24

Market-based Instruments for NOx abatement in the Baltic Sea

by Per Kågeson

Air Pollution & Climate Secretariat
AirClim

AIR POLLUTION AND CLIMATE SERIES

No. 1	The eastern atmosphere (1993)
No. 2	The "Black Triangle" – a general reader (1993)
No. 3	Sulphur emissions from large point sources in Europe (1995)
No. 4	To clear the air over Europe (1995)
No. 5	Large combustion plants. Revision of the 1988 EC directive (1995)
No. 6	Doing more than required. Plants that are showing the way (1996)
No. 7	Attacking air pollution. Critical loads, airborne nitrogen, ozone precursors (1996)
No. 8	Better together? Discussion paper on common Nordic-Baltic energy infrastructure and policy issues (1996)
No. 9	Environmental space. As applied to acidifying air pollutants (1998)
No. 10	Acidification 2010. An assessment of the situation at the end of next decade (1999)
No. 11	Economic instruments for reducing emissions from sea transport (1999)
No. 12	Ground-level ozone. A problem largely ignored in southern Europe (2000)
No. 13	Getting more for less. An alternative assessment of the NEC directive (2000)
No. 14	An alternative energy scenario for the European Union (2000)
No. 15	The worst and the best. Atmospheric emissions from large point sources in Europe (2000)
No. 16	To phase out coal (2003)
No. 17	Atmospheric emissions from large point sources in Europe (2004)
No. 18	Status and impacts of the German lignite industry (2005)
No. 19	Health impacts of emissions from large point sources (2006)
No. 20	The costs and health benefits of reducing emissions from power stations in Europe (2008)
No. 21	Last gasp of the coal industry (2008)
No. 22	Carbon capture and storage in Norway (2008)
No. 23	Boreal forest and climate change (2009)

AIR POLLUTION AND CLIMATE SERIES 24

Market-based instruments for NOx abatement in the Baltic Sea

By Per Kågeson, Nature Associates

Cover illustration: Lars-Erik Håkansson (Lehån)

ISBN: 978-91-975883-6-2

ISSN: 1400-4909

Published in October 2009 by the Air Pollution & Climate Secretariat (AirClim), the European Environmental Bureau (EEB) and the European Federation for Transport and Environment (T&E) - see presentations on the back cover inside.

Further copies can be obtained free of charge from the publishers as above. The report is also available in pdf format at www.airclim.org.

The views expressed here are those of the author and not necessarily those of the publishers.

Contents

Summary

Large emissions of nitrogen oxides (NOx) are a cause of major environmental problems in the Baltic Sea area. Ships account for a large and growing share of these emissions. However, in 2008 the International Maritime Organization (IMO) decided to strengthen somewhat the NOx requirements for new ships from 2011. In addition, the IMO decided that in Emission Control Areas (ECAs) very stringent rules will apply from 1 January 2016. Ships will have to reduce emissions of NOx by about 80 per cent from the current limit values that took effect in 2000. The States surrounding the sea are expected to apply to the IMO for a Baltic Sea ECA for NOx.

However, a problem in the context of the new rules is that they will apply to new ships only, and the turnover of the fleet is slow. The aim of this report is therefore to assess potential market-based instruments for reducing emissions from existing vessels and an early introduction of efficient NOx abatement technologies for newly built ships (ahead of 2016).

Three technologies can achieve emissions that meet the stringent ECA requirements: Selective Catalytic Reduction (SCR), Humid Air Motor (HAM) and LNG engines. The benefits of reducing NOx from Baltic Sea shipping by these technologies are estimated to be about five times the average cost so long as a pay-off time of 10 years is allowed. However, some, less expensive, technologies can also reduce emissions significantly, which is relevant when considering the economic efficiency of retrofitting old engines.

This paper proposes the introduction of a NOx-differentiated en-route charge. Port authorities around the Baltic Sea would be mandated to assist a common authority that collects a mandatory charge reflecting the visiting ship's NOx emissions during its latest trip in Baltic Sea waters. The charge would correspond to emissions emitted from the point of entry into Baltic Sea waters or since departure from another Baltic port.

A NOx-differentiated en-route charge would be relatively easy to operate. However, as long as the revenues are not returned to the industry, the scheme runs the risk of being legally challenged by third parties. It may therefore be wise to allow the proceeds to finance grants to ships along the lines used for recycling the revenues from the existing Norwegian NOx tax.

A charge that is similar in size to the current Norwegian tax[1], €470 per ton NOx, may be sufficient when the proceeds are used for grants. The combined effect of a grant and a modest charge should, for frequent visitors, be enough to justify investment in SCR in engines with a remaining life of about ten years. Ships should be equally eligible for the grants regardless of flag and ownership. The grant should not correspond to more than, say, 50 per cent of the incremental cost, as a higher subsidy would overcompensate some ship owners at the expense of others (e.g. infrequent visitors).

Ideally there should be only one fund for the Baltic Sea run jointly by the participating coastal States. To improve the overall efficiency one may contemplate widening the scheme to include the ports of the North Sea.

1 After it was converted into a contribution to the Business Sector's NOx Fund.

A rough calculation of the emission reduction potential indicates that application of an emissions charge, as outlined above, could cut NOx emissions from ships in the Baltic Sea by 72 per cent in 2015. If it is assumed that only four out of five of ship owners respond to the incentives in the way foreseen, the actual effect on emissions would be lowered to 58 per cent. This would correspond to a reduction of about 270,000 tons in NOx, from a business-as-usual level of approximately 460,000 tons in 2015.

Accumulated over the years 2013 to 2030, the emissions charge incentive scheme can be expected to cut NOx emissions in the Baltic Sea by a total of about 7.3 million tons, corresponding to socio-economic benefits of at least €5.8 billion.

Introduction

Large emissions of nitrogen oxides (NOx) are a cause of major environmental problems in the Baltic Sea area. The sea itself is highly sensitive to eutrophication and most of its drainage area suffers from acidification. NOx contributes to both. Furthermore, many cities in the region have difficulties attaining the Community's air quality standards for NO_2, PM and ozone. For the formation of the two latter, NOx is a precursor.

The European Union and the governments of its Member States have in relatively recent years imposed stringent restrictions on emissions of NOx from a wide range of industrial and commercial activities, including transport by road vehicles. Little has been done to reduce emissions from ships that now account for more than a quarter of total emissions of nitrogen oxides in Europe and the surrounding seas. As most inexpensive measures aimed at emissions from land-based sources have already been implemented, the shipping sector must in coming years contribute a great deal more to the abatement of NOx. Studies for the European Commission show that in relative terms it is very cost-effective to reduce emissions from shipping. Several low-cost techniques for reducing considerably the emissions of NOx from shipping are available.

In 2008 the International Maritime Organization (IMO) decided to strengthen somewhat the requirements for new ships from 2011 (Tier II). However, for Emission Control Areas (ECAs), such as the Baltic Sea, very stringent rules will apply from 1 January 2016 for new ships (Tier III). They will have to reduce emissions of NOx by about 80 per cent from the current limit values (Tier I) that took effect as of 1 January 2000.

Projections, prepared for the European Commission's Clean Air For Europe (CAFE) programme, show that emissions of NOx from shipping in European waters will nevertheless increase by about 20 per cent between 2000 and 2020, (IIASA, 2008). A problem in this context is that the new rules apply to new ships only, and the turnover of the fleet is slow. Ships tend to remain in service for 25–35 years before being scrapped.

The aim of this report is to assess potential market-based instruments for reducing emissions from existing vessels and an early introduction of efficient NOx abatement technologies in newly built ships (ahead of 2016). The objective is to design a scheme that can be used in a pilot project for providing incentives to ship owners to improve the performance of vessels operating in the Baltic Sea. Being a vulnerable brackish water ecosystem makes the Baltic Sea a suitable candidate for such a project. The Baltic is an ideal area for a trial of market-based instruments, as its boundaries are well defined and competition with ports in other areas is limited.

This paper is partly based on Kågeson (2005) and Kågeson et al (2008). The latter report presented a scheme for distance-related NOx charges for making the shipping industry invest in advanced technologies for the abatement of emissions of NOx. However, it became obsolete only a few weeks after having been approved by the German Environmental Protection Agency. What happened was that the IMO to the surprise of many decided to enforce the more stringent requirements for new ships mentioned above. However, most of the findings of the report would also be relevant in the context of developing market-based incentives for a voluntary early introduction of the new limits and for retrofitting of existing engines. Therefore this paper may be seen as an attempt to update parts of the previous report. In doing so some proposals for market-based instruments that have been launched since the spring of 2008 will also be considered.

1. Emissions and trends

Worldwide, NOx emissions from shipping (international and domestic) have been estimated at about 25 million tons in 2007, equivalent to about 30 per cent of total global anthropogenic emissions (MEPC, 2009). In 2000, emissions from ships engaged in international trade in the seas surrounding Europe were estimated to have been 3.7 million tons (IIASA, 2006).

Institut für Seeverkehrswirtschaft und Logistik (ISL) has calculated shipping emissions of NOx to have been about 384,000 tons in the Baltic Sea in 2004 (Kågeson et al, 2008), and Denmark et al (2007) estimate them to have been at least 370,000 tons in 2006. Based on the assumption that traffic grows by an average of four per cent per year, emissions would under business-as-usual reach 600,000 tons by 2020. However, as a result of existing and new MARPOL rules, and taking the longer-term effects of the current recession into account, the 2020 figure may end up being around 460,000 tons. The exact amount is difficult to forecast as it depends on the scrapping and replacement rate and on spontaneous use of measures for NOx abatement onboard ships built prior to 2016.

2. Effects on human health, climate change and natural ecosystems

Emissions of NOx affect human health and the environment in numerous ways. Nitrogen is an inert gas that makes up one fifth of the volume of the lower layers of the earth's atmosphere. In the combustion of fuels, nitrogen reacts with oxygen to form oxides of nitrogen (NOx). NOx has residence times of several days in the atmosphere, which means it can be transported over distances of more than 1,000 km.

Although great amounts are deposited at sea, shipping is a large source of acid deposition in many countries in Europe. Especially in sensitive coastal regions, ship emissions of NOx (and of sulphur) contribute notably to overstepping the critical loads of acidification.

NOx also causes eutrophication, affecting biodiversity both on land and in coastal waters. In 2000, depositions of nitrogen exceeded the critical loads for eutrophication over an area of 800,000 square kilometres, representing about 60 per cent of sensitive terrestrial ecosystems in the EU25 (Amann et al, 2004). NOx from shipping also contributes significantly to the severe eutrophication of the Baltic Sea itself. According to the European Monitoring and Evaluation Programme (EMEP, 2009), ship emissions are responsible for nearly a quarter of the atmospheric deposition of oxidized nitrogen compounds to the Baltic Sea, which equals about 12 per cent of the total nitrogen deposition.

Emissions of NOx cause the formation of nitrate aerosols that contribute to increased atmospheric concentrations of PM_{10} and $PM_{2.5}$.

Nitrogen oxides also play a roll in the formation of ozone, a major health hazard in many regions of Europe and a cause of vegetation damage and reduced crop yields. Around three quarters of the urban population in southern Europe, and 40 per cent of

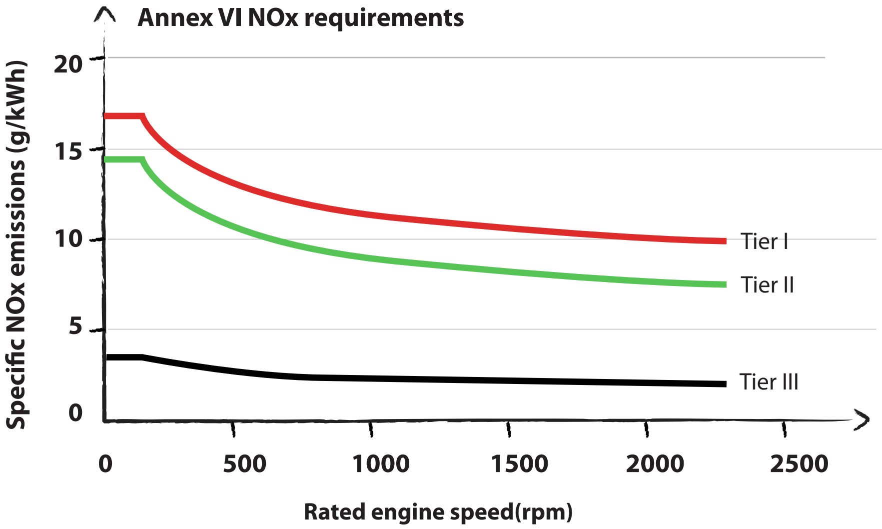

Figure 1.
The IMO's NOx curve.

The Tier I regulation, having affected 40 per cent of the current fleet (that was built after January 2000), is believed to have reduced NOx from shipping in 2007 by a little more than six per cent (MEPC, 2009).

that in northern Europe live in cities where levels exceed the EU air quality standard for ozone. The exposure to high levels of ozone and $PM_{2.5}$ results in 370,000 annual cases of premature death, of which $PM_{2.5}$ accounts for about 350,000 and ozone for approximately 20,000 in Europe (European Commission, 2005a and 2005b). Under current trends, the number of fatalities is likely to stay high even in 2020, and by then maritime shipping may have become the most important source in Europe of the main precursor, NOx.

Ozone (O_3) is also a greenhouse gas, contributing to global warming. Ozone is formed under the influence of sunlight in combination with anthropogenic and natural hydrocarbons over the oceans, especially at tropical latitudes where the intensity of solar radiation is high. However, the positive radiative forcing of O_3 is balanced by the negative forcing (cooling effect) caused by the reduction of ambient methane (CH_4) for which NOx acts as an agent. Important in this context is that ozone has a life-time of weeks while CH_4 stays in the atmosphere for years (MEPC, 2009). The indirect effect of NOx on climate change is therefore disregarded in the following evaluation of the merits of reducing NOx from shipping.

3. IMO's regulation of NOx

The International Maritime Organization (IMO), a UN body, is the organization with competence to enforce technical and operational standards on ships. The IMO's Marine Environment Protection Committee (MEPC) is the subcommittee in charge of preparing and adopting regulations concerning the environmental impacts of international shipping. Annex VI of the IMO's MARPOL Convention regulates NOx emissions from large marine diesel engines.

The current NOx regulation

The Technical Code of MARPOL Annex VI regulates NOx emissions from diesel engines with a power output greater than 130 kW installed on a ship constructed after January 2000. The specified NOx limit currently enforced on new ships represents only a small reduction in emissions compared to unregulated engines.

The NOx emission requirements of MARPOL's Technical Code, shown in Figure 1, relate to engine revolutions. The permissible emission level for NOx is a function of the engine's rpm and varies from 17.0 g/kWh, when the rated engine speed is less than 130 rpm, to 9.8 g/kWh, when the engine speed is equal to or above 2,000 rpm. The lower the engine's revolutions, the more polluting it is thus permitted to be.

The revised rules

In 2008, the MEPC 58 decided to strengthen the NOx emission requirements in two steps. The first, Tier II, will apply worldwide to new ships from 1 January 2011, and is expected to cut emissions by 15–20 per cent below business-as-usual. Tier III, to be introduced from 1 January 2016, will only apply to new ships when travelling through an ECA (see next section for details).

Table 1 provides an overview of the current and the forthcoming regulations. Please note that Tier III applies only in emission control areas. The Tier III standard is approximately 80 per cent lower than the current Tier I.

Tier	Year of entry into force	NOx limit (g/kWh)		
		n <130	130≤n<2000	n≥2000
I	2000	17.0	45×n-0.2	9.8
II	2011	14.4	44×n-0.23	7.7
III	2016	3.4	9×n-0.2	1.96

Table 1. The NOx limits of MARPOL Annex VI. n refers to rated engine speed (rpm)

It should be noted that the regulation applies to every engine of 130 kW or larger. This limit implies that not only the main engines of commercial vessels but also most auxiliary engines must comply. Auxiliary engines are used for providing the ship with electricity and heat, and are used at berth when the main engine has been turned off.

Special areas

MARPOL Annex VI provides an opportunity for coastal states to designate part of the sea as an Emission Control Area (ECA) in order to prevent or reduce the adverse impacts on human health and the environment through measures that control emissions of NOx and SOx. The North Sea (including the English Channel) and the Baltic Sea have been designated as Sulphur Emission Control Areas (SECAs). No area has yet been designated as an ECA for NOx but a proposal has been made by the governments of Canada and the United States for a combined SOx/PM/NOx ECA along most of the coasts of the two countries that would extend 200 nautical miles from the coast (370 km). Assuming the earliest possible approval by the MEPC 60, which is planned for March 2010, the new ECA could enter into force in August 2012.

The States surrounding the Baltic Sea are also expected to apply to the IMO for an ECA for NOx. The Helsinki Commission (HELCOM)[2] is currently preparing a submission. However, a potential negative side-effect of creating an ECA for NOx could be that ship owners respond by predominantly using ships built before 2016 in the ECA. This may thus delay the renewal of the fleets operating in the Baltic Sea, to the disadvantage of safety and the environment.

2 HELCOM is the governing body of the "Convention on the Protection of the Marine Environment of the Baltic Sea Area". HELCOM works to protect the marine environment of the Baltic Sea from all sources of pollution through intergovernmental co-operation between Denmark, Estonia, the European Community, Finland, Germany, Latvia, Lithuania, Poland, Russia and Sweden.

4. Measures for reducing emissions of NOx

The marine diesel engine is the dominant method of propulsion used by merchant ships. Most ships have several engines, including auxiliary engines for onboard electricity production. Nitrogen oxides are formed in the combustion chamber of the engine when some of the nitrogen in the combustion air is oxidised due to high temperature and pressure. The amount of emissions generated is very dependent on the circumstances under which the fuel is burned. In the past decades the maximum combustion pressure and temperature in marine diesels have been markedly increased as a result of successful efforts to improve the energy efficiency (by as much as 20 per cent). However, increased emissions of NOx have been a negative side-effect.

Slow-speed diesel engines (SSD) are more energy-efficient than medium-speed diesel engines (MSD) but emit more nitrogen oxides. Table 2 shows the approximate emission factor for each of the IMO's current and future standards for new ships, in comparison with ships built prior to the introduction of Tier I in 2000. Besides SSD and MSD, figures are also given for engines running on Liquefied Natural Gas (LNG) that have inherently low emissions of NOx.

	Tier 0	Tier I	Tier II	Tier III
SSD	90	78	66	18
MSD	60	51	41	12
LNG	6	6	6	6

Table 2. Estimated NOx emission factors by emission standard. Grams per kg of fuel.
Source: MEPC (2009)

There are in principle two different ways of reducing NOx emissions:

- Modifications to the engine and/or injection of water or steam into the engine.
- After-treatment of the exhaust gas.

Combinations of the two methods are feasible.

While Tier II can be achieved with relatively simple modifications of the internal-combustion process, only three technologies can at present achieve emissions that meet the Tier III limit; Selective Catalytic Reduction (SCR), Humid Air Motor (HAM) and LNG engines. However, several technologies presented in the next sections can reduce emissions below "Tier 0" and Tier I, which is relevant when the economic efficiency of retrofitting old engines is considered.

Basic internal engine modifications

The most widespread basic internal engine modification is the replacement of conventional fuel valves by low-NOx slide valves, a method that is currently applicable only to slow-speed two-stroke engines. Most new engines of this type have these valves fitted as standard, as a means of meeting the current IMO NOx standard. Retrofitting is considered easy. In 2005 more than 500 commercial installations of basic IEM had already taken place (Entec, 2005).

Advanced internal engine modifications

Advanced IEM involves combinations of a number of techniques – such as retarded injection, higher compression ratio, increased turbo efficiency and common rail injection – optimised for particular engine types.

Miller cycling

The Miller cycle is an adaption of the Otto cycle and characterised by lower compression ratio, high-pressure turbocharging, variable air inlet timing and charge-air-cooling. It can be applied to two-stroke as well as four-stroke engines. The Miller cycle allows for a lower combustion chamber temperature without a loss in power output (Wahlström et al, 2006). Miller cycling, in combination with two-stage turbocharging, has resulted in reductions of more than 40 per cent and improved fuel efficiency in four-stroke engines (MEPC, 2009).

Direct Water Injection (DWI)

Injecting water to cool the combustion chamber is a way of reducing NOx formation by up to 60 per cent. The method requires rebuilding the engine and bunkering fresh water on board, which is either injected directly with separate nozzles or sprayed into the combustion air at the inlet to the cylinder. The system is technically fairly complicated. The heat consumed in the evaporation of the water is lost with the exhaust gas. Typical ratios of water to fuel consumption are 40–70 per cent. By 2005, 23 ships had installed DWI on approximately 50 engines (Entec, 2005).

Exhaust Gas Recirculation (EGR)

Part of the exhaust gases are filtered, cooled and redirected into the engine intake air, thus reducing the combustion temperature. This technique is used in road vehicles and may be best suited to engines running on high-grade low-sulphur fuels. The reduction in efficiency in ships is estimated to be around 30 per cent. Some trials are currently being undertaken within the scope of the Norwegian program for NOx reduction (Næringslivets NOx-fond, 2009).

Selective Catalytic Reduction (SCR)

SCR is a system for after-treatment of exhaust gases and reduces the emissions of nitrogen oxides by up to 97 per cent[3]. The method is suitable for both new vessels and retrofit installations. SCR requires an exhaust temperature above 300°C. NO and NO_2 are reduced to N_2 and H_2O by mixing a solution of urea in water into the exhaust gas before it passes through a catalytic converter. This reaction takes place in a satisfactory manner only within a certain "temperature window". The exhaust temperature of medium-speed four-stroke engines is normally within this window, but often only at full engine load with large slow-speed two-stroke diesel engines, as the temperature of the exhaust gases from marine engines at partial load is not sufficiently high for effective operation of the catalyst.

The urea consumed in the SCR amounts to about seven per cent of the fuel consumption (EPA, 2009).

3 http://www.sjofartsverket.se/templates/SFVXNewsPage____1365.aspx

An advantage of after-treatment of exhausts is that it allows the engine to be optimised for low fuel consumption without risking high emissions of NOx. Thus the normal contradiction between fuel efficiency and low emissions of NOx can be overcome. Optimising engines in order to meet the Tier 1 and Tier 2 NOx requirements would, on the other hand, increase fuel consumption.

Another advantage of SCR is that VOCs are simultaneously reduced by about the same percentage and PM emissions by as much as half. The latter effect is primarily related to the oxidation of soot over the catalyst (Fridell et al, 2007).

In addition to SCR, the EPA (2009) expects that manufacturers will use compound or two-stage turbo-charging as well as electronic valving to enhance performance and emission reductions to meet Tier III.

By mid-2009 and worldwide, around 800 engines on about 200 ships were equipped with SCR[4].

Humid Air Motor (HAM)

HAM is a technique for preventing NOx formation during combustion by adding water vapour to the engine's combustion air. The compressed and heated turbo air passes through a specially designed cell that humidifies and chills the hot air from the turbo charger by taking up moisture from the warm cooling water until saturation of the intake air is achieved. Saline seawater heated by thermal losses from the engine's jacket cooling and the turbo charger is utilised in the HAM process for humidifying the intake air. The salt brine from the process is rejected back into the sea. This means there is no need for fresh water as is the case with DWI. The system makes the intercooler superfluous as the HAM system constitutes a replacement.

HAM makes combustion smoother, the combustion temperature more uniform and prevents so called "hot spots". The method is independent of the bunker oil quality and the engine's workload. HAM does not demand a warm-up period before being operated. However, the system needs to be shut down ten minutes before the diesel engine is stopped. NOx reduction also takes place at low load and independently of the exhaust temperature.

Fuel consumption does not increase, and HAM has the advantage over Selective Catalytic Reduction (SCR) of somewhat reducing operating costs instead of increasing them. This means that with HAM there is no risk of tampering. The HAM method is able to reduce NOx by around 75 per cent. However, there is as yet only one commercial vessel, the Viking Line ferry Mariella, that has installed HAM on its Pielstick engines (starting in 1999). By early 2009 it had been in service for approximately 100,000 operational hours with an availability factor of 99 per cent.

The Mariella has been certified by the Swedish Maritime Administration (2007) as having reduced its NOx emissions from 15 to 4.4 g/kWh (-71%). The Viking Line reports that installation of HAM reduced lube oil consumption by about 50 per cent and that the engine life has been extended. The engines run cleaner, and service intervals have therefore been extended by 25 per cent. Fuel consumption is down by an average of five per cent, and operating and maintenance costs have been reduced considerably. According to the Swedish Maritime Administration (2009), HAM is more cost-efficient than SCR when the financial depreciation period can be allowed to exceed five years.

4 Personal communication by Per Holmström, D.E.C. Marine AB, 4 August 2009.

The main drawbacks of HAM are the high initial costs and the need for integration with the engine (Entec, 2005). An initial problem to overcome for a more widespread application of the HAM technology is that additional space is required, and research and trials may be necessary before installation is possible on engines other than those produced by Pielstick (which holds only a tiny share of the global market for medium-speed diesel engines).

Recently the Swedish Maritime Administration (2009) has suggested that HAM should be installed in combination with a direct-acting turbo compound unit for reducing fuel consumption further. However, the additional cost of installing the turbo compound unit is not yet known as no such installation has yet been made. The turbo compound units onboard existing vessels are not direct-acting but work via a steam cycle. In the case of a direct-acting system the exhaust emissions will instead be immediately directed to a second turbine unit, whereby a higher total efficiency can be achieved. The maritime administration says that a conservative assumption suggests that combining a direct-acting turbo compound unit with HAM will boost power by at least eight per cent.

Low-NOx engines

Other means of reducing NOx include using gas turbines or gas engines with low-NOx burners. Such engines, however, have thermal efficiencies well below those of slow- and medium-speed diesel engines. LNG operation can reduce NOx by 90 per cent in four-stroke engines. The price of LNG is currently significantly lower than that of distillate fuels, providing an incentive to switch.

Costs

The costs per tonne NOx abated for various technologies, according to Entec, are as summarised in Table 3.

Technology	Ship type	Euro per tonne NOx abated Vessel size		
		Small	Medium	Large
Basic IEM	New	12	9	9
Basic IEM	Retrofit	12-60	9-24	9-15
Advanced IEM	New	98	33	19
DWI	New	411	360	345
HAM	New	268	230	198
HAM	Retrofit	306	282	263
SCR inside SECA	New	543	424	398
SCR inside SECA	Retrofit	613	473	443
SCR, ships using MDO	New	413	332	313
SCR, ships using MDO	Retrofit	483	381	358

Table 3. Emissions reduction efficiencies and estimated costs
Source: Entec (2005)

Exhaust gas re-circulation is not included in Table 3 as no installations have yet been made in commercial ships, and because the ship would for technical reasons have to switch from heavy residual oil to marine distillates. None of the technologies affect the specific fuel consumption significantly (Entec, 2005). However, the Viking Line claims a five per cent reduction for HAM (see above) and SCR allows engines to be fully optimised for low fuel consumption.

It should finally be noted that reduced speed, besides cutting fuel consumption, results in reduced exhaust emissions, including NOx. However, the IMO's method for regulating NOx does not provide any credit for this as it is expressed as grams of NOx per kWh used.

EPA (2009) gives a significantly higher cost for reduction by SCR in the US-Canadian ECA, USD 1,200 per ton NOx[5]. The difference is presumably explained by the fact that the equipment will only be used in the ECA, which for many ships will only represent a fraction of their annual voyages. Outside the ECA (beyond 200 nm off the coast), most ship operators will probably refrain from using the catalyst in order to avoid the cost of the urea. According to the EPA, the cost of a 32.5 per cent urea solution is USD 1.52 per gallon.

5. Existing policy instruments for advanced abatement technologies

A few countries and some ports have introduced market-based instruments that provide an incentive to ship owners to take measures to reduce emissions of nitrogen oxides from their ships.

Differentiated port and fairway dues

Recognising the need for abatement measures, the Swedish Maritime Administration, the Swedish Port and Stevedores Association and the Swedish Shipowners' Association in 1996 arrived at a Tripartite Agreement to use differentiated fairway and port dues to reduce emissions of NOx and SOx by 75 per cent by the end of the first decade of the new millennium. The parties concluded that vessels engaged in dedicated trade and other frequent vessel traffic involving Swedish ports, regardless of flag, should reduce emissions of NOx by installing SCR or other cost-effective NOx abatement techniques. Shifting to lower sulphur bunker fuels would reduce sulphur emissions.

The Swedish Maritime Administration (SMA) is funded by fairway dues on shipping. The fairway dues consist of two parts, one related to the gross tonnage (GT) of the ship and one based on the amount of cargo carried. It is only the former that is differentiated for environmental performance. When the differentiation was introduced, the basic levels were raised to make room for substantial deductions for ships that emit less sulphur and nitrogen oxides.

From 1 January 2005 the basic rate is SEK 1.80 (€0.18) per GT for passenger ships, SEK 2.05 (€0.20) for oil tankers and SEK 2.05 (€0.20) for other types of ship[6]. Cruise ships were included in 2006 (SEK 0.80). On top of this rate, vessels are charged an ad-

5 30 years net present value discounted at 3%.

6 SEK 1 is equal to € 0.099 (25 September 2009)

ditional SEK 0.70 (€0.07) per GT unless they use fuels containing less than a certain percentage of sulphur.

The NOx-related reduction of the due is based on the emissions measured in grams per kWh. If the emissions at 75 per cent engine load are above 10 g/kWh, no NOx discount is given. Below this level the discount increases continuously down to a level of zero grams per kWh, where the gross tonnage based fairway due is zero. For emissions below two grams per kWh there is a multiple factor for the ship's total installed engine power. The reason for this is to provide an economic incentive to ship owners to apply NOx reduction technology on auxiliary engines.

The maximum total discount (for NOx and SOx) is 100 per cent for all vessels. The number of calls that are subject to fairway dues is limited to five per calendar month for passenger vessels and two per month for other vessels. The incentive provided by the Swedish fairway due is currently on average well below €100 per ton NOx (Swedish Energy Agency et al, 2007).

By July 2009, 37 ships had a valid NOx certificate that allows them a NOx-related discount on the fairway due (excluding vessels owned by the Swedish Maritime Administration). Among them 34 have installed SCR, two apply water injection, one has installed HAM, one is a cargo vessel that has relatively low emissions (7–8 g/kWh) without having installed SCR, and one is a high-speed craft powered by low-NOx-emitting gas turbine engines. Some vessels apply different abatement technologies to the main engine and the auxiliary engines, which explains why the total number of installations by type exceeds 37. The National Maritime Administration estimates that the scheme reduces NOx emissions from ships calling at Swedish ports by around 44,000 tonnes per year.

One reason why NOx abatement measures take longer to introduce than low-sulphur fuel is that ship owners have to invest in new technology. This involves a certain degree of risk-taking, as the investments in most cases will have to be written off over a period of approximately 10 years. The response would, presumably, have been swifter had other North European countries provided a similar incentive.

To overcome initial problems and encourage the installation of SCR technologies, the Swedish Maritime Administration (SMA) offered ship owners partial subsidies for installations made during the first five years following 1 January 1998. Of the 37 ships currently enjoying reduced fairway dues because of low NOx emissions, 13 received an investment subsidy from the SMA for the abatement equipment.

By June 2009, 19 Swedish ports had introduced discounts for low emissions of nitrogen oxides. They apply a differentiation based on data for qualified ships from the SMA, but their systems are outside the influence of the SMA. Each port is an autonomous body, which in competition with other ports has to cover its costs. The challenge lies in differentiating the port due in a way that provides an incentive additional to that of the fairway due without risking a loss of customers or revenue. Such difficulties explain why the port dues are much less differentiated than the SMA's fairway dues. Table 3 shows the current rates in the most important Swedish harbours.

Port	g NOx/kWh	Discount (SEK/GT)
Port of Gothenburg	≤ 12	0.05
	≤ 6	0.10
	≤ 2	0.20
Port of Malmö	≤ 12	0.05
	≤ 6	0.15
Port of Stockholm	≤ 10	0.15
	≤ 5	0.25
	≤ 1	0.30

Table 3. Discounts for NOx emissions in selected Swedish ports in 2009.
SEK per GT (SEK 1 = € 0.099)

The discounts are small compared to the nominated rates. For instance, in the case of Stockholm the nominated tariff is SEK 2.90 (€0.29) per GT with a lower fee of SEK 1.73 (€0.17) for scheduled service vessels (at least four calls per week). The port fee is supplemented by cargo and passenger fees. The cargo fee depends on the type of cargo and the amount loaded or unloaded. It should also be kept in mind that substantial rebates may occur as a result of bargaining.

When assessing the Swedish schemes, one obvious observation is that the system does not reflect real emissions. Even if there may in most circumstances be a relatively accurate relationship between GT and engine output, neither the fairway due itself nor the discount take into account the distance travelled. The fact that the fairway due is limited to a certain number of port calls per month is another deviation from making ships pay for real emissions (or granting them a discount for reducing them).

However, even a scheme that does not truly reflect real emissions may provide sufficient incentives to ship owners to clean up their operations.

Where the environmental differentiation of port dues is concerned, one should keep in mind that if such a scheme proves very successful, the port would be forced to continuously increase its basic dues in order to balance its cash flow. When the most frequent visitors have undertaken the necessary investments to reduce their emissions, all rebates would have to be paid by the infrequent port users. They would in such a case consider calling at an alternative port, which would make it problematic for the first port to maintain its nominal rate of differentiation. In the case of Sweden, much of this problem appears to have been avoided as all major ports decided to follow the recommendation of the Swedish Port and Stevedores Association to participate in the effort by differentiating their port dues. Being situated on a peninsula, Swedish ports may also be less vulnerable to foreign competition than ports that share a coastline with ports of neighbouring countries.

Since 2000, the Finnish Port of Mariehamn (in Åland) also differentiates its basic dues with regard to ships' emissions of NOx and SOx. Most vessels are certified by the Swedish Maritime Administration as they also take advantage of the differentiation of fairway and port dues in Sweden.

Norwegian NOx tax and NOx fund

From 1 January 2007 Norway introduced a tax on NOx emissions from ship engines above 750 kW. The rate is NOK 15 per kilo (equivalent to €1,765/ton)[7]. The tax applies to emissions from ships within Norwegian territorial waters irrespective of the nationality of the vessel and her activities in the area. However, for Norwegian registered vessels, the tax applies to emissions in "near waters", which are defined as sea areas within 250 nautical miles of the Norwegian coast. Ships in international traffic are exempt, including vessels operating in direct traffic between Norway and foreign ports (Norwegian Directorate of Customs and Excise, 2007).

The tax is calculated on the basis of actual NOx emissions. If these are not known, it is calculated on the basis of a source-specific emission factor. If neither actual emissions nor the source specific factor are known, factors determined by standard values will be used. When source-specific or standard values are used, they are multiplied by the quantity of energy product consumed.

Since the introduction of the NOx tax, 14 Norwegian business organizations have entered into an agreement with the Ministry of the Environment to reduce the effective tax to 4 NOK/kg NOx (€0.47) and 11 NOK/kg (€1.29) for the offshore sector. For participant enterprises, payments to the Business Sector's NOx Fund replace the government's NOx tax. Enterprises that sign an agreement to pay NOK 4 (€0.47) per kg to the NOx Fund will be exempt from paying NOx tax for a period of three years, but in return they have to commit themselves to investigate investments required to reduce NOx and to report back to the board of the fund.

More than 90 per cent of the emissions (approx. 100,000 tons) that were initially subject to the tax are now covered by agreements that exempt them from paying the duty. The establishment of the NOx Fund means that NOK 600 million per year will be allocated to NOx reduction projects. The board of the NOx fund will pick the most cost-effective projects, which may receive 75 per cent of the investment costs from the fund. The fund will also support operational costs such as urea for the SCR reactor. The incentive for urea is 1.5 NOK (€0.18) per kg of urea used. It is estimated that approximately 80 per cent of the reduction will come from maritime projects onboard vessels.

By mid-2009 the fund estimated that measures undertaken during 2008 and 2009 will cut annual emissions by close to 14,000 tons. At the end of 2011, the program is believed to have contributed to measures that will reduce annual emissions by 30,000 tons. The average cost for measures to be undertaken on ships will, based on 250 applications, be NOK 8.86 per kilo (€1.04). The grants have provided an opportunity for new suppliers to enter the market and have given a boost to investment in NOx abatement technologies, including some novel applications, such as EGR (Næringslivets NOx-fond, 2009).

Green Award (Rotterdam)

In 1994 the Green Award Foundation was established to initiate market incentives to promote quality shipping. In collaboration with the Port of Rotterdam the Green Award programme was launched. It is designed as an incentive to large vessels to improve safety and environmental protection. Worldwide, more than 1,500 tankers

7 NOK 1 is equal to €0.118 (25 September 2009).

and 1,500 bulk carriers are operational in the categories for which the Green Award is available. Today more than 35 ports in nine different countries offer reduced port dues for vessels that carry a Green Award Certificate. Most of them offer discounts of five or six per cent on port dues. Around 200 ships have been certified. Most of these vessels are larger than 50,000 DWT and are not used in short-sea shipping.

The certification procedure consists of audits of crew and management procedures and technical provisions. The emphasis is on safe and environmentally friendly management and crew competence. The ship owner must demonstrate environmental and safety awareness in a number of areas affecting management and crew competence, as well as technical provisions. For each element a certain minimum score must be obtained in order to be granted a Green Award, and a certain minimum total score for the entire ranking list must also be obtained. Criteria related to air emissions can contribute a maximum of 10 per cent of the total number of ranking points available. Points are awarded for NOx emissions of no more than 17 g/kWh. The assessment procedure is carried out in absolute confidentiality, which means third parties are not offered any scrutiny.

6. Use of market-based policy instruments

Market-based instruments such as emission charges and cap-and-trade systems have the advantage of allowing subjects a large degree of flexibility in their choice of response. Where NOx is concerned, it makes sense for ship owners to install abatement technologies in ships travelling in the Baltic Sea in response to a market-based instrument provided that the vessel has an expected remaining life that is long enough to allow the equipment to be written off. For ships with few remaining years in operation and for infrequent visitors to the Baltic Sea it may be better to pay the full charge.

As shown above, several technological measures are available for abatement of NOx emissions from maritime shipping. Most of them can be used in new vessels and for retrofitting in old. Among these measures, the abatement potentials and costs differ, which allows ship owners to select from the menu a method that fits the engine and the remaining life of each specific vessel. While a reduction by 90 per cent would be clearly cost-effective in some ships, others can minimise expenditure by choosing a less costly method. NOx abatement, therefore, is well suited for schemes of market-based instruments as they can provide ship owners flexibility in their choice of response.

The conclusion is that environmentally differentiated incentives for reducing NOx in the Baltic Sea area offer a large degree of flexibility and would contribute towards the development/implementation of cost-efficient pollution abatement measures.

The next chapters will present various market-based instruments that could potentially be used in a pilot scheme for the reduction of NOx emitted from vessels travelling in the Baltic Sea, among them an en-route charge (chapter 8), a baseline and credit system (chapter 9), and some recent proposals for environmentally differentiated port dues, emissions trading and other market-based instruments (chapter 11). Chapter 10 is devoted to a short analysis of the legal feasibility of introducing en-route charges or a baseline and credit system. In later chapters the pros and cons of the various options will be discussed.

7. A scheme for NOx differentiated en-route charging

The proposal for environmentally differentiated en-route charges in this paper, based on Kågeson (2005) and Kågeson et al (2008), is to mandate the port authorities around the Baltic Sea to assist a common authority that collects a mandatory charge reflecting the calling ship's emissions of NOx during its latest trip in Baltic Sea waters. The charge would apply to emissions from the point of entry into Baltic Sea waters (e.g. at 57° 44.43'N or the Kiel Canal) or since departure from another Baltic port. The authority in charge of the scheme would check the distance and time travelled in Baltic Sea waters and carry out a limited number of random checks of on-board facilities for compliance with a certified situation on board and with available NOx abatement technologies.

Reflecting actual emissions

Currently it is not possible to measure the exact amount of NOx being emitted from individual ships. For the time being, emissions will therefore have to be estimated. The calculation can make use of official data on the amount of NOx that is released for each kilowatt-hour produced by the vessel's engines, assuming that on average a certain percentage of the engine capacity is utilised when the ship is moving. The Technical Code of MARPOL's Annex VI can also be used for registering specific emission levels below the mandatory value. Assuming that the average capacity utilisation of the engines is equal to that prescribed in MARPOL's technical code, an authority responsible for collecting the en-route charges can with reasonable accuracy calculate the emissions from individual vessels, provided it also has access to information on the time and distance travelled by the ship.

Since the late 1990s, the Swedish National Maritime Administration has registered the specific emissions of NOx (per kWh) for ships applying for reduced fairway dues. Its simplified method, however, cannot consider differences that occur due to a higher or lower speed or the force and direction of the wind, and does not take into consideration any emissions at berth or at anchor[8]. An additional opportunity would be to measure the true emissions of NOx as the ship moves. This is already standard for land-based furnaces of a size equal to those of the main engines of large ships, and technologies for continuous monitoring of NOx from ships are now being developed. At a later stage, when emissions are continuously measured on board each ship, the scheme could be further developed.

Establishing a scheme for environmentally differentiated en-route charges in the Baltic Sea would necessitate a common environmental ships register, which could build on the existing register administered by the Swedish Maritime Administration that already includes more than one thousand commercial vessels, most of which have registered to achieve a discount for low-sulphur fuel. Each ship would be registered by its IMO number, which remains the same throughout the life of the vessel.

8 The same kind of simplification is currently used in the environmental differentiation of road tolls.

To make charges reflect overall emissions, it would be necessary to register the time and/or distance travelled by each ship in the area covered by the scheme. For ships that never leave the Baltic Sea the simplest method would be to base the calculation on the fuel consumed. This could be done by making use of the bunker delivery notes that are already obligatory for ships above 400 GT. These must be kept on board until three years after any delivery of fuel. For these ships it would not be necessary to register distance travelled, and emissions at berth would automatically be covered.

For ships that spend part of their time on journeys outside the Baltic Sea, participating ports would have to register the port of departure for vessels calling at their facilities. The amount of fuel consumed on the journey would be calculated automatically by a computer that uses data from the ships register based on the assumption that the ship makes use of, say, 85 per cent of its engine capacity. Covering emissions when idling or in port would be difficult without having access to technologies that monitor emissions as they happen. However, the use of engines at berth will diminish as ports invest in facilities for delivery to ships of shore-side electricity. Port authorities may differentiate their dues in order to stimulate ships to invest in equipment that enables them to connect to the grid.

The existing Automatic Identification System, AIS, which automatically transmits the identity of ships, can be used for monitoring compliance and for verification of the exact time and location when a ship enters or leaves the Baltic Sea via the Kiel Canal or by passing 57° 44.43'N in the waters between Gothenburg (Vinga lighthouse) and Skagen (the Skaw) in Denmark. The heart of the AIS is a transponder on board. It consists of three main components: a GPS receiver, a VHF transceiver, and in between them a computerised data processor. The Global Positioning System (GPS) uses signals from multiple satellites to give the position of its antenna and also a very accurate time reference. The system gives updated information about other ships in the vicinity that are also equipped with AIS and thus helps the watch officer on board to take appropriate measures to avoid collisions or other calamities. In addition, the system also transmits information to onshore coastal centres.

The range of the VHF transmission is equal to "the line of sight" which in most cases is no more than 60 nm. A high antenna on board or a base station located on a hill or equipped with a tall antenna may extend the range somewhat. The conditions in the Kattegat should give sufficient coverage at 57° 44.43'N.

The emissions per kWh would then have to be multiplied by the amount of energy used under normal/average circumstances to propel the ship for the duration of the trip at 85 per cent engine capacity. In other words, this type of charge is aimed at limiting emissions per kWh used, rather than setting a cap on the total emissions emitted in the area concerned. The latter also depend on the growth (or decline) in traffic.

The conclusion is that determining emissions and/or registering the specific emissions from different vessels appears not to be a technical problem. The AIS system makes it possible to identify all ships and to measure the distance and time that each ship travels in the Baltic Sea area.

Acceptable in the context of inter-port competition

The launch of a market-based pilot scheme that applies to ports in the Baltic Sea area would give ports in neighbouring non-participating states and/or areas a competitive advantage. This might potentially be a problem for participating ports that to a large extent attract visitors from other parts of the world. The ships calling at such ports would in many cases pay en-route charges above average. If there is a non-participating port in the vicinity they may consider calling at that port. Such a move, however, is conditional on the approval of freight owners who would have to consider potential negative side-effects such as delayed deliveries or incremental costs for extended land transport by truck or train. The road toll system used on the German motorways, which after the revision of the "Eurovignette Directive" (2006/38/EC) may be followed by the introduction of kilometre-charging on the roads of other Member States, is a system that would have to be considered in this context.

If inter-port competition is regarded as a problem, the founders of the Baltic Sea pilot project would have to consider lowering the charges in order to diminish the burden put on participating ports. However, in doing so they would also affect the cost-effectiveness of the scheme. To lower the en-route charge for NOx to a level where it no longer provides an incentive to ships with many remaining years in operation to install SCR or HAM would severely weaken the scheme. In such a case, it would be better to choose a cap-and-trade system as this would guarantee some improvement, even in a case where the cap is initially set relatively high in order not to disturb competition with outside ports.

One should also remember that the charge would only be enforced on journeys to participating ports in the Baltic Sea area. As a result, all trips from such ports to ports outside the area would not be covered. In addition, trips from outside ports to ports in the southern and western part of the Baltic, which are most vulnerable to competition from neighbouring North Sea ports, would only be charged for the relatively short distance from the Kiel Canal or 57°44.43'N to the ships' destination in the Baltic Sea.

One should be aware that the problem with competition from non-participating ports exists in all regional schemes. For example, if the ports of the North Sea, the British Channel and the Irish Sea were to be included, some participating ports would face problems with ports on the other side of the "border". This may, in fact, become a (minor) problem by establishing ECAs. Moving the limits of the pilot area to some other geographical point would, of course, just shift the burden to other participating ports.

The Baltic, being relatively well separated from neighbouring seas, should be the ideal place for a trial if all coastal states take part, and would provide better conditions for a pilot project than most other sea areas, even if Russia chose not to participate.

However, a potential problem with the Baltic Sea is that high-emitting ships calling at ports along the northern part of the Swedish Baltic coast will encounter higher costs than equally high-emitting vessels calling at the Port of Gothenburg on the North Sea coast. The fact that Sweden is part of the Scandinavian Peninsula is a disadvantage to the former ports as many freight customers prefer to unload at Gothenburg and use road or rail for the journey across the peninsula.

This problem is to some extent caused by the fact that the Swedish government makes sea transport pay for the fixed costs of the fairways while at the same time exempting rail from the financial burden of most of its much higher infrastructural costs. Sweden could level the playing field by enforcing the same principle of liability on all modes. This implies raising the track fee for trains (currently among the lowest in Europe) and introducing kilometre-charging for heavy goods vehicles, which several Member States of the EU have already done or are in the process of doing.

Applicable to vessels of all types?

From a technical point of view, all types of vessels can be included in the pilot scheme. However, for practical reasons it might be better to exempt small vessels (e.g. fishing boats and small passenger ships). The rules of MARPOL and AIS are relevant to reaching a decision on the minimum size of ships that are obliged to participate in the pilot scheme. According to MARPOL Annex VI, an International Air Pollution Prevention Certificate (IAPP) must be issued to any ship of 400 GT or more engaged in voyages to ports under the jurisdiction of other Parties. All ships concerned must have received their certificate no later than the first scheduled dry-docking after entry into force of the Annex VI protocol, but in no case later than three years after entry into force of the protocol (i.e. 19 May 2008). The AIS is compulsory for all passenger ships and all cargo ships of 300 GT and more engaged in international voyages. Bunker delivery notes are mandatory for all commercial ships of 400 GT or more.

From these regulations it is clear that all vessels of 400 GT or more that engage in international traffic carry both bunker delivery notes, an IAPP Certificate and an AIS transponder. Ships of 500 GT or more engaged in domestic voyages must also be equipped with AIS, but current regulations do not force them to carry an IAPP Certificate.

In order not to discriminate against ships in international traffic, it is necessary to set the limit at 400 GT and ask the participating states to demand that all vessels in domestic traffic of that size be equipped with AIS transponders and an IAPP Certificate or, alternatively, set the limit at 500 GT. The charges should, of course, apply to all ships regardless of flag.

A common Authority for monitoring and enforcement

A common agency needs to be in charge of the en-route system, here referred to as the Authority. Among the duties of the Authority should be to:

- Keep a Baltic Sea environmental ships register
- Receive and store data transmitted from participating ports on ship movements and port calls
- Use the AIS system for monitoring of compliance
- Use these data for calculating the charges to be paid by individual ships
- Collect the charges
- Redistribute the revenues
- Collaborate with port state authorities in making random inspections on board vessels calling at participating ports to ensure that they carry the appropriate documents and are equipped accordingly
- Red-listing ships that violate the rules

There is no European authority for emissions at sea, but Kågeson (2005) identifies several existing institutions that could potentially harbour the Baltic Sea Authority. HELCOM's authority could be extended to the tasks now in question, but a decision to that effect would have to be taken by the Parties to the Helsinki Convention. This might be difficult in a situation where, potentially, one or several coastal states may choose not to participate.

The new European Maritime Safety Agency (EMSA) is another option, at least if the decision to launch the pilot project is taken by the European Union rather than by some of its Member States. The goals of EMSA are to reduce the risk of maritime accidents, marine pollution from ships and the loss of human lives at sea. The agency, however, is primarily concerned with the prevention of accidents and illegal discharges rather than with the "normal" emissions of sea vessels, and it is based in Portugal, far from the Baltic Sea.

The Authority would use vessel-specific data from its register and information from participating ports and the AIS system to calculate the charges to be paid by individual ships. The responsibility of participating ports would be limited to controlling each ship's bunker delivery note and asking the ship owner or the operator to sign a statement confirming that he/she accepts responsibility to pay the en-route charge for NOx based on the ship's latest journey in Baltic waters. Based on this information, the Authority would later bill the company. This could be done on a monthly, quarterly or annual basis.

The Authority, or alternatively the national maritime administration (port state control), should carry out random inspections on board vessels calling at participating ports to ensure that they carry the appropriate documents and are equipped accordingly. To deter ships from cheating, the scheme must also include rules on how the Authority and the participating states shall penalise ships that violate the regulations. The simplest way would be to rule that non-complying ships will be denied the right to make voluntary port calls until the debt and a penalty has been paid.

Recycling the revenues?

The proceeds from the charge could, in light of the polluter pays principle, be seen as a price that the shipping industry should pay for the damage that it causes. However, distributing the money among millions of potential "victims" would hardly be feasible, and if the treasuries of coastal states were to keep the money, land-locked neighbours may see this as a way of taxing goods belonging to firms or citizens of their countries. An alternative may therefore be, at the end of each fiscal year, to recycle the revenue from the en-route charges on shipping.

In the case of an existing Swedish charge on NOx emissions from large land-based furnaces, the money is returned to the owners based on their annual net energy production. However, in the case of shipping, a better basis for recycling money might be to divide the total annual revenue from the scheme by the number of GT or DW kilometres produced in the designated area by each ship owner, provided that reliable data are available. One could also contemplate other ways of recycling, for instance to use the revenue for funding grants to ships that invest in NOx abatement technologies. The latter type of recycling is used by Norway after remodelling its tax on NOx.

Provided that the level of the charge is accurately set, the programme would provide a correct marginal incentive without causing the average ship to pay more than it will receive back. However, ship owners who invest in abatement technologies would receive more than they pay, and owners of high-polluting ships would pay more than they get back. Apart from administration costs for the industry as such it would be a zero sum game. In this respect, this type of charge would resemble an emissions trading scheme.

8. A baseline-and-tradeable-credit scheme

An alternative to charges would be to design the en-route system as a baseline-and-tradeable-credit scheme (NERA, 2005, and Kågeson et al, 2008). Each ship would in this case receive credits equal to a baseline or benchmark value (g/kWh), which is multiplied by the amount of fuel used. The ships would have to surrender emission credits for NOx that correspond to their exhaust emissions on their journeys in the Baltic Sea.

Initially the baseline could be, say, 60 per cent of the respective value in the MARPOL Annex VI technical NOx curve (Tier I), to be gradually lowered over the years. These values would then have to be multiplied by the amount of energy used under normal/average circumstances to propel the ship at 85 per cent engine capacity and the distance and time travelled. This type of baseline cap therefore limits emissions per kWh used rather than sets a cap on the total emissions emitted in the area concerned. The level of total emissions also depends on the growth (or decline) in traffic.

In the baseline-and-credit system, the Authority would collect credits surrendered by each individual ship that equate to the vessel's emissions over a certain period of time. Ships with emissions per kWh above the baseline would have to buy credits from ships with emissions below the baseline. The scheme would thus require either the industry or the Authority to establish a trading place for emission credits.

With a limited number of acting participants, there is always a risk that strong players will try to manipulate the market, for instance by withholding credits from trading. This may argue in favour of making the Authority collect not only the credits surrendered by a liable ship to match its emissions but also the surplus credits created by ships that fall below the benchmark value. The latter would then be sold by the Authority at auction to ships that have been recorded as having excess emissions. The revenue from the auction would in such a case be returned to the initial owners of the credits in relation to the numbers surrendered. This could be done on the basis of the average price for NOx credits over a certain period of time. In order to minimise the number of transactions, in particular for frequent visitors to participating ports, it should be sufficient to make ship owners liable for final submission of credits for all their ships on a quarterly basis or once every six months. Designing the system in this way should guarantee transparency and prevent discrimination.

The Authority would thus in the case of a baseline-and-credit system:

- register to what extent each calling ship under-scores or exceeds the baselines for NOx;
- calculate the total quantities to be surrendered by different ships;
- collect credits surrendered by individual ships;
- sell excess credits at public auction and return the revenue to the ship owners who provided them.

An obvious advantage of a baseline-and-tradable-credit scheme is that it does not generate any net-revenue. The trade reallocates money between net-sellers and net-buyers without burdening the industry with any expenditure beyond the cost of compliance. Thus no effort has to be made to find a special model for recycling money. As will be shown later, a baseline-and-credit scheme may also be more legally feasible than a system of charges.

One obvious difficulty with a baseline-and-credit scheme is to define the baseline. If set too high, there will not be credits enough on sale to cover the excess emissions caused by high-emitting ships. As scarcity will result in a high credit price, it will provide ship owners a strong incentive to invest in NOx abatement technologies so the deficit may only be temporary. However, so long as there is an imbalance, some high-emitting ships cannot sail without violating the rules. One way around this problem might be to impose a high penalty on non-complying ships. The penalty would then, in practice, act as a cap on the price of credits.

9. Legal issues when introducing market-based instruments

For political and institutional acceptance, it is important that an introduction of NOx-related charges or a baseline-and-credit system is in line with the principles expressed in the United Nations Convention on the Law of the Sea (UNCLOS), adopted in 1982. UNCLOS provides a universal legal framework for the management of marine resources and regulates international aspects of marine-related activities.

According to UNCLOS Article 24, the coastal state shall not hamper the innocent passage of foreign ships through the territorial sea except in accordance with the Convention. However, Article 211(3) permits states to "establish particular requirements for the prevention, reduction and control of pollution of the marine environment as a condition for the entry of foreign vessels into their ports". Limiting the en-route scheme for NOx to ships calling at participating ports may therefore be a way to avoid a conflict with the right of innocent passage. This means that no ship is charged for crossing the Baltic Sea on its way to a port that is not participating. This would, for instance, be the case for trips to Russian ports, if the coastal states belonging to the European Union chose to participate but Russia decided not to.

Port States have wide discretion under UNCLOS and are allowed to make voluntary port calls conditional on unilaterally enforced standards if they consider this necessary for the protection of their environment. However, the requirements must be proportional to the subject pursued and non-discriminatory. They can be enforced on all vessels regardless of flag. Examples of States having made use of this opportunity are the United States Oil Pollution Act, the European Union's ban on single hull tankers, the 1996 Stockholm agreement on roll-on-roll-off ferries, the US ballast water requirements, and a recent ruling by the Swedish Supreme Environment Court on the use of SCR in the case of the city of Helsingborg versus two ferry lines. Most of these unilaterally introduced requirements applied to domestic and foreign flagged ships for the right of entry to a port have also affected the vessels when travelling in the territorial sea and the Exclusive Economic Zone on their way to the ports.

From this evidence it seems reasonable to conclude that the states around the Baltic Sea should legally be able to design a scheme for differentiated charges or a baseline-and-credit system that takes account of emissions from a journey to a port of those states. However, Article 26 declares that no charge may be levied upon foreign ships by reason only of their passage through the territorial sea, and that charges may be levied upon a foreign ship passing through the territorial sea as payment only for specific services rendered to the ship and only in a non-discriminatory manner. This may be interpreted to rule out the use of distance-related charges.

As shown above, it would in principle be possible to require all ships to be equipped with advanced technologies for the abatement of NOx, e.g. SCR, as a condition of entry into a port. However, from a cost-effectiveness point of view, it does not seem reasonable to require infrequent visitors or ships with few remaining years in operation to install technologies that would require 10 or more years to be written off. In such cases charging high emitters appears to be a more flexible and less costly solution. As this offers a greater flexibility to owners and operators of foreign flagged ships, it should in principle be regarded as less far-reaching than a fixed standard.

One way of limiting the risk of conflict over the interpretation of Article 26, may be to design the en-route scheme in a revenue-neutral way so as to avoid any net payment being levied on the average ship, though low-emitting ships would receive more than they pay, and owners of high-polluting ships would pay more than they get back. The latter would thus pay a net fee, which reflects higher than average damage to the environment. This is exactly what happens within the existing Swedish scheme for environmentally differentiated fairway dues, which however does not take distance into account. The risk of conflict with Article 26 would diminish even further if the scheme was designed as a baseline-and-credit system, where no charges would be involved at all.

The legal situation is evidently not entirely clear. Both UNCLOS and MARPOL were adopted at a time when air pollution from ships was not a major concern, and cap-and-trade systems and schemes for baseline-and-tradeable credits had not yet been invented. Therefore it is difficult to say how far a port state can go in introducing schemes that take account of emissions from ships in the territorial water and the economic zone on their way to a voluntary port of call. However, one may assume that what is not prohibited according to general principles or specifically forbidden, should be legitimate.

As baseline-and-credit schemes neither enforce mandatory standards that go beyond generally accepted international rules nor raise any charges, they seem to be more feasible from a legal perspective than en-route charges, even in a case where the latter are designed in a revenue-neutral manner.

The survival of a scheme that potentially operates under legal uncertainties depends to an extent on whether any flag state or any owner of a foreign flagged ship cares to complain. The risk of legal complaints is presumably small as long as the scheme is fair and efficient and the rules are transparent. The risk of conflict should be very small in a case where the objective is to incentivise ships to meet an agreed IMO regulation ahead of time.

The responsible entity

In maritime law, a ship has a distinct legal personality. It may be arrested and have legal proceedings brought against it separate from the legal owner or operator. Sweden's enforcement of its fairway dues requires all ships to submit electronically a declaration for fairway dues. According to the ordinance, "those who sign" declarations for fairway dues assume payment liability for these dues. The ordinance does not specifically place the liability with any legal entity. It is understood to be the ship that needs to comply with the regulation.

Making the ship responsible for submitting allowances or paying the tax or charge would make it possible to rule that a non-complying ship would be denied the right of calling voluntarily at participating ports until its debt was paid. To maintain the ship's right to call it would make no difference whether the charge or the credits were paid or submitted by the owner, the charterer, the operator or by someone else. Change of flag state or ownership would not alter the liability of the ship.

Making the owner or the charterer of the ship liable would potentially be less effective, as several different charters may be involved over time and as vessel ownership may change. It may be difficult to deny a ship the right of entrance in a case where a former charterer or owner was legally responsible and had not submitted enough NOx credits or paid the en-route charge.

A non-complying ship would be black-listed by the Authority and denied the right of calling voluntarily at participating ports until its deficit was balanced or the debt paid.

10. Other market-based instruments

This chapter discusses briefly three different proposals for use of market-based instruments for the reduction of NOx that have been presented in the last few years.

Emissions trading

The ship owners in the North Sea and Baltic Sea areas have discussed the possibility of creating a scheme for cap-and-trade between land-based emitters that are currently subject to regulation and ships which are not (or at least not much). The idea is that land-based installations should be allowed to offset emissions of NOx and SOx by financing less expensive reductions at sea (Swedish Shipowners Association, 2006). A theoretical pilot trial with ship internal SOx trade has been undertaken (SEAaT, 2006).

Emissions trading has also been investigated jointly by four Swedish state agencies (Swedish Energy Agency et al, 2007) but this has not resulted in any decision by the government. Recently, the European Commission has launched studies into the subject, one of them with the objective of analysing whether it is a good idea to create a pilot SO_2 and NOx emissions trading scheme in the Baltic Sea where shipping would be allowed to trade with other sectors. However, one difficulty in this context is that several existing EU directives may have to be changed in order to allow this to happen. Another problem is that the proposed scheme may be seen as a deviation from the Polluter Pays Principle. A third obstacle is, that in the years since the discussion started, land-based emitters have continued to invest in advanced NOx reduction technologies whereby the potential for trade with ships has been gradually reduced.

New system of differentiated port dues

CE Delft (2009), commissioned by the ports of Le Havre, Antwerp, Rotterdam, Bremen and Hamburg, has recently developed an Environmental Ships Index (ESI) that identifies ships that go beyond the current average technology in reducing emissions. 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 NOx and reports its CO_2 performance index. Ten of the 100 points are reserved for ships that report the IMO's Energy Efficiency Operational Index for the previous year (regardless of what it shows). The remaining 90 are split between NOx and sulphur so that the former is given a maximum of 60 points. According to CE Delft, this reflects the fact that the average environmental damage from NOx in ship emissions is approximately twice that caused by SOx from the same sources.

For NOx it is proposed that the index should indicate the reduction per unit of power below the current technology average. All engines would be covered and weighted together according to rated power. This must be taken to mean that the operating time, which may differ greatly between the main engine(s) and auxiliary engines, will not be accounted for. However, this is in line with the CE proposal that the ESI should assign greater weight to a kg of NOx reduced in an auxiliary engine. The authors say this is justified on the basis that emissions in and near ports are more damaging than emissions on the high seas. However, to be able to take full and accurate account of this, one would need to know the extent to which different engines are used. It is not clear from the report how this could be achieved and what it would require from the port authorities in terms of monitoring.

The effect on behaviour of the ESI will, of course, depend on the incentives provided by the participating ports.

One problem associated with an introduction of voluntary differentiation of dues in a competitive environment is that in order to preserve revenue neutrality, ports would need to offset any incentive offered to low-polluting ships by higher dues for high-polluting vessels. They would thus risk losing the latter category to competitors that do not differentiate their port dues. In general, the more price-sensitive the customers of a port, the more difficult it would be to maintain revenue neutrality. One way of diminishing the risk of losing traffic would be to depress the degree of environmental differentiation. This, however, would reduce the environmental benefits of the scheme. If all major ports in an area decide to enforce a common model, the problem will at least partly disappear. It is notable that in the case of the ESI the study was sponsored by six major ports that compete for the same customers.

Another problem with voluntary differentiation of port dues is that many ports offer regular customers negotiated rates that differ from published port dues. These negotiated rates are normally not public information, but NERA (2005) says that ports consulted by its researchers indicated that the difference from published rates may be substantial. The port may take into account the environmental performance of ships covered by a negotiated contract, but in the absence of transparency, both ship operators and competing ports will be left in doubt. One result is that ship owners cannot be certain to recoup the costs of emissions abatement measures ex ante. NERA finds it hard to see how this issue can be addressed in a commercial setting.

There are also limits to the incentives that can be provided for different kinds of vessels. With reference to a study by GAUSS (2001) of the charging structure in five German ports, NERA (2005) says that port and quay dues generally do not constitute more than 20–30 per cent of the overall port costs of most ships, even when the costs of cargo handling are excluded. Payments made to private firms offering different kinds of services in the port usually cannot be expected to be available for environmental differentiation. NERA's conclusion is that in some cases even very large discounts (percentage-wise) of port dues may not be able to offer incentives that match a significant proportion of the ship's expenditure on emission abatement measures.

The Clean Shipping Project

The Clean Shipping Project, commissioned by local and regional authorities in western Sweden, has developed an environmental index – the Clean Shipping Index – which major shipping customers can use during procurement to evaluate the environmental performance of shipping operators. The index addresses 20 factors that can affect the environment, including quality of marine fuel, energy consumption, NOx emissions, lubricants, bilge water, ballast water, antifouling paint, refrigerants and waste. Twelve of Sweden's largest industrial companies are now asking shipowners to report the environmental data needed to calculate the index. These companies have also jointly requested 77 of the world's largest shipping operators to report environmental information through the Clean Shipping Index[9].

The Clean Shipping Index identifies cargo owners as an important group of stakeholders. However, it is unclear whether the weight given to NOx is strong enough to provide a significant incentive to ship owners and operators to reduce emissions.

11. Costs and benefits

Costs

There is considerable uncertainty about the costs of NOx reduction. Some of the technologies are well established and have been installed in numerous vessels, others are in an early stage of development. The extent to which these various abatement measures affect fuel consumption and emissions of other substances is less well documented. Costs vary with size and may differ greatly when the technology is installed in existing vessels (retrofitting). Therefore any figures on capital costs and operational costs should be taken with a pinch of salt. Cost-efficiency will also be affected by the actual emission reduction efficiency, which may differ a bit from the values chosen here.

The most authoritative and comprehensive evaluation of the abatement costs is a study by Entec (2005) for the European Commission. Later reports base their economic analysis on this study (e.g. Cofala et al, 2007, Swedish Energy Agency et al, 2007, Kågeson et al, 2008). Thus the below figures have also been taken from the Entec report.

When considering retrofitting existing vessels with abatement technologies it is necessary to take account of the expected lifespan of the equipment installed. Entec has based its calculations on the assumption about lifespan shown in Table 4. For SCR, the cost of rebuilding the reactor (every 5 years) has been regarded as part of the operational cost. According to Entec, the combined uncertainty of costs and abatement efficiency is 30–50 per cent.

It should be noted that all figures in Table 4 are mid-range abatement costs. The marginal cost for reaching an ambitious target will therefore be higher. The actual capital cost will also be influenced by the interest rate (which is not mentioned by Entec).

9 www.cleanshippingproject.se

Measure	Ship type	Reduction efficiency	Lifespan	Small vessel	Medium vessel	Large vessel
		%	years	€/ton NOx		
Basic IEM [1]	New	20	2.5[2]	12	9	9
Basic IEM, young engines [1]	Retrofit	20	2.5[2]	12	9	9
Basic IEM, older engines [1]	Retrofit	20	2.5[2]	60	24	15
Advanced IEM [3]	New	30	25	98	33	19
Direct water injection [3]	New	50	4-25[4]	411	360	345
HAM	New	70	25	268	230	198
HAM	Retrofit	70	12.5	306	282	263
SCR inside SECA [5]	New	90	15[6]	543	424	398
SCR inside SECA [5]	Retrofit	90	12.5[6]	613	473	443

Table 4.
Estimated cost effectiveness of NOx abatement technologies (mid-range values). €/ton NOx abated.

1. Two-stroke slow speed engines only.
2. Fuel valves must be replaced.
3. Costs for retrofitting advanced IEM and DWI were not included by Entec due to a very high uncertainty in cost estimation.
4. Water injectors every fourth year, rest of the equipment likely to last 25 years.
5. Sulphur Emission Control Area (SECA), such as the Baltic Sea.
6. The reactor is likely to have to be rebuilt every 5 years.

An analysis by the United States and Canada (2009) shows that the requirements imposed on shipping for the reduction of NOx in the proposed ECA along the Pacific coast would cost USD 2,600 per ton avoided, which may be compared with the cost of implementing the current American programme for cleaning up the emissions from heavy-duty diesel trucks that has been estimated at USD 2,700 per ton. However, this high figure (compared to the costs given by Entec) is explained by the assumption that most of the vessels will only use their SCR when operating inside the ECA (i.e. within 200 nm of the coast), and then switch the SCR off when operating outside the ECA. This means the capital cost will be distributed over rather few tons.

Incremental benefits

Installation of SCR and other advanced technologies for the abatement of NOx will reduce emissions dramatically and result in lower costs to society as the damage caused by NOx and ozone diminishes. Studies have shown that the socio-economic benefits are greater than the estimated costs and that it is much less costly to reduce emissions from maritime transport than to cut emissions from land-based sources even further (IIASA et al, 2007). Kågeson et al (2008) found, based on cost-data from Holland and Watkiss (2002), that the benefits from reducing NOx from Baltic Sea shipping were about five times the average cost. This paper, therefore will not elaborate any further on the benefits of the proposed scheme. So long as a pay-off time of 10 years is allowed it is assumed that investment in SCR is socio-economically justified, and in most cases by a broad margin.

12. Reduction potential

In order to reduce emissions in 2020 significantly below the levels achieved by Tier I and II and the introduction of Tier III in new ships from 2016, all new ships built between 2010 and 2016 that regularly call at ports in the area would have to use HAM or SCR. In addition most ships with many remaining years of operation will also have to be equipped with advanced technologies for NOx reduction.

As described in chapter 12, the cost of equipping an existing vessel with SCR may fall in the range of €443 and €613 per ton depending on the size of the ship. For new ships the range is estimated to be €398–543 per ton. In order to promote retrofitting with SCR of the most frequent visitors, the en-route charge for NOx would have to be set at €550–600 per ton emitted, and in order to take account of the uncertainty in cost estimates, it may even have to be set higher unless the proceeds of the charge are used as grants for abatement measures. If the revenue is recycled to the industry in line with the rules for current Norwegian NOx tax, the level of the charge may be set somewhat lower as the combined incentive will be strong enough. After having been renegotiated in a deal between the government and the industry, the Norwegian tax now corresponds to €440 per ton NOx.

It should be recognised that the average cost of applying SCR to new and old vessels may amount to less than €400 per ton. However, in order to provide an incentive to all ships with more than 10 years of remaining life, the charge must reflect the marginal cost.

In order to have a significant effect on shipping emissions, the marked-based incentives would have to be introduced within the next few years. Given the time a decision process involving several states usually takes, a new scheme probably cannot enter into force before 2013, by which time the Baltic Sea ECA for NOx may be in force. It will therefore have limited effect on newly built ships, as such ships that are used in the Baltic Sea from 2016 will have to be equipped with technologies for NOx abatement, and as a consequence of the financial crisis presumably relatively few vessels will be ordered for delivery in 2011–2015. However, for some ships, not yet ordered but to be launched before 2016, the owner may choose to install SCR if early notice is given about the introduction of the incentive system.

On the other hand, the scheme's effect on pre-existing tonnage may turn out to be considerable. However, assuming an average life of 25 years and that few ship owners would contemplate retrofitting ships with a remaining expected life of less than, say, ten years, the incentives, if introduced in 2013, will only affect ships built between 1998 and 2015. As the transaction and monitoring costs will not be insignificant, the States of the Baltic Sea probably would prefer to close the scheme in a situation when in practice it would only apply to a small share of the Baltic Sea fleet. By 2025, given an annual fleet growth of four per cent after 2015, about half of the then existing ships will be younger than 10 years and thus equipped with SCR, HAM or some other low-emission technology. Five years later only a small fraction of the total fleet will consist of vessels built before 2010.

The above analysis clearly indicates that the most cost-effective use of a scheme of market-based instruments would be to launch the system as soon as possible and allow it to operate over a period of only 10–15 years. The period would, of course, have to be long enough to allow for the successful depreciation of investments in retrofitting engines with HAM or SCR that were made during the first three to five years of the scheme. The exact length of the period required for break-even would depend on the strength of the incentives provided by the system, and on the cost of borrowing capital. Assuming that most investment decisions would be made shortly after the introduction of the scheme but that scarcity of supply may cause some installations to be delayed for a year or two, a few years of investment followed by ten years of depreciation of the last installations appear to be sufficient. The scheme should then enter into force in 2013 to be closed in 2025 or 2030. It is essential that the participating States give a guarantee to the shipping sector that the scheme and its rules and incentives will apply throughout the period, as any uncertainty in this respect may cause ship owners to hesitate about making the investments.

In addition to investments in SCR and HAM, the incentives will also make ship-owners invest in basic IEM, as such investments can be written off in a very short time. However, its contribution to NOx abatement will be limited as the reduction efficiency is small and the lifespan short.

Assuming that all vessels with a remaining expected life of 10 years that operate solely within the Baltic Sea or are frequent visitors invest in SCR and that most ships with less than ten remaining years and some infrequent visitors invest in less costly abatement measures that can be written off in a few years time, the total theoretical effect of the scheme on emissions in 2015 may be as high as minus 70 per cent.

This figure is based on an estimate in Denmark et al (2007) that ships built prior to 1990 accounted for 40 per cent of overall emissions in 2006 and an assumption by the author that by 2015 all of these vessels will have been replaced by new ships. All replacements and all new capacity after 2006, the latter representing an overall growth of traffic by 40 per cent, would in a business-as-usual scenario have to comply with either MARPOL Tier I or Tier II (depending on whether they were built before or after 2011). In the abatement scenario it is assumed that all new vessels would be retrofitted with SCR (frequent visitors) or DWI or advanced IEM (infrequent visitors). These measures would, if applied to all new ships, on average reduce emissions from this category by about 80 per cent compared with BAU[10].

According to Denmark et al (2007), ships that were built between 1990 and 2000 in 2006 accounted for 28 per cent of shipping emissions of NOx in the Baltic Sea. Assuming that all ships have an operational life of 25 years, these vessels would by 2013 on average have seven years to go. This means that only about half of the frequent visitors in this group would probably find it profitable to invest in SCR. The emissions caused by this group in 2015 can be expected to be reduced approximately 45 per cent below BAU (under which no retrofitting is assumed to take place).

Denmark et al (2007) found that 32 per cent of the 2006 emissions were caused by ships that were built after the year 2000. These vessels will by 2013 on average have 15 more years in operation. For the frequent visitors among them it will make sense to retrofit their engines with SCR, while for infrequent visitors it would be better to invest in basic IEM. These measures are estimated on average to have the capacity to reduce emissions from this group of ships by about 75 per cent in 2015.

Provided that the above calculations are reasonably well founded, the average reduction below the emissions in the BAU scenario would be 72 per cent. However, this is the maximum theoretical reduction. In practice maybe only 80 per cent of ship owners will respond to the incentives in the way foreseen. The actual effect on emissions may thus be 58 per cent. This would correspond to a reduction by a little less than 270,000

10 Under the assumption of 75% frequent visitors and 25% infrequent, both categories split 50/50 between SSD and MSD.

tons in 2015 (from a BAU level of approx. 460,000 tons). Such an outcome does not appear totally unrealistic given a relatively high charge combined with generous grants.

Over the years between 2013 and 2030 and under the assumptions made above, the incentives can be expected to cut emissions by a total of about 7.3 million tons. This corresponds to a socio-economic benefit of €5.8 billion[11].

The current Norwegian scheme provides an incentive of NOK 1.5 per kg of urea (€0.18) when urea is used in SCR. With a charge of €440 per ton of NOx emitted, such a subsidy may not be needed to make ship operators use their SCR installations. However, if the Baltic Sea scheme is closed before all pre-2016 ships have been scrapped, there may be cause to contemplate a temporary incentive for urea directed at the remaining ships that in the absence of a subsidy may choose not to use their installations.

11 Based on BeTa-values for the Baltic Sea (only NOx, not including the benefits of simultaneous reduction of PM and VOC).

Conclusion

By 2016 the use of advanced technologies for the reduction of NOx will become necessary in new ships provided that the IMO, on application by the coastal States, decides to make the Baltic Sea an ECA for NOx. However, these stringent rules will not apply to ships built prior to 2016. As sea vessels tend to have a life of at least 25 years, it is essential to find ways to stimulate the industry to invest in advanced technologies such as SCR and HAM well ahead of 2016 and to contemplate retrofitting existing machinery.

The incentive provided by the Swedish fairway due is currently on average well below €100 per ton of NOx (Swedish Energy Agency et al, 2007), and the incentive provided by differentiated port dues is even smaller. Such incentives cannot alone make ship owners invest in advanced methods for NOx abatement. The Norwegian combination of a modest charge and generous grants appears to provide a better incentive.

In this report two instruments have been seriously considered; a charge on NOx emissions and a baseline-and-credit system. Both would take account of the distance sailed so as to reflect actual emissions. Although both systems could be expected to deliver similar results, the base-line-and-credit system is more complicated and may create uncertainty among ship owners.

To create the baseline-and-credit scheme, it would be necessary for the authorities to take an early decision on where to set the baseline. When doing so they will not know how the industry will respond and what the credit price will be. In order to avoid a situation where demand for credits initially is far greater than the supply, the States may have to allow relatively high emissions during the first phase of the scheme. This means losing some momentum and a need to take subsequent decisions on how to reduce the baseline step-wise. A base-line-and credit system could also be expected to give rise to somewhat higher transaction costs than a charge, although the difference is not likely to be great.

To prevent a possible shortage of credits from hampering shipping in the Baltic Sea area, the scheme would have to allow ships to call at participating ports even in the event that they were not capable of buying enough credits to balance a NOx deficit. Instead, failing ships would have to pay a high penalty when emissions exceed the baseline. However, the existence of such a penalty would act as a charge that puts a cap on the price of credits. If so, it may be better to choose a charge rather than a baseline-and-credit system right from the outset.

A NOx-differentiated en-route charge along the lines presented in greater detail in Kågeson et al (2007), a report commissioned by the Federal German Environmental Protection Agency (UBA), would be relatively easy to design and to operate. However, as long as the revenues are not recycled to the industry the scheme runs the risk of being legally challenged by third Parties. In chapter 8 various ways of recycling the proceeds were mentioned. Among them was the alternative of returning the money to the ships concerned based on the GT or DW kilometres travelled by each of them. However, this would be rather data-consuming and make it impossible to use a simplified reporting system for ships that never operate outside the area covered by the scheme. A better idea, therefore, may be to allow the proceeds to finance grants to ships along the lines used for recycling the revenues from the Norwegian NOx tax.

A charge of the size of the current Norwegian NOx tax (see chapter 6) after it was converted into a contribution to the Business Sector's NOx Fund (NOK 4/kg = €470/ton)[12], may be sufficient when the proceeds are used as grants for investment in advanced abatement technologies. The combined effect of a grant and a reduced charge (as a result of reduced emissions) should, for frequent visitors, be enough to justify investment in SCR in engines with a remaining life of about ten years. Ships should be equally eligible for the grants regardless of flag, ownership and frequency of calls at participating ports. However, in a case of shortage it appears reasonable to give priority to ships with many reported annual miles in the area covered by the scheme.

The grant should not correspond to more than, say, 50 per cent of the incremental cost, as a higher subsidy would over-compensate some ship owners at the expense of others (e.g. infrequent visitors), and as a high grant may give equipment manufacturers and shipyards an opportunity to improve their margins. A third reason is that lots of money will be needed in the first few years of the scheme. The imbalance between the initial years and the remaining part of the life of the scheme may even call for an opportunity for the Fund to borrow money for financing part of the investments. It should in this context also be noted that the Norwegian tax applies not only to ships but also to emissions from the offshore sector and to some major land-based installations that emit NOx. This means that the balance between payments and grants is different than that of a scheme which is designed to address ship emissions only. The exact level of the charge and the size of the grants therefore need to be investigated in greater detail to make sure that a long-term balance between revenues and expenses can be achieved.

Ideally there should be only one fund for the Baltic Sea run jointly by the participating coastal States.

To improve the overall efficiency one may contemplate widening the scheme to include the ports of the North Sea.

12 Exchange rate 0.118.

References

CE Delft (2009), **Proposal for an Environmental Ship Index. Air pollutants and CO_2.** Delft, the Netherlands, 26 February 2009.

Committee on the Environment, Public Health and Consumer Policy (2003), **Report on a European Union strategy to reduce atmospheric emissions from seagoing ships**, (COM(2002) 595, 2003/2064(INI)), FINAL, A5-0400/2003.

Denmark, Estonia, Finland, Germany, Lithuania, Latvia, Poland, the Russian Federation and Sweden (2007), **Information on NOx Emissions from Shipping in the Baltic Sea Area.** Submission to the IMO's MEPC57, December 2007.

EMEP (2009). **Transboundary acidification, eutrophication and ground level ozone in Europe in 2007.** EMEP Status Report 1/2009.

Entec UK Limited (2005), **Service Contract on Ship Emissions: Assignment, Abatement and Market-based Instruments. Task 2b – NOx Abatement Technologies.**

EPA (2009), **Proposal to Designate an Emission Control Area for Nitrogen Oxides, Sulphur Oxides and Particulate Matter.** Technical Support Document. United States Environmental Protection Agency.

European Commission (2005a), **Thematic Strategy on Air Pollution.** COM(2005) 446.

European Commission (2005b), Commission staff working paper: **Impact assessment of the thematic strategy on air pollution and the directive on "Ambient air quality and cleaner air for Europe".** SEC(2005) 1133.

Finnish Environment Institute (2006), **Ship emissions and technical reduction potential in the northern Baltic Sea.** Report 8/2006.

Fridell, E., Steen, E. and Peterson, K. (2007), **Primary particles in ship emissions.** Atmospheric Environment 2007.10.042.

GAUSS (2001), **Entwicklung eines Modells für ein integrative und international einsetzbares Bonussystem Quality Shipping – Ergebnisse der Studie.** Bremen.

Hagström, U. (2005), **Humid Air Motor (HAM) and Selective Catalytic Reduction (SCR)**, presentation at Swedish Maritime Administration Symposium/Workshop on Air Pollution from Ships, Stockholm 24-26 May 2005.

Holland, M. and Watkiss, P. (2002), **SHIPPING Marginal external costs from emissions at sea, year 2000 prices, Benefits Table database: BeTa Version E1.02a**, DG Environment, 2002.

IIASA (2008), **NEC Scenario Analysis Report Nr. 6: National Emission Ceilings for 2020 based on the 2008 Climate & Energy Package.**

IIASA, Entec UK, and the Norwegian Meteorological Institute (2007), **Analysis of Policy Measures to Reduce Ship Emissions in the Context of the Revision of the National Emissions Ceilings Directive**, Final Report, Submitted to the European Commission, DG Environment, April 2007.

Kågeson, P. (2005), **Reducing Emissions from Ships in the Baltic Sea Area. The feasibility of introducing a distance-related en-route charge**, European Federation for Transport and Environment and Svenska Naturskyddsföreningen, Brussels and Stockholm.

Kågeson, P., Bahlke, C., and Hader. A. (2008), **Market Based Instruments for Abatement of Emissions from Shipping. A pilot project for the Baltic Sea**. Nature Associates, GAUSS and ISL, commissioned by the German Environmental Protection Agency.

MEPC (2008), **Report of the Marine Environment Protection Committee on its Fifty-Eighth Session**, MEPC 58/23, 17 October 2008.

MEPC (2009), **Second IMO GHG Study 2009. Update of the 2000 IMO GHG Study.** Final report covering Phase 1 and Phase 2. Note by the Secretariat. MEPC 59/INF.10, 9 April 2009.

NERA (2005), **Economic Instruments for Reducing Ship Emissions in the European Union**. NERA Economic Consulting on behalf of the European Commission, DG Environment.

Norwegian Directorate of Customs and Excise (2007), **Tax on Emissions of NOx**. Circular No. 14/2007 S, Oslo 12 January 2007.

Næringslivets NOx-fond (2009), **Rapport om oppfyllelse av utslippsforpliktelsen i 2008**, 27 May 2009.

SEAaT (2006), **Sulphur Emissions Offsetting Pilot. S-Offset**. Final Report. Prepared by BMT Ltd for Shipping Emissions Abatement and Trading, SEAaT. V2: October 2006.

Swedish Energy Agency et al (2007), **Emission Trading for Sulphur and Nitrogen Oxides. Means to Green Maritime Shipping**. The Swedish Energy Agency, the Swedish Environmental Protection Agency, the Swedish Institute for Transport and Communications Analysis, and the Swedish Maritime Administration. 1 October 2007.

Swedish Maritime Administration (2007), **Certified NOx measures in ships**, Swedish Maritime Administration, 10 January 2007.

Swedish Maritime Administration (2009), **Basic Report Regarding HAM and Direct Acting Turbo Compound**, draft version 1.1, 11 February 2009.

Swedish Shipowners Association (2006), **Emission Trading Scheme for SO_2 and NOx including Shipping**. Gothenburg 12 May 2006.

United States and Canada (2009), **Proposal to Designate an Emission Control Area for Nitrogen Oxides, Sulphur Oxides and Particulate Matter**. Submitted to MEPC 59, 2 April 2009.

Wahlström, J., Karvosenoja, N. and Porvari, P. (2006), **Ship emissions and technical reduction potential in the Northern Baltic Sea**. Finnish Environment Institute, Report 8/2006.

Air Pollution & Climate Secretariat (AirClim)

The essential aim of the Secretariat is to promote awareness of the problems associated with air pollution and climate change, and thus, in part as a result of public pressure, to bring about the needed reductions in the emissions of air pollutants and greenhouse gases. The aim is to have those emissions eventually brought down to levels that the environment can tolerate without suffering damage.

- In furtherance of these aims, the Secretariat:
- Keeps up observation of political trends and scientific developments.
- Acts as an information centre, primarily for European environmentalist organisations, but also for the media, authorities, and researchers.
- Produces information material.
- Supports environmentalist bodies in other countries in their work towards common ends.
- Participates in the lobbying and campaigning activities of European environmentalist organisations concerning European policy relating to air quality and climate change, as well as in meetings of the Convention on Long-range Transboundary Air Pollution and the UN Framework Convention on Climate Change.

AirClim, Box 7005, 402 31 Göteborg, Sweden. Phone: +46 (0)31 711 45 15. Website: www.airclim.org

The European Environmental Bureau (EEB)

The European Environmental Bureau is a federation of over 145 environmental citizens' organisations based in all 27 EU Member States and most candidate and potential candidate countries as well as in a few neighbouring countries. These organisations range from local and national, to European and international.

EEB's aim is to protect and improve Europe's environment and enable its citizens to play a part in achieving that goal, by promoting environmental policy integration and sustainable policies, particularly at EU level. The office in Brussels was established in 1974 to provide a focal point for EEB members to monitor and respond to the EU's emerging environmental policy.

EEB has an information service, runs working groups of EEB members, produces position papers on topics that are, or should be, on the EU agenda, and represents members in discussions with the Commission, the European Parliament and the Council. EEB closely co-ordinate EU-oriented activities with national member organisations and also track the EU enlargement process and some pan-European issues.

EEB, Bd. de Waterloo 34, 1000 Brussels, Belgium. Phone: +32 (0)2 289 10 90. Website: www.eeb.org

European Federation for Transport and Environment (T&E)

The European Federation for Transport and Environment is Europe's primary non-governmental organisation campaigning on a Europe-wide level for an environmentally responsible approach to transport.

The Federation was founded in 1989 as a European umbrella for organisations working in this field. At present T&E has 35 member organisations covering 21 countries.

T&E closely monitors developments in European transport policy and submits responses on all major papers and proposals from the European Commission. T&E frequently publishes reports on important issues in the field of transport and the environment, and also carries out research projects.

T&E, Mundo-B Building, rue d'Edimbourg 26, 1050 Brussels, Belgium. Phone: +32 (0)2 893 08 41. Website: www.transportenvironment.org

Large emissions of nitrogen oxides (NOx) are a cause of major environmental damage, and ships account for a large and growing share of these emissions.

A problem with the emission standards for NOx adopted by the International Maritime Organisation is that they will apply to new ships only, and the turnover of the fleet is slow. This report assesses potential market-based instruments for reducing emissions from existing vessels and an early introduction of efficient NOx abatement technologies for newly built ships.

A rough calculation of the emission reduction potential indicates that application of an emissions charge, as outlined in the report, could cut NOx emissions from ships in the Baltic Sea by around 60 per cent. This would correspond to a reduction of about 270,000 tons in the year 2015.

Air Pollution & Climate Secretariat AirClim