CE Delft
Solutions for
environment,
economy and
technology

Oude Delft 180
2611 HH Delft
The Netherlands
tel: +31 15 2 150 150
fax: +31 15 2 150 151
e-mail: ce@ce.nl
website: www.ce.nl
KvK 27251086

Proposal for an
Environmental Ship Index

Air pollutants and CO_2

Report, version 1.1

Delft, February 26th, 2009

Author(s): Eelco den Boer
Jasper Faber
Dagmar Nelissen

Publication Data

Bibliographical data:
Eelco den Boer, Jasper Faber, Dagmar Nelissen
Proposal for an Environmental Ship Index
Air pollutants and CO_2
Delft, CE, February 2009

Shipping / Emissions / CO_2 / Air pollutants / Environment / Pollution Index

Publication number: 09.7848.05

CE-publications are available from www.ce.nl

Commissioned by: Port of Rotterdam Authority.
Further information on this study can be obtained from the contact person Eelco den Boer.

CE Delft
Solutions for environment, economy and technology

CE Delft is an independent research and consultancy organisation specialised in developing structural and innovative solutions to environmental problems. CE Delfts solutions are characterised in being politically feasible, technologically sound, economically prudent and socially equitable.

For the latest information on CE Delft check out our website: www.ce.nl.

This report is printed on 100% recycled paper.

Preface

This proposal for an environmental ship index has been developed by CE Delft for the ports of Le Havre, Antwerp, Rotterdam, Bremen and Hamburg. The authors would like to express their gratitude to the representatives of these ports who provided us with comments on drafts in two meetings.

In version 1.1 of this report the correct sulphur content of 2.7% has been used in Figure 6 and Table 6. This has also some implications in the text.

The authors

Contents

Summary

This report develops an environmental index for the air emissions of seagoing ships. The ports of Le Havre, Antwerp, Rotterdam, Bremen and Hamburg want to develop a uniform Environmental Ship Index (ESI) that identifies ships that go beyond the current average technology in reducing air emissions. The index should be transparent, easy to determine and easy to verify. It should build on current legislation on air pollutant emissions. Therefore, the report reviews current legislation, existing indices in the maritime sector and in other modes of transport.

The proposed index ranges from 0 for a ship that meets the current environmental average performance to 100 for a ship that emits no sulphur and NO_x and reports its CO_2 performance index. Reductions in emissions are taken into account both at berth and at sea (both ECA and high sea). The index gives a relatively higher weight on emissions at berth and in the ECA, as these have a larger environmental impact in and near the ports. The formula for the index is[1]:

$$ESI = \frac{1}{3.1}\left(2 * ESI\_NO_x + ESI\_SO_x + RR\_CO_2 \right)$$

Where

- ESI_NO_x is the environmental ship index for NO_x (see below).
- ESI_SO_x is the environmental ship index for SO_x (see below).
- RR_CO_2 is the reward for reporting the energy efficiency operational index (EEOI) index (see below).

The weight of the ESI_NO_x in the overall index is twice the weight of ESI_SO_x. This reflects the fact that the average environmental damage from NO_x in ship air emissions is approximately twice the damage from SO_x.

The ESI_NO_x indicates the reductions of NO_x emissions per unit of power below the current technology average. It covers all engines and weighs them according to rated power. Implicitly, the ESI_NO_x assigns greater weight to a kg of NO_x reduced in an auxiliary engine than in a main engine. This is justified on the basis that emissions in and near ports are more important for ports than emissions on the high seas (more mathematical detail is provided below).

The ESI_SO_x reflects the reduction in sulphur content of the fuel below the current average (at high sea) or below the limit value (in SECA or at berth). The ESI_SO_x assigns the same weight to the same relative emission reduction in each of the relevant regions. As a result, a kg of SO_x reduced in ports has a larger weight than a kg reduced at the high seas. This is justified on the basis

[1] The sum ($2*ESI\_NO_x+ESI\_SO_x+RR\_CO_2$) is maximal 310. For the highest ESI score to be 100 we divide the sum by 3.1.

that emissions in and near ports are more important for ports than emissions on the high seas (more mathematical detail is provided below).

CO_2 emissions are not reflected in the index directly. The reason is that there is no established baseline for CO_2 efficiency of ships. However, in order to be, encourage ships to report CO_2 so that a baseline could be established in the future, ships can get a reporting award for CO_2 (more details are provided below).

PM emissions are not reflected in the index either. The reason is that engine PM emissions are neither certified nor regulated. Including them would involve measuring them and establishing a baseline, which would make the index costly and complex. However, it should be noted that reducing sulphur also significantly reduces PM emissions.

Mathematically, ESI_NO_x is defined as:

$$ESI\_NO_x = \frac{100}{\sum_{i=1}^{n} P_i} \times \sum_{i=1}^{n} \frac{(NO_x \lim it\_value_i - NO_x rating_i) \times P_i}{NO_x\_\lim it\_value_i}$$

Where:

- P_i is the rated power of engine i.
- $NO_x rating_i$ is the certificated NO_x emissions of engine i in g/kWh.
- $NO_x\_limit\_value_i$ is the maximum allowable NO_x emissions for an engine with the speed of engine i.
- n number of engines.

ESI_NO_x can be unequivocally calculated using the EIAPP certificates of the engines on board a ship.

Mathematically, ESI_SO_x is defined as:

$$ESI\_SOx = \frac{a\% + b\% + c\%}{3} * 100$$

Where:

- a is the relative reduction of the average sulphur content of fuel used at berth and the sulphur content of this fuel aboard the ship.
- b is the relative reduction of the average sulphur content of fuel used in the ECA and the sulphur content of this fuel aboard the ship.
- c is the relative reduction of the average sulphur content of fuel used on the high seas and the sulphur content of this fuel aboard the ship.

ESI_SO_x can be established after inspection of the bunker fuel delivery notes of a ship either over the past year or over another period.

The reporting reward for CO_2, RR_CO_2, can have two values: 10 if the IMO energy efficiency operational index over the last year is reported, and 0 if it is not. The energy efficiency operational index (EEOI) is defined as:

$$EEOI = \frac{\sum_i FC_i \times C_{Carbon}}{\sum_i m_{cargo,i} \times D_i}$$

Where:

- FC_i denotes fuel consumption on voyage i.
- C_{carbon} is the carbon content of the fuel used.
- $m_{cargo,i}$ is the mass of cargo transported on voyage i. And
- D_i is the distance of voyage i.

1 Introduction

This report develops an environmental index for the air emissions of ships. An environmental index is an indicator reflecting the environmental performance of a ship. It can either be a single indicator or a multilateral indicator, combining different emissions or environmental themes.

The Environmental Ship Index (ESI) is intended to identify clean ships. These are ships that go beyond the current average technology in reducing air emissions. The index is developed for the ports of Le Havre, Antwerp, Rotterdam, Bremen and Hamburg.

1.1 Why a voluntary index?

The ports of Le Havre, Antwerp, Rotterdam, Bremen and Hamburg want to develop a uniform Environmental Ship Index (ESI) that identifies ships that go beyond the current average technology in reducing air emissions. The index is intended to be used also by other ports, carriers and shippers worldwide to provide an incentive to introduce clean and efficient techniques for seagoing ships.

The environmental performance of ports is becoming increasingly important as a ‘license to operate’. The international emission regulations for oceangoing vessels (MARPOL-ANNEX VI, revised in 2008) are a significant step forward but it is felt that individual ships can go well beyond the standards. In different countries, environmental zoning for trucks and passenger cars, and environmentally differentiated road user charges have been widely introduced, putting a disadvantage on the most polluting categories.

In recent years, a large number of studies have been published on the environmental performance of ships and on possible indices. However, none of these studies or proposed indices currently allows for the introduction of an ESI that is simple, transparent and verifiable, feasible to be implemented in 2010, and satisfies the criteria of the abovementioned ports.

1.2 Study objective and project framework

The main aim of this project is to develop an environmental shipping index (ESI) that can be used to discern between ships that perform differently regarding their emissions of air pollutants and CO_2.

All available knowledge on environmental indexation from the maritime sector as well as other sectors should be used for the development of the new index. Therefore, we distinguish the following sub goals:

1. Evaluation of existing indices in the maritime sector and studies that propose indices will be in the light of the objectives mentioned in the specifications (see below).
2. Highlight the lessons learned and experiences gained from other modalities.
3. Develop a draft ESI.
4. Indicate how ports can proceed in indicating the index.

1.3 Requirements for the index?

To be useful in day-to-day business, the ports have laid out the following criteria for the index:

- The ESI should fit within criteria for emissions set up by UN/IMO/MEPC.
- The ESI should be a kind of an industrial standard.
- The ESI is transparent.
- The ESI should be able to be easily verified or certified (by a Classification Society).
- The ESI should be simple.
- The ESI may have several levels (and quantify the differences).
- The ESI is linked to a ship (not a fleet or type), so a ship has one label.
- The ESI should involve level of emissions from CO_2, NO_x, SO_x and PM_{10}.
- The ESI can be developed stepwise for these pollutants and expanded later on with other items.
- The ESI can make a distinction between types of ships.
- The ESI should be ready to use from 1-1-2010, for at least one pollutant.
- The ESI should have effect on the emissions at sea and at berth.

1.4 Report structure

The next chapter describes existing legislation on air emissions from ships and recent developments in this regulation. Chapter 3 provides an overview of the most important environmental indices currently used in maritime transport, while chapter 4 summarises experiences in other sectors with environmental indices and instruments based on these indices. Chapter 5 drafts the index and indicates the way forward.

2 Existing legislation and recent developments

2.1 Air pollution

In October 2008, the MEPC of the IMO adopted a tightened set of emissions standards for sea going vessels, replacing existing NO_x emission standards and fuel sulphur concentration caps. The legislation applies to ships >400GT and engines >130kW.

2.1.1 NO_X emissions

Tier I
For diesel engines installed on ships constructed from 1 January 2000 to 1 January 2011, the maximum allowable NO_x emissions are:
- 17.0g/kWh when the engine speed (n) is less than 130 rpm.
- $45.0*n^{-0.2}$ g/kWh when n is 130 rpm or more but less than 2.000 rpm.
- 9.8 g/kWh when n is 2.000 rpm or more.

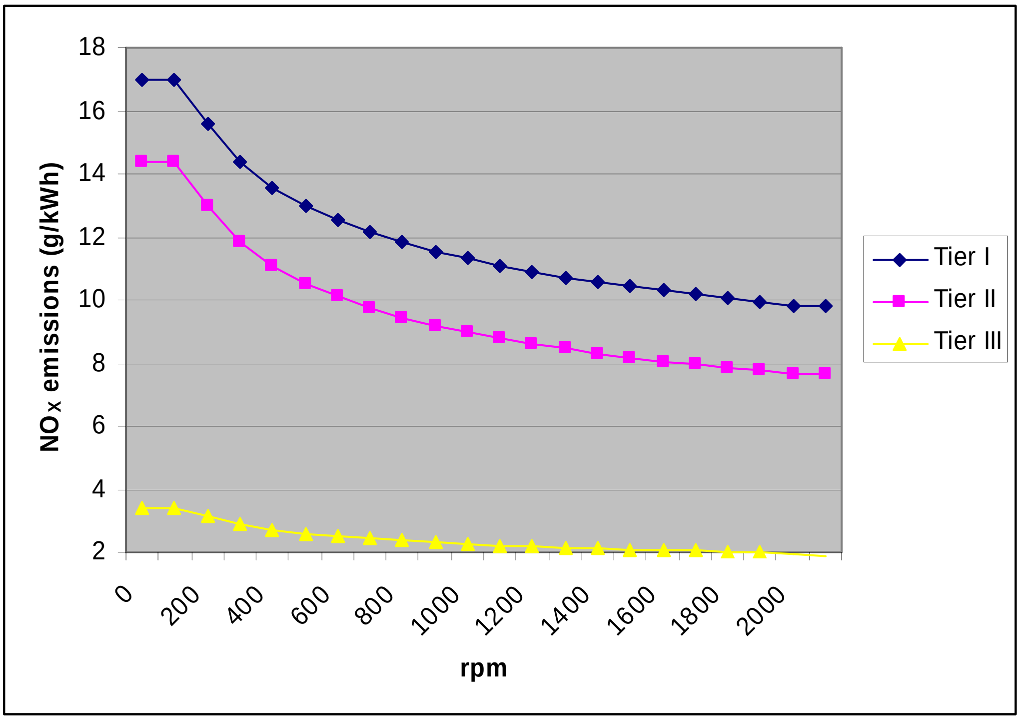
Tier II
For diesel engines installed on ships constructed on or after 1 January 2011, the maximum allowable NO_x emissions are:
- 14.4g/kWh when the engine speed (n) is less than 130 rpm.
- $44.0*n^{-0.23}$ g/kWh when n is 130 rpm or more but less than 2.000 rpm.
- 7.7 g/kWh when n is 2.000 rpm or more.

Tier III
Ships constructed on or after 1 January 2016 will have additional limitations when operating in an Emission Control Area (ECA). No ECAs have yet been designated for NO_x emissions, but it is expected that both the Baltic Sea and North Sea will be designated as NO_x ECAs well ahead of 1 January 2016. For Tier III ships operating in the NO_x ECAs, the maximum allowable NO_x emissions are:
- 3.4g/kWh when the engine speed (n) is less than 130 rpm.
- 9.0*n(-0.2) g/kWh when n is 130 rpm or more but less than 2.000 rpm.
- 2.0 g/kWh when n is 2.000 rpm or more.

It should be noted that the Tier III limits can probably not be achieved without additional means, such as Selective Catalytic Reduction (SCR) and Water Injection.

The different Tiers are depicted in Figure 1.

Figure 1 IMO Tier I, II and III



NO_x emission limits for engines constructed prior to 1 January 2000
Ships constructed on or after 1 January 1990 but prior to 1 January 2000 will be required to comply with the NO_x emission limits in force today (Tier I). However, the requirement has been narrowed down to apply to engines with a power output of more than 5.000 kW and a per cylinder displacement of 90 litres or above. Moreover, compliance is only required if an Approved Method for obtaining the necessary NO_x reduction is available for the engine(s) in question. The regulations also contain a mechanism to ensure that an Approved Method meets a cost-effectiveness criterion which will set a maximum cost for purchasing and installing a method.

Some 38% of all pre-2000 engines are over 5.000 kW and a per cylinder displacement of 90 litres. In terms of NO_x emission, the share of engines over 5.000 kW is even higher, around 80% (EMSA, 2008). This is because these engines emit relatively more NO_x, because of their high power output.

Necessary engine adjustments or the fitting of NO_x reducing kits must take place no later than the first renewal survey that occurs twelve months or more after approval of an applicable method. However, if the supplier of an Approved Method is not able to deliver this at the time of this renewal survey, installation may take place at the next annual survey. Detailed requirements for the approval of NO_x reducing methods have been included in the revised NO_x Technical Code.

Engine certification

Annex VI requires all ships built after 1 January 2000 and all engines undergoing a major revision to obtain an Engine International Air Pollution Prevention (EIAPP) certificate. In the EIAPP certificate, a reference is made to an engine family test report, which contains a NO_x emission test. In order to obtain the EIAPP certificate one needs to provide a technical file. The certificate is issued by classification societies.

The technical file is a record containing all details of parameters, including components and settings, which may influence the NO_x emissions of the engine.

The normal procedure to obtain a technical file is to start by measuring the actual emission level. Most engine types can be adjusted to fulfil the NO_x emission level requirements, usually by minor adjustments to injector nozzle specification and fuel injection timing. Whether the engine must be adjusted or not, the engine components concerned have to be coded and marked.

With an EIAPP certificate, one can e.g. prove to already meet the IMO Tier II regulations with an existing engine. An EIAPP certificate could also be used as proof for engines wherefore an EIAPP is not compulsory.

An engine can also be certified with an SCR catalyst connected.

2.1.2 Limits for Sulphur Content in Fuel Oil

The revised MARPOL ANNEX VI defines new limits for sulphur content in fuel oil. These will be:
Globally

- 4.5% until 1 January 2012.
- 3.50% from 1 January 2012.
- 0.50% from 1 January 2020.

The current average sulphur content is 2,7%, based on quantity of fuel sold (IMO, 2008).

In ECAs:

- 1.5% until 1 March 2010.
- 1.00% from 1 March 2010.
- 0.10% from 1 January 2015.

Sulphur scrubbing will be an acceptable method for compliance. So fuel with a higher sulphur content may be used as long as the sulphur oxides are removed from the exhaust gas to a level comparable to low sulphur fuel.

Concerning sulphur, the North sea and Baltic sea are defined as an ECA at the moment. The European Union's Marine Fuel Sulphur Directive (2005/33/EC) identifies these seas as ECAs. In addition, it also introduced a 0.1% maximum sulphur requirement for fuels used by ships at berth in EU ports from 1st January 2010.

Enforcement of low sulphur fuel use

The use of low sulphur fuels is to be confirmed from the bunker delivery note that the sulphur content of fuel oil is within the limit. Also, installations for a fuel oil changeover and a log-book by which fuel oil changeover prior to entry into a SO_x Emission Control Area are required. The port state control performs inspections within the scope of IMO legislation, within the framework of The Paris Memorandum of Understanding.

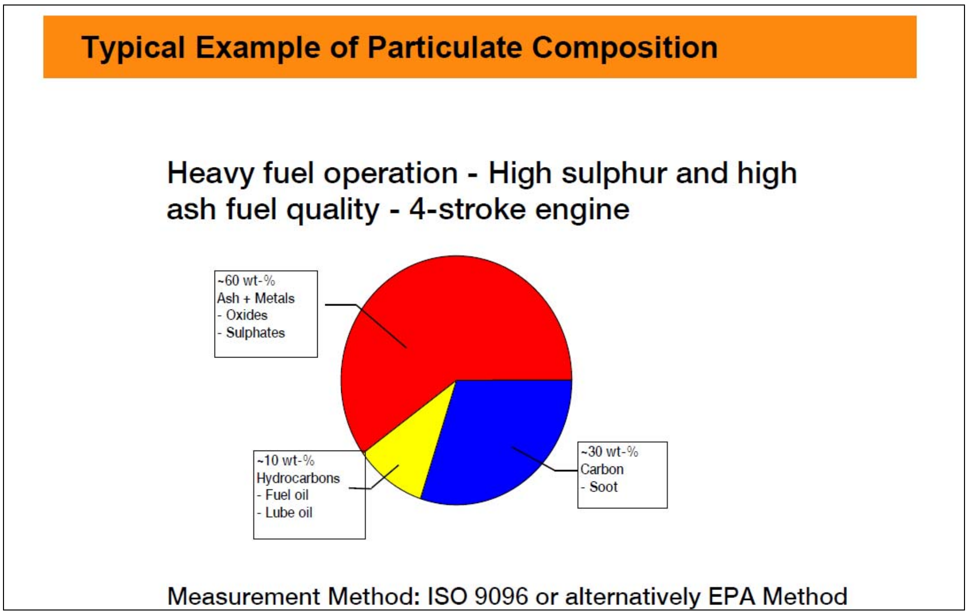
The control of the sulphur content of marine diesel oil used at berth (EU legislation) is performed by the Environment Ministry in co-operation with the seaport police.

2.1.3 PM emissions

There are currently no emission standards for the emissions of PM_{10}, so that an index cannot be built on industrial standards or criteria set by IMO. Because PM_{10} is not part of the IMO standards, engine emissions of PM_{10} are not documented on a large scale, apart from single measurements.

Roughly 50% of the PM emissions is directly related to sulphur ad ash content of bunker fuel (Wärtsilä, 2005), see Figure 2. Some 30% of the particulate composition can be linked to an engines soot emissions. These can be reduced by internal engine measures.

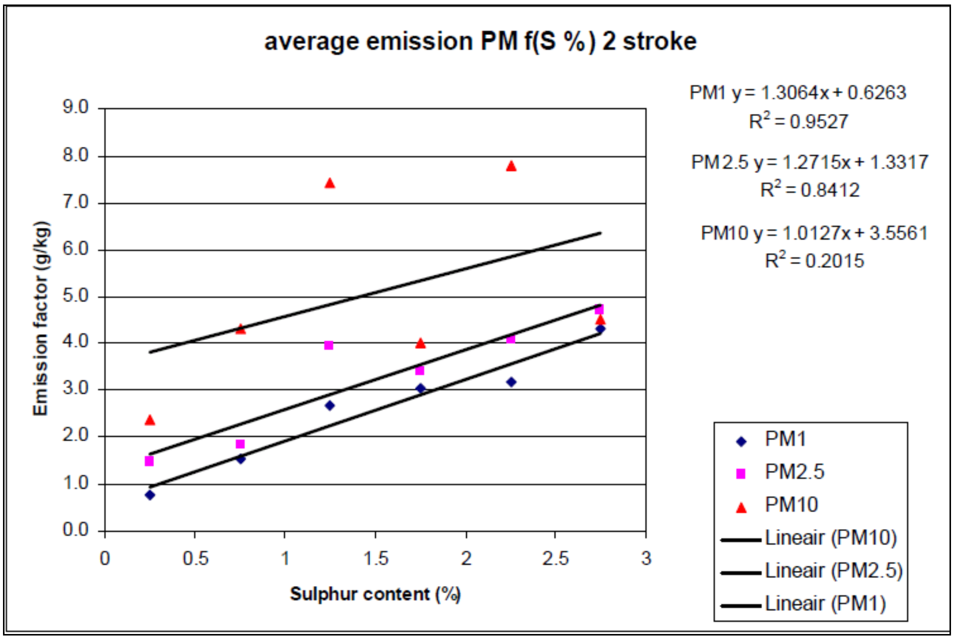
Figure 2 Typical example of particulate composition



Source: Wärtsilä, 2005.

By reducing the sulphur content of the fuel, the emission factors of PM can be reduced. Figure 3 illustrates that reducing the sulphur content from 2.7% to 0.5% reduces the emissions of PM_1 and $PM_{2.5}$ with more than factor 3. The link with PM_{10} is less clear. PM_{10} emissions have a closer link to the mineral and ash content of the fuel. This is illustrated by the low coefficient of determination (R^2=0.20) (TNO, 2007).

Figure 3 Emission factor of PM as function of the sulphur content for 2 stroke engines



Source: TNO, 2007.

2.2 CO_2 emissions

CO_2 emissions are not regulated by the IMO or by other legislation. The IMO has developed an interim guideline on CO_2 indexing for use in trials (IMO, 2005). This index is:

$$EEOI = \frac{\sum_i FC_i \times C_{Carbon}}{\sum_i m_{cargo,i} \times D_i}$$

Where:
- FC_i denotes fuel consumption on voyage i.
- C_{carbon} is the carbon content of the fuel used.
- $m_{cargo,i}$ is the mass of cargo transported on voyage i. And
- D_i is the distance of voyage i.

2.3 The California Air Resource Board regulations

The California Air Resource Board has two kinds of regulations to tackle the emissions from oceangoing vessels[2]. On the one hand the at-berth-use of auxiliary diesel engines is being regulated and on the other hand there are fuel sulphur requirements for vessels when operating within 24 nautical miles of the California Coastline. The regulation concerning the auxiliary engines at berth will legally become effective in November 2008. The regulation of the fuel sulphur has been approved by the California Air Resource Board and is expected to become legally effective in early 2009. In the following we first describe the regulation of the diesel auxiliary engines before turning to the prospective fuel sulphur requirements.

Regulation of auxiliary engines of vessels at berth

The aim of the regulation is to reduce the emissions stemming from auxiliary engines of container vessels, passenger vessels, and refrigerated cargo vessels that are docked at a California port. The requirements defined in the regulation do not have to be fulfilled when the auxiliary engines are operating primarily on liquefied natural gas or compressed natural gas. Vessels may comply with the regulation in two ways. These two options will be presented successively.

First compliance option

On the one hand the operational time of an auxiliary engine per visit to a berth is being restricted. This time limit is three or five hours per visit to a berth, depending on whether or not a vessel uses a synchronous power transfer process to change from vessel-based power to shore-based power. These time restrictions however do not have to be fulfilled every time a vessel visits a port. From 2014 on, the time limit has to be fulfilled for at least 50% of the fleet’s visits to the port.[3] This share is increased to 70% in 2017 and to 80% in 2020.

On the other hand, a fleet’s onboard power-generation by means of auxiliary diesel engines while docked has to be reduced. In 2014 it has to be reduced by at least 50% from the fleet’s baseline power-generation. This percentage is increased to 70% in 2017 and to 80% in 2020.

Notwithstanding these two requirements, any oceangoing vessel equipped to receive shore power that visits a terminal with a berth equipped to provide compatible shore power shall utilize the shore power during every visit to that berth.

---

[2] The California Air Resource Board defines an ocean going as a vessel that meets any one of the following criteria: a) Length overall is greater than or equal to 400 feet, b) gross tons are greater of equal to 10,000 and c) the propulsion engine is a marine compression ignition engine with per-cylinder displacement of greater than or equal to 30 liters.

[3] ‘Fleet’ means all container, passenger, and refrigerated cargo vessels, visiting a specific California port, which are owned and operated by or otherwise under the direct control, of the same person.

Table 1 Overview first compliance option

	Operational time limit of diesel auxiliary engines per visit	Time limit has to be fulfilled in … % of the fleet's visits	% reduction of fleet's power-generation with diesel auxiliary engines under baseline power-generation
2014	3 resp. 5 hours	50	50
2017		70	70
2020		80	80

Electrical power that is used on the vessel and that is not generated by the vessel's on-board auxiliary diesel engines and which is not supplied by the local utility has to meet the following emission standards:

- NO_x emissions <= 0.03 g/kWh.
- PM emissions equivalent to the combustion of natural gas with a fuel sulphur content <= 1 grain per 100 standard cubic foot.
- Carbon dioxide (CO_2) emissions <= 500 g/kWh.
- Ammonia emissions <= 5 ppmdv, if selective catalytic reduction (SCR) is used.

Second compliance option

When the fleet is using one or more control technique that are not part of an utility's electrical grid or alternative control technologies to reduce the emissions of the fleet, the owner or operator of the fleet shall comply with the following schedule and compliance period:

NO_x and PM emissions from the fleet's auxiliary engines when the vessels are docked at the berth must be reduced (in comparison to the baseline fleet emissions):

- In each calendar year by:
  - 10 percent (2010-2011).
  - 25 percent (2012-2013).
  - 50 percent (2014).
- In each quarter by:
  - 50 percent (2015-2016).
  - 70 percent (2017-2019).
  - 80 percent (from 2020 on).

Electrical power that is used on the vessel and that is not generated by the vessel's on-board auxiliary diesel engines and which is not supplied by the local utility has to meet the following emission standards:

- NO_x emissions:
  - <= 2 g/kWh at any time (until the end of 2013).
  - <= 0.2 g/kWh at any time (from 2014 on).
- PM emissions equivalent to the combustion of natural gas with a fuel sulphur content <= 1 grain per 100 standard cubic foot.
- Carbon dioxide (CO_2) emissions <= 500 g/kWh.
- Ammonia emissions <= 5 ppmdv, if selective catalytic reduction (SCR) is used.

Regulation of the fuel sulphur

The fuel sulphur requirements in the proposed regulation will apply to the main (propulsion) diesel engines, auxiliary diesel engines, and auxiliary boilers of all oceangoing vessels when operating within 24 nautical miles of the California Coastline. The requirements and the respective effective dates are summarized in Table 2.

Table 2 Fuel sulphur requirements within 24 nautical miles of California Coastline

Fuel	**Effective Date**
Phase I Fuel Requirement Marine gas oil (DMA) <= 1.5% sulphur or Marine diesel oil (DMB) <= 0.5% sulphur	Auxiliary diesel engines: when regulation legally effective (expected early in 2009) Main diesel engines and auxiliary boilers: July 1, 2009
Phase II Fuel Requirement Marine gas oil (DMA) or marine diesel oil (DMB) <= 0.1% sulphur	January 1, 2012

3 Environmental Indexation in maritime transport

In this chapter we will provide an overview of the existing indices used in maritime shipping. We will firstly provide an overview of all indices existing, and study the indices that are specifically designed to reduce air pollution.

3.1 Overview of existing indices

Below we provide an overview of the most important indices known within maritime transport. We thereby restrict ourselves to index criteria that are related to NO_x, SO_x, CO_2 and particulate matter emissions. For a more comprehensive overview see also EMSA, 2005, pp. 155. Note that in Sweden there are both, environmentally differentiated fairway and harbour dues. In Table 3 we only give two examples for harbours in Sweden where the dues are differentiated, whereas there are many other harbours making use of this instrument.

Table 3 Overview of environmental shipping indices

Index, Policy, Project	Pollutant/scale	Index is being applied to	Indexation Criterion	Index Classes	Identification of assignment criterion	Control	Economic incentive
NO_x tax, Norway	NO_x	Vessels with installed engine power > 750kW	Mass NO_x – Main engine. – Auxiliary engine. – Boiler.	Continuous: Actual emissions or Consumed fuel x source-specific emission factor	Emission measurement or Measurement fuel consumption & EIAPP certificate	– Total operating time – Total energy production Documentation regarding the chemical consumption	Charge on the basis of NO_x emitted
Harbor dues, Helsingborg, Sweden	NO_x		g NO_x/kWh	Classes 0.0-0.4 0.5-0.9 1.0-1.9 2.0-2.9 … 8.0-9.9	Certificate sjovartsverket (Swedish Maritime Administration)		% discount GT-based harbour dues differentiated by passenger ships, other vessels, ship with mineral oil in bulk (descending order)
	SO_x		Sulphur content fuel	<= 1%	In special certificate it must be undertaken that only low-sulphur fuel is used and stored in all bunker tanks.		Discount on harbour due : 0.1 SEK/GT

Index, Policy, Project	Pollutant/scale	Index is being applied to	Indexation Criterion	Index Classes	Identification of assignment criterion	Control	Economic incentive
Harbor dues, Goteborg, Sweden	NO_x	All	g NO_x/kWh	0-2 2-6 6-12	Certificate sjovartsverket (Swedish Maritime Administration)		Reduction in SEK per unit of the ship's GT
	SO_x		Sulphur content fuel	Passenger vessel: <= 0,5% All other vessels: <= 1%	Certificate sjovartsverket (Swedish Maritime Administration)		Charge 0.20 SEK/GT
Green Award	Safe, clean shipping, 200 ships World wide	Compliance with (inter)national legislation. Specific requirements for crew and management. Requirements of the technical equipment of the vessels.	Max. 2,715 awarded points, with a threshold of 1,810 and minimum requirements per question	Points at eight themes: 1 General 2 Navigation/bridge operations 3 Machinery/engine operations 4 Cargoes/cargo operations 5 Prevention of pollution 6 Maintenance/surveys 7 Crew 8 Requirements according to nen-en iso 9001:2000		Yearly certification	Reduction of port dues, 5% on average
IMO CO_2 index (former EEOI)	CO_2	All ships performing transport work	Mass of CO_2 in a year/transport work in that year Transport work takes into account ballast voyages	Continuous	Determination of index on basis of reporting sheet: Existing ships: one year average Newly built ships: average of not less than six months		

Index, Policy, Project	Pollutant/scale	Index is being applied to	Indexation Criterion	Index Classes	Identification of assignment criterion	Control	Economic incentive
INTERTANKO index	CO_2	Oil tankers	Mass of CO_2 in a year/transport work in that year Transport work *does not* take into account ballast voyages	Continuous			
BSR Clean Cargo Group Index	CO_2	Container ships - index is a route and company index, not a ship index	Average CO_2 emissions of all ships of a shipping company on a route/transport performance if maximum loaded	Continuous			
Clean Shipping Project	NO_x	Diesel engines > 130kWh; 1985-2000 and 2000 onwards	% reduction from original emission level; at least below IMO curve ('97) No CO_2 penalty	2007-2009: -20% 2010-2012: -40% 2013-2015: -80%		See below	
	NO_x	Diesel engines > 130kWh; New engines	% reduction below IMO curve ('97) No CO_2 penalty	2007-2012: -40% 2013-2015: -80%			

Index, Policy, Project	Pollutant/scale	Index is being applied to	Indexation Criterion	Index Classes	Identification of assignment criterion	Control	Economic incentive
Clean Shipping Project	SO_x		Sulphur content fuel used for main engine	Non-distillate fuel : 1% until 2009, 0.5% 2010-2012 in ECAs Distillate fuel (at least DMB) 1% until 2012 0.5% 2013-2015		A received certification during one period is valid until the following period expires, unless regulations stipulate otherwise; Periods: 2007-2009 2010-2012 2013-2015 Ships are evaluated on how they score when all criteria are taken into account. When a ship gets 40% and more of the maximum score it is denoted as being 'green'.	
	SO_x		Sulphur content fuel used for auxiliary engines at berth /boilers or Shore side electricity	2007-2009: 0.2% 2010-2015: 0.1% also within 12 nautical miles of port limit Used when offered			
	SO_x		g SO_2/kWh of exhaust gas cleaning system	<= 2			
	Particulate matter		g PM /kWh of exhaust gas cleaning system	<= 5			

Index, Policy, Project	Pollutant/scale	Index is being applied to	Indexation Criterion	Index Classes	Identification of assignment criterion	Control	Economic incentive
Clean Shipping Project	CO_2		2007-2009 Reporting 2010-2015 Improvements in CO_2 efficiency	2007-2009: Reporting of MEPC index (2005), of Transport & planning and of Speed Planning 2010-2015: Improvements of combustion technique, ship/hull design and efficiency propulsion; Use of biofuels, other renewables		See above	
Certificate : Der Blaue Engel; **RAL-UZ 110/ Environment-conscious Ship Operation; Compulsory Requirements**	NO_x	Not applicable to tank ships (oil tankers, product carriers, chemical tankers, gas carriers) and to ships under High Speed Craft Code, to fishing vessels, recreational and navy ships.	MARPOL Annex IV			When the 10 compulsory and 3 optional requirements are met certification is granted ; Current labels expire December 2009.	
	SO_2		MARPOL Annex IV				

3.2 Conclusions and lessons to be learned

- Compared with environmental indices used in other transport modes, several indices in use (Green Award, Der Blaue Engel) or proposed (Clean shipping) are complex. This reduces the attractiveness of the index. Only about 7% of all ships that fit within the criteria for certification are certified with the Green Award certificate. For oil tanker carriers the Green Award is attractive even when a carrier never calls an incentive port, since charterers consider these vessels to have a reduced risk.

- The fact that oil tanker charterers prefer Green Award vessels as they consider them to have a reduced risk means that an index could have an additional value if it is developed in close cooperation with shipping companies.

- In Sweden, the clean shipping incentive consists of an index for NO_x and an index for SO_x. Different ports, however, apply different index levels, which gives different incentives. This is not efficient from an economic point of view, as one port may give and incentive for a certain measure, while another port does not. Shipping lines prefer a univocal system applied in all ports.

- All incentives currently in force that go beyond the IMO regulations, provide incentives for the use of low sulphur fuel and the reduction of NO_x emissions.

- There are several CO_2 performance indices and CO_2 efficiency is part of the Clean Shipping project. However, currently there is no experience with such an index other than for monitoring and reporting.

- The IMO energy efficiency operational index (EEOI) is currently being designed.

4 Examples of indices used in road and air transport

In this chapter, we explore several environmental indices used in other transport sectors. Finally, we draw general conclusions that can be used to construct an index for seagoing ships.

4.1 Road transport

Examples where environmental indices are used are:
- EU passenger car labelling.
- Vehicle registration tax.
- Environmental zoning for trucks.
- Differentiation of infrastructure charges (Germany, Switzerland).

4.1.1 EU passenger car energy labelling

Introduction:
In the framework of EU Directive 2003/73/1999/94, EU Countries need give consumers information about the fuel efficiency of a new car, by an energy label.

Basically there have been two types of labels introduced:
- Relative energy label (Austria, The Netherlands and Belgium).
- Absolute energy label (United Kingdom, Portugal).

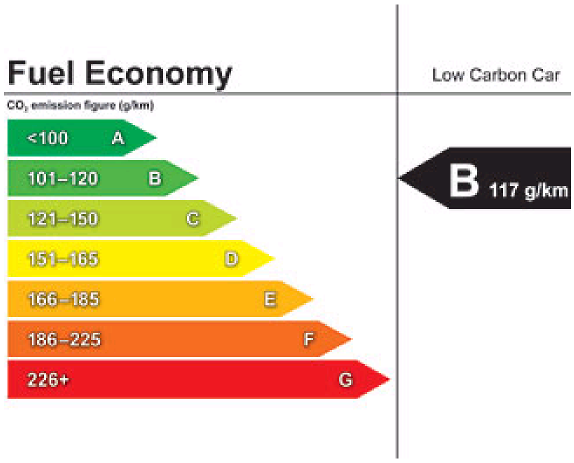
In the relative system, energy efficiency classes are discerned, based on the relative energy efficiency (%). The label shows the relative energy efficiency of a car in comparison to the average energy efficiency of cars with the same size and fuel.

In the absolute system, the label is based on the actual fuel consumption.

Basis for index:
The EU type approval test data (CO_2 in g/km). Type approval is compulsory according to Directive 80/1268/EEC and 93/116/EC.

Design:
Energy labels are developed on the basis of type approval data and used to develop labelling systems with absolute classes and systems where a comparison is made within vehicle classes.

Figure 4 Example of passenger car energy label



Inspection/enforcement:
The system is only developed to inform costumers.

Scale:
Applied in the EU.

4.2 Vehicle registration tax

In the Netherlands, the energy labels are currently also used as the basis for a differentiation of the vehicle registration tax (VRT). The Dutch tax plan 2009 implies a change of basis for taxation in the VRT from catalogue price to CO_2 emissions measured over the type approval test.

4.2.1 Infrastructure charging (Germany, Switzerland) based on external costs

Introduction:
Heavy good vehicles with a total admissible weight of more tons are subject to a charge, including foreign vehicles.

The charge level depends partly on the emission category of the vehicle and the distance traveled.

Inspection/enforcement:
The kilometres travelled are recorded by an On-Board-Unit (OBU). Further information is stored directly in the OBU (e.g. weight, emission category). Administration offices can control the distance travelled and whether the charge has been paid or not.

Scale:
Applied in Germany, Switzerland and planned to be introduced in the Netherlands.

4.2.2 Environmental zoning for lorries (NL)

Introduction:
In the Netherlands, several cities have problems with meeting the air EU quality Directive. This Directive prescribes maximum concentrations of NO_x and PM_{10} in the air. The contribution of traffic to this concentration is 50% in some cases. The Dutch government, cities and the transport unions have agreed the exclusion of older polluting vehicles in so-called environmental zones. In return, the government proposed a subsidy programme for Euro 5/EEV vehicles and a subsidy programme for particulate filters.

Basis for index:
The EU emission standard and installation of type approved particulate filter. EU emission standards have a history since the beginning of the 90's. Since then all vehicles brought on the market need to meet the standard and type approval test. The emissions are expressed in g/kWh.

Table 4 EU emission standards

Tier	Euro I	Euro II	Euro III	Euro IV	Euro V	Euro VI
Date	1992	1996-1998	2000	2005	2008	2013

Design:
Until 2010: Vehicles older than Euro II and not equipped with a particulate filter are prohibited to enter an environmental zone.
After 2010: All vehicles older than Euro III will be prohibited from the environmental zones.

Inspection/enforcement:
Manual/camera control in cooperation with Dutch road authority database. The Euroclass and installation of particulate filters are stored in a database.

Scale:
National. Vehicles from abroad are exempted from the system.

Germany has a comparable system for all vehicles, which is based on the EU emission standards as well.

4.3 Air transport

In air transport, indices exist for aircraft noise and engine emissions and both are used as a basis for environmentally differentiated charges.

Aircraft jet engine emissions are regulated by ICAO. Engine types introduced after a certain date may not emit more NO_x and smoke than a certain limit value, which depends on the thrust of the engine and its overall pressure ratio. Moreover, ICAO demands that all types of engines are certificated and emission measurements are part of the certification process. As a result, emission characteristics of all jet engines are known. They are compiled in a public database (http://www.caa.co.uk/default.aspx?catid=702).

The European Civil Aviation Conference (ECAC), which is the European organisation of civil aviation authorities has developed an index and guidelines for the environmental differentiation of landing charges at airports. These so-called ERLIG recommendations basically state that the basis for any differentiation should be the mass of NO_x emitted by the engine according to its type approval (and as documented in the public database). The differentiation should be continuous, so no classes should be made.

Aircraft type/engine combinations have to be certificated in order to be allowed to fly and transport passengers or cargo. As part of the certification process, the noise of the aircraft is measured in different situations. The type approval certificates are public and an aircraft noise database is compiled for public use by the French civil aviation authority (http://noisedb.stac.aviation-civile.gouv.fr/). Many airports use this database to differentiate airport fees. Again, often a continuous scale is used.

4.4 Conclusions and lessons to be learned

From the indices used in road and air-transport, the following conclusions can be drawn:

- All indices are relatively simple and cover only one environmental theme.
- Data availability is important. In the case of banning, charging or differentiation of taxes or levies, data availability is more important than in the case of stimulation of innovative groups.
- Emissions standards and type approval data are mainly used as the basis for an index. This is the case in both road transport and air transport.
- Basically indices used widely are:
  - EU emission standards (g/kWh).
  - Noise standards aircraft engines.
  - Aircraft engine type approval data (g/LTO).
- In the case if truck engines, fuel consumption and CO_2 emissions are not type approved. Consequently, environmental indices for truck transport do not tackle CO_2 emissions. Passenger cars are type approved for CO_2, which is reflected in the availability of indices that distinct in fuel efficiency.
- In road and air transport, banning (noise, environmental zoning), differentiation (infrastructure charging) and stimulation (particulate filters) are all used to improve the environmental performance.

5 Development of ESI

5.1 Introduction

In this chapter, we draft a relatively easy to understand environmental ship index. Developing such an index is outweighing scientific soundness and practical usability. Our approach is to propose a simple index that is practical in use, but to illustrate the effects of certain choices.

We propose an index for NO_x, SO_x and CO_2. These indices are combined into one overall index, the ESI. The ESI also ranges from 0 to 100. The formula for the ESI is:

$$ESI = \frac{1}{3.1}\left(2 * ESI\_NO_x + ESI\_SO_x + RR\_CO_2 \right)$$

Where:
- ESI_NO_x is the environmental ship index for NO_x.
- ESI_SO_x is the environmental ship index for SO_x.
- RR_CO_2 is the reward for reporting the energy efficiency operational index.

We use continuous scales as far as possible without thresholds. Thus, every improvement in environmental performance is reflected in the index.

5.2 General requirements for the ESI

In principle, the index applies to all ships and ship types. The SO_x index is based on the sulphur content of the fuel, for which all ships can or must obtain bunker fuel delivery notes. The NO_x index is based on the Engine International Air Pollution Prevention (EIAPP) certificate. This certificate is compulsory for all engines with a rated power of 130 kW or more either built after 2000 or having undergone a major overhaul. Engines below 130 kW are not included in the ESI.

Ships smaller than 400 GT are not regulated by IMO and may therefore have no certified engines or no bunker fuel delivery notes. But they are free to prove to meet the demands. The same holds for engines built before 2000.

The ESI will not discern between new ships and existing ships. From an environmental point of view there is also no difference between new and existing ships when developing an index. From an effectiveness point, a separate index for existing ships could incentivise shipping companies for investments for smaller improvements. Tier I and Tier II could than for example be used as (additional) baselines for engine build before and after 1990.

Shore side electricity will not be included is this general index. The reason for this is a) simplicity and b) the stimulation of shore side electricity is a local issue. An additional reward for shore side electricity can be made at the local level, when giving incentives.

5.3 Development of ESI NO_x

The updated IMO regulations give possibilities to stimulate early adopters on the field of NO_x. The state-of-the-art in engine technology is slightly better than Tier II now, although the share of ships performing better than IMO Tier 2 is unknown at the moment. The baseline for NO_x of new engines could therefore be set at 20-30% below Tier II (Wärtsilä[4])[5]. However, ideally this value should be based on a comprehensive analysis of EIAPP certificates which was beyond the scope of this project.

The NO_x emissions (g/kWh) can be approved by the EIAPP certificates each post-2000 engine has. Technical improvements at the engine need to go together with an update of the EIAPP certificates. Pre-2000 engines do not need an EIAPP certificate, but can be certified to prove the emission level.

Ships have several engines and each engine may have different NO_x emissions. We propose to have the index reflect the weighted average of the percentage by which the engines exceed the current average technology, which is assumed to be 20% below Tier II. In formula, the index would be:

$$ESI\_NO_x = \frac{100}{\sum_{i=1}^{n} P_i} \times \sum_{i=1}^{n} \frac{(NO_x \lim it\_value_i - NO_x rating_i) \times P_i}{NO_x\_\lim it\_value_i}$$

Where:

- ESI_NO_x is the index value for NO_x, ranging from 0 to 100.
- P_i is the rated power of engine i.
- $NO_x rating_i$ is the certificated NO_x emissions of engine i.
- $NO_x\_limit\_value$ is the maximum allowable NO_x emissions for an engine with the speed of engine i (Tier II - 20%).
- n is the number of engines.

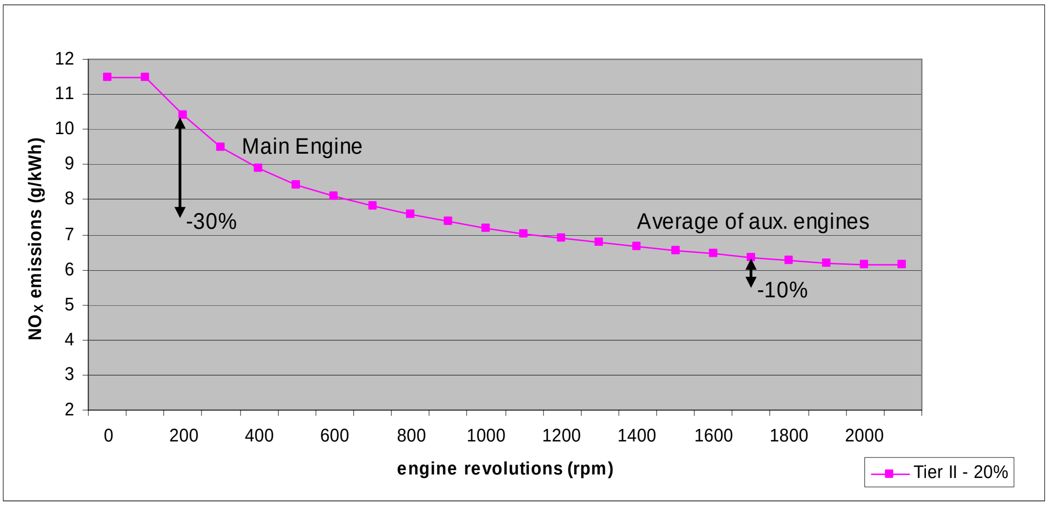
In Figure 5 we illustrate the method for the calculation of the ships NO_x performance, taken into account the emission level of both the main and the auxiliary engines. This reflects the importance of both the main and the auxiliary engines in the port area where air quality is important.

---

4 Personal communication with Robin van Burkum, Wärtsilä.

5 In Germany Inland Waterway engines that are 30% under CCR-2 are subsidized.

Figure 5 Determination of average NO_x emissions of a ship



The approach calculates one single indicator that includes both the main and all auxiliary engines. The main and auxiliary engines are weighted on the basis of their nominal power rating. A weighing factor could - if desired - be applied to attribute a different weighing to the main and auxiliary engines. For the auxiliary engines, the average emission level is based upon the contribution of the power rating of the different engines.

The IMO NO_x curve, which recognises that emission reduction at low speed engines is more complicated, is taken as starting point. Therefore, the formula rates relative emission reduction at main engines at the same way as auxiliary engines.

The emissions of boilers and incinerators are not regulated at the moment by IMO and therefore not included in the index. The contribution of boilers to total NO_x emissions at berth is limited to 5% in the Netherlands (TNO, 2003). Crude oil tankers have higher boiler emissions at berth than average.

In Table 5, the baseline level and the maximum level are indicated, and the scores.

Table 5 Baseline and maximum levels and scores

Baseline level	20% below Tier II
Score	0
Maximum level	100% below Tier II
Score	100

Engines at the end of lifetime can be replaced by rebuild engines or new ones. An existing ship can therefore contain engines meeting different Tiers, if for instance the main engine is replaced by a new one. If one or more engines do not meet the baseline level, this need to be more than compensated by the other engines to achieve a positive score.

5.4 Development of ESI SO_x

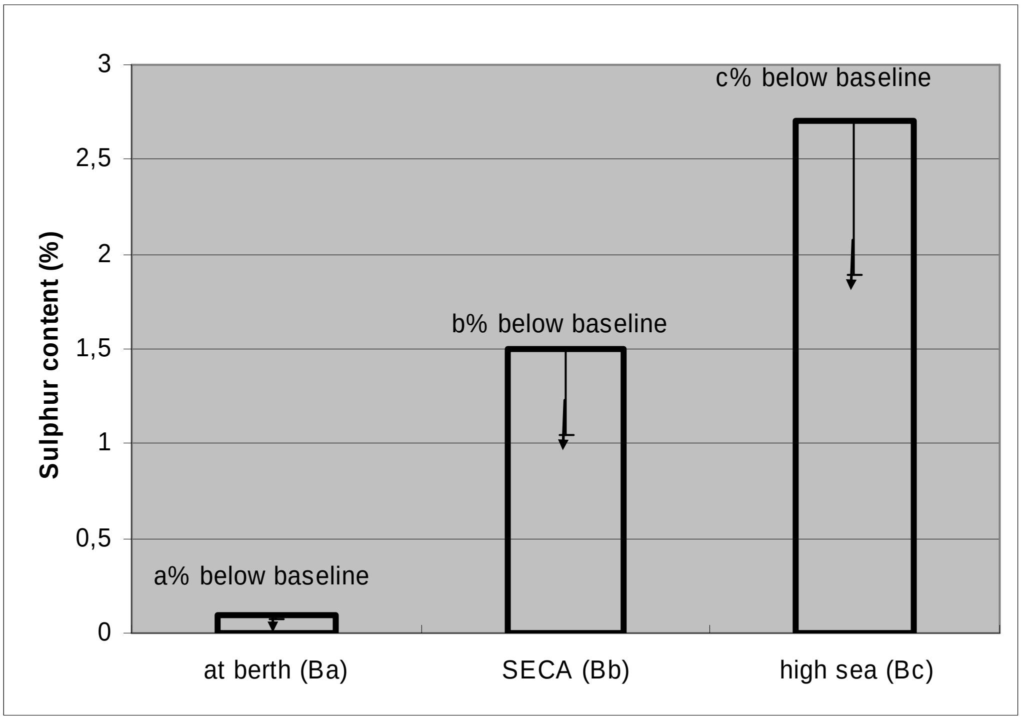
For SO_x we propose a three-track approach, taking the emissions at berth and at sea into account:
- Emissions at high sea.
- Emissions in ECA sulphur.
- Emissions at berth.

Instead of using low sulphur, a scrubber may be either used. In that case, the scrubber emissions (g/kWh) need to be calculated into fuel sulphur contents and offset against the baseline. Regarding scrubber waste water, if tight criteria for waste water are set, impacts on marine ecosystems would be limited, although this merits further research (CE et al., 2006).

Scrubber use can be verified as is done currently under the IMO regulations[6].

The index for fuel sulphur calculates the relative reduction of the sulphur emission. With different weighing factors, the importance of sulphur reduction in port and coastal areas can be stated.

Figure 6 Determination of average reduction of sulphur content



[6] IMO Resolution MEPC.130(53).

The relative reduction of the fuel sulphur used compared to the baseline can be calculated by the following basic formula (0):

$$ESI\_SOx = \frac{W_A * a\% + W_B * b\% + W_C * c\%}{W_A + W_B + W_C} * 100$$

Where:
- a%,b%,c% are the relative improvements of the fuel sulphur content of the fuel used over the last year compared to the baseline.
- W_A,W_B,W_C are the weighing factors to attribute a different weighing to emissions at high sea and close to build areas.

With the weighing factor W, different weightings can be applied:
1 No additional weighing (W =1).
2 Weighing on the basis of fuel bunkered.
3 Weighing of the basis of fuel bunkered and baseline fuel sulphur content.

In the first case, every % of reduction from the baseline is valued the same. The sulphur baseline level and the amount of fuel bunkered per fuel are not taken into account. Implicitly, a weighing is given to the different fuels that amounts to the product of the difference in fuel sulphur content, multiplied by the difference in amount of fuel bunkered.

The formula (1) is simply:

$$ESI\_SOx = \frac{a\% + b\% + c\%}{3} * 100$$

In the second case, a weighing is based on amount of fuel bunkered per year for the respective zone. The formula (2) is:

$$ESI\_SOx = \frac{B_A * a\% + B_B * b\% + B_C * c\%}{B_A + B_B + B_C} * 100$$

Where:
- B_A, B_B, B_C are the amounts of fuel bunkered over the last year for use at berth, in ECA and at high sea (ton/year).

In the third case, a weighing is based on the amount of fuel bunkered and the sulphur content of the fuel. In fact, the relative amount of kilogrammes SO_x reduced is calculated. The formula (3) is:

$$ESI\_SOx = \frac{B_A * (Baseline_A * a\%) + B_B * (Baseline_B * b\%) + B_C * (Baseline_C * c\%)}{B_A + B_B + B_C} * 100$$

Where:
- $Baseline_{A,B,C}$ are the fuel sulphur contents set as the baseline.

With applying weighing factors in this formula, the formula is turned into a formula with implicit weighing like formula 1 or 2. This formula should therefore only be used when no weighing factors are applied, and every kg SO_x is treated the same.

In a numerical example, we illustrate the effect of implicit weighing. As can be seen from Table 6, the weighing depends strongly on the ships type and size.

Table 6 Weighing on the basis of fuel sulphur content and fuel consumption, relative to operation at high seas

	Tanker	Tanker	Bulker	Bulker	Unitized	RoRo	Passenger
DWT class (*1000)	80-120 dwt	-5 dwt	35-60 dwt	-10 dwt	3-5 teu	-2 lm	C 10-60 gt
Average GT	56.921	1.056	27.596	1.942	45.317	3.557	29.559
Fuel consumption main engine (ton/year)	12.155	578	7.040	882	25.183	1.689	12.462
Fuel consumption aux. engines (ton/year)	955	135	750	313	2.822	378	2.368
Fuel consumption							
% in ECA/ % at sea	10%	80%	10%	80%	10%	80%	50%
ECA (ton/year)	1.215	462	704	705	2.518	1.351	6.231
High seas (ton/year)	10.939	116	6.336	176	22.664	338	6.231
At berth (ton/year)	955	135	750	313	2.822	378	2.368
SO_x emissions							
ECA (ton/year)	18,2	6,9	10,6	10,6	37,8	20,3	93,5
High seas (ton/year)	295,4	3,1	171,1	4,8	611,9	9,1	168,2
At berth (ton/year)	1,0	0,1	0,7	0,3	2,8	0,4	2,4
Weighing							
Due to not taking fuel use into account							
At berth	11,5	0,9	8,5	0,6	8,0	0,9	2,6
ECA	9,0	0,3	9,0	0,3	9,0	0,3	1,0
High seas	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Due to not taking sulphur content into account							
At berth	27,0	27,0	27,0	27,0	27,0	27,0	27,0
ECA	1,6	1,6	1,6	1,6	1,6	1,6	1,6
High seas	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Total weighing							
At berth	309,2	23,0	228,2	15,2	216,8	24,1	71,1
ECA	14,4	0,4	14,4	0,4	14,4	0,4	1,6
High seas	1,0	1,0	1,0	1,0	1,0	1,0	1,0

Note: For this analysis it is assumed that auxiliary engines only operate at berth.
Source: MARINTEK et al., 2008.

As is shown in Table 6, not weighing for the sulphur content gives a 27 times higher weight to sulphur reduction at berth compared to at high seas for all ships. Not taking the consumption of the different fuels into account, gives for large ships a higher weighing to emissions at berth. For small ships (feeders) the weighing by leaving out fuel consumption is small, because the consumption at berth is comparable with the consumption at high seas. In some cases, emissions in the ECA and at berth get a lower weighing than at high sea, because the fuel consumption at high sea is lower than at berth.

5.4.1 How to treat the weighing of SO_x?

When using the formula (3) where every kg of SO_x is treated the same, fuel sulphur reduction at berth has a very limited impact on the index for large ships. This is because of the high amount of SO_x emitted at high seas.

Sulphur emission at berth is concerned with bigger effects on humans and ecosystems than at open seas, because of the people living in the port region. This can be reflected by the use of weighing factors.

Formula 1 is a balance between simplicity and the use of weighing factors. The relative reduction of the fuel sulphur content is awarded equally for all fuels. The consequence is, however, that feeders in an ECA region can relatively easy lower the fuel content of their fuel used at high seas, because of the low consumption.

When using formula 2, fuel used at berth is weighted 27:1, compared with high seas. In this case, the weighing is the same for all ships. This needs however fuel consumption data to calculate the ESI.

As both formulas have advantages and disadvantages, a field test will be performed as to get a better view on the effect of the use of both formulas.

In Table 7, we show the maximum score on the basis of the use of formula 1.

Table 7 Baseline and maximum levels and scores

	At high sea	In ECA	At berth
Baseline level	2.7%	1.5%	0.1%
Score	0	0	0
Maximum level	0%		
Score	100		

5.5 Weighing between NO_x and SO_2

We have two scales now, ranging from 0-100. These scale could be combined to one scale, ranging from 0-200. To combine these scales, the damage costs (€/kg emissions) and the emissions per unit of work (kWh) need to be taken into account for a proper weighing. Damage costs are objective figures about the harmfulness of different emissions to human health and ecosystems.

The weighing between NO_x and SO_2 can be made on the basis of damage costs. Table 8 shows that per kilogramme, damage costs of NO_x and SO_2 have the same order of magnitude. These data is obtained from the EU CAFE[7] scenario's and applies to the European Union. In other regions of the world, the damage costs may be lower or higher, the interrelationship between the figures will not be very different.

Table 8 Damage costs of SO_2 and NO_x (CAFE)

	€/kg
SO_2	5.6
NO_x	4.4

Note: The damage costs of SO_2 also include the contribution to secondary PM.
Source: CE, 2008.

Per unit of output (kWh), the emission level of NO_x and SO_x is not the same. The NO_x emissions are on average around 12 g/kWh (Figure 5). Taken the ECA into account[8], the SO_x emissions are around 200 g/kWh * 1,5%S * 32/16 = 6 g/kWh.

Per unit of output, the difference between the NO_x and SO_x is roughly factor 2. Therefore, we attribute a weighing of 2 to the relative NO_x emission reduction.

This factor is a rough estimate, because:
- An auxiliary engine uses fuel with a lower sulphur content and at high sea the content is higher.
- Auxiliary engines have lower NO_x emissions than main engines.

It is however not possible to weigh on the basis of different fuels and engines, because both indices are based on different fuels and engines. Applying factor 2 is the best available option. This implies that for NO_x, a maximum of 200 points can be achieved on the overall ESI scale, since the emissions per unit of work are two times the emissions of SO_x.

5.6 Rewarding IMO energy efficiency operational index reporting

For CO_2, there is no baseline available that can be used for an index. In order to be able to establish this baseline over time, regards could be had to granting points to reporting the IMO energy efficiency operational index (EEOI) over the last year. At a later stage, the collected data can be analysed and turned into a baseline. For CO_2, an additional score of 10 points will be awarded for only reporting the energy efficiency operational index. Because the costs are limited, the amount of points awarded is limited.
The following data need to be reported:
- Fuel consumption.
- Ship type/GT.
- Amount of cargo shipped.

[7] CAFE refers to Clean Air For Europe.
[8] Note that for the other fuels the weighing is different, but the ECA is used as an average.

– Energy efficiency operational index (EEOI).

5.7 Particulates

There is no data available from engine measurement and certification on particulate emission, apart from the data from single measurement programmes. The reason for this is that PM is not regulated by IMO. Due to the lack of data and regulation it is not possible to prepare an index for PM.

PM emissions are however to a big extent influenced by the sulphur content of the fuel. Reducing the sulphur in the fuel reduces also the PM emissions. Sulphur dioxide and other sulphur compounds react in the atmosphere to form sulphuric acid (acid deposition) and secondary PM.

Incentivizing a measurement programme, to obtain data, would be an option. It is however kept out of the ESI, because of the high costs correlated.

5.8 Conclusion: overall ESI formula

The ESI can be build up of NO_x and SO_x emissions. For these pollutants, there is IMO regulation available to set the baseline and there is enough data available to calculate the indices for seagoing ships. Engine certification data (EIAPP certificate) and the allowed and average fuel sulphur contents in different shipping areas, can be used as a baseline. For PM and CO_2, no standards are available, and no data is available that can be used a baseline for individual ships. Regarding CO_2, the ESI will award gathering data to calculate and report the energy efficiency operational index of a ship.

The proposed overall index ranges from 0 for a ship that meets the current environmental average performance to 100 for a ship that emits no sulphur and NO_x and reports its energy efficiency operational index. A ship can achieve maximum 310 point on the individual indices, as argued. Reductions in emissions are taken into account both at berth and at sea (both ECA and high sea). The index gives a relatively higher weight on emissions at berth and in the ECA, as these have a larger environmental impact in and near the ports. The formula for the index is:

$$ESI = \frac{1}{3.1}\left(2 * ESI\_NO_x + ESI\_SO_x + RR\_CO_2 \right)$$

Where:
- ESI_NO_x is the environmental ship index for NO_x.
- ESI_SO_x is the environmental ship index for SO_x.
- RR_CO_2 is the reward for reporting the energy efficiency operational index.

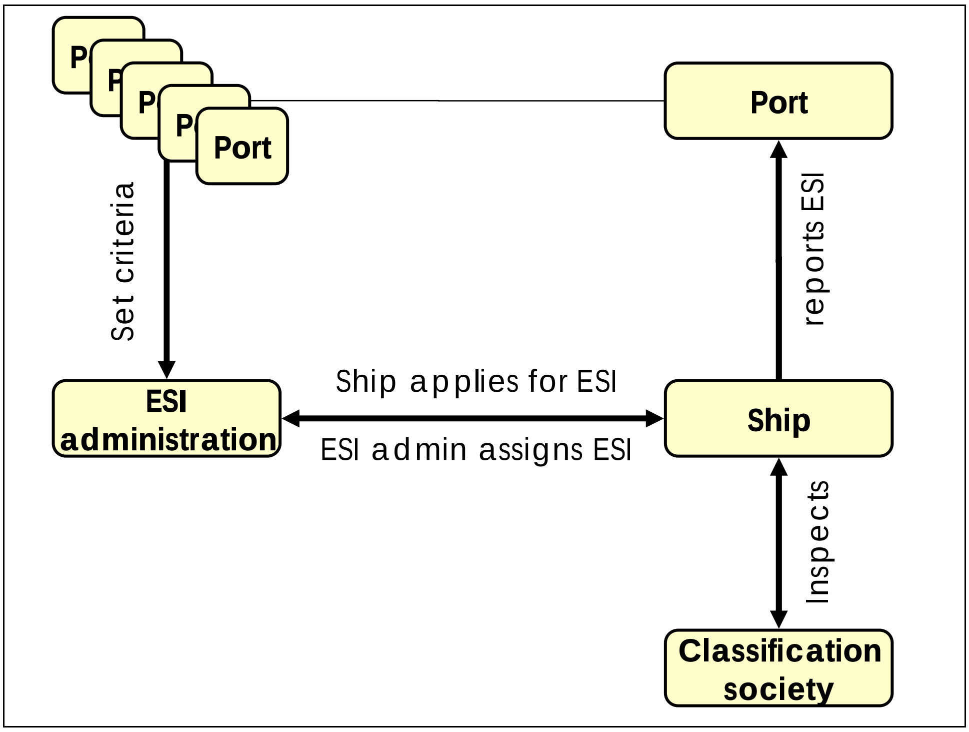
6 Organisation and verification of the ESI

The ESI can be used in instruments to encourage clean shipping. In order for this to work, a number of functions have to be performed:

- A formula for the ESI has to be established.
- Ships have to be inspected.
- Ships have to apply for an ESI.
- The ESI has to be calculated.
- A database has to be set up for the ESI of ships.
- Ports have to recognize the ESI value and apply an instrument.

We propose to assign these functions to different organizations. **Ports** have to collectively establish the formula for the ESI and instruct an **ESI administration** to set up a database for compliant ships. It has been suggested that the IAPH may set up this administration. **Ships** can apply for an ESI value by sending in EIAPP certificates and bunker fuel delivery notes. These documents have to be verified by trusted third parties, e.g. **classification societies** that the ESI administration recognizes. The ESI administration would calculate the ESI and enter the ship and its ESI in its database. When entering a **port**, the **ship** would inform the port about the ESI, based on the database of the ESI administration. The port could then apply the preferred instrument for encouraging improvement of ESI. Figure 7 depicts the organisational setup.

Figure 7 Proposed organisational set up of the ESI system



The ship would use the following documents to apply for the ESI. Classification societies would ascertain that the documentation is complete and true. As all these documents are available on board ships, and since classification societies often inspect these documents for other purposes, the additional administrative burden of the system is expected to be low.

NO_x

- For every engine the ship owner has to dispose of an EIAPP certificate to be able to qualify for a reward.
- A classification society would be in charge of verifying the EIAPP certificates and demonstrating that all the engines on board a ship have been included in the application for the ESI.

SO_x

The index is determined on a yearly basis based on the sulphur content indicated in the bunker fuel delivery notes. The Classification society inspects the following documents:

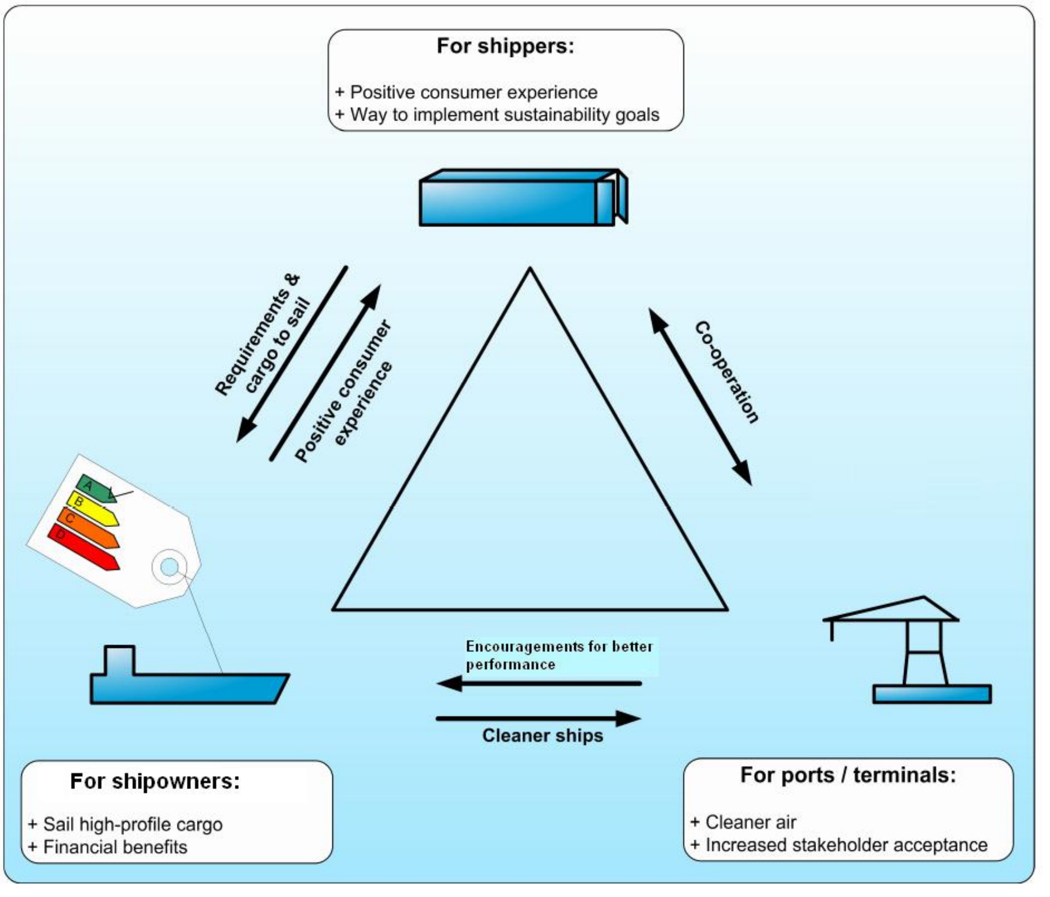
- Bunker delivery notes.

And ascertains that the reported bunker fuel delivery notes cover all the fuel bunkered in a year.

Depending on the instrument chosen, there may be need for inspection of ships in order to establish whether they comply.

The index may have uses beyond the ports. For example, shippers may adopt the index to demonstrate their environmental performance. This is depicted in Figure 8.

Figure 8 The ESI system and other stakeholders



6.1 The proposed way forward

This report provides the draft formula for an ESI. In order for the ESI to be implemented, a number of factors affecting the baseline have to be established. These are:

- The average NO_x rating of current engines as a function of engine speed.
- The average sulphur content of fuel used in ECAs and on the high seas.
- Possibly weighing.

Furthermore, it would be worthwhile to test the formula on a sample of ships, in order to establish whether it is really applicable to all ship sizes and types. The ESI_SO_x may turn out to be different for feeders and ocean going vessels, because of the difference in the use of fuel of the different types.

Finally, the organisation of the ESI system needs to be agreed with the actors involved.

6.2 Updating of the ESI

There are two reasons for updating the ESI and the formulas:

- Technological development. When incorporation of PM and/or CO_2 in the ESI is technologically possible, as the index ideally should also include these emissions. The expectation is that this will last several years, and depends on the developments at IMO level.
- Autonomous development. The NO_X emissions of ship engines and the sulphur content of heavy fuel oil decrease every year. From an accuracy point of view, the baselines in the formulas *used* should be updated every year. However, from the point of view of practicability and communication a yearly update may not be the most desirable option.

Literature

AVV, 2003
Jan Hulskotte (TNO-MEP) ; Ernst Bolt, Dick Broekhuizen (RWS-AVV)
EMS-protocol, Verbrandingsemissies door stilliggende zeeschepen in havens
Versie 2
Rotterdam : Adviesdienst Verkeer en Vervoer, 2003

California Government, 2008
Airborne toxic control measure for auxiliary diesel engines operated on oceangoing vessels at berth in California port, Final Regulation Order
http://www.arb.ca.gov/regact/2007/shorepwr07/fro93118.3.pdf

California Government, 2008
Advisory on Plans to Implement a Proposed ARB Regulation on Fuel Sulphur and Other Operational Requirements for Ocean-Going Vessels
http://www.arb.ca.gov/ports/marinevess/documents/advisory1008.pdf

CE et al., 2006
CE Delft, Germanischer Lloyd, MARINTEK, Det Norske Veritas
Greenhouse Gas Emissions for Shipping and Implementation of the Marine Sulphur Directive
Delft : CE Delft, 2006

CE et al., 2008
M. Maibach, C. Schreyer, D. Sutter (INFRAS); H.P. van Essen, B.H. Boon, R. Smokers, A. Schroten (CE Delft); C. Doll (Fraunhofer Gesellschaft – ISI);
B. Pawlowska, M. Bak (University of Gdansk)
Handbook on estimation of external costs in the transport sector Internalisation Measures and Policies for All external Cost of Transport (IMPACT)
Delft : CE Delft, 2008

EMSA, 2005
Study on Ships producing reduced quantities of ships generated waste : present situation and future opportunities to encourage the development of cleaner ships.
Lisboa : European Marine Safety Agency (EMSA), 2005

EMSA, 2008
Germanischer Lloyd, department MPU - combustion engines - environmental
Possible technical modifications on pre-2000 marine diesel engines for NO_x reduction
Lisboa : European Marine Safety Agency (EMSA), 2005

IMO, 2005
Interim guidelines for voluntary ship CO_2 emission indexing for use in trials
MEPC/Circ.471, 29 July 2005, Ref. T5/1.08
London : International Maritime Organization (IMO), 2005

IMO, 2008
Prevention of Air Pollution from Ships : Sulphur monitoring for 2007
MEPC 57/4/24
London : International Maritime Organization (IMO), 2008

MARINTEK et al., 2008
MARINTEK, CE Delft, Dalian Maritime University, Deutsches Zentrum für Luft- und Raumfahrt e.V., DNV, Energy and Environmental Research Associates, Lloyd's Register-Fairplay, Mokpo National Maritime University (MNMU), National Maritime Research Institute (Japan), Ocean Policy Research Foundation (OPRF)
Updated Study on Greenhouse Gas Emissions from Ships, phase 1 report
S.L. : S.n., 2008

TNO, 2007
Jan Duyzer, et al. ; Arjan Hensen , et al. (ECN)
Assessment of emissions of PM and NO_x of sea going vessels by field measurements
Delft : TNO/ECN, 2007

Wärtsilä, 2006
Tom Sundell
Emission measurements & evaluation of results : presentation at Environmental Seminar/Kristian Vekas 15 December 2006
Helsinki : Wärtsilä, 2006