SCIENTIFIC SUPPORT PLAN FOR A SUSTAINABLE DEVELOPMENT POLICY
(SPSD II)

Part 2

Global change, Ecosystems and Biodiversity

FINAL REPORT

MOPSEA
MOnitoring Programme on air pollution from SEA-going vessels

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1. INTRODUCTION

1.1 Objectives

Within the MOPSEA project we firstly wanted to gain insight in the environmental air legislation, the international reporting obligations and the current emission inventory for sea-going vessels. Secondly, we wanted to develop a new activity based emission model to map historical emissions and to make emission projections to the near future. MOPSEA is the acronym for "MOnitoring Programme on air pollution from SEA-going vessels", being the initial name of the project.

We defined the following subsidiary aims:

- ⇨ making an inventory of the environmental air legislation and the international reporting obligations;
- ⇨ writing down the current emission inventory methodology;
- ⇨ developing a new activity based emission model;
- ⇨ delivering recommendations to national policies related to emissions of sea-going vessels.

1.2 Context

Waterborne transport has the potential to make a considerable contribution to the efficiency of the transport system and the required increase in capacity of intra-European transport in order to meet current and future demands arising from economic growth, leading to an increase in employment throughout Europe.

Waterborne transport is basically an environmentally friendly and safe mode of transport, especially compared to congested road transport. The external costs are low and the energy efficiency is high. However, there is still considerable scope for improvement, especially with regard to NO_x and SO_2 emissions. In order to tackle this problem the International Maritime Organisation (IMO) adopted Annex VI to the Marpol 73/78 Convention. This is the main international Convention that covers prevention of pollution of the marine environment by ships from operational or accidental causes and was adopted in November 1973 by IMO. Annex VI, 'prevention of air pollution from ship', was adopted in 1997 and entered into force on the 19th of May 2005. With this annex, limits have been applied to SO_2 and NO_x emissions from sea-going vessels. Currently the extension with standards for all greenhouse gases from ships is also being considered.

On top of this, studies have shown that the share of sea-going vessels in transport emissions will increase between 2000 and 2020 (2030) and therefore the importance of shipping for the environment [1]. The cause of this evolution is on the one hand the average long life span of applied technologies in the shipping fleet and on the other hand the more and more stringent European emission regulation for road vehicles that came into force during the last decade. This trend will continue in the coming years as shown by the European Directives 98/69/EC (passenger cars), 98/69/EC (light duty vehicles) and 1999/96/EC (heavy duty vehicles). These directives ensure that road transport improves its environmental impact at a fast rate. This is partly possible by the short economic lifecycle of trucks so that the newest technological developments are speedily implemented. Waterborne transport however is lagging behind in this respect by the (very) long economic lifespan of ships. For ships there is no such tradition for European Directives, as ships are supposed to be more energy efficient and more environmentally friendly then road traffic. This is true when comparing the different transport modes up to the beginning of the nineties. After that, one can be sure that ships are more fuel efficient per ton-kilometre), but their profits towards environmental impact per ton-kilometre becomes less obvious [2].

As already mentioned, IMO is taking actions on an international level to enhance the environmental performance of sea-going vessels. On a European level a new EU Directive to reduce atmospheric emissions from sea-going vessels entered into force on the 11th of August 2005 (EU Directive 2005/33/EC). In order to get a clear view on the emissions resulting from ships a few international agreements still have to be made.

Reporting methodologies and monitoring programmes already exist for a longer time for other transport modes and industry related emissions. For ships, the existing monitoring programmes and reporting methodologies are currently being optimised and made consistent.

Within the IPCC (Intergovernmental Panel on Climate Change) methodology, emissions from sea-going vessels are not attributed to countries due to the lack of the relationship between the location fuels are bought and the regions were pollutants are emitted. At this moment for example CO_2-emissions from sea-going vessels are reported (EU- European Union, UNFCCC- United National Convention on Climate Change, …) as international bunker fuels. Depending of the allocation method the emission levels attributed to a country can thus differ in a great extent.

Within the Kyoto Protocol, emissions from international ocean shipping are left aside. In the future these emissions may also be allocated, but at the moment it is not clear what the development of this allocation will be. In this perspective, countries (with access to sea) need more than ever a valuable monitoring programme to feed international policy making and evaluation of measures.

1.3 Bookmarker

Chapter 2	In this chapter we give an overview of environmental problems related to air pollution and relating international and European legislation that is established to abate impacts due to air emissions.
Chapter 3	Chapter 3 includes international reporting obligations and methodologies for the assessment of emissions from ships.
Chapter 4	This chapter entails a description of the current methodology that is used in Belgium for emission inventory of sea-going vessels. We also give an overview of activity based emission assessments for maritime navigation used in Europe.
Chapter 5	Here we define the scope of the new activity based emission model.
Chapter 6	This chapter shows an overview of the necessary data input for the new activity based emission model.
Chapter 7	Here, we present the methodology of the new activity based emission model for sea-going vessels. We elucidate the methodology for statistical years and for projections to the future.
Chapter 8	In this chapter we calculated the emissions of sea-going vessels for the two baseline scenarios. We quantify the effect of the IMO and EU legislation for the years 2004 and 2010.
Chapter 9	Here we deliver recommendations to national policies related to emissions of sea-going vessels.
Chapter 10	In this chapter we present the general conclusions of this study together with the scientific progress made and future work that

has to be done.

Chapter 11 At the end of this report, we report a joint note from the MOPSEA and ECOSONOS team to explain the differences in results between both projects.

Annexes Background information on different topics can be found in the annexes.

2. ENVIRONMENTAL AIR LEGISLATION

2.1 Object

Since several years, emission regulations have been drafted with respect to road vehicles resulting in the improvement of their environmental performance at a fast rate. Regulations with regard to emissions from waterborne transport however have been lagging behind for a long time. Nevertheless waterborne transport was and still is considered to be one of the most environmentally friendly modes of transport. This however is being diminished by the fact that ships attribute to an increasing contribution in the total transport emissions.

The impact of transport emissions on the environment has been a point of concern for a number of years now, both on a national and international level. The European Commission has for a long time been at the forefront of paying attention to the environmental dimension of transport. A prominent illustration of this concern was the 1992 Green Paper of the European Community on 'The impact of Transport on the Environment'[3]. The 1992 Green paper was, amongst other things, an answer to the call from the European Parliament in September 1991, which called the Commission to submit to the Council a framework programme for optimum environmental protection in the European transport market in line with the 5th Framework programme.

In this chapter we will go deeper into the existing legislations that lay on the basis or were drafted in order to reduce transport emissions.

In order to deal with air pollution, legislation on this topic addresses two things:

1. Air quality: dealing with the safeguard of the air that we breath; and
2. Emissions: ensuring that less pollution is emitted into the atmosphere.

Emissions from transport in general contribute to the greenhouse effect, acidification, ozone formation in the troposphere and the formation of photochemical smog and therefore pose a threat to human health and the environment. The most important parameters that are responsible for these threats are emissions of nitrogen oxides (NO_x), sulphur dioxide (SO_2), carbon monoxide (CO), carbon dioxide (CO_2), methane (CH_4), non-methane volatile organic compounds (NM-VOC) and fine particulate matter (PM_{10}).

2.2 International environmental (air) legislation

On an international level several agreements have been made with regard to emission reductions in general. Air quality guidelines have not been set.

The Convention on Long-range Transboundary Air pollution of 1979 [4] was the first international agreement to deal with global air pollution problems. Since its entry into force in 1983 six different protocols have been launched (protocols of Helsinki, Sofia, Geneva, Oslo, Arhus and Göteborg), all identifying specific rules or measures dealing with the reduction of pollutants responsible for acidification, eutrophication, ozone depletion and human health effects. The Framework Convention on Climate Change [5] and its Kyoto Protocol of 1997 set restrictions towards emissions of greenhouse gases. Table 1 lists the different international treaties, conventions and protocols with respect to air emissions.

Most of these agreements, however, exclude guidelines with regard to emissions from sea-going vessels. The only international agreement that covers emissions from ships is Annex VI of the Marpol-treaty [6].

Annex A to this report entails more detailed information on all different conventions and protocols. Since the Marpol-treaty is the most important one for the subject of this study, it is dealt with in more detail in this part of the report.

Table 1: international legislation on emissions to air

Convention / Treaty	Established	Protocol	Date	Target	Date of entry into force	Belgium Signed	Belgium Ratification	Belgium Date of entry into force	Specific for shipping
Geneva Treaty	1979			LRTAP - first agreements	1983	13/11/1979	15/07/1982		
		EMEP Protocol (Geneva)	1984	European Monitoring and Evaluation Programme	28/01/1988	25/02/1985	05/08/1987		
		Helsinki Protocol	1985	30% SO2-reduction by 1993 vs 1980	02/09/1987	09/07/1985	09/06/1989		No
		Sofia Protocol	1988	NOx Stabilisation by 1994 vs 1987	14/02/1991	1/11/1988	8/11/2000	6/02/2001	No
		Geneva Protocol	1991	30% VOC-reduction by 1999 vs 1988	29/09/1997	19/11/1991	8/11/2000	6/02/2001	No
		Oslo Protocol	1994	74% SO2-reduction by 2010 vs 1980	05/08/1998	14/06/1994	8/11/2000	6/02/2001	No
		Arhus Protocol	1998	POP production prohibition and use	23/10/2003	24/06/1998	-		No
				Reduction of Cd, Hg, Pb to level of 1990	29/12/2003	24/06/1998	-		No
		Göteborg Protocol	1999	SO2, NOx, NH3 and VOC National Emission Ceilings	17/05/2005	04/02/2000	-		No

Convention / Treaty	Established	Protocol	Date	Target	Date of entry into force	Belgium Signed	Belgium Ratification	Belgium Date of entry into force	Specific for shipping
Convention of Vienna	1985			Stratospheric ozone: Measures to reduce ozone; Measures were never specified; Intended for exchange of information, International collaboration and research			17/10/1988		No
		Montréal Protocol	1992	Stratospheric ozone: Reduction and elimination of anthropogenic ozone depletion compounds					No
Rio Conference	1992			Protection of the atmosphere: Global strategy on Climate change					No
		Kyoto Protocol	1997	Implementation of the Rio Conference: 5% reduction of CO2 by 2008-2012 vs 1990					No
OSPAR	1992			Prevention and elimination of pollution in the marine environment					Yes
NSC	1984			Up to date 5 North Sea Conferences held Protection of the Marine environment against different substances					Yes
IMO	1958			Organisation established for adoption of the MARPOL Treaty	17/03/1958				Yes
MARPOL 73/78	1973 - 1978	MARPOL (Annex VI)	1997	Convention for the prevention of marine pollution	19/05/2005				Yes

2.2.1 International Maritime Organization (IMO) and MARPOL

In 1958 the Convention establishing the International Maritime Organization (IMO) [7] entered into force in order to establish a framework for governmental regulation and practices relating to technical matters of all kinds affecting shipping engaged in international trade. IMO currently groups 164 member States. One of the IMO's most important concerns is the adoption of the maritime legislation adopted by the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto (MARPOL 73/78) [6]. This 'Convention' covers not only accidental and operational oil pollution but also pollution by chemicals, goods in packaged form, sewage, garbage and air pollution.

Since the adoption of MARPOL, several Annexes have been accepted. As an answer to the concern of the contribution of airborne emissions from ships, an international instrument was developed during an IMO-Conference in order to deal with this kind of air pollution. Annex VI of the MARPOL treaty (also known as the 1997 Protocol) was born and has been accepted on 26 September 1997. It was stated that the 1997 Protocol to the MARPOL Convention, which includes Annex VI, would enter into force 12 months after being accepted by 15 States with not less than 50% of world merchant shipping tonnage. Samoa, the fifteenth State to ratify the instrument[I], deposited its ratification on 18 May 2004. Annex VI has now been ratified by States with 54.57% of world merchant shipping tonnage and has been entered into force on 19 May 2005.

In order to reduce emissions from sea-going vessels, Annex IV includes limit values on sulphur oxides, nitrogen oxides and prohibits deliberate emissions of ozone depleting substances (including halons and chlorofluorocarbons (CFCs). It sets limits on emissions of nitrogen oxides (NO_x) from diesel engines depending on the engine maximum operating speed (Table 2). A mandatory NO_x Technical Code, developed by IMO, defines how this is to be done. These limits for NO_x emissions apply to every ship of >400GT and every fixed and floating drilling rig and other platform. The NO_x Technical Code defines mandatory procedures for the testing, survey and certification of marine diesel engines to ensure that all applicable engines comply with the NO_x emission limits defined in it. The requirements for the control of emissions apply to all engines >130kW installed

[I] Before, the Annex VI has been ratified by following states: Bahamas, Bangladesh, Barbados, Denmark, Germany, Greece, Liberia, Marshal Islands, Norway, Panama, Singapore, Spain, Sweden and Vanuatu.

on ships constructed after 1 January 2000 and all engines that undergo a major conversion after 1 January 2000.

Table 2: NO_x-standard for sea-going vessels according to Annex VI of MARPOL

Engine speed - n (rpm)	n < 130	130 ≤ n < 2 000	n ≥ 2 000
Limit value [g/kWh]	17,0	$45 * n^{-0,2}$	9,8

Apart from standards for NO_x, Annex VI also includes limit values for SO_2. In the Annex, a global cap of 4,5 % m/m on the sulphur content of fuel oil for seagoing vessels is set as well as two emission control areas (SO_x Emission Control Areas – SOxECA's) with more stringent controls on sulphur emissions. Ships in these areas can only use fuel oil with a sulphur content lower then 1,5% m/m. Alternatively, ships must fit an exhaust gas cleaning system or use any other technological method to limit SO_x emissions.

In the original protocol, the Baltic Sea area has been designated as SO_xECA, the North Sea and the Channel have been appointed in 2000 [II] after negotiations with the EU-member states.

Annex VI furthermore prohibits deliberate emissions of ozone depleting substances, which include halons and chlorofluorocarbons (CFCs). New installations containing ozone-depleting substances are thereby prohibited on all ships. But new installations containing hydro-chlorofluorocarbons (HCFCs) are permitted until 1 January 2020.

The Annex also prohibits the incineration onboard ship of certain products, such as contaminated packaging materials and polychlorinated biphenyls (PCBs).

Compliance with the provisions of Annex VI is determined by periodic inspections and surveys. Upon passing the surveys, the ship is issued an "International Air Pollution Prevention Certificate", which is valid for 5 years.

[II] In 2000 approved by the Marine Environment Protection Committee of IMO (MEPC 44).

2.2.2 IMO and greenhouse gases

MARPOL does not say anything about the emission of greenhouse gases. In November 2003, IMO adopted resolution A.963(23) ***IMO Policies and practices related to the reduction of greenhouse gas emissions from ships***.

At its 52nd session in October 2004, the Marine Environment Protection Committee (MEPC) made progress on developing draft *Guidelines on the CO_2 Indexing Scheme* and urged Members to carry out trials using the scheme and required reporting to the next session. One purpose of developing guidelines on CO_2-emission indexing is to develop a simple system that could be used voluntarily by ship operators during a trial period.

The Committee agreed that a CO_2 indexing scheme should be simple and easy to apply and take into consideration matters related to construction and operation of the ship, and market based incentives.

Meanwhile, the Committee recognized that IMO guidelines on greenhouse gas emissions have to address all six greenhouse gases covered by the Kyoto Protocol (Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), and Sulphur hexafluoride (SF_6)).

2.3 European environmental (air) legislation

In the 1980's, the European Union began to regulate various air pollutants by setting limit values for different pollutants.

On a European level these regulations are twofold.

1. Emission Regulations, dealing with the emissions directly emitted from the source; and
2. Air quality Regulations, drafted to prevent human health and ecological systems from pollution.

To date, most existing EU-legislation on atmospheric emissions and air pollution does not apply to ships. However there are a number of Community measures that require the Commission to take action on ship emissions.

With respect to emission regulation the directive on national emission ceilings (NEC-directive) [8] and fuel related regulations are the most important ones.

With regard to air quality, the Air Quality Framework directive (96/62/EC) [9] and its daughter directives are the most important.

2.3.1 Emission Regulation

NEC – National emission ceilings (2001/81/EC)

The emission ceilings as defined in the Göteborg Protocol have been used by the European Commission to set its own national emission ceilings in the NEC-directive. The Council of Ministers and the European Parliament have adopted this directive in July 2001. The NEC's that have been laid down in this directive are more stringent then those set by the Göteborg Protocol.

The directive covers emissions in the territory of the Member States and their exclusive economic zones from all sources of the pollutants as a result of human activities. It does not cover:

- Emissions from international maritime traffic;
- Aircraft emissions beyond the landing and take-off cycle;
- For Spain, emissions in the Canary Islands;
- For France, emissions in the overseas departments; and
- For Portugal, emissions in Madeira and the Azores.

The NEC-directive establishes national emission ceilings in every member state to be attained by 2010 for Nitrogen oxides (NO_x), Sulphur dioxide (SO_2), Volatile organic compounds (VOC) and Ammonia (NH_3).

Belgium needs to restrict its emissions to 99 kton for sulphurdioxide, 176 kton for nitrogen oxides, 139 kton for VOC and 74 kton for ammonia.

In relation towards emissions from ships the NEC-directive commits the Commission to report on the extent to which emissions from maritime traffic contribute to acidification, eutrophication and the formation of ground-level ozone.

The directive was scheduled for review and revision by 2004, thus providing an opportunity to strengthen the emission ceilings for 2010, to set new ceilings for later target years (2015 and/or 2020), and to decide when the long-term environmental objectives should be achieved. The review and revision of the directive has, however, been delayed, the reason being that the analysis and evaluation are to be co-ordinated with the ongoing Clean Air For Europe (CAFE) programme, initiated by the Commission in 2001[10].

The CAFE programme resulted in a so-called thematic strategy for air pollution and has been presented by the Commission on the 21st of September 2005.

This strategy is accompanied by proposals for revised and/or new directives relating to air pollution. Current developments under CAFE indicate that the NEC directive may also be extended to include national emission ceilings for fine particles (PM_{10} or $PM_{2.5}$, or both).

Fuel based regulation

The existing emission regulation for sea-going vessels of the European union is based upon the fuel type used.

Table 3 gives an overview of the types of fuel used by different types of ships. A distinction is made between fuel used for cruising (A = main engines), manoeuvring (B = bow screw propeller engines) and other energy needs on a ship (G = generators).

Table 3: fuel used per type of ship

	Fuel type	Inland Navigation			Coastal ships			Sea ships		
		A	B	G	A	B	G	A	B	G
Marine distillates	Gas oil (MGO)	X	X	X	X	X	X	X	X	X
	Diesel Oil (MDO)				X	X	X	X	X	X
	Heavy Fuel Oil (HFO or RO)				X	X	X	X	X	X

A = main engine; B = bow screw propeller engine(s); G = generators.

Gas oil (GO) is lighter and of more quality with a lower S-content as compared with diesel oil (DO) or heavy fuel oil (HFO) which is also called residual oil (RO). These are the most common used fuel types for ships. Boilers for steam turbines on LNG-tankers can also use gas. Recreational ships use normal gas oil as fuel.

Table 4 lists all fuel based EU-directives that have been launched in order to reduce emissions from ships. The EU priorities lay in the field of reducing NO_x, PM_{10} and SO_2 emissions. In order to reduce NO_x emissions, standards from Annex VI are being applied. The EU is in favour of more restrictions and aims to reduce NO_x emissions of all ships entering European seas and not only those ships under European flag.

Table 4: EU-directives on the S-content in marine fuels

	Directive	Introduction	Maximum S-content [% m/m]	Applicable to
EU	93/12/EEC	01/10/1994	0,2	- territorial waters[III] - gas oil, including marine gas oil
EU	1999/32/EU	01/07/2000	0,2	- territorial waters - gas oils, including marine gas oil
EU	2005/33/EC	19/05/2006	1,5	- in SOx Emission control Areas and by passenger ships - marine fuels
		01/01/2010	0,1	- by inland water vessels and ships at berth in Community ports - marine fuels

Directive 1999/32 [11] relates to reducing the sulphur content of marine gas oils. These are defined in the directive to include all marine distillate fuels: DMX and DMA grades, which are known as marine gas oils, but also DMB and DMC grades, which are known as marine diesel oils. Currently, the Directive does not apply to the third (and most widely used) type of marine fuel, which is heavy fuel oil (HFO)[IV].

The Directive also states that the commission shall consider which measures could be taken to reduce the contribution to acidification of the combustion of marine fuels other than distillates.

The aim of Directive 2005/33/EC is to reduce the impact of ship emissions of sulphur dioxide (SO_2 or SO_x) and particulate matter (PM) on environmental acidification and human health. This Directive consists of new maximum standards for S-content in marine fuels (see also Table 4):

- A sulphur limit of 1,5 % m/m on marine fuels used by all seagoing vessels on the Baltic Sea, the North Sea and the English Cannel in line with the sulphur limits set in Annex VI of the MARPOL treaty and according the SO_x ECA areas;

III Territorial waters: including seas 12 nautical miles from shore and inland waterways

IV The limit for heavy fuel oils (1 % by mass) put forward in the directive (art. 3 and 4) does not apply to petroleum derived liquid fuels used by seagoing ships, except fuels for marine gas oil.

- A sulphur limit of 1,5 % m/m on marine fuels used by passenger vessels in regular service to or from any EU-port. A transition period of 12 months after entry into force of the IMO designation (19/05/2005) is foreseen ending 19 May 2006.
- A sulphur limit of 0,1 % m/m on lighter marine fuels used by ships at berth in ports and inland vessels (with effect from 2010).

If member countries take other measures to subside new technologies to reduce emissions, the limits listed above are not binding.

2.3.2 Framework Directive on Air Quality

On November 21st 1996, the Framework Directive (FWD) on air quality (96/62/EG) [9] came into force. This FWD has to be translated into national law by every member state. The FWD forms together with a few daughter directives the basis for a new quality policy on air within the European Union. The directive lays down common rules and principles for setting limit values as well as for the assessment and the management of air quality throughout Europe.

The daughter directives include:

1. Directive 1999/30/EC [12] from the Council of the European Union on April 22nd 1999 concerning sulphur dioxide, nitrogen oxides and nitrogen dioxides, particles and lead. This directive was implemented in Flemish law on January 18th 2002 in VLAREM II;
2. Directive 2000/69/EC [13] from the European Parliament and the Council of the European Union on November 16th 2000 concerning benzene and carbon monoxide. Implemented into Flemish law on March 14th 2003;
3. Daughter Directive 2002/3/EC [14] on limitations for ozone. Implemented into Flemish law on March 14th 2003;
4. Daughter Directive 2004/107/EC [15] sets limitations to heavy metals among which arsenic, cadmium, mercury and nickel as well as polycyclic aromatic carbon hydroxides (PAH's). This directive is not yet implemented into Flemish law (March, 2005).

An overview of the daughter directives is presented in Table 5.

Table 5: air-quality guidelines according to the Air Quality Framework Directive

Pollutant	Averaging period	Limit Value	Margin of tolerance	Date by which limit value is to be met
Sulphurdioxide (SO_2)				
Hourly limit value for protection of the human health	1 hour	350 µg/m3 not to be exceeded more than 24 times per calendar year	150 µg/m3 (43%) on the entry into force of this Directive, reducing on 1 January 2001 and every 12 months thereafter by equal annual percentages to reach 0 % by 1 January 2005	1 January 2005
Daily limit value for the protection of human health	24 hours	125 µg/m^3 not to be exceeded more than 3 times a calendar year	none	1 January 2005
Limit value for the protection of ecosystems	Calendar Year and winter (1 October to 31 March)	20 µg/m^3	none	19 July 2001 (in agricultural areas)
Nitrogen dioxide (NO_2) and Nitrogen oxides (NO_X)				
Hourly limit value for the protection of human health	1 hour	200 µg/m^3 NO_2 not to be exceeded more than 18 times a calendar year	50 % on the entry into force of this Directive, reducing on 1 January 2001 and every 12 months thereafter by equal annual percentages to reach 0% by 1 January 2010	1 January 2010
Yearly limit value for the protection of human health	Calendar Year	40 µg/m^3 NO_2	50 % on the entry into force of this Directive, reducing on 1 January 2001 and every 12 months thereafter by equal annual percentages to reach 0% by 1 January 2010	1 January 2010
Limit value for the protection of vegetation	Calendar Year	30 µg/m^3 NO + NO_2	none	19 July 2001 (in agricultural areas)

Pollutant	Averaging period	Limit Value	Margin of tolerance	Date by which limit value is to be met
Carbon monoxide				
Limit value for the protection of human health	Mean daily 8h maximum	10 mg/m^3	6 mg/m^3 on the 13th of December 2000, on the 1st of January 2003 and thereafter each 12 months, reducing with 2 mg/m^3, to end at 0% on the 1st of January 2005	1 January 2005
Particles (PM_{10})				
Stage 1				
Daily limit value for the protection of human health	24 hours	50 $\mu g/m^3$ PM_{10} not to be exceeded more than 35 times a calendar year	50 % on the entry into force of this Directive, reducing on 1 January 2001 and every 12 months thereafter by equal annual percentages to reach 0% by 1 January 2005	1 January 2005
Yearly limit value for the protection of human health	Calendar Year	40 $\mu g/m^3$ PM_{10}	20% on the entry into force of this Directive, reducing on 1 January 2001 and every 12 months thereafter by equal annual percentages to reach 0% by 1 January 2005	1 January 2005
Stage 2 (1)				
Daily limit value for the protection of human health	24 hours	50 $\mu g/m^3$ PM_{10} not to be exceeded more than 7 times a calendar year	To be derived from data and to be equivalent to the stage 1 limit value	1 January 2010
Yearly limit value for the protection of human health	Calendar Year	20 $\mu g/m^3$ PM_{10}	50 % on 1 January 2005 reducing every 12 months thereafter by equal annual percentages to reach 0% by 1 January 2005	1 January 2010
(1) Indicative limit values to be reviewed in the light of further information on health and environmental effects, technical feasibility and experience in the application of Stage 1 limit values in the Member States.				
Lead				
Yearly limit value for the protection of human health	Calendar Year	0,5 $\mu g/m^3$	100 % on 1 January 2001 and reducing every 12 months thereafter to 0 % on 1 January 2005 (2010)	1 January 2005 (1 January 2010)
Benzene				
Yearly limit value for the protection of human health	Calendar Year	5 $\mu g/m^3$	5 $\mu g/m^3$ (100%) on the 13th of December 2000, on the 1st of January 2006 en thereafter each	1 January 2010

Pollutant	Averaging period	Limit Value	Margin of tolerance	Date by which limit value is to be met
			12 months 1 µg/m³ reducing to 0% on the 1st of January 2010	
Daily limit value for the protection of human health	24 hours	50 µg/m³ as 98ste percentile of daily means over one calendar year	-	-
Ozone				
Limit value for the protection of human health	Daily average maximum over 8 hours	120 µg/m³ (25 x average over 3 years)	Limit value not final	1 January 2010
Limit value for the protection of vegetation	AOT[V] 40 hourly average	18000 µg/m³/hour (average over 5 years)	Limit value not final	1 January 2010
Other pollutants (Target values[(1)])				
Arsenic	Calendar Year	6,0 ng/m³		
Cadmium	Calendar Year	5,0 ng/m³		
Mercury	Calendar Year	?		
Nickel	Calendar Year	20,0 ng/m³		
Benzo(a)pyrene (PAH)	Calendar Year	1,0 ng/m³		

(1) For the total content in the PM_{10} fraction averaged over a calendar year.

2.4 National environmental (air) legislation

Belgium is a federal state, which implies that competences regarding the jurisdiction of Belgium with respect to the marine environment are divided between the federal and the regional authorities (see also Annex B).

Emissions and air quality guidelines or not regulated on a Federal level. These kinds of regulations need to be dealt with by the separate regions.

Climate Change however is regulated as well as on a federal as on a regional basis for which different policies apply.

V AOT (Accumulated Excess over Threshold (expressed in µg/m³.hour).

2.4.1 Federal legislation

The Belgian Federal government on 'Human health, Safety of the food chain and the environment' has four objectives:

1. Coordination and integration of national and international environmental policies;
2. Prevention from damage to human health and the environment by chemical and other substances;
3. Preparation and implementation of an integrated product policy; and
4. Enforcement.

The protection of the environment, soil, subsoil, water, air, waste and prevention from noise pollution falls under the competence of the different separate regions.

The federal government regulates the product policy, whereas the regional governments deal with the protection of the environment by regulations (not product related).

Climate Change policy

Together with 140 different countries Belgium has engaged itself to the Kyoto protocol in order to reduce the emission of greenhouse gasses by 7,5% over the period 2008-2012. On the 16th of February 2005, the protocol became officially effective.

The Belgian Federal government decided to buy 12,3 million ton emission reduction units over the period 2008-2012. These units are bought through projects, based upon Joint Implementation and on Clean Development Mechanism.

2.4.2 Regional legislation (Flanders)

Distinction can be made between:

1. Legally binding matters as defined by law and regulated in the Flemish regulation for environment (Vlarem); and
2. Policy matters as prescribed in the Environmental Policy Action Plan, which is renewed every 3 to 4-years.

Emission standards and air quality guidelines

Sector bound specifications on emission standards and limit values for air quality are being incorporated in the Flemish environmental legislation (Vlarem).

Emission standards in Vlarem are listed for different sectors excluding the transport sector. The air quality guidelines in Vlarem are also sector based and taken from the EU framework directive on air quality.

The only emission standards that exist on behalf of the transport sector are included in the 'Environmental Policy Plan 2003-2007', based upon the NEC-directive. The emission standards granted to the transport sector, however, exclude emissions from seagoing vessels.

Recently (August 2004) the emission standards were recalculated by the administration of 'AMINAL, section air'.

NEC-directive

Table 6 gives an overview of the emission standards cfr. the NEC-directive and recalculated by Aminal with regards to the Flemish emission goals and reflected into the Environmental Policy Plan 2003-2007 (MPB 2003–2007) [16].

Table 6: emission standards according to the NEC-directive and Aminal

In kton/year	Emission standards 2010 – NEC directive	Emission standards 2010 transport sector - Aminal, 2004	Guiding emission standards 2010 for the transport sector (MBP 2003-2007)
Acidifying components			
SO_2 [VI]	65,8	1,25	-
NO_x	58,3	42,67	35,7
NH_3	45	-	-
Ozone forming components			
NMVOC	70,9	20,96	22,2
NO_x	58,3	42,67	35,7

A recent study conducted by the Flemish administration of Aminal – section air– shows that the indicative emission targets for the transport sector will not be met within the existing policy strategy. Therefore measures need to be applied corresponding the mobility scenario from the Flemish mobility plan.

[VI] Ceiling for Flanders for all sources except transport (Vlarem)

Climate Change policy

The Flemish climate change policy was laid down in the Environmental policy plan and by the CO_2/REG (Rational Energy Use) plan. In answer to the high need for a better co-ordination a taskforce for Climate Change in Flanders was established. This taskforce works policy exceeding. The first product of the taskforce was the Flemish Climate Policy Action Plan. On short term this Policy Action Plan envisages a stabilization of greenhouse gases by 2005. This policy plan also gives the policy vision of the Flemish government with regard to their intentions to fulfil the requirements of the Kyoto protocol.

In March 2004, the different regions reached an agreement with regard to burden sharing of greenhouse gases. An emission reduction of 5,2% for Flanders and 7.5% for Wallonia with regards to the basic year 1990 was agreed.

2.4.3 Regional legislation (Brussels and Walloon Region)

Since this study does not take into account any harbour located in the Brussels or the Walloon Region, legislation of those regions has not been taken into account in this report.

3. INVENTORY OF INTERNATIONAL REPORTING OBLIGATIONS

3.1 Object

Chapter 2 of this document includes an overview of environmental problems related to air pollution and relating international and European legislation that is established to abate impacts due to air emissions. In a final section, it detailed the Belgian and Flemish legal responsibilities with regard to emissions at the coastal zone and inland waters.

For monitoring the state of the environment, to check whether targets are being achieved and to inform policy makers, it is necessary to have quantitative information on emissions and emission sources. This information is also needed to define or redefine environmental priorities and objectives and to identify activities and actors responsible for the emissions.

To ensure accurate monitoring and evaluation of emissions, inventories have to be made at global scale. Therefore, the United Nations Framework Convention on Climate Change (UNFCCC) and the Convention on long-range transboundary air pollution (CLRTAP) established guidelines for consistent reporting of greenhouse gasses (GHG) and other gaseous emissions at international scale. The International Maritime Organisation (IMO) currently also started the design of reporting requirements with regard to ship emissions.

Based on these intentional conventions and reporting requirements, the European Union established Decisions and Directives with interim environmental targets and guidelines for Member States. As a EU Member State, Belgium has to report, according to the set EU requirements.

Many studies and policy documents have been published in the last ten years on the issue of emission data inventories and monitoring methodologies, for national and international shipping. This chapter details the above-mentioned reporting requirements and methodologies for the assessment of emissions from ships. Table 7 gives an overview of ship and vessel emission reporting requirements at international and European level, as described in the paragraphs beneath.

Table 7: ship and vessel emission reporting requirements

Reporting requirement	Reporting information	Reporting time	Reporting format	Gasses to be reported
UNFCCC	From 1990 to Year x-2	15 April Year X	CRF	CO_2, CH_4, N_2O, PFC, HFCs, SF_6, CO, NO_x, NMVOCs, SO_x
CLRTAP	From 1980 to Year X-2 Every 5 years: gridded data	15 February Year X	NFR	SO_2, NO_x, NH_3, NMVOC CO, PM, HM, POPs
MARPOL	To be defined	To be defined	To be defined	CO_2
EU/CO2	From 1990 to Year X-2	15 January Year X	CRF	CO_2, CH_4, N_2O, HFCs, PFCs, SF_6
	From 1990 to Year X-3			CO, SO_2, NO_x, VOC
EU/NEC	From 2000 to Year X-2	31 December Year X	NFR	SO_2, NO_x, VOC, NH_3

3.2 United Nations (UN)

Three UN Conventions address emission reporting at international level and give guidelines for emission monitoring and calculation. The United Nations Framework Convention on Climate Change and the Convention on long-range transboundary air pollution both address emissions from all kinds of sources, including shipping, while the Marpol Convention only addresses pollution from ships. The paragraphs beneath aim to detail the reporting requirements of these three conventions.

3.2.1 United Nations Framework Convention on Climate Change (UNFCCC)

The ultimate objective of the United Nations Framework Convention on Climate Change is to achieve stabilization of greenhouse gas concentrations in the atmosphere at a level, which prevents dangerous anthropogenic interference with the climate system.

All parties to the Convention have an obligation to report national inventories of anthropogenic emissions by sources and removals by sinks, of all greenhouse gases not controlled by the Montreal Protocol. At a minimum, inventories shall contain information on the following gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), perfluorcarbons (PFC), hydrofluorcarbons (HFCs) and sulphur hexafluoride (SF_6). They should also provide information on emissions of indirect greenhouse gases: carbon monoxide (CO), nitrogen oxides (NO_x) and non-methane volatile organic compounds (NMVOCs) and are encouraged to provide information on emission of sulphur oxides (SO_x) [17] [18].

Reporting has to be done according to both the 'revised 1996 IPCC guidelines for National Greenhouse Gas Inventories' (IPCC guidelines) and the 'IPCC good practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC good practice guidance) (2000)'. Guidance includes advice on choice of methodology, emission factors, activity data and uncertainties, and on a series of quality assessment and quality control procedures, which may be applied during the preparation of inventories.

When it comes to methodology, two emission estimation methods can be applied. The 'trier 1' is a simplified method that applies emission factors to fuel statistics while it ignores differences in fuel type, combustion technology, operating conditions, control technology and maintenance and age of the equipment. In case more detailed information is available, the 'trier 2' method can be applied.

Both trier 1 and 2 use emission factors to calculate emissions. Emission factors for US and for Europe, for different kinds of engines (diesel or gasoline, 4-stroke and 2-stroke) and for inland waterways and ocean going ships are listed in the revised 1996 IPCC guidelines [19].

Parties may use different methods ("tiers"), giving priority to those methods, which are believed to produce the most accurate estimates. Parties can also use national methodologies which they consider more able to reflect their national situation provided that these methodologies are compatible with the IPCC Guidelines and are well documented (FCCC/SBSTA/1999/L.5).

UNFCCC reporting requires the common reporting format (CRF). This is a standardized format for reporting estimates of greenhouse gas emissions and removals and other relevant information. The UNFCCC secretariat provides the format to the Parties and it is also available at it's website [20].

Reporting has to be done by the 15th of April for the last year but one, to the UNFCCC secretariat. For example data of 2004 have to be submitted to the secretariat by the 15th of April 2006.

Currently, the IPCC is finalizing the development of the '2006 IPCC guidelines for National Greenhouse Gas Inventories (2006 IPCC guidelines)'. This guidance is expected to be finished in May 2006 [21] and it will incorporate both the 1996 IPCC Guidelines and the IPCC good practice guidance.

3.2.2 Convention on long-range transboundary air pollution (CLRTAP) (1979)

The main aim of the Convention on long-range transboundary air pollution is to protect the human environment against air pollution and to gradually reduce and prevent air pollution, including long-range transboundary air pollution. According to the CLRTAP, reporting to the Executive Body of the Convention, the EMEP steering body (UNECE/CLRTAP secretariat) is required [18].

Reports should contain information on the following air pollutants: sulphur (SO_2), Nitrogen oxides (NO_x), ammonia (NH_3), non-methane volatile organic compounds (NMVOC), carbon monoxide (CO), particulate matter (PM), heavy metals (HM) (in particular: cadmium, lead, mercury and if the Party considers it appropriate: arsenic, chromium, copper, nickel, selenium and zinc) and persistent organic pollutants (POPs) (in particular: aldrin, chlordane, clordane, DDT, Dieldrin, endrin, heptachlor, hexachlorobenzene, mirex, toxaphene, hexachlorocyclohexane, hexabromobiphenyl, polychlorinated biphenyls, dioxins, furans, polycyclic aromatic hydrocarbons and if the Party considers it appropriate: short chained chlorinated paraffins and pentachlorophenol) [22].

Reporting of national totals has to be done every calendar year. Values of the previous year but one have to be submitted by February 15th of the next year. For example, data of 2003 have to be submitted to the secretariat, by February the 15th, 2006. All submissions should be done in the NFR format in accordance with the 2002 Reporting Guidelines (ECE/EB.AIR/80, Air Pollution Studies series, No. 15) [23]. These guidelines are designed in accordance with the reporting guidelines under the IPCC and allow EU member states to compare with national emission reporting under the NEC directive [22]. Moreover, to ensure that data are complete and submitted in the correct format, Parties should check with the electronic tool 'REPDAP'[24]. For further technical assistance, Parties may use the third edition of the EMEP/CORINAIR Atmospheric Emission Inventory Guidebook, both as a reference book and as a checklist to ensure that all relevant activities are considered and quantified.

As the IPCC guidelines, the EMEP Corinair guidebook also details a simple and a detailed method for emission calculation and it details emission factors for international and national sea traffic, as well as for inland waterways.

It is required that Parties list where the EMEP/Corinair guidebook is used and where not. If another guidebook was used, then Parties should provide additional explanations [18].

Parties within the geographical area of EMEP[VII] are also required to periodically (every fifth year, starting from 2000) provide emission data for the grid squares that overlay its territory, also known as the EMEP grid [18]. Parties outside the geographical scope of EMEP are encouraged to also make available similar information.

For the years 2010, 2015 and 2020, Parties are also required to report on projected activities and projected national total emissions.

3.2.3 International Maritime Organisation (IMO)

Annex VI to the Marpol convention (as described in Chapter 2) entered into force in May 2005. It addresses prevention of air pollution form ships. Based on this annex, IMO is currently working on guidelines for the establishment of a common approach for voluntary ship CO_2 emission indexing for use in trials. This will allow ship-owners to evaluate the performance of their fleet with regard to CO_2 emissions [25].

Data required for this indexing should include distance travelled, the quantity and type of fuel used, cargo type and other information that may affect the amount of carbon dioxide emitted. Fuel information is provided on the bunker delivery notes that are required under regulation 18 of Annex VI to MARPOL and distance travelled should be calculated by actual distance travelled, as contained in the ship's logbook. The unit used for distance travelled and quantity of fuel should be expressed in nautical miles and metric tones. The cargo should be expressed as detailed in Table 8.

The format that will be used for reporting still has to be agreed upon by IMO.

It is important that sufficient information is collected on the ship with regard to fuel type and quantity, distance travelled and cargo type so that the efficiency of the ship can be compared with other modes of transport.

[VII] The geographical scope of EMEP means the area in which, coordinated by the international centers of EMEP, monitoring is carried out. The EMEP area is defined in a polar conical projection and is approximately the are East o 40°W, West of 60°E and North of 30°N. [EMEP Corinair 804 842] Technical description of the EMEP grid is available in Annex V of the 'guidelines for Estimating and Reporting Emission Data under the Convention on Long-range Transboundary Air Pollution' [UN, 2003]

Table 8: definition of cargo as described by IMO [25]

For bulk and general cargo ships, the mass of transported cargo should be defined in metric tones (t).
For ships carrying a combination of containers and other cargoes a TEU mass of 10 t should be applied for loaded TEUs and 2 t for empty TEUs.
For other types of ship, the following units could be applied:
• For bulk carriers and tankers: cubic meters (m3)
• For passenger vessels: number of passengers
• For car ferries and car carriers: number of car units or occupied lane metres
• For container ships: number of TEUs (empty or full)
• For railway and ro-ro vessels: number of railway cars and freight vehicles, or occupied lane meters

3.3 OESO

3.3.1 Eurostat

With a two-yearly survey, the European Statistical Bureau, Eurostat, also used to gather information on emissions form air pollutants. The latest reporting was carried out in 2000, collecting emissions until 1998. From then on, Eurostat uses other international reporting on atmospheric emissions.

3.4 European reporting requirements

The European Union describes several emission-reporting requirements in Council Decisions and Directives. Council Decision 2001/80/EG requires reporting on emissions from large combustion plants (LCP), except from technical devices used for the propulsion of a ship. Other Council Decisions and Directives that are relevant for emissions from shipping are summarized in the paragraphs beneath.

3.4.1 EU/CO2

The first European monitoring mechanism for anthropogenic CO_2 and other greenhouse gases was established in June 1993, following the adoption of Council Decision 93/389/EEC, by the Council of Environment Ministers. This was revised in April 1999 (Council Decision 99/296/EC), to allow for the updating of the monitoring process in line with the inventory requirements incorporated into the Kyoto Protocol (KP) [26].

To take care of developments on international level, a new Decision 'concerning a mechanism for monitoring Community greenhouse gas emissions and for implementing the Kyoto Protocol' was established in February 2004 (Council Decision 280/2004/EC) [27].

According to the latter Decision, Member States are required to determine and report emissions to the Commission on annually basis, before the 15th of January. Details on this emission reporting are included in Table 9.

By the 15th of March every two years (started in 2005), Member States also have to report the assessment of projected progress. Details on this reporting are added in Table 10.

Table 9: reporting requirements for EU Member States for the assessment of actual progress [27]

By the 15th of January each year, Member States have to determine and report to the Commission:
a) their anthropogenic emissions of greenhouse gases listed in Annex A to the Kyoto Protocol (carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6)) during the year before last (year X-2);
b) provisional data on their emissions of carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen oxides (NO_x) and volatile organic compounds (VOC) during the year before last (year X-2), together with final data for the year three years previous (year X-3);
c) their anthropogenic greenhouse gas emissions by sources and removals of carbon dioxide by sinks resulting from land-use, land-use change and forestry during the year before last (year X-2);
d) information with regard to the accounting of emissions and removals from land-use, land-use change and forestry, in accordance with Article 3(3) and, where a Member State decides to make use of it, Article 3(4) of the Kyoto Protocol, and the relevant decisions there under, for the years between 1990 and the year before last (year X-2);
e) any changes to the information referred to in points (a) to (d) relating to the years between 1990 and the year three years previous (year X-3);
f) the elements of the national inventory report necessary for the preparation of the Community greenhouse gas inventory report, such as information on the Member State's quality assurance/quality control plan, a general uncertainty evaluation, a general assessment of completeness, and information on recalculations performed;
g) information from the national registry, once established, on the issue, acquisition, holding, transfer, cancellation, withdrawal and carryover of assigned amount units, removal units, emission reduction units and certified emission reductions during the previous year (year X-1);
h) information on legal entities authorised to participate in mechanisms under Articles 6, 12 and 17 of the Kyoto Protocol, in compliance with relevant national or Community provisions;
i) steps taken to improve estimates, for example where areas of the inventory have been subject to adjustments;
j) information on indicators for the year before last (year X- 2); and
k) any changes to the national inventory system.
Member States shall communicate to the Commission, by 15 March each year (year X), their complete national inventory report.

Table 10: reporting requirements for EU Member States, for assessment of projected progress [27]

a) information on national policies and measures which limit and/or reduce greenhouse gas emissions by sources or enhance removals by sinks, presented on a sectorial basis for each greenhouse gas, including:
i) the objective of policies and measure;
ii) the type of policy instrument;
iii) the status of implementation of the policy or measure;
iv) indicators to monitor and evaluate progress with policies and measures over time, including, inter alia, those

indicators specified in the implementing provisions adopted pursuant to paragraph 3;

v) quantitative estimates of the effect of policies and measures on emissions by sources and removals by sinks of greenhouse gases between the base year and subsequent years, including 2005, 2010 and 2015, including their economic impacts to the extent feasible; and

vi) the extent to which domestic action actually constitute a significant element of the efforts undertaken at national level as well as the extent to which the use of joint implementation and the clean development mechanism and international emissions trading, pursuant to Articles 6, 12 and 17 of the Kyoto Protocol, is actually supplemental to domestic actions, in accordance with the relevant provisions of the Kyoto Protocol and the Marrakech Accords;

b) national projections of greenhouse gas emissions by sources and their removal by sinks as a minimum for the years 2005, 2010, 2015 and 2020, organized by gas and by sector, including:

i) 'with measures' and 'with additional measures' projections such as mentioned in the guidelines of the UNFCCC and further specified in the implementing provisions adopted pursuant to paragraph 3;

ii) clear identification of the policies and measures included in the projections;

iii) results of sensitivity analysis performed for the projections; and

iv) descriptions of methodologies, models, underlying assumptions and key input and output parameters.

c) information on measures being taken or planned for the implementation of relevant Community legislation and policies, and information on legal and institutional steps to prepare to implement commitments under the Kyoto Protocol and information on arrangements for, and national implementation of, compliance and enforcement procedures;

d) information on institutional and financial arrangements and decision making procedures to coordinate and support activities related to participation in the mechanisms under Articles 6, 12 and 17 of the Kyoto Protocol, including the participation of legal entities.

3.4.2 EU/NEC

In 2001, the European Parliament and Council established Directive 2001/81/EC on national emission ceilings, also known as NEC directive [8]. The aim of this Directive is to limit emissions of acidifying and eutrophying pollutants and ozone precursors.

According to art 7 of the Directive, Member States have to prepare and annually update national emission inventories and emission projections for 2010 for SO_2, NO_x, VOC and NH_3. They have to report their final emissions inventories for the previous year but one and their provisional emission inventories for the previous year.

Article 7(2) of the NEC Directive requires the use of the LTRAP reporting methodology. This entails reporting of inventories and projections using the EMEP/CORINAIR guidelines as described above.

The Commission, assisted by the European Environment Agency, shall, in co-operation with the Member States and on the basis of the information provided by them, establish inventories and projections of the pollutants. This information shall be made publicly available, according to the requirements of the Aarhus Convention.

Reported data are used to check national emissions with fixed emission ceilings for a country. Furthermore, these data are used for modelling in the CAFE programme (Clean Air For Europe). Models in the framework of this programme show European air quality evolutions from now to 2020, with the current policy measures and it can be used to visualize the impact of new policy measures.

The Directive on national emissions does not cover emissions from international maritime traffic (art 2).

3.5 National reporting requirements

Belgium ratified the CLRTAP Convention in 1982 and therefore has to yearly report on emissions and emission predictions as described in this Convention. In this framework, Belgium yearly submits an Informative Inventory Report, together with the EMEP/LRTAP emission figures. This report details the reported emission figures.

Belgium also submits a National Inventory Report (NIR) to the UNFCCC secretariat.

With relation to annex VI of the IMO Marpol Convention, the North Sea was adopted as SOx Emission Control Area (SECA) in July 2005. This regulation is anticipated to enter into force from November 2006, with a 12-month period after that date before full implementation [28]. Requirements for reporting in this framework are not developed yet.

Belgium furthermore has to comply with EU reporting requirements in the framework of the NEC Directive and Council Decision 280/2004/EC.

Emissions from shipping in Flanders are reported in the VMM report 'Lozingen in de lucht 1990-2004'[29].

4. CURRENT MONITORING PROGRAMME

In this chapter we describe the current emission inventory used for local and international navigation in Belgium. Furthermore, we give an overview of activity based emission assessments for maritime navigation as used in Europe.

4.1 Current emission monitoring inventory in Belgium

The preparation of environmental emission inventories falls under the authority of the three regions in Belgium, mostly based on regional energy-data (except for marine bunkers). The compilation of the three regional inventories is done by the Interregional Cell for the Environment (IRCEL). As maritime navigation does only occur in the North Sea and because Flanders is the only Belgian region that borders on the sea, all emissions from maritime navigation are attributed to the Flemish region. The Flemish Environmental Agency (VMM) and the VITO determine the emission figures for maritime transport in Flanders (= Belgium).

However, energy figures fall under the national authority and are managed by the Federal Public Service Economy, SMEs, Self-employed and Energy.

In following we first give an overview of the emission approaches used within the different navigation sectors. Then we describe the different sectors separately. Finally, we give the main bottlenecks within the current emission monitoring programme.

4.1.1 Overview current approach in Belgium

Figure 1 gives an overview of the emission calculations for local and international navigation in Belgium, together with the basic sources and responsible organisations.

To better understand the bottlenecks of the current methodology we also discuss how the emissions for inland navigation are calculated.

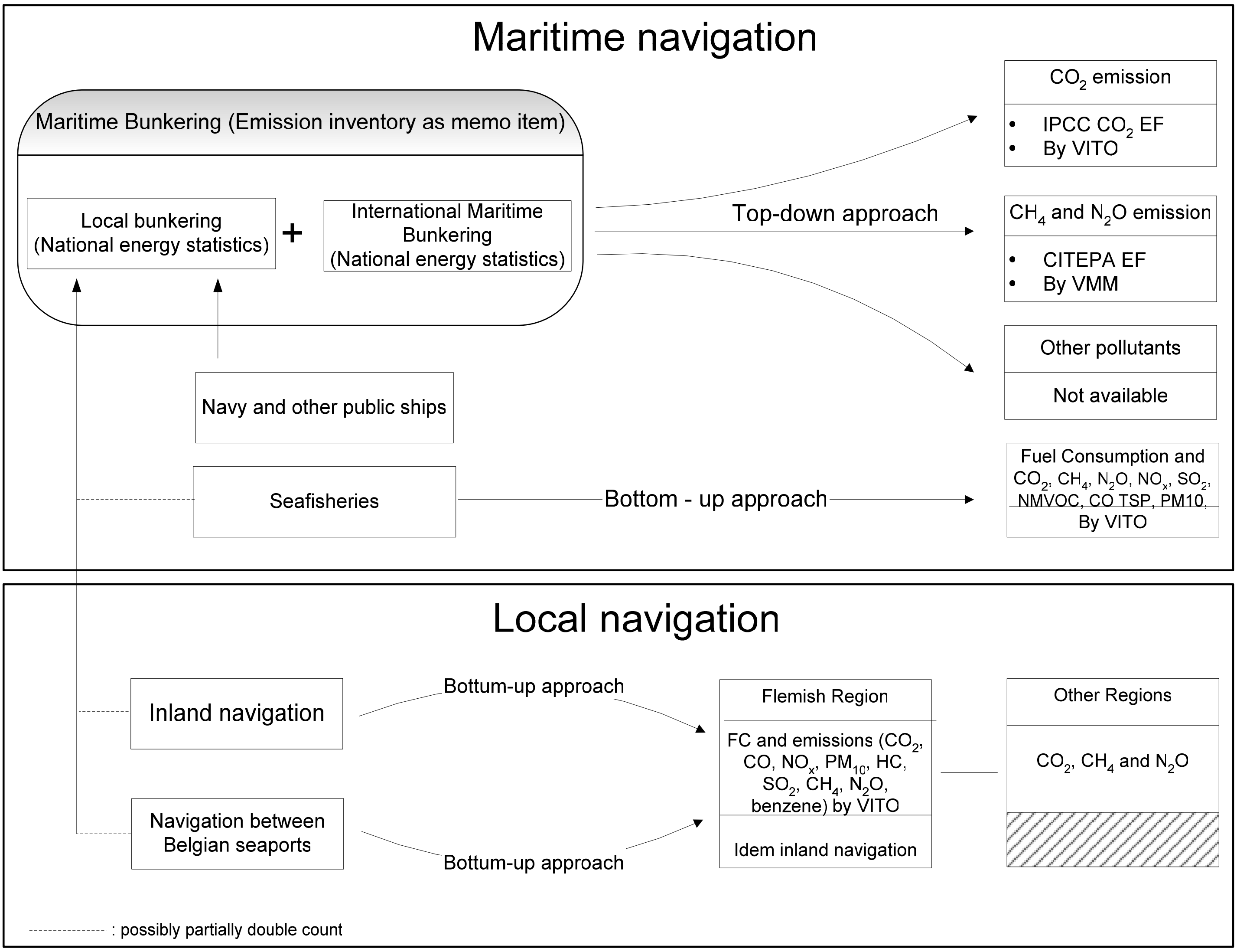


Figure 1: overview of emission calculations for local and international navigation in Belgium

4.1.2 Bunker fuel related monitoring programme

In Belgium, the current emission-monitoring programme for maritime transport is based on the national energy statistics published by the Federal Public Service Economy, SMEs, Self-employed and Energy in its yearly 'Petroleum Balance' [30]. The statistics are fed with fuel delivering data, which are the result of surveys to fuel suppliers.

The emission calculations for maritime transport are based upon the total amount of bunker fuel for maritime transport allocated to Belgium. The total bunker fuel has been defined as the sum of 'international bunkering' and 'local bunkering' as reported in the national energy statistics.

By multiplying the total amount of bunker fuels with the IPPC CO_2 emission factors, VITO computes CO_2 emissions of maritime transport. The used default CO_2 emission factors for all relevant energy vectors are shown in Table 11 [31].

In 2006, the VMM will report for the first time CH_4 and N_2O emissions from bunker fuels. Estimations are based on the same total amount of bunker fuels as used by VITO. CH_4 and N_2O emission factors of industrial plants, as stated by CITEPA, are used for these emission calculations (see Table 11) [32]. This because of the CITEPA report does not record CH_4 and N_2O emissions factors for maritime shipping. Those emission factors are neither reported in the IPCC-guidelines or the EMEP/CORINAIR-handbook. The VMM is aware of the inaccuracy of their approach. Until now bunker fuels are not integrated in the emission inventory, they are only reported as a memo item in international reporting, so no further attention is paid to this inaccuracy. When new information becomes available, the VMM will adjust its approach.

Besides CO_2, CH_4 and N_2O, no other emissions are estimated for maritime transport within the current monitoring system.

Table 11: applied emission factors (EF) for maritime navigation in Belgium

EF in g/GJ	CO_2	CH_4	N_2O
Gas/Diesel Oil	73 326	0,1	13,4
Heavy Fuel Oil	76 593	0,1	13,4

Sources: CO_2 [31], CH_4 and N_2O [32].

4.1.3 Offshore and coastal fisheries

The national energy statistics notify sea fisheries within a separate section, although the quality of the figures is very uncertain and there seems to be no regularity in the figures between the different years. The total fuel consumption by fisheries as reported in the national statistics (2004) is less than 10 % of those estimated by the Flemish Energy Balance [33] using a bottom-up approach.

The main explanation for this low figure is *probably* the large amount of undefined sectors in the national energy statistics; about 15 % in 1999 and 19 % in 2004. A possible secondary effect could be the incorrect assignment to sectors by the fuel suppliers involved in the energy surveys.

In the following we describe the bottom-up approach to estimate fuel consumption and CO_2 emissions from fisheries as used within the Flemish Energy Balance [33].

The energy consumption of offshore and coastal fisheries is strongly dependant on the ship type (size and power) and the method of fishing. The total consumption is therefore calculated on the basis of average consumption per fisheries' type and per unit power, the average power and the number of sea days [34, 35]. The yearly variable parameters (average engine power and number of sea-days) are published by the Flemish Sea Fisheries Department (Dienst Zeevisserij van de Afdeling landbouw- en visserijbeleid van de Administratie land- en tuinbouw van de Vlaamse overheid) [34].

Table 12 shows per fisheries' type the number of sea-days, the average power and average consumption per unit power and sea-day for the year 2004.

Table 12: overview per fisheries' type of the number of sea-day, the average engine power and the unit fuel consumption in 2004 [34, 35]

	# sea-days	kW	MJ per kW*sea day
otter trawling	730	469	182
shrimp	1 746	192	195
beam trawl	19 060	666	197
lobster	572	386	190
other	422	383	182
Total	**22 530**		

To calculate CO_2 emissions, VITO uses the IPCC emission factors, see Table 11 [31].

For fisheries the VMM assesses the emissions of total suspended particulates, PM10, CO, CO_2, SO_2, NO_x, NMVOC, CH_4 and N_2O [36].

4.1.4 Navy ships and non-commercial State owned ships

In the national energy statistics there is a separate section for military forces and other state services. Here, we could make the same comments as we did for offshore and coastal fisheries: maybe the national energy statistics give an underestimation of the total fuel consumption by this (small) sector.

For navy ships and non-commercial State owned ships, VITO does not estimate the fuel consumption and CO_2 emissions separately. Although this sector may be partially integrated in the local bunker fuels.

4.1.5 Inland navigation

The Flemish Region

The basis for the calculations are on one hand the amount of ton kilometres transported on Belgian/Flemish inland waterways and on the other hand fuel consumption figures and emission factors per ton kilometre.

Historical figures for ton kilometres on the different waterways in Belgium are available at NIS (Belgian National Institute of Statistics) [37]. For Flanders, direct information of ton kilometres on inland waterways is used. Those figures were put available by the different waterway administrators (the figures are placed earlier at disposal than those of NIS) and the figures are further processed by VITO within the Flemish Energy Balance [33].

Within the SUSATRANS study and a study for the Flemish organization for the promotion of inland shipping, VITO recently developed a new, technology based, model for calculating fuel consumption and emissions from inland vessels in Belgium [38,39].

By way of an inquiry to Belgian and Dutch vessel operators, VITO gathered information on the ship fleet on Belgian inland waterways and the energy use by the different on-board energy systems. A correction for the energy used by auxiliaries was made: i.e. we used a correction factor for the bow screw propeller engine to manoeuvre a ship and the generators for e.g. electricity. The emission model has been calibrated for the year 2002 with the findings of the fuel consumption inquiry.

Table 13 gives an overview of the evolution of the fleet emission factors for inland navigation in Belgium expressed in gram per 1000 tonne-kilometres. The figures take into account the emissions due to propulsion engines and auxiliaries, also empty trade is incorporated.

Table 13: fleet emission factors for inland navigation in Belgium, sum of propulsion engines and auxiliaries, taken into account empty trade, in g/1000 tonkm [38]

Year	CO_2	NO_x	NMVOC	PM	CH_4	N_2O
1990	33 100	781	41,3	31,2	1,27	7,3
2000	29 700	573	28,8	20,9	1,14	6,5
2010	28 000	489	17,5	14,8	1,07	6,2
2020	27 700	361	12,1	8,6	1,06	6,1

One of the results of the above-mentioned studies is a better average energy-use (per tonkm) of inland vessels. This improved average is also used within the calculations of energy-use and emissions (ea. CO_2) from inland navigation in the Flemish region. For CO_2 the calculated energy-use and default IPCC CO_2-emission factors are used, whereas for N_2O emission factors from STOWA are applied [31, 40, 41]. For the other emissions the basis is Hulskotte et al. [38, 42].

Within this model we also took into account the emission legislation set by the Central Commission for navigation on the Rhine and the recent European directive on non-road mobile machinery [43,44].

More detailed information about the model can be found in De Vlieger et al. (2005) [38].

The Walloon Region

In the Walloon Region the estimations for CO_2, CH_4 and N_2O from inland vessels are based on activity data (tonkm) given by the MET (Ministère Wallon de l'équipement et des transports). These data are used in combination with an average fuel consumption in the navigation to estimate the total fuel consumption. For CO_2, the default IPCC CO_2 emission factors are used, for CH_4 and N_2O the EMEP/CORINAIR emission factors.

The Brussels' Region

In the Brussels' Region the estimations for CO_2, CH_4 and N_2O from inland vessels are based on data given by the Port of Brussels. These data cover the entirety of the network of inland waterways, which is only 15 km. For CO_2 the default IPCC CO_2 emission factors are used, whereas for CH_4 and N_2O EMEP/CORINAIR emission factors are used.

4.1.6 Transport between Belgian seaports

The emission calculation for transport between Belgian (Flemish) seaports are executed by VITO based on three input parameters:

- Amount transported (in ton) given by the VRIND statistics [45];
- Average distance between two ports on Flemish territory (20 km);
- Average energy-use per ton kilometre and emission factors per ton kilometre as used for inland navigation (see Table 13).

VITO and the VMM are aware that this approach is very rudimentarily as emission factors for inland ships are used and thus not for coastal ships.

4.1.7 Bottlenecks

Accuracy of the Belgian maritime bunker fuels

The current methodology of summation the local and international bunker fuels for the emission monitoring programme for maritime navigation possibly results in an overestimation by about 5 % in energy consumption and emissions. Since energy consumption related to the sum of local and international bunker fuels lies about 5 % higher than this related to only international bunker fuels.

Furthermore, there possibly is an even more important source of overestimation of the overall international bunker fuels in the federal energy balance, as fuel distributors may attempt to attribute as much heavy diesel fuel as possible to international bunkering because these are free from duties. This affects also the maritime bunkering in Belgium. For agriculture, probably too little heavy diesel oil is reported in the national energy statistics and too many gas oil (gas oil = duty free for agriculture and horticulture). Due to reasons mentioned above, the international bunkering could probably be overestimated by about 20 % [46].

From the two paragraphs above we can conclude that within the current emission programme the energy and emission figures for maritime bunkering are possibly overestimated by more than 20 %.

On the other hand there is a significant amount of fuel within the national energy statistics that remains not assigned to a specific sector: 17 % in 2003 and 19 % in 2004. It is not clear in which way better insights could affect the figures for maritime bunker fuels.

Since 2003, a working group under the surveillance of the National Climate Commission has been working on the harmonisation of the regional and national energy balances. The number of questionnaires and the format of the questionnaires used to establish a national petroleum balance will be altered in the years to come. At present state, the new provisional questionnaires make a division between marine bunkering, local bunkering and sea fisheries, and interior and coastal navigation. Local bunkering and sea fisheries are described as 'quantities delivered in Belgium as board supplies or bunker supplies to sea going vessels of the Administration, Marine or to fishing boats without distinction of flag'. Interior navigation and coastal navigation are described as 'quantities delivered in Belgium to inland navigation vessels, to coastal vessels, to Rhine vessels without a distinction of flag'. It has to be evaluated whether this division and the descriptions are sufficiently clear.

Double counting of energy consumption and emissions from fisheries

It seems that not all fuel used for fisheries and inland navigation is reported within the appropriate sectors in the national energy statistics. A part of the missing fuel is possibly reported in the local bunker fuels. As VITO calculates the fuel consumption and CO_2 emissions from fisheries with the bottom-up approach (see 4.1.3) and because local bunker fuels are added to the international bunkers, partially double counting might occur for fisheries.

Although not relevant for the MOPSEA study the same comment could be made for inland navigation.

At present this possible double counting is of minor concern as maritime bunkering is only mentioned as a memo item within current emission inventories. This will probably change with post Kyoto 2012.

On the other hand fishing vessels may buy fuel abroad and thus would not be registered in the national statistics [47].

Little emission figures for maritime navigation

In Belgium, there are no sufficient emission figures for navigation to fulfil international emission reporting. Only for CO_2, rather good figures are available. Just for inland shipping appropriate information is available for most of the required pollutants.

4.2 Activity based methodologies in Europe

In this section we evaluated different European methodologies to estimate emissions from sea-going vessels. We screen the utility of the different activity based methodologies for mapping emissions from sea-going vessels in Belgium. We do this on the basis of a drawn list of strengths and weaknesses of the different methodologies. In the following section we first give a brief introduction on the methodologies

4.2.1 European methodologies

In this section we give a brief elucidation on the evaluated European approaches. More detailed information upon these methodologies could be found in Annex C. An overview of the strengths and weaknesses of these methodologies is listed in Table 14.

MEET

The European project 'Methodologies for estimating air pollutant emissions from transport (MEET)' describes a methodology for calculating the emissions from sea-going vessels, among the methodology for the other transport modes [48].

ENTEC

ENTEC UK Limited has conducted a study on behalf of the European Commission, to quantify among other things the ship emissions of SO_2, NO , CO_2 and hydrocarbons for the year 2000 in the North Sea, Irish Sea, English Channel, Baltic Sea and Mediterranean [49]. For the pollutant PM, they have only quantified the in-port emissions (manoeuvring, loading/unloading and hotelling).

EMS

The project 'Emission registration and –Monitoring for Shipping (EMS = Emissieregistratie en –Monitoring Scheepvaart) [50], carried out by the Dutch Adviesdienst Verkeer en Vervoer (AVV) (head performer) by order of Directoraat-Generaal Goederenvervoer (DGG), had as target to (better) map the different emissions from sea-going vessels en inland shipping for the Netherlands.

TREMOVE

Transport & Mobility Leuven has recorded maritime shipping in there transport model 'TREMOVE'. They calculate the emissions from sea-going vessels with the methodology set up by ENTEC.

TRENDS

TRENDS stands for TRansport and ENvironment Database System [51]. The authors of TRENDS have set up a methodology to determine the emissions from the 4 most important transport modes (road transport, railways, shipping, aviation).

The module in the study 'Energy Consumption and Air Pollutant Emissions from Rail and Maritime Transport' [52] is based on TRENDS.

Within ARTEMIS the calculation of emissions from sea-going vessels is based on the TRENDS methodology.

4.2.2 Summary of strength weakness analysis

A summary of the strengths and weaknesses of the evaluated approaches is given in Table 14. Main conclusions from a strength-weakness analysis are:

- Most of the methodologies do not pay any attention to the technological evolution of sea-going ships. The EMS approach is the only exemption at that point;
- Most methodologies are difficult to apply for Belgium, because of the specific situation in Belgium and the lack of transparency of the approaches or referred documents. For the EMS approach a handbook is available for the Belgian situation;
- Although not a common methodology in Europe, the EMS approach seems to be the most suitable option for the MOPSEA project.

Table 14: strengths and weaknesses of European activity based emission approaches for sea-going vessels

Methodology	*Strengths*	*Weaknesses*
MEET	▪ European accepted methodology for emission inventory ▪ distinction in different navigation stages ▪ fishing boats taken into account ▪ good results for long journeys (amount of days)	▪ for short journeys ~ Belgian territory to rough ▪ no technological evolution taken into account
ENTEC	▪ used in Europe as input for policy ▪ distinction in different navigation stages ▪ emission factors available ▪ fishing boats taken into account	▪ not transparent as regards to input and assumptions, what complicates the use by a third party (outside an European project) ▪ ships under 500 GT are not taken into account ▪ very detailed division, by which the uncertainty on the input parameters increases ▪ no technological evolution taken into account
EMS	▪ distinction in different navigation stages ▪ clear hand guide available, so reproducible ▪ geometry of the harbour taken into account ▪ technological evolution taken into account ▪ emission factors available in detail	▪ no European approach, but a Dutch
TREMOVE	▪ analogous to ENTEC	▪ analogous to ENTEC
TRENDS/ ARTEMIS	▪ used in an European project	▪ common approach by EC ▪ no distinction in different navigation stages

5. SCOPE OF THE NEW EMISSION MODEL

Exhaust emissions will be determined for the cruising and hotelling of sea-going vessels (freight and passenger transport) in the Belgian territorial waters. Table 15 gives an overview of what is included in the new emission model and what not.

Table 15: overview of the working area of the new emission model

	included	*not included*
GEOGRAPHIC	▪ North Sea (12-mile zone) ▪ River Scheldt (Belgian ▪ Harbour of Antwerp ▪ Harbour of Ghent ▪ Harbour of Ostend ▪ Harbour of Zeebrugge	▪ National Continental Shelf
EMISSIONS	▪ CO_2 ▪ SO_2 ▪ HC ▪ CO ▪ NO_X ▪ PM	▪ N_2O ▪ CH_4
SEA-GOING VESSELS	▪ Chemical tanker ▪ Containers ▪ Dry bulk carrier ▪ Gas tanker ▪ General cargo ▪ LNG tanker ▪ Oil bulk (crude) ▪ Passenger ship ▪ Reefers ▪ RoRo	▪ Dredger ▪ Tug ▪ Tankbarge ▪ Fishing boats ▪ Pleasure crafts ▪ Navy
EMISSION SOURCES	▪ Cruising (energy use) ▪ Hotelling (energy use)	▪ Loading and unloading ▪ energy consumption ▪ release of gases ▪ CO_2 as inert gas produced by a separate gas generator

Bottlenecks

1. An inventory of the emissions from the National Continental Shelf cannot be made because of missing activity data. This bottleneck can be solved in future projects because the Administration of Waterways and Marine Affairs (AWZ) will map the activities from sea-going vessels on the National Continental Shelf with the Automatic Identification System (AIS) in the near future.
2. Technological dependant emission factors for N_2O and CH_4 are not available. Emission measurements are necessary to figure out these factors.
3. The scope of this study does not include all vessels on Belgian territory. The new model makes an emission inventory for sea-going vessels and not all vessels that travel on Belgian Territory. Another methodology is necessary for the following vessels:
    - dredger
    - tug
    - tankbarge
    - fishing boats
    - pleasure crafts
    - navy

   For fishing boats the old emission inventory methodology can be used. For dredger and tug the top-down approach from ECOSONOS [53] can be applied.
4. Energy for loading and unloading can be supplied from the vessel engines or from the harbour energy facilities. A detailed study is necessary to map these emissions correctly.

6. DATA COLLECTION

The share of the emissions from sea-going vessels will increase in the future as the exhaust emissions of other transport modes decreases. This is due to the more stringent emission regulation and fuel specifications for road transport, railway traffic and inland navigation. The technological evolution of sea-going vessels is slower as compared to other modes. We have to take this evolution into account to get the right picture of the emission problems of these vessels.

It is therefore important to know:

- the characteristics of the sea-going vessels that call at Belgian harbours (fleet composition);
- the duration of the voyages and hotelling time of the different vessels (activity data);
- the emission factors for the different technologies.

6.1 Fleet composition

The fleet composition for the year 2004 is put into the model through a combination of data from the Administration of Waterways and Marine Affairs (AWZ) and Lloyd's Register Fairplay. AWZ keeps up a database with among other things the Lloyd's numbers of all vessels travelling on Belgian territorial waters. We extracted for the year 2004 all Lloyd's numbers for sea-going vessels that called in at a Belgian Harbour (or travelled in the 12-mile zone of the North Sea). VITO then bought the following characteristics of those sea-going vessels from Lloyd's Register Fairplay:

▪ Ship Type	▪ RPM
▪ Length	▪ TEU
▪ Fuel Type	▪ Refrigerated containers
▪ Date of building	▪ Speed
▪ Main engine type	▪ Flag
▪ Power main engine	

To complete the fleet composition for the year 2004, we made use of average characteristics per ship type for the few sea-going vessels where detailed information is missing. These averages are based on the available data in the Lloyd's Register Fairplay database.

Starting from the Lloyd's Register Fairplay database, we adapted some characteristics to be conform with the data in the new emission model.

6.1.1 Ship type

The new emission model works with 10 different ship types:

- Chemical tanker
- Containers
- Dry bulk carrier
- Gas tanker
- General cargo
- LNG tanker
- Oil bulk (crude)
- Passenger ship
- Reefers
- RoRo

The Lloyd's Register Fairplay database consists of about 80 different vessel types of which about 40 are subject to the new emission model. We subdivided these vessel types into the 10 defined ship types in the new emission model (see Annex D).

6.1.2 Length

To prevent getting a distorted view on the size of sea-going vessels, we made a classification according to their length instead of their gross tonnage. We classified the length of the different sea-going vessels into 5 categories.

- > 250 meter
- 200 – 250 meter
- 150 – 200 meter
- 100 – 150 meter
- < 100 meter

6.1.3 Fuel type

The new emission model works with 3 different fuel types (heavy fuel oil, diesel oil and gas oil), where the Lloyd's Register Fairplay database has more than these 3 fuel categories. Data from the Lloyd's Register Fairplay database was found not realistic. Therefore, we made assumptions on the used fuel types for main engines and auxiliaries and for the different regions (see paragraph 7.2).

6.1.4 Date of building

We assume that the year of building of the main engine is similar to the year of construction of the sea-going vessel. We classified the years of building of the main engines of the different sea-going vessels into 7 categories. The model foresees in eighth category (> 2005) for emission modelling in the future.

- < 1974
- 1975 - 1979
- 1980 - 1984
- 1985 - 1989
- 1990 - 1994
- 1995 - 1999
- 2000 - 2004
- > 2005

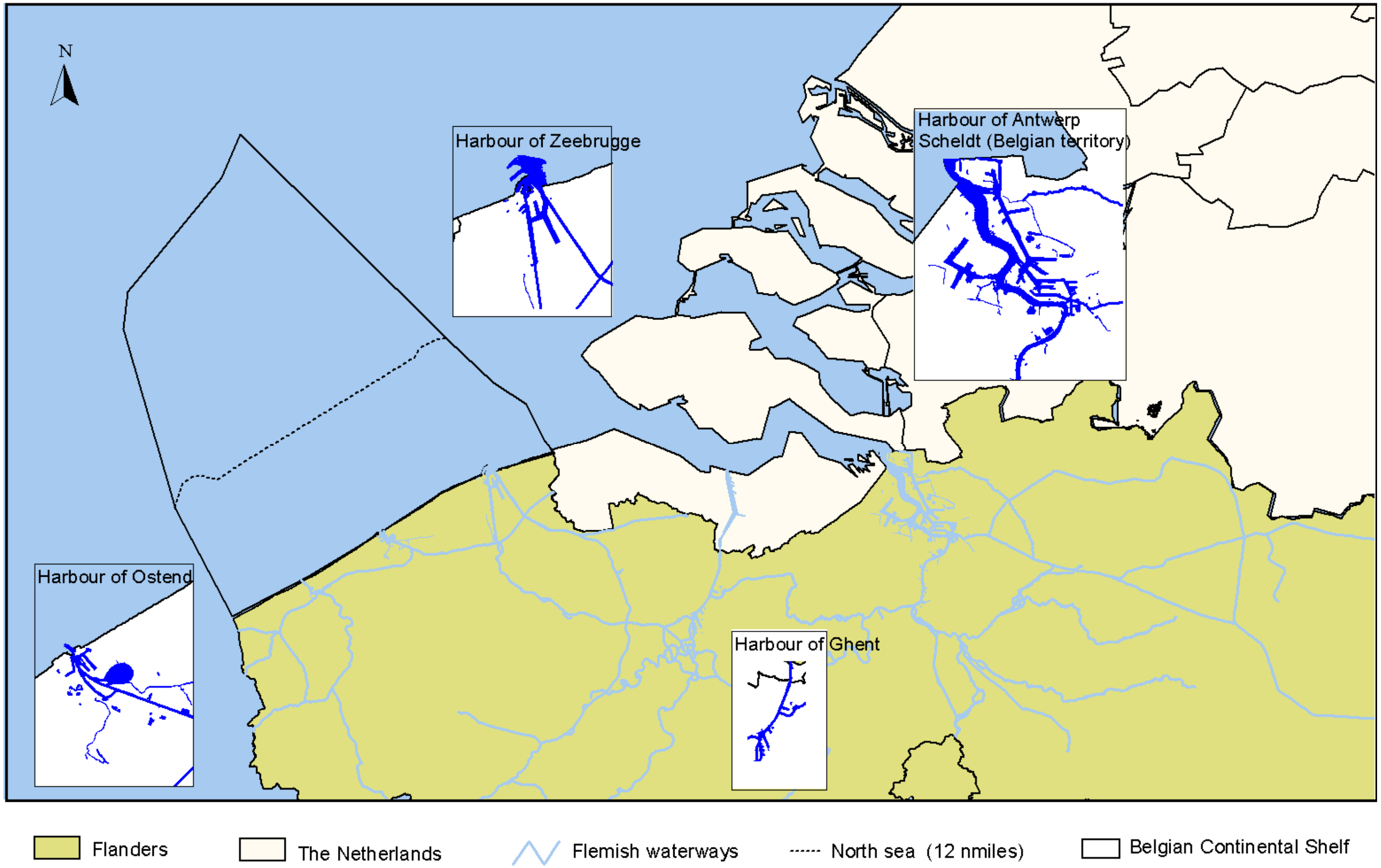
6.2 Activity data

VITO visited AWZ and the four harbours to collect as much as possible detailed activity data. Since 1997, AWZ keeps all traffic in Belgian territorial waters in the Vessel Traffic System (VTS). This system collects detailed information on courses of navigation, times of arrival on varied passage points, ... for sea-going vessels, among those which sail on Belgian territorial waters. The four Belgian harbours (Antwerp, Ghent, Ostend and Zeebrugge) provided specific and detailed information about the geometry of their harbour and the activities (times) in it. The information system of the harbour of Antwerp also maps the activities on the river Scheldt (Belgian territory).

We received activity data for the year 2004 from all authorities and this allowed us to map the activities in the 6 different geographical areas in Belgium (Figure 2).

- North Sea (12-mile zone)
- River Scheldt (Belgian territory)
- Harbour of Antwerp
- Harbour of Ghent
- Harbour of Ostend
- Harbour of Zeebrugge

Figure 2: the 6 different geographical areas in the new emission model



The activity data consists of times of arrival/departure of the different vessels for various entry/exit points:

- geo points in the North Sea;
- the Belgian territory on the river Scheldt;
- the harbours;
- the locks;
- the quays.

The model itself is based on voyages and hotelling periods of sea-going vessels. We define a voyage as the journey of a ship between an entry and exit point. Therefore, a round trip comprises at least two voyages and sailing from one lock to another in the same harbour is defined as a separate voyage.

We extracted the duration of every voyage and hotelling time for the year 2004 from the delivered activity databases and used this as activity input for the new emission model.

6.3 Emission factors

We performed an international literature study to select the best possible emission factors for the new emission model. We examined the following sources:

▪ Bouscaren [54]	▪ COM [55]	▪ CSD [56]
▪ EEB [57]	▪ EMS [50]	▪ EMEP/CORINAIR [18]
▪ ENTEC [49]	▪ EPA [58]	▪ Eurostat [59]
▪ Hulskotte [60]	▪ IMO [61]	▪ Lloyd's [62]
▪ MEET [48]	▪ Melhus [63]	▪ Norwegian Ministry of Environment [64]
▪ OECD [65]	▪ RIVM [66]	▪ Scott [67]

As mentioned before, we have to take into account the technological evolution of sea-going vessels, to get the right picture of the emission problems of these vessels. Therefore, technology related emission factors are needed. Such emission factors are present in the project EMS [50]. These emission factors lay-down the basis for the technology related emissions.

We further report all the integrated emission factors in the new emission model to allow computing:

- fuel related emissions
- technology related emissions
  - 2-stroke main engine
  - 4-stroke main engine
  - steam turbine
  - auxiliaries

6.3.1 Fuel related emission factors

The pollutants CO_2 en SO_2 are fuel related.

CO_2

The emission factors for CO_2 in the new emission model are tuned to those of the Flemish Energy Balance [33], which correspond with the IPCC CO_2 emission factors [31].

SO_2

The worldwide average sulphur content in heavy fuel is 2,7 mass % and 0,2 mass % in diesel and gas oil [68]. On the 19th of May 2005, the MARPOL Annex VI convention came into force (see Chapter 2). This Annex includes among other things that the sulphur content of heavy fuel oil may not exceed 1,5 % in the "Sulphur Emission Control Areas (SECA's)" ,to which the North Sea belongs, after 19th of May 2006 [69]. Recently, the 1,5 mass % sulphur is also prescribed by the 2005/33/EC Directive. This Directive also imposes the use of 0,1 mass % sulphur from the 1ste of January 2010 on for inland navigation and see-going vessels at berth with a minimum berth duration of 2 hours.

As well as for the main engines as for the auxiliaries, we use the CO_2 en SO_2 emission factors presented in Table 16.

Table 16: overview of the CO_2 and SO_2 emission factors (kg/tonne fuel)

EF (kg/tonne)	*Heavy fuel oil*	*Diesel and gas oil*	*Gas boil off*
CO_2	3 110	3 100	2 930
SO_2 (… - 18/05/2006)	54	4	~0
SO_2 (19/05/2006 - 2009)	30	4	~0
SO_2 (2010 - ...)	30	4 or 2*	~0

* 2 kg SO_2/tonne diesel or gas oil at berth (minimum duration of 2 hours)

6.3.2 2-stroke engine: technology related emission factors

The technology related emission factors for HC, CO, NO_X and PM for 2-stroke engines are those of the project EMS [50]. They are modelled as a combination of a basic emission factor and correction factors for the technology (age and NO_X regulation) and the percentage of the maximum continuous rate (MCR).

$$\text{emission factor}\,(g/kWh) = \text{basic emission factor}\,(g/kWh) \times \text{CorrAge} \times \text{CorrNO}_X \times \text{CorrMCR}$$

Correction for technology

Two correction factors have to be implemented on the basic emission factor to take into account the technology of the sea-going vessels:

1. emissions are dependant on the year of construction of the vessels because of on evolution in engine technology;
2. main engines built after the year 1999 have restrictions for their NO_X emissions, starting from May the 19^{th} 2005 (IMO Annex VI convention, see chapter 2).

Correction factor for % of MCR

The basic emission factors are based on a test cycle, this is an average of all stages of navigation. Therefore, they are not representative for the individual stages of navigation (expressed in % of MCR). A correction factor has to be implemented on the basic emission factor to get emission factors for the individual stages.

The basic emission factors are presented in Table 17, the correction factors are presented in Table 18 (age), Table 19 (NO_X regulation) and Table 20 (% of MCR).

Table 17: basic emission factors (g/kWh) for a 2-stroke engine

EF (g/kWh)	*Heavy fuel oil*	*Diesel and gas oil*
HC	0,6	0,6
CO	3	3
NO_X	16	16
PM	1,7	0,5

Table 18: correction factor for the age of the 2-stroke engine

	Heavy fuel oil				*Diesel and gas oil*			
Date of building	*HC*	*CO*	*NO_X*	*PM*	*HC*	*CO*	*NO_X*	*PM*
< 1974	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
1975 – 1979	1,00	1,00	1,13	1,00	1,00	1,00	1,13	1,00
1980 – 1984	1,00	1,00	1,19	1,00	1,00	1,00	1,19	1,00
1985 - 1989	1,00	0,83	1,25	1,00	1,00	0,83	1,25	1,00
1990 – 1994	0,83	0,67	1,13	1,00	0,83	0,67	1,13	0,80
1995 – 1999	0,67	0,67	0,94	0,88	0,67	0,67	0,94	0,60
> 2000	0,50	0,67	0,91	0,88	0,50	0,67	0,91	0,60

Table 19: correction factor for the NO_X regulation (IMO Annex VI)

Date of building	***g NO_X/kWh (test cycle)***	***RPM***	***g NO_X/kWh***	***CorrNO_X***
> 2000	14,5	290 - 2000	$45*n^{-0,2}$	$3,10*n^{-0,2}$
> 2000	14,5	> 2000	9,8	0,68

Table 20: correction factor for the % of MCR

% of MCR	*HC*	*CO*	*NO_X*	*PM*
85	0,84	0,70	0,97	0,97
80	0,87	0,76	0,97	0,98
75	0,89	0,82	0,98	0,98
70	0,92	0,88	0,98	0,99
65	0,95	0,94	0,99	0,99
60	0,98	1,00	0,99	1,00
55	1,00	1,06	1,00	1,00
50	1,03	1,12	1,00	1,01
45	1,09	1,23	1,01	1,01
40	1,16	1,38	1,02	1,03
35	1,27	1,56	1,03	1,05
30	1,42	1,80	1,04	1,08
25	1,65	2,14	1,06	1,12
20	2,02	2,66	1,10	1,19
15	2,74	3,51	1,17	1,32
10	4,46	5,22	1,34	1,63
0	0,00	0,00	0,00	0,00

6.3.3 4-stroke engine: technology related emission factors

The technology related emission factors for HC, CO, NO_X and PM for 4-stroke engines are those of the project EMS [50]. They are modelled, just like for a 2-stroke engine, as a combination of a basic emission factor and correction factors for the technology (age and NO_X regulation) and the percentage of the maximum continuous rate (MCR).

The basic emission factors are presented in Table 21, the correction factors for the technology (age) are presented in Table 22. The correction factors for the NO_X regulation (IMO Annex VI) and for the % of MCR are the same as for 2-stroke engine (Table 19 and Table 20).

Table 21: basic emission factors (g/kWh) for a 4-stroke engine

EF (g/kWh)	*Heavy fuel oil*	*Diesel and gas oil*
HC	0,6	0,6
CO	3	3
NO_X	12	12
PM	0,8	0,5

Table 22: correction factor for the age of the 4-stroke engine

	Heavy fuel oil				*Diesel and gas oil*			
Date of building	*HC*	*CO*	*NO_X*	*PM*	*HC*	*CO*	*NO_X*	*PM*
< 1974	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
1975 – 1979	1,00	1,00	1,17	1,00	1,00	1,00	1,17	1,00
1980 – 1984	1,00	1,00	1,25	1,00	1,00	1,00	1,25	1,00
1985 - 1989	1,00	0,83	1,33	1,00	1,00	0,83	1,33	1,00
1990 – 1994	0,83	0,67	1,17	1,00	0,83	0,67	1,17	0,80
1995 – 1999	0,67	0,67	0,92	0,88	0,67	0,67	0,92	0,60
> 2000	0,50	0,67	1,21	0,88	0,50	0,67	1,21	0,60

6.3.4 Steam turbine: technology related emission factors

The technology related emission factors for HC, CO, NO_X and PM for steam turbines in the new emission model are based on findings from a TNO study [70].

Different emission factors for different maximum continuous rate (MCR) were put into the new emission model. The used emission factors are presented in Table 23.

Table 23: basic emission factors (kg/tonne) for a steam turbine

	EF (kg/tonne) gas boil off			
%MCR	*CO*	*NOx*	*HC*	*PM*
85	0,23	7,75	0,18	0,00
80	0,30	7,12	0,20	0,00
75	0,38	6,49	0,22	0,00
70	0,45	5,87	0,24	0,00
65	0,52	5,24	0,26	0,00
60	0,72	4,97	0,33	0,00
55	0,92	4,71	0,39	0,00
50	1,11	4,45	0,46	0,00
45	1,31	4,19	0,52	0,00
40	1,51	3,93	0,59	0,00
35	1,70	3,67	0,65	0,00
30	1,90	3,40	0,72	0,00
25	2,09	3,14	0,79	0,00
20	2,29	2,88	0,85	0,00
15	2,49	2,62	0,92	0,00
10	2,68	2,36	0,98	0,00
0	0,00	0,00	0,00	0,00

A correction for the NO_X regulation is not necessary. The NO_X emissions for steam turbines are already lower than the maximum values from the IMO Annex VI convention and the NO_X regulation only applies to diesel engines.

6.3.5 Auxiliary: technology related emission factors

The technology related emission factors for HC, CO, NO_X and PM for auxiliaries are those of the project EMS [50]. They are modelled as a combination of a basic emission factor (kg/tonne) and a correction factor for the technology (age).

$$\text{emission factor (kg/tonne)} = \text{basic emission factor (kg/tonne)} \times \text{CorrAge}$$

The basic emission factors are presented in Table 24, the correction factors for the technology (age) are presented in Table 25.

Table 24: basic emission factors (kg/tonne) for an auxiliary

EF (kg/tonne)	*Heavy fuel oil*	*Diesel and gas oil*
HC	5,1	5,1
CO	19,1	19,1
NO_X	43	43
PM	3,4	2,6

Table 25: correction factor for the age of the auxiliary

	Heavy fuel oil				*Diesel and gas oil*			
Date of building	*HC*	*CO*	*NO_X*	*PM*	*HC*	*CO*	*NO_X*	*PM*
< 1974	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
1975 – 1979	0,69	0,84	1,33	1,03	0,69	0,84	1,33	1,00
1980 – 1984	0,61	0,72	1,56	1,06	0,61	0,72	1,56	1,04
1985 - 1989	0,53	0,62	1,70	1,06	0,53	0,62	1,70	0,88
1990 – 1994	0,45	0,52	1,49	1,06	0,45	0,52	1,49	0,69
1995 – 1999	0,39	0,46	1,26	1,00	0,39	0,46	1,26	0,58
> 2000	0,29	0,39	0,93	1,03	0,29	0,39	0,93	0,58

A correction for the NO_X regulation is not necessary. The NO_X emissions for auxiliaries are already lower than the maximum values from the IMO Annex VI convention.

6.4 Bottlenecks

1. Data from Lloyd's Register Fairplay was acquired to gain good insights in the fleet composition. It is recommended to update these data at least every 5 years and to adapt the database. Unfortunately, these data are not available for free.
2. The information systems where the activity data are extracted from are not modelled for the emission inventory purpose. It takes time to transform the data into the right form for the emission model and experience and time is necessary to simplify the work method for the transformation of these data.
3. The emission factors for the pollutant PM are based on a small number of measurements, completed with estimations on the basis of assumptions. Emission measurements are necessary to get a better idea of these factors.

7. DEVELOPPING A NEW METHODOLOGY (ACTIVITY BASED)

In this chapter, we focus on the development of a new emission model for sea-going vessels, based on shipping movements. The object of this new model is to determine Belgian CO_2, SO_2, HC, CO, NO_X and PM emissions for a well-defined baseline scenario (chapter 8). It is therefore necessary to create a model that is specific for the Belgian situation, more in particular for the geometry of the Belgian harbours. The results can offer support to Belgian experts who follow up actual obligations, participate in working out future international pacts or attend working groups concerning traffic and transport.

Firstly, we define the approach for a new emission model based on shipping movements. Secondly, we elucidate the methodology for statistical years and for projections to the future.

The scope of the new emission model was already defined in chapter 5.

7.1 Defining the approach for a new emission model based on shipping movements

To estimate the emissions from sea-going vessels as good as possible, we prefer to use a detailed methodology. One needs to make sure that the degree of detail does not become an obstruction for making the model operational and reproducible. Also necessary detailed statistical information has to be available for future statistical years. A detailed methodology is possible because we only have to map Belgian emissions. Necessary detailed statistical data is available for the year 2004 and beyond.

As well as a reproducible methodology, the integration of the technological aspects of the sea-going vessels is an important selection criterium. Both are important for the scientific relevance for policy-making and for the practical side, in particular feasibility. Therefore, preference goes to an approach similar to the one presented by researchers in the EMS-protocols, but with specific adaptations to the Belgian situation.

Figure 3 presents the different stages of navigation that are taken into account in the model.

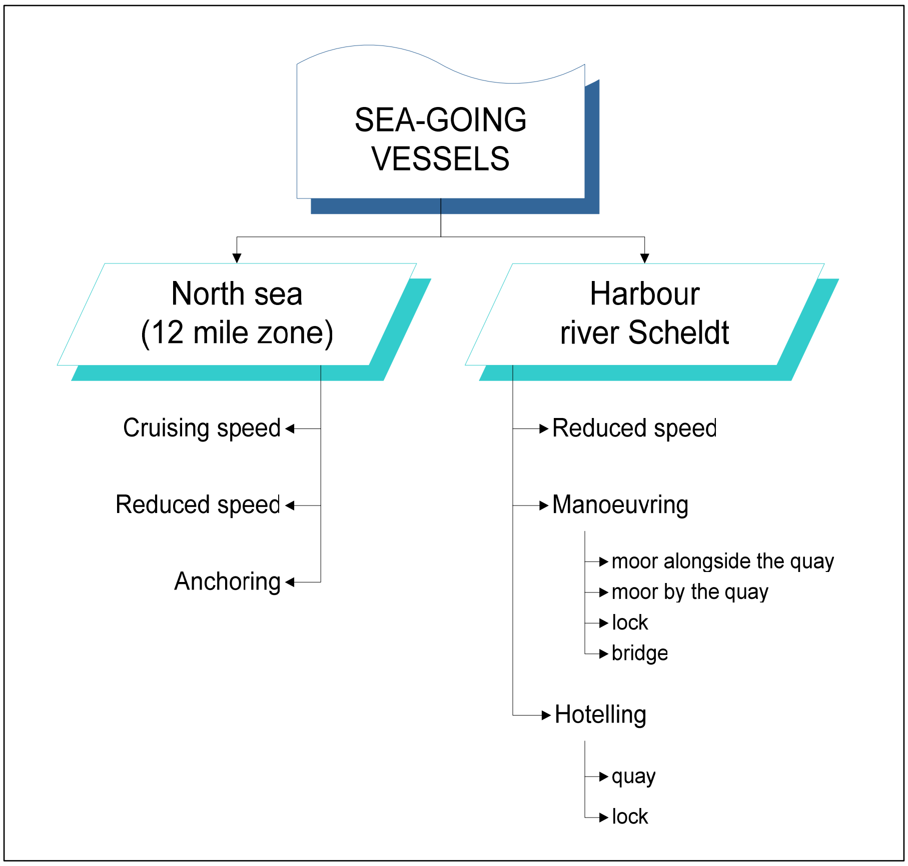


Figure 3: different stages of navigation integrated in the new emission model to determine the emissions (energy consumption) from sea-going vessels in Belgium

Final emission results will only be reported as a total for Belgium. The degree of detail of the results will be defined by mutual agreement with the users' committee and the authorities that delivered confidential information.

7.2 Methodology of the new emission model (activity based) for statistical years

In this paragraph, we describe how we have set up the new emission model for sea-going vessels for statistical years. The user interface of the model is MS Access. Before the actual development of the new emission model, we collected information from several experts to provide (and develop) the model with the best possible activity data and assumptions.

Firstly, we define the activity data for the different stages of navigation. Later, we explain how we calculate the energy consumption and emissions for the main engines and the auxiliaries for a statistical year.

7.2.1 Activity data

The model is designed to calculate emissions and energy consumption for the different stages of navigation for every voyage and hotelling period.

For every voyage, the following information is known:

- the route (stages of navigation);
- the duration of the total voyage or hotelling time (see paragraph 6.2);
- the ship characteristics through Lloyd's number (Lloyd's Register Fairplay database) (see paragraph 6.1).

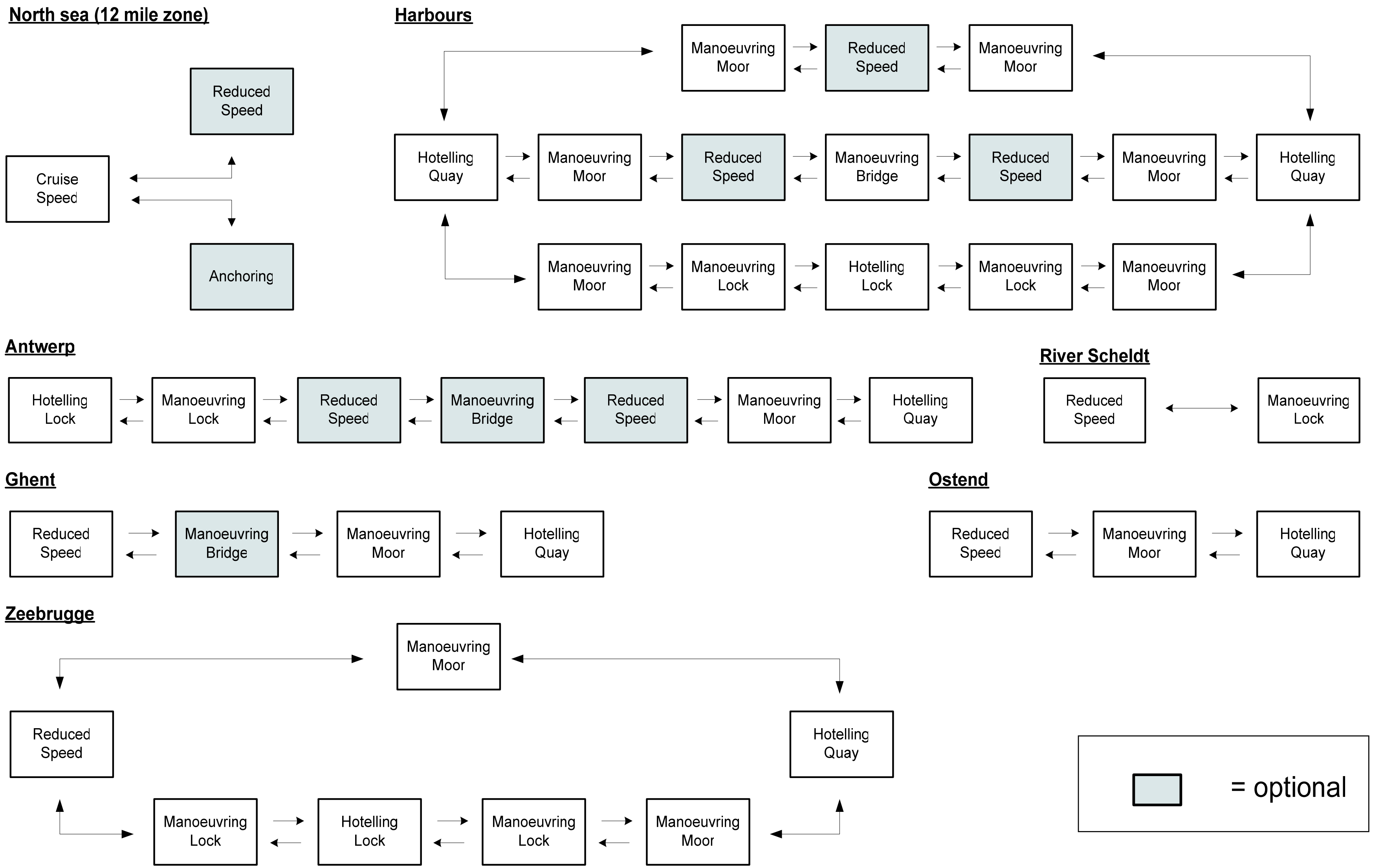
Furthermore, we estimate for every voyage:

- the duration of the different stages of navigation for every voyage;
- the percentage of the maximum continuous rate (MCR) for the different stages of navigation.

The different stages of navigation

For the calculation of the emissions (and energy consumption) of sea-going vessels, we divide the navigation process into different stages. We present these different stages in Figure 4 for the 6 different geographical areas presented in the model (in-out) and for traffic from one lock to another in the same harbour.

Figure 4: the different stages of the navigation process in the North Sea, the river Scheldt and the 4 harbours



Assumptions

The *percentage of MCR* is dependant of the stage of navigation, the ship type and the ship length. We give a summery of the assumptions made in the emission model (Table 26). These assumptions are taken from the project EMS [50] and slightly adjusted after a consultation with the pilotage in Ghent, and the harbour master of Antwerp and Zeebrugge.

Table 26: correlation stages of navigation and % of MCR

c	*stage of navigation*	*% MCR*
NORTH SEA	▪ Cruise speed	85
	▪ Reduced speed	25 - 50
	▪ Anchoring	0
RIVER SCHELDT	▪ Reduced speed	40 - 65
	▪ Manoeuvring (lock)	15 - 20
HARBOUR OF ANTWERP	▪ Reduced speed	40 - 65
	▪ Manoeuvring (moor/lock)	15 - 20
	▪ Manoeuvring (bridge)	15 - 40
	▪ Hotelling	0
HARBOUR OF GHENT	▪ Reduced speed	25 - 50
	▪ Manoeuvring (moor)	15 - 20
	▪ Manoeuvring (bridge)	15 - 40
	▪ Hotelling	0
HARBOUR OF OSTEND	▪ Reduced speed	25 - 50
	▪ Manoeuvring (moor)	15 - 20
	▪ Hotelling	0
HARBOUR OF ZEEBRUGGE	▪ Reduced speed	25 - 50
	▪ Manoeuvring (moor/lock)	15 - 20
	▪ Hotelling	0

The assumptions about the *duration* of the different stages of navigation were also made in close consultation with the pilotage in Ghent, the harbour master of Antwerp, Ostend and Zeebrugge. We estimated the average maximum cruise speed time per ship type for the voyages in the North Sea. These estimations are based on the average maximum speed of the sea-going vessels, which travelled in the 12-mile zone of the North Sea (Lloyd's Register database) and the distance of this voyage. We assumed that the ships anchor if the remaining duration of the voyage is more than 2 hours; otherwise we assume that the ships reduce their percentage of MCR (reduced speed) while waiting for a pilotage or permission to sail further. For the harbours, we divided the total voyage time over the different stages of navigation, taking into account the ship types and length.

The combustion of fuel in the main engine and the auxiliaries causes emissions. There are 3 types of main engines for the sea-going vessels provided in the model:

- 2-stroke engine;
- 4-stroke engine;
- steam turbine.

The model calculates the energy consumption and emissions for every stage of the navigation process. We use a different methodology for the 2-stroke and 4-stroke engines, the steam turbine and the auxiliaries.

Speed

The used power of the main engines is dependant on the speed of the sea-going vessels and on rates of flow. This is indirectly taken into account through the combination of duration and used power for every stage of navigation for every voyage.

7.2.2 2-stroke and 4-stroke engines

Fuel type

2-stroke and 4-stroke engines are the most common main engines for sea-going vessels. The model foresees three different fuel types for these engines, namely heavy fuel oil, diesel oil and gas oil. We do not use the fuel types registered for every ship in the Lloyd's Register Fairplay database, because they are not really realistic. The users committee of the MOPSEA project decided to implement the following assumptions on fuel type into the new emission model:

River Scheldt and harbours

Until the beginning of the eighties, the majority of the main engines in sea-going vessels used diesel oil as fuel type for manoeuvring activities. Improvements in technology made it possible (manoeuvrability) for main engines built at the end of the eighties to use heavy fuel oil [71]. The fuel type assumed for the 2-stroke and 4-stroke engines in the new emission model is dependant of the year of construction of the auxiliary:

- $<$ 1985: diesel oil
- $\geq$ 1985: heavy fuel oil

<u>*North Sea (12-mile zone)*</u>

All 2-stroke and 4-stroke engines use heavy fuel oil in the North Sea (12-mile zone).

We determine emissions by multiplying the energy/fuel use with the correct emission factor. The model makes a distinction between technology related emissions and fuel related emissions.

Calculation of technology related emissions

Energy use (kWh)

We calculate the e*nergy use* by multiplying the used power and the duration:

$$\text{energy use}\,(\text{kWh}) = \text{power}\,(\text{kW}) \times \text{duration}\,(\text{h})$$

We explained in paragraph 7.2.1 how we determined the *duration* of the different stages of navigation.

The *used power* is dependant of the maximum installed power and the percentage of the maximum continuous rate (MCR) that is used:

$$\text{power}\,(\text{kW}) = \%\text{ of MCR} \times \text{maximum installed power}\,(\text{kW})$$

VITO has the *maximum installed power* for almost all sea-going vessels in question from the Lloyd's Register Fairplay database (see paragraph 6.1). The model uses an average maximum installed power per ship type for the other few sea-going vessels. The averages are based on the available data in the Lloyd's Register Fairplay database.

Technology related emission factors (g/kWh)

CO, HC, NO_X and PM are technology related emissions. The model is foreseen of the technology dependant emission factors from EMS [50]. You can find a detailed description of these emission factors in paragraph 6.3.

Technology related emissions (tonne)

Finally, we calculate the emissions according to the following formula:

$$\text{emission (tonne)} = \text{emission factor (g/kWh)} \times \text{energy use (kWh)} \times 10^{-6}$$

Calculation of fuel related emissions

Fuel use (tonne)

We calculate the *fuel use* by combining the energy use and the specific fuel consumption, multiplied with a factor 1,1 to get real practice fuel consumptions.

$$\text{fuel use (tonne)} = \text{energy use (kWh)} \times \text{specific fuel consumption (g/kWh)} \times 1{,}1 \times 10^{-6}$$

$$\text{specific fuel use (g / kWh)} = \frac{\text{calorific value of fuel (g/kWh)}}{\text{efficiency (\%)}}$$

How we determine the *energy use* is already explained for the calculation of technology related emissions.

The *specific fuel us* is dependent of:

- main engine type
- % of MCR
- age of engine

In Table 27, the range of specific fuel uses that we integrated into the model is presented for the 2-stroke and 4-stroke engines. These assumptions were made in close consultation with the Royal Belgian Ship owners' Association (BVR).

Table 27: range of specific fuel use for 2-stroke and 4-stroke engines

	Specific fuel use (g/kWh)
2-stroke engine	157 – 218
4-stroke engine	185 – 235

Fuel related emission factors (kg/tonne)

CO_2 and SO_2 are fuel related emissions. You can find a detailed description of these emission factors in paragraph 6.3.

Fuel related emissions (tonne)

Finally, we calculate the emissions according to the following formula:

$$\text{emission (tonne)} = \text{emission factor (kg/tonne)} \times \text{fuel use (tonne)} \times 10^{-3}$$

7.2.3 Steam turbine

Fuel type

In a steam turbine, fuel is burned to transform water into steam. Therefore, the steam is lead to the turbine. By doing so, there is no direct contact between the released combustion gas and the turbine. Unfortunately, these engines are not really energy efficient in comparison with 2-stroke and 4-stroke engines. The model foresees only steam turbines on LNG tankers, because of the presence of the 'gas boil off' of methane (fuel source). The steam turbine functions as main engine and auxiliary.

Fuel use (tonne)

We calculate the *fuel use* by combining the energy use and the specific fuel consumption, multiplied with a factor 1,1 to get real practice fuel consumptions.

$$\text{fuel use (tonne)} = \text{energy use (kWh)} \times \text{specific fuel consumption (g/kWh)} \times 1{,}1 \times 10^{-6}$$

$$\text{specific fuel use (g / kWh)} = \frac{\text{calorific value of fuel (g/kWh)}}{\text{efficiency (\%)}}$$

The determination of the *energy use* is the same as for 2-stroke and 4-stroke engines (see paragraph 7.2.2).

The *specific fuel use* for a steam turbine lies between 290 g/kWh and 510 g/kWh, depending on the percentage of MCR used. These assumptions were made in close consultation with the Royal Belgian Ship owners' Association (BVR).

Emission factors (kg/tonne)

The emissions factors for gas boil off are presented in paragraph 6.3.

Emissions (tonne)

Finally, we calculate the emissions according to the following formula:

$$\text{emission (tonne)} = \text{emission factor (kg/tonne)} \times \text{fuel use (tonne)} \times 10^{-3}$$

7.2.4 Auxiliaries

The model only foresees the energy use for air conditioning, ventilation, hotel requirements, preheating of heavy fuel oil, by auxiliaries. Energy use for loading and unloading activities is not included (see chapter 45). LNG tankers use their steam turbine for these necessities (see paragraph 7.2.3).

Analogous to the methodology for the main engines, we determine emissions by multiplying the fuel use with the correct emission factor.

Fuel Type

The model foresees three different fuel types for the auxiliaries, namely heavy fuel oil, diesel oil and gas oil. Until the beginning of the eighties, the majority of the new auxiliaries in sea-going vessels used diesel oil as fuel type. Improvements in technology made it possible for auxiliaries built at the end of the eighties to use heavy fuel oil [71]. The fuel type assumed for the auxiliaries in the new emission model is dependant of the year of construction of the auxiliary:

- < 1985: diesel oil
- ≥ 1985: heavy fuel oil

Fuel use (tonne)

We calculate the *fuel use* by combining the energy use and the specific fuel consumption.

$$\text{fuel use (tonne)} = \text{energy use (kWh)} \times \text{specific fuel consumption (g/kWh)} \times 10^{-6}$$

$$\text{specific fuel use (g / kWh)} = \frac{\text{calorific value of fuel (g/kWh)}}{\text{efficiency (\%)}}$$

The determination of the *energy use* is the same as for 2-stroke and 4-stroke engines (see paragraph 7.2.2).

We already explained in paragraph 7.2.1 how we determined the *duration* of the different stages of navigation. We do not take into account corrections for percentage of MCR. Auxiliaries always operate on full power.

We made assumptions for the *power* of the auxiliaries taking into account the ship type and the known power of the main engine (Lloyd's Register Fairplay database, see paragraph 6.1). An average ship needs between 250 and 500 kW of energy for air conditioning, ventilation, preheating of heavy fuel oil, ... [72]. Table 28 shows the assumptions that we made for the power of auxiliaries per ship type.

Table 28: power of the auxiliaries

	Main engine power (kW)	*Power auxiliary (kW)*
Dry bulk carrier [72]		300
General Cargo [72]		300
Passenger ship		500
Other	▪ < 5 000	250
	▪ 5 000 – 25 000	250 - 500
	▪ > 25 000	500

Ferries and cruise ships are classified as 'passenger ships'. These kind of ships use more energy because of the presence of a kitchen and laundry on board and because more parts of the ship are provided with air conditioning.

The model also takes into account the extra energy use for refrigerated TEU's (Twenty-Foot Equivalent Unit). We calculate the extra energy use according to the following formula:

$$\text{energy use}\,(\text{kWh}) = \text{amount of refrigerated TEU} \times 5\,(\text{kW}) \times \text{refrigerated duration}\,(\text{h})$$

The estimation of the *amount of refrigerated TEU's* for every ship is based on the total present TEU's and the amount of refrigerated containers in the Lloyd's Register Fairplay database. The model takes into account an *extra energy use of 5 kW per refrigerated TEU*. We assume that these TEU are cooled for half the time:

$$\text{refrigerated duration}\,(h) = \frac{1}{2} \times \text{duration}\,(h)$$

The model foresees this extra energy use for every stage of navigation.

The *specific fuel use* depends on the age of the auxiliary. We assume that the age is approximately the same as the age of the main engine. The range of the specific fuel use that we integrate into the model is 200 – 235 g/kWh [73].

Emission factors (kg/tonne)

You can find a detailed description of these emission factors in paragraph 6.3.

Emissions (tonne)

The methodology for calculating the emissions is the same as for fuel related emissions of the main engines:

$$\text{emission}\,(\text{tonne}) = \text{emission factor}\,(\text{kg/tonne}) \times \text{fuel use}\,(\text{tonne}) \times 10^{-3}$$

7.3 Methodology new emission model for projections to the future

In this paragraph, we explain how projections to the future are modelled. Future energy consumption and emissions are calculated in the model by using activity growth factors, fleet evolution, existing legislation and detailed data from the last statistical year.

7.3.1 Traffic evolution

We implemented traffic evolution for the four harbours, river Scheldt and North Sea (12-mile zone), based on economic growth rates (transported freight in tonnes) of the different harbours.

Activity growth factors

The determination of the activity growth factors is exogenous to the model. We use economic growth rates to model future activities.

Merchant ships

The bases are the transported freight tonnes by sea-going vessels per harbour in the year 2004 [74]. The prospective tonnages for Antwerp are founded on the growth factors derived from the ECSA study [75]. For the other harbours we applied figures from the latest strategic plans of each harbour. Most harbours dispose of figures for a low economic growth scenario (low baseline) and high economic growth scenario (high baseline). For Zeebrugge there are only figures available for a high baseline. So, we defined ourselves a low baseline with growth rates half of those in the high baseline. Table 29 shows per harbour an overview of the tonnages in 2004 and the growth rates in the period 2004 to 2015.

Table 29: transported tonnages in the year 2004 and economic growth rates for merchant ships (2004-2015) in the Belgian harbours

	10^6 tonnage 2004	yearly growth (2004-2015)	
		low baseline	high baseline
Antwerp			
Dry bulk	27,32	-1,79%	0,00%
Liquid bulk	35,28	-1,77%	0,00%
Containers	68,28	5,11%	6,92%
RoRo	7,09	1,67%	3,44%
General cargo	14,36	1,27%	3,05%
Gent			
Dry bulk	18,38	0,78%	3,69%
Liquid bulk	2,81	0,78%	3,69%
Containers	0,26	3,47%	10,10%
RoRo	1,58	3,47%	10,10%
General cargo	1,93	3,47%	10,10%
Ostend			
Dry bulk	1,54	-0,51%	1,08%
Liquid bulk			
Containers	0,08	11,37%	17,30%
RoRo	5,93	5,58%	6,60%
General cargo	0,01	-0,51%	1,08%
Zeebrugge			
Dry bulk	1,60	4,16%	8,32%
Liquid bulk	4,29	4,16%	8,32%
Containers	14,01	3,38%	6,76%
RoRo	11,10	5,81%	11,61%
General cargo	0,80	4,18%	8,36%

Passenger ships

For passenger ships, we used activity projections from a study carried out for the Federal Public Service of Public Health, Food Chain Safety and Environment - DG Environment [76]. These activity projections are expressed in person kilometres. From 2004 until the year 2010, for each harbour, we implemented in the emission model an annual growth rate of 1 % in the low baseline scenario and 2 % in the high baseline scenario.

Harbours and river Scheldt

To implement the growth rates of the different harbours into the emission model, we made a distinction between passenger and merchant vessels and for the latter a distinction between a positive and negative growth. The growth rates for the harbour of Antwerp also apply to the river Scheldt.

Passenger ships

We increased the activity data of the passenger ships with the accumulated growth rates over 6 years.

Positive growth of merchant vessels

In consultation with the users committee, we assumed that the increase in traffic would be filled in by newly built sea-going vessels. The extra tonnages have to be transported to the different harbours with those new ships. We determined how many extra visits the new ships will have to make by taking into account the gross tonnage of the new ships. We determined the ratios between gross tonnage and transported tonnage per ship type for the year 2004 and used these ratios for the year 2010.

Negative growth of merchant vessels

We assumed the a negative growth rate between the years 2004 and 2010 has an effect on all ship categories (lengths). Therefore, we decreased the activity data of the different ship types with accumulated negative growth rates over 6 years.

North Sea (12-mile zone)

Passenger ships

The methodology for passenger ships in the North Sea (12-mile zone) is the same as those for the harbours. We increased the activity data with the accumulated growth rates over 6 years.

Positive growth of merchant vessels

The extra visits to and from the harbours were extended to the North Sea (12-mile zone).

Negative growth of merchant vessels

We calculated a weighted average of the negative growth rates per ship type for the North Sea (12-mile zone) on the basis of:

- the amount of visits per harbour;
- the average duration of a visit per harbour;
- the negative growth rate per harbour.

We decreased the activity data of the different ship types with the accumulated negative growth rates for the North Sea (12-mile zone) over 6 years fleet evolution

We made the following assumptions to define the ship characteristics of the new sea-going vessels and this for each harbour and each ship type to take into account geometry of the harbours and the docks:

- new ships have the length of the largest ship visiting in 2004;
- the characteristics of a new ship are based on average ship characteristic from all available ships in the Lloyd's Register Fairplay database with the corresponding length that were built from 2000 on.

7.3.2 Existing legislation

We took the IMO and EU legislation into account in the low and high baseline scenario.

IMO

On the 19th of May 2005, the MARPOL Annex VI convention went into force (see Chapter 2). This required the implementation of:

- the NO_x correction factor (Table 19) for all vessels built from 2000 on;
- a sulphur content of 1,5 mass % for heavy fuel oil.

EU

The sulphur content of 1,5 mass % for heavy fuel oil is also prescribed by the 2005/33/EC Directive. This Directive also imposes the use of 0,1 mass % sulphur for vessels at berth with a minimum berth duration of 2 hours. We assumed the use of diesel oil with a sulphur content of 0,1 mass % for all vessels at berth because the duration at berth is in most cases (> 97 %) longer than two hours.

7.3.3 Duration of the visits

We calculated average durations for every stage of navigation of a voyage from the 2004 activity database, taking into account:

- ship characteristics:
    - ship type;
    - length;
    - date of building.
- region
    - North Sea (12-mile zone);
    - harbours (Antwerp, Ghent, Ostend and Zeebrugge);
    - river Scheldt.

8. DRAW UP A BASELINE SCENARIO 1990-2010

After visits to AWZ and the different harbours, it became clear that a baseline scenario starting from the year 1990 is not possible because of missing activity data. The year 2004 is the first year of the baseline scenario because reliable statistical data is available from 2004 on. We do not only determine the emissions for the past, but we also make predictions of emissions in the near future (2010).

8.1 Emissions for the year 2004

The fleet and traffic data for the year 2004 is based on statistical data (see chapter 6). The fleet does not meet the IMO Annex VI regulation in the year 2004, except for passenger ships. Therefore, only for passenger ships built from 2000 on, we implement the NO_X correction factor (Table 19), for the IMO Annex VI regulation, on the basic emission factor [71].

Table 30 presents the emissions of the main engines and auxiliaries of the sea-going vessels (in Belgium) for the year 2004 in. These emissions are the sum of the emissions in all regions (North Sea (12-mile zone), the river Scheldt and the four harbours) and for all different stages of navigation (cruise speed, reduced speed, manoeuvring, anchoring and hotelling).

Table 30: emissions (kton) of sea-going vessels for the year 2004 in Belgium

kton	Main engines	Auxiliaries	Total
CO_2	494	226	720
SO_2	8,09	2,82	10,9
NO_X	12,7	4,21	16,9
PM	1,04	0,236	1,28
CO	1,97	0,801	2,77
HC	0,389	0,179	0,569

The implementation of the IMO Annex VI regulation for passenger ships built after 1999 results in a NO_X reduction of merely 45 ton or 0,3 % of the total NO_X emissions for sea-going vessels in the year 2004 in Belgium.

The CO_2, NO_X and SO_2 emissions of the different ship types (Belgium, 2004) are presented in respectively Figure 5, Figure 6 and Figure 7. The emissions of the main engines and auxiliaries are shown separately.

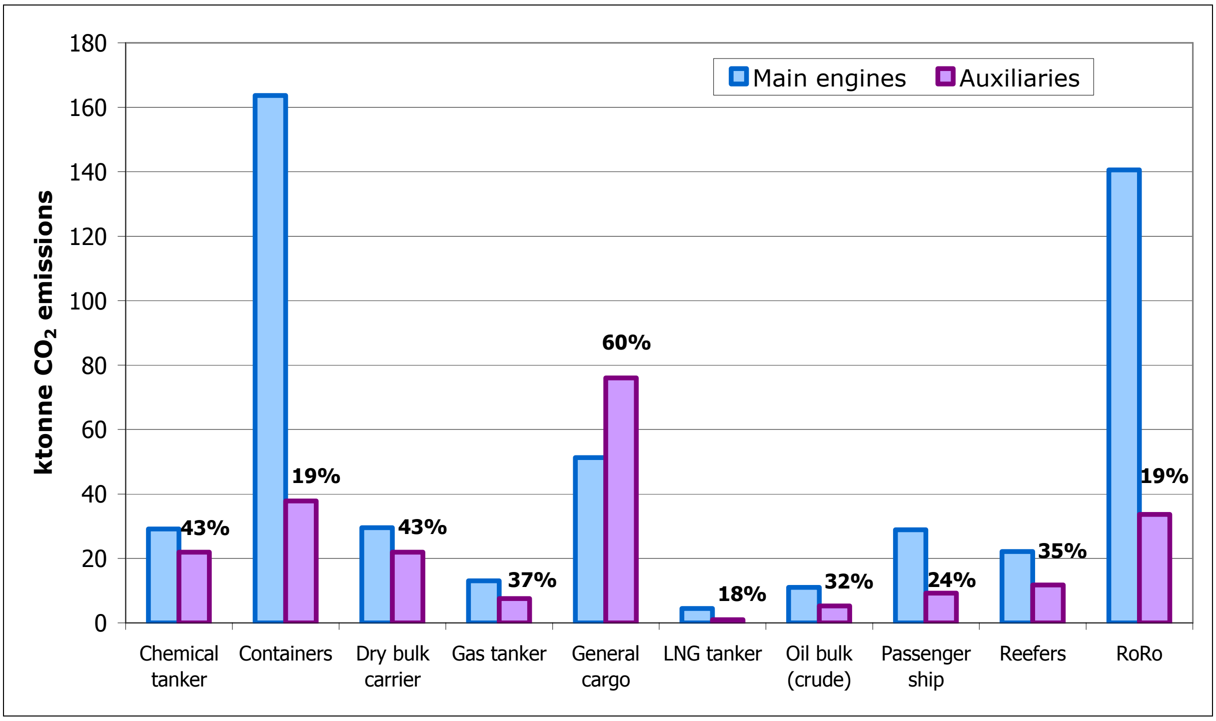


Figure 5: CO_2 emissions of the different ship types for the year 2004 in Belgium

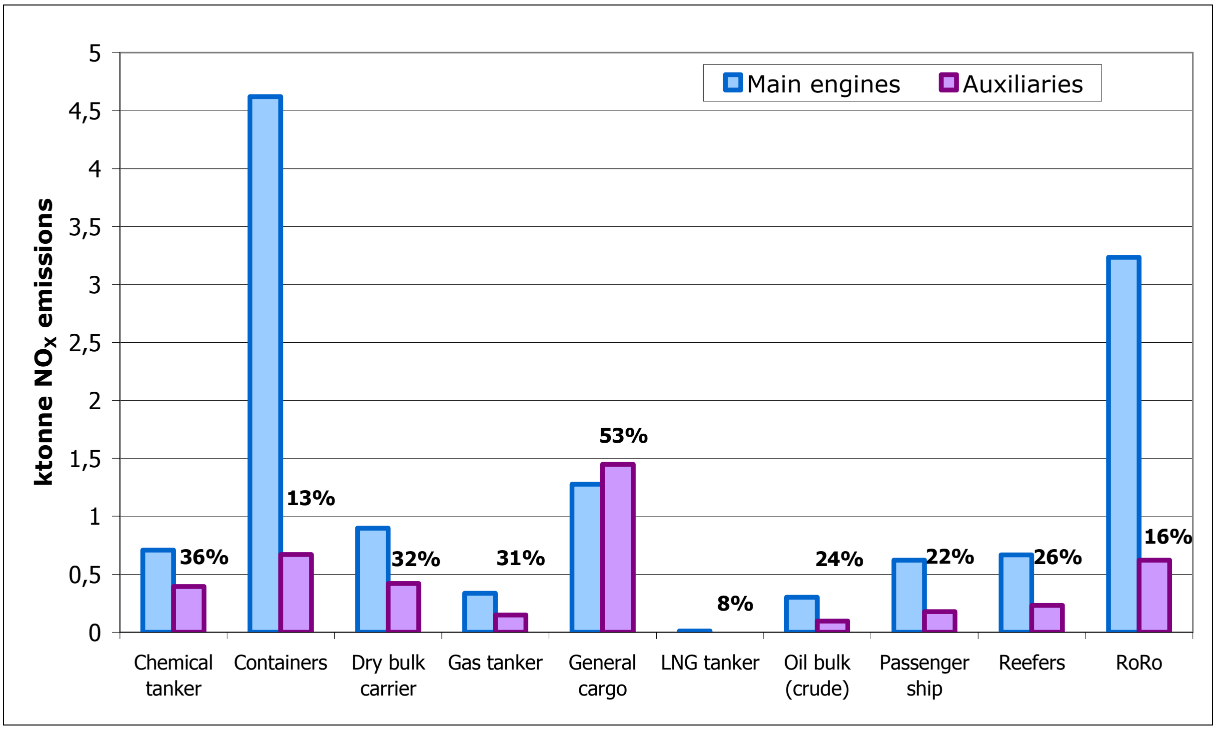


Figure 6: NO_X emissions of the different ship types for the year 2004 in Belgium

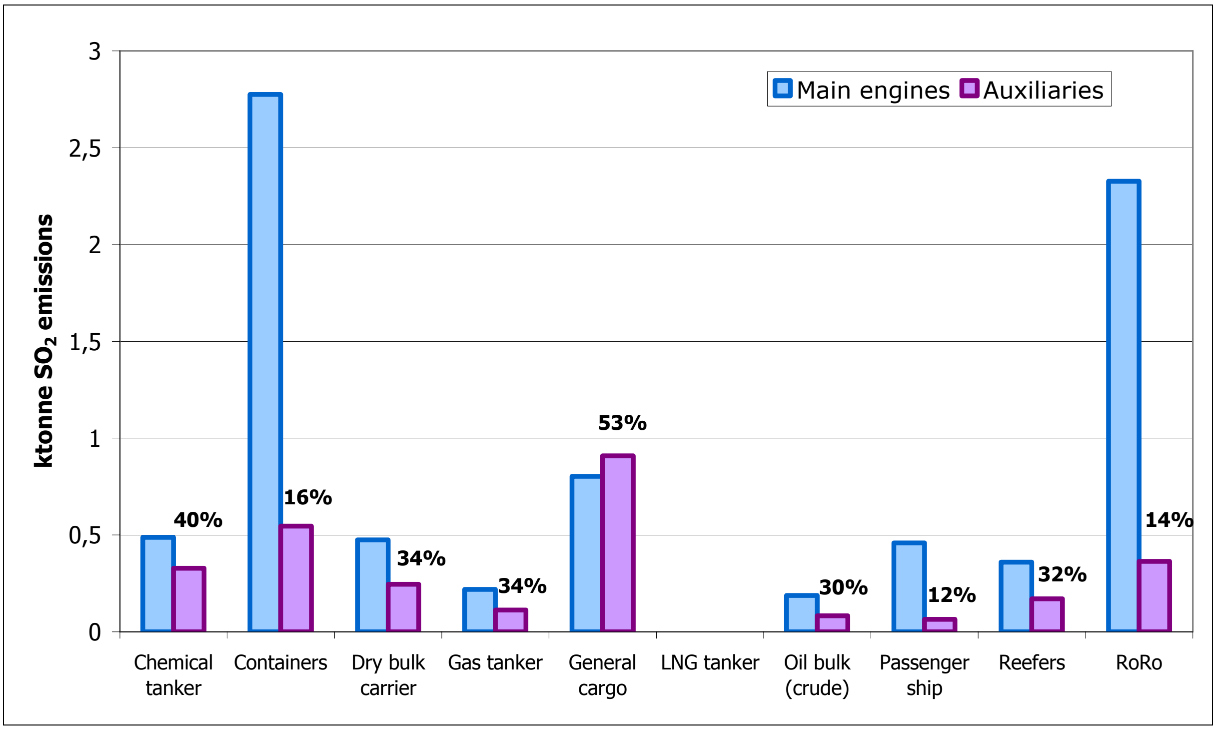


Figure 7: SO_2 emissions of the different ship types for the year 2004 in Belgium

The containers, general cargo and RoRo vessels emit ~70 % of the total CO_2-NO_x- and SO_2 emissions of sea-going vessels for the year 2004 in Belgium.

The auxiliaries of the general cargo vessels emit more CO_2, NO_x and SO_2 emissions than the main engines of these vessels. This is due to the large amount of used auxiliary power compared to the used main engine power. The opposite is true for containers, LNG tankers and RoRo vessels. The contribution of the auxiliaries is small because of the large amount of used main engine power compared to the used auxiliary power (total energy consumption (TJ) of auxiliaries < 20 %).

8.2 Emissions for the year 2010

We made predictions of the emissions of sea-going vessels in Belgium for the near future (2010) by taking into account a low and a high baseline scenario, the traffic evolution, the fleet evolution and the existing legislation (IMO and EU). To compute the effect of the existing legislation, we calculated the emissions for the year 2010 only taking into account the traffic and fleet evolution (reference scenario).

The methodology for the simulation of the whole fleet data can be found in paragraph 7.3. The traffic data for the year 2010 is based on activity growth rates from the different harbours (Table 29). We present the emission results for the year 2010 in the low and high baseline scenario in Table 31. A distinction is made between main engines and auxiliaries.

Table 31: emissions of sea-going vessels in the year 2010 (Belgium) in a low and high baseline scenario

	Main engines		**Auxiliaries**		**Total**	
kton	**low**	**high**	**low**	**high**	**low**	**high**
CO_2	509	540	226	243	735	783
SO_2	4,66	4,94	0,499	0,538	5,16	5,48
NO_X	13,0	13,8	4,12	4,37	17,1	18,1
PM	1,09	1,17	0,166	0,177	1,25	1,34
CO	2,10	2,28	0,785	0,832	2,89	3,11
HC	0,404	0,429	0,175	0,185	0,579	0,614

We present in Figure 8, Figure 9 and Figure10 the emissions of sea-going vessels in Belgium for the years 2004 and 2010 in the reference, low baseline and high baseline scenario. Figure 8 shows the CO_2 emissions and Figure 9 the regulated emissions SO_2 and NO_X. Figure 10 shows the effect of the IMO and EU regulation on the PM, CO and HC emissions.

Due to an increase in activity, the CO_2 emissions increase with 2 % in the low baseline scenario and 9 % in the high baseline scenario over the period 2004-2010

The NO_X emissions increase slightly (1 %) in the low baseline scenario, the increase in activity offset the reductions of the IMO en EU regulations. An increase of 8 % of the NO_X emissions takes place in the high baseline scenario between the years 2004 and 2010. The IMO en EU regulations are most effective for the reduction in SO_2 emissions. A decrease of 53 % (low baseline) and 50 % (high baseline) in SO_2 emissions is accomplished despite to the increase in activity between the years 2004 and 2010.

The PM emissions of sea-going vessels decrease with 2 % (low baseline) or increase with 5 % (high baseline) over the time period 2004-2010. The CO emissions increase with 4 % or 12 %, respectively in the low and high baseline scenario, the HC emissions increase with 2 % or 8 %.

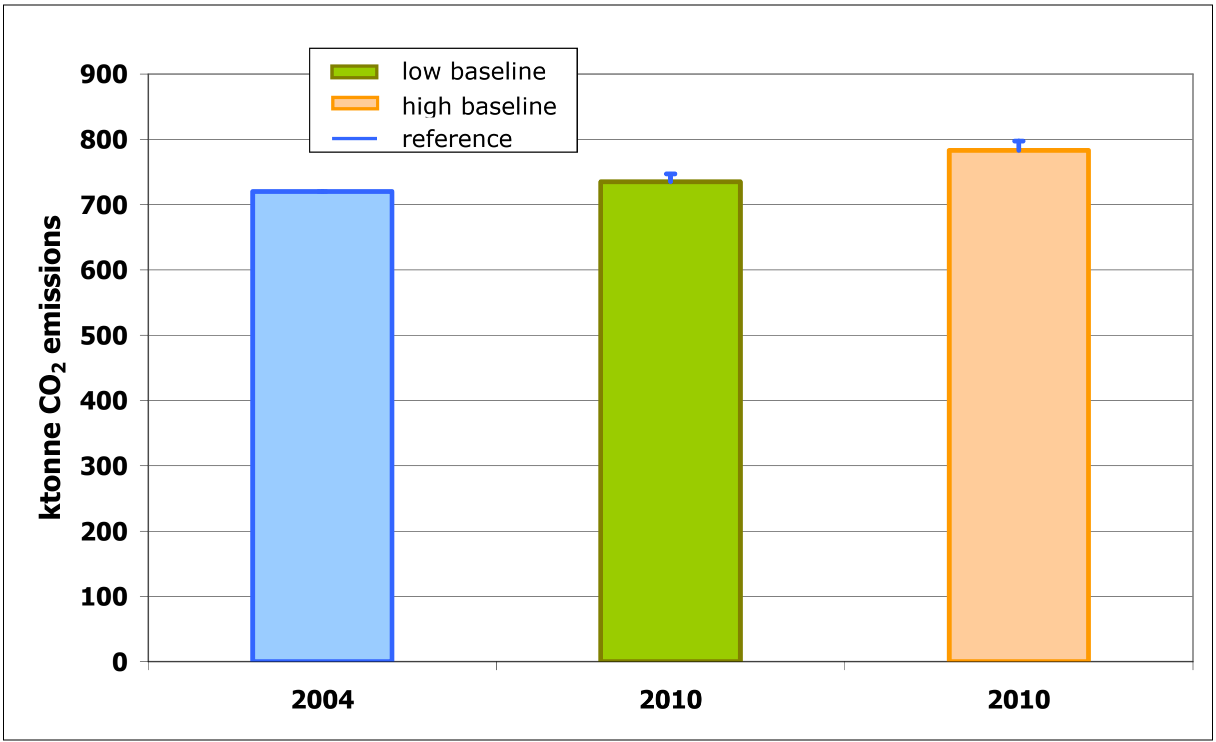


Figure 8: CO_2 emissions of sea-going vessels in the reference and baseline scenario's

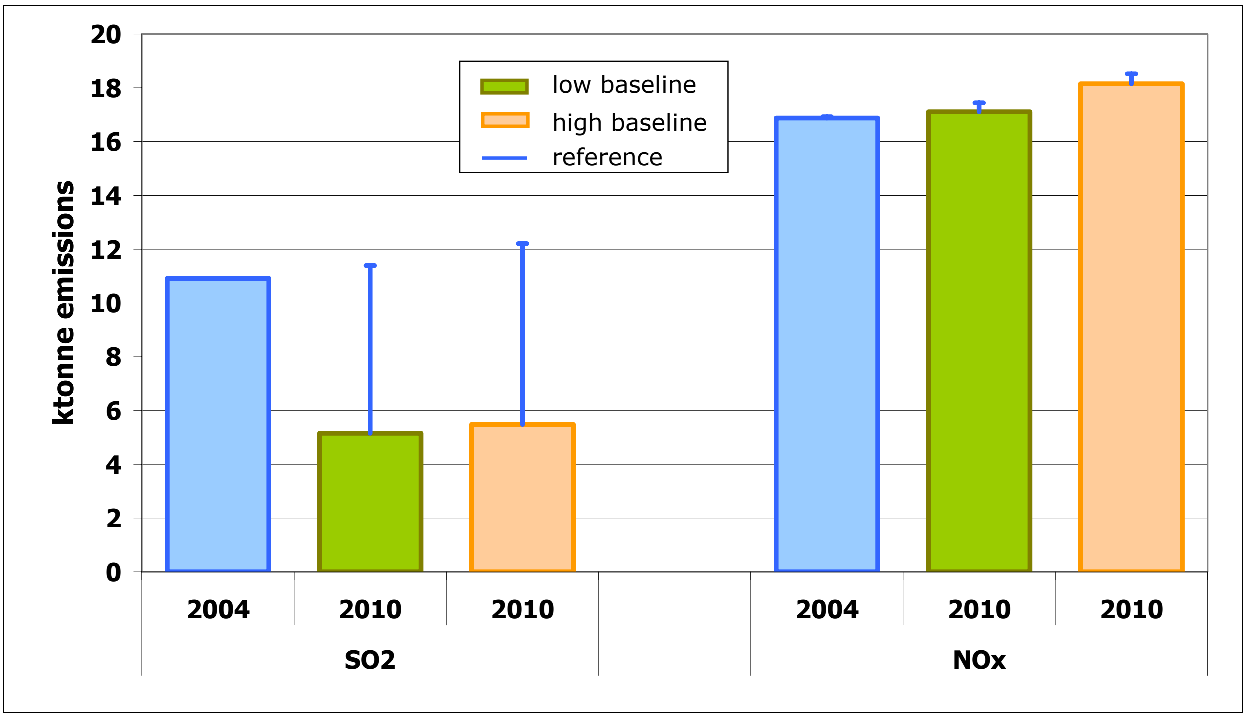


Figure 9: SO_2 and NO_X emissions of sea-going vessels in the reference and baseline scenario's

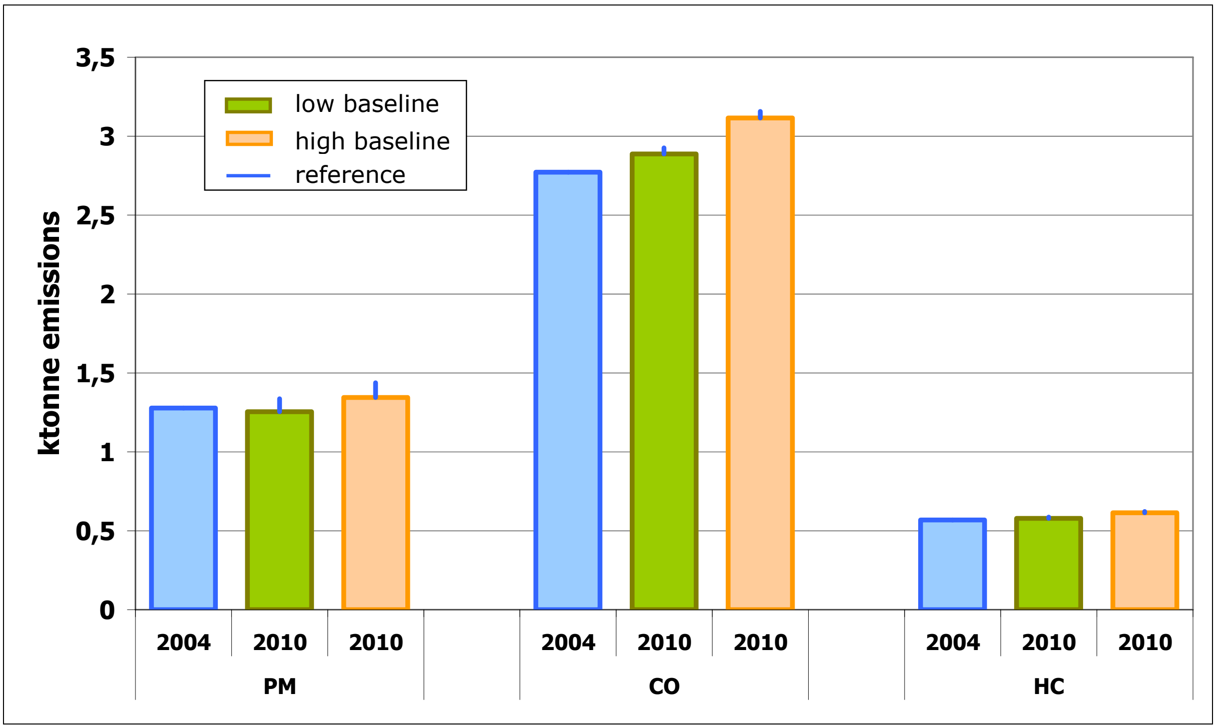


Figure 10: PM, HC and CO emissions of sea-going vessels in the reference and baseline scenario's

Table 32 presents the effect of the IMO and EU regulations for emissions of sea-going vessels in the year 2010 by comparing the baseline scenarios with the reference scenario.

Table 32: emission reduction in the year 2010 (baseline to reference) due to the IMO en EU regulations

	Main engines	Auxiliaries	Total
CO_2	0%	-5%	-2%
SO_2	-44%	-84%	-55%
NO_X	-1%	-5%	-2%
PM	0%	-33%	-6%
CO	0%	-4%	-1%
HC	0%	-4%	-1%

The IMO regulation results in a reduction of merely 1 % of the NO_X emissions of main engines in the year 2010. The total reduction of 55 % in SO_2 emissions is due to both the IMO and EU regulations:

- a decrease of the sulphur content for heavy fuel oil;

- a decrease of the sulphur content for fuels used at berth, which also implies a switch from heavy fuel oil to diesel oil for vessels at berth built after 1984.

The switch form heavy fuel oil to diesel oil for vessels at berth results for the auxiliaries in a large emission reduction (33 %) for PM and small emission reductions for CO_2 (5 %), NO_X (5 %), CO (4 %) and HC (4 %).

8.3 Evaluation and conformation of results

In this paragraph, we compare the results of our bottom-up activity based methodology for emissions calculation of maritime transport with:

- the current top-down methodology;
- the bottom-up methodology used in ECOSONOS [53].

8.3.1 Current top-down methodology

The total amount of the CO_2 emissions of shipping activities for the year 2004 in Belgium, calculated with the activity based methodology (bottom-up) is equal to 0,7 Mton. At this moment, the official emission calculations for maritime transport are based upon the total amount of bunker fuels for maritime transport allocated to Belgium (top-down). The reported CO_2 emissions [33] for maritime transport in Belgium are equal to 24,2 Mton for the year 2004, about thirty-five times more than the calculated CO_2 emissions with the bottom-up approach.

Besides the overestimation of the Belgian maritime fuels due to:

- the summation of local and international bunkers (~5 %);
- the attribution of as much heavy diesel fuel as possible to international bunkering because these are free from duties (~20%);

There is also a discrepancy between the bottom-up and top-down approach with respect to the area where the CO_2 emissions are emitted. The bottom-up approach makes an inventory of the CO_2 emissions emitted in Belgian territory, where the top-down approach makes an inventory of the CO_2 emissions of fuels sold on Belgian territory. Policy makers have to be aware that the use of the top-down or bottom-up methodology for emission assignment, within the scope of post-Kyoto 2012, to Belgium and other maritime bunker countries, makes an enormous difference.

8.3.2 ECOSONOS

See chapter 11.

9. RECOMMENDATIONS FOR POLICY MAKERS

Within Europe, in the preparation of the CAFÉ programme, it was concluded that emissions from maritime shipping become increasingly important and still have a very large emission reduction potential compared to the stationary combustion sources from industry or the mobile combustion sources from road traffic. Therefore emission reductions for sea-going ships and in harbours are to be considered.

Figure 11 shows the relative CO_2, SO_2, NO_x and PM emission contribution of maritime transport compared to the transport modes road, rail and inland waterway in Belgium. Emission levels for road transport, rail traffic and inland navigation for Belgium can be found in the SUSATRANS project [38]. The relative emission contribution of maritime transport increases in time for all four pollutants. Maritime transport is responsible for 3 % of the CO_2 emissions. This is rather small compared to the relative SO_2 contribution (92 % in 2004 and 95 % in 2010). The decrease in SO_2 emissions due to the IMO and EU regulations is small, relatively considered, compared to the decrease in SO_2 emissions for the other transport modes. This is due to the more stringent European regulation on sulphur content in gasoline and diesel fuels for road vehicles. The same conclusions apply to the relative NO_x and PM emission contribution of maritime transport. The effect of the more stringent European NO_x and PM regulation for new road vehicles is larger than the effect of the IMO and EU regulation for maritime transport. Maritime transport is responsible for 10 – 13 % of the NO_x and 16 – 24 % of the PM emissions, respectively in the years 2004 and 2010.

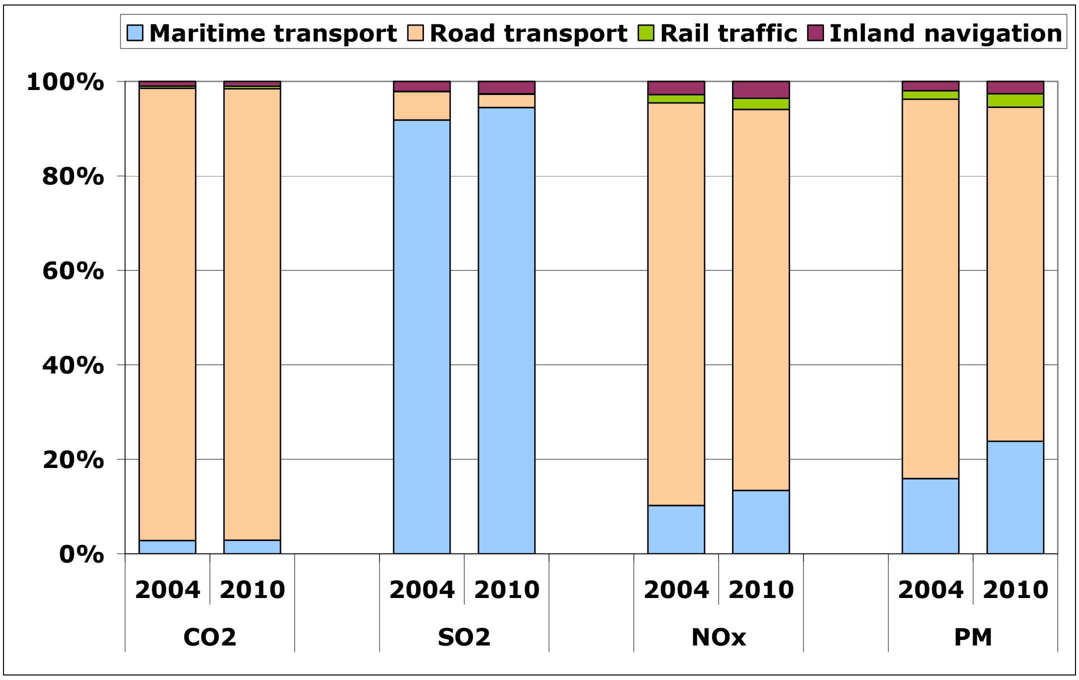


Figure 11: relative importance of maritime transport in transport emissions in Belgium

As described above and presented in Figure 11, the emissions of maritime transport are not negligible compared to those of other transport modes, certainly not for SO_2. It is most likely that maritime transport will be included in the future national emission ceilings. Policy makers have to be aware that the total amount of national emissions will increase significantly when maritime transport is included in the national emission ceilings.

The activity based methodology (bottom-up) and the methodology based on the amount of bunker fuels for maritime transport allocated to Belgium (top-down) result in very different emission estimates for maritime transport. Table 33 presents the CO_2 emissions for the year 2004 (Belgium), calculated with the bottom-up and top-down approach.

Table 33: calculated CO_2 emissions for Belgium (2004) with the bottom-up and top-down approach

bottom-up	top-down
0,7 Mton CO_2	24,2 Mton CO_2

The bottom-up approach is better suited for emission inventory for Belgium because:

- The bottom-up approach makes an inventory of the CO_2 emissions emitted in Belgian territory, where the top-down approach makes an inventory of the CO_2 emissions of fuels sold on Belgian territory.

- The use of the top-down or bottom-up methodology for emission assignment, within the scope of post-Kyoto 2012, to Belgium and other maritime bunker countries makes an enormous difference.
- In air quality management, command and control is for policy makers a simple but efficient measure to improve air quality. Emission reductions through technological improvements are easy to implement and very cost-efficient in most circumstances. It is important to allocate the necessary emission reduction to the different sectors in society to achieve the best result at the lowest cost to society and the different stakeholders. The bottom-up methodology makes identification of specific policy measures for air quality improvement in Belgium possible, whereas the top-down approach does not come up to the mark.

Furthermore, it is important to achieve the highest reduction in air pollution where exposure of the population is expected to occur. This means that emission reductions of ships needs to be disaggregated by port to assess whether additional measures are necessary in ports and harbours close to densely populated urban areas.

10. CONCLUSIONS

10.1 Outline of the emission contribution of maritime transport

The emissions of maritime transport are not negligible compared to those of road transport, rail traffic and inland navigation:

- CO_2 emissions: 3%;
- SO_2 emissions: 92 – 95 %, respectively for 2004 and 2010;
- NO_X emissions: 10 – 13 %, respectively for 2004 and 2010;
- PM emissions: 16 – 24 %, respectively for 2004 and 2010.

10.2 Legislation

On international scale, ship emissions are tackled by IMO, who added an Annex VI to the Marpol Convention and thereby limits sulphur oxide and nitrogen oxide emissions from ship exhausts and prohibits deliberate emissions of ozone depleting substances.

In Europe, IMO regulations are translated into Directives. Limit values for ship emissions are mainly a result of the NEC-Directive and the Framework Directive on Air Quality with their daughter Directives.

At national level, the Kyoto protocol is effective since 2005. Actually, international ocean shipping is not yet incorporated in this protocol. Translations of Belgian emission limits into Flemish standards are made in the 'Environmental Policy Plan 2003-2007'.

10.3 Current methodology

We made an overview of the emission approaches used within the different navigation sectors and described them briefly. We listed the main bottlenecks within the current emission monitoring programme.

At this moment, the official emission calculations for maritime transport are based upon the total amount of bunker fuels for maritime transport allocated to Belgium (top-down). The total quantity of bunker fuels has been defined as the sum of 'international bunkering' and 'local bunkering' as reported in the national energy statistics. There is an overestimation of the Belgian maritime fuels due to:

- the summation of local and international bunkers (~5 %);

- the attribution of as much heavy diesel fuel as possible to international bunkering because these are free from duties (~20%).

10.4 Activity based methodology

We developed an activity based technology model (bottom-up approach) to calculate fuel consumption and emissions of sea-going vessels taking into account the technological evolution of ship engines en fuels.

The container, general cargo and RoRo vessels emit ~70% of the total CO_2-, NO_x and SO_2 emissions of maritime transport for the year 2004 in Belgium. The amount of used main engine power to auxiliary power determines the relative contribution of these engines to emissions and energy use. The reported CO_2 emissions for maritime transport in Belgium with the top-down approach are about thirty-five times higher than the calculated CO_2 emissions with the bottom-up approach.

The activity based emission model made it possible to forecast the emissions from sea-going vessels for the near future. The IMO regulation will result in a reduction of merely 1 % of the NO_x emissions of main engines in the year 2010 in Belgium. Both the IMO and EU regulations will realize a total reduction of 55 % in SO_2 emissions.

10.5 Future work

In the future, Belgium will be required to translate new reporting requirements as will be developed by IMO. Here it is advisable to coordinate this reporting with reporting under CLTRAP and UNFCCC Conventions.

It became clear that good activity data is a priority area. Detailed activity data from AWZ and the different harbours is available, but not always in the correct format. It would be timesaving if the different activity databases could be harmonized and provided with the most accurate data.

Updating the new activity based emission model for maritime transport with the newest information remains necessary to come up with well founded information to feed policy makers.

- The assumptions on fuel use and percentage of MCR can be further refined by monitoring these parameters in practice.
- Data from Lloyd's Register Fairplay has to be updated at least every 5 years to get a good insight in the technological evolution for sea-going vessels in future statistical years.

- The emission factors for the pollutant PM are based on a small number of measurements, completed with estimations on the basis of assumptions. Emission measurements are necessary to get a better idea of these factors.

11. ECOSONOS – MOPSEA: EXPLAINING THE DIFFERENCES IN RESULTS

11.1 Introduction

Belgian Science Policy (BELSPO) financed under the Scientific Support Plan for a Sustainable Development Policy (SPSD II)) two related projects: **ECOSONOS** (Emissions from CO_2, SO_2 and NO_X from Ships) and **MOPSEA** (MOnitoring Programme on air pollution from SEA-going vessels). Eventually, it was decided that both projects would work out their estimates independently. This is an interesting way to proceed, as both projects can validate each others results. Though, at the end of both projects, the results differ significantly. A number of meetings have been organised to discuss these differences and to try and find an explanation. Hopefully, this can contribute to future modelling efforts for shipping emissions in Belgium and abroad.

On 15th September 2006 a workshop was organised by both research teams. This workshop brought 4 international experts and the national stakeholders who were also involved in both ECOSNOS and MOPSEA steering groups together. The conclusions of this workshop are available on the website: www.maritieminstituut.be.

11.2 Main differences

On 16th February 2007 a final meeting was organised and it was decided that this joint note on possible explanations and assessments of the different results would be added to the final reports of both studies.

In preparation of the workshop both teams consulted each other and had several meetings to identify a number of issues that can explain the differences. These where also presented at the workshop. Unfortunately, some differences can only be judged from a qualitative perspective, and can not be compared in a quantitative way. Therefore, it is not clear which of these issues is the most important. Each of these issues contributes to a certain (non calculable) extent to the difference and the sum of these differences equals to the final difference.

Table 34: overview of main differences

	ECOSONOS	**MOPSEA**
Ship types	Sea-going vessels Towing/pushing Dredgers Fishery	Sea-going vessels
(Un)loading activities	Included	Excluded
Activity data	Aggregated, per ship type	Detailed calculations, per individual ship
Vessel characteristics	Aggregated, per ship type	Detailed data, per individual ship
Stages of navigation	1. cruising 2. reduced speed / manoeuvring 3. hotelling 4. anchoring	1. cruising 2. reduced speed 3. manoeuvring lock / mooring / bridge 4. hotelling 5. anchoring
Emission factors	Taken from ENTEC (CO_2, SO_2, NO_X,) Per ship type	Taken from EMS Age dependent Fuel related (CO_2, SO_2) Technology related (NO_X, PM, CO)

The *first* difference between both projects is the **type of vessels** included. ECOSONOS investigated sea-going vessels, towing/pushing, dredgers and fishery, whereas the aim of the MOPSEA project was to investigate sea-going vessels only. For the latter, only the CO_2, SO_2 and NO_X emissions of the sea-going vessels have been compared. Table 2 presents the final estimated emissions for sea-going vessels for both projects. The figures show a difference of about factor 2.5.

Table 35: ECOSONOS and MOPSEA final estimated emissions for sea-going vessels (kton / year)

	ECOSONOS (kton)			**MOPSEA (kton)**		
	NO_X	**SO_2**	**CO_2**	**NO_X**	**SO_2**	**CO_2**
Sea-going vessels	38,4	30,2	1849	16,9	10,9	720

The *second* main difference is that ECOSONOS takes into account **loading and unloading activities of ships in port**, while MOPSEA does not. This leads to significant differences in the assumptions for the use of auxiliary power. For ECOSONOS, the assumptions for the use of auxiliary power can be found in the different tables in the ECOSONOS report. The MOPSEA model only foresees the energy use for air conditioning, ventilation, hotel requirements, preheating of heavy fuel oil. … by auxiliaries. Based on expert opinion this energy use has been assumed to be between 250 and 500 kW depending on the ship type. In the end, this contributes to higher port emission estimates for ECOSONOS. An extra assessment was made to compensate the MOPSEA figures for the loading and unloading activities (table 3) based on ECOSONOS figures. The remaining difference in emissions of sea-going vessels - ECOSONOS/MOPSEA - is decreased to a factor 1.8.

Table 36: MOPSEA emissions for sea-going vessels with estimated loading and unloading emission

kton / year	NO_X	SO_2	CO_2
MOPSEA	16,9	10,9	720
Loading and unloading	4,3	5,1	265
TOTAL	**21,2**	**16,0**	**985**

There is also a difference in how the **activity data** for the different ship types or individual ships were calculated.

Taking *sailing times in the North Sea*, ECOSONOS determines the distance between every way-point of the IVS-SRK registration and multiplies this with an average speed (taken from ENTEC), depending on the ship type. Multiplying the registered number of ships per ship type and the sailed distance with the average speed at sea per ship type, ECOSONOS estimates the total sea time, per ship type. MOPSEA on the other side, uses per individual ship the times registered in the IVS-SRK system.

For the *activities in ports*, both projects started from the same data sets, provided by the different ports. The ECOSONOS team carried out a random sample survey to come up with average activity data per ship type, while the MOPSEA team calculated the activity data for each individual vessel. The hotelling times and the sailing times are respectively 1.2 and 1.3 times higher in the ECOSONOS project compared to the MOPSEA project.

In addition, two other important groups of parameters in the emission models are:

– **vessel characteristics**, more specific the installed engine power;
– **different stages of navigation**, more specific the load factor (% of engine power that is being applied).

The *installed main engine* power of the different ship types in ECOSONOS is based on a sample of one hundred ships per ship type, whereas MOPSEA takes into account the real main engine power for every ship separately based on Lloyd's register Fairplay data. The different approach leads to higher emissions in the ECOSONOS study compared to MOPSEA.

The *used auxiliary power* during sailing times differs greatly between the two models, factors up to seven – ECOSONOS compared to MOPSEA - for the most important vessel types.

MOPSEA used a more detailed method, taking into account more stages of navigation. ECOSONOS estimated port activity times per ship type on an aggregated level and more simple way.

Of course the use of different **emission factors/functions** influences the emission figures. For the purpose of sensitivity analysis the MOPSEA model has been run with the widely used ENTEC (2005) emission factors. Emissions for the year 2004 have been calculated by using the ENTEC average emission factors per ship type instead of the detailed EMS emission factors per individual ship. This resulted in emissions figures which are higher than those calculated with the EMS emission factors, namely 13% for CO_2, 25% for SO_2, 3% for NO_X. One can conclude that the use of different emission factors in the MOPSEA and ECOSONOS studies explain the differences in emissions to a small extent.

11.3 More results from the workshop

When comparing both projects conceptually, the conclusion is that MOPSEA performed a very detailed calculation of shipping activity and related atmospheric emissions for the year 2004. Performing similar inventory work every year again would be very time consuming. ECOSONOS on the other side used more aggregate assumptions that could be used for a number of consecutive years. This approach is more suitable for a yearly update.

It would also be interesting to collect and test data over several years and see whether this way, one can distil more accurate average manoeuvring / hauling / berth times per ship type for each port and more accurate sailing times for activities at sea.

11.4 Some general conclusions from the workshop

There is an urgent need to improve the available data:

- How to deal with missing data
- Make the data sets more reliable
- Implementation and use of AIS-data (Automatic Identification System)

When reporting the data it will be important to do so in a consistent and comparable way in all countries. It was suggested to present the results in the following way:

- Total ship km travelled in the Belgian part of the North Sea
- Emissions per ship km
- Number of port calls (per year)
- Emissions per port call

Confidentiality of data does not always allow such detailed reporting. A task for researchers and policy makers in the future, is to convince data suppliers of the importance of this issue for environmental studies.

Furthermore, more research needs to be performed on the engine loads during different shipping activities (stages of navigation).

11.5 Final conclusions

Obviously, it is the first time that an extensive exercise of estimating / calculating shipping emissions in the Belgian part of the North Sea and the seaports was performed. This was an interesting learning process and by comparing both projects, a number of issues can be identified that need to be taken into account in the future.

Data collection is one of these issues. Most likely, AIS-data can bring a solution to this, as it will allow future researcher to have very detailed and accurate activity data.

Furthermore, some more work can be performed to identify the exact load factor at different stages of navigation: full speed at sea, reduced speed at sea when approaching a port, entering a port, manoeuvring and hauling. The same can be performed for (un)loading activities in port and for engine loads when mooring.

For future emission data from shipping activity in the Belgian ports and in the Belgian part of the North Sea, it will be interesting to combine the strengths of both projects and find a solution for the weaknesses. While MOPSEA performed a very detailed inventory, ECOSONOS focused more on producing a conceptual model. With the information from MOPSEA, the model can probably be better fine tuned to take into account the specific characteristics of shipping traffic in the Belgian ports and in the Belgian part of the North Sea.

Finally, we would like to warn the reader not to try and make an average number out of both projects. For the moment no one can judge where exactly the exact figure is to be found. Both projects each have there strengths and weaknesses.

With this, the differences are put in some perspective. Hopefully, this will help readers and users to interpret the final results of the ECOSONOS and MOPSEA studies in the correct way.

ABBREVIATIONS

AIS	Automatic Identification System
AMINAL	Administratie Milieu, Natuur, Land en Waterbeheer (Administration Environment, Nature, Land and Water of the Flemish Government)
AWZ	Administratie Waterwegen en Zeewezen (Administration of Waterways and Marine Affairs of the Flemish Government)
BPF	Belgische Petroleum Federatie
BVR	Royal Belgian Ship Owners' Association
CAFE	Clean Air For Europe
CCR	Central Commission for navigation on the Rhine
Cd	Cadmium
CFC	Chlorofluorocarbon
CH_4	Methane
CITEPA	Centre Interprofessionnel d'Etudes de la Pollution Atmosphérique
CLRTAP	Convention on long-range transboundary air pollution = UNECE international treaty about SOx and NOx
CO	Carbon monoxide
CO_2	Carbon dioxide
CRF	Common reporting format
DDT	4,4'-(2,2,2-trichloroethane-1,1-diyl)bis(chlorobenzene)
DMA	Marine fuel A, Sulphur content max 1,5%, m/m
DMB	Marine fuel B, Sulphur content max 2,0%, m/m
DMC	Marine fuel C, Sulphur content max 2,0%, m/m
DMX	Marine fuel X, Sulphur content max 1,0%, m/m
DO	Diesel Oil
EC	European Commission
ECOSONOS	Emissions of CO_2, SO_2 and NO_X from Ships
ECSA	European Centre for Strategic Analysis
EMEP	Co-operative Programme for Monitoring and Evaluation of the Long-range Transmissions of Air Pollutants in Europe
EMS	Emission registration and –Monitoring for Shipping
EU	European Union
FWD	Framework Directive
g	Gram
GHG	Greenhouse Gas
GT	Gross ton

GO	Gas Oil
HC	Hydrocarbons
HCFC	Hydro-chlorofluorocarbon
HFC	Hydrofluorocarbon
HFO	Heavy Fuel Oil
Hg	Mercury
HM	Heavy Metals
IMO	International Maritime Organisation
IPCC	Intergovernmental Panel on Climate Change
IRCEL	Intergewestelijke Cel voor het Leefmilieu (Interregional Cell for the Environment)
FC	Fuel consumption
kg	Kilogram
km	Kilometre
kWh	Kilowatt hour
l	Litre
LCP	Large Combustion Plant
LNG	Liquid Natural Gas
MBP	Milieubeleidsplan (Environmental Programme)
MCR	Maximum continuous rate
MEPC	Marine Environment Protection Committee, is IMO's senior technical body on marine pollution related matters
MEET	Methodology for calculating transport emissions and energy consumption
MJ	Mega Joule
MOPSEA	MOnitoring Programme on air pollution from SEA-going vessels
NEC	National Emission Ceilings
NIR	National inventory Report
NIS	National Instituut voor de Statistiek (Belgian National Institute of Statistics)
N_2O	Dinitrogen oxide (laughing gas)
NH_3	Ammonia
NMVOC	Non methane volatile organic compounds
NO_2	Nitrogen dioxide
NO_x	Nitrogen oxides
NRF	New Reporting Format
Pb	Lead
PCB	Polychlorinated biphenyls

PFC	Perfluorocarbon
PM	Particulate Matter
PM_{10}	Particulate matter with an aerodynamic diameter of less than 10 μm
$PM_{2,5}$	Particulate matter with an aerodynamic diameter of less than 2,5 μm
POP	Persistent Organic Pollutant
REG	Rational Energy Use
RO	Residual Oil
RPM	Round Per Minute
SECA	SOx Emission Control Area
SF_6	Sulphur hexafluoride
SO_2	Sulphur dioxide
STOWA	Stichting Toegepast Onderzoek Waterbeheer (Foundation for applied water research)
SUSATRANS	Sustainability assessment of technologies and modes in the transport sector in Belgium
TEU	Twenty-Foot Equivalent Unit
TJ	Terra Joule
tonkm	Ton kilometre
TRENDS	TRansport and ENvironment Database System
TSP	Total Suspended Particles
UNECE	UN Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
US	United States
VITO	Vlaamse Instelling voor Technologisch Onderzoek (Flemish Institute for Technological Research)
VMM	Vlaamse Milieumaatschappij (Flemish Environmetnal Angency)
VOC	Volatile Organic Compounds
VLAREM	Flemish environmental legislation
VRIND	Vlaamse Regionale INDicatoren (Flemish Regional Indicators)
VTS	Vessel Traffic System

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ANNEXES

ANNEX A CONVENTIONS AND PROTOCOLS WITH RESPECT TO EMISSIONS

A.1 Convention of Vienna (1985)

During the Convention of Vienna the first international agreements were made for protection of the stratospheric ozone layer. The different countries agreed to take measures in order to reduce the dilution of the ozone layer. Which measures to take was not agreed upon. The objective of the Convention was in the first place exchange of information, serving international cooperation and scientific research.

On October 17th 1988, the Convention was ratified by Belgium.

No specifications, targets or limit values for sea-going vessels.

A.2 Protocol of Montreal (1987)

A worldwide cooperation concerning the protection of the stratospheric ozone layer finds its foundation in the protocol of Montreal and the Convention of Vienna. So far the protocol was modified 5 times of which the last time in Beijing in 1999. With this protocol it is strived for a reduction and possible elimination of anthropogenic ozone depletion substances. This agreement eventually led to some European regulations concerning ozone depletion substances.

No specifications, targets or limit values for sea-going vessels.

A.3 Rio Conference (1992)

During the conference in Rio the Janeiro in 1992 on 'Environment and Development' a strategy for sustainable development for the 21st century was agreed upon (the so called Agenda 21 was launched). In this strategy environment-friendly economic and social development are key issues.

Chapter 9 of Agenda 21 concerns the protection of the atmosphere. A global strategy on Climate Change was for the first time agreed upon during this conference.

No specifications, targets or limit values for sea-going vessels.

A.4 Kyoto Protocol (1997)

During the third 'Conference Of the Parties' (COP3) in Kyoto in 1997, developed countries agreed upon specific targets for cutting their emissions of greenhouse gases. A general framework for this was defined, with specifics to be detailed over the next few years. This became known as the Kyoto Protocol.

In the end, there was a trade off, and industrialized countries were committed to an overall reduction of emissions of greenhouse gases to 5.2% below 1990 levels for the period 2008 - 2012. (The Intergovernmental Panel on Climate Change stated in its 1990 report that a 60% reduction in emissions was needed).

No specifications, targets or limit values for sea-going vessels where set.

A.5 Geneva Treaty (1979) and Göteborg Protocol (1999)

In 1979, first agreements were made on long range transboundary air pollution (LRTAP). This treaty strives to protect human health and the environment against air pollution. The Convention on Long-range Transboundary Air Pollution entered into force in 1983. It has been extended by different protocols among which:

1. Protocol on SO2-emissions, Helsinki (1985). The Protocol to the Convention on Long-range Transboundary Air Pollution on the Reduction of Sulphur Emissions or their Transboundary Fluxes by at least 30 per cent entered into force in 1987. Twenty-one ECE countries are Party to this Protocol, which aims at abating one of the major air pollutants. As a result of this Protocol, substantial cuts in sulphur emissions have been recorded in Europe: Taken as a whole, the 21 Parties to the 1985 Sulphur Protocol reduced 1980 sulphur emissions by more than 50% by 1993 (using the latest available figure, where no data were available for 1993). Also individually, based on the latest available data, all Parties to the Protocol have reached the reduction target. Eleven Parties have achieved reductions of at least 60%. Given the target year 1993 for the 1985 Sulphur Protocol, it can be concluded that all Parties to that Protocol have reached the target of reducing emissions by at least 30%. The EC has however never signed this protocol.
2. Protocol on NOx-emissions, Sofia (1988). In 1988 the Protocol concerning the Control of Emissions of Nitrogen Oxides or their Transboundary Fluxes was adopted in Sofia (Bulgaria). This Protocol requires as a first step, to freeze emissions of nitrogen oxides or their transboundary fluxes. The general reference year is 1987 (with the exception of the United States that chose to relate its emission target to 1978). Belgium signed the protocol on 01/11/1988 in Sofia. This was

translated by law of 25/03/99 (Belgian Bulletin of 21/12/00) and was ratified on 08/11/00 (entered into force on 06/02/01).

3. Protocol on VOC-emissions. 30% reduction in emissions of volatile organic compounds (VOCs) by 1999 using a year between 1984 and 1990 as a basis. Belgium chose 1988 to be the reference year and signed the protocol on 19/11/1991 in Geneva. It was approved by the law of 24/06/00 (Belgian Bulletin of Acts, Orders and Decrees of 18/01/01). It was ratified on 08/11/00, and has become effective on 06/02/01.
4. The protocol of Oslo of 1994 concerning the reduction of sulphur emissions was signed and ratified by the EC. This protocol has become effective in 1998, and contains a number of reduction objectives for the emission of sulphur. This protocol wants the emission of sulphurdioxide (SO2) for Belgium in 2000, 2005 and 2010 to be reduced with respectively 70, 72 and 74%, with regard to 1980. Belgium signed the protocol on 14/06/1994 in Oslo. It was approved by the law of 24/06/00 (Belgian Bulletin of Acts, Orders and Decrees of 13/12/00) and was ratified on 08/11/00, and has become effective on 06/02/01.
5. Furthermore two other Protocols have in addition been signed in Århus (Denmark) in 1998. The first protocol is related to persistent organic substances (`POPs) and contains a (immediately or future) restriction on the production and use of sixteen products. The second protocol is related to heavy metals. Its aim is to reduce the level of emission of cadmium, mercury and lead and bring it back to the level of 1990. Both protocols have been immediately signed by the EC and al its Member States.
6. Protocol of Goteborg (1999). In this protocol national emission ceilings were determined for several air polluting components among which SO_2, NO_X, NH_3 and VOC. The protocol of Goteborg concerns the protocol to 'Abate Acidification, Eutrophication and Ground-level Ozone'. In February 2000 this protocol was signed by Belgium.

A.6 Treaty of Paris of 1992 on the Protection of the Marine environment of the North- East Atlantic (OSPAR)

In 1972, the Oslo Convention on dumping waste in the North Sea came into force. Two years later the Paris Convention on land-based sources of marine pollution was signed. In 1992, both treaties where combined in the OSPAR-treaty and entered into force on 25th March 1998. The work under the convention is managed by the OSPAR Commission, made up of representatives of the Governments of 15 Contracting Parties and the European Commission, representing the European Community. On a regular basis the different administrations of the different OSPAR-countries meet. Once every 4-years accompanied by their ministers.

The general objective of the OSPAR Convention is to take all possible steps to prevent and eliminate pollution and to take the necessary measures to protect the marine environment against adverse effects of human activities so as to safeguard human health and to conserve marine ecosystems and, when practicable, restore marine areas which have been adversely affected. The Convention is built on the fundamental principles of precaution and polluter pays and relies on the implementation of technologies and practices, including the development of clean technologies, in order, as far as possible, to prevent pollution at source.

In 1998, and 1999, the OSPAR Commission drafted a number of strategies among which one on hazardous substances. This strategy was drawn in order to achieve continuous reduction in releases of hazardous chemicals, and progressive and substantial reductions in releases of radioactive substances, with the aim of cessation of these discharges within a generation (by 2020). http://weblog.greenpeace.org/island/archives/OsparFinal.pdf

A.7 North Sea Conference / North Sea Commission

The First International Conference on the Protection of the North Sea was held in Bremen 1984 with participation from Belgium, Denmark, France, Germany, the Netherlands, Norway, Sweden, United Kingdom and the European Commission. The aim was to provide political drive for the intensification of the work within relevant international bodies, and to ensure more efficient implementation of the existing international rules related to the marine environment in all North Sea States. The Bremen Conference initiated a continuous process where focus is put on the protection of the North Sea at regular Ministerial Conferences. At each Conference, ministers have made commitments to take certain measures aimed at protecting or enhancing the environment of the North Sea.

Up to now five North Sea conferences were held. The North Sea Conferences are political events. The decisions of Ministers, as recorded in the Ministerial Declarations, are political commitments, which have played an important role in influencing legally binding environmental management decisions both nationally and within the framework of competent international bodies.

The Ministerial Declaration of the Fourth International Conference on the Protection of the North Sea, addresses a wide range of strategies as regards the protection of the North Sea such as species and habitats issues, pollution by hazardous substances and nutrients, radioactive substances and pollution from ships and offshore installations. Due to the concern about the impact of fisheries on the commercially important fish stocks, on other fish stocks and on the marine ecosystem in general, the fishery activities were introduced as a new issue.

The policy of the European Commission concerning environmental dangerous substances is influenced in large degree on agreements made during the North Sea Conferences (NSC) and OSPAR-meetings.

http://odin.dep.no/md/nsc/history/bn.html

ANNEX B JURISDICTION OF BELGIUM WITH REGARDS TO THE MARINE ENVIRONMENT

The description of the jurisdiction of Belgium with regards to the marine environment is a summary of the report 'Juridische inventarisatie van de kustzone in België', by Cliquet et al (2002)[i].

B.1 Belgian part of the North Sea

The Belgian coast is 66 km long and the Belgian part of the North Sea has a surface of about 36.000 km². This part represents less then 0.5 % of the total surface of the North Sea (Source: MUMM). Depth of the Belgian waters is maximally 20 to 30 m.

The geographical location of the Belgian part of the North Sea is given in Figure 1.

Belgian Continental Shelf

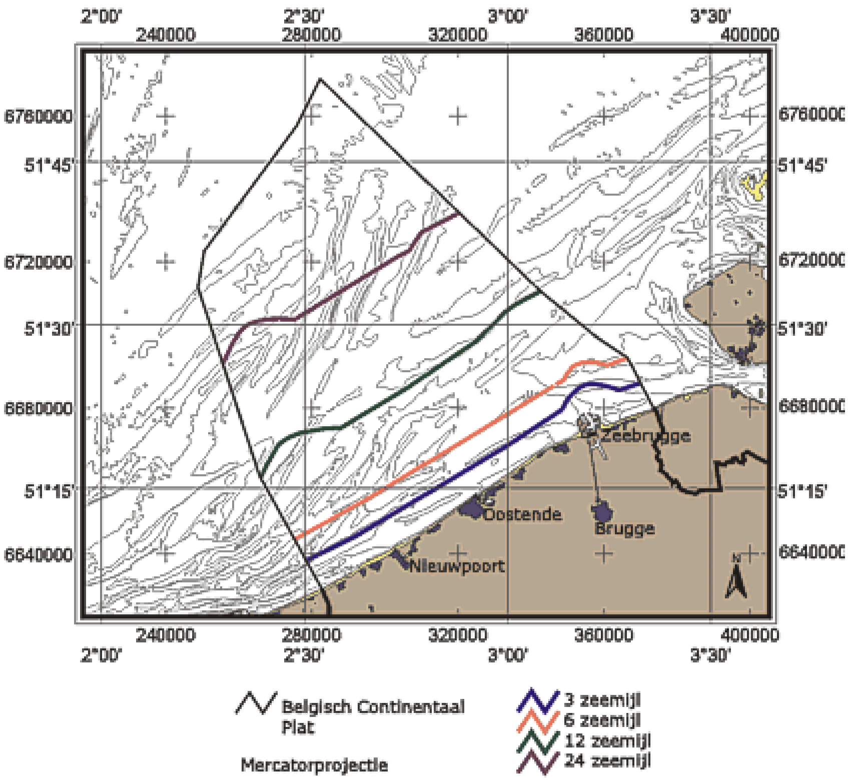

Figure 1: Location of the Belgian part of the North Sea (Source: MUMM)

Beyond Belgian territorial waters and adjacent to these, an Exclusive Economic Zone (EEZ or Belgian Continental Shelf) has been established, which comprises the water, the seafloor and the sediment. The Belgian EEZ covers the part of the North Sea whose outer edge consists of a line made up of segments linking the points below, in the order given, defined by their coordinates (latitude and longitude, expressed using the European geodesic system, 1950):

1.	51°16'09"N	02°23'25"E
2.	51°33'28"N	02°14'18"E
3.	51°36'47"N	02°15'12"E
4.	51°48'18"N	02°28'54"E
5.	51°52'34,012"N	02°32'21,599"E
6.	51°33'06"N	03°04'53"E

Within the EEZ, the Kingdom of Belgium exercises:

- Sovereign rights for the purposes of exploration and exploitation, conservation and management of natural resources, whether biological or non-biological, the waters above the sea floor, the sea floor and the sediment beneath, as well as for other activities stemming from the exploration and exploitation of the zone for economic purposes, such as the production of energy from water, currents and wind
- Jurisdiction as regards:
  - the establishment and use of artificial islands, installations and structures;
  - marine scientific research;
  - the protection and conservation of the marine environment;
- other rights laid down by international law.

B.2 Competences of the federal and regional authorities with respect to the coastal zone

The coastal zone integrates the marine area and a part of the land-based area. The marine part includes all zones of which Belgium has competence, such as the Territorial sea, Fishery zone, Continental Shelf and the Exclusive Economical zone. The land-based part includes dunes, coastal polders and beaches.

The territory for which the Flemish authorities are competent is limited from the baseline, country-inward, i.e. the baseline is characterized by the average low water spring tide. The Flemish authorities can carry out activities in the Belgian continental shelf if these activities are necessary for the execution of the regional competences with respect to waterways, port activities, etc.

Beyond this baseline, seaward, the federal authorities are competent.

In accordance with the special law of July 13th 2001 (Law Lambermont), sea fishery also belongs to the regional competences.

B.2.1 Competent authorities

The competent federal and regional authorities are summarized in table 1.

Table 1: Distribution of responsibilities between federal and regional authorities

	Sea		Land	
	Legal description	**Ecological description**	**Legal description**	**Ecological description**
Competent authority	Territorial sea EEZ Continental shelf	Seawater Seabed and underground	Internal waters Territory of coast municipalities	Intertidal zone Mudflats and saltmarshes Beach Dunes Coastal polders
Federal authority	Navigation Military activities Exploitation of the seabed Energy (off-shore wind energy) Cables and pipelines Protection of the marine environment Control (police) Calamity suppression Science policy		Navigation Military activities Energy Control (police) Calamity suppression	
Flemish authority	To dredge To pilot Rescue on sea Shipping accompaniment To clear wrecks Sea fisheries		Environment and nature conservation Spatial planning Groundwater extraction Tourism Ports Coastal defense Management public zones Science policy	
Provincie West-Vlaanderen	Aid at calamity suppression		Implementation of higher right	
Coast municipalities			Implementation of higher right Police Maintenance of the beach (concession)	

Source: Cliquet and Maes (2001) Beleidsondersteunend onderzoek voor een geïntegreerd kustzonebeleid in België: welk geïntegreerd kustzonebeleid? In: Vlaams instituut voor de zee. VLIZ Special Publication 4 (2001) Beheer van kust en zee: beleidsondersteunend onderzoek in Vlaanderen. Studiedag 9 november 2001.

Federal authorities

Several federal ministries are competent for part of the Belgian North Sea (Cliquet *et al*. 2002).

- **Ministry of social affairs, health and environment**: competent for the protection of the marine environment, the control over the pollution of the sea and the integral management of the coastal zone. The minister of Environment is competent for the execution of international laws and directives, for the identification of protective zone in the sea, for the protection of species, for giving permissions, and for the execution of Environmental Impact Assessments (EIA) or judging the EIA's.
- **MUMM (Management Unit of the North Sea Mathematical Models)** carries out several tasks for Belgium with respect to the management and the protection of the marine environment, for instance: the modeling of the marine environment, control on the execution of the law with respect to the protection of the marine environment, etc.
- **Ministry of Traffic and infrastructure** is competent for navigation and the prevention of pollution of the marine environment due to navigation.
- **Ministry of internal affairs – civil protection** is competent for fighting against disasters, for instance pollution of the sea with oil. The minister of internal affairs is competent for the draw up of intervention plans with respect to the averting and fighting against pollution in the sea.
- **Ministry of defense of the realm** gives logistic support to the MUMM for their scientific research on the sea. The Marine is also the instance to be contacted when oil pollution occurs at sea (or in the estuary of the Scheldt river). Besides, the ministry is competent for the control on sea fishery.
- **Ministry of economic affairs** is competent for the attribution of permissions with respect to the exploitation of mineral and other non-living materials of the seabed and the underground in the territorial sea and the Belgian Continental Shelf.
- **Ministry of the North Sea.** This Ministry was formed in July 2003. All policy matters with regards to the North Sea are coordinated by this Ministry. One of the main goals is the establishment of a Masterplan for the North Sea, the building of an off-shore windfarm on the Thorntonbank, the optimalisation of oilpollution at sea and the xx of marine protected areas.

Regional authorities

The department of environment and infrastructure is the most important department of the Ministry of the Flemish Community with respect to policy of coastal zones.

- The **Ministry of Agriculture** is charged with the supervision on biological wealth in the Sea. The department of Sea fisheries is competent of the supervision of different laws on sea fisheries and for control on the compliance with the law concerning the protection of the marine environment as far as it concerns violations that are related to the fishery
- **Minister of Economic Affairs** – together with the minister of environment - is competent for the Environment Impact Analysis for the activities which fall under the law concerning the continental shelf.
- The **Ministry of Economic Affairs** is also responsible for the control on the compliance with the terms of the law concerning the protection of the marine environment.
- The **department of Sea fisheries** of the Centre of Agronomic Research is charged with research on fishery and quality research.
- The **Minister of Agriculture** is competent to limit and to prohibit the professional and to limit the sport fishery in sea zones.

Provincial authorities

The province of West-Vlaanderen is charged with the execution of administrative tasks such as procedures of permission attribution. The provincial authorities act as implementation and advisory bodies for the regional and federal authorities.

Municipal authorities

Municipal governments get tasks of the higher authorities with respect to environment. The coast municipalities are competent for the pollution of the beaches and the maintenance of the beaches.

B.3 Legal matters in the coastal zone

In this report we will look deeper into legal matters with respect to the marine zone (seaward bound part of the coastal zone), marine pollution, navigation and sea harbors.

B.3.1 Beaconing of marine zones

Different territories can be distinguished in the marine zone:

- the territorial sea (up to 12 sea miles);
- the corresponding zone (up to 24 sea miles);
- the fishery zone;
- the exclusive economic zone; and
- the continental shelf.

The treaty of the United Nations with respect to the right of the sea (Montenego Bay, 10 December 1982) fixes the competences of the countries with respect to different marine territories.

In June 1998, this treaty has been accepted in Belgium (published in the BS in September 1999).

The boundary of the **Belgian territorial sea** had been fixed before: in the treaty of 8 October 1990 with France and in the treaty of 18 December 1996 with the Netherlands. The law of 6 October 1987, the width of the territorial sea has been fixed at 12 sea miles, in accordance to the treaty of the United Nations with respect to the right of the sea.

The **corresponding zone** for Belgium has been fixed in the law of 22 April 1999 with respect to the exclusive economic zone. This law is concretizing the competences of Belgium in this zone.

The **fishery zone** for Belgium has been laid down by the law of 10 October 1978 which was changed by the law of 22 April 1999 with respect to the exclusive economic zone. Outside the Belgian territorial sea, a national fishery zone has been fixed. The boundary of the fishery zone is the same as these of the exclusive economic zone.

The **exclusive economic zone** is that zone in which the country has rights about: 1. exploration and exploitation, preservation and management of the natural riches, the waters and the seabed and 2. other activities for economic exploration of the exclusive economic zone. Other countries can use this zone for navigation, flying over and putting in cables and pipelines. These rights are set by the treaty of the United Nations of 10 December 1982 and were accepted by the Belgian authorities in the law of 18 June 1998.

The law of 22 April 1999 with respect the exclusive economic zone of Belgium in the North Sea concerns the concretization of the competences of Belgium in this zone.

The **Belgian continental shelf** is the zone where Belgium has the competence to explore and exploit non-living and living riches in permanent contact with the sea bed. The competences of Belgium on the continental shelf have been described in detail in the law of 13 June 1969 with respect to the exploration and exploitation of non-living riches of the territorial sea and the continental shelf which has been changed by the law of 20 January 1999 with respect to the protection of the Marine Environment and the Law of 22 April 1999 with respect to the exclusive economic zone of Belgium in the North Sea.

In the treaty of 29 May 1991 the boundary of the Belgian continental shelf has been fixed with the United Kingdom and North-Ireland. This treaty has been accepted by the Belgian authorities in the Law of 17 February 1993. The boundary between the Belgian and the Dutch continental shelf has been fixed by the treaty of 18 December 1996 and accepted by the Belgian authority in the Law of 10 August 1998.

B.3.2 Navigation

Navigation is regulated by federal regulations. Following items have been regulated by federal laws:

- General aspects with respect to navigation: name of the ship and the home port, signs vor ships, wreks, etc., obligations for the for the owner, the operators, captains or captains of vessels
- Maintenance of the navigation routes and ports
- Registration of Sea-going vessels

The safety on sea has been regulated by the international treaty of 1974 and the protocol of 1978 (SOLAS, 1974/78). This treaty contains important provisions which complete MARPOL and have to do have with general safety regulations which contribute to the prevention of shipping accidents.

Apart from this treaty two European directives have been accepted in Belgium with respect to safety measures for pleasure vessels, roro vessels, fisherman vessels and passenger vessels (respectively, dir. 94/25/EC, regulation 3051/95, dir. 97/70/EC and 98/18/EC).

Finally, directive 79/115/EEC regulates the piloting by North Sea pilots on the North Sea and the Channel. Every Member State has to take measures so that ships can appeal to qualified pilots.

B.3.3 Marine Pollution

Marine pollution due to navigation

International jurisdiction with respect to marine pollution due to navigation (Marpol-treaty) has been implemented in Belgium by the Law of 17 January 1984. It regulates the operation pollution due to navigation (oil and other pollutants).

The Law of 6 April 1995 with respect to the prevention of the pollution of the sea due to navigation executes the Marpol-treaty. The law includes hard punishments for offences on the law.

The agreement with respect to fight the pollution of the North Sea by oil and other pollutants has been signed in Bonn on 13 September 1983 (being changed on 22 September 1989) regulates the control from air for the identification of pollution and collection of proofs in case of offences on the law. This agreement has been executed in Belgium by the Law of 16 June 1989.

National jurisdiction on the protection of the marine environment has been set by Law of 20 January 1999 (changed by the Law of 3 May 1999). This law includes the prevention and the limitation of the pollution due to navigation and the possibilities for the authorities to take emergency measures for the protection of the marine environment.

Marine pollution due to dumping

Two international treaties are being implemented in Belgium:

- Treaty with respect to the prevention of pollution of the sea due to dumping of waste (London, 29 December 1972, changed by the Protocol, London, 8 November 1996).
- Treaty with respect to the protection of the marine environment of the northeastern Atlantic Ocean (Paris, 22 September 1992).

An agreement has been made between the federal authorities and the Flemish authorities with respect to the protection of the North Sea against disadvantageous environmental effects due to dredging activities and dumping the dredged material.

The law of 20 January 1999 with respect to the marine environment prohibits dumping and detritus combustion in sea. The prohibition of dumping waste in sea does not include dredged material, waste of fishes and other inert materials of natural origin.

Pollution origination from land

Appendix 1 of the treaty with respect to the protection of the marine environment of the northeastern Atlantic Ocean deals with the prevention of pollution originating from land. The law of 11 May 1995 in Belgium stipulates that the regional authorities are charged with the jurisdiction of the pollution on the proper territory.

The Law of 20 January 1999 with respect to the protection of the marine environment stipulates that direct discharging of effluent from land to the sea is prohibited.

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i Cliquet A., Lambrechts J., Maes F. Juridische inventarisatie van de kustzone in België. Studie in opdracht van de afdeling Waterwegen Kust (AWZ – Min.Vl.Gem.).

ANNEX C ACTIVITY BASED METHODOLOGIES IN EUROPE

In this annex we describe the different methodologies for the mapping of emissions from sea-going vessels, which we found in international literature. The described methodologies are based on the ships activity. Following monitoring programmes are considered:

- MEET
- ENTEC
- EMS
- TREMOVE
- TRENDS

C.1 MEET

The authors of the project 'Methodologies for estimating air pollutant emissions from transport (MEET)' describe among other things a methodology for calculating the emissions from sea-going vessels [i].

MEET makes, for the emission calculations from sea-going vessels, a subdivision per ship type, fuel type and engine type (see Table 1).

Table 1: classification system in MEET for the emissions from sea-going vessels.

Ship type	Fuel type	Engine type
Solid Bulk	Bunker fuel oil	Steam turbines
Liquid Bulk	Marine diesel oil	High speed motor engines
General Cargo	Marine gas oil	Medium speed motor engines
Container	Gasoline fuel	Slow speed motor engine
Passenger/Ro-Ro/Cargo		Inboard engines – pleasure craft
Passenger		Outboard engines
High speed ferries		Tanker loading and offloading
Inland Cargo		
Tugs		
Fishing		
Other		

MEET considers the following different navigation stages for the calculation of emissions from sea-going vessels:

- cruising;
- manoeuvring;
- hotelling;
- tanker offloading;
- auxiliary generators.

The following input data is necessary, per ship type (k), engine type (l), fuel type (j) and possibly operating mode (m), or calculating the emissions from sea-going vessels by pollutant (i):

- daily consumption of fuel;
- number of days in navigation;
- average emission factors.

The formula MEET works with for the calculation of the emissions is the following:

$$E = \sum_{j,k,l,m} E_{i,j,k,l,m}$$

with $E_{i,j,k,l,m} = S_{j,k,m} \times t_{j,k,l,m} \times F_{i,j,l,m}$

where

E_i	=	the total emissions of pollutant i
$E_{i,j,k,l,m}$	=	the total emission of pollutant i from use of fuel j on ship class k with engine type l
$S_{j,k,m}$	=	the daily consumption of fuel j in ship class k as a function of GT
$t_{j,k,l,m}$	=	the number of days in navigation of ships of class k with engine type l using fuel j
$F_{i,j,l,m}$	=	the average emission factor of pollutant i from fuel j in engines type l

C.1.1 Daily consumption of fuel

Data of fuel consumption of the ships have been derived from information supplied by Lloyd's Maritime Information Service Ltd. [ii]. Regression analyses on fuel consumption (full power) as a function of gross tonnage (GT[1]) were performed for each ship class.

The effective fuel consumption is obtained by taking into account the operating mode. The effective fuel consumption is a fraction of the maximum fuel consumption (full power). The default fractions that are used for the different operating modes are shown in Table 2.

[1] GT = Gross Tonnage = the brute tonnage is the volume of all closed rooms in the ship

Table 2: MEET: fraction of maximum fuel consumption in different mode.

Operating mode		Fraction
Cruising		0,80
Manoeuvring		0,40
Hotelling		0,20
	Passenger	0,32
	Tanker	0,20
	Other	0,12
Tug	Ship assistance	0,20
	Moderate activity	0,50
	Under tow	0,80

C.1.2 Number of days in navigation

The number of days in navigation are estimated from the speed of the ship and the distance covered. Average speed data from Lloyd's are used for this purpose.

C.1.3 Average emission factor

Fuel or energy specific emission factors (NO_x, CO, CO_2, VOC, PM en SO_x) for each type of engine are taken from the literature. Emission factors for SO_2 , and in some cases PM, are given in function of the sulphur content of the fuel.

Unit: gram pollutant by kilogram fuel (g/kg)

C.2 ENTEC

Entec UK Limited has conducted a study on behalf of the European Commission, to quantify among other things the ship emissions of SO_2, NOx, CO_2 and hydrocarbons for the year 2000 in the North Sea, Irish Sea, English Channel, Baltic Sea and Mediterranean [iii]. For the pollutant PM, they have just quantified the in-port emissions (manoeuvring, loading/unloading and hotelling).

Here we describe the method of Entec for quantifying these emissions. They make a subdivision for different navigation stages for the emission calculations from sea-going vessels:

- cruising on sea;
- manoeuvring in harbours;
- hotelling and loading/unloading in harbours.

Also subdivisions to type of ship, fuel type en engine type are taken into account (Table 3). Vessels of less than 500 gross tonnes have not been included in the estimation of emissions from ship movements.

They have determined the subdivision into fuel and engine type by type of ship from data from Lloyd's. They made assumptions for incomplete data.

Table 3: classification system in ENTEC for the emissions from sea-going vessels.

Ship type	Fuel type	Engine type
Liquefied Gas	Marine gas oil	Slow speed diesel
Chemical	Marine diesel oil	Medium speed diesel
Oil	Residual oil	High speed diesel
Other Liquids		Gas Turbine
Dry Bulk		Steam turbine
Bulk Dry/Oil		
Self-Discharging Bulk Dry		
Other Bulk Dry		
General Cargo		
Passenger/General Cargo		
Container		
Refrigerated Cargo		
Ro-Ro Cargo		
Passenger/Ro-Ro Cargo		
Passenger		
Other Dry Cargo		
Fish Catching		
Other Fishing		
Offshore Supply		
Other Offshore		
Research		
Towing/Pushing		
Dredging		
Other Activities (B34)		
Other Activities (W11)		
Other Activities (W12)		
Other Activities (W13)		

C.2.1 Cruising on sea

Entec calculates emissions for cruising on sea with the following method (in each case per ship type, fuel type and engine type):

$$E_{sea} = A_{sea} \times EF_{sea}$$

where

E_{sea} = emissions (g)

A_{sea} = total amount of covered ship kilometres (km)

EF_{sea} = emission factor $\left(g/_{km} \right)$

The *total amount of covered ship kilometres* are derives from Lloyd's data.

Entec determines the emission factor per covered ship kilometre by the following formula:

$$EF_{sea} = EF_{energy} \times E_{sea}$$

where

EF_{sea} = emission factor $\left(g/_{km} \right)$

EF_{energy} = emission factor $\left(g/_{kWh} \right)$

E_{sea} = amount of $kWh/_{km}$

Through studying the Lloyd's database, Entec has determined *emission factors by kWh* per engine type and fuel type. They take the operating mode into account (% full power) during cruising on sea. They obtain the percentages for the operating mode from literature, contacts with manufacturers of sea-going vessels and experts. They formulated emission factors by kWh for main engines and auxiliary engines.

On the basis of average speed per ship type and capacity, they determine the *amount of kWh per covered kilometre*. The average speed per type of ship is derived from the Lloyd's database.

C.2.2 Manoeuvring, hotelling en loading and unloading in harbours

Entec calculates emissions for manoeuvring, hotelling, loading/unloading in harbours with the following method (in each case per ship type, fuel type and engine type):

$$E_{harbour} = A_{visit} \times EF_{visit}$$

where

$E_{harbour}$ = emissions (g)

A_{visit} = amount of visits in the harbour

EF_{visit} = emission factor $\left({}^{g}\!/_{visit} \right)$

The *amount of visits in the harbour* are taken from the Lloyd's database.

They determine the emission factor per visit with the following method:

$$EF_{visit} = EF_{energy} \times V \times T$$

where

EF_{visit} = emission factor $\left({}^{g}\!/_{visit} \right)$

EF_{energy} = emission factor $\left({}^{g}\!/_{kWh} \right)$

V = capacity (kW)

T = time (hour by visit)

Through studying the Lloyd's database, Entec has determined *emission factors by kWh* per engine type and fuel type. They take the operating mode into account (% full power) during manoeuvring, hotelling and loading/unloading. They obtain the percentages for the operating mode from literature, contacts with manufacturers of sea-going vessels and experts. They formulated emission factors by kWh for main engines and auxiliary engines.

Questionnaires were sent to over 100 port operators asking among other things the time in hours that a vessel was manoeuvring, loading/unloading and hotelling. Useful data responses were received from 14 ships. These were reviewed and a median for each vessel type was drawn up.

C.3 EMS

The project 'Emissieregistratie en –Monitoring Scheepvaart (EMS) [iv]', carried out by the Adviesdienst Verkeer en Vervoer (AVV) (head performer) by order of Directoraat-Generaal Goederenvervoer (DGG), had as target to (better) map the different emissions from sea-going vessels and inland shipping for the Netherlands.

The authors of the project EMS have made a subdivision per ship type, fuel type and engine type for the calculation of the emissions from sea-going vessels (Table 4).

Table 4: classification system in EMS for the emissions from sea-going vessels.

Ship type	Fuel type	Engine type
Oil Bulk (crude)	Fuel oil	Main engine 2-takt
Other Bulk (liquid, chemicals)	Diesel oil	Main engine 4-takt
	Gas oil (and light marine gas	
Cargo	oil)	Generators
Containers		Boilers
General Cargo		
Ferry's/RoRo		
Reefers		
Other Activities		

They have drawn up a whole new emission calculation for this assignment. The authors have considered 3 different navigation stages (Figure 1):

1. hotelling in Dutch harbours;
2. cruising;
3. manoeuvring.

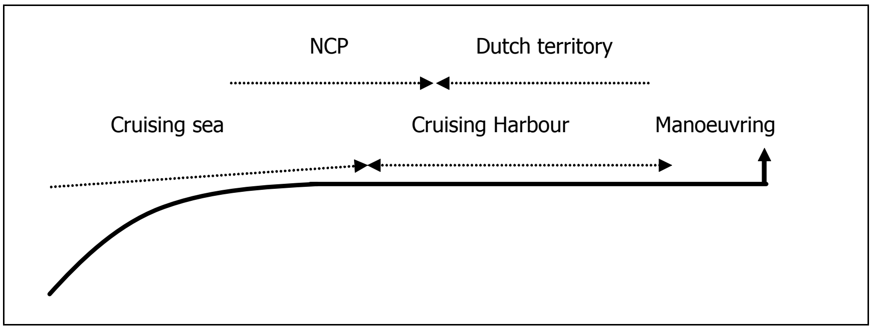

Figure 1: The 3 different navigation stages for sea-going vessels in EMS.

The generators supply the ship of electric power and this during all the different navigation stages. Boilers supply hot water.

Here we describe the methodology that was used in this study to calculate the emissions from sea-going vessels for the above mentioned different navigation stages.

C.3.1 Hotelling in Dutch harbours

The emissions from sea-going vessels per ship type (v), fuel type (f), engine type (m) en pollutant (s) at hotelling ($EI_{ms,\ v,\ f,\ m}$) are calculated by the following formula:

$$EM_{s,v,f,m} = F_{v,f,m} \times EF_{s,f,m}$$

where

$EM_{s,v,f,m}$ = Emission (kg)

$F_{v,f,m}$ = Amount of fuel used per ship type, fuel type and engine type (kg)

$EF_{s,f,m}$ = Emission factor per pollutant, fuel type and engine type $\left(\frac{kg}{kg}\right)$

TNO has determined *technological dependant emission factors* [v]. They do not work with ageing factors.

They use the following formula for the calculation of the *amount of fuel used, specified to fuel type and engine type*:

$$F_{v,f,m} = f_{v,f} \times f_{v,m} \times F_v$$

where

$F_{v,f,m}$ = Amount of fuel used per ship type, fuel type and engine type (kg)

$f_{v,f}$ = Fraction fuel per ship type (%)

$f_{v,m}$ = Fraction engines per ship type (%)

F_v = Amount of fuel used per ship type (kg)

TNO has subjected 89 large sea-going vessels to a survey in the year 2003 in the harbour in Rotterdam. They have estimated the following data for sea-going vessels which are hotelling on the basis of those questionnaires.

- the *subdivision* of the used *fuel types* per type of ship;
- the *subdivision* of the use of *different engines* per type of ship.

They use the following formula for calculating the *amount of fuel used per ship type:*

$$F_v = N_v \times V_v \times T_v \times E_v$$

where

F_v = Amount of fuel used (kg)

N_v = Amount of visits in the harbour

V_v = Volume of the ship (GT = gross ton)

T_v = Time of hotelling $\left(\frac{uur}{bezoek}\right)$

E_v = Amount of fuel used $\left(\frac{kg}{GT \times hour}\right)$

From the questionnaire that TNO has subjected in the harbour of Rotterdam, they also have estimated what the *average amount of fuel used* is per type of ship and unit of time during the time that the sea-going vessels are hotelling in the harbour.

The hotelling times of the sea-going vessels are based on registrations of median times of hotelling in Rotterdam, Amsterdam, North Netherlands and on data from the ENTEC-study [iii].

The Central Bureau of Statistics (CBS) in the Netherlands collects yearly the *visits of sea-going vessels* to Dutch harbours, together with the *volume of the ship* (GT).

C.3.2 Cruising

Both on the NCP and the Dutch territory, it is possible that the sea-going vessels navigate on cruising speed or on reduced speed. For the year 2000, about 70 % of the travelling ships on the NCP were connected tot the Dutch harbours by origin or destination. These ships switch between navigating on cruising speed and navigating on reduced speed.

We describe here the method for the calculation of emissions from sea-going vessels for ships that navigate on cruise speed, next we explain how the method needs to be adjusted to calculate the emissions from sea-going vessels that navigate on reduced speed. The authors of EMS distinguish engine dependant emissions (t) and fuel dependant emissions (f).

They calculate the engine dependant emissions for ships that navigate on cruise speed by the following formula:

$$EM_t = E_s \times EF_{t,m,f,y}$$

where

EM_t = Emission of pollutant that are motor specific (kg)

E_s = Amount of energy used (kWh)

$EF_{t,m,f,y}$ = Emission factors of pollutant, engine type, fuel type and year of construction $\left({}^{kg}/_{kWh} \right)$

They calculate the amount of energy used of a ship that navigates on cruise speed by the following formula:

$$E_s = \frac{P_s \times F_s \times L_s}{V_s}$$

where

E_s = Amount of energy used (kWh)

P_s = Installed capacity (kW)

F_s = Fraction used capacity

L_s = Total covered distance (nautical mile)

V_s = Design speed $\left(\text{nautical mile}/\text{hour}\right)$

They get the *installed capacity* and the *design speed* for each ship from the Lloyd's database. They get the effective fraction of full power from the questionnaire that TNO subjected in the harbour of Rotterdam. The *fraction* is taken equal to a constant, namely 85 %. With the travel data from the Lloyd's database, and the traffic database en route division from SAMSON [vi], they determine the distance that each ship type covers in sea (cruising speed) on the Dutch waters.

They calculate the fuel dependant emissions for ships that navigate on cruising speed by the following formula:

$$EM_f = Q_s \times EF_{f,b}$$

where

EM_f = Emission of pollutants that are fuel specific (kg)

Q_s = Amount of fuel used (kg)

$EF_{f,b}$ = Emission factors for pollutants, fuel $\left(\text{kg}/\text{kg}\right)$

They calculate the amount of fuel used from each ship that navigates on cruising speed by the following formula:

$$Q_s = \frac{E_s}{R_{m,f,y} \times W_f}$$

where

Q_s = Amount of fuel used (kg)

E_s = Amount of energy used (kWh)

$R_{m,f,y}$ = Performance for engine type, fuel en year of construction $\left(\text{kWh}/\text{kWh}\right)$

W_f = Energy content of fuel $\left(\text{kWh}/\text{kg}\right)$

The method for navigating on <u>reduced speed</u> differs somewhat from the method for navigating on cruising speed. They take into account:

1. the fact that reduce in speed leads to a much *smaller energy demand*;
2. the science that the *emission factors by lower capacity* can differ from the emission factor for navigating on cruising speed;
3. the *amount of visits in the harbour*;
4. the fact that the *distance* that a ship covers on reduced speed is *dependant* of the ship type, the volume of the ship en the geometry of the harbour;
5. the fact that there is *no reduced capacity demand by auxiliaries*.

C.3.3 Manoeuvring

The switch from 'Navigate Harbour' to 'Manoeuvring' is the point where the ship slows down to navigate into the harbour.

The emission calculations for manoeuvring by type of ship is likewise derived from the emission calculations for navigating.

- First of all, they transform the emission factor for navigating on cruising speed to an emission factor that is time dependant.
- They take into account the reduced capacity demand (average used capacity as a percentage from the available maximum continuous capacity). There is no reduced capacity demand by auxiliaries.
- They take into account the manoeuvring time, together with the amount of visits to the harbour en the volume of the ship (GT).

The authors estimate the manoeuvring time of the different ship types by dividing the process into several steps:

<u>Navigate into the harbour</u>

1. navigate (the distance that ships cover between starting to manoeuvre and the quayside, the speed by which this happens is dependant on the volume of the ship);
2. turning (the turning speed (°/min) is dependant on the volume of the ship);
3. align with the quayside;
4. more alongside the quayside;

<u>Navigate from the harbour</u>

5. more by the quayside;
6. start to move;
7. turning;
8. navigate.

The manoeuvring time is mainly dependant on the volume of the ship and the geometry of the harbour.

C.4 TREMOVE

Transport & Mobility Leuven has recorded maritime shipping in there transport model 'TREMOVE'. They calculate the emissions from sea-going vessels with the methodology that Entec has set up (see 1.1.1.1.1C.2 ENTEC). There is no modal shift between transport with sea-going vessels and other transport mode possible.

They modulate ship kilometres and no ton kilometres. 27 different ship types are put into the model, together with 5 different engine types and 3 different fuel types (Table 3).

They take into account the total amount of ship kilometres per ship type by sea region and the amount of visits in the harbour per ship type by country.

They calculate the emissions from sea-going vessels for the sea region and the visits to harbours the same way as ENTEC.

C.5 TRENDS

TRENDS stands for TRansport and ENvironment Database System [vii]. The authors of TRENDS have set up a methodology to determine the emissions from the 4 most important transport mode:

- road transport;
- railways;
- shipping;
- aviation.

The module for the calculation of emissions from sea-going vessels in the study 'Energy Consumption and Air Pollutant Emissions from Rail and Maritime Transport' [viii] is based on TRENDS.

Here we describe the methodology (module) for the calculation of sea-going vessels according to TRENDS.

In TRENDS, they make a subdivision in the following ship types, fuel types and engine types for the calculation of emissions from sea-going vessels (Table 5).

Table 5: Classification system in TRENDS for the emissions from sea-going vessels.

Ship type	Fuel type	Engine type
Container	Fuel oil	Slow speed engines
Dry Bulk	Gas oil	Medium speed engines
General Cargo		Steam engine
Liquid Bulk		
RoRo/cargo		

They calculate the emissions from sea-going vessels for different countries for the time period 1970-2020. The formula they operate with for the calculation of total emissions from sea-going vessels for all countries per ship type, fuel type and engine type is the following:

$$E_i = A_i \times EF_i$$

where

E_i = the total emissions in all countries

A_i = the total covered distance

EF_i = the emission factor

They use for the whole time series the *emission factors* (g/km) of the year 2000. These emission factors are dependent on country, ship type, fuel type and engine type.

The calculations of the *total covered distance* are based on tonnes of cargo moves and passengers transported per year. A split based on the detailed database for the year 2000 (Eurostat) was applied to attribute the tonnage to different vessel types and derive ton-kilometre and vehicle kilometre estimations.

The procedure for disaggregating the data is the following:

- The tonnage of goods per country was attributed to vessel type according to the split of the total tonnage per country carries by a specific vessel type in the year 2000.
- Further disaggregating was done by applying a capacity share between medium and slow speed engine vessels.
- The number of vessels was calculated using an average load per vessel as derived from the detailed database for the year 2000.
- The total number of vessels was in turn divided into medium and slow speed engine vessels.

Using the number of vessels and the representative tonnage of goods or passengers carries by each ship type, vessel-kilometre, passenger-kilometre and ton-kilometre estimates were calculated based on the average distance travelled by each vessel type in the year 2000. The database operates on statistical data provided by Eurostat. Data is port to Maritime Coastal Area (MCA) (in stead of port-to-port because of missing data).

They attribute the emissions to the different countries on the basis of import and export. The division of the emissions is shared equally to origin and destination.

The aggregation of statistics to MCA level creates a lot of problems for the estimation of distances travelled while introducing significant inaccuracy to the calculation. More detailed data is not available or is confidential data.

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ANNEX D SHIP TYPE: LLOYD'S REGISTER FAIRPLAY- MOPSEA

We present in Table 2 the corresponding ship types between the Lloyd's Register Fairplay database and the emission model MOPSEA.

Table 2: corresponding ship types

Lloyd's Register Fairplay		MOPSEA
MAIN TYPE	SUB TYPE	
BULK CARRIERS	Aggregates Carrier	Dry bulk carrier
BULK CARRIERS	Bulk Carrier	Dry bulk carrier
BULK CARRIERS	Bulk/Oil Carrier	Dry bulk carrier
BULK CARRIERS	Cement Carrier	Dry bulk carrier
BULK CARRIERS	Limestone Carrier	Dry bulk carrier
BULK CARRIERS	Ore Carrier	Dry bulk carrier
BULK CARRIERS	Ore/Oil Carrier	Dry bulk carrier
BULK CARRIERS	Refined Sugar Carrier	Dry bulk carrier
BULK CARRIERS	Self-Discharging Bulk Carrier	Dry bulk carrier
BULK CARRIERS	Wood Chips Carrier	Dry bulk carrier
DRY CARGO/PASSENGER	Barge Carrier	General Cargo
DRY CARGO/PASSENGER	Container Ro-Ro Cargo Ship	Containers
DRY CARGO/PASSENGER	Container Ship	Containers
DRY CARGO/PASSENGER	Deck Cargo Ship	General Cargo
DRY CARGO/PASSENGER	General Cargo Ship	General Cargo
DRY CARGO/PASSENGER	Heavy Load Carrier	General Cargo
DRY CARGO/PASSENGER	Livestock Carrier	General Cargo
DRY CARGO/PASSENGER	Nuclear Fuel Carrier	General Cargo
DRY CARGO/PASSENGER	Palletised Cargo Ship	General Cargo
DRY CARGO/PASSENGER	Passenger (Cruise) Ship	Passenger ship
DRY CARGO/PASSENGER	Passenger Ship	Passenger ship
DRY CARGO/PASSENGER	Passenger/General Cargo Ship	Passenger ship
DRY CARGO/PASSENGER	Passenger/Ro-Ro Cargo Ship	Passenger ship
DRY CARGO/PASSENGER	Refrigerated Cargo Ship	Reefers
DRY CARGO/PASSENGER	Ro-Ro Cargo Ship	RoRo
DRY CARGO/PASSENGER	Stone Carrier	General Cargo
DRY CARGO/PASSENGER	Vehicles Carrier	RoRo
FISHING	Fish Carrier	-
FISHING	Fish Factory Ship	-
FISHING	Fishing Support Vessel	-
FISHING	Fishing Vessel	-
FISHING	Trawler	-
MISCELLANEOUS	Buoy/Lighthouse Vessel	-
MISCELLANEOUS	Cable-Layer	-
MISCELLANEOUS	Crane Ship	-
MISCELLANEOUS	Dredger	-
MISCELLANEOUS	Hopper Dredger	-
MISCELLANEOUS	Icebreaker	-
MISCELLANEOUS	Motor Hopper	-
MISCELLANEOUS	Pilot Vessel	-
MISCELLANEOUS	Pollution Control Vessel	-
MISCELLANEOUS	Pusher Tug	-

Lloyd's Register Fairplay		MOPSEA-
MAIN TYPE	SUB TYPE	
MISCELLANEOUS	Search & Rescue Vessel	-
MISCELLANEOUS	Training Ship	-
MISCELLANEOUS	Trans-Shipment Vessel	-
MISCELLANEOUS	Tug	-
MISCELLANEOUS	Utility Vessel	-
MISCELLANEOUS	Waste Disposal Vessel	-
MISCELLANEOUS	Work/Repair Vessel	-
NON-MERCHANT SHIPS	Naval/Naval Auxiliary	-
NON-MERCHANT SHIPS	Other Non-Merchant Ships	-
NON-MERCHANT SHIPS	Sail Training Ship	-
NON-MERCHANT SHIPS	Yacht	-
NON-PROPELLED	Pontoon	-
NON-SEAGOING MERCHANT SHIPS	Chemical	-
NON-SEAGOING MERCHANT SHIPS	General Cargo	-
NON-SEAGOING MERCHANT SHIPS	Oil	-
NON-SEAGOING MERCHANT SHIPS	Passenger	-
NON-SEAGOING MERCHANT SHIPS	Ro-Ro Cargo	-
NON-SEAGOING MERCHANT SHIPS	Towing/Pushing	-
NON-SHIP STRUCTURES	Platform	-
OFFSHORE	Offshore Supply Ship	-
OFFSHORE	Offshore Support Vessel	-
OFFSHORE	Offshore Tug/Supply Ship	-
OFFSHORE	Production Testing Vessel	-
OFFSHORE	Standby-Safety Vessel	-
TANKERS	Bitumen Tanker	Chemical tanker
TANKERS	Chemical Tanker	Chemical tanker
TANKERS	Chemical/Oil Products Tanker	Chemical tanker
TANKERS	Crude Oil Tanker	Oil bulk (crude)
TANKERS	Edible Oil Tanker	Chemical tanker
TANKERS	Fruit Juice Tanker	Chemical tanker
TANKERS	LNG Tanker	LNG tanker
TANKERS	LPG Tanker	Gas tanker
TANKERS	Molasses Tanker	Chemical tanker
TANKERS	Oil Products Tanker	Oil bulk (crude)
TANKERS	Vegetable Oil Tanker	Chemical tanker
TANKERS	Wine Tanker	Chemical tanker

ANNEX E ACKNOWLEDGEMENT

This study has been set up with coordination of the promoter Els Van Cleemput. During the project, we lost her and the project team regrets that she cannot see the final result of the research. Therefore, we want to honour her with the work that we have put in this study and we want to dedicate this report to her.

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