast emissioner från i Sverige sålda marina bränslen ingår. Detta arbete presenterar emissionsfaktorerna anpassade till aktivitetsdatan så att de totala emissionerna för perioden 1990-2002 kan beräknas.

Jämfört med de tidigare uppskattningarna (med de gamla emissionsfaktorerna) är SO_2-emissionerna ca. fem gånger större baserade på denna studie. De nya HC- och CO-emissionerna är däremot ungefär hälften av de som har rapporterats tidigare. Vad gäller NO_x-emissionerna finns det inga signfikanta skillnader mellan de gamla och nya beräkningarna.

Contents

1 Introduction

The Swedish Methodology for Environmental Data (SMED) has initiated a multi-phase project with the aim to improve the quality of Swedish marine emission reporting. Recently a comprehensive review of emission factors for ships (> 100 gross tonnage and using Swedish sold fuels) was undertaken and completed in January 2004 (Cooper and Gustafsson, 2004). Thus emission factors were proposed for 28 different pollutants as a function of engine and fuel type and taking into account emission reduction measures.

A key issue to be resolved however before these emission factors could be used directly to calculate the total emissions, was their compatibility with the available activity data (Swedish marine fuel sales). Since the emission factors reported in Cooper and Gustafsson, 2004 depend on engine / fuel type, they needed to be weighted against the distribution of engine / fuel types of the ships using Swedish sold fuel. An additional issue raised at the last reference group (Andersson, 2004) concerned the importance of reliable data on the fuel sulphur content for the Swedish sold fuels. To this end, data from Swedish refineries was incorporated in the final report after the reference group meeting and the revised fuel sulphur values were included in the final report. A further point discussed at the reference group meeting concerned the possible adjustment of HCB, PCB and dioxin/furan emission factors since new data would hopefully become available during the Spring of 2004 (comprehensive measurement project funded by the Swedish Environmental Protection Agency).

1.1 Aim of project

To gather latest engine / fuel distribution, HCB, PCB and dioxin/furan emission factor data and thereby provide agglomerated emission factors based on those reported in Cooper and Gustafsson, 2004. In turn this work permits a calculation of the total marine emissions for Swedish reporting duties 2004.

1.2 Engine distribution and other emission factors data

As discussed at the last reference group meeting (Andersson, 2004), it was anticipated that data from the Swedish Maritime Administration could enable a good estimate of the engine / fuel type distribution for ships using Swedish fuel. Unfortunately, this information has not been obtained and since the deadline for reporting the Swedish 2004 emissions is imminent, alternative measures have been necessary (see section 2.2). Regarding, new emission factor data, a preliminary report covering measurements of HCB, PCB and dioxin/furan from ship exhaust has however become available (Gunnarsson and Johansson, 2004) and thus the previous factors for these species in Cooper and Gustafsson, 2004 can be revised (Table I).

Table I. New HCB, PCB and dioxin/furan emission factors used in this work.

	Residual Oil ng/kWh	**Marine Distillate Ng/kWh**
Old emission factors [a)]		
HCB	8	8
Total PCB	100	100
Dioxin / Furan (given as TEQ International)	1	1
New emission factors [b)]		
HCB	30	20
Total PCB	120	90
Dioxin / Furan (given as TEQ WHO)	0,1	0,03

[a)] Reported in Cooper and Gustafsson, 2004. Note that this data focused largely on very few measurements from the early 1990s.
[b)] Preliminary report from an on-going study financed by Swedish Environmental Protection Agency (Gunnarsson and Johansson, 2004).

2 Methodology

2.1 Assumptions

Four key assumptions have been made to allow a stepwise derivation of the so-called ”usable emission factors” (i.e. those factors which can be directly multiplied with the activity data to calculate the total emissions).

- Regarding the available activity data compiled by Statistics Sweden (SCB); marine diesel and fuel oil Eo1, are all essentially covered as “marine distillate fuel (MD)” and fuel oils Eo2 – Eo6 can be equated with “residual oil fuel (RO)”. These 3 SCB fuel groups can thus be agglomerated to the nomenclature of the 2 marine fuel types without any significant loss of emission information (see section 5.1 in Cooper and Gustafsson, 2004.)

- Although the emission factors for the three operating modes provided in Cooper and Gustafsson, 2004 provide valuable knowledge for predicting local emissions (Andersson, 2004), the emissions ”in port” and ”manoeuvring” are relatively very small compared to those ”at sea” when considering the national total emissions. For this reason, the derived usable emission factors have been obtained only from the main engine (ME) emission factors for ”at sea” operation. For quick reference purposes, these factors are presented in Appendices 1 and 2 of Cooper and Gustafsson, 2004 for the years 1990-2002.

- An important step in this work is to agglomerate the emission factors in Cooper and Gustafsson, 2004 so that no distinction is made between engine types. In order to weight the emission factors correctly, data on the distribution of engine / fuel types for all the ships using Swedish sold fuel is required. Unfortunately this has not been available and instead a weighting based on the engine / fuel distribution of the European fleet has been attempted (see section 2.2 below and 5.2 in Cooper and Gustafsson, 2004.). This distribution has thus been assumed to be valid for ships using Swedish sold fuel and unchanged for all years 1990 – 2002.

- Although almost all ”International sea traffic” is associated with larger ships (> 100 gross tonnage) operating on marine distillates (marine diesel + Eo1 fuels) and residual oils (Eo2 – Eo6 fuels), this is not so for “National Navigation”. In this case some of the fuel used will be by smaller vessels < 100 gross tonnage and some vessels are operated using petrol as a fuel. A review and update of emission factors for these smaller vessels is planned as a future work item within SMED. Bearing this in mind, combining solely the emission factors in this report with activity data (marine distillates and residual oils for national navigation) will not yield the correct total emissions for “National Navigation” [1].

2.2 Engine / fuel distribution

As outlined in section 5.2 of Cooper and Gustafsson, 2004, engine / fuel distributions can be derived for the European shipping fleet using several assumptions. These results are presented in Table II and are assumed as the best available estimate at present to match and weight with the emission factors given in Cooper and Gustafsson, 2004. It should be noted that even in deriving this data for the European fleet (based on LMIS data) some anomalies in the data were encountered which raises its uncertainty further.

Table II. Assumed engine / fuel distribution of ships operating with Swedish sold fuel.

Engine / Fuel type [a)]	**Fraction of all ships using Swedish sold fuel**
SSD / MD	0.0002
SSD / RO	0.4346
MSD / MD	0.0016
MSD / RO	0.4604
HSD / MD	0.0165
HSD / RO	0.0243
GT / MD	0.0109
GT / RO	0.0005
ST / MD	0.0054
ST / RO	0.0455
Sum	1.0000

[a)] SSD = Slow speed diesel, MSD = Medium speed diesel, HSD = High-speed diesel, GT = Gas turbine. ST = Steam turbine, MD = Marine Distillate fuel and RO = Residual Oil fuel.

Since virtually all MD fuel use in Table II is associated with turbine and high-speed diesel machinery, the NO_x emission factors in Appendix 1 for this fuel are considerably lower than those for RO.

[1] Especially for HC and CO emissions since the specific emission factors for these species are significantly greater for small vessels compared to ships > 100 gross tonnage.

3 Results

3.1 Emission factors

Ship emission factors (> 100 gross tonnage and years 1990 – 2002) for calculating the total marine emissions for Swedish reporting duties 2004 are presented in Appendix 1.

3.2 Implications

In light of the results generated in this work and the activity data provided by SCB (Appendix 3 in Cooper and Gustafsson, 2004), it is possible to make tentative comparisons between previously reported international sea traffic emissions with the new estimates for 1990 - 2002. Appendix 2 presents the comparisons as simple diagrams for some pollutants [2] (i,e, for NO_x, SO_2, CO, NMVOC, CO_2, CH_4, and N_2O). The following comments can be drawn:

- The general trend over the 12 year period is similar for all pollutants which is largely due to the amount of fuel sold for each year[3]. Changes in the trends due to for example the introduction of NO_x reduction equipment and fuel sulphur content are less pronounced.
- SO_2 emissions have been previously, grossly underestimated (ca. 5 times too small for International traffic). This was due to a previous (and acknowledged) error in the value of the fuel sulphur content used for residual oil. One can however observe a slower increase in SO_2 emissions over the period due to cut backs in fuel sulphur content in comparison to CO_2 (which are solely due to increased fuel use).
- The new HC and CO emission estimates are approximately half of those calculated earlier. This is explained by the higher emission factors previously used (based on data from 1980s).
- For NO_x, the older estimates agree reasonably well with the new estimates despite the introduction of NO_x reduction measures (accounted for in the new estimates but not accounted for in the previous estimates). As pointed out in Cooper and Gustafsson, 2004 only 5,7% of the RO fuel sold in Sweden in 2002 was used for ships with catalytic equipment for NO_x reduction (SCR) for international traffic. If all the SCR ships calling on Swedish ports had chosen to purchase Swedish fuel, this percentage would increase to 11,8%. One should note that the difference observed for the curves between the old and new emissions is also partly due to the variation of the old emission factor over the period i.e. the factor decreased by 3% from 1990 to 1996 and then increased again by 2% from 1996 to 2001.
- CO_2 emissions are ca. 3% higher in the new estimates largely as a result of improved data on the heating value and density of the fuels.
- For N_2O emissions, the new estimates are ca. 30% higher while the CH_4 emissions are more than 10 times lower. These differences can be explained by the very uncertain emission factors cited in IPCC and CORINAIR which have been used in the old estimates. This is discussed further in European Commission, 2002.
- For NH_3 and PM only previous emission data for 2002 have been obtained (LRTAP reporting). For the new estimates, NH_3 emissions are nearly 4 times higher and the PM emissions marginally lower i.e. by 24%, 20% and 27% for PM_{10}, $PM_{2,5}$ and TSP respectively.

[2] Note that for many of the pollutants included in this work, e.g. heavy metals and persistent organic pollutants, no previous reporting of emissions has been made and therefore no direct comparisons are possible.
[3] One should note however that Swedish fuel sales may vary for different years due to primarily fluctuating fuel prices within the international fuel market. Thus they do not reflect the total amount of sea transport occurring in the region.

4 References

Andersson, P. (2004) Meeting notes from reference group meeting, 23rd January 2004. Swedish Environmental Protection Agency, Stockholm.

Cooper, D. A. and Gustafsson, T. (2004) '*Methodology for calculating emissions from ships: 1 Update of emission factors*', SMED project report, 2nd February 2004.

European Commission (2002) '*Quantification of emissions from ships associated with ship movements between ports in the European Communi*ty'. Entec UK Ltd and IVL Swedish Environmental Research Institute, July 2002.

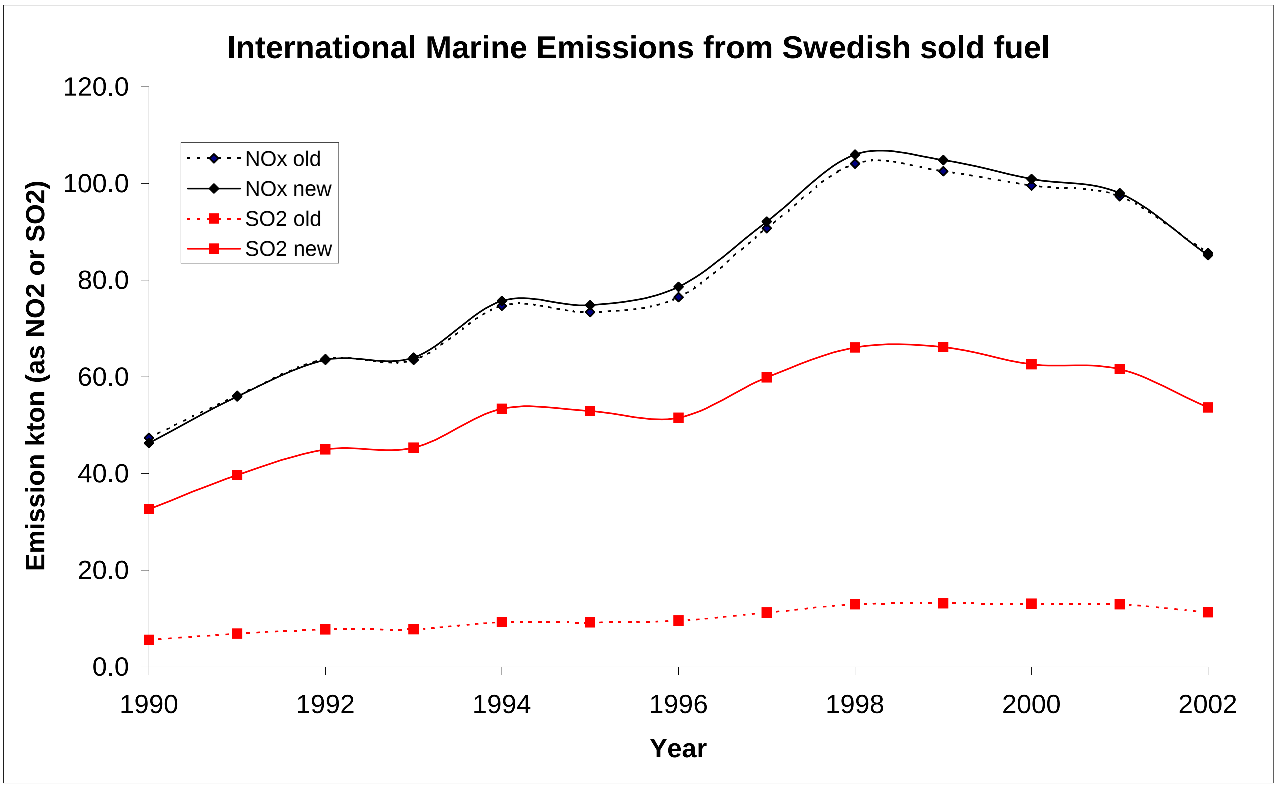
Gunnarsson, M. and Johansson, N. (2004) Swedish Environmental Protection Agency. Personal communication 14th July 2004.

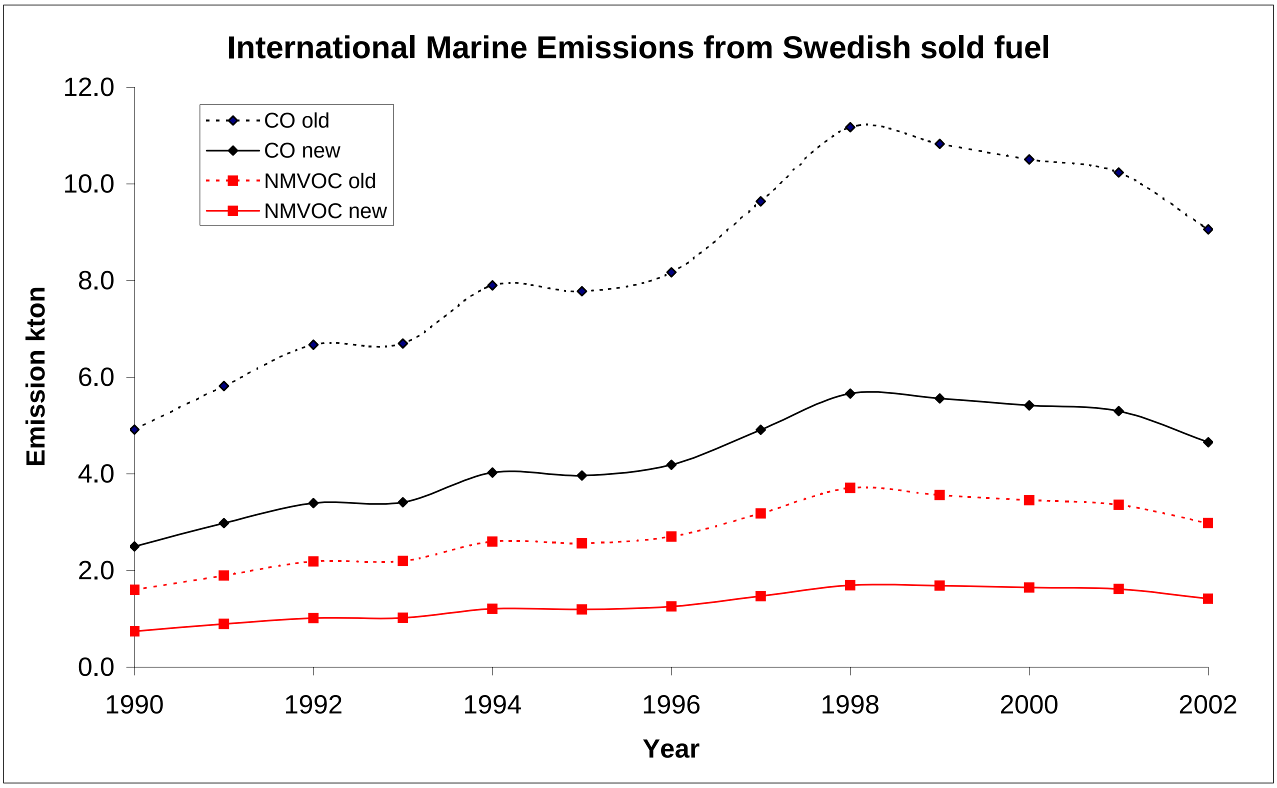
Appendix 1 Ship emission factors

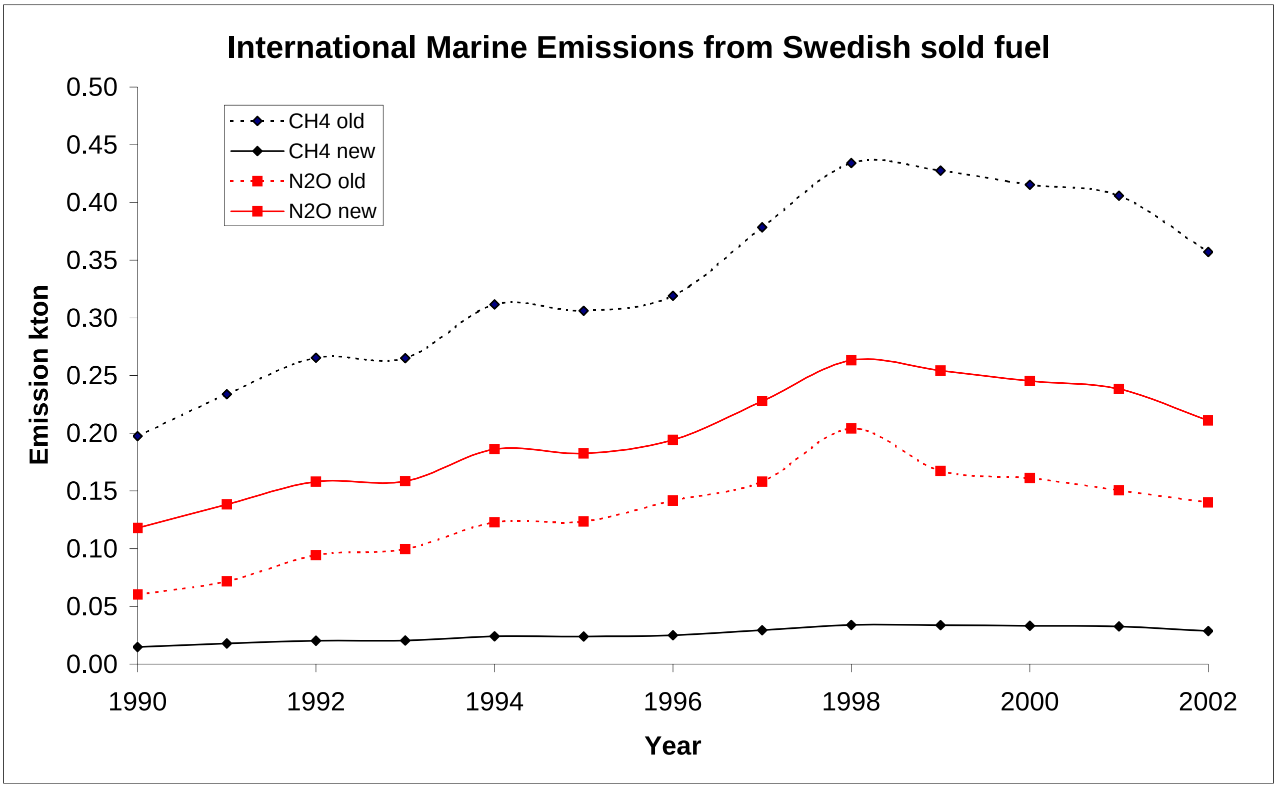
***Emission Factors in** Gg/TJ as fuel supplied energy*

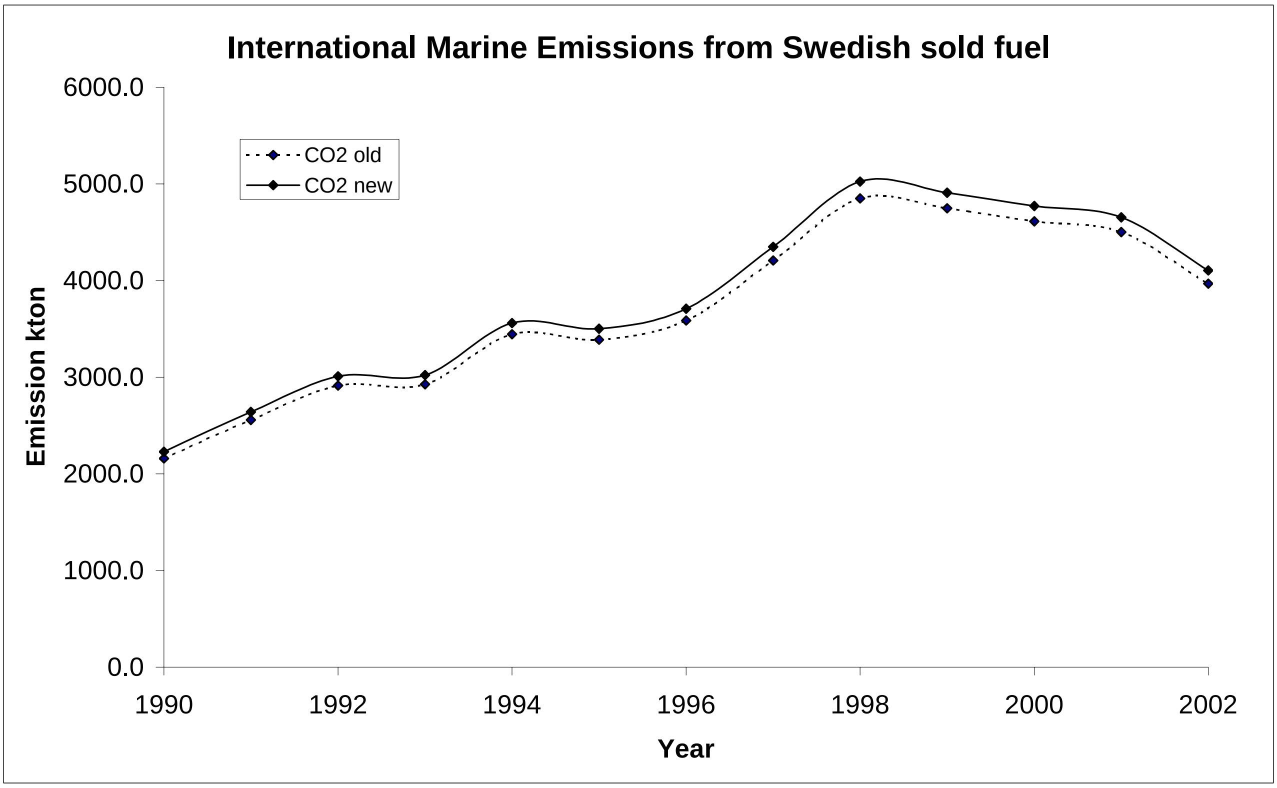
	Fuel	*Main Pollutants*					*Particulate Matter*			*Priority Metals*			*Other Metals*						*Persistent Organic Pollutants*								*Greenhouse gas pollutants*		
	type	**NOx**	**CO**	**NMVOC**	**SOx**	**NH3**	**TSP**	**PM10**	**PM2,5**	**Pb**	**Cd**	**Hg**	**As**	**Cr**	**Cu**	**Ni**	**Se**	**Zn**	**PCB**	**Diox/Fur**	**Ben(a)pyr**	**Ben(b)flu**	**Ben(k)flu**	**Indenopyr**	**PAH-4**	**HCB**	**CO2**	**CH4**	**N2O**
2002																													
Int.	MD	0.00089	7.1E-05	1.6E-05	1.9E-04	2.0E-07	1.6E-05	1.6E-05	1.6E-05	3.5E-09	1.2E-10	1.2E-12	7.0E-10	1.2E-09	4.0E-08	2.3E-08	1.2E-12	2.3E-08	8.8E-12	2.9E-15	9.7E-11	1.9E-10	9.7E-11	1.9E-10	5.8E-10	1.9E-12	0.0744	3.2E-07	4.8E-06
Int.	RO	0.00170	9.0E-05	2.8E-05	1.1E-03	6.4E-07	1.0E-04	1.0E-04	1.0E-04	3.7E-09	3.2E-10	7.3E-11	2.1E-08	3.0E-08	4.9E-08	8.3E-07	4.9E-10	3.4E-08	1.4E-11	1.2E-14	1.2E-10	2.3E-10	1.2E-10	2.3E-10	7.0E-10	3.5E-12	0.0776	5.7E-07	3.9E-06
Nat.	MD	0.00084	6.9E-05	1.5E-05	1.9E-04	7.2E-07	1.6E-05	1.6E-05	1.6E-05	3.5E-09	1.2E-10	1.2E-12	7.0E-10	1.2E-09	4.0E-08	2.3E-08	1.2E-12	2.3E-08	8.8E-12	2.9E-15	9.7E-11	1.9E-10	9.7E-11	1.9E-10	5.8E-10	1.9E-12	0.0744	3.2E-07	4.8E-06
Nat.	RO	0.00144	8.2E-05	2.7E-05	1.1E-03	2.7E-06	1.0E-04	1.0E-04	1.0E-04	3.7E-09	3.2E-10	7.3E-11	2.1E-08	3.0E-08	4.9E-08	8.3E-07	4.9E-10	3.4E-08	1.4E-11	1.2E-14	1.2E-10	2.3E-10	1.2E-10	2.3E-10	7.0E-10	3.5E-12	0.0776	5.7E-07	3.9E-06
2001																													
Int.	MD	0.00090	7.1E-05	1.6E-05	1.9E-04	2.0E-07	1.6E-05	1.6E-05	1.6E-05	3.5E-09	1.2E-10	1.2E-12	7.0E-10	1.2E-09	4.0E-08	2.3E-08	1.2E-12	2.3E-08	8.8E-12	2.9E-15	9.7E-11	1.9E-10	9.7E-11	1.9E-10	5.8E-10	1.9E-12	0.0744	3.2E-07	4.8E-06
Int.	RO	0.00172	9.0E-05	2.8E-05	1.1E-03	5.9E-07	1.0E-04	1.0E-04	1.0E-04	3.7E-09	3.2E-10	7.3E-11	2.1E-08	3.0E-08	4.9E-08	8.3E-07	4.9E-10	3.4E-08	1.4E-11	1.2E-14	1.2E-10	2.3E-10	1.2E-10	2.3E-10	7.0E-10	3.5E-12	0.0776	5.7E-07	3.9E-06
Nat.	MD	0.00084	6.9E-05	1.6E-05	1.9E-04	6.9E-07	1.6E-05	1.6E-05	1.6E-05	3.5E-09	1.2E-10	1.2E-12	7.0E-10	1.2E-09	4.0E-08	2.3E-08	1.2E-12	2.3E-08	8.8E-12	2.9E-15	9.7E-11	1.9E-10	9.7E-11	1.9E-10	5.8E-10	1.9E-12	0.0744	3.2E-07	4.8E-06
Nat.	RO	0.00143	8.2E-05	2.7E-05	1.1E-03	2.9E-06	1.0E-04	1.0E-04	1.0E-04	3.7E-09	3.2E-10	7.3E-11	2.1E-08	3.0E-08	4.9E-08	8.3E-07	4.9E-10	3.4E-08	1.4E-11	1.2E-14	1.2E-10	2.3E-10	1.2E-10	2.3E-10	7.0E-10	3.5E-12	0.0776	5.7E-07	3.9E-06
2000																													
Int.	MD	0.00090	7.1E-05	1.6E-05	2.3E-04	2.0E-07	1.6E-05	1.6E-05	1.6E-05	3.5E-09	1.2E-10	1.2E-12	7.0E-10	1.2E-09	4.0E-08	2.3E-08	1.2E-12	2.3E-08	8.8E-12	2.9E-15	9.7E-11	1.9E-10	9.7E-11	1.9E-10	5.8E-10	1.9E-12	0.0744	3.2E-07	4.8E-06
Int.	RO	0.00174	9.0E-05	2.8E-05	1.1E-03	5.8E-07	1.0E-04	1.0E-04	1.0E-04	3.7E-09	3.2E-10	7.3E-11	2.1E-08	3.0E-08	4.9E-08	8.3E-07	4.9E-10	3.4E-08	1.4E-11	1.2E-14	1.2E-10	2.3E-10	1.2E-10	2.3E-10	7.0E-10	3.5E-12	0.0776	5.7E-07	3.9E-06
Nat.	MD	0.00085	6.9E-05	1.6E-05	2.3E-04	6.6E-07	1.6E-05	1.6E-05	1.6E-05	3.5E-09	1.2E-10	1.2E-12	7.0E-10	1.2E-09	4.0E-08	2.3E-08	1.2E-12	2.3E-08	8.8E-12	2.9E-15	9.7E-11	1.9E-10	9.7E-11	1.9E-10	5.8E-10	1.9E-12	0.0744	3.2E-07	4.8E-06
Nat.	RO	0.00140	8.1E-05	2.6E-05	1.1E-03	3.1E-06	1.0E-04	1.0E-04	1.0E-04	3.7E-09	3.2E-10	7.3E-11	2.1E-08	3.0E-08	4.9E-08	8.3E-07	4.9E-10	3.4E-08	1.4E-11	1.2E-14	1.2E-10	2.3E-10	1.2E-10	2.3E-10	7.0E-10	3.5E-12	0.0776	5.7E-07	3.9E-06
1999																													
Int.	MD	0.00091	7.1E-05	1.6E-05	2.8E-04	2.0E-07	1.6E-05	1.6E-05	1.6E-05	3.5E-09	1.2E-10	1.2E-12	7.0E-10	1.2E-09	4.0E-08	2.3E-08	1.2E-12	2.3E-08	8.8E-12	2.9E-15	9.7E-11	1.9E-10	9.7E-11	1.9E-10	5.8E-10	1.9E-12	0.0744	3.2E-07	4.8E-06
Int.	RO	0.00178	9.0E-05	2.8E-05	1.2E-03	4.7E-07	1.0E-04	1.0E-04	1.0E-04	3.7E-09	3.2E-10	7.3E-11	2.1E-08	3.0E-08	4.9E-08	8.3E-07	4.9E-10	3.4E-08	1.4E-11	1.2E-14	1.2E-10	2.3E-10	1.2E-10	2.3E-10	7.0E-10	3.5E-12	0.0776	5.7E-07	3.9E-06
Nat.	MD	0.00085	6.9E-05	1.6E-05	2.8E-04	6.8E-07	1.6E-05	1.6E-05	1.6E-05	3.5E-09	1.2E-10	1.2E-12	7.0E-10	1.2E-09	4.0E-08	2.3E-08	1.2E-12	2.3E-08	8.8E-12	2.9E-15	9.7E-11	1.9E-10	9.7E-11	1.9E-10	5.8E-10	1.9E-12	0.0744	3.2E-07	4.8E-06
Nat.	RO	0.00144	8.1E-05	2.6E-05	1.2E-03	3.0E-06	1.0E-04	1.0E-04	1.0E-04	3.7E-09	3.2E-10	7.3E-11	2.1E-08	3.0E-08	4.9E-08	8.3E-07	4.9E-10	3.4E-08	1.4E-11	1.2E-14	1.2E-10	2.3E-10	1.2E-10	2.3E-10	7.0E-10	3.5E-12	0.0776	5.7E-07	3.9E-06
1998																													
Int.	MD	0.00091	7.1E-05	1.6E-05	3.3E-04	2.0E-07	1.6E-05	1.6E-05	1.6E-05	3.5E-09	1.2E-10	1.2E-12	7.0E-10	1.2E-09	4.0E-08	2.3E-08	1.2E-12	2.3E-08	8.8E-12	2.9E-15	9.7E-11	1.9E-10	9.7E-11	1.9E-10	5.8E-10	1.9E-12	0.0744	3.2E-07	4.8E-06
Int.	RO	0.00179	9.0E-05	2.8E-05	1.2E-03	4.1E-07	1.0E-04	1.0E-04	1.0E-04	3.7E-09	3.2E-10	7.3E-11	2.1E-08	3.0E-08	4.9E-08	8.3E-07	4.9E-10	3.4E-08	1.4E-11	1.2E-14	1.2E-10	2.3E-10	1.2E-10	2.3E-10	7.0E-10	3.5E-12	0.0776	5.7E-07	3.9E-06
Nat.	MD	0.00090	7.1E-05	1.6E-05	3.3E-04	2.4E-07	1.6E-05	1.6E-05	1.6E-05	3.5E-09	1.2E-10	1.2E-12	7.0E-10	1.2E-09	4.0E-08	2.3E-08	1.2E-12	2.3E-08	8.8E-12	2.9E-15	9.7E-11	1.9E-10	9.7E-11	1.9E-10	5.8E-10	1.9E-12	0.0744	3.2E-07	4.8E-06
Nat.	RO	0.00143	8.1E-05	2.6E-05	1.2E-03	3.2E-06	1.0E-04	1.0E-04	1.0E-04	3.7E-09	3.2E-10	7.3E-11	2.1E-08	3.0E-08	4.9E-08	8.3E-07	4.9E-10	3.4E-08	1.4E-11	1.2E-14	1.2E-10	2.3E-10	1.2E-10	2.3E-10	7.0E-10	3.5E-12	0.0776	5.7E-07	3.9E-06
1997																													
Int.	MD	0.00091	7.1E-05	1.6E-05	3.7E-04	2.0E-07	1.6E-05	1.6E-05	1.6E-05	3.5E-09	1.2E-10	1.2E-12	7.0E-10	1.2E-09	4.0E-08	2.3E-08	1.2E-12	2.3E-08	8.8E-12	2.9E-15	9.7E-11	1.9E-10	9.7E-11	1.9E-10	5.8E-10	1.9E-12	0.0744	3.2E-07	4.8E-06
Int.	RO	0.00180	9.1E-05	2.8E-05	1.2E-03	3.4E-07	1.0E-04	1.0E-04	1.0E-04	3.7E-09	3.2E-10	7.3E-11	2.1E-08	3.0E-08	4.9E-08	8.3E-07	4.9E-10	3.4E-08	1.4E-11	1.2E-14	1.2E-10	2.3E-10	1.2E-10	2.3E-10	7.0E-10	3.5E-12	0.0776	5.7E-07	3.9E-06
Nat.	MD	0.00091	7.1E-05	1.6E-05	3.7E-04	2.0E-07	1.6E-05	1.6E-05	1.6E-05	3.5E-09	1.2E-10	1.2E-12	7.0E-10	1.2E-09	4.0E-08	2.3E-08	1.2E-12	2.3E-08	8.8E-12	2.9E-15	9.7E-11	1.9E-10	9.7E-11	1.9E-10	5.8E-10	1.9E-12	0.0744	3.2E-07	4.8E-06
Nat.	RO	0.00178	9.0E-05	2.8E-05	1.2E-03	5.3E-07	1.0E-04	1.0E-04	1.0E-04	3.7E-09	3.2E-10	7.3E-11	2.1E-08	3.0E-08	4.9E-08	8.3E-07	4.9E-10	3.4E-08	1.4E-11	1.2E-14	1.2E-10	2.3E-10	1.2E-10	2.3E-10	7.0E-10	3.5E-12	0.0776	5.7E-07	3.9E-06
1996																													
Int.	MD	0.00091	7.1E-05	1.6E-05	4.2E-04	2.0E-07	1.6E-05	1.6E-05	1.6E-05	3.5E-09	1.2E-10	1.2E-12	7.0E-10	1.2E-09	4.0E-08	2.3E-08	1.2E-12	2.3E-08	8.8E-12	2.9E-15	9.7E-11	1.9E-10	9.7E-11	1.9E-10	5.8E-10	1.9E-12	0.0744	3.2E-07	4.8E-06
Int.	RO	0.00180	9.1E-05	2.8E-05	1.2E-03	3.4E-07	1.0E-04	1.0E-04	1.0E-04	3.7E-09	3.2E-10	7.3E-11	2.1E-08	3.0E-08	4.9E-08	8.3E-07	4.9E-10	3.4E-08	1.4E-11	1.2E-14	1.2E-10	2.3E-10	1.2E-10	2.3E-10	7.0E-10	3.5E-12	0.0776	5.7E-07	3.9E-06
Nat.	MD	0.00091	7.1E-05	1.6E-05	4.2E-04	2.0E-07	1.6E-05	1.6E-05	1.6E-05	3.5E-09	1.2E-10	1.2E-12	7.0E-10	1.2E-09	4.0E-08	2.3E-08	1.2E-12	2.3E-08	8.8E-12	2.9E-15	9.7E-11	1.9E-10	9.7E-11	1.9E-10	5.8E-10	1.9E-12	0.0744	3.2E-07	4.8E-06
Nat.	RO	0.00180	9.1E-05	2.8E-05	1.2E-03	3.4E-07	1.0E-04	1.0E-04	1.0E-04	3.7E-09	3.2E-10	7.3E-11	2.1E-08	3.0E-08	4.9E-08	8.3E-07	4.9E-10	3.4E-08	1.4E-11	1.2E-14	1.2E-10	2.3E-10	1.2E-10	2.3E-10	7.0E-10	3.5E-12	0.0776	5.7E-07	3.9E-06
1995																													
Int.	MD	0.00091	7.1E-05	1.6E-05	4.2E-04	2.0E-07	1.6E-05	1.6E-05	1.6E-05	3.5E-09	1.2E-10	1.2E-12	7.0E-10	1.2E-09	4.0E-08	2.3E-08	1.2E-12	2.3E-08	8.8E-12	2.9E-15	9.7E-11	1.9E-10	9.7E-11	1.9E-10	5.8E-10	1.9E-12	0.0744	3.2E-07	4.8E-06
Int.	RO	0.00180	9.1E-05	2.8E-05	1.3E-03	3.4E-07	1.0E-04	1.0E-04	1.0E-04	3.7E-09	3.2E-10	7.3E-11	2.1E-08	3.0E-08	4.9E-08	8.3E-07	4.9E-10	3.4E-08	1.4E-11	1.2E-14	1.2E-10	2.3E-10	1.2E-10	2.3E-10	7.0E-10	3.5E-12	0.0776	5.7E-07	3.9E-06
Nat.	MD	0.00091	7.1E-05	1.6E-05	4.2E-04	2.0E-07	1.6E-05	1.6E-05	1.6E-05	3.5E-09	1.2E-10	1.2E-12	7.0E-10	1.2E-09	4.0E-08	2.3E-08	1.2E-12	2.3E-08	8.8E-12	2.9E-15	9.7E-11	1.9E-10	9.7E-11	1.9E-10	5.8E-10	1.9E-12	0.0744	3.2E-07	4.8E-06
Nat.	RO	0.00180	9.1E-05	2.8E-05	1.3E-03	3.4E-07	1.0E-04	1.0E-04	1.0E-04	3.7E-09	3.2E-10	7.3E-11	2.1E-08	3.0E-08	4.9E-08	8.3E-07	4.9E-10	3.4E-08	1.4E-11	1.2E-14	1.2E-10	2.3E-10	1.2E-10	2.3E-10	7.0E-10	3.5E-12	0.0776	5.7E-07	3.9E-06
1994																													
Int.	MD	0.00091	7.1E-05	1.6E-05	4.2E-04	2.0E-07	1.6E-05	1.6E-05	1.6E-05	3.5E-09	1.2E-10	1.2E-12	7.0E-10	1.2E-09	4.0E-08	2.3E-08	1.2E-12	2.3E-08	8.8E-12	2.9E-15	9.7E-11	1.9E-10	9.7E-11	1.9E-10	5.8E-10	1.9E-12	0.0744	3.2E-07	4.8E-06
Int.	RO	0.00180	9.1E-05	2.8E-05	1.3E-03	3.4E-07	1.0E-04	1.0E-04	1.0E-04	3.7E-09	3.2E-10	7.3E-11	2.1E-08	3.0E-08	4.9E-08	8.3E-07	4.9E-10	3.4E-08	1.4E-11	1.2E-14	1.2E-10	2.3E-10	1.2E-10	2.3E-10	7.0E-10	3.5E-12	0.0776	5.7E-07	3.9E-06
Nat.	MD	0.00091	7.1E-05	1.6E-05	4.2E-04	2.0E-07	1.6E-05	1.6E-05	1.6E-05	3.5E-09	1.2E-10	1.2E-12	7.0E-10	1.2E-09	4.0E-08	2.3E-08	1.2E-12	2.3E-08	8.8E-12	2.9E-15	9.7E-11	1.9E-10	9.7E-11	1.9E-10	5.8E-10	1.9E-12	0.0744	3.2E-07	4.8E-06
Nat.	RO	0.00180	9.1E-05	2.8E-05	1.3E-03	3.4E-07	1.0E-04	1.0E-04	1.0E-04	3.7E-09	3.2E-10	7.3E-11	2.1E-08	3.0E-08	4.9E-08	8.3E-07	4.9E-10	3.4E-08	1.4E-11	1.2E-14	1.2E-10	2.3E-10	1.2E-10	2.3E-10	7.0E-10	3.5E-12	0.0776	5.7E-07	3.9E-06
1993																													
Int.	MD	0.00091	7.1E-05	1.6E-05	4.7E-04	2.0E-07	1.6E-05	1.6E-05	1.6E-05	3.5E-09	1.2E-10	1.2E-12	7.0E-10	1.2E-09	4.0E-08	2.3E-08	1.2E-12	2.3E-08	8.8E-12	2.9E-15	9.7E-11	1.9E-10	9.7E-11	1.9E-10	5.8E-10	1.9E-12	0.0744	3.2E-07	4.8E-06
Int.	RO	0.00180	9.1E-05	2.8E-05	1.3E-03	3.4E-07	1.0E-04	1.0E-04	1.0E-04	3.7E-09	3.2E-10	7.3E-11	2.1E-08	3.0E-08	4.9E-08	8.3E-07	4.9E-10	3.4E-08	1.4E-11	1.2E-14	1.2E-10	2.3E-10	1.2E-10	2.3E-10	7.0E-10	3.5E-12	0.0776	5.7E-07	3.9E-06
Nat.	MD	0.00091	7.1E-05	1.6E-05	4.7E-04	2.0E-07	1.6E-05	1.6E-05	1.6E-05	3.5E-09	1.2E-10	1.2E-12	7.0E-10	1.2E-09	4.0E-08	2.3E-08	1.2E-12	2.3E-08	8.8E-12	2.9E-15	9.7E-11	1.9E-10	9.7E-11	1.9E-10	5.8E-10	1.9E-12	0.0744	3.2E-07	4.8E-06
Nat.	RO	0.00180	9.1E-05	2.8E-05	1.3E-03	3.4E-07	1.0E-04	1.0E-04	1.0E-04	3.7E-09	3.2E-10	7.3E-11	2.1E-08	3.0E-08	4.9E-08	8.3E-07	4.9E-10	3.4E-08	1.4E-11	1.2E-14	1.2E-10	2.3E-10	1.2E-10	2.3E-10	7.0E-10	3.5E-12	0.0776	5.7E-07	3.9E-06
1992																													
Int.	MD	0.00091	7.1E-05	1.6E-05	4.7E-04	2.0E-07	1.6E-05	1.6E-05	1.6E-05	3.5E-09	1.2E-10	1.2E-12	7.0E-10	1.2E-09	4.0E-08	2.3E-08	1.2E-12	2.3E-08	8.8E-12	2.9E-15	9.7E-11	1.9E-10	9.7E-11	1.9E-10	5.8E-10	1.9E-12	0.0744	3.2E-07	4.8E-06
Int.	RO	0.00180	9.1E-05	2.8E-05	1.3E-03	3.4E-07	1.0E-04	1.0E-04	1.0E-04	3.7E-09	3.2E-10	7.3E-11	2.1E-08	3.0E-08	4.9E-08	8.3E-07	4.9E-10	3.4E-08	1.4E-11	1.2E-14	1.2E-10	2.3E-10	1.2E-10	2.3E-10	7.0E-10	3.5E-12	0.0776	5.7E-07	3.9E-06
Nat.	MD	0.00091	7.1E-05	1.6E-05	4.7E-04	2.0E-07	1.6E-05	1.6E-05	1.6E-05	3.5E-09	1.2E-10	1.2E-12	7.0E-10	1.2E-09	4.0E-08	2.3E-08	1.2E-12	2.3E-08	8.8E-12	2.9E-15	9.7E-11	1.9E-10	9.7E-11	1.9E-10	5.8E-10	1.9E-12	0.0744	3.2E-07	4.8E-06
Nat.	RO	0.00180	9.1E-05	2.8E-05	1.3E-03	3.4E-07	1.0E-04	1.0E-04	1.0E-04	3.7E-09	3.2E-10	7.3E-11	2.1E-08	3.0E-08	4.9E-08	8.3E-07	4.9E-10	3.4E-08	1.4E-11	1.2E-14	1.2E-10	2.3E-10	1.2E-10	2.3E-10	7.0E-10	3.5E-12	0.0776	5.7E-07	3.9E-06
1991																													
Int.	MD	0.00091	7.1E-05	1.6E-05	4.7E-04	2.0E-07	1.6E-05	1.6E-05	1.6E-05	3.5E-09	1.2E-10	1.2E-12	7.0E-10	1.2E-09	4.0E-08	2.3E-08	1.2E-12	2.3E-08	8.8E-12	2.9E-15	9.7E-11	1.9E-10	9.7E-11	1.9E-10	5.8E-10	1.9E-12	0.0744	3.2E-07	4.8E-06
Int.	RO	0.00180	9.1E-05	2.8E-05	1.3E-03	3.4E-07	1.0E-04	1.0E-04	1.0E-04	3.7E-09	3.2E-10	7.3E-11	2.1E-08	3.0E-08	4.9E-08	8.3E-07	4.9E-10	3.4E-08	1.4E-11	1.2E-14	1.2E-10	2.3E-10	1.2E-10	2.3E-10	7.0E-10	3.5E-12	0.0776	5.7E-07	3.9E-06
Nat.	MD	0.00091	7.1E-05	1.6E-05	4.7E-04	2.0E-07	1.6E-05	1.6E-05	1.6E-05	3.5E-09	1.2E-10	1.2E-12	7.0E-10	1.2E-09	4.0E-08	2.3E-08	1.2E-12	2.3E-08	8.8E-12	2.9E-15	9.7E-11	1.9E-10	9.7E-11	1.9E-10	5.8E-10	1.9E-12	0.0744	3.2E-07	4.8E-06
Nat.	RO	0.00180	9.1E-05	2.8E-05	1.3E-03	3.4E-07	1.0E-04	1.0E-04	1.0E-04	3.7E-09	3.2E-10	7.3E-11	2.1E-08	3.0E-08	4.9E-08	8.3E-07	4.9E-10	3.4E-08	1.4E-11	1.2E-14	1.2E-10	2.3E-10	1.2E-10	2.3E-10	7.0E-10	3.5E-12	0.0776	5.7E-07	3.9E-06
1990																													
Int.	MD	0.00091	7.1E-05	1.6E-05	4.7E-04	2.0E-07	1.6E-05	1.6E-05	1.6E-05	3.5E-09	1.2E-10	1.2E-12	7.0E-10	1.2E-09	4.0E-08	2.3E-08	1.2E-12	2.3E-08	8.8E-12	2.9E-15	9.7E-11	1.9E-10	9.7E-11	1.9E-10	5.8E-10	1.9E-12	0.0744	3.2E-07	4.8E-06
Int.	RO	0.00180	9.1E-05	2.8E-05	1.3E-03	3.4E-07	1.0E-04	1.0E-04	1.0E-04	3.7E-09	3.2E-10	7.3E-11	2.1E-08	3.0E-08	4.9E-08	8.3E-07	4.9E-10	3.4E-08	1.4E-11	1.2E-14	1.2E-10	2.3E-10	1.2E-10	2.3E-10	7.0E-10	3.5E-12	0.0776	5.7E-07	3.9E-06
Nat.	MD	0.00091	7.1E-05	1.6E-05	4.7E-04	2.0E-07	1.6E-05	1.6E-05	1.6E-05	3.5E-09	1.2E-10	1.2E-12	7.0E-10	1.2E-09	4.0E-08	2.3E-08	1.2E-12	2.3E-08	8.8E-12	2.9E-15	9.7E-11	1.9E-10	9.7E-11	1.9E-10	5.8E-10	1.9E-12	0.0744	3.2E-07	4.8E-06
Nat.	RO	0.00180	9.1E-05	2.8E-05	1.3E-03	3.4E-07	1.0E-04	1.0E-04	1.0E-04	3.7E-09	3.2E-10	7.3E-11	2.1E-08	3.0E-08	4.9E-08	8.3E-07	4.9E-10	3.4E-08	1.4E-11	1.2E-14	1.2E-10	2.3E-10	1.2E-10	2.3E-10	7.0E-10	3.5E-12	0.0776	5.7E-07	3.9E-06

Appendix 2 Comparison of old and new estimates






International Marine Emissions from Swedish sold fuel
Emission kton
Year
CH4 old
CH4 new
N2O old
N2O new
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
1990
1992
1994
1996
1998
2000
2002


International Marine Emissions from Swedish sold fuel
Emission kton
Year
CO2 old
CO2 new
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
1990
1992
1994
1996
1998
2000
2002