SNAP CODES:	**080402** **080403** **080404** **080304**
SOURCE ACTIVITY TITLE:	**SHIPPING ACTIVITIES** ***National sea traffic*** ***National Fishing*** ***International sea traffic*** ***Inland goods carrying vessels***
NOSE CODES:	**202.04.01** **202.04.02** **202.04.03**
NFR CODE:	**1 A 3 d i** **1 A 3 d ii** **1 A 4 c iii**
ISIC:	**5011** **5012** **0311** **5022**

1 ACTIVITIES INCLUDED

Shipping activities include all ship activities, whether at sea, in port or on inland waterways.

All ships, including fishing vessels, of more than 100 gross tonnes are covered. Note that these emissions are reported under NFR 1A4c iii. Military vessels should also be included if data are available and reported under NFR 1A5b.

The emissions should be split as follows:
Shipping Activities (SNAP sub-sector 0804):

- Other Transport - Harbours (SNAP 080401);
- National sea traffic (SNAP 080402);
- National Fishing (SNAP 080403);
- International sea traffic (SNAP 080404);

Inland Waterways (SNAP sub-sector 0803):

- Inland goods carrying vessels (SNAP 080304) (see also chapter B810).

Smaller boats and leisure craft are included under SNAP 080301-080303 (chapter B810).

SNAP 080402 and 080403 are reported to ECE and UNFCCC as part of national totals and are subject to reductions in accordance with the protocols. SNAP 080404 is reported to UNFCCC for information only. The latter category includes emissions from all bunker fuel sold to international sea traffic in the reporting country, regardless of the flag of the ships consuming it.

On board incineration of waste is to be included in SNAP 090201. Evaporation of NMVOC is to be included in SNAP 050401 or if gasoline in SNAP 050502.

2 CONTRIBUTION TO TOTAL EMISSIONS

Table 2.1: Ranges of contribution of national shipping to total emissions of the CORINAIR-94 inventory

	Contribution to total emissions [%]
SO_2	0-80
NOx	0-30
NMVOC	0-5
CH_4	0-2
CO	0-18
CO_2	0-40
N_2O	0-1
NH_3	-
TSP*	0-3
PM_{10}*	0-4
$PM_{2.5}$*	0-5

* From EMEP, http://webdab.emep.int/, official emissions for 2004 from country submissions in 2006.
0 = emissions are reported, but the exact value is below the rounding limit (0.1 per cent)
\- = no emissions have been reported
.

On an European scale, SO_2 and NO_x emissions from national shipping can be important with respect to total national emissions (Table 2.1). However, emissions from *national shipping* generally only represent a few percent of the emissions from *shipping* operating *internationally*. Globally, shipping is estimated to be responsible for around 5-12 % and 3-4% respectively of anthropogenic NO_x and SO_2 emissions (extrapolations from Marintek (1990) and Lloyd's Register (1995)). Estimated total NO_x attributable to shipping in the North-eastern Atlantic is approximately equivalent to the national total for France and Denmark combined, and slightly greater than the emissions attributed to road transport in Germany in 1990. Total SO_2 emissions are estimated to be equivalent to the total emission from France and half that emitted by UK power stations in 1990. Shipping generated exhaust emissions of hydrocarbons (VOC) and CO are relatively insignificant in comparison to national land based sources (Lloyd's Register (1995)).

The contribution to total particulate emissions for National Navigation has a typical contribution of less than 1% (Table 2.2).

Table 2.2: Contribution to total particulate matter emissions from 2004 EMEP database (WEBDAB)

NFR Sector*	Data	PM_{10}	$PM_{2.5}$	TSP
1 A 3 d ii - National Navigation	No. of countries reporting	20	20	19
	Lowest Value	0.0%	0.0%	0.0%
	Typical Contribution	0.5%	0.7%	0.4%
	Highest Value	1.7%	2.2%	1.2%

* Includes contribution from Chapter 810

3 GENERAL

3.1 Description

Exhaust emissions arise from:

- marine diesel engines used as main propulsion engines or auxiliary engines;
- boilers used for steam turbine propulsion or other purposes;
- gas turbines.

The majority of emissions will derive from combustion in diesel engines and are well defined. Emission factors for steam turbine propulsion and gas turbines are available, but these are less well defined. Should other fuel or engine types become available, the same general methodology can be adopted, substituting the emission factors, where appropriate.

3.2 Definitions

Ship Types
The ship types are defined in the World fleet statistics and are summarised in Table 4.1.
EMEP area
The EMEP area is defined in a polar conical projection and is approximately the area East of 40 deg W, West of 60 deg E and North of 30 deg N.

National Sea Traffic
This activity includes all national ship transport including ferries, irrespective of flag, between ports in the same country.

Statistical data for fuel use is generally split between national and international bunkers. This does not readily allow for the splitting of emissions into both national and international elements on the same voyage.

Distinction between domestic and international navigation.
The distinction is consistent with IPCC Good Practice and the reporting guidelines for reporting under the UNECE protocol.

This distinction depends only on the **origin** and **destination** of a ship. The recommended criteria are presented in Table 3.1. [The IPCC criteria *(IPCC, 1996)* have been the starting point for the distinction.]

Table 3.1 Criteria For defining International Or Domestic navigation

Journey Type	Domestic	International
Originates and terminates in same country	Yes	No
Departs from one country and arrives in another	No	Yes
Departs in one country, makes a 'technical' stop in the same country without dropping or picking up any passengers or freight, then departs again to arrive in another country	No	Yes
Departs in one country, stops in the same country and drops and picks up passengers or freight, then departs finally arriving in another country	Domestic Segment	International Segment
Departs in one country, stops in another country and drops and/or picks up more passengers or freight, then departs, finally arriving in the same country	Domestic Segment	International Segment
Departs in one country, stops in the same country and only picks up more passengers or freight and then departs finally arriving in another country	No	Yes
Departs in one country with a destination in another country, and makes an intermediate stop in the destination country where no passengers or cargo are loaded	No	Yes

N.B. The criteria in this table are **independent** of the **nationality** or **flag** of the carrier.

It is important to note that this Table relates to **all** water-borne vessels, whether they operate on the sea, on rivers or lakes. Although this table gives clear guidance, the approach is rather theoretical. In order to be able to apply these criteria, it is necessary to have sufficient (statistical) data. When this is not the case, a country may use another - more feasible - approach. This country is obliged to describe clearly the methodologies and assumptions that have been used.

National fishing
Emissions from all national fishing according to fuel sold in the country. By definition, all fuel supplied to commercial fishing activities in the reporting country is considered domestic, and there is no international bunker fuel category for commercial fishing, regardless of where the fishing occurs.

International sea traffic
Emissions from bunkers sold to international sea traffic in the reporting country. The emissions are to be reported to UNFCCC and UNECE for information only.

International inland shipping
Emissions from bunkers sold to international inland shipping in the reporting country. The emissions are to be reported to UNFCCC and UNECE for information only.

Further guidance.
In general the distinction domestic versus international emissions on basis of the criteria in Table 3.1 is clear. However it is useful to have guidance on some aspects.

Long distance territories
When part of the territory of a country is at long distance (e.g. for France) and there is no intermediary stop in other countries, the journey is always domestic. For UNFCCC, the allocation is always domestic and included in the national total. Previously for UNECE, only the

part of emissions within the EMEP area was considered, so that when the location of the over-seas territory was outside the EMEP area, a specific allocation rule was necessary. In the new (2002) EMEP Reporting Guidelines there is no longer a reference to the EMEP area with respect to what is included, in order to harmonise with UNFCCC so that the same fuel estimate could be used in both cases. The exception is for countries that have footnotes in their protocols excluding certain areas, in which case the situation is different.

Lack of availability of statistical data
When the necessary statistical data are not available a country should describe in its National Inventory Report clearly the approach it has used. One possible option would be as follows:
For UNECE as well as UNFCCC, the distinction between domestic and international can be *approximated* by fuel sales. However, a country is encouraged to verify the definition of bunkers used for this fuel allocation in national statistics (checking that it is similar to the one used for emissions, as it will never be exactly the same). When shipping is a key source, a country should also verify the sales data by performing the ship movement methodology, however this may prove too much to perform on an annual basis.
NB. For UNFCCC all bunker fuel and related GHG emissions are therefore often considered as "international" (sea ships as well as inland ships).

National grids and "international emissions"
The distinction domestic/international is relevant to assess the (future) compliance of a country to its Protocol requirements. When reporting, the Parties are requested to report their national shipping emissions by grid cell. When emission data are used for modelling purposes by EMEP, it is necessary to also take into account the "international" emissions. International emissions are only reported as memo items, and thus shall not be gridded by the Member States. EMEP thus does not request international maritime emission data by grid cell. For EMEP, the location of maritime emissions is carried out separately including international and transit traffic (prepared by the Lloyds Register). However, Lloyds does not cover the Mediterranean, the Baltic and inland waters, therefore gridding of the emissions from these areas will requires a centrally organised special investigation by EMEP.

Harbour emissions
UNECE and EMEP do not require the distinction between emissions in harbours, etc. and emissions during cruise in international waters. Such information can, however, be relevant for other applications, for example local inventories. To determine the location of emissions from seagoing ships it is possible to apply the MEET methodology (Trozzi and Vaccaro, 1998), where several phases in shipping are distinguished (outlined in section 5.2.1).

3.3 Techniques

Marine diesel engines are the predominant form of power unit within the marine industry for both propulsion and auxiliary power generation. In 1991 motorships accounted for around 98% by number of the world merchant fleet, the remaining 2% of vessels were powered by steam plant. Marine diesel engines are generally categorised into two distinct groups (Lloyd's Register (1993)):

Slow speed engines, operating on the two stroke cycle at speeds between 80-140 rpm, are normally crosshead engines of 4-12 cylinders. Some current designs are capable of developing in excess of 4000 kW/cylinder and with brake mean effective pressures of the order of 17 bar. Within the marine industry such engines are exclusively used for main propulsion purposes and comprise the greater proportion of installed power and hence fuel consumption within the industry.

Medium speed engines, generally operating on the four stroke cycle at speeds ranging from 400-1000 rpm, are normally trunk piston engines of up to 12 cylinders in line or 20 cylinders in vee formation. Current designs develop powers between 100-2000 kW/cylinder and with brake mean effective pressures in the range 10-25 bar. Engines of this type may be used for both main propulsion and auxiliary purposes in the marine industry. For propulsion purposes such engines may be used in multi-engined installations and will normally be coupled to the propeller via a gearbox. Engines of this type will also be used in diesel electric installations.

Exhaust emissions from marine diesel engines comprise nitrogen, oxygen, carbon dioxide and water vapour, with smaller quantities of carbon monoxide, oxides of sulphur and nitrogen, partially reacted and non-combusted hydrocarbons and particulate material. Metals and organic micropollutants are emitted in very small quantities.

3.4 Controls

The simplest technical way to reduce SO_2 emissions is reducing the sulphur content of the bunker oil. SO_2 can also be removed (> 90%) by seawater scrubbing (CONCAWE, 1994). Regulations on SO_2 limitation are presently being prepared by The European Commission and by the International Maritime Organization (IMO).

NO_x emissions from marine engines are to be controlled by regulations developed by IMO. The following limits are likely to be applied to new diesel engines above 130 kW. The limits are effective from the year 2000.

17 g/kWh when $n < 130$,
$45 * n^{-0.2}$ g/kWh when $130 < n < 2000$
9.84 g/kWh when $n > 2000$

where n is the rated engine speed in rpm.

There are a number of technological options for reducing NO_x from ships. Use of these technologies may be dependent upon whether residual fuel oil or distillate fuel is being burnt. Three options are mentioned here (based on Klokk, 1995):

- Exhaust Gas Recirculation (EGR) where a portion of the exhaust gas is routed back to the engine charge air whereby the physical properties of the charge air is changed. For marine diesel engines, a typical NO_x emission reduction of 10-30% can be found. This technique has not yet been in regular service for ships;
- Selective Catalytic Reduction (SCR) where a reducing agent is introduced to the exhaust gas across a catalyst. Hereby NO_x is reduced to N_2 and H_2O. However this technology imposes severe constraints on the ship design and operation to be efficient. A reduction of 85-95% can be expected applying this technology. The technology is in use in a few ships and is still being developed;

- Selective Non Catalytic Reduction (SNCR) where the exhaust gas is treated as for the SCR exhaust gas treatment technique, except the catalyst is omitted. The process employs a reducing agent, supplied to the exhaust gas at a prescribed rate and temperature upstream of a reduction chamber. Installation is simpler than the exhaust gas treatment, but needs a very high temperature to be efficient. Reductions of 75-95% can be expected. However, no installations have been applied yet on ships.

3.5 Projections

Future emissions from shipping will be governed by future change in activity, new engine technologies and penetration of new technologies. SO_2 emissions will depend on future sulphur content of fuel as well as the changes in activity rates.

Information about future change in activity of domestic shipping may be available in national transport plans. Economic development tends to increase the demand for freight transport. On the other hand changes in infrastructure (e.g. building of bridge connections) may lead to decrease in the demand for passenger transport by ferries.

Regulations may put a ceiling on sulphur content of fuel. IMO has agreed on a cap of 4.5 % sulphur content of fuel, this is, however, higher than the average used in Europe. There are also restrictions on sulphur content of fuel used in certain areas, this should be checked by the national authorities. For example, the Baltic Sea area is a so called "Sulphur Emission Control Area" (SECA) from May 19, 2006 where the sulphur content in fuel is restricted to 1.5%. The same will apply to the North Sea from November 22, 2007.

As mentioned above (3.4) there are regulations of NO_x emissions from year 2000. The effect of this on the national total emissions from shipping is dependent of the penetration of new technologies. In a baseline scenario is it recommended to assume an average 10 % reduction in the NO_x emission factors for diesel engines if better information not is available (MEET 1998). Emissions factors for other engines (steam and gas turbines) should be kept constant.

Emission factors for other pollutants than SO_2 and NO_x should be kept constant in a baseline analysis.

There is research going on to test alternative fuels on ships. Although such fuels are phased in at a small scale, e.g. use of natural gas in ferries, is large-scale use not expected in the near future. Consequently, should alternative fuels not be incorporated into a baseline scenario.

It is in principle possible to reduce the PM emissions with filters. This technique has not been applied to large marine engines yet and one may expect difficulties due to size and fuel quality. The use of scrubbers influences the emissions of PM to some extent (25% reduction).

4 SIMPLE METHODOLOGY

Emissions should be estimated as follows

$$\text{Emission} = \text{Fuel sold} \times \text{Emission factor} \qquad \text{(eq. 1)}$$

Fuel sold should be divided into Residual Bunker Fuel Oil (heavy fuel oil) and Distillate fuel (gas oil and marine diesel oil), although in some countries other fuel qualities may also be in use. This is important since fuel type significantly influences SO_2 and heavy metal emissions.

Relevant emission factors are given in Table 8.1, 8.2 and 8.3.

The simple methodology should always be used for estimating the CO_2 emissions, even if the detailed methodology is used for other pollutants.

Table 4.1: Estimated speed factors, main engine power and auxiliary engine power by ship type and gross tonnage

Ship Type	**Speed Factor**	**Estimated Main Engine Power kW (total power of all engines)**							**Estimated Auxiliary Power kW (medium speed)**					
	Knots	<500 GRT	500-999 GRT	1000-4999 GRT	5000-9999 GRT	10000-49999 GRT	>=50000 GRT	All	<500 GRT	500-999 GRT	1000-4999 GRT	5000-9999 GRT	10000-49999 GRT	>=50000 GRT
Liquified Gas Tanker	16	650 (m)	700 (m)	2250 (m)	5350 (#)	11600 (s)	15200 (s)	5900	75	100	125	300	400	1000
Chemical Tanker	15	1000 (m)	-	2000 (m)	5000 (#)	10250 (s)	-	5700	40	50	165	300	435	-
Other Tanker	14	600 (m)	950 (m)	2200 (m)	4300 (#)	9600 (s)	17200 (s)	7900	40	50	165	300	435	530
Bulk Dry Cargo	14	550 (m)	750 (m)	2700 (m)	5000 (#)	8800 (s)	17000 (s)	9100	20	40	175	300	380	500
General Cargo	14	550 (m)	950 (m)	1800 (m)	5500 (#)	8500 (s)	-	3300	20	40	175	300	380	-
Passenger/General Cargo	18	450 (m)	900 (m)	2850 (m)	6450 (#)	12600 (s)	-	4900	20	40	175	300	380	-
Container	20	1000 (m)	1750 (m)	2950 (m)	6000 (#)	17200 (s)	35000 (s)	16300	40	60	160	500	1400	1400
Refrigerated Cargo	20	900 (m)	900 (m)	3100 (m)	8850 (#)	10000 (s)	-	6700	40	140	180	455	580	-
Ro-Ro Cargo	18	1500 (m)	1900 (m)	4300 (m)	7200 (#)	11600 (#)	12550 (s)	7700	100	150	350	1000	2500	4000
Passenger/Ro-Ro	20	600 (m)	-	6500 (m)	12300 (#)	16650 (#)	-	12800	100	150	350	1000	2500	-
Passenger	20	550 (m)	-	3350 (m)	7800 (#)	16800 (#)	50000 (m)	14400	100	150	350	1000	2500	4000
Other Dry Cargo	15	900 (m)	-	2050 (m)	4450 (#)	17600 (#)	-	5900	20	40	175	300	380	500
Fish Catching	11	-	1050 (m)	2500 (m)	-	-	-	2200	-	80	200	-	-	-
Other Fishing	15	650 (m)	800 (m)	2300 (m)	5300 (m)	5400 (s)	-	2600	40	105	180	550	550	-
Offshore	14	1800 (m)	2150 (m)	3800 (m)	7450 (#)	11800 (#)	-	4000	40	60	150	350	450	-
Research	14	900 (m)	1300 (m)	3250 (m)	5300 (#)	8950 (s)	-	2900	40	60	150	400	400	-
Tug	11	3000 (m)	4050 (m)	6450 (m)	-	-	-	4400	40	60	150	-	-	-
Dredger	9	400 (m)	550 (m)	2400 (m)	7350 (#)	9250 (#)	-	4500	40	50	60	130	770	-
Cable	7	1100 (m)	-	3850 (m)	5950 (m)	13400 (s)	-	5300	80	-	200	300	-	-
Other Activities	-	500 (m)	900 (m)	3300 (m)	7650 (#)	8500 (#)	-	3700	40	60	150	300	500	-
Non-propelled	2	-	400 (m)	2750 (m)	-	-	-	2200	-	-	-	-	-	-
All		900 (m)	1200 (m)	2400 (m)	6200 (#)	9900 (#)	18700 (s)		50	80	200	450	900	1750

m = predominantly medium speed
s = predominantly slow speed
# = both medium and slow speed

5 DETAILED METHODOLOGY

The data sources available for performing a detailed methodology may vary between countries. Also the scope of such a study may vary. We will present here two detailed methodologies for shipping, one based on ship movement data and one based on fuel statistics. In addition, we will sketch how to perform a port inventory e.g. for inclusion in an urban emission inventory. The methodologies may of course also be combined, either for cross checking or for using one for a particular category of vessels and the other for a different category.

The *fuel consumption* methodology is recommended when statistics on fuel use for vessel categories or individual ships are available. It is particularly suited for estimating national emissions. The emission estimate can be directly compared with fuel sales figures. The spatial information may be less accurate than when using the ship movement methodology. The fuel consumption methodology is suited to show trends in emissions.

The *ship movement* methodology is recommended when detailed ship movement data as well as technical information on the ships are available. It is suited for estimating national and international emissions. The methodology may be quite time consuming to perform. The output is difficult to compare with the fuel statistics. The methodology is not very well suited to show annual trends in emissions.

The methodologies may be used to calculate the emissions following the UNECE/EMEP definition of national shipping, as well as other definitions (flag, ownership, geographical area etc.).

5.1 Fuel Consumption Methodology

The methodology is based on annual fuel consumption data for vessel categories or individual ships (see section 6). This methodology indirectly includes emissions from ships alongside or at anchor.

1. Compile information on fuel consumption by individual ships or vessel categories. For estimating the emissions of SO_2 and heavy metals, residual fuel oil and distillate fuel should be distinguished.
2. If data for individual ships are available, use Table 8.2 to determine a NO_x emission factor based on the ship engine type. If data for individual ships are not available, use Table 4.1 to determine the proportion of slow speed to medium speed engines for each vessel category and use Table 8.2 to determine a weighted emission factor. For the other pollutants a single emission factor is applicable (Table 8.1, 8.2 and 8.3).
3. Multiply the fuel consumption data in tonnes by the fuel based emission factors to obtain an annual emission estimate.
4. If a spatial disaggregation is required, use information on routes and ship movements to distribute the emissions.

5.2 Ship Movement Methodology

The methodology is based on ship movement information for individual ships (see section 6). Using the ship movement methodology, emissions from ships hotelling in port, or at anchor awaiting a berth or awaiting orders, are excluded - and must be estimated using port statistics. Previous studies have indicated that «in port» and harbour traffic emissions are significant sources of emissions (up to 26% of the overall total in the English Channel area). However, routine quantification of harbour traffic is not considered feasible using the detailed methodology presented here. Only emissions from shipping on passage or arriving or departing from a berth are included.

1. Compile the ship movement data; place of departure, place of arrival, time of departure and time of arrival for each individual ship. This may be done for the whole year or a representative sample of the year, for all ships or for a representative sample of the ships. This choice will depend on the resources available and the required accuracy of the study.
2. Determine the sailing routes and distances between ports. This may be done individually or fitted into the main shipping lanes. A GIS (Geographical Information System) is useful, but not necessary, for this task. If a GIS not is available, there are standard distance tables for distances between main ports (Thomas Reed Publications, 1992).
3. Group the ships into vessel categories (Table 4.1). This step is optional, but will require less work than continuing with the data set containing the individual ships.
4. Determine the sailing time for each ship/vessel category, either based on the distance and speed factors (Table 4.1) or time of departure and arrival. The choice should be based on an assessment of the quality of the data.
5. Determine emission rates in kg/h. The emission rates should be based on the data in Table 8.5 and the engine power of each individual ship or the average for each vessel category (Table 4.1). Both the main and auxiliary engines should be included.
6. Combine the sailing time (in hours) with emission rates in (kg/h) to obtain a total emission estimate of CO, NMVOC and NO_x:

   $$E = e * t \qquad \text{(eq 2)}$$

   where

   E = The emission in the defined area per ship
   e = emission rate (kg/h)
   t = time in defined area (d/s)
   d = distance travelled within defined area
   s = speed of vessel

   If the study is based on samples, scale the result to get an annual total. A GIS can be used to spatially disaggregate the data.

7. To estimate emissions of SO_2 and heavy metals, information about fuel type is needed. Assumptions about the fuel type should be made from the engine type or sale statistics, as this information is not directly available from the ship movement methodology. The fuel

consumption may be estimated from the data in Table 8.6. Estimate the emissions of the remaining pollutants of interest from the estimated fuel consumption and the fuel based emission factors or, if possible, using the simple or fuel based methodology.

5.2.1 Emissions in ports

An emission inventory for ports must be based on local knowledge and is best performed for individual ports. An outline methodology only is sketched here. The methodology is based on port calling statistics showing the exact time of arrival and departure of individual ships. There are four main types of emission sources in a port:

- Ships' hotel loads, alongside or at anchor;
- Cargo working, alongside or at anchor;
- Manoeuvring emissions by ships leaving and arriving in port;
- Emissions from harbour craft.

To determine the location of emissions from seagoing ships it is possible to apply the MEET methodology (Trozzi and Vaccaro, 1999), where several phases in shipping are distinguished:

(a) *cruising* in international waters;
(b) *cruising* in national x-miles zone;
(c) *approaching to* the harbour (by a river or a canal);
(d) *docking in* the harbour;
(e) *hotelling* in the harbour;
(f) *departing from* the harbour (by a river or a canal);
(g) *cruising* in x-miles zone;
(h) *cruising* in international waters.

Phase (c) starts when the ship's deceleration begins and ends at the moment of the docking, while phase (f) starts with departure from the berth and ends when cruising speed has been reached. From a consumption and emissions point of view, there are three manoeuvring phases (c, d, e), one hotelling phase (e) and four cruising phases (a, b and g, h). After its arrival in harbour, a ship continues to emit at the dockside (while in the hotelling phase (e)).

However, EMEP does not need very detailed and exact data since the EMEP grids are quite large (50*50 sq km) and therefore an approach using lesser detail may be sufficient. One approach may be to use harbour statistics to get time in dock, multiply by a dock fuel consumption factor per ship type (if appropriate), see where the ship goes from (sample) transport statistics and multiply by a consumption factor per nm (nautical mile). The emissions are then distributed by a straight line going from departure to destination. Section 8.1 and Table 6 from the MEET methodology (Trozzi C., Vaccaro R., 1998) are useful for this purpose.

5.2.2 Alongside emissions

In dock the main engine is unlikely to be in use. Ships are likely to use shore power or auxiliary engine(s) only. One exception is some types of ferries which will use their main engine whilst in dock. These considerations must be based on local knowledge for each port.

The alongside emissions are determined from the time in dock estimated from the time of arrival and departure for each individual ship. The emission factors in Table 8.5 in (kg/h) are applicable for auxiliary (medium speed engines).

5.2.3 Manoeuvring emissions

Different ports will have different sizes, speed limits and other characteristics. Hence, the emission estimate should be based on local knowledge. In principle, once the time spent manoeuvring is known, the emission factors in Table 8.5 are applicable. The engine load will variable when manoeuvring, but the same emission factors may be used as ships at sea.

5.2.4 Emissions from harbour craft

This includes emissions from various vessels and craft operating in the port (tug boats, pilot boats, dredgers etc.). Emissions from shore based equipment are included under SNAP 0810. The emission estimate should be based on a local inventory of such craft, the number, engine type and hours of operation or their annual fuel use. Based on this information and the emission factors in section 8 or chapter 0806-0810 (as some of this craft will be small and consequently covered here) an annual emission estimate can be obtained.

This methodology is also applicable for ships at anchor where these emissions are considered to be significant.

N.B. There may be a double counting of emissions for ports estimated by the fuel based and to a lesser extent the ship movement methodology.

6 RELEVANT ACTIVITY STATISTICS

6.1 Simple methodology

A national statistic for fuel used by ships and split between fisheries, national traffic and international bunker is necessary. The statistics should also be split between residual fuel oil and distillate fuel. All countries report these data annually to IEA (the International Energy Agency) (published in "Energy Statistics of OECD Countries").

6.2 Detailed methodology

The requirements for activity statistics will depend on the methodology chosen.

6.2.1 Ship particulars

A ship register, giving the size and engine type of individual ships, will be useful for either methodology. Such a register of the national fleet will be available in most countries but usually only covering national ships.

Lloyds Register’s Register of Ships will provide details of national and international shipping greater than 100 grt.

6.2.2 Fuel use

Ship or ferry companies: Fuel use data may be recorded by the companies and be available on request.

Statistical offices: Fuel use data may be collected in sample or full surveys. More often data on fuel expenditures will be available. However, the price of fuel for ships is highly variable as large discounts are very common.

Individual ships: Virtually all ships are statutorily required to keep a record of their fuel use. However, such a data collection will probably be very time consuming.

6.2.3 Ship movement

LMIS (Lloyd's Maritime Information Service): This database records all ship movements world-wide. The database includes ship size, destination, approximate time of arrival and departure, engine type and number etc. The data are available in computerised form. The database covers all ships greater than 250-500 gross tonnes. Ferries and fishing vessels are typically not included. Smaller ports are also excluded. A week or a whole year may be chosen. A selection may also be made on area or ship nationality. The dataset will have to be purchased.

Port calling statistics
Port calling statistics will be available from national sources (statistical offices or the harbour authorities) in all countries, in some countries covering the larger ports only. The information is similar to the LMIS data without engine details. On the other hand it will give more accurate information about the actual time spent in port. The national port calling statistics may also be useful for validating other sources.

Survey of ship owners
In some countries detailed statistics on individual ships are performed. Such statistics may include a ship movement survey for at least a sample of the fleet.

Ferry timetables
For ferries ship movement data will be available from timetables giving the departures and destinations. "Thomas Cook international rail timetable" includes all main ferry routes in Europe, but more detailed information (covering smaller ferries) will be available from national sources. Such information must be supplemented with engine information. It should be distinguished between summer and winter when applying timetables.

Fishing deliveries
The International Council for the Exploration of the Seas collects information on fishing deliveries (catch area and port of landing) which gives an indication of the vessel movements. The data here are confidential, but is based on national reporting which may be available. The information must be linked to a vessel register. Additional information must be collected on the time spent fishing, as fishing vessels will not move in straight lines when operating. Fishing vessels may also be used for other activities than fishing. Factory ships and trawlers

may have significant fuel use connected to trawling, processing and refrigeration, in addition to the vessel movement.

The customs or coast guard authorities may keep records of the international ship traffic in national territorial water.

6.2.4 Ships' routing

The main shipping routes are given in the IMO publication «Ships' Routing» (International maritime Organization, 1987).

Distances are given in Reed's Marine Distance Table (Thomas Reed Publications, 1992).

7 POINT SOURCE CRITERIA

Not applicable.

8 EMISSION FACTORS

Emission factors may vary between the simpler and the detailed methodology, in particular for NO_x, where a single emission factor is specified for the simple methodology, but two factors relating to the engine type (slow/medium speed) are specified in the detailed methodology.

8.1 Fuel Based Methodology

Table 8.1: Emission factors - Fuel composition dependent emissions.

	kg/tonne fuel
CO_2	3170
SO_2	20 * %S

S = sulphur content of fuel (% by wt)

Source: Lloyd's Register, 1995

	distillate fuel g/tonne fuel	**residual fuel oil g/tonne fuel**
As	0.05	0.5
Cd	0.01	0.03
Cr	0.04	0.2
Cu	0.05	0.5
Hg	0.05	0.02
Ni	0.07	30
Pb	0.1	0.2
Se	0.2	0.4
Zn	0.5	0.9
TSP*	1100	6700
PM_{10}*	1100	6700
$PM_{2.5}$*	1100	6700

Source: Lloyd's Register, 1995; *Cooper and Gustafsson, 2004

The average sulphur content of fuel may be obtained from national sources. Values may also be obtained from organisations such as CONCAWE, DNV or Lloyd's Register. In the absence of specific information on fuel sulphur content, default values of:

2.7% (by wt) - residual fuel oil
0.5% (by wt) - distillate fuel

may be used (Lloyd's Register 1995).

Heavy metal emissions will depend on the metal content of the fuel. This will, in turn, depend upon the metal content of the original crude and will vary significantly (by orders of magnitude) between oil fields. Generally, the metal content will be higher in residual fuel oil than in distillate fuel. Heavy metal emission factors are given in Table 8.1. These represent average fuel concentrations but are based on a small sample number, and should be considered to be highly uncertain.

Table 8.2: Engine dependent emission factors

	kg/tonne fuel		
NO_x	87*	72†	57‡
CO	7.4		
NMVOC	2.4		
CH_4	0.05		
N_2O	0.08		

* slow speed † composite factor ‡ medium speed
Source: Lloyd's Register (1995), IPCC (1997), Cooper (1996)

The emission factors for methane and nitrous oxide (IPCC, 1997) are highly uncertain. NO_x emissions factors for medium and slow speed engines differ significantly; however, a combined factor is provided for use in the simpler methodology.

Table 8.3: Emission factors for POPs

	Unit	**Range**
HCB	mg/tonne	0.01-0.4
Dioxin	TEQµg /tonne	0.1-8
Total PAH	g/tonne	2.0
PAH*	g/tonne	0.04

Source: Lloyd's Register (1995), * PAHs included in ECE protocol

The emission factors for POPs (Persistent Organic Compounds) are highly uncertain as they are based on a very limited data set. Actual ranges may be greater than indicated.

Table 8.4: Emission factors for steam turbine propulsion and gas turbines, Cruise, kg/tonne fuel

	NO_x	CO	VOC	TSP*	PM_{10}*	$PM_{2.5}$*
Steam turbine propulsion - distillate fuel	3.3	0.6	0.5	1.0	1.0	1.0
Steam turbine propulsion - residual fuel	7.0	0.4	0.1	2.6	2.6	2.6
Gas turbines	16	0.5	0.2	0.2	0.2	0.2

Source: Techne (1997), derived from EPA (1985), *Cooper and Gustafsson, (2004)

8.2 Ship Movement Methodology

Speed factors are given in Table 4.1 for various vessel categories. The emission rates are shown in Table 8.5.

Table 8.5: Emission rates for medium and slow speed diesel engines (kg/hours)

	Medium speed & auxiliary engines	Slow speed
NO_x	$4.25 \times 10^{-3} \times P^{1.15} \times N$	$17.50 \times 10^{-3} \times P \times N$
CO	$15.32 \times 10^{-3} \times P^{0.68} \times N$	$0.68 \times 10^{-3} \times P^{1.08} \times N$
HC	$4.86 \times 10^{-3} \times P^{0.69} \times N$	$0.28 \times 10^{-3} \times P \times N$
SO_2*	$2.31 \times 10^{-3} \times P \times N$	-
SO_2**	$12.47 \times 10^{-3} \times P \times N$	$11.34 \times 10^{-3} \times P \times N$

P is the engine power (kW) x engine load (85% MCR), N is the number of engines
* is valid for engines < 2000 kW
** is valid for engines ≥ 2000 kW.
Source: Lloyd's Register (1995)

In order to estimate fuel consumption for use with emission factors listed in the fuel use methodology, the default factors given in Table 8.6 are suggested. The consumption at cruise will be about 0.8 of the given figures. Manoeuvring and hotelling will be 0.4 and 0.2, respectively (Techne, 1997). Such average fuel consumption factors should be considered to be highly uncertain.

Table 8.6: Fuel consumption factors, full power

Ship type	Average consumption (tonne/day)	Consumption at full power (tonne/day) as a function of gross tonnage (GT)
Solid bulk	33.8	20.186 + 0.00049*GT
Liquid bulk	41.1	14.685 + 0.00079*GT
General cargo	21.3	9.8197 + 0.00143*GT
Container	65.9	8.0552 + 0.00235*GT
Passenger/Ro-Ro/Cargo	32.3	12.834 + 0.00156*GT
Passenger	70.2	16.904 + 0.00198*GT
High speed ferry	80.4	39.483 + 0.00972*GT
Inland cargo	21.3	9.8197 + 0.00143*GT
Sail ships	3.4	0.4268 + 0.00100*GT
Tugs	14.4	5.6511 + 0.01048*GT
Fishing	5.5	1.9387 + 0.00448*GT
Other ships	26.4	9.7126 + 0.00091*GT
All ships	32.8	16.263+ 0.001*GT

Source: Techne (1997)

9 SPECIES PROFILE

The speciation of PAHs as determined by Lloyd's Register (1995) are given here (Table 9.1). Cooper et al, 1996 presents a measurement covering other species.

Cooper et al, (1996) has measured the C_2-C_6 and C_6-C_{12} hydrocarbon concentrations in exhaust from two ferries (Table 19).

Table 9.1: PAH emissions, Distribution by species

	Average (%)	Range (%)
Phenanthrene	37	32-54
Anthracene	1	0-2
Fluoranthene	11	9-15
Pyrene	14	12-20
3,6-dimethylphenanthrene	4	3-5
Triphenylene	12	9
Benxo(b)-fluorene	6	2-19
Benzo(a)anthracene	2	0-2
Chrysene	5	3-9
Benzo(e)-pyrene	2	0
Benzo(j)fluoranthene	0	0
Perylene	0	0-3
Benzo(b)-fluoranthene	1	0-2
Benzo(k)-fluoranthene	0	0
Benzo(a)pyrene	0	0
Dibenzo(a,j)anthracene	0	0-1
Dibenzo(a,l)pyrene	0	0
Benzo(g,h,i)perylene	1	0-2
Dibenzo(a,h)anthracene	1	0-6
Ideno(1,2,3-c,d)pyrene	0	0-1
3-methyl-cholanthrene	0	0
Anthanthrene	0	0

Source: Lloyd's Register, 1995

Table 9.2: Exhaust hydrocarbon concentrations, Percent.

	Ferry 1	**Ferry 2**
Ethane	0	0
Ethene	5	20
Propane	0	0
Propene	2	6
Ethyne	0	0
Propadiene	0	0
Butane	0	0
trans-2-Butene	0	0
1-Butene	0	1
Isobutene	1	18
cis-2-butene	0	0
Pentane	0	0
Propyne	0	0
3-Methyl-1-butene	0	0
trans-2-Pentene	0	0
1-Pentene	0	1
cis-2-Pentene	0	0
Hexane	0	0
Other C_6 alkenes	0	0
1-Hexene	0	0
Nonane	10	0
Decane	25	0
Undedecane	19	0
Dodecane	14	0
Benzene	4	35
Toluene	5	15
Ethylbenzene	1	0
o-Xylene	2	0
m Plus p-Xylene	4	4
1,3,5-Trimethylbenzene	2	0
1,2,4-Trimethylbenzene	2	0
1,2,3-Trimethylbenzene	3	0

Source: Cooper et.al, 1996

10 UNCERTAINTY ESTIMATES

For the ship movement methodology NO_x emissions are highly dependent upon the type of the ship engines. Lloyd's Register (1995) shows variations in emission profiles for HC and NO_x. In addition the activity data will be uncertain. Uncertainties associated with estimates of HC and NO_x should therefore be considered to be more than ± 20%. The simpler methodology will give higher uncertainties.

Using the fuel consumption methodology, the uncertainty will depend on the quality of the fuel data collected. The NO_x emissions will be more uncertain if information about the engine types not is available.

For SO_2, uncertainty depends on the variation of the sulphur content and fuel consumption which may be estimated to be within ± 5%.

Emissions of heavy metals and POPs are uncertain within an order of magnitude.

For particulate matter the uncertainty is around ± 50%. The available data imply that the value for $PM_{2.5}$ is close to the value for PM_{10} (80-100%)

11 WEAKEST ASPECTS / PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY

The weaknesses differ with the methodology used.

The estimation of emissions in the *simple methodology* is dependent upon the split of fuel into ship categories. It is uncertain to which extent the assumptions about what fuel is actually used in which ships is true (Rypdal, 1995). Factors are based on assumptions about national and international sea traffic, which may not be in accordance with the present guidelines. Furthermore, when emission estimations are based on statistics of fuel sold for various ship categories, there may be divergence from reality. For some vessels the statistics are not necessarily registering all fuel use. Fishing boats may particularly buy fuel abroad and therefore this fuel would not be registered in the national statistics. International fuel use statistics may include fuel burned outside the EMEP area or used during national voyages. The national/fishing split might not be available in some countries. The simple methodology does not give any spatial disaggregation.

When applying the *detailed methodology*, the main assumptions have been made in the text and will vary with quality of the data sources used.

12 SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES

The ship movement methodology provides a spatial disaggregation of the emissions.

For the simple and fuel based methodology the spatial disaggregation may be determined by ship routing data. Such statistics are described under “relevant activity statistics”, but less detail and accuracy will result than when using in the ship movement methodology.

13 TEMPORAL DISAGGREGATION CRITERIA

Seasonal variation through the year is insignificant (see Lloyd's Register, 1995). However, there may be exceptions in certain areas and for certain vessel types. A greater proportion of fishing and 'other activity vessels' (such as dredgers, tugs and research ships) as well as cruise ships are more active in the late summer months.

14 ADDITIONAL COMMENTS

Military vessels are often omitted from the shipping inventories. They should, however, in principle be included. Often statistics can be found on military fuel data, and the most important ship movements.

15 SUPPLEMENTARY DOCUMENTS

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16 VERIFICATION PROCEDURES

Comparing emissions estimated by the simple and the two detailed methodologies will be useful. However, such a comparison may not be straight forward due to different scopes.

Comparison with central inventories, like the Lloyd’s Register inventory, should be made if possible.

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18 BIBLIOGRAPHY

No additional documents.

19 RELEASE VERSION, DATE AND SOURCE

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