S E R I E

127

recursos naturales e infraestructura

Report on maritime transport and the environment for Latin America

Bart Boon

NACIONES UNIDAS

CEPAL

División de Recursos Naturales e Infraestructura

Santiago, Chile, october 2007

This document was prepared by Bart Boon, Associated Expert under the supervision of Ricardo J. Sánchez, Economic Affairs Officer of the Division of Natural and Infrastructure of the Economic Commission for Latin America and the Caribbean (ECLAC).

The views expressed in this document, which has been reproduced without formal editing, are those of the authors and do not necessarily reflect the views of the Organization.

United Nations Publication
ISSN printed version 1680-9017 ISSN online version 1680-9025

ISBN: 978-92-1-121655-4
LC/L.2792-P
Sales No.: E.07.II.G.126

Printed in United Nations, Santiago, Chile.

Table of contents

Tables

Figures

Box

Abstract

This report presents information on the environmental impact of vessels during their general operation. It is shown that the emissions from vessels can substantially contribute to local air quality problems over land and also impact the climate change process.

Up to now, the contribution of the maritime sector to air quality problems in Latin American and Caribbean coastal cities has received little or no attention. Studies for the United States and Europe show that the contribution of this sector may however be significant. Given the persistence of air quality problems in Latin America, it appears worthwhile to consider this sector in emission inventories and mitigation policies.

The recommendations at the end of the report include several measures that may be implemented at little or no costs, but that do provide incentives to improve the environmental performance of the sector. Based on further research on the particular contribution of the shipping sector to air quality problems, more far reaching measures may have to be considered. With respect to climate change, it is recommended to stimulate participation in trials with the IMO CO_2 index that is under development.

.

I. Introduction

The aim of this report is to provide a general background on the impact maritime transport has on the environment. We will discuss the different emissions caused by vessels and how they may impact human health, local and global environment. Best practice measures and policy developments from around the world aimed at limiting the impact of shipping on the environment will be discussed. Special attention will be given to the role Latin America can play in these processes.

In the past, discussions on the impact of maritime shipping on the environment have often been in conjecture with discussions on maritime safety. Pollution from the maritime shipping sector was mainly seen as a safety problem. From an historical perspective, this is not altogether incorrect bringing into remembrance the enormous environmental impacts from oil spills resulting from accidents. Examples are the incident with the Exxon Valdez near Alaska in 1989, and from more recent times the sunken Erika (1999) and the Prestige (2002) near the coasts of Europe.

In this report, however, the focus will be on the impact of maritime shipping on the environment as a result of the general operation of the vessel. This is further refined to the impact on local air quality of the emissions of local air pollutants and the impact on climate change due to emission of greenhouse gases (GHG).

The impacts from collisions and other safety aspects will not be considered, nor will sewage, ballast water and trash. This is not to say that these are very important issues, but they will not be dealt with in this report.

Maritime shipping is generally regarded as an environmentally friendly mode of transport. Compared to other transport modes, emissions of greenhouse gases are often much lower per ton kilometer.[1] For this reason, shifting freight transport by road to sea is in some regions regarded desirable from an environmental perspective and is sometimes an official policy aim. However, the impact of maritime transport on the environment is very substantial due to the sheer size of the sector. Mitigation of greenhouse gases is becoming a more and more important topic in the international policy scene. It is said that many relatively cheap mitigation measures can be taken in the maritime shipping sector.

The shipping sector is often thought to play only a minor role in local air pollution, because most emissions take place at sea. However, especially in densely populated coastal areas and ports, the impact of shipping may be substantial. This is substantiated by numerous studies for United States and European Unit ports.

In general it appears however, that knowledge on the environmental impact of shipping is not widespread yet in Latin America and the Caribbean. This report aims to partially rectify this. There are several reasons why this may be an interesting subject for this region.

First of all, in Latin America and the Caribbean there are significant problems with local air quality in large (coastal) cities. So far, the contribution of the shipping sector to these problems has hardly been analyzed or reviewed for the Latin American situation. Based on research for United States and European Unit ports, it appears plausible that the shipping sector may contribute substantially to problems. This implies that measures in this sector may offer part of the solution.

Second, if indeed the shipping sector contributes to local air quality problems, now may be a very appropriate moment to take measures. The sector is growing rapidly (UNCTAD, 2005) and requires new investments in infrastructure. It is a lot cheaper to be able to take environmental issues into account when designing new infrastructure, than having to adjust for it after the infrastructure has been taken in use. Moreover, in times of expansions and investment the support for measures may be larger than in times of overcapacity and tight markets.

Third, especially in the United States and the European Unit, increased attention is being paid to the shipping sector as contributing substantially to greenhouse gases and local air quality problems. Mitigation measures in many other sectors are being implemented. Despite these efforts, also in the other transport modes, problems remain. Therefore the contribution from short sea shipping and ships movements inside or near ports to local air pollution is receiving increased attention. Because the shipping sector has so far been somewhat overlooked, it is expected that relatively cheap abatement measures are available in the sector. Such regional United States or European Unit regulations will impact Latin American ship owners and shippers.

In the fourth place the developments within the IMO should be regarded. Although Latin American countries do not have any GHG emission reduction commitments under the Kyoto Protocol, it may be wise to actively participate in current discussions so to influence the design of future policy measures.

1 Clearly, this depends on the specific circumstances. For a comparison, see e.g. CE Delft (2003).

BOX 1
UN MILLENNIUM DEVELOPMENT GOALS

The impact of shipping on the environment is related to the following Millennium Development Goals specified by the United Nations:

Millennium Development Goal 4: Reduce child mortality

Millennium Development Goal 7: Ensure environmental sustainability

Millennium Development Goal 28: Carbon dioxide emissions per capita

As will be clarified in this report, emissions from shipping have a substantial impact on local air pollution. Air pollution itself has been associated with infant mortality, low birth weight, children's emergency room visits and wheezing bronchitis for infants. Maternal exposure to air pollutants during pregnancy has also been linked to adverse affects on fetus growth[2]. Clearly, air pollution has also an impact on less than 5 mortality rate and infant mortality rate (indicators 13 and 14 of the Millennium development goals).

The relation with development goals 7 and 28 is less straightforward. Maritime transport uses fossil fuels and one would thus expect a relation with millennium goal 28, 'carbon dioxide emissions per capita'. Emissions from maritime transport (as holds for international aviation) are not included in country's totals due to lack of agreement on how to allocate emissions from international transport between countries. Therefore there is no direct link with indicator 28. Nonetheless, clearly, environmental sustainability is enhanced when CO_2 emissions from maritime transport are reduced.

In the section I of this report provides a background on the history of environmental issues in the maritime shipping sector.

Sections III to V deal with the emissions from maritime shipping. In section II it is discussed which emissions come free during operation of a vessel, how they come about and how they impact human health and the environment. Section III presents estimates for the total amount of emissions from maritime transport, where they take place and how they relate to other sources of emissions. In section V we discuss the potential impact of emissions from the shipping sector. A distinction is made between the impact on local air quality and the impact on climate change. With regard local air quality (section 5.1), we first discuss the situation in the region in general. Next, we discuss how environmental impacts can be valuated and then we discuss briefly the impact of emissions from the shipping sector on the local air quality situation. This approach is taken because there are no studies available that focus on the impact of the shipping sector on the local air quality in Latin America and the Caribbean. In section 5.4 we discuss the impact of shipping on climate change. Because climate change is a global problem, no specific discussion with respect to Latin America and the Caribbean is included.

After having discussed the problems, sections V to VI present potential solutions. Section V relates to air pollutants. In 5.1. technical and operational measures to limit the ship emissions of air pollutants are presented. Next, international policy developments that may induce such measures are discussed. Section 6.3 deals with regional developments. Chapter 5.2 has a similar structure but focuses on measures related to the climate impact of shipping. Recommendations for greening the shipping sector in Latin America and the Caribbean are provided in section VI.

2 For an overview of studies on the health effects of air pollution in Latin America and the Caribbean, see PAHO (2005) and Bell et al. (2006).

II. Background on environmental issues in maritime shipping sector

This chapter provides a general overview on environmental concerns related to shipping activities. This section is partly based on Farthing (1993), Farthing & Brownrigg (1998), Ma (2002) and information from the IMO website.

Shipping is by its nature a very international business.[3] The first initiatives towards some form of regulation of this international business, emerged in the time of the Phoenicians in the first millennium BC. As Farthing (1993) points out, these regulations included ‘elements of insurance law, rules relating to salvage and to the carriage of goods by sea, compensation for seamen lost of injured and the like.’ With the Greeks a low governing of maritime matters began to develop and this was continued under the reign of the island of Rhodes and, in a later stage, the Romans.

Although regulation of transport by sea has such a long history, regulations to control for environmental pollution are very recent. Clearly, before the change from sail to the steam engine and later the diesel engine and before the transportation of hazardous goods, there was very limited need for environmental control.

[3] See http://college.hmco/history/readerscomp/ships/html/sh.092600 torreycanyon.htm and www.lboro.ac.uk/ departaments/ hu/ergsinhu/aboutergs/torrey.html (consulted February 2, 2006).

The first initiative towards prevention of pollution stems from 1922. After the First World War governments first began to be concerned about oil pollution because of the increase in the number of ships not only carrying oil as cargo, but also burning oil rather than coal in their engines. This led to the British Oil in Navigable Waters.

The discharge of oil and oily mixtures within United Kingdom territorial waters is an Act which is prohibited. Several years later ship owner's voluntary adopted similar rules in the United States, United Kingdom, Sweden, Norway, the Netherlands and Belgium.

Not until the 1950, these voluntary agreements were succeeded with a more regulative approach by the first international convention on pollution from ships, the 1954 Oil Pollution Convention (OILPOL). OILPOL only posed restrictions for discharges of oil in certain areas and left unrestricted discharges of oil over large sections of the oceans.

The necessity of increased international regulation became clear with the grounding of the Torrey Canyon.[4] The Torrey Canyon was one of the first large crude oil tankers to sail the seas. It grounded in broad daylight of the coast of Cornwall, Great Britain on March 18, 1967, carrying 118.000 tons of crude oil. Within three days, its entire cargo of oil (an estimated 37 million gallons of oil) had spilled into the sea. Efforts to limit the environmental impact included hitting the ship with 1000 tons bombs and dumping aviation fuel and napalm on the wreck attempting to start a fire before the oil could spread. Despite these efforts, up to 115 km of beaches were seriously contaminated with in some cases sludge up to a foot deep. The spilled oil contaminated over 20.000 sea birds.

The disaster with the Torrey Canyon led to rapid developments with respect to liability and compensation schemes. The Inter-Governmental Maritime Consultative Organization (IMCO, in 1982 changed to become the IMO)[5] established a Legal Committee to deal with liability questions. IMCO also convened a conference on marine pollution, which gave rise to the 1973 Convention for the Prevention of Pollution by Ships (MARPOL). While the Conference recognized that accidental pollution was significant, it considered that operational pollution was still the bigger threat.[6] Furthermore, in 1975 IMCO formed the Marine Environment Protection Committee (MEPC) and prevention and control of marine pollution from ships became an integral part of the work program of the IMCO.

Apart from oil pollution, MARPOL 1973 also intended to address other forms of pollution from ships, such as chemicals, harmful substances carried in packaged form, sewage and garbage. With only three ratifications received by 1976, in 1978 a new Conference was held. This resulted in some adaptations and additional measures, laid down in MARPOL 73/78, which finally entered into force in 1983.[7]

---

[4] To illustrate the point that shipping is an international business: The Torrey Canyon was originally built in the US with a cargo capacity of 60.000 tons. In Japan, it was later expanded to twice that size. The owner was a Liberian-based subsidiary (the Barracuda Tanker Corporation) of the US based Union Oil Company. The vessel was on its way from Kuwait to England, under the charter to the British Petroleum Company and manned by an Italian crew.

[5] The convention establishing this UN body was adopted in 1948. Its main aims were originally related to economic action to promote 'freedom' and end 'discrimination'. The IMCO was definitely established in 1959 after Egypt had ratified the Convention as 21st State twelve months earlier.

[6] During normal operations, oil tankers discharge into the sea a certain amount of oil contained in the ballast and tank washing water. Both OILPOL and MARPOL conventions currently set limits to the amount of oil and the rate at which it is discharged. Note that in 1985, the share of accidental spillages in total transportation losses were estimated at about 28% (NRC, 1985, total transportation losses 1.45 mta, spills due to accidents 0.41 mta).

[7] This holds for the main Convention and annexes I (prevention of oil pollution) and II (control of noxious liquid substances). Annexes III (harmful substances in packaged form), IV (sewage) and V (garbage) entered into force between 1988 and 2003.

In response to new incidents with oil tankers, especially the Exxon Valdez[8] incident, the United States Congress passed in 1990 the Oil Pollution Act (OPA). This act requires the US Coast Guard to strengthen its regulations on oil tank vessels and oil tank operators and owners.

In 1997 a new annex to MARPOL 73/78 was negotiated. This Annex VI relates to emissions of air pollutants during the general operation of the ship. Limits are posed to the emissions of sulphur and nitrogen oxides from ship exhausts. It also prohibits deliberate emissions of ozone depleting substances. This Annex entered into force in 2005 and will be described in more detail in chapter VI of the underlying report.

In the next sections, we describe the emissions that take place during the general operation of vessels in more detail.

8 The Exxon Valdez grounded for the coast of Alaska in 1989. In total, 37,000 tones of crude oil were spilled in the sea.

III. The type of emissions caused by maritime shipping

Shipping is generally regarded as an environmentally friendly mode of transport. Indeed, maritime transport is a very fuel-efficient manner of transporting goods. For some gases, however, transport by ship causes more emissions per ton kilometer than transport by other modes. Moreover, maritime transport takes up the lion's share of all freight transport, and therefore absolute emission levels are substantial.

In this section we will discuss.[9]

- Which emissions take place during the operation of a vessel
- How they come about
- How they may affect the environment

Estimates for the total amount of emissions and the size of their actual impact are discussed in sections IV and V, respectively.

In the main and auxiliary engines of vessels fuel is combusted to deliver energy. Directly related to combustion of fossil fuels are emissions of carbon dioxide. Apart from these, combustion engines can emit:[10]

- Nitrogen oxides
- Carbon monoxides

9 The information presented is based on various sources, including CICERO (2004), WHO (2003), Eyring et al. (2005), Marintek et al. (2000) and the websites of Wikipedia and Edugreen.

10 In the literature different classifications and terminologies can be encountered. The terminology here follows Eyring et al. (2005a).

- Sulphur dioxides
- Hydrocarbons
- Particulate matter

On top of the emissions from the main and auxiliary engines of vessels, emissions may arise from the cargo carried or loaded or be related to the cooling system in case of refrigerated transport. Emissions may have an impact on human health, the local environment and also the global environment by impacting climate change. We briefly describe the main types of emissions and their potential impact on the environment and human health.

Carbon dioxide (CO_2) is an important greenhouse gas. Emissions are directly related to the carbon content of fuel. CO_2 can stay in the atmosphere for centuries. Due to this long lifetime, the impacts of CO_2 are global and do not depend on where it is emitted. CO_2 absorbs infrared radiation and therefore has an important warming effect on the global atmosphere.

The amount of nitrogen oxides (NO_x) emitted depends on the engine characteristics. In general, combustion at a higher temperature creates more NO_x. At lower temperatures, the combustion process will be less fuel-efficient and more fuel will be required to obtain the same energy. This would in turn increase the amount of CO_2 emissions. Moreover, combustion at a lower temperature will be less complete, increasing the amount of soot and unburned hydrocarbons, which are discussed below.

NOx emissions can impact human health, the environment and also have an impact on climate change. Short-term exposure to NO_x can result in severe pulmonary damage. Long-term exposure may lead to respiratory problems.[11] The lifetime of NO_x in the troposphere is in the order of hours to days. However, NO_x emissions can oxidize in the atmosphere to form nitrate, which leads to acidification and eutrophication, impacting the local environment. NO_2 is a so-called precursor for ozone, whose climate impact will be discussed below. Apart from these effects, NO_x emissions also affect the amount and lifetime of methane in the atmosphere. Because methane itself is a strong greenhouse gas, the losses of methane in the atmosphere due to NO_x emissions provoke a cooling effect.

Carbon monoxides (CO) are formed through the incomplete combustion of fossil fuel (complete combustion forms carbon dioxide). High concentrations of CO in the air can have severe health impacts, such as headache, dizziness, chest pain and even unconsciousness and death. CO contributes to climate change by reacting with other chemical compounds that would otherwise destroy methane and ozone in the atmosphere.

The emissions of sulphur oxides (SOx) are related to the amount of sulphur in the fuel used. High-speed vessels generally make use of Marine Destillate Oil (MDO). The quality is relatively good and SOx concentration is relatively low. Lower speed vessels generally run on heavy fuel oil (HFO, or sometimes called heavy grade oil), with a higher SOx concentration. Where regulations require, vessels may shift to combustible with a lower sulphur dioxide (SO2) concentration.

SO2 in the air leads to diseases of the lung and other lung disorders such as shortness of breath. Sulphur dioxides can oxidize in the atmosphere and cause acid rain. Acid deposition can be harmful for the environment. SO2 is also a precursor for sulfate aerosols (SO4, see below). SO2 has a lifetime of 0.5 to 2 days in the atmosphere, but sulfates have a longer lifetime varying from a few days to several weeks.

[11] For an overview of health aspects associated with emissions of NOx, ozone and particulate matter, see WHO (2003).

Hydrocarbon (HC) emissions take place through incomplete combustion of fuel and evaporation. Hydrocarbons are often called volatile organic compounds (VOC), which is actually a somewhat wider group of molecules. HC can be split in two groups, methane (CH_4) and non-methane hydrocarbons (NMHC).

The quantity of exhaust HC depends on many factors, including engine design, condition of the engine, operating temperature etc. About half of total emissions of HC from shipping take place during tanker loading operations in ports, by evaporation. NMHC can cause irritation of the eye, nose and throat. In the long run, some of them are suspected to cause damage to the liver and other parts of the body. Emissions of HC also play a role in the formation of ozone, see below.

Methane itself is a strong greenhouse gas with a warming effect on climate, but has no direct effects on human health. The level of methane emissions of maritime transport is relatively low and the net effect on the methane concentration in the atmosphere is dominated by the impact of NO_x emissions on methane concentrations.

The term particulate matter (PM[12]) refers to many fine particles of different elements, organic and inorganic. Primary fine particles are emitted directly from the combustion engine. Secondary particles such as sulphates may be formed by chemical reactions in the air.

Particles suspended in the atmosphere are often called aerosols. In general, the lifetime of aerosols in the atmosphere depends on their size. The smaller the particles are, the longer their lifetime in the atmosphere. A longer lifetime allows for transportation in the air, extending the range of impacts from local to regional or even global.

Following Eyring et al. (2005a), the main determinants of particulate matter emissions from shipping are:

- Black carbon
- Organic carbon
- Fly ash
- Sulfate
- Other particulate matter

Black carbon or soot is the effect of incomplete combustion. It tends to have a warming effect on climate. It absorbs outgoing infrared radiation due to its black color.

Organic carbon is also called white smoke and reflects sunlight. It therefore has a cooling effect.

Sulfates (SO_4) are formed by a chemical reaction involving SO_2. Sulfate has two cooling effects on climate. Its direct effect is back scattering of solar radiation, due to its white color. The indirect effect is that the sulfate particulates help to create more low-level clouds through the introduction of more cloud condensation nuclei (CCN) than would otherwise have been there. All cloud droplets must nucleate on a particle, because water vapor does generally not self nucleate. As a result, there are more clouds and they have a higher droplet density of smaller size. These clouds are 'optically bright' and back scatter solar radiation (Lee, 2006).

When breathed in, (both primary and secondary) particulates can reach into the lungs and settle there. The smaller the particulates, the further they reach and the more dangerous they may

[12] At many instances one will find a number right after PM, such as PM10 or PM2.5. The number indicates the maximum aerodynamic diameter in µm. PM10 refers to all particles with a diameter of 10 µm or less.

be. Very small particles may even enter the bloodstream. Long-term exposure to PM may lead to a marked reduction in life expectancy through cardio-pulmonary and lung cancer mortality. Short-term exposure has been associated with asthma attacks and myocardial infarctions.

To understand the effects of ozone (O_3) on the environment and on human health, we need to distinguish several layers of the atmosphere. The troposphere is the lowermost layer of the atmosphere, ranging from 8 to 16 kilometers deep. The layer around the troposphere is called the stratosphere.

In the troposphere, ozone is considered both a pollutant and a greenhouse gas. It damages human long tissue, causing increases in respiratory disorders such as asthma. Also irritations to the eye are increased. There are also some non-human health impacts. Ozone can reduce crop yields of agriculture and may damage forests. Tropospheric ozone has different climate impacts. Ozone itself is a greenhouse gas and leads to global warming. It has a relatively short lifespan. When it is broken down, chemicals are released that it shortens the lifetime of other greenhouse gases such as methane.

Ozone is not emitted directly into the troposphere, but is formed from NO_2 in the presence of sunlight. The availability of HC affects the efficiency with which this process takes place.[13] Ozone is subject to long-range atmospheric transport and therefore not just a local problem, but a trans-boundary problem. NO_x emissions from ships often take place in areas that are relatively unpolluted. Here they can have a particularly large effect on ozone formation, much larger than for example, the same amount of NOx emissions from road traffic would have (CICERO, 2004).

In contrast to ozone in the troposphere, ozone in the stratosphere is generally a ‘good thing’. Here ozone protects the surface of the earth from harmful ultraviolet radiation.

In addition to the emissions related to the combustion process and the secondary gases thus induced, the refrigeration equipment of maritime vessels causes fluorinated gas emissions, which is a strong greenhouse gas. Average leakage rates are relatively high in maritime refrigeration equipment, compared to similar emissions from other transport modes or stationary sources. These emissions are not further discussed here, but see CE Delft (2006) and IPCC (2005).

[13] For a more elaborate and precise description of this process, consult Marintek et al. (2000), Crutzen (1987), or Endresen et al. (2003).

IV. The amount of emissions caused by maritime shipping

In the previous section we discussed which emissions occur during the general operation of vessels. We furthermore explained how they could influence the environment, both locally through air pollution and globally through their impact on climate change. In this chapter we discuss information on the quantity of emissions. How much emissions are caused by maritime transport and how does this relate to other sources of emissions?

We will start this section with discussing estimates of global emissions from maritime transport. Next, we present some numbers for the emissions that may be related to Latin American and Caribbean countries. In section V we will discuss the impact that these emissions may have on local air quality and climate change.

4.1 Global emission levels from maritime transport

Estimates for the global emissions from maritime transport differ substantially. Basically, two different approaches have been applied to estimate emission levels. In the first place, top down methodologies have been applied. Based on the total amount of fuel sold for shipping (from bunker statistics), emissions of CO_2 can be determined. Other emissions can then be estimated by using average emission factors for the shipping sector. An alternative method works bottom up, combining traffic and fleet data with average emission factors to estimate global fuel use and

CO2 emissions. Other emissions are estimated by applying specific emission factors for different vessel types. Table 1 provides an overview of the results from different studies.

TABLE 1
ESTIMATES OF GLOBAL EMISSIONS FROM MARITIME TRANSPORT

Source	Year	Method	Million metric tones fuel	Tg[14] CO_2	Tg NOx	Tg SO_2	Tg PM_{10}
Marintek et al. (2000)[15]	1996	Energy statistics	138	438	10.3	5.8	n.a
EDGAR (2005)	2000	Extrapolation of 1995 energy statistics	n.a.	428	9.6	7.3	n.a.
Endresen et al.(2003)[16]	2000	Energy statistics	166	526	12.5	7.1	0.96
Corbett & Koehler (2003)[17]	2001	Activity-based	289	912	22.6	13.0	1.64
Eyring et al. (2005a)	2001	Activity-based	280	813	21.4	12.0	1.67

Note: Studies differ somewhat in their exact scope, regarding military and fishing fleet, passenger fleet, domestic and inland shipping, fuel use of auxiliary engines and cut off value of vessels included.

It is clear that there is a large difference between figures based on bunker fuel statistics and activity-based figures. It appears that some bunker fuels used for international maritime transport are not reported as such. It is beyond the aim of this study to discuss the relative merits of each of these studies. The main points are:

a) Emissions from maritime transport are very substantial,

b) Uncertainty remains about exact emission levels.

IEA (2004) estimated the emissions from the shipping sector in 2002 on 460 Tg CO_2, based on recorded fuel sales. According to IEA, this amounted to a contribution to the global GHG emissions from fossil fuels of 2.5%. The actual contribution may be up to almost twice as high, if the higher estimates from table 1 proof to be correct.

Below, we will discuss the results of more detailed analyses from some of these studies, such as the contribution of different shipping segments and historical developments. Please hold in mind that the numbers presented in the tables below originate from the studies presented in table 1. There are substantial uncertainties with regard absolute amounts of emissions, and the presented numbers should only be used as indicators of the relative importance of different sectors / countries etc.

In their study for the IMO, Marintek et al. (2000) provide an overview of the contribution of different maritime sectors to total emissions. This overview is represented in table 2.

[14] Tg = Teragram. One Tg corresponds to 1 megaton, equivalent to thousand gigagram (Gg) or thousand kiloton.
[15] Presented numbers relate to mid-estimates based on Corinair emission factors.
[16] Including a correction factor of 5% for emissions related to port operations, as indicated in Endresen et al. (2003).
[17] Note that estimates in the original paper for CO_2, NO_x and SO_2 are presented in Tg of C, N and S respectively.

TABLE 2

OVERVIEW OF CONTRIBUTION OF DIFFERENT SHIPPING SECTORS TO EMISSION LEVELS

(Results from statistical emission model for 1996, emissions only for main engines)

Ship type	Fuel supply (Tg)	CO2 (Tg)	NOx (Tg)	SO2 (Tg)
Liquid gas tanker	4.2	13.4	0.29	0.20
Chemical tanker	4.5	14.2	0.32	0.20
Oil tanker	29.4	93.2	2.00	1.44
Bulk carrier	30.3	96.0	2.60	1.58
General cargo	25.7	81.5	1.77	0.70
Container	20.3	64.4	1.63	0.89
Ro-Ro cargo	9.7	30.9	0.66	0.24
Passenger	4.2	13.4	0.29	0.11
Refrigerated cargo	3.9	12.3	0.27	0.11
Sum	132.3	419.3	9.82	5.46

Source: Marintek et al. (2000), table 1-2

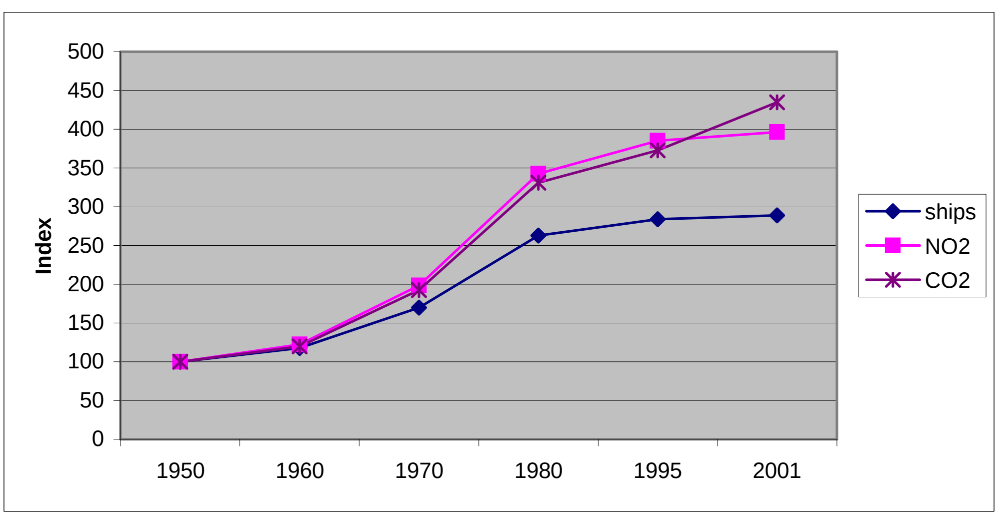
Note: the sum totals do not match with table 1. The reason is that Marintek et al. applied two methodologies, one including also the emissions of auxiliary engines, the results of which are represented in table 1. This table represents emissions estimated according to the alternative methodology. No results including emissions of auxiliary engines were provided for different vessel types.

The oil tankers, bulk carriers, general cargo ships and container ships are responsible for the most emissions. Noteworthy, although emissions of CO_2 are in the same range for these four segments, emissions of SO_x are substantially higher for bulk and oil transport. It appears container ships and general cargo ships use relatively low sulphur fuel compared to bulk carriers and oil tankers.

Eyring et al. (2005a) have studied the development of maritime transport over the period 1950-2001. Figure 1 shows the historic development of ship emissions since the 1950s. The index for the emissions of SO_2 and NO_x is equal to the index for CO_2. Emissions have grown more rapidly than the number of ships, which may be explained by the deployment of increasingly larger ships.

FIGURE 1

HISTORIC DEVELOPMENT OF MARITIME EMISSIONS



Source: Eyring et al. (2005a)

Note: Index numbers are used with 1950 as base year.

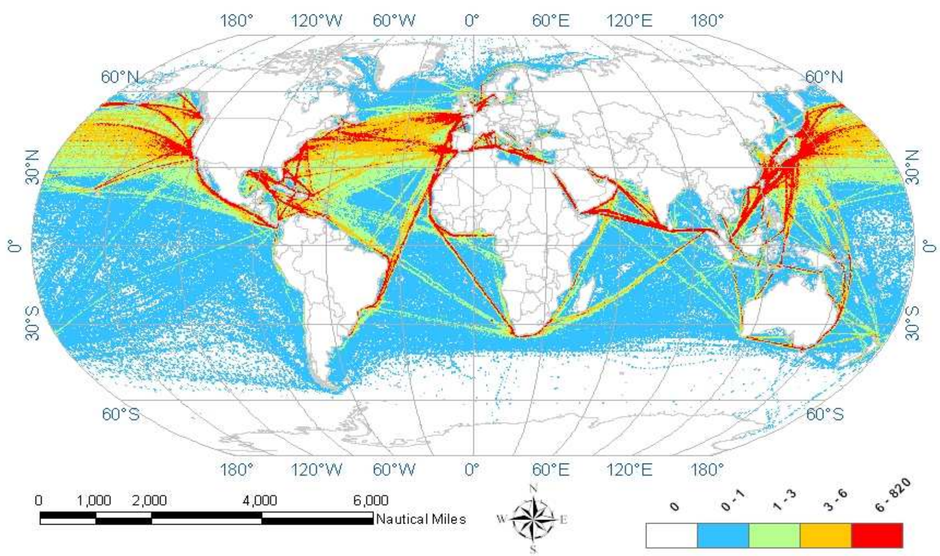
Eyring et al. (2005b) is a companion study presenting the impact of future technologies on emission scenarios until 2050. For this purpose future ship traffic demand scenarios were combined with future technology scenarios. Outcomes for emission vary widely along with the scenarios. For more information, we refer to the original document.

4.2 Location of emissions

To provide an indication of the impact of emissions on local air pollution in Latin America, we need to know where the emissions of air pollutants take place. In this section we present some data on this subject, before discussing the impacts in the next chapter.

Apart from estimating the total amount of emissions, most of the studies listed in table 1 also provide an indication of where emissions take place. Based on updated data, Figure 2 provides an overview of the location of nitrogen emissions from ships.[18]

FIGURE 2
GLOBAL SHIP NITROGEN EMISSIONS



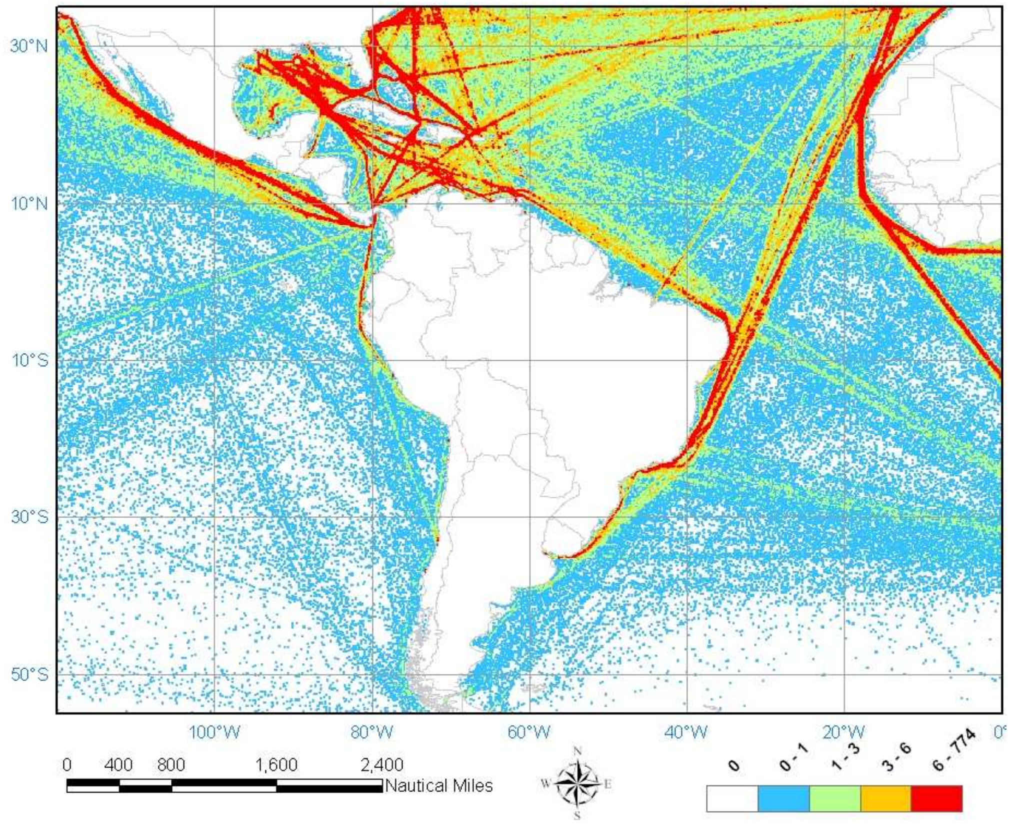
Source: Figure based on information from AMVER (2005), Corbett et al. (1999), Corbett & Koehler (2003), Wang et al. (2006) and ICOADS (2005)

Note: Value of each 0.1 by 0.1 degree cell is the number of metric tons of ship nitrogen emissions in that grid cell in 2002.

Most maritime traffic takes place on the Northern hemisphere. Figure 2 illustrates that most nitrogen emissions from maritime traffic take place there. According to Marintek et al. (2000), about 85% of total emissions from maritime transport take place on the Northern hemisphere. Emissions are clearly concentrated along the main shipping routes. Especially in Europe and the coasts of the US and Asia, emissions levels are high.

[18] There are several studies that provide similar figures with in some cases more detailed information. For example, the studies by Eyring et al. (2005a, 2005b) both contain figures with gridded emission data. Similarly, Corbett et al. (1999) contains figures with gridded sulphur and nitrogen emissions. Endresen et al. (2003) also includes several interesting graphs.

FIGURE 3
SHIP SULPHUR EMISSIONS IN LATIN AMERICA

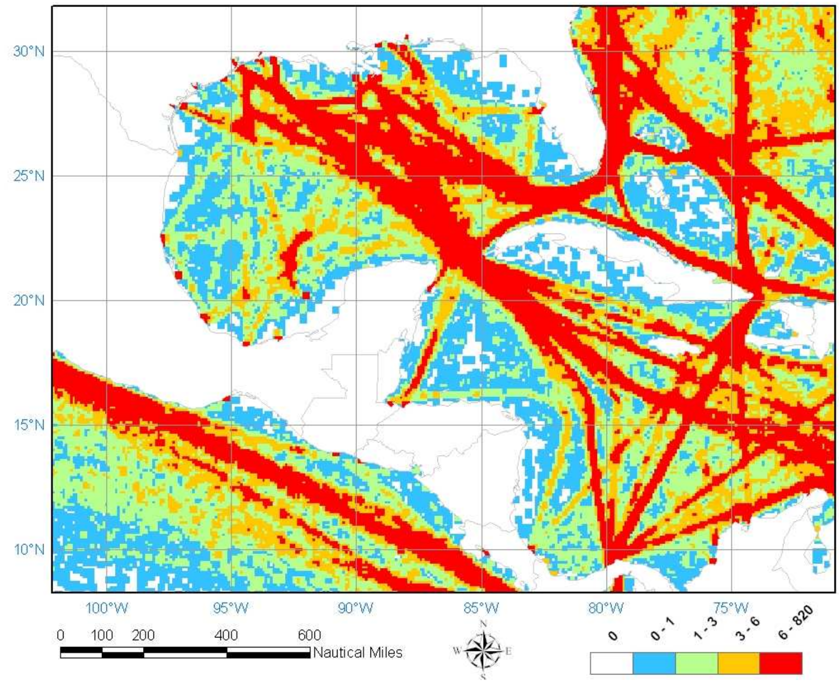


Source: Figure based on information from AMVER (2005), Corbett et al. (1999), Corbett & Koehler (2003), Wang et al. (2006) and ICOADS.

Note: Value of each 0.1 by 0.1 degree cell is the number of metric tons of ship sulfur emissions in that grid cell in 2002.

Figures 3 and 4 focus in more detail on emissions in Latin America and the Caribbean. Emissions levels are particularly high in the Gulf of Mexico (see figure 4), the Caribbean Sea, along the west coast of Central America and the east coast of Brazil. In general, it becomes clear that a substantial share of maritime traffic takes place relatively close to the coast. Problems with air pollution from maritime traffic can be expected to be worst where emission levels are the highest.

FIGURE 4
SHIP NITROGEN EMISSIONS IN THE GULF OF MEXICO



Source: Figure based on information from AMVER (2005), Corbett et al. (1999), Corbett & Koehler (2003), Wang et al. (2006) and ICOADS (2005).

Note: Value of each 0.1 by 0.1 degree cell is the number of metric tons of ship nitrogen emissions in that grid cell in 2002.

An alternative source of information is provided by bunker fuel statistics. Tables 3 and 4 represent some of the data from the EDGAR database for the year 2000 (EDGAR, 2005). It provides information on emissions from different sources worldwide. One of the sources distinguished is maritime transport. CO_2 emissions are based on bunker fuel statistics. Emissions are allocated to the country where the bunker fuel was sold. By specific emission factors the emissions for the other pollutants were calculated. We mention once more that it should be noted that these numbers may be underestimating the actual emission levels of emissions from shipping and hence also the share of maritime transport in total emissions.

Table 3 shows for 13 regions of the world the emissions associated with the purchase of bunker fuels for maritime transport and the share of these emissions in total emissions. It can be seen that the share in total emissions varies substantially worldwide.

TABLE 3
OVERVIEW OF EMISSIONS OF MARITIME TRANSPORT AROUND THE WORLD

	CO2		NOx		SO2	
	Maritime transport	Share in total CO2 emissions	Maritime transport	Share in total NOx emissions	Maritime transport	Share in total SO2 emissions
	Tg CO2	%	Tg NOx	%	Tg SO2	%
Canada	1.95	0.33	0.04	1.79	0.03	1.14
USA	85.99	1.38	1.93	9.95	1.42	7.96
OECD Europe	114.98	2.98	2.58	17.80	1.89	13.39
Oceania	3.90	0.91	0.09	2.58	0.06	2.36
Japan	19.38	1.47	0.43	13.07	0.37	14.16
Eastern Europe	1.61	0.17	0.04	1.25	0.03	0.26
Former USSR	20.26	0.73	0.46	4.89	0.32	2.18
Latin America	27.26	1.00	0.61	3.91	0.45	3.46
Africa	24.86	1.20	0.56	3.36	0.42	4.81
Middle East	47.98	3.30	1.07	18.16	0.92	11.41
South Asia	2.83	0.19	0.06	0.78	0.04	0.49
East Asia	37.28	0.78	0.84	4.68	0.62	1.50
Southeast Asia	39.43	3.11	0.88	11.98	0.71	13.36
Total	427.72	1.43	9.57	7.56	7.29	4.85

Source: EDGAR 3.2 Fast Track 2000, EDGAR (2005).

Note: For the exact definitions of the regions, see EDGAR (2005).

We have not included the emissions of CO and VOC in this table. According to the database, maritime transport only contributes about 0.01% to overall emissions of these pollutants. Therefore these pollutants are not extensively discussed further in this report.

For most of the emissions in table 3, the contribution of maritime transport to global and regional emission levels is relatively modest. It should however be remembered that these numbers are based on bunker fuel statistics and not necessarily indicate where emissions actually take place. Other more detailed sources indicate that in certain regions emissions from maritime transport do in fact contribute considerably to total emission levels. For example, EC (2002) indicates that ships emissions in EU seas may compare to 78% of all EU land emissions of SO_2 by 2010, and 68% of all land emissions of NO_x. In 2020, ship emissions may be higher than those of land based sources (EC, 2005). Global NOx emissions from ships may be as high as the entire amount of NOx emissions from the US.

European studies further show that maritime transport may emit more NOx and SO_2 than all land-based sources combined in 2020 (EC, 2005). For some seabordering countries such as Denmark, emissions from ships sailing near the border already surpass emissions from all land based sources. Emissions from ships may bring as much nitrogen oxide to the atmosphere as the total amount of emissions coming from the US. A Canadian study (GVRD, 2002) indicates that marine transport is responsible for 22% of all NO_x emissions, 33% of SO_x emissions and 7% of PM10 emissions in the Lower Fraser Valley Airshed (including natural emission sources).[19] Moreover, the bulk shipping terminals are responsible for a further 9% of PM10 emissions. Marine transport is responsible for 12% of the more dangerous PM2.5 emissions.

[19] For a clear distinction of the contribution of various types of vessels, see the underlying report (Levelton, 2002).

Unfortunately, for Latin America and the Caribbean such detailed information is not available and our analysis will be based on bunker fuel statistics. Table 4 presents estimates for all the countries included in the Latin American category in the EDGAR database.

For some countries it is reported that emissions are zero. For land-locked countries this is correct, for other countries such as for example Cuba it appears unlikely. Possibly information on bunker fuel statistics for maritime transport was not available for these countries.

TABLE 4

OVERVIEW OF EMISSIONS OF MARITIME TRANSPORT IN LATIN AMERICAN COUNTRIES

	CO2 Maritime transport Gg CO2	Share in total CO2 emissions %	NOx Maritime transport Gg NOx	Share in total NOx emissions %	SO2 Maritime transport Gg SO2	Share in total SO2 emissions %
Aruba	51	5.12	1.1	22.74	0.8	16.11
Anguilla	0	0.00	0.0	0.00	0.0	0.00
Netherlands Antilles	5 313	47.82	118.6	80.77	95.6	64.25
Argentina	1 751	1.14	39.5	3.44	26.1	5.71
Antigua and Barbuda	9	5.14	0.2	8.55	0.2	1.30
Bahamas	48	5.14	1.1	28.07	0.8	17.31
Belize	12	0.20	0.3	0.91	0.2	2.94
Bermuda	13	5.50	0.3	23.90	0.2	17.64
Bolivia	0	0.00	0.0	0.00	0.0	0.00
Brazil	7 567	0.67	169.8	2.43	124.9	4.38
Barbados	21	3.32	0.5	13.64	0.3	14.08
Bouvet Island	0	0.00	0.0	0.00	0.0	0.00
Chile	1 177	2.01	26.1	7.03	23.1	0.75
Colombia	449	0.32	10.4	1.64	3.4	1.27
Costa Rica	0	0.00	0.0	0.00	0.0	0.00
Cuba	0	0.00	0.0	0.00	0.0	0.00
Cayman Islands	9	4.95	0.2	21.55	0.1	15.98
Dominica	2	3.34	0.1	10.30	0.0	16.18
Dominican Republic	0	0.00	0.0	0.00	0.0	0.00
Ecuador	1 146	4.93	25.1	15.69	21.0	14.65
Falklands Islands (Malvinas)	1	5.82	0.0	30.19	0.0	14.55
Guadeloupe	40	4.19	0.9	20.61	0.7	15.88
Grenada	5	4.44	0.1	19.80	0.1	17.77
Guatemala	381	1.03	8.8	4.18	2.6	3.19
French Guiana	24	2.53	0.6	17.41	0.4	13.87
Guyana	26	0.52	0.6	2.08	0.4	5.84
Honduras	0	0.00	0.0	0.00	0.0	0.00
Haiti	0	0.00	0.0	0.00	0.0	0.00
Jamaica	117	1.00	2.7	4.58	0.8	0.65
St Kitts & Nevis (St Christopher)	3	4.67	0.1	18.61	0.0	16.91
St Lucia	5	4.01	0.1	14.94	0.1	16.17
Mexico	1 918	0.39	44.4	1.97	14.7	0.50

TABLE 4 (CONCLUSION)

	CO_2 Maritime transport	Share in total CO_2 emissions	NOx Maritime transport	Share in total NOx emissions	SO_2 Maritime transport	Share in total SO_2 emissions
	Gg CO_2	%	Gg NOx	%	Gg SO_2	%
Montserrat	1	3.27	0.0	28.20	0.0	9.79
Martinique	54	4.75	1.2	23.40	0.9	16.34
Nicaragua	0	0.00	0.0	0.00	0.0	0.00
Panama	3 269	33.31	72.7	49.77	61.6	65.11
Peru	90	0.16	2.0	0.52	1.8	0.16
Puerto Rico	0	0.00	0.0	0.00	0.0	0.00
Paraguay	0	0.00	0.0	0.00	0.0	0.00
El Salvador	0	0.00	0.0	0.00	0.0	0.00
Suriname	60	0.90	1.3	7.74	1.0	12.24
Turks & Caicos Islands	0	0.00	0.0	0.00	0.0	0.00
Trinidad and Tobago	159	0.75	3.6	6.47	2.6	6.59
Uruguay	1 181	14.15	26.6	28.41	18.8	35.18
St Vincent & The Grenadines	4	3.26	0.1	10.94	0.1	16.01
Venezuela	2 052	0.92	45.8	4.73	37.3	5.82
British Virgin Islands	1	0.16	0.0	0.37	0.0	2.04
Virgin Islands (US)	303	7.64	6.8	29.72	5.0	25.89
Total	27 260	1.00	611.4	3.91	445.6	3.46

Source: EDGAR 3.2 Fast Track 2000, EDGAR (2005).

Note: Countries included are those as defined in EDGAR to be part of Latin America.

It can be seen from this table that based on the allocation to countries by bunker fuel sales, emissions from maritime transport can be substantial compared to the emissions from all land-based sources (transport and non-transport).

So far we have discussed the types of emissions that are caused by maritime transport, and how these emissions may impact on human health and the environment. We then discussed estimates for the global amount of emissions or maritime transport and presented graphs that indicate where these emissions take place.

In the next chapters we will provide information on the actual impact of emissions on local air quality and climate change, and discuss what technical and policy measures can be taken to limit emissions.

V. Impact of emissions

In the previous sections we described the different emissions caused by maritime transport and the total amount of emissions caused. In this section, we go into more details regarding the impact these emissions may have. The first part of this chapter deals with local air pollution and the last part with climate change impacts.

The section on local air pollution starts off with a background on the current situation with respect to local air quality in Latin America and the Caribbean. We then provide some evidence on the contribution of ship emissions to air pollutant concentrations over land. Next we describe how the impact of emissions of air pollutants may be economically valuated.

Finally, in section 5.4 the impact of ship emissions on climate change will be discussed. Although scientific knowledge is currently not able to provide any definite answers, some indications about the size of the different effects of shipping on climate change are presented.

5.1 Air quality in Latin America and the Caribbean

In this section we briefly describe the different sources of air pollution. Next, we discuss the general situation in Latin America. For a good overview of studies on the impact of air pollution on health in Latin America and the Caribbean, see PAHO (2005) and Bell et al. (2006).

Air pollution is a broad term and is both caused by natural processes and anthropogenic sources (human activity). Natural sources include dust, methane from food digestion by animals, volatile organic compounds from pine trees and sulphur and particulates from volcanic activity. For an overview of 'natural sources' of air pollution in Latin America, see PAHO (2005).

Air pollution caused by human activity is primarily related with the burning of different kinds of fuels. This can relate to internal combustion engines in vehicles, but also to fuel burned in power plants, fireplaces, stoves, incinerators etc. Controlled fires in agriculture and forest management also contribute to air pollution. Other human activities that are not related to the burning of fuel but do contribute to air pollution include oil refining, fumes from paints and waste deposition in landfills, which generates methane.

Air pollution is a very serious problem. Worldwide exposure to particulate matter alone is estimated to cause 800,000 premature deaths annually. Local air quality problems in Latin America have roused attention since the 1990s. Due to urban development and industrialization, air pollution became a serious problem, especially in the major cities of the region with large populations. Examples are Mexico City, Santiago, Bogotá, Sao Paulo, Lima and Quito.[20]

In many instances, the specific geographical and meteorological situations of these cities play a significant role in enhancing the problems. Outside of urban areas, air pollution has been less of a problem.

According to PAHO (2005) ambient concentrations of particles and other pollutants exceed national air quality standards in many cities of Latin America and the Caribbean. Over 110 million people in Latin America and the Caribbean live in areas with air pollution concentrations above the health-based WHO guidelines (WHO, 2000). This is over 21% of the total population in Latin America and the Caribbean. ECLAC (2003) provides a more detailed overview of air pollution in Mexico City, Santiago and Sao Paulo.[21]

Exposure to the type of pollutants and level of concentrations commonly found in urban areas has been linked to an increased of mortality and morbidity. It is estimated that every year, 35,000 people in Latin America die prematurely due to air pollution. However, PAHO (2005) that this is most probably an underestimation and the real number is likely to be higher. Clearly, the costs to society associated with air pollution are much larger than the burden from premature deaths alone. People are ill and cannot go to work, they are less productive, there are medical costs etc. Moreover, air pollutants also affect the environment by causing acidification and eutrophication and damaging ecosystems. In section 5.3 we discuss ways to valuate the costs of air pollution to society.

In general, emission inventories on the emissions from different sectors are relatively scarce for cities in Latin America and the Caribbean. Similarly, reliable measurements of concentrations of air pollutants are not generally available. The data that are available indicate clearly however that exhaust gases from road traffic are often the main source of air pollution in Latin American cities. For example, it is estimated that the contribution of the transportation sector to emissions of particles (PM10) is 40% in Mexico City and up to 86% in Santiago. In both cities, road transport contributes over 75% of all emissions of NOx (O'Ryan & Larraguibel, 2000).

Since some time now attention has been paid to these problems, focusing primarily on reducing emissions from road traffic, one of the largest single sources of emissions. In the last decade, progress has been made and concentrations of air pollutants have gone down gradually.

[20] It should be noted, that also in other large cities the air is often polluted, sometimes up to a severe level. However, civil society is often unaware of the existence or seriousness of the situation, possibly due to a lack of monitoring data; see e.g. ECLAC (2003).

[21] On the website of the ECLAC further information can be found for Buenos Aires, Lima and Rio de Janeiro.

The Clean Air Initiative for Latin American cities (Cleanairnet, 2006) established under guidance of the Worldbank is one of the (international) initiatives to improve air quality in Latin America. Despite these efforts, in many instances recommended values of the WHO are still frequently exceeded.

5.2 Impact of ship emissions on air quality over land

We have seen in chapter IV, that the contribution of shipping emissions to overall emission inventories can be substantial. As noted, these contributions were based on statistics on bunker fuel sales, and are in general not a good indicator of where emissions actually take place.

To be able to determine whether emissions from maritime transport are an important source of air pollution in Latin America and the Caribbean, detailed information on the contribution of different emission sources to concentrations of air pollutants over land would be required. Such information is not available. Up to our knowledge, there do not exist detailed emission inventories for Latin American cities that include the shipping sector. Nor is information available on the contribution of emissions of maritime transport to the concentrations of pollutants. To provide an indication of the potential impact of the shipping sector nonetheless, we present information for other regions.

Emissions from maritime transport cannot be directly compared to emissions over land or even within cities. The impact of emissions depends in part on where they take place and on where emissions are depositioned. One argument often heard is that the emissions from maritime transport take place at sea and that therefore the impact on local air quality over land is negligible. This argument is not generally valid. The majority of emissions from ships take place close to the coast. Although different gases have different lifetimes, if the wind direction is inland, these gases may reach land. Moreover, a substantial part of the emissions from maritime transport (up to 10%, Entec 2002), takes place during operations within ports.[22] Many ports are located within or near large cities and emissions from vessels during port operations may contribute significantly to air quality within these cities.

ARB (2005) provides ample evidence of the impact of offshore emissions on onshore air quality. We present here some of the issues discussed in that document.[23] Approximately 80% of global emissions from vessels take place near the coast. Traces studies have shown that off shore emissions can be transported over water, with sometimes very little dispersion (depending on meteorological conditions). The distance that offshore pollutants can be transported depends on their lifetime in the atmosphere, the models used and the meteorology of the coastal area.

A study[24] using 10 years of hourly surface wind data was performed to estimate the probability that offshore emissions will impact land from specified distances. The study showed that for California the probability that emissions from 50 nautical miles offshore would reach the coast within 96 hours was over 80%.

Further evidence of the impact of offshore emissions on onshore air quality was collected during a strike in the ports of Los Angeles and Long Beach (US). Because of the strike, port operations shut down and 200 ships were idling on the coast. Researchers analyzing air quality before, during and after the strike found statistically significant increases in concentrations of particles, NOx and CO during the strike.

22 For more details about in port emissions in European ports, see Entec (2002).
23 Please refer to ARB (2005) for the primary references.
24 ARB (2005) refers to Eddington & Rosenthal (2003), see references. We have not been able to locate this note.

A Danish study (Saxe & Larsen, 2004) has specifically looked at the dispersion of emissions from ships in Danish ports. In the Copenhagen port, ship emissions caused concentrations of NOx exceeding the European legal limit. In the port of Elsinore, ferries contributed significantly to the NO_x pollution in the neighborhood around the harbor. Particulate emissions contribute 8 to 15% of that of all urban road traffic to the background PM10 levels in the harbor neighborhoods of Copenhagen.

Two further papers show that the impact of ship traffic emissions to the concentrations of pollutants in European coastal regions may be considerate. Fagerli & Tarrason (2001) carried out model calculations to show that the contribution of ship emissions to concentrations of nitrate, sulphate and ammonium varies between 20 to 30% in most western European coastal areas. Secondary particulates formed from SO_x and NO_x emitted to the atmosphere may be deposited several hundreds of kilometers away from the ship.

According to NMI (2000), also based on model calculations, the relative contribution of international shipping to the deposition of sulphur in European countries may be as high as 15 %. Especially countries bordering to the sea are affected. The relative contribution to deposition of oxidized nitrogen is slightly higher, with outliers of 38 and 24% for Malta and Cyprus respectively.[25] More important than these relative contributions is probably the notion that for most countries bordering the sea, international shipping is one of the largest single contributors, both for oxidized sulphur as for oxidized nitrogen.[26]

Capaldo et al. (1999) note that nearly 70% of ocean-going ship emissions occur within 400 kms of land. Ship emissions often contribute more than 5% and as much as 30% to the modeled SO_2 concentrations in coastal regions.

With tightening regulations on cars and light vehicles in the EU and the US, emissions from shipping become more and more an important contributor to local air quality problems. It is expected that this trend will further be strengthened in the future due to significant increases in maritime transport. For example, shipping traffic to and from the US is projected to double by 2020. Entec (2005d) assumes a 2,6% annual growth rate of maritime transport for Europe up to 2020. Examples of where emissions from shipping cause local problems in the US are Southern California, Houston and Galveston, Pittsburgh and the Columbia River Gorge between Oregon and Washington.[27]

There is a thus a lot of evidence that emissions from ships have an impact on local air quality. This holds especially for port cities, but also in general for coastal regions. We have not been able to find specific studies for Latin America and the Caribbean, but there is no reason to suspect that matters will be different.

Of the seven Latin American cities with over 5 million inhabitants in 2002, São Paulo, Buenos Aires, Rio de Janeiro and Lima/Callao are all port cities. Santiago is at least in theory located near enough to the coast to be affected by emissions from maritime transport.[28] All of these cities struggle with air quality problems. Examples of other coastal and port cities in Latin America that may be affected are Puerto Santos (Venezuela), Santos (Brazil), Panama, Havana, Montevideo and Guayaquil.

25 Clearly, the relative contribution of international shipping depends both on the emissions from the shipping sector and on the emissions from land based sources. For this reason, the percentage contribution of countries with major land based sources, such as the Netherlands, Belgium and the UK may be a better indicator. For these countries, contributions to deposited oxidized nitrogen are 13, 9 and 11% respectively.

26 NMI (2000) also models the impact of ship emissions on ozone levels. We do not go into this here.

27 For an extensive article on ship pollution in the US, see USA Today (2004).

28 Whether this is actually the case should be studied by specified models.

5.3 Economic valuation of air pollution

In some situations it can be useful to express the impact on environment in monetary values. This can be useful when trying to get attention to the seriousness of a problem. Alternatively, it may be useful when in doubt about whether to implement a costly mitigation measure. Do the benefits of reduced emissions weigh up against the cost of the measure? Also, in some cases one has to make a choice between for example reducing the NO_x emissions or the CO_2 emissions. One then wants to know what is better for society.

In this section we briefly discuss different ways to put a monetary value on the costs of air pollution. The focus will be on the costs associated with the impacts on human health.

Subsequently, we discuss several studies in which valuation methods have been applied for the environmental costs of air pollution for Latin America and the Caribbean.

Air pollution leads to different costs for society. First, there are costs associated with the impact on human health. These include the costs of medical treatment and human suffering of both patient and family, but also the costs of reduced activity. A person that is ill or has died prematurely cannot contribute to the economy. Some of these costs can be related to actual expenditures, such as for example the expenditures on medical treatment and other costs such as the costs of human suffering cannot.

Second, there are costs for society due to the impact on the environment. For example, ozone and hydrocarbons may affect crop production. Air pollutants in general may affect ecosystems and cultural heritage. Buildings may also be affected.

In general, shadow prices may be used to determine the economic value of goods for which no market value exists. Shadow prices can be based on the valuation of damage costs, but also on other methods such as for example willingness to accept, the compensation costs and hedonic pricing. The preferred method depends on the specific situation.

It is not straightforward to determine the shadow price of air pollution. In the first place, one needs to know exactly to what extent air pollution has actually caused the costs above. For example, which respiratory problems can be associated with air pollution, and which are caused by other factors? Crop loss may be the effect of air pollution, but can also be costs by lack or abundance of rainfall.

In the second place, one needs to put monetary values on the impacts caused by air pollution. For some things this may be easy (e.g. the costs of medicines, the costs of crop loss), for others such as premature deaths, human suffering and degradation of ecosystems this is much more difficult.

Bottom up evaluation of health costs may take the following approach. In a first step, the amount of emissions is estimated. Next, the impact of these emission levels on the concentration of air pollutants needs to be estimated. Dose-response or concentration-response functions are then used to determine the probability of different health impacts (e.g. acute mortality, acute respiratory hospital admission, chronic adult bronchitis) occurring. This results in estimates for the number or premature deaths etc. and also in a number for the person-days of work loss or other restricted activity.[29] By putting a value on these different medical impacts, the costs per unit of emission can be estimated. Such a value can be determined by estimating the productivity loss, or the cost of

[29] See for example Cifuentes et al. (2001).

medical expenditures. Alternatives are hedonic valuation and contingent valuation methods.[30] For more information on economic valuation of health impacts, see also CAI-LAI (2002).

Table 5 provides examples of shadow prices for different pollutants. Information on shadow prices for air pollutants that apply to Latin America and the Caribbean is scarce.

TABLE 5
EXAMPLES OF SHADOW PRICES (IN € PER TON)

	Region	SOx	NOx	PM2.5	VOC
BeTa database	EU hypothetical port (2 million inhabitants)	95,000	1,500 – 8,200	509,000	490 –7,200
Beta database	EU hypothetical port (100.000 inhabitants)	11,500	1,500 – 8,200	47,000	490 –7,200
BeTa database	EU, at sea in Eastern Atlantic	4,500	4,800	9,100	1,500
Worldbank (1994)	Santiago, Chile	$ 82	$ 12,336	$ 3,831 (PM10)	$ 33,167

Note: values are in Euros of the year 2000, dollars relate to 1994.

The Benefits Table for the EU (Netcen, 2001) distinguishes emissions in ports, emissions close to the shore and emissions somewhat further from the shore. Emissions wide at sea in oceans have not been considered. It should be noted that numbers cannot be used for other regions. We refer to Netcen (2001) for a discussion of the effects that have been taken into account. The study by the World Bank is relatively old and since then knowledge of health impacts of emissions has increased enormously. Shadow prices were calculated based on the potential health gains certain control programs were expected to deliver. Making use of dose-response functions related to concentrations of pollutants, shadow prices were determined.

Estimates differ regionally for various reasons. First, in densely populated areas, more people are exposed and more people are likely to be affected. Table 5 indicates that the cost of emissions of SO_x and PM2.5 vary widely with the population density in the area where the emissions take place. This is not so much the case for NO_x and VOC, because the quantified impacts are linked to the formation of secondary pollutants such as ozone in the atmosphere. Given that these take time to be generated in the atmosphere, the impacts will take place more geographically dispersed and local variation in population density has little effect on the costs. Second, in different regions health may be valued differently, and also the prices of health care may be different.[31]

Although shadow prices per unit of emission are not available for Latin America and the Caribbean, some studies have related changes in the concentration of pollutants to health costs. We briefly discuss two studies.

Cifuentes et al. (2005) evaluate the benefits to society of a uniform reduction of 10% in the annual ambient concentration of PM10 in 41 Latin American cities. The study makes use of the integrated assessment approach. Changes in concentrations of pollutants are related to changes in human exposure to pollutants. The changes in exposure are related to changes in health effects by applying concentration-response functions. In a final step, valuation models are applied to value the changes in health effects. For the valuation of health two different methods are applied. According to this study, the total premature deaths avoided by pollution control could be in the order of 2 to 2.6% of total annual deaths in the cities considered. Valuation of health benefits by either method

[30] For a short overview and suggested readings, see Glover (1995).
[31] Impacts also depend on meteorological conditions and background concentrations. These effects are not included in the estimates.

indicates that the benefits of pollution control may be more that $ 1.5 billion per year. Benefits of this order clearly warrant significant investments in pollution control.

Bell et al. (2006) studied the health effects of air pollution in three Latin American cities, namely Santiago, São Paulo and Mexico City. They have estimated the impact of a control policy aimed at lowering air pollution emissions in the period 2000 to 2020. The economic value of avoided health impacts resulting from lower annual levels of ozone and particulate matter for these three cities alone were estimated at $21 to $165 billion (US) over the period 2000 to 2020.

5.4 Impacts of ship emissions on climate change

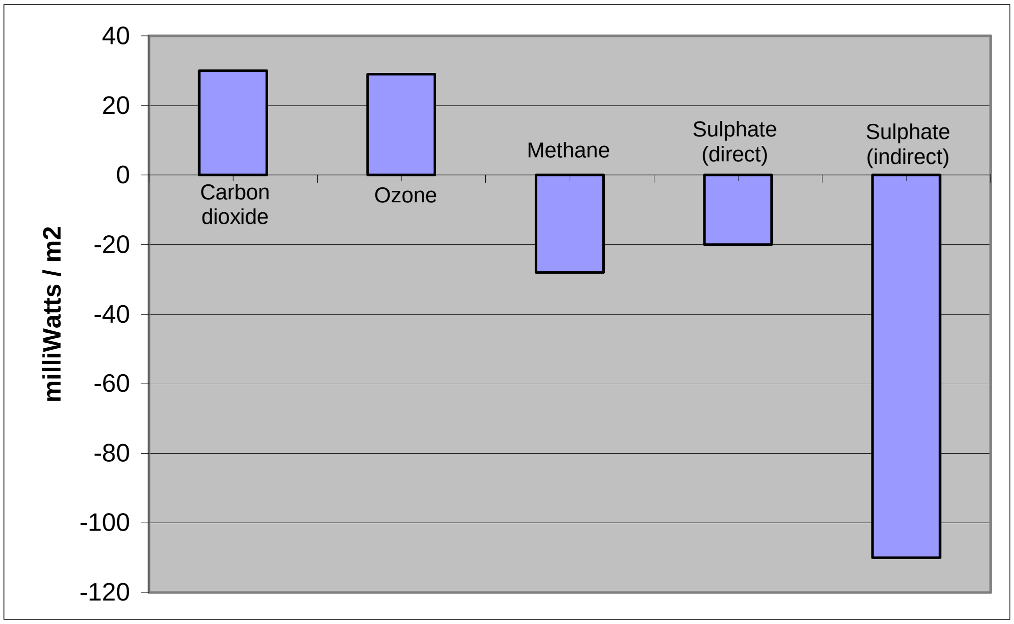
To induce the overall effect of ship emissions on climate change[32] is not an easy task. As we have seen in chapter III, many gases interact in the atmosphere and a lot of the effects are highly non-linear. Impacts do not only depend on current emission levels, but due to the long lifetimes of some of the gases, also depend on past and future emission levels (and of emissions from other sources). Some gases have fore mostly a local impact, whereas the impact of others is global. For these reasons, very complicated climate models are needed to evaluate the impact of emission scenarios. Despite these models, scientific uncertainty about some of the effects remains, because not all of the scientific processes are yet well understood.

Overall, the net impact of ship emissions on climate change may well be a cooling effect and thus counteract global warming. The emissions of carbon dioxides have a warming effect, just as the ozone formed from NO_x. The reduction in methane levels in the atmosphere induced by the NO_x emissions may be in the same order as the ozone impact, but in opposite direction. The direct impact of sulfates is cooling, and especially the indirect impact of sulfates is expected to be very large and cooling. The climate impact of black carbon and organic carbon from shipping is very small.

Figure 5 collects best estimates of impacts from shipping. It should be kept in mind the scientific uncertainty with respect to the level of the impacts is large. These stem both from uncertainties with respect to the emission levels from shipping (as indicated in section 4.1) and the science of the climate system.

32 For an extensive background on the problem of global warming and the evidences thereof, visit the website of the UNFCCC at: http://unfccc.int/essential_background/feeling_the_heat/items/2902.php

FIGURE 5
ESTIMATES OF GLOBAL RADIATIVE FORCINF EFFECTS FROM SHIPPING



Source: Carbon dioxide, ozone, methane and direct sulphate from Endresen et al (2003), indirect sulphate effect from Capaldo et. al (1999).

Could we conclude that maritime transport is actually good for the environment because of the net cooling effect, counteracting global warming? This is definitely not the case. First of all, some impacts are local and regional (SO_4), whereas others (CO_2) are global. The *net global* radiative forcing may be negative, however most scientists do not believe that the cooling and warming effects actually cancel out in terms of climate. Radiative forcing is related to temperature changes, but there are also other climate effects such as change of winds, changes in precipitation etc.

Second, shipping has an impact on local air pollution. This cannot be compared directly to the climate impact. The cooling effect of SO_4 with respect to climate change cannot be weighted against the negative impact of the SO_2 emissions on the local environment and human health.

VI. Policies and measures

In this part of the report we discuss how the environmental impact of maritime transport can be reduced by so-called emission mitigation measures. We will distinguish between policies targeted at local air pollutants and those that aim to limit the climate impact of maritime transport. As will be clear by now, the distinction is not always so clear-cut and many measures aimed at for example reducing emissions of CO_2 will also influence emission levels of other gases. Moreover, air pollutants also have climate impacts. Policies are often primarily targeted at either local air pollutants or greenhouse gases.

In section 6.1, we describe what measures can be taken to reduce emissions of local air pollutants from maritime shipping. These include both technical measures such as installing a fuel-efficient engine, and operational measures such as increasing the load factor, reducing speed and using low-sulfur fuel.[33] Where available, an indication of the emission reduction potential by these measures will be provided. Next, we discuss international and national / regional policies to incentive the application and implementation of the mitigation measures. Section 6.1.2 discusses developments within the international framework and in section 6.1.3 national/regional measures and best practices will be discussed.

[33] This may also be regarded a technical measure. We included it under operational measures because it does not alter the technical layout of the ship.

The section on climate change has a similar set up. We first discuss concrete technological and operational measures to reduce emissions (section 6.2.1). Then, international actions within the UNFCCC and the IMO on this subject are presented. Last, regional and national policies and best practices are discussed.

Based on these discussions, we provide some recommendations with regard to environmental policy for maritime transport in Latin America and the Caribbean in the final chapter.

6.1. Local air quality

6.1.1 Technical and operational mitigation measures

In this section we discuss the actual technical and operational measures that can be implemented to influence emissions from shipping. Where available, the potential emission reduction and costs of measures are also provided. The information presented in primarily based on studies by Entec (2005) for the European Commission and a study by Martintek et al. (2000) for the IMO. For more information concerning mitigation options, we refer to the original studies.

It should be noted first, though, that there is a marked difference between the impact of technical measures on emission levels of the world fleet and the impact of operational measures. In general, it may be some time before technical measures related to new ships impact emission levels substantially. The useful life of ships reaches well over twenty years. Changes to new ships will therefore take a long time to be adapted by the whole fleet. Technical measures that can be applied 'retrofit', i.e. after a ship has been taken in service, will generally have an impact sooner.

Operational measures, in contrast to technical measures, may be implemented within a very short timeframe and can therefore directly impact the emissions of the fleet. Changes in speed, load factor and routes may be implemented almost directly.

The study for the IMO (Marintek et al., 2000) provides a good overview of the possibilities to reduce emissions. Some results are presented here. For the workings of the different techniques, we refer to the original document.

TABLE 6
SEVERAL MEASURES FOR DIESEL ENGINES ON NEW SHIPS IMPACTING EMISSIONS

Measure	Impact
Reducing fuel consumption	Reduction of HC and CO
Retarded timing	Reduced NOx, increased CO2
Low NOx combustion	
Water injection	
Water emulsion	
Humid air motor /	Reduced NOx, minor impact on CO2
Exhaust gas re-circulation	
Selective catalytic reduction	
Miller cycle	
Seawater scrubbing	
Fuel specification	Reduction of sulphur

Source: Marintek et al. (2000).

To some extent, these measures can also be applied to existing ships. Retarded timing on existing ships can reduce NO_x emissions by about 10% at little financial costs, but CO_2 emissions will increase by about 10%. Low NO_x combustion processes may reduce NO_x emissions by up to 30%, and has the benefit of reducing CO_2 emissions by 2 to 5%. Water injection and water emulsion come at medium costs, and may reduce NO_x by 60 and 25% respectively. The humid air motor, exhaust gas re-circulation and selective catalytic reduction can effectively reduce NO_x (by 60, 20 and 90% respectively), but would require the installation of new space. This would imply extra investments and additional operating costs.

The fuel specifications have an impact on the emissions of various gasses. Different fuel types can be distinguished:

- marine gas oil (MGO)
- marine diesel oil (MDO)
- intermediate fuel oil (IFO)
- heavy fuel oil (or residual fuel oil, HFO)

About 80% of the fuel consumption for shipping is HFO. This is the product that results at the end of the processing line in a refinery. Marintek et al. (2000) note that over the years refinery plants have been introduced that enable to extract more and more light distillates from the crude oil. The result has been that the quality of the residue of this process, HFO, has deteriorated. HFO needs to be heated onboard a ship before it can be used for combustion. The sulphur content of HFO lies between 2.5 and 4.5%.

Intermediate fuel oil, marine diesel oil and marine gas oil are lighter fuels that contain less sulphur and do not require heating before use. IFO and MDO can be mixtures of heavy fuel oil and distillates. The maximum sulphur content of MDO is 1.5%. For coastal shipping, the use of MDO with a sulphur content of around 0.5% is gradually increasing.

The main environmental benefit from replacing HFO by a lighter fuel is the reduced emissions of sulphur. There are some additional co-benefits as well. Marintek et al. (2000) note that the combustion properties of light fuel oil are good, and therefore the production of NO_x is somewhat lower than that of HFOs. CO_2 emissions may also be reduced by as much as 5%. There is further evidence that the use of MDO instead of HFO reduce the maintenance costs of engines, since MDO is cleaner the HFO. The workload of the engine crew and second engineer may be reduced by as much as 65% or more.[34]

Heavy fuel oil is however cheaper than lighter fuels that contains less sulphur. Desulphurization of oil is expensive and energy consuming. Acid Rain (2003) noted that the price differential between low-sulphur bunker fuel (<1% sulphur) and high-sulphur fuel (3.5%) averaged around $19 per ton in the period 1990 – 2001. The European Commission estimated the costs as a result of new investments in desulphurization at the refineries at € 50 to € 90 per ton of fuel.

In a series of studies for the European Commission, Entec studied the potential of specific NO_x and SO_x emission reduction measures. Some of these measures were also included in Marintek et al. (2000). We briefly present the results below.

For measures targeting NOx emissions, the estimated reduction potentials are listed in table 7. Most of these measures are still at an early stage of development.

34 Information from the website of Wallenius: http://www.walleniusmarine.com/qse.jsp?art_id=37.

TABLE 7
ESTIMATED EMISSION REDUCTIONS FOR DIFFERENT MEASURES TARGETING NO_X

Measure	NO_x	SO_2	PM	HC
Basic internal engine modifications	-20	0	0	0
Advanced internal engine modifications	-30	0	0	0
Direct water injection	-50	0	0	0
Humid air motors	-70	0	0	0
Exhaust gas recirculation	-35	-93	> - 63	?
Selective catalytic reduction (2.7% HFO)[a]	-90	0	0	0
Selective catalytic reduction (1.5% HFO)	-90	-44	-18	?
Selective catalytic reduction (0.1% MDO)	-90	-96	> - 63	?

Source: Entec (2005b)

[a:] the impact of this measure depends on the fuel used. Therefore this measures is included thrice, with different fuel assumptions. The 2.7% sulphur content coincides with the average sulphur content of fuel used for shipping.

Apart from the emission reduction potential of these different measures, Entec (2005b) also lists cost estimates in €'s per ton of NO_x avoided. Costs differ between small and large vessels, with costs for large vessels typically lower per ton of NO_x avoided. Similarly, retrofit application is generally more expensive than application to new ships. Costs of internal engine modifications (IEM) vary between € 9 and € 19 per ton of NOx avoided for large ships. For small vessels, costs of IEM vary between € 12 and € 98 per ton of NOx. Application of any of the other measures will cost more than € 200 per ton of NOx avoided. Note that these cost estimates do not take account of any co-benefits such as in the case of exhaust gas recirculation and selective catalytic reduction. For more details, see Entec (2005b).

With regard to the reduction of SO_2 emissions, three specific measures were investigated:

- Sea water scrubbing
- Fuel switching from 2.7% sulphur HFO to 1.5% sulphur HFO
- Fuel switching from 2.7% sulphur HFO to 0.5% sulphur HFO

The emission reduction potential of these measures is listed in table 8.

TABLE 8
ESTIMATED EMISSION REDUCTIONS FOR DIFFERENT MEASIRES TARGETING SO_2

Measure	NO_x	SO_2	PM	HC
Sea water scrubbing	0%	-75%	-25%	?
Fuel switch from 2.7% to 1.5% sulphur	?	-44%	-18%	?
Fuel switch from 2.7% to 0.5% sulphur	?	-81%	-20%	?

Source: Entec (2005c).

The costs of these measures, expressed in € per ton of avoided SO_2 emission, were also calculated. The costs of applying sea water scrubbing on new ships varied between € 320 per ton of avoided SO_2 emissions for a large vessel to € 390 for a small vessel. Retrofit costs were about € 180 per ton of SO_2 more. The costs of fuel switching are independent of the size of the vessel whether it applies to new or existing ships. Estimates varied however considerably depending on the source of the average fuel price differential. The costs of the fuel switch from 2.7% sulphur to 1.5% sulphur vary between € 1,230 and € 2,053 per ton of SO_2 avoided. For the switch from 2.7% sulphur to 0.5% cost estimates ranged between € 1,439 and € 1,690.

Another option to reduce the emissions of local air pollutants is to provide shore-side electricity to vessels in the port. Instead of using auxiliary engines to provide electricity for hotelling, unloading and loading activities, ships can then utilize the electricity offered from ashore (cold ironing). There are several examples of ports around the world that have implemented this measure, such as Pittsburg, Gothenburg and Los Angeles.

Table 9 presents the emission reductions that may occur, as estimated in Entec (2005a). These relate to vessels that can indeed make use of shore-side electricity.

TABLE 9
ESTIMATED EMISSION REDUCTIONS FOR USING SHORE SIDE ELECTRICITY

Measure	NO_x	SO_2	PM	HC
Shore-side electricity compared to 2.7% sulphur	-97%	-96%	-96%	-94%
Shore-side electricity compared to 0.1% sulphur	-97%	0%	-89%	-94%

Source: Entec (2005a).

There are still emissions related to the productivity of electricity, but these take place somewhere else, often in less densely populated areas. Moreover, electricity plants may have implemented more emission reduction measures. Because electricity plants are generally much more efficient in producing power, CO_2 emissions associated with in port activities may be reduced by 50%.

The costs of shore-side electricity vary widely, depending on the electricity infrastructure near the port and the whether the port infrastructure is existing or whether installation can take place at the time of construction. Moreover, it depends on prices of fuel and electricity. According to Entec (2005a), it may become a financially attractive option for fuel prices above € 450 per ton (even without accounting for the benefits to society of reduced SO_2 emissions). For specific cost estimates[35] and practicalities of providing shore-side electricity to vessels docking in ports, see Entec (2005a).

Apart from these techniques that are to some extent already available, fuel cells are extensively being studied. One of the pioneering companies is Wärtsilä that unveiled a prototype fuel cell in 2005. This system uses a combination of methanol, natural gas and liquefied natural gas as fuel. According to the company, compared to MDO, emissions of CO_2 can be reduced by 20%, NO_x by 80% and SO_x completely. The company expects that initially fuel cells will mainly be suitable for auxiliary engines on relatively small vessels. A problem of fuel cell technology is that there are high initial investment costs and the fuel storage tanks require substantially more space than the tanks for traditional fuels.

In theory, we could now determine whether the implementation of mitigation measures would be desirable from a social point of view. In section 5.3 shadow prices of emissions were listed. These reflect the costs to society of emissions. Above we have listed estimates for the costs of reducing these emissions. If the costs of the reduction measures were below the benefits to society of reducing emissions, implementing reduction measures would make sense from a social point of view. We will however not carry out the comparison of costs and benefits because of the large uncertainties in both estimates and the lack of specific data for Latin America and the Caribbean.

[35] We have not included these here for two reasons. First, the uncertainty regarding the estimates is high. Second, cost estimates were presented as costs per ton of specific avoided local pollutant, while we think all local pollutants should be accounted for by weighting in the cost estimates.

6.1.2 International policies

In this section we describe the action undertaken within the IMO to limit the emission of air pollutants from ships. Although local air pollution is by definition a local problem, policies may be more effective when coordinated internationally. The reason is that maritime transport is a very international business. Unilateral policies may be difficult to enforce. National policies can be made to apply to nationally flagged vessels, but if meeting the requirements of the policies becomes too costly, ship owners may flag out. This would substantially reduce the environmental impact of the policy. Moreover, treating different vessels differently may lead to economic distortions. This is often regarded as unfair. For these reasons, internationally coordinated actions may be more effective. A disadvantage of internationally coordinated action is however that many parties have to reach agreement before any measure can be implemented. If not all parties agree, the implementation of environmental policy may be stalled.

The Marine Environmental Protection Committee (MEPC) of the IMO included air pollution in its work program in 1988. Two years later Norway submitted a number of papers to the MEPC giving an overview of air pollution by ships. Emissions of sulphur were then estimated at 4.5 to 6.5 million tons per year, and those of NOx at 5 million tons annually (for current estimates, see section 4.1). The aroused attention gave rise to a new Annex to the Marpol convention, Annex VI on the prevention of air pollution from ships. This Annex, which was adopted in September 1997, only entered into force May 19, 2005. It sets limits on sulphur oxide and nitrogen oxide emissions from ship exhausts and prohibits deliberate emissions from ozone depleting substances.

Annex VI sets a global cap of 4,5% m/m[36] on the sulphur content of fuel oil and calls on IMO to monitor the worldwide average sulphur content of fuel once the Protocol comes into force. Over the period 2002-2004 the average sulphur content used on board of ships was 2.67%, so the impact of the 4.5% global cap may in practice be very limited. The annex also contains provisions allowing for special 'SO_x Emission Control Areas' to be established. In these areas, the sulphur content of fuel oil used on board of ships may not exceed 1,5%. Alternatively, ships are required to fit an exhaust gas cleaning system or another technology to limit SOx emissions as to such a level as would have been achieved when using fuel with a sulphur content of 1.5%.

Suppliers of fuel in a country that signed Annex VI are legally required to comply with Annex VI. Fuel suppliers in other countries are not. However, vessels that purchase fuel of one of these suppliers will need to ensure that the fuel complies if they intend to call at a port in one of the signatory countries within three years of purchase of the fuel.

Annex VI furthermore poses limits to the emissions of NOx from diesel engines. The mandatory NOx technical code developed by IMO defines how this is done. Standards apply to diesel engines with a power output greater than 130 kW installed on ships constructed (or undergoing a major conversion) on or after January 2000. Annex VI furthermore lays down (voluntary) provisions for the regulation of emissions of volatile organic compounds that come free during the loading and unloading of oil tankers.

6.1.3 Regional policies and best practices

In this section we describe regional and national approaches to reduce pollutant emissions of the shipping sector. Also some best practice approaches will be presented.

[36] 45,000 parts per million.

European Union

Air pollution is a serious problem in Europe. Already a lot of attention has been paid to emissions from land-based sources. More and more attention is being paid to emissions from maritime transport now. The reason is that the contribution of this sector is now relatively high and many relatively cheap abatement measures may be available. Although the EU is keen on remaining working within the IMO to improve local air quality, many Member States recognize that EU measures would be a good way to deliver local air quality improvements and to increase momentum towards more stringent international standards at the IMO (EC, 2003). The EU does not find the NOx standards and the global sulphur cap agreed within IMO sufficiently stringent.

Under EU regulation (directive 1999/32/EC), marine gas oils within the territory[37] of EU Member States may not exceed 0,2% sulphur as of 2000 (and 0,1% from 1 January 2008). No regulation exists however for marine heavy fuel oil, which is used by the large majority of seagoing ships.

Two European regions, the Baltic Sea and the North Sea & English Channel have been marked as SO_x Emission Control Area under IMO regulations. On top of these areas, directive 2005/33/EC requires EU Member States to take all necessary measures that the sulphur content of marine fuels shall not exceed 1.5% within territorial seas and exclusive economic zones as well. Ships at berth in EU ports may not use marine fuels with a sulphur content exceeding 0.1% as of 2010.

United States

The US Environmental Protection Agency (EPA) is actively targets emission reductions from maritime transport.[38] Following regulations on the sulphur content of fuel used in road vehicles, the sulphur content of fuel for the non-road sector is being regulated. The current regulations only refer to distillates used in ships and do not yet apply to heavy fuel oil. EPA is of the opinion that standards for fuel sold in the US do not necessarily ensure the use of low sulphur fuel in US waters. Instead, the US EPA plans to investigate the designation of one or more areas in the US are SO_x emission control area under the IMO.

Emission standards for new vessels with engines up to 30 liters per cylinder are in place and are scheduled to be further strengthened (see EPA, 2004a and EPA, 2004b). Emission standards for new ocean going vessels with an engine of over 30 liters per cylinder are discussed in EPA (2003). These relate to vessels flagged or registered in the US and are in line with IMO standards. However, a second tier of standards in future rulemaking is foreseen. This will be completed before April 27th, 2007. For this future rules, EPA 'will consider the state of technology that may permit deeper emission reductions and the status of international action for more stringent standards. […EPA] will also consider the application of such a second tier of standards to engines on foreign vessels that enter U.S. ports' (EPA, 2003). New standards may be up to 30% stricter than the current norms.

Apart from obligatory standards, the EPA has developed the Blue Sky voluntary program. An engine qualifies as a Blue Sky engine when emissions are at least 80 percent below Marpol Annex VI levels. Incentive programs to develop and apply such engines can be put in place by users and state and local governments.

For more information on developments in the US, see the proceeds of two workshops on this issue that are provided on the MARAD website (NMREC, 2006). Other sources of information are the Clean ports workshop (Northeast, 2006) and an EPA workshop (EPA, 2006).

---

37 Territorial waters including seas 12 nautical miles from shore and in land waterways.
38 See also the website: http://www.epa.gov/otaq/marine.htm

BOX 2
COST EFFECTIVENESS OF POLICY MEASURES

Various sources provide information on the potential cost effectiveness of reduction measures in the maritime transport sector. It should be noted that such information relates to the specific situation studied. Acid Rain (2003) reports on EU calculations related to a strategy for combating acidification. If the EU interim target were to be attained solely by technical measures on land, the annual costs would be around 7 billion Euros in 2010. The overall cost could be brought down by 2.1 billion Euros annually, if more cost-effective measures to reduce emissions of NO_x and SO_2 from ships in the Baltic, North Sea and northeastern Atlantic.

The European Commission accompanied the EU sulphur strategy outlined in EC (2002) with some estimates of the cost effectiveness. According to the Commissions' calculations, the benefits of the strategy outweighed the costs by more than 2:1. Costs of reduced sulphur emissions were estimated at € 50 per ton of fuel, with total annual costs of € 1.1 billion. The proposal was expected to cut SO_2 emissions by about 10% or 507,000 metric tons and PM emissions by 8,000 metric tons. The benefits of the proposal included annually 2,000 fewer life years lost due to long term exposure, 750 fewer deaths from short-term exposure and 300 fewer hospital admissions for respiratory illnesses. Excluding the benefits from reduced acidification, which could not be monetized, annual total benefits were estimated at € 2.7 billion.

The US EPA put forward highway and non-road diesel programs to reduce emissions from diesel engines. These programs are expected to cut 90% of all harmful pollutants from these engines. The annual costs of these programs were estimated to come down to $ 4.2 billion and $ 2 billion respectively, in 2030. At the same time, the public health and welfare benefits were estimated at over $ 70 billion and $ 83 billion for the highway and non-road program respectively (EPA, 2004a).

Best practices

The state of California (US) has introduced regulations additional to those that apply for the US.[39] All vessels that are within 24 nautical miles of the coast of California are required to use low sulphur fuel in their auxiliary engines. As of 2007, emissions of auxiliary engines may not exceed emission levels of engines using marine gas oil or marine diesel oil with a sulphur content of 0.5%. As of 2010, the limit will be set by marine gas oil with a sulphur content of 0.1%.

The port of Los Angeles has introduced a voluntary speed reduction program or commercial cargo ships. Within a 20 nautical mile range of the port, a voluntary speed restriction of 12-knots applies, in order to reduce air pollutant emissions. There is generally good compliance with this measure. The emission reduction has been estimated at 1 tons of NOx per day (SeattlePI, 2004).

In Norway the tonnage tax, payable by Norwegian flagged vessels only, is differentiated depending on the environmental rating of the ship against several criteria.

In 1998 a system of environmentally differentiated fairway dues was introduced in Sweden. Fairway dues are a national levy payable by ships of all flags visiting Swedish ports, based on their gross tonnage and the volume of cargo transported. Since 1998 these dues are differentiated with respect to a ships' emissions of NO_x and SO_2. Ships that installed NO_x reduction technologies and/or used low sulphur fuel are liable to reduced dues.

The North Sea Conference held in Gothenburg in 2006 called in a declaration for a 40% cut in NO_x emissions from shipping in the long term, and a reduction in the permitted sulphur content of fuel to 1%. Ministers also launched the Clean Ship concept, under which criteria for the evaluation of the environmental performance of ships will be developed and used as an incentive for to encourage sustainable shipping. Furthermore, tax incentives to encourage the use of shore-side electricity will be put forward.[40] In a following EU recommendation, the EU called on governments to offer economic incentives to port operators such as electricity tax reductions to incentivice supply and use of shore-side electricity (ENDS, 2006).

The Green Award (see www.greenaward.org) is an initiative that offers incentives for socially responsible shipping. Ship owners that adhere to standards in the field of quality, safety and environmental protection can apply for a Green Award. With this award, they receive beneficial treatment, such as a reduction in port dues at around 50 ports around the world.

---

39 See: http://www.arb.ca.gov/regact/marine2005/marine2005.htm
40 See press release: http://www.sweden.gov.se/sb/d/6233/a/63463;jsessionid=aARgKpnjscMf, consulted May 12, 2006.

EcoPorts (www.ecoports.org) is an EU sponsored research project aiming to harmonize the environmental management approach of ports in Europe.

Apart from countries and regions, some shipping companies have implemented progressive environmental policies. For example, Wallenius Marine has been able to reduce NO_x emissions by the fleet by 19.9% since 1998 and the average sulphur content of the fuel is 1.16%. NO_x reductions were achieved by installing low NO_x auxiliary engines on new ships and installing low-NO_x valves of sliding type on existing ships. SO_x reductions came about by adjusting the fuel used in the vessels. Speed adjustments and route planning have been introduced to reduce CO_2 emissions, see Wallenius (2005). Wallenius uses MDO in the auxiliary engines, thus reducing PM emissions substantially while at berth and hence a particularly large number of people could be exposed.

Wallenius Wilhelmsen (see http://www.2wglobal.com/expo2005/english/index.jsp) is working on the development of a zero emissions car carrier, combining all sorts of environmentally friendly techniques.

Examples of progressive techniques that have already been applied can be found on the Clean Marine website (http://europa.eu.int/comm/environment/clean_marine/). Clean Marine is an initiative by the European Commission, providing awards to EU ship operators, EU shippers and EU authorities that are engaged in environmentally responsible shipping.

As discussed before, several ports furthermore offer shore-side electricity to reduce in port emissions.

6.2 Climate change

6.2.1 Technical and operational mitigation measures

In this section we describe technical and operational options to limit the amount of CO_2 emissions from shipping. As discussed before, CO_2 emissions are directly associated with fuel use. Only technical measures that improve the efficiency of the power production will be of use. Such measures will generally also reduce the emissions of HC and CO. Operational measures that reduce fuel use will also reduce CO_2 emissions. Clearly, operational reduction measures most probably reduce pollutant emissions as well. Most of the information presented here stems from Marintek et al. (2000).

Marintek et al. (2000) present a number of technical measures that can be implemented on either existing and new ships, see tables 10 and 11. For the exact specifications of these options, we refer to original study.

TABLE 10
CO2 REDUCTION POTENTIAL BY TECHNICAL MEASURES FOR NEW SHIPS
(Percentage)

Measure	Reduction potential fuel / CO_2	Combined[a]	Total[a]
Optimized hull shape	5 – 20		
Choice of propeller	5 – 10	5 – 30	
Efficiency optimized	10 – 12[b]		
	2 – 5[c]	14 – 17[b]	5 – 30
Fuel (HFO to MDO)	4 – 5	6 – 10[c]	
Plant concepts	4 – 6		
Fuel (HFO to MDO)	4 – 5	8 – 11	
Machinery monitoring	0.5 – 1		

Source: Marintek et al. (2000)

[a] Where potential for reduction from individual measures are well documented by different sources, potential for combination of measures is based on estimates only.

[b] State of art technique in new medium speed engines running on HFO.

[c] Slow speed engines when trade-off with NOx is accepted.

TABLE 11
CO2 REDUCTION POTENTIAL BY TECHNICAL MEASURES FOR EXISTING SHIPS
(Percentage)

Measure	Reduction potential fuel / CO_2	Combined[a]	Total[a]
Optimal hull maintenance	3 – 5		
Propeller maintenance	1 – 3	4 – 8	
Fuel injection	1 – 2	5 – 7	
Fuel (HFO to MDO)	4 – 5		4 – 20
Efficiency rating	3 – 5		
Fuel (HFO to MDO)	4 – 5	7 – 10	
Eff. Rating + TC upgrade	5 – 7		
Fuel (HFO to MDO)	4 – 5	9 – 12	

Source: Marintek et al. (2000)

[a] Where potential for reduction from individual measures are well documented by different sources, potential for combination of measures is based on estimates only.

The emission reduction potential on new ships is somewhat larger than on existing ships. Switching from HFO to MDO reduces the CO_2 emissions by about 5%. Additional to the retrofit options listed in table 11, measures regarding the propeller may also be an option, depending on the ship specifications. The reduction potential depends to a large extent on the vessels' specifications.

Apart from these technical measures, operational measures may also be implemented. An overview of the potential is provided in table 12.

TABLE 12

CO_2 REDUCTION POTENTIAL BY OPERATIONAL MEASURES

(Percentage)

Measure	Reduction potential fuel / CO_2	Combined[a]	Total[a]
Operational planning / speed selection			
Fleet planning	5 – 40		
'Just in time' routing	1 – 5	1 – 40	
Weather routing	2 – 4		
Miscellaneous measures			
Constant RPM	0 – 2		
Optimal trim	0 – 1	0 – 5	
Minimum ballast	0 – 1		1 – 40
Optimal propeller pitch	0 – 2		
Optimal rudder	0 – 0.3		
Reduced time in port			
Optimal cargo handling	1 – 5		
Optimal berthing, mooring and anchoring	1 – 2	1 – 7	

Source: Marintek et al. (2000)

[a]: Where potential for reduction from individual measures are well documented by different sources, potential for combination of measures is based on estimates only.

It should be noted that, especially given the rise in fuel prices lately, some of the measures mentioned are actually already profitable to implement. For more details regarding the options, see Marintek et al. (2000). In some cases, more information on the costs of measures is also included therein.

Much the same measures are discussed in SOF (2000). SOF (2000) also discusses the potential of speed reductions to reduce CO_2 emissions. The impact of a 10% reduction in speed is estimated at a reduction of fuel (and hence CO_2 emissions) of 10 to 20%.

BOX 3

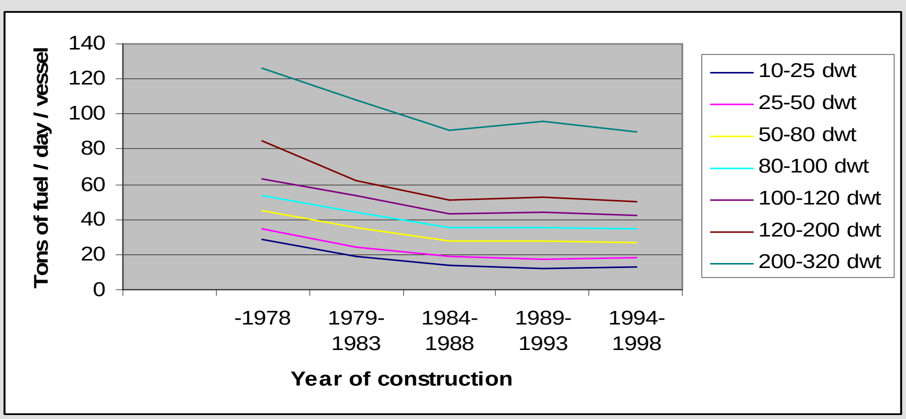
THE IMPACT OF TECHNOLOGICAL CHANGE ON FUEL EFFICIENCY

Technological improvements can make sea transport more efficient. Improvements can speed up the loading and unloading of ships, the routing of trips, but can also make ships more fuel efficient. In this case, there are clearly not only financial benefits, but also environmental benefits. If less fuel is required for the same trip, the carbon dioxide emissions are reduced and hence the impacts on climate change.

There is some incidental evidence on the fuel efficiency of ships over time. Data for tankers is presented in figure @. Ships constructed in the 1990s are more fuel efficient than ships constructed in the 70s.

FIGURE

FUEL EFFICIENCY OF NEWLY BUILT TANKERS



Source: Based on data from SOF (2000).

UNCTAD (2005, table 51) makes very clear that the fleet of Latin America and the Caribbean is relatively old compared to the world fleet. Modernizing the fleet could increase efficiency, reduce fuel costs and reduce CO_2 emissions substantially.

6.2.2 International policy framework

The primary international policy framework for the prevention of climate change is laid down in the United Nations Framework Convention of Climate Change (UNFCCC). It sets an overall framework for intergovernmental efforts to tackle the challenge posed by climate change. Under the Convention, governments:

- Gather and share information on carbon dioxide and other greenhouse gas emissions, national policies and best practice measures,
- Launch national strategies for addressing GHG emissions and adapting to expected impacts, including the provision of financial and technological support to developing countries
- Cooperate in preparing for adaptation to the impacts of climate change

The Convention entered in force in 1984 and has been ratified by 189 countries.[41]

More recently, a number of nations have approved an addition to the UNFCCC treaty, which is named the Kyoto Protocol (KP). Under the KP, some nations have committed themselves to more powerful and legally binding measures. The Kyoto Protocol entered into force in 2005 and has been ratified by 162 countries.

Part of the Protocol is the establishment of three innovative mechanisms, namely emissions trading, joint implementation (JI) and the clean development mechanism (CDM). These mechanisms are designed to help Annex I parties cut the cost of meeting their targets by taking advantage of opportunities to reduce emissions that cost less in other countries than at home.

BOX 4
DIFFERENTIATED RESPONSIBILITIES

One of the main features of both the UNFCCC and the KP is the notion of common but differentiated responsibilities. Three groups of parties are distinguished under the UNFCCC, depending partly on their stage of economic development:

Annex I

Annex II

Non-Annex I

Annex II parties include the industrialized countries that were members of the OECD in 1992. Annex II parties are required under the Kyoto Protocol to provide financial resources to enable developing countries to undertake emission reduction activities.

The list of Annex I countries consists of the Annex II countries, plus countries with economies in transition, such as the Russian Federation, the Baltic States and several Central and Eastern European States. Annex I countries have emission reduction commitments under the Kyoto Protocol.

Non-Annex I parties are mostly developing states and include almost all Latin American States. These parties do not have specific emission reduction commitments.

Under JI, an Annex I party may reduce emissions in the territory of another Annex I party, counting the resulting emission reduction credits against its own target. Under CDM, Annex I parties may implement emission reduction projects in non-Annex I parties. The resulting certified emission reductions may be counted against its own target.

With respect to the underlying report, it is of importance to note that the commitments of Annex I parties under the Kyoto Protocol do not relate to the emissions from international aviation and maritime transport. The reason is that no agreement has so far been reached on how to allocate

[41] For more information, see http://unfccc.int/2860.php

these emissions to particular countries.[42] The Kyoto Protocol does require Annex I parties to pursue limitation or reduction of emissions of GHG from these sectors working through two specialized UN agencies, the International Civil Aviation Organization (ICAO) and IMO.

Before discussing the developments under the IMO, we first briefly discuss a second international policy framework, the Asia-Pacific Partnership on Clean Development and Climate (the Partnership). The six signatory countries are the Australia, India, Japan, the People's Republic of China, South Korea and the United States. This voluntary non-legally binding Partnership launched in 2006 focuses on working together in the development and transfer of technology. This agreement allows member countries to set their goals for reducing emissions individually, with no mandatory enforcement mechanism such as under the KP. As to our knowledge, no concrete measures directed at the climate change impact of maritime transport have been included in its work program.

The first work within the IMO on climate change dates from 1997.[43] Just before the adoption of the Kyoto Protocol, an IMO conference adopted a resolution calling for a study on CO_2 emissions from ships and the MEPC to identify feasible CO_2 reduction strategies. This resulted in 2000 in the previously referenced study by Marintek et al. (2000). It identified a number of proposals for limiting or reducing GHG emissions from ships, including voluntary agreements, environmental indexing, emission standards for new and existing vessels and emissions trading.

In March 2002 the MEPC established a correspondence group to prepare an IMO strategy/policy on GHG emissions from ships. This resulted in interim guidelines for voluntary ship CO_2 emission indexing for use in trials.[44] Industry, organizations and administrations are welcomed to submit their experiences with indexing so to update the draft guidelines. These interim guidelines form the most concrete policy action of the IMO with respect to the limitation of GHG emissions from the shipping sector.

We will briefly discuss the CO_2 index. In the interim guidelines the Carbon Dioxide Transport Efficiency Index is defined. It provides an indicator of the energy efficiency of a ship in operation. It is defined as the ratio of mass of CO_2 emitted per unit of transport work, where transport work is defined as the product of distance and cargo mass transported.

To be able to calculate the index for a specific trip, information is required on the type and amount of fuel used during the trip, the distance sailed and the mass of the cargo transported. Because cargo levels can vary over different trips, partly due to the imbalance in the international freight market, the index can vary widely between different trips. Therefore it is recommended that the CO_2 index should represent an average value of the energy efficiency of the ship operation over the period of one year.

First results from India, Germany and Norway submitted at the 53st and 54th meeting of the MEPC (MEPC, 2005a, 2005b, 2006a and 2006b) indicate that the index may vary according to the type, size and operational speed of a ship. Emission indices for bulk carriers differ from those for tankers, and both differ from those for passenger ferries. In general, the index is lower for ships of higher dead weight tonnage. Also, high-speed passenger ferries have a higher index that ferries that travel more slowly. None of these results is very surprising. More information is expected to be submitted at MEPC 55 in October 2006.

---

42 For a background, see http://unfccc.int/adaptation/methodologies_for/vulnerability_and_adaptation/items/3416.php The options under discussion are: 1 no allocation; 2 allocation according to the country where the bunker fuel was sold; 3 allocation according to nationality of transporting company; 4 allocation according to the country of departure or destination of the vessel and 5 allocation according to the country of departure or destination of the cargo or passenger.

43 For a background of developments on GHG within IMO and its interaction with other institutions, see Ecologic (2003).

44 A draft of which can be found in annex I of MEPC 53/WP.11, see MEPC (2005c).

The work on GHG emissions within IMO has been judged slow on several accounts; see e.g. Ecologic (2003). One of the reasons is that further steps require the support of all parties. Some non-Annex I countries under the KP have urged that the principal of common but differentiated commitments is also incorporated in any action on GHG emissions under the IMO. Meanwhile Annex I countries fear for distortions of competition is policies only apply to them. This impasse may have stalled developments of concrete policy options within IMO.

6.2.3 Regional policies and best practices

Some countries and regions have instigated or are investigating national or regional policies to reduce the GHG emissions from maritime transport. The reason may be that they judge the rate of developments within the IMO as not quick enough, or may want to take the lead given the idea of common but differentiated responsibilities.

In this section we present some of the regional and best practice developments from around the world. It should be noted that many initiatives mentioned in 6.1.3 also impact emissions of GHGs. These initiatives and policies are not repeated here.

European Union

The European Commission intends to work with the IMO to ensure that IMO's greenhouse gas strategy is concrete and ambitious. At the same time, however, the Commission is investigating specific EU actions to reduce GHGs from shipping. This split strategy is reflected in the current research program. A report prepared for the Commission is due in 2007 inter alia describing current practical experiences with the CO_2 index and making recommendations for possible improvements. This study will however also look at alternative climate policies for international shipping. Options under study are:

- voluntary commitments
- a requirement to use and report on the IMO CO2 index
- a requirement to meet a unitary CO2 index limit or target
- differentiation of port infrastructure charges by a CO2 element
- inclusion of shipping in the EU emissions trading system
- Future policies will most likely depend on the outcome of the study

Canada

As part of its commitment to reduce GHG emissions under the Kyoto protocol, the Canadian government developed an action plan[45] [46]. Part of this plan was directed at freight transport under which a freight sustainability demonstration program was set up. Several different innovative measures that aimed at reducing GHG emissions from maritime transport have been financially supported. These are listed below.

A project determining the impact of best practices on fuel consumption and engine emissions from ferries. The project identified the best operational parameters for ferry maneuvers, engine setting and cargo loading. As such, information is obtained about the optimal vessel draft and trim, engine dynamic settings and rudder utilization.

[45] It should be noted that the after the change of government, Canada no longer intends to meet its commitments under the Kyoto Protocol.

[46] The information here is based on the website: http://www.tc.gc.ca/programs/environment/Freight/menu.htm

A project to demonstrate the potential reduction of CO_2, NO_x and PM emissions through use of system that injects water in the into the combustion air in the engine.

A project to evaluate and quantify the impact on emissions of operational measures, including the overhaul of propulsion engines, adjustment in transit operation and presence of performance indicators on ships.

A project to demonstrate the use of biodiesel in container ships. Biodiesel is made from organic materials that sequestrate CO_2 during growth. In this way, the net emissions of CO_2 can be substantially reduced.[47]

A pilot project to demonstrate the potential use of software to facilitate the use of tidal current to reduce fuel consumption.

Best practices

In general, fairly little policies and best practice measures have so far been implemented that directly target the CO_2 emissions of the shipping sector. Some of the measures aimed at improving local air quality will also reduce CO_2 emissions, such as the voluntary speed reduction in the port of Los Angeles and the development of a zero emission ship. Also, shore-side electricity has the potential to reduce CO_2 emissions.

47 They are generally not climate neutral, because of the CO_2 that is related to the production process.

VII. Conclusions and recommendations

Ships emit many different gases that can have serious health and environmental impacts. Although there is some uncertainty about the total amount of emissions, it is clear that the shipping sector is a large emitter. With respect to emissions of air pollutants, the shipping sector can be compared to the US. The emissions of carbon dioxide may surpass those of Australia. Moreover, emissions of the shipping sector are expected to grow due to increased levels of transport.

A majority of the maritime transport takes place close enough to the coast for emissions to reach land. Emissions in port furthermore may make up 5 to 10% of all emissions of maritime transport. Scientific studies provide ample evidence that vessels contribute substantially to air quality problems over land in the US and Europe. No studies for Latin America and the Caribbean have been carried out.

Based on the literature for other regions, it appears likely that also in Latin America and the Caribbean, the shipping sector contributes to the problem of air pollution. Based on graphs specifically elaborated for this study, especially countries around the Gulf of Mexico, the Caribbean Sea, along the west coast of Central America and the east coast of Brazil may be affected.

There are very serious problems with air quality in Latin American cities and policies have been implemented in especially the road traffic sector. So far, the emissions from the shipping sector have not appeared in the emission inventories available for Latin American and Caribbean cities. Possibly as a result of this, no national or regional policies that target air pollution by ships have been implemented. There are many examples of policy instruments that can be introduced to reduce the impact of shipping on the local air quality. These policies can be implemented at little or no cost to the regional economy.

Measures taken elsewhere in the world may have benefits for the air quality in Latin America as well. To the extent that NO_x emissions from the engines are reduced, or SCR is applied on a vessel in reaction to local policies elsewhere, emissions of ships will be reduced also when cruising in Latin American and Caribbean waters. However, other effective measures, such as the use of low sulphur fuel and voluntary speed restrictions, need to be introduced in Latin America and the Caribbean in order to reduce emissions locally.

We have the following recommendations with respect to environmental policy for the shipping sector in Latin America and the Caribbean.

- Consideration of policy measures that have proven their effectiveness elsewhere and that can be implemented at little or no additional costs to the sector, such as:
  - Voluntary speed restrictions within a certain radius around the port
  - Require use of low-sulphur fuel within a certain radius around the port
  - Join the Green Award scheme and introduce beneficial treatment.
  - Introduce differentiated port dues based on the environmental performance of ships.[48]
- Include the shipping sector when making emission inventories for large coastal cities with ports that have air quality problems
- Based on the outcomes, implement more far-reaching policies to reduce emissions from the shipping sector. A cost benefit analysis could be carried out to investigate the options of shore-side electricity, low-sulphur fuel requirements in a larger region and a possible installment of SO_x emission control area under IMO regulation. Other port side measures may also be considered.

Where deemed necessarily to reduce the potential for aversive behavior by avoiding ports with environmental policies in place, measures may be implemented nationally or regionally. Negative affects may be very limited. Differentiated port dues for example, can be introduced with a closed budget. Dues for relatively dirty ships can be increased, whereas dues for with environmentally friendly behavior can be reduced.

With respect to CO_2 emissions of maritime transport, it may be judged unfair to introduce measures in the absence of similar measures from Annex I countries. On the other hand, the shipping sector is a very international sector and it is not easy to imagine measures that would only affect Annex I countries without inducing unfair economic competition. From this perspective, pilot schemes for the IMO CO_2 index may be stimulated, possible by offering reduced port dues for vessels that participate in such projects.

[48] This could be based on the Green Award to limit costs of implementation and control.

Bibliography

Acid Rain (2003), “Air pollution from ships; Needing Attention”, The Swedish NGO secretariat on Acid Rain. Environmental Factsheet No. 13. May 2003. Available from: www.acidrain.org. Consulted May 5, 2006.

AMVER (2005), “Welcome: Amver”, http://www.amver.com/index.htm

ARB (2005), “Offshore emissions impacts on onshore air quality”, Air Resources Board, California, http://www.arb.ca.gov/regact/marine2005/appf.pdf, Consulted March 14, 2006.

Bell et al. (2006), Michelle L. Bell, Devra L. Davis, Nelson Gouveia, Victor H. Borja-Aburto, Luis A., Cifuentes, “The avoidable health effects of air pollution in three Latin American cities: Santiago, Sao Paulo, and Mexico City”, in Environmental Research 100 (2006) 431-400.

CAI-LAC (2002), “Economic valuation of the health impacts of air pollution”, Clean Air Initiative in Latin American Cities, http://www.cleanairnet.org/lac_en/1415/articles-48678_word.doc, Consul-ted March 15, 2006.

Capaldo et al. (1999), Kevin Capaldo, James J. Corbett, Prasad Kasibhatla, Paul Fischbeckand,Spyros N. Pandis . “Effects of ship emissions on sulphur cycling and radiative climate forcing over the ocean”, in Nature vol. 400, 19 August 1999.

CE Delft (2006), “Policy and data on non-road modes; Status report for the European Environment Agency”, Delft, 2006.

___ (2003), “To shift or not to shift, that's the question; The environmental performance of the principal modes of freight and passenger transport in the policy making-context”, Delft, March 2003.

CICERO (2004), Centre for International Climate and Environmental Research, “The effect of transport emissions on the climate”, Terje Berntsen, in Cicerone 4-2004.

Cifuentes et al. (2005), Cifuentes, L., Krupnick, A.J., O'Ryan, R., Toman, M.A., “Urban air quality and human health in Latin America and the Caribbean”. Working Paper. Pontificia Universidad Cat6lica de Chile, Santiago, Chile, 2005. See http://www.iadb.orglsds/env/publicationI95e.htm, Consulted April, 2006.

___ (2001), Luis Cifuentes, Victor H. Borja-Aburto, Nelson Gouveia, George Thurston, and Devra Lee Davis, “Assessing the health benefits of urban air pollution reductions associated with climate, change mitigation (2000-2020): Santiago, Sao Paulo, Mexico City and New York City”, Environmental Health Perspectives, Volume 109, Supplement 3, June 2001.

Cleanairnet (2006), “Clear Air Initiative in Latin American Cities”, http://www.cleanairnet.orgllac en/1415/channel.html, Consulted March 15, 2006.

Corbett et al. (1999), Corbett, J.J., P.S. Fischbeck and S.N. Pandis, “Global nitrogen and sulfur emissions inventories for oceangoing ships”, Journal of Geophysical Research, vol.104 (D3), 3457-3470, 1999.

Corbett & Koehler (2003), James J. Corbett and Horst W. Koehler, “Updated emissions from ocean shipping”, Journal of Geophysical Research, vol.108, No. D20, 4650, 2003.

Crutzen (1987), Crutzen, P.J., “Tropospheric ozone: An overview”, In Isaksen, I.S.A., editor, Tropospheric Ozone: Regional and global Scale Interactions, NATO ASI series, vol.32, pages 3-33. D-Reidel-Publishing-Company, Dordrecht, the Netherlands.

Devasthale et al. (2006), Abhay Devasthale, Olaf KrUgerand Hartmut Grazl, “Impact of ship emissions on cloud properties over coastal areas”, in Geophysical research, letters, vol.33, 2006.

EC (2005a), European Commission, SEC(2005) 1133 Commission staff working paper Annex to: The communication on thematic strategy on air pollution and The directive on "Ambient air quality and cleaner air for Europe", Impact Assessment, Brussels, 21-9-2005.

___ (2005b), European Commission, Directive 2005/33/EC of the European Parliamen~and of the Council of 6 July 2005, amending Directive 1999/32/EC as regards the sulphur content of marine fuels, Brussels, 6-7-2005.

___ (2002), European Commission, “A European Union strategy to reduce atmospheric emissions from seagoing ships” COM (2002) 595 Final Communication from the Commission to the European Parliament, and the Council, Brussels, 20.11.2002.

___ (1999), European Commission, Council Directive 1999/32/EC of 26 April 1999 “Relating to a reduction in the sulphur, content of certain liquid fuels and amending”, Directive 93/12/EEC, Brussels, 26-4-2005.

ECLAC (2003), Daniele Simioni (eds.), “Contaminación Atmosférica y conciencia ciudadana” (also available in English: Air pollution and citizen awareness), Libro de CEPAL 73, Santiago de Chile, junio de 2003. Consulted March 15, 2006.

Ecologic (2003), Sebastian Oberthiir, “Interactions of the climate change regime with ICAO, IMO and the EU borden-sharing agreement”; Project delivery No. D 3, Final draft (February 2003). See also: http://www.ecologic.de/download/proiekte/850-899/890Iin-depth/unfcc.pdf, Consulted April 13, 2006.

Eddington & Rosenthal (2003), Eddington, Lee and Rosenthal, Jay, “The frequency if offshore emissions reaching the continental UW Coast based on hourly surface winds from a 10 year mesoscale model simulation”, Geophysics Branch Technical, Note. March 2003.

EDGAR, MNP (2006), “Emission database for global atmospheric research”, www.mnp.nl/edgar/, Consulted March 14, 2006.

Edugreen website, http://edugreen.teri.res.in/explore/health.htm, consulted March 10,2006.

Endresen et al. (2003), Endresen, am Sirgaard, E, Sundet, J.K., Dalsoren, S.B., Isaksen, I.S.A., Berglen, T.P. and G.Gravir, Emission rom international sea transportation and environmental impact, Journal of Geophysical Research, vol.108 (D17), 4560, 2003.

ENDS (2006), ENDS Europe Daily, EU plugs “Shore-side electricity for shipping Issue 2093”, Tuesday 9 May, 2006.

Entec (2002), Entec UK Limited, “Quantification of emissions from ships associated with ship movements between ports in the European Community”; Final report, July 2002.

Entec (2005a), Entec UK Limited, “Service contract on ship emissions: assign:p1ent,abatement and market-based instruments, Task 2a: Shore-side Electricity, Final report. August 2005. Downloadable from: http://europa.eu.int!comm/environment!air/transport.htm#3

___ (2005b), Entec UK Limited, “Service contract on ship emissions: assignment, abatement and market-based instruments”, Task 2b: NOx abatement, Final report, August 2005. Downloadable from: http://europa.eu.int!comm/environment!air/transport.htm#3

___ (2005c), Entec UK Limited, "Service contract on ship emissions: assignment, abatement and market-based instruments", Task 2c: Sox abatement, Final report. August 2005. Downloadable from: http://europa.eu.int!commlenvironment!air/transport.htm#3

___ (2005d), Entec UK Limited, Service contract on ship emissions: assignment, abatement and market-based instruments, Task 1: Preliminary assignment of ship emissions to European countries, Final report, August2005, Downloadable from: http://europa.eu.int!comm/environment!air/transport.htm#3

EPA (2006), United States Environmental Protection Agency, "Conference on marine vessels and air quality", February 1 and 2, 2001. http://www.epa.gov/region9/air/marinevessellindex.html, Consulted May 5, 2006.

___ (2004a), United States Environmental Protection Agency, 40 CFR Parts 92 and 94; "Control of emissions of air pollution from new locomotive engines and new marine compression-ignition engines less than 30 liters per Cylinder"; Proposed rule, June 29, 2004.

___ (2004b), United States Environmental Protection Agency, Regulatory Update; "Overview of EPA's emission standards for marine engines", August 2004.

___ (2003), United States Environmental Protection Agency, 40 CFR Parts 9 and 94; "Control of emissions of air pollution from new marine compression-ignition engines at or above 30 liters per Cylinder"; Final rule, February 28, 2003.

Eyring et al. (2005a), V. Eyring, H.W. Koehler, J. van Aardenne and A. Lauer, "Emissions from international shipping. Part 1: The last 50 years", Journal of Geophysical Research, vol.llO, D17305, 2005.

___ (2005b), V. Eyring, H.W. Koehler, A. Lauer and B. Lemper, "Emissions from international shipping. Part 2: Impact of future technologies on scenarios until 2050", Journal of Geophysical Research, vol. 110, D17305, 2005.

Fagerli &Tarrason (2001), Hilde Fagerli and Leonor Tarrason, "The influence of ship traffic emissions on the air concentrations of particulate matter" Preliminary estimate from EMEP/MSC-W under request of DG Environment Oslo, November 2001.

Farthing (1993), Bruce Farthing, "International Shipping", second edition, Lloyd's of London Press Ltd, 1993.

Farthing & Brownrigg (1997), Farthing, Rand M. Brownrigg, "Farthing on international shipping", Lloyd's of London Press Ltd, 1997.

Glover (1995), "Valuing the health impacts of pollution: Notes and suggested readings", http://www.idrc.ca/uploads/user-S/I 0305683830acf2a6.html, Consulted March 13, 2006.

GVRD (2002), Greater Vancouver Regional District, "2000 Emission inventory for the Lower Fraser Valley Airshed" October 2002, http://www.gvrd.bc.ca/air/pdfs/2000EmissionInventory.pdf, Consulted March 14, 2006.

ICOADS (2004), "The International Comprehensive Ocean-Atmosphere Data Set" (ICOADS) http://dss.ucar.edu/pub/coads/.

lEA (2004), International Energy Agency (lEA), Energy Balances of OECD Countries, Energy Balances of Non:'OECD Countries Ivation Datasystems Inc, Release 5.2, 2004 (software Beyond 20/20) 2004.

IMO website, www.lmo.org, consulted February 1, 2006.

IPCC (2005), Intergovernmental Panel on Climate Change (IPCC), "Safeguarding the Ozone Layer and the Global Climate System: Issues Related to Hydrofluorocarbons and Perfluorocarbons" IPCC/TEAB Special Report S.1.: IPPC, 2005.

Lee (2006), David Lee, Centre for Air Transport and the Environment, Manchester Metropolitan University Personal communication by email, March 16, 2006.

Levelton (2002), Levelton Engineering Ltd., Marine vessel air emissions in the Lower Fraser Valley for the year 2000, 30 April, 2002. http://www.gvrd.bc.ca/air/pdfs/MarineVesselEmission2000.pdf, Consulted March 14, 2006.

Ma (2002), S.Ma, "Economics of maritime safety and environmental regulations", in C. Th.Grammenos (ed.) The Handbook of maritime economics and business, Informa Professional, London, 2002.

Marintek et al. (2000), Marintek, Det Norske Veritas, Econ Centre for Economic Analysis, Carnegie Mellon University "Study of greenhouse gas emissions from ships"; Final report to the International Maritime Organization, Norway, March 2000.

MEPC (2006a), Marine Environmental Protection Committee, International Maritime Organization, MEPC 54/4/5 Prevention of air pollution from ships; Trials using the interim guidelines for ship CO2emission indexing based on operational data, Submitted by India, 12 January 2006.

___ (2006b), Marine Environmental Protection Committee, International Maritime Organization, MEPC 54/4/51Add.1 Prevention of air pollution from ships; Trials using the interim guidelines for ship CO2emission indexing based on operational data, Submitted by India, 12 January 2006.

___ (2005a), Marine Environmental Protection Committee, International Maritime Organization, MEPC 53 Inf.6 Prevention of air pollution from ships; Trials using the draf (guidelines for CO2emission indexing, Submitted by Norway, 15 April 2005.

___ (2005b), Marine Environmental Protection Committee, International Maritime Organization, MEPC 53 Inf.5 Prevention of air pollution from ships; Investigation of different ship types with regard to emission indexing based on statistical and operational data, Submitted by Germany, 15 April 2005.

___ (2005c), Marine Environmental Protection Committee, International Maritime Organization, MEPC 53 WP.11, “Prevention of air pollution from ships”, Report of the working group, 21 July 2005.

Netcen (2001), BeTa Benefits Table database: Estimates of the marginal external costs of air pollution in Europe, Version E1.02a http://europa.eu.intlcommlenvironmentlenvecolair/betaec02aforprinting.pdf, Consulted March 13, 2006.

NMI (2000), The Norwegian Meteorological Institute, Effects of international shipping on European pollution levels, EMEP MSC-W Report 2000, ISSN 0332-9879, NMI research report No. 41.

NMREC (2006), U.S. Maritime Administration National Maritime Resource and Education Centre, http://www.marad.dot.gov/nmrec/conferences workshops/nmrec conf.html, Consulted May 5,2006.

Northeast (2006), Northeast Clean Ports Workshop, “Successful strategies and funding to reduce diesel emissions at ports”, February 1, 2006, http://www.northeastdiesel.org/marine.htm, Consulted May 5, 2006.

NRC (1985), National Research Council, “Oil in the sea; Inputs, fates and effects”, National Academy Press, Washington D.C., 1985.

PAHO (2005), Pan American Health Organization, “An assessment of health effects of ambient air pollution in Latin America and the Caribbean” Washington D.C., 2005, http://www.cepis.org.pe/bvsacd/ cd47/assess.pdf, Consulted April, 2006.

Q'Ryan & Larraguibel (2000), Q'Ryan, R. and Larraguibel, L., “Contaminación del aire en Santiago: estado actual y soluciones”. Documento de trabajo CEA No. 75, Universidad de Chile, 2000.

Saxe & Larsen (2004), H. Saxe and T. Larsen, “Air pollution from ships in three Danish ports, Atmospheric Environment”, 38,4057-4067,2004.

Seattle PI, Seattle Post-Intelligencer (2004), “Air pollution from cargo ships stirs growing concern; Emissions pour from visiting vessels, and restrictions are few”, January 20,2004, http://seattlepi.nwsource.com/local/ 157322 portpollute20.html, consulted May 5, 2006.

SOF, Ship and Ocean Foundation (2000), “A report on research concerning the reduction of CO2 emissions from vessels”, Japan, August 2000, http://www.soLor.jp/houkoku/rpOO08 .pdf, Consulted May 15, 2006.

UNCT AD (2005), Review of maritime transport 2005; Report by the UNCTAD secretadat, United Nations, New York and Geneva, 2005.

USA today (2004), “Ship pollution clouds USA's skies” http://www.usatoday.com/news/nation/2004-08-30-ship-pollution.x.htm, Consulted March 14, 2006.

Wallenius (2005), Wallenius Marine AB, “Wallenius Marine's environmental policy”, Stockholm, February 2005, http://www.walleniuslines.comldoc upload/environmental policy05.pdf.

Wang, c., J.J. Corbett, and J. Firestone (2006), “Improving Spatial Representation of Global Ship Emissions Inventories” (under review), Journal of Geophysical Research.

WHO World HealthOrganization (2003), “Health aspects of air pollution with particulate matter, ozone and nitrogen oxide”, Report on a WHO working group, Bonn, Germany, 13-15 January 2003.

___ (2000), “Guidelines for air quality” WHO, Geneva, 2000.

Wikipedia website (2006), http://en.wikipedia.org/wiki/Air pollution, Consulted March 10, 2006.

World Bank (1994), “Chile. Managing environmental problems: Economic analysis of selected issues”, Report no. 13061-CH, December 19th,1994.

NACIONES UNIDAS

Serie

CEPAL

Recursos naturales e infraestructura

Issues published:

Complete list of this collection, as electronic versions in pdf are available in our web site: www.cepal.org/publicaciones

127. Report on maritime transport and the environment for Latin America, Bart Boon, (LC/L.2792-P), Sales No.: E.07.II.G.126 (US$ 10,00) 2007.

126. Servicios de agua potable y alcantarillado en la cuidad de Buenos Aires, Argentina: factores determinantes de la sustentabilidad y el desempeño, María Begoña Ordoqui Urcelay, (LC/L. 2751-P), No de venta S.07.II.G.88 (US$ 10,00), mayo de 2007.

125. Buenas prácticas en la industria minera: el caso del Grupo Peñoles en México, Eduardo Chaparro (LC/L. 2745-P), No de venta S.07.II.G.81 (US$ 10,00), mayo de 2007.

124. Infraestructura y servicios de transporte ferroviario vinculados a las vías de navegación fluvial en América del Sur, Gordon Wilmsmeier (LC/L.2737-P), No de venta S.07.II.G.75 (US$ 10,00), mayo de 2007.

123. Servicios urbanos de agua potable y alcantarillado en Chile: factores determinantes del desempeño, Soledad Valenzuela y Andrei Jouravlev (LC/L.2727-P), No de venta S.07.II.G.65 (US$ 10,00), abril de 2007.

122. Gestión mixta y privada en la industria de hidrocarburos, Humberto Campodónico (LC/L.2711-P), No de venta S.07.II.G.59 (US$ 10,00), marzo de 2007.

121. La gestión de la industria de hidrocarburos con predominio del Estado, Humberto Campodónico. (LC/L.2688-P) No de venta S.07.II.G.39 (US$ 10,00), marzo de 2007.

120. La agenda minera en Chile: revisión y perspectivas, Juan Carlos Guajardo B. (LC/L.2674-P) No de venta S.07.II.G.23 (US$ 10,00), febrero de 2007.

119. Mercado de energías renovables y mercado del carbono en América Latina: Estado de situación y perspectivas, Lorenzo Eguren (LC/L.2672-P) No de venta S.07.II.G.22 (US$ 10,00), febrero de 2007.

118. Sostenibilidad y seguridad de abastecimiento eléctrico: estudio de caso sobre Chile con posterioridad a la Ley 20.018, Pedro Maldonado, Benjamín Herrera (LC/L.2661-P) No de venta S.07.II.G.12 (US$ 10,00), enero de 2007.

117. Efectos económicos de las nuevas medidas de protección marítima y portuaria, Martín Sgut (LC/L2615-P), No de venta S.06.II.G.140 (US$ 10,00), septiembre de 2006.

116. Oportunidades de negocios para proveedores de bienes, insumos y servicios mineros en Chile, Guillermo Olivares y Armando Valenzuela. Retirada

115. Instrumentos para la toma de decisiones en políticas de seguridad vial en América Latina, José Ignacio Nazif, Diego Rojas, Ricardo J. Sánchez, Álvaro Velasco Espinosa, (LC/L.2591-P), No de venta S.06.II.G.XX (US$ 10,00), agosto de 2006.

114. La importancia de la actividad minera en la economía y sociedad peruana, Miguel E. Santillana, (LC/L.2590-P), No de venta S.06.II.G.120 (US$ 10,00), agosto de 2006.

113. Conectividad, ámbitos de impacto y desarrollo territorial: análisis de experiencias internacionales, Oscar Figueroa y Patricio Rozas (LC/L.2586-P), No de venta S.06.II.G.119 (US$ 10,00), agosto de 2006.

112. Indicadores de productividad para la industria portuaria. Aplicación en América Latina y el Caribe, Octavio Doerr y Ricardo Sánchez, (LC/L.2578-P), No de venta S.06.II.G.108 (US$ 10,00), julio de 2006.

111. Water governance for development and sustainability, Miguel Solanes y Andrei Jouravlev, (LC/L.2556-P), No de venta S.06.II.G.84 (US$ 10,00), junio de 2006.

110. Hacia un desarrollo sustentable e integrado de la Amazonía, Pedro Bara Nieto, Ricardo J. Sánchez, Gordon Wilmsmeier (LC/L.2548-P), No de venta S.06.II.G.76 (US$ 10,00), junio de 2006.

109. Minería y competitividad internacional en América Latina, Fernando Sánchez-Albavera y Jeannette Lardé, (LC/L.2532-P), No de venta S.06.II.G.59 (US$ 10,00), junio de 2006.

108. Desarrollo urbano e inversiones en infraestructura: elementos para la toma de decisiones, Germán Correa y Patricio Rozas (LC/L.2522-P), No de venta S.06.II.G.49 (US$ 10,00), mayo de 2006.

107. Los ejes centrales para el desarrollo de una minería sostenible, César Polo Robilliard (LC/L.2520-P), No de venta S.06.II.G.47 (US$ 10,00), mayo de 2006.

106. La integración energética en América Latina y el Caribe, Ariela Ruiz-Caro (LC/L.2506-P), No de venta S.06.II.G.38 (US$ 10,00), marzo de 2006.

105. Sociedad, mercado y minería. Una aproximación a la responsabilidad social corporativa, Eduardo Chaparro Ávila (LC/L.2435-P), No de venta S.05.II.G.181 (US$ 10,00), diciembre del 2005.

104. Conectividad, ámbitos de impacto y desarrollo territorial: el caso de Chile, Oscar Figueroa y Patricio Rozas (LC/L.2418-P), No de venta S.05.II.G.165 (US$ 10,00), diciembre del 2005.

103. Ciudades puerto en la economía globalizada: alcances teóricos de la arquitectura organizacional de los flujos portuarios, José Granda (LC/L.2407-P), No de venta S.05.II.G.154 (US$ 10,00), noviembre del 2005.

102. La seguridad vial en la región de América Latina y el Caribe, situación actual y desafíos, Rosemarie Planzer (LC/L.2402-P), No de venta S.05.II.G.149 (US$ 10,00), octubre del 2005.

101. Integrando economía, legislación y administración en la administración del agua, Andrei Jouravlev (LC/L.2389-P), No de venta S.05.II.G.132 (US$ 10,00), octubre del 2005.

100. La volatilidad de los precios del petróleo y su impacto en América Latina Fernando Sánchez-Albavera y Alejandro Vargas, (LC/L.2389-P), No de venta S.05.II.G.132 (US$ 10,00), septiembre del 2005.

99. Conceptos, instrumentos mecanismos y medio de fomento en la minería de carácter social en México, Esther Marchena Léon y Eduardo Chaparro (LC/L.2393-P), No de venta S.05.II.G.136 (US$ 10,00), noviembre del 2005.

98. Las industrias extractivas y la aplicación de regalías a los productos mineros, César Polo Robilliard (LC/L.2392-P), No de venta S.05.II.G.135 (US$ 10,00), octubre del 2005.

97. Bridging infrastructural gaps in Central America: prospects and potential for maritime transport, Ricardo Sánchez and Gordon Wilmsmeier (LC/L.2386-P), Sales No.: E.05.II.G.129, (US$ 10,00), September, 2005.

96. Entidades de gestión del agua a nivel de cuencua: experiencia de Argentina, Víctor Pochat (LC/L.2375-P), No de venta S.05.II.G.120 (US$ 10,00), septiembre del 2005.

95. Condiciones y características de operación de la industria minera en América Latina, durante el bienio 2004-2005, Eduardo Chaparro y Jeannette Lardé (LC/L.2371-P), No de venta S.05.II.G.113 (US$ 10,00), septiembre del 2005.

94. Provisión de infraestructura de transporte en América Latina: experiencia reciente y problemas observados, Ricardo J. Sánchez y Gordon Wilmsmeier (LC/L.2360-P), No de venta S.05.II.G.86 (US$ 10,00), agosto del 2005.

93. Privatización, reestructuración industrial y prácticas regulatorias en el sector telecomunicaciones, Patricio Rozas Balbontín (LC/L.2331-P), No de venta S.05.II.G.82 (US$ 10,00), junio del 2005.

92. Los recursos naturales en los tratados de libre comercio con Estados Unidos, Ariela Ruiz-Caro (LC/L.2325-P), No de venta S.05.II.G.68 (US$ 10,00), mayo del 2005.

91. Situación y perspectivas de la minería metálica en Argentina, Oscar Prado (LC/L.2302-P), No de venta S.05.II.G.47 (US$ 10,00), abril del 2005.

90. Administración del agua en América Latina: situación actual y perspectivas, Andrei Jouravlev (LC/L.2299-P), No de venta S.05.II.G.38 (US$ 10,00), marzo del 2005.

89. Bases conceptuales para la elaboración de una nueva agenda sobre los recursos naturales, Fernando Sánchez Albavera (LC/L.2283-P), No de venta S.05.II.G.35 (US$ 10,00), marzo del 2005.

- Readers wishing to obtain the listed issues can do so by writing to: Distribution Unit, ECLAC, Casilla 179-D, Santiago, Chile, Fax (562) 210 2069, E-mail: publications@cepal.org.

Name: ....

Activity: ....

Address: ....

Postal code, city, country: ....

Tel.: .... Fax: .... E.mail: ....