

Economic instruments for reducing emissions from sea transport



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Economic instruments for reducing emissions from sea transport

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Cover illustration: The vessel Cellus, equipped with SCR to reduce NO_x emissions and running on low-sulphur fuel. Cellus is used for the shipping of paper products by the forest company Södra.

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Publisher's foreword

The massive emissions of sulphur dioxide and nitrogen oxides from shipping were overlooked for many years. When they did come under the spotlight they were regarded as difficult to regulate. International negotiations continued for several years without yielding any significant results.

Last year, however, Sweden unilaterally introduced environmentally differentiated fairway and port dues, which give shipping lines financial incentives to buy low-sulphur fuel and invest in technologies to reduce emissions of nitrogen oxides.

The system has already shown to be effective, especially in reducing sulphur emissions. The impact, however, would be much greater if similar systems were introduced in other countries.

This report explains the importance of reducing emissions from shipping, and shows that measures at sea make economic sense. It also suggests how existing administrative obstacles can be overcome. This knowledge can and should be used by decision-makers at national and European level.

Göteborg, December 1999

Christer Ågren

Director, The Swedish NGO Secretariat on Acid Rain

Author's foreword

Many individuals have, one way or the other, contributed to this project, among them Per Elvingson, Roger Karlsson, Sveinung Oftedal, Alf Olofsson, Susanne Ortmanns, Kaj Rehnström, Jan Wettergård and Lars Vieweg.

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1. Introduction

In several ways shipping has clear environmental advantages: Infrastructure requirements are very small compared to land-based modes, and comparatively little energy is needed for the propulsion of ships. However, conventional sea vessels emit large quantities of sulphur and nitrogen oxides (NO_x). The emissions from international shipping in the north-eastern Atlantic, the North Sea, and the Baltic Sea have been estimated at 1.6 million tonnes of sulphur dioxide (SO_2) and 2.3 million tonnes of nitrogen oxides (expressed as NO_2). If emissions from land-based sources in the European Union and eastern Europe continue to fall in line with current plans and emissions from shipping remain unchanged, international shipping in these sea areas will by 2010 account for 11 and 15 per cent of pan-European emissions of sulphur and NO_x respectively. In addition there are considerable emissions from shipping in national waters and the Mediterranean. Reducing emissions at sea can be achieved at much lower costs than additional abatement measures on land-based emission sources. A cost-effective abatement strategy thus must include measures on ships.

2. NO_x and sulphur emissions and their impact on human health and the environment

Air pollution is a major environmental problem in Europe. Large areas, in particular in Scandinavia and central Europe, suffer from acidifying and eutrophying deposition in excess of the critical loads. Moreover, large parts of the continent are exposed to levels of tropospheric ozone well above those recommended by the World Health Organisation, which are used as guide values for the protection of human health and the environment.

Acidification and eutrophication

Emissions of sulphur dioxide (SO_2), nitrogen oxides (NO_x) and ammonia (NH_3) cause soil and water acidification in sensitive areas and damage to plants, especially mosses and certain lichens, and fish, as well as damage to buildings and other man-made structures.

Despite a substantial decrease in sulphur dioxide emissions since 1980, parts of Europe suffer from sulphur and nitrogen depositions which are still at least ten times higher than was the case during the pre-industrial period. Deposition is also considerably above the critical loads of many sensitive ecosystems. Although some lakes now are showing a trend of decreasing acidity, soils in many areas are continuing to deteriorate, the reason being that base cations are leached out by the acid deposition. In the longer term, this leads to a deficiency of nutrients, especially of magnesium and potassium. In most soils, acidification also results in the formation of insoluble

aluminium phosphates, which leads to a deficit of phosphorus. Acidification increases the availability of metals in forest soils, which leads to a higher uptake in organisms. Acid groundwater is causing damage to drinking water supply systems and increases the amount of metals (eg. Al, Cd, Cu) in the water (Rodhe et al, 1996).

The critical load for acid deposition is the quantity of acid – expressed as acid equivalents per hectare per year – that can be absorbed by the soil without causing harmful long-term effects on the ecosystems. The sensitivity of soils differs greatly. The most sensitive soils can at most withstand a deposition of 200 acid equivalents per hectare per year (equal to 3.2 kg of sulphur), while less sensitive soils typically have higher critical loads (RIVM, 1993).

Through deposition on soil and water, nitrogen compounds contribute towards the occurrence of surplus nitrogen, which, besides acidification, can lead to changes in ground flora and eutrophication of coastal seas.

The effects on the environment depend on the total deposition of nitrogen, i.e. both from nitrogen oxides and from ammonia. Vegetation is affected by the proliferation of nitrogen-loving species at the expense of other species. The biggest threat is to plants in natural meadowlands and wooded pastures. Heathlands are also affected, changing gradually into grassland moors (Rodhe et al, 1996). Critical nitrogen loads for terrestrial ecosystems are mainly defined with reference to forest soils. Using the Simple Mass Balance (SMB) approach results in a critical load of 7-20 kg nitrogen (N) per hectare per year, depending on the productivity of the forest. For natural (unmanaged) forests in non-polluted areas, nitrogen has been found to balance within the system at an annual input of less than 2-5 kg N/ha. Currently, total deposition of nitrogen over much of central Europe is 30-40 kg/ha. To avoid acidification of the most sensitive ecosystems, total nitrogen deposition needs to be reduced to below 5 kg/ha annually (Grennfelt and Thörnclöf, 1992).

The Baltic Sea is heavily polluted by nitrogen. About 60 per cent originates from land-based sources and the remaining 40 per cent comes from atmospheric inputs. Around 75 per cent of the former and close to 100 per cent of the latter is anthropogenic in origin (EEA, 1995). The average annual input of nitrogen into the Baltic almost doubled between the early 1970s and the late 1980s (Swedish EPA, 1990). High nutrient concentrations contribute to oxygen depletion and the occurrence of hydrogen sulphide in deep areas of most of the Baltic Proper. In addition, strong algae blooms occur frequently in areas such as the Kattegatt and the Gulf of Finland, causing additional depletion of oxygen as well as mortality of benthic fauna.

The situation in the North Sea is similar to that of the Baltic with regard to the input of nitrogen, but eutrophication is limited mainly to coastal waters, in particular the Wadden Sea, the German Bight and the Skagerrack.

The critical loads for marine waters cannot yet be calculated with any accuracy, due to limited knowledge of exactly how individual species and ecosystems react to nitrogen (and phosphorus) (Tickle, 1992).

Ground-level ozone

The formation of ozone and other photochemical oxidants is caused by sunlight-driven chemical reactions in the atmosphere involving, primarily, volatile organic compounds (VOCs) and nitrogen oxides. The formation takes place in the lower part of the troposphere (from the ground to the tropopause at a height of about 10 km) and is separated from the ozone layer in the stratosphere (at a height of 15-40 km). Ozone is the dominant compo-

ment in photochemical smog. Ozone formation can occur locally or regionally, and ozone can be transported over very long distances.

Concentrations of so-called background ozone have at least doubled over the past century in Europe and appear to have increased slightly over the last three decades. The impact on the respiratory tract is deemed the most important health effect of ozone. Increased incidence of asthmatic attacks and respiratory symptoms have been observed in asthmatics exposed to concentrations in the range of 80 to 150 ppb (EEA, 1995). A recent study of 6 000 non-smoking Seventh-Day Adventists in California has revealed a connection between ozone and lung cancer (Air Quality Management, May 1999). Ground-level ozone also has a major economic impact on agricultural crops. High ozone levels cause acute damage which can easily be observed in the form of chloroses and necroses on leaves. Increased sub-acute concentrations may also damage crops. The effects are generally observed in the form of reduced yields. A number of crops are especially sensitive to ozone. This is true of species like alfalfa, potatoes, tomatoes, wheat and spinach. Many trees are also sensitive.

Required reductions in emissions

In order to eventually attain the ultimate target of no exceedance of the critical loads, it is obvious that further significant reductions in emissions must take place. A scenario analysis made by the CLRTAP's expert group on integrated assessment modelling has demonstrated that even the application of so-called maximum technically feasible reductions would not be enough. This scenario assumes a reduction in the emissions of sulphur, nitrogen oxides, volatile organic compounds, and ammonia of about 90, 80, 75, and 40 per cent respectively, as compared to emissions in 1990. Despite these reductions, the critical loads for acidification and eutrophication would still not be achieved everywhere. Damaging levels of ground-level ozone would also remain.

Based on internationally agreed scientific data on critical loads, more than twenty European environmental organisations have agreed on the following as objectives with regard to overall emissions of air pollutants in Europe: At least a 90 per cent reduction in emissions of sulphur dioxide and nitrogen oxides, and at least a 75 per cent reduction in emissions of volatile organic compounds and ammonia (Elvingson & Ågren, 1995). These are minimum demands, but they do not necessarily imply that every country or region must achieve equal reductions. In areas with very high emissions, greater reductions will be necessary, while in some other areas the reductions would be permitted to be lower.

European abatement strategies for sulphur and NO_x

The first sulphur protocol under the Convention on Long-Range Transboundary Air Pollution, CLRTAP, was signed in Helsinki in 1985. This protocol required the signatories to reduce sulphur emissions by at least 30 per cent between 1980 and 1993. This they have done. The average reduction was 46 per cent and many western European signatories went further than that. The reduction of sulphur emissions has resulted in ambient levels of sulphur dioxide being reduced by 40-60 per cent in most places in western Europe. In 1994 a new sulphur protocol was signed in Oslo. It stipulates that most western European countries shall reduce their emissions by 70 to 80 per cent by the year 2000, while eastern European nations have reduction targets of typically between 40 to 50 per cent (from 1980 levels).

The Sofia protocol on the control of NO_x emissions was signed in 1988. It requires all signatories to ensure that their emissions as from 1994 do not exceed their 1987 levels. According to recent statistics, of the 25 countries who

have so far ratified the protocol (Belgium has signed but not yet ratified it), four have not managed to fulfil even this modest commitment.

In September 1999 environmental diplomats from more than 30 countries reached agreement on a new so-called multi-effect and multi-pollutant protocol to the Convention on Long-Range Transboundary Air Pollution. The draft "Protocol to Abate Acidification, Eutrophication, and Ground-level Ozone" sets binding emission ceilings for four major air pollutants: sulphur dioxide (SO₂), nitrogen oxides (NO_x), volatile organic compounds (VOCs), and ammonia (NH₃) that are to be achieved by 2010. It also prescribes the application of emission and fuel standards. Dealing with several effects and several pollutants in a co-ordinated manner, and in a single protocol, is expected to boost overall cost-effectiveness.

In March 1997, the Commission presented an EU strategy to combat acidification (COM(97)88 final). Based on this strategy the EU Commission in June 1999 adopted a proposal for a new directive setting National Emission Ceilings (NECs) for sulphur dioxide, nitrogen oxides, volatile organic compounds, and ammonia (COM(1999)125 final). The proposed new directive is designed to reduce acidification and ground-level ozone in line with interim environmental targets for 2010, as outlined in the acidification strategy and an ozone strategy, presented in June 1999. The proposed ceilings of the NEC directive have been devised by assessing the cost-effectiveness of using different abatement technologies in all Member States. This was done using IIASA's RAINS computer model (Amann et al, 1999). The benefits were assessed in a supplementary study by Holland et al (1999). Even under the most conservative assumptions and without having been able to quantify all benefits in monetary terms, it was estimated that the benefits would by far outweigh the costs.

If the proposed NEC Directive is adopted and implemented, by 2010 total EU emissions of SO₂ and NO_x will be reduced by 78 and 55 per cent respectively, as compared to the base year 1990. Holland et al (1999) estimates that such emission reductions will reduce the area in which ecosystems are not protected from acidification (i.e. with critical loads for acidification being exceeded) by nearly 90 per cent, from 37 million hectares in 1990 to 4.4 million ha in 2010. The degree to which health-affecting and vegetation-affecting ozone exceeds the critical levels is expected to be reduced by about 75 and 50 per cent respectively. Although no explicit environmental targets were set for the reduction of eutrophication, improvements can nevertheless be expected as a result of lower emissions of NO_x and ammonia.

There is also an EU Directive on the Sulphur Content of Certain Liquid Fuels (99/32/EEC amending 93/12/EEC) and a proposal (COM (98)415) for the revision of the Directive on Emissions from Large Combustion Plants (88/609/EEC). Neither has any bearing on emissions from large sea vessels and heavy bunkering oils. The former Directive, however, limits the sulphur content of gas oil to 0.20 per cent by mass from July 2000 (lowered to 0.10 per cent from 1 January 2008), and this regulation applies to marine gas oils as well as to gas oils used on land. According to Article 7:3 of that same directive, the Commission shall investigate measures to reduce the contribution to acidification of the combustion of marine bunker fuels, and, "if appropriate, make a proposal by the end of 2000."

In conclusion it can be noted that so far the emission abatement measures taken under the CLRTAP or the EU have never included any action to reduce emissions from shipping in international waters.

3. Sea and land based emissions of sulphur and nitrogen oxides

Table 1 shows the expected outcome of the abatement of emissions between 1990 and 2010 in Europe. However, emissions from international shipping are assumed to remain at the levels of the early 1990s since no common agreement has been reached with effect on these emissions. Please note that “international shipping” in Table 1 does not include all emissions from shipping. Emissions from shipping in internal waters (within 12 nautical miles from land) are accounted for in the national inventories of Member States and other countries (EU 15 and non-EU in the table).

Table 1. Emissions of SO₂ and NO_x in Europe in 1990 and 2010 (million tonnes).

	1990		2010	
	SO ₂	NO _x	SO ₂	NO _x
EU 15	16.3	13.2	3.6 ¹	5.9 ¹
Non-EU	21.6	10.2	9.9 ²	7.3 ²
International shipping	1.6	2.3	1.6	2.3
Sum Europe	39.5	25.7	15.1	15.5

¹ Projection according to the European Commission's proposed NECS directive.

² Projection according to the CLRTAP multi-effect protocol.

Sources: Amann et al (1999), EMEP (1999a).

The emissions from shipping contribute significantly to depositions of sulphur and oxidised nitrogen compounds in Europe. As regards sulphur, the share of depositions originating from international shipping was in 1997 around 10 per cent or more for Denmark, Sweden, Netherlands, and Norway, and between 5 and 10 per cent for countries such as Belgium, Finland, France, Ireland, Latvia, and the UK. Turning to oxidised nitrogen, the share was higher than 20 per cent for Ireland and Denmark, between 10 and 20 per cent for Finland, Latvia, Lithuania, Netherlands, Sweden, and the UK. To this should be added emissions from “domestic” shipping, i.e. from ships plying within countries' territorial and inland waters (EMEP, 1999b). The share of sulphur and oxidised nitrogen originating in shipping is expected to grow rapidly during the next decade if no or few measures are taken at sea.

4. The cost-effectiveness of land versus sea based abatement measures

As already mentioned above, the International Institute for Applied Systems Analysis (IIASA) has carried out comprehensive calculations on the cost-effectiveness of numerous measures for reducing emissions of sulphur and nitrogen oxides from a variety of sources in Europe. Aided by the RAINS computer model, IIASA has on behalf of the European Commission calculated the cheapest ways of achieving the targets proposed in the Commission's acidification strategy (Amann et al, 1999).

Earlier calculations by IIASA show that if the proposed interim environmental quality target for acidification (the so-called 50 per cent gap closure) is to be achieved solely by relying on additional technical measures on land-based sources of emissions, the annual cost would amount to about 7 billion Euro by the year 2010. However, that cost could be reduced by 2.1 billion a year if cost-effective measures limiting shipping emissions of sulphur and nitrogen oxides in the Baltic, North Sea and north-east Atlantic are used. This broader focus would increase costs at sea by 300 million Euro per year and reduce costs on land by around 2.4 billion per annum (Amann et al, 1996). This means a saving of eight Euro for each Euro spent on emission abatement at sea.

5. Relying on IMO and Marpol?

The International Maritime Organisation (IMO) is a UN organ that has for several years been engaged in developing a set of rules to cover marine emissions. These rules cover pollution by oil, noxious substances in bulk, sewage and refuse as well as discharges of noxious liquid substances. In 1997 a new Annex VI on "Regulations for the prevention of air pollution from ships" was eventually agreed at a conference in London and will be added to the International Convention for the Prevention of Pollution from Ships, MARPOL 73/78. As a result, the Baltic Sea will be declared a "SO_x emission control area", where the maximum sulphur content of the marine fuel oil must not exceed 1.5 per cent, and NO_x-emission standards will be enforced. The latter will apply to diesel engines with a power output of more than 130 kW installed on ships constructed on or after 1 January 2000 (with some major derogations). The operation of such diesel engines will be prohibited except when their emissions of nitrogen oxides fall within specified limits according to the Technical Code on Control of Emissions of Nitrogen Oxides from Marine Diesel Engines. The permitted emissions are represented as a line on the so-called "NO_x Curve" in the Technical Code. This requirement is generally regarded as likely to reduce emissions by some 30-50 per cent compared to the average for all marine diesel engines in operation in 1990.

However, compared to engines installed on new ships today the MARPOL requirement means next to nothing.

IMO's Marine Environment Protection Committee (MEPC) will consider follow-up actions towards implementation of the new Annex. Annex VI, however, will not enter into force until "12 months after the date on which not less than 15 states, the combined merchant fleets of which constitute not less than 50 per cent of the gross tonnage of the world's merchant shipping, have become parties". If several "flag-countries" do not support measures to reduce emissions of air pollutants, the ratification process could take many years.

Annex VI also sets an upper limit to the amount of sulphur in bunker fuels. When the Annex has been ratified the global cap will be 4.5 per cent. However, an international survey suggests that this limit will have no or little effect on the average sulphur content as in 1996 only 0.02 per cent of the fuels used world wide contained more than 4.5 per cent sulphur (Cullen, 1996).

While the 1997 IMO conference agreed to make the Baltic Sea a SO_x Emission Control Area, it turned down proposals to make the same arrangement for the North Sea and the Irish Sea.

It is obvious that Annex VI to the MARPOL Convention will not have any major effect on reducing emissions from shipping. The voting rules of this Convention and experiences so far indicate that no move of any significance to reduce emissions of sulphur and nitrogen oxides from shipping can be expected of the IMO in the foreseeable future.

6. Measures for reducing sulphur emissions

Sulphur emissions from sea vessels are directly proportional to the sulphur content of the bunker oil. The average sulphur content of today's bunker oils is around 3 per cent. Low sulphur oils do exist. The incremental cost has varied considerably over the years and is currently about US\$ 10 per tonne for 1.0 per cent sulphur and US\$ 30 per tonne for 0.5 per cent sulphur (Roger Karlsson, Swedish Shipowners' Association, personal communication)¹. This is equivalent to approximately Euro 0.5 and 1.2 per kg sulphur reduced for fuel oils containing respectively 1.0 and 0.5 per cent sulphur.

Shifting to a low sulphur bunker requires no engine modifications. On the contrary the higher quality of the low-sulphur bunker oil leads to smoother running and less risk of operating problems. Several ferries operating in the Baltic have for some years used bunker oils with a content of less than 0.5 per cent sulphur. Environmental demands from major customers and environmentally differentiated fairway and harbour dues in Sweden have contributed to a fast increase in cargo vessels operating on low-sulphur oil. Currently close to 1 300 ships calling at Swedish ports run on low-sulphur bunker oils (generally with a sulphur content between 0.5 and 0.9 per cent).

A growing demand for low-sulphur oils may increase somewhat the difference in price between low and high-sulphur bunkers. Growing demand for

¹The price of high sulphur bunker fuel is currently around US\$ 130 per tonne (October 1999).

low-sulphur bunker oils may also make it more difficult for refineries to use sea transport as a way of disposing of residuals. A small increase in the cost of low sulphur fuel oils is expected to trigger a shift to high sulphur residual oils among most land-based users as power stations and other customers will find it cheaper to invest in flue gas desulphurisation to be able to shift to high sulphur fuels. The power stations will then become the new sink for high sulphur residual oils.

A potential alternative to low-sulphur bunker oil is to remove sulphur from the exhaust gas by some kind of treatment. In an experiment on a Norwegian vessel a prototype scrubber was used for cleaning the exhaust gas with sea water. However, the acidic effluent from the scrubber should not be released in harbours nor in brackish waters (Ives and Klok, 1993). This rules out the use of this method in a large part of northern Europe.

7. Measures for reducing emissions of nitrogen oxides

The marine diesel engine is today the dominant prime mover of merchant ships. It is also used for electricity production onboard. Most ships have several diesel engines.

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. In the last few 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 nitrogen oxides have been a negative side-effect.

There are in principle two different methods for reducing NO_x emissions:

- Modifications of the engine and/or media to the engine.
- After-treatment of the exhaust gas.

Combinations of the two methods are also feasible. It should also be kept in mind that the amount of emissions per tonne of payload is heavily influenced by parameters such as propulsion efficiency, under-water hull resistance, speed, ship size and cargo carrying capacity. These design and operation elements, however, fall outside the coverage of this paper.

A reduction of NO_x of up to 20 per cent can often be achieved solely by optimising the control of fuel injection and ignition timing, and without sacrificing the thermal efficiency of the engine. It is also possible to give priority to the abatement of NO_x by retarding somewhat the timing of the fuel injection in order to avoid high peak combustion temperatures. This measure, however, reduces the thermal efficiency of the engine and results in higher emissions of carbon dioxide (CO_2). There is thus a trade-off between fuel efficiency and NO_x abatement.

Adding a water emulsion to the fuel or injecting water directly into the combustion chamber are other methods for reducing the combustion temperature. These methods will be further described in the sections below. To reduce NO_x by 90-95 per cent it is necessary to use Selective Catalytic Re-

duction, SCR. Other means of reducing NO_x include using gas turbines or gas engines with low NO_x burners. Such engines, however, have thermal efficiencies well below those of slow and medium speed diesel engines, as shown in Table 2. In future fuel cells could potentially be used in ships. They emit virtually no NO_x but are expected to have thermal efficiencies which are only marginally higher than those of slow speed marine diesels. It is therefore questionable whether they will become economically feasible for installations at sea.

Table 2. Energy efficiency and NO_x emission levels of selected marine engines.

Engine type	Efficiency [%]	NO _x emission [g/kWh]
Slow speed diesel (60-250 rpm)	48-54	11-21
Medium speed diesel (250-1000 rpm)	43-50	8-12
High speed diesel (1000 rpm)	40-43	6-8
Gas turbine 10 MW	32-39	0.5-2
Steam turbine*	30-37	
Gas diesel engine, medium speed	43-50	4
Gas Otto engine, medium speed	46-47	1
Gas Otto engine, high speed	37-40	1-2

* Used in old ships, not common today.

Source: Oftedal et al, 1996.

Water injection

Injecting water into the combustion chamber is a way of reducing NO_x-formation by 20 to 50 per cent. The method requires rebuilding the engine and using fresh water, which is either injected directly with separate nozzles or sprayed into the combustion air at the inlet to the cylinder. The system is technically rather complicated. The heat consumed in evaporation of the water is lost with the exhaust gas. Increased fuel consumption occurs in proportion to the NO_x reduction. A water/fuel ratio of 0.3-0.4, corresponding to a NO_x reduction of 20-40 per cent, can be applied without any significant increase in fuel consumption (Oftedal et al, 1996).

Water injection is currently used in two Nordic ferries, the Silja Serenade and Silja Symphony. Retrofitting an engine for direct injection of water is reported to cost approximately 30 per cent of a SCR installation (Hellen, 1995).

Water emulsion

Blending the fuel with a water emulsion is another method for reducing NO_x emissions at sea. The installation is technically simple and can be done at low cost. The method, however, is associated with stability problems related to the water/oil emulsion and can cause problems with quick stops and manoeuvre. Fuel consumption increases at high NO_x-reduction levels.

HAM

HAM stands for Humid Air Motor and is a technique for preventing NO_x-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 and no operating cost for water. The system makes the inter-cooler superfluous as the HAM system constitutes a replacement.

HAM makes the 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. Fuel consumption does not increase, and HAM has the advantage over 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 NO_x by 70-80 per cent. Trials indicate reduction costs similar to those of SCR installations.

A pilot test with the HAM technique has been carried out in collaboration with the Swedish National Maritime Administration, and the Viking Line is currently carrying out an endurance test on the main engine of one of its ferries, the Mariella. The installation has so far (October 1999) been in use for 800 hours and with good results.

Selective Catalytic Reduction (SCR)

Selective Catalytic Reduction (SCR) is a system for after-treatment of exhaust gases and reduces the emissions of nitrogen oxides by up to 95 per cent by using urea. The method requires low-sulphur bunker oil of good quality and an exhaust temperature above 300° C. NO and NO_2 are reduced to N_2 and H_2O by mixing a water solution of urea 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 which, however, is only the case at full engine load with large slow speed two-stroke diesel engines. In the latter case, the catalytic converter must be placed between the engine cylinder and the turbocharger where the temperature is high enough. This is sometimes a handicap when retrofitting existing vessels as it requires more space in the engine room.

The urea consumed amounts to 2-3 per cent of the fuel consumption. There is no increase in fuel consumption. To avoid excess emissions of ammonia the engine may have to be equipped with an oxidation catalyst, which in addition effectively reduces emissions of hydrocarbons.

By June 1999 and worldwide, 38 ships with a total of 139 engines were equipped or were in the process of being equipped with SCR. Half of them are Swedish and several of the others are ships frequently calling at Swedish ports. A majority of them have medium speed engines, but there are also examples of slow and high speed diesel engines being equipped with SCR (factsheet from ABB Fläkt Marine covering all makes).

The cost of installing a catalytic converter in existing ships is in the range of SEK 250 000-400 000 per MW or Euro 29 000-46 500. Installing SCR in new ships costs around 250 000 per MW (personal communication, Örjan Götmalm, ABB Fläkt Marine). In addition, the method increases running costs by around SEK 18 (Euro 2.07) per MWh due to the urea consumption and wear/maintenance (spreadsheet from the Swedish Shipowners' Association). The cost per kg NO_x reduced is generally below Euro 0.60 (for more recent installations). By comparison, many of the remaining abatement techniques applicable on stationary sources cost more than Euro 2 per kg. The cost of reducing NO_x in order to comply with the expected EU 2005 standards is estimated by IIASA at Euro 11.70 per kg for diesel cars and Euro 2.50 for diesel trucks in Germany (Cofala and Syri, 1998). The ferry Aurora

af Helsingborg has used SCR on one of its engines for more than 45 000 hours, and the rate of reduction is still an extraordinary 98 per cent (personal communication, Örjan Götmalm, ABB Fläkt Marine).

8. Environmental differentiation of fairway and port dues

A few European countries have already introduced or are about to introduce differentiated fairway and/or port dues.

The Swedish system

Recognising the need for abatement measures at sea, 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 harbour dues to reduce emissions of NO_x and sulphur by 75 per cent within five years. The parties concluded that vessels engaged in dedicated trade and other frequent vessel traffic involving Swedish ports, regardless of flag, should reduce emissions of nitrogen oxides by installing SCR or other cost-effective NO_x-abating techniques. Shifting to low sulphur bunker fuels should reduce sulphur emissions.

Fairway dues

The Swedish fairway dues consist of two parts, one related to the gross tonnage of the ship and one based on the amount of cargo. It is only the former that is differentiated according to environmental criteria. The ship-related due used to be SEK 3.90 per gross tonne (GT) for oil tankers and SEK 3.60 per GT for ferries and other ships. From 1 January 1998, when the new system was introduced, these basic levels were raised to SEK 5.30 and 5.00 respectively (Euro 0.61 and 0.58) to make room for substantial deductions for ships that emit less sulphur and nitrogen oxides.

Shipowners who verify and state their continuous operation of ships on bunker oils of a sulphur content of less than 0.5 per cent by weight for ferries and less than 1.0 per cent for other ships get a discount of SEK 0.90 per GT (Euro 0.10).

The NO_x-related reduction of the due is based on the emissions measured in grammes per kWh. If the emission at 75 per cent engine load is above 12 g/kWh, no NO_x discount is given. Below this level the discount increases continuously down to a level of 2 grammes per kWh, where the discount amounts to SEK 1.60 per GT (Euro 0.18). This means that a ferry or general cargo vessel that runs on low-sulphur bunker oil and applies the most far-reaching means for reducing NO_x emissions enjoys a total discount of SEK 2.50 per GT (Euro 0.28). Subsequently the remaining fee is only SEK 2.50 per GT, which is SEK 1.10 below the level applied prior to 1998.

The diagram shows the combined effects of the sulphur rebate and the discount for various levels of NO_x emissions for ferries and other vessels (rates are higher for tankers).

By November 1999, 1 350 ships had been granted the SEK 0.90 discount for low-sulphur bunker fuel. These vessels represent around 65 per cent of the annual ferry tonnage and around 30 per cent of the cargo tonnage calling at

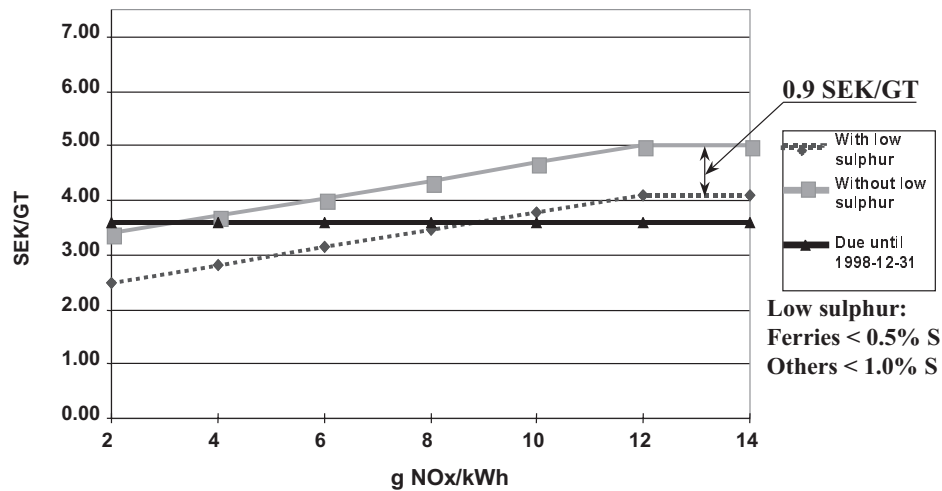
Swedish ports. Some of them, especially ferries and coastal vessels, used low sulphur bunker oils prior to the introduction of the scheme. The ferry lines voluntarily agreed to use low-sulphur fuel oils in the early 1990s. The Swedish National Maritime Administration expects that the differentiation will result in a 60 per cent reduction of sulphur emissions from ships calling at Swedish ports compared to the situation in 1990 (i.e. including the effect of the voluntary agreements with the ferry lines).

By November 1999 13 ships had been certified for a NO_x-related discount of the fairway due. Seven had installed SCR, two apply water injection, three are cargo vessels that have relatively low emissions (7-8 g/kWh) without having installed SCR, and one is a high speed craft moved by low-NO_x-emitting gas turbine engines. Based on known planned installations, the National Maritime Administration expects that by 1 January 2001 the scheme will have reduced NO_x emissions from ships calling at Swedish ports by 40-45 per cent compared to the situation in 1995.

The reason why NO_x abatement measures take longer is that shipowners have to invest in new technology. This involves a certain degree of risk-taking compared with shifting to low sulphur bunker oils as the investments will have to be written off over a period of 8-10 years. The response would have been swifter had other North European countries provided a similar incentive.

To overcome initial problems and encourage the installation of catalytic converters, the Swedish Maritime Administration reimburses shipowners for the fairway dues paid during the first five years following 1 January 1998. Installations made before 1 January 2000 qualify for reimbursement of as much as 40 per cent of the investment cost. Thereafter the maximum level is 30 per cent. The offer applies to all vessels calling at Swedish ports. This means the Swedish Maritime Administration is actually using government funds for promoting investments in foreign ships. A considerable number of ships are known to be preparing for installations of SCR so the pay-back of part of the fairway due may turn out to be a costly scheme for the Maritime Administration. When introduced the scheme did not apply to abatement techniques other than SCR. It thus had the disadvantage of not promoting new and potentially even more cost-effective techniques such as HAM. Recently the Maritime Administration therefore decided to open the

Diagram 1. The Swedish fairway due with discounts for low NO_x and sulphur emissions. SEK/GT for ferries and vessels other than tankers. SEK 1 = Euro 0.115 (5.10.1999)



Source: The Swedish National Maritime Administration

reimbursement scheme to installations other than SCR that reduce NO_x by a similar amount (i.e. the HAM technique).

Port dues

More than 20 Swedish ports (of a total of 52) have introduced environmentally differentiated harbour dues. Each port is an autonomous body, which in competition with other ports has to cover its costs. This makes the situation of ports different from that of the Maritime Administration. 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 harbour dues are much less differentiated than the fairway dues. Table 3 provides information on the sulphur differentiation of selected major Swedish ports. The table shows that the port of Gothenburg has raised the due for ships running on high-sulphur fuels by SEK 0.13/GT (increasing to 0.20 by 1 January 2000), while the ports of Helsingborg, Malmö and Stockholm offer a small discount for vessels that use low-sulphur bunker oils. The border between low and high sulphur content is set at 0.5 per cent for ferries and 1.0 per cent for other ships.

Table 3. Discounts for low-sulphur bunker oils and penalties on high-sulphur fuels in selected Swedish ports in October 1999. SEK per GT.

	Discount	Penalty
Port of Gothenburg		0.13
Port of Helsingborg	0.10	
Port of Malmö	0.10	
Port of Stockholm*	0.10	0.10

* In Stockholm the combined effect is a difference of SEK 0.20 per GT.

SEK 1 = Euro 0.115 (5.10.1999)

Only around ten Swedish ports have so far (October 1999) introduced discounts for low emissions of nitrogen oxides. Table 4 shows the current rates in the most important Swedish harbours.

Table 4. Discounts and penalties for NO_x emissions in selected Swedish ports in October 1999. SEK per GT.

Selected ports	Discounts			Penalty
	<2 g/kWh	2-6 g/kWh	6-12 g/kWh	>12 g/kWh
Port of Gothenburg	0.20	0.10	0.05	
Port of Helsingborg*	0.10	0.06-0.09	0.01-0.05	
Port of Malmö	0.15	0.15	0.05	
Port of Stockholm	0.20	0.15	0.05	0.10

* The Port of Helsingborg offers a SEK 0.01 discount for each reduction by an additional gramme below 12 g/kWh. SEK 1 = Euro 0.115 (5.10.1999)

The discounts are fairly small compared to the nominated rates. For instance, in the case of Malmö the nominated harbour tariff is SEK 3.65 per GT for cargo ships and SEK 1.85 for ferries (Euro 0.42 and 0.21 respectively). The harbour 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. If no rebates were negotiated and the vessel had to pay nominated fees for each entry, the effect of the port due differentiation for NO_x would

approximately equal the effect of the annual fairway discount for a ferry between Stockholm and Helsinki. In reality, the effect of port due differentiation is probably a great deal smaller than the incentive provided by the differentiated fairway due.

Differentiated port dues in Åland

The Port of Mariehamn, on the Finnish Island of Åland, will from 1 January 2000 differentiate its basic dues with regard to ships' emissions of NO_x and sulphur. The proposal (to be decided upon as this report went to press) is to give ships emitting less than 10 g NO_x/kWh a rebate on a linear scale where the reduction of the port due is 8 per cent for ships emitting less than 1 gramme, and 1 per cent for ships emitting 9 g/kWh. Ships using bunker oils with less than 0.5 per cent sulphur (by weight) will receive an additional reduction of 4 per cent. For vessels meeting the latter criteria and having NO_x emissions of less than 1 g/kWh the proposal is to offer an extra rebate of 8 per cent. Such ships will, if the scheme is adopted, get a total reduction of 20 per cent (Mariehamns Stad, 1999).

The proposed Norwegian scheme

The Norwegian government recently presented a proposal for environmental differentiation of the tonnage tax (Proposition No 1 1999/2000). The proposal is expected to be adopted by the Norwegian Parliament in the course of the autumn of 1999 and come into effect as of 1 January 2000. The differentiation is based on a Ship Environment Index System (SEIS) which is based on up to seven different environmental parameters, including sulphur and NO_x emissions, and ships that meet all requirements can at best receive 10 environmental points. Abatement of NO_x and sulphur emissions makes up six out of the system's 10 maximum points for tankers, general cargo vessels and passenger ships. For "other ships" (including towboats, fishing vessels, research ships, barges and supply and standby ships related to Norwegian off-shore activities) all 10 points refer to emissions of NO_x and sulphur. This means, as shown in Table 5, that not all ships get the same credit for an equal reduction of NO_x and sulphur.

Table 5. Points earned for different reductions of NO_x and sulphur in the Norwegian model.

	Points earned			
	Tankers	General cargo	Passenger ships	Other ships
NO_x				
IMO NO _x -curve*	0.75	0.75	1.05	1.75
(IMO curve) - 15%	1.50	1.50	2.10	3.50
(IMO curve) - 60%	3.00	3.00	4.20	7.00
Sulphur				
2.5% S	0.75	0.75	0.45	0.75
1.5% S	1.50	1.50	0.90	1.50
0.5% S	3.00	3.00	1.80	3.00
Total points for best emission reduction practice	6.00	6.00	6.00	10.00

* The IMO's NO_x curve is approximately equal to emissions from new ships that do not use any special abatement technique such as SCR or HAM. Any of these techniques will earn a new ship a maximum credit. Source: Norske Veritas (1999).

The environmental index system will be used for differentiating the Norwegian tonnage tax, which is a substitute for corporate taxation in the Norwegian shipping sector. However, the bill to Parliament says the scheme could in future also be used for environmental differentiation of port and fairway dues. The tonnage tax will from 1 January 2000 be raised by 50 per cent, and ships registered according to the environmental index system will receive rebates in proportion to their environmental score. Ships that earn 10 points will not pay more than they did before the new scheme began operating and ships that do not register or do not earn any points will have to pay the full tax (Norske Veritas, 1999).

The current tonnage tax is very moderate. No tax is paid for ships of less than 1 000 Nett Tonnes (NT). Ships liable to the tax pay only around NOK 3.5 per NT per year which is equal to NOK 2.2/GT (Euro 0.42 and 0.27 respectively). The part of the proposed new level of the tax which is open to rebates corresponds to about half of this amount, i.e. little more than NOK 1 per GT per year (Euro 0.12). The maximum reduction for a cargo vessel will then be in the order of NOK 0.6 per GT and year (Euro 0.07). By comparison, the differentiation of the Swedish fairway due provides a maximum annual incentive of SEK 40.80 (Euro 4.69) per GT. To have any significant effect, the Norwegian model must be extended to the country's fairway and port dues. This would also imply it should be used on fees paid by foreign ships.

The Green Award

The Green Award Foundation in collaboration with the Port of Rotterdam and some ports in Portugal and South Africa offers reduced harbour dues for tankers of more than 20 000 DWT (Dead Weight Tonnes). During 1998 29 ships were certified, bringing the total quantity of certified ships to 92 at the end of the year. Most of these vessels are larger than 50 000 DWT and are not used in short sea shipping. Of the total number of tankers in the range of over 20 000 DWT calling at the Port of Rotterdam, the percentage of Green Award ships in 1998 was 14 per cent. They made altogether 172 calls at Rotterdam and received an average discount of 5.7 per cent on the harbour dues (Green Award Foundation, 1999).

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. A certificate is valid for three years. To earn the award, the shipowner and the vessel must comply with national and international laws and regulations. On top of this basic requirement the shipowner must demonstrate environmental and safety awareness in a number of areas affecting management and crew competence, as well as technical provisions. They include manning, maintenance systems, tank and hull arrangements, oil leakage prevention, vapour emission control, accidental oil pollution prevention, spill collection, bilge water treatment, waste disposal, tank cleaning and exhaust emissions. However, there are no specified requirements. Instead, it is the task of the Green Award Committee to assess whether the arrangements are in line with the general rules of the Green Award. The procedure is carried out in absolute confidentiality, which means third parties are not offered any insight. The committee consists of representatives of the Dutch Ministry of Transport, the Port of Rotterdam, the Dutch Pilotage Organisation and the Royal Association of Netherlands Shipowners.

9. The EU on infrastructure charging and external costs of transport

In June 1998 a joint Transport/Environment Council called for measures to make the best use of existing infrastructure, to achieve a shift to less environmentally damaging modes of transport, and the use of economic instruments to reduce fuel consumption, emissions and noise.

The White Paper on infrastructure charging

In July 1998 the European Commission presented its White Paper “Fair payment for infrastructure use: a phased approach to a common transport infrastructure charging framework in the EU” (European Commission, 1998) which is a follow-up on the earlier Green Paper “Towards Fair and Efficient Pricing in Transport (European Commission, 1995). The White Paper recognises the need for a pricing system that is based on short term social marginal costs, including for instance the costs of congestion, transport accidents and exhaust emissions. The Commission wants these principles to be applied to all four modes of transport to avoid a negative impact on competitiveness and the distortions of the single market caused by the many shortcomings of today’s pricing system, including taxes and charges.

Within a framework based on common principles Member States would to a large extent be free to set charge levels. Should pricing based on short-term social marginal costs not lead to recovery of infrastructure capital costs and Member States wish to arrive at a higher level of cost recovery, then the Commission considers this should be done through the imposition of additional non-discriminatory and non-distorting fixed charges. The Commission concludes that the co-ordination of transport charging and the development of efficient charging levels is expected to produce a small desirable change in modal split and a small reduction in the growth of demand for mobility. Most of the adjustment will take place within each mode of transport, and Commission studies suggest that the new pricing system would lead to overall welfare benefits in the order of at least 30-80 billion Euro per year.

The Commission proposes a step-by-step approach to the implementation of common principles for infrastructure and externality charging. After a preparatory phase (1998-2000), the second phase (2001-2004) is intended to involve adapting particular charges to better reflect real costs and to harmonise charging systems between modes. Charging levels for externalities having a Community dimension should, according to the White Paper, be set at Community level, probably at an agreed low rate to begin with. During the third phase (beyond 2004) the harmonised charging principles should be further implemented, both in terms of the marginal cost basis and the consistency of cost estimation.

The White Paper says maritime shipping has comparatively low infrastructure and external costs, although emissions of sulphur and nitrogen oxides are significant and give rise to concern. Therefore the first phase should include consideration of emissions from shipping in the context of ongoing international discussions on the matter. In the second phase, consideration should be given to the introduction of minimum fuel standards, and the Commission will also consider the feasibility of levying environmental fuel

charges that vary according to emissions. Alternatively, fairway charges could be introduced and differentiated on the same basis.

The first phase of the work has to a large extent been carried out by a "High Level Group on Infrastructure Charging". However, the High Level Group's final report on estimating transport costs does not add much to what had already been accomplished by the White Paper. Neither the final report nor the four background papers make any reference to shipping (High Level Group, 1999).

The Commission has recently commissioned a consultant to carry out a study of the economic, legal, environmental and practical implications of the European Union system to reduce ship emissions of SO₂ and NO_x, which is expected to be finalised by the end of 1999.

Green Paper on sea ports and maritime infrastructure

Prior to the White Paper, the Commission in 1997 presented a Green Paper on Sea Ports and Maritime Infrastructure (European Commission, 1997). The reason for publishing a Green Paper came from the fact that the completion of the internal market has intensified competition significantly among ports. The Commission wants to avoid open or hidden subsidies that give rise to trade distortions. It therefore says port charges should be set in line with marginal costs and also take into account new investments.

The Green Paper, however, is hesitant about charging shipping the full marginal cost of maritime access. It notes that a number of European ports, mainly those on the North Sea, are located on river estuaries or are river ports subject to chronic silting. This gives rise to substantial outlays for dredging, which are at present in most cases publicly funded. Although there is no *a priori* reason why marine access should be treated differently from other infrastructural costs, the Commission thinks the recovery principle should in this case be approached with caution. The Green Paper notes that navigational aids, such as lighthouses and buoys, have traditionally been seen as public goods. Now the Commission proposes that common principles should be established for recovering the development and investment costs of aids for coastal navigation.

ESPO's response to environmentally differentiated charges

The General Assembly of ESPO, the European Sea Port Organisation, has endorsed the following policy on differentiated charging, arising out of a proposal from its Environment Committee:

- As responsible organisations committed to environmental progress, ports should consider the scope for using price mechanisms to achieve environmental improvements and/or other benefits. This could be one of a number of measures aimed at improving the environment.
- ESPO will review existing and future schemes to assess their effectiveness in achieving their objectives and their compatibility with port charging structures.
- The use and construction of differential charging must be entirely the decision of the port concerned, as mandatory differential charging schemes are unlikely to take account of both the commercial realities of port operation and the principles of 'user pays' and 'polluter pays'. Otherwise the result could be that ports find themselves subsidising the shipping sector, which is not acceptable.

10. Current systems for fairway and harbour dues in northern Europe

The infrastructure costs of shipping are related to fairways and ports. However, all countries do not charge shipowners for costs related to investment in and maintenance of fairways. Pilotage dues can be part of either fairway dues or port dues (and in a few cases of both). As pilotage is a service which is only to a limited extent mandatory it is hardly feasible as a common basis for environmental differentiation. Pilotage dues will therefore be disregarded in this context.

Fairway dues

National fairway dues exist in Estonia, Finland, Latvia, Norway and Sweden, but the degree of cost recovery differs greatly among them, being the highest in Sweden. Elements of fairway charging exist in the port due systems of Lithuania, Russia and the UK. Denmark, Germany, Poland and the Netherlands do not, in principle, charge sea vessels for costs of providing and maintaining fairways.

Denmark is a special case where fairway costs are concerned. The only national due related to maritime traffic in Denmark is the ice due. All other costs related to fairways are financed from the general state budget. Denmark refrains from charging sea vessels with reference to the "Sound Treaty of 1857", which obliges Denmark to ensure navigational marking of all Danish waters forever without making foreign ships pay for the service. The treaty was negotiated in order to end the lucrative Danish right to collect the "Sound Tax" from all vessels passing the Sound. Denmark received a one-time lump sum in compensation (Sonne, 1999).

Estonia has a system of national shipping fees that are collected by the ship agencies. The dues are not earmarked for a specific purpose. They include lighthouse dues, ice dues and pilotage dues. Ice dues are collected from 1 January until 31 March. The lighthouse and ice dues are differentiated in 17 GT intervals from 100 GT to 60 000 and above. In classes ranging from 5 000 to 40 000 GT, the lighthouse due is approximately EEK 1 per GT per entry. However, it is not collected for a ship in its first year of calling at Estonian ports. Ships with segregated ballast tanks get a discount (Rehnström and Thalenius, 1999a).

In Finland, the Customs Department collects the fairway due. The revenue, however, is earmarked for the Finnish Maritime Administration for covering the costs of channels, lighthouses, icebreakers and so on. The cost coverage was 95 per cent in 1998. Pilotage is subject to a separate due. All merchant ships calling at a Finnish port have to pay the fairway due. However, ships that only sail through Finnish territorial water without calling at a Finnish port are exempt. Ships in international traffic have to pay the fee on each arrival from abroad. Vessels in domestic traffic pay an annual and,

relatively speaking, much lower charge. The system also favours ships of high ice classes by giving them a large discount (Sjöström, 1999).

Germany does not charge shipping for the costs of maintaining channels and other fairways or for the cost of lighthouses and other navigation aids. There is, however, a fee for using the Kiel Canal (Fiedler and Cardebring, 1999a).

Latvia enforces a lighthouse due of US\$ 0.11 per GT. The due is payable upon the first six entrances per calendar year. Ro-Ro and container vessels are granted a 20 per cent reduction, while passenger ships enjoy a 30 per cent reduction. Pilotage is subject to a separate due (Pålsson, 1999a).

Klaipeda is the only coastal port in Lithuania. The Klaipeda State Seaport Authority is not only responsible for harbour services but is also assigned a range of duties that in most other countries fall under the supervision of a national maritime administration, such as search, rescue and navigation aids. The costs of the latter type of services are covered by the port's vessel and tonnage dues and not accounted for separately (Pålsson, 1999b).

In the Netherlands the provision and maintenance of access fairways are paid out of general tax revenue. Nautical charting and hydrographical surveys are partly financed by harbour dues (Sundaeus, 1999).

The national shipping dues in Norway consist of a lighthouse due, a safety due and pilotage dues. The lighthouse due covered 20 per cent of all costs related to lighthouse and marking services in 1997. The safety due covered 100 per cent of related costs. The lighthouse due is levied on ships above 200 GT arriving from or leaving for a foreign port. There is no fee on domestic traffic. The fee is very moderate, only NOK 0.0024 per GT (Euro 0.0003) but paid both upon entering the port and when leaving. Shipowners can alternatively choose to pay an annual fee of NOK 10.32–29.80 per GT (Euro 1.25–3.60), depending on the size of the ship (Kibsgaard Lunde and Sundvor, 1999).

In Poland the Maritime Administration is in charge of the infrastructure associated with the access to ports. All fairway costs are paid for out of the state budget, and the policy is to try to attract sea transport by not charging for this service (Rehnström and Thalenius, 1999c).

The Swedish system covers all ships larger than 400 GT and the fairway due is split into two parts. One portion is based on the gross tonnage and is set at SEK 5.30 per GT for oil tankers and SEK 5.00 for all other ships. This part of the due is, as described above, heavily differentiated for specific emissions of nitrogen oxides and sulphur. Charging is limited to 12 calls per year for cargo ships and 18 calls for ferries. The other portion of the fairway due is based on the volume of cargo being transported by the ship. The revenue from the Swedish fairway dues covers 100 per cent of the cost of fairway investment and maintenance as well as the cost of icebreaking.

In Russia light dues and navigation dues are collected by the harbours. In St. Petersburg and Kaliningrad the light due for foreign ships amounts to US\$ 0.025 per cubic metre. The navigation due is US\$ 0.013 in St. Petersburg and 0.0067 in Kaliningrad. Vessels involved in Russian coastal trade are charged in Russian Roubles (Fiedler and Cardebring, 1999b).

In the United Kingdom, local authorities are in charge of fairways and have the right to charge for related costs (Rehnström and Thalenius, 1999b). For instance, in the case of the Port of Felixstowe (the largest container port in the UK), the Harwich Haven Authority levies charges for the provision and maintenance of the fairway between the dock and the North Sea, including sea rescue, dredging, lights and buoys (Sundaeus, 1999).

Port dues

The system for harbour dues differs greatly between countries and sometimes even among ports in the same country. The ports may be state owned, privately owned or owned by towns and cities. The general tendency in northern Europe is that municipal harbours are turning into limited companies, and this may in some cases be the first phase on the route to privatisation. Most ports apply several different dues. Ship dues (sometimes called tonnage due or vessel due) and commodity (or cargo) and passenger dues cover the general expenses for providing and maintaining docks and quays. Many ports apply specific charges for boatmen (often called mooring due), towage, anchorage and pilotage. The two latter services are sometimes carried out by separate, privately owned companies. The same is true for stevedoring.

Price has increasingly become a competitive factor and port dues are often negotiated. Numerous discounts are given in order to attract regular traffic. Prices agreed between shipowners and ports can be up to 50 per cent below the official price list (Sundaeaus, 1999). Some ports give discounts to vessels with segregated ballast tanks in line with an IMO recommendation.

Growing competition among ports as well as shipowners has resulted in an unwillingness to share real prices with third parties. This lack of transparency is an obstacle both with regard to environmental differentiation of port dues and violations of EU regulations on government aid. Municipally owned harbours are often subsidised in one way or the other by the local community.

11. Shipping in the North Sea and the Baltic

According to Lloyd's Voyage Record 4 882 cargo ships made 75 000 calls at ports in the Baltic Sea during the second half of 1998. The traffic is dominated by general cargo (33 per cent), while tankers and Ro-Ro vessels accounted for 16 and 11 per cent respectively. Close on 80 per cent was intra Baltic Sea trade (Sjöfartsverket, 1999). On an annual basis the calls by cargo vessels at Baltic Sea ports come to around 150 000. Ferries in international traffic make around 235 000 calls per annum.

Most of this traffic is regular. The average number of calls per cargo vessel was 15.4 during the second half of 1998. Ro-Ro vessels made on average 30.1 calls and general cargo ships 19.2. Ferries often make one call per day and in some cases several calls. The high frequency of all ferries and most cargo ships is a pre-requisite for making environmental fees work well.

During the second half of 1998, 82 000 cargo vessels called at ports in Belgium, the Netherlands and the United Kingdom. Close to 90 per cent of them came from ports in northern continental Europe, Scandinavia and the British Isles and 91 per cent went on to ports in that area. International ferry traffic between the United Kingdom and Belgium and the Netherlands accounted for 15 500 calls in (all of) 1998 (spreadsheet from the Institute of Shipping Analysis, Göteborg).

The figures indicate that short sea shipping may account for close on 90 per cent of all calls made at North Sea and Baltic Sea ports. This, however, is

not entirely correct as some ships in long-distance trade may call at more than one port in the north-east Atlantic in the course of one journey. In terms of total annual tonnage, short sea shipping clearly accounts for less than 90 per cent as long-distance ships tend to be larger than those engaged in coastal and short sea shipping. The same is, of course, true for overall emissions.

12. Need for a common system of economic incentives

The current Swedish system provides a limited incentive for ships that make frequent calls at Swedish harbours. This can be illustrated by two real examples, a large ferry in traffic between a Swedish port and a neighbouring country and a Ro-Ro vessel with 50 annual calls at Swedish ports. In both cases they call at Swedish harbours more than the 12 and 18 times per annum for which they have to pay the fairway due. Excluding the effect of the temporary reimbursement of part of the due (see section 8 above), the total annual cost of reducing NO_x (including the cost of urea and maintenance) is 3.6 times the discount for the ferry and 4.9 times for the Ro-Ro vessel (spreadsheets from the Swedish Shipowners' Association). This means that the fairway rebate enjoyed by a frequent visitor usually covers only one quarter to one third of the additional cost.

If the port dues are truly differentiated according to the nominated fees shown in Table 3, the incremental cost of the NO_x reduction of the ferry would "only" be 1.8 times the total discount (fairway due + port due). The ferry makes around 180 calls in Sweden per year. Similarly the Ro-Ro vessel (making 50 calls/year in Sweden) would have incremental costs "only" 3.7 times the annual value of the combined fairway and port discount. However, for a frequent visitor the negotiated port dues probably do not fully reflect the tariff's nominated difference between high and low emitters. This means that the combined effect of differentiated fairway and port dues at "both ends" (Sweden and the other country) is needed for providing a sufficient incentive. It should be underlined in this context that the abatement costs in the above examples are relatively low; SEK 6.08 per kg NO_x for the ferry and SEK 4.41 for the Ro-Ro vessel (Euro 0.70 and 0.51 respectively).

The same reasoning applies to the cost of running on low-sulphur bunker fuel. Based on the differentiated fairway due, the rebate for low sulphur fuel oil covers only around 20 per cent of the additional costs (based on cost data from the Swedish Shipowners' Association). The differentiated port due may cover another 10-20 per cent of the cost (depending on the size of the negotiated fee).

In cases when ships plying the North Sea and/or the Baltic Sea never or only rarely call at Swedish ports, there is at present no incentive at all for shifting to low sulphur fuel or investing in means for reducing NO_x . As Sweden is the destination of only a small part of the total shipping in the North Sea and the Baltic, its differentiated fairway and port dues will only have a limited effect on the overall emissions from short sea shipping in this region. To make a real difference a much broader incentive, based on differentiated fairway and/or port dues in all countries, is needed.

13. Potential policy instruments for reducing emissions of NO_x and sulphur

In the case of controlling emissions from shipping, EU regulation does not appear to be the best option. Ships in long distance traffic would not always be able to find low sulphur bunker fuels in other parts of the world and may therefore have to be allowed a derogation. Investing in NO_x abatement technologies would not be cost effective in cases when, say, 90 per cent of the journey takes place in waters where the emissions do not do much harm. An alternative in this case might be to enforce strict emission limits on ships used solely for short sea shipping. However, exempting long distance ships from regional rules on sulphur content and NO_x abatement will affect competition between such vessels and short sea feeders and make it economically advantageous for the former to call at ports further into the environmentally sensitive area than would otherwise have been the case. Another problem with regulation is that installing techniques for NO_x abatement on ships with few remaining years in operation is not cost effective. If, on the other hand, the regulation is only to be applied on new vessels or new machinery it will take 20-30 years before most of the tonnage has become clean. It is also unclear whether EU regulations could in all circumstances be applied on ships from flag states not belonging to the Union. For these reasons the main option is to introduce environmentally differentiated charges and to treat all vessels alike.

According to the Commission's White Paper on infrastructure charging, all four modes of transport ought to pay for their short-term marginal costs, including damage caused by emissions. This means that charging for sulphur and NO_x emissions is something that should be done in addition to charges for fairway and port costs rather than through a differentiation that does not raise the average fee. However, so long as competing modes do not pay their environmental costs through special charges, enforcing such a liability on shipping would not be fair. Differentiating port and/or fairway dues then appears to be the best short-term solution.

The White Paper says that charges should reflect true costs as much as possible. The Swedish system for environmental differentiation clearly does not meet this requirement as neither port dues nor fairway dues reflect distance. The distance travelled is very important as the amount of pollutants emitted is roughly proportional to the length of the haul. In the Swedish system ships that make short journeys pay relatively more than those travelling longer distances between ports. This effect, however, is at least partly counteracted by discounts given to frequent visitors. One way of making the charge fully reflect emissions would be to take account of the distance travelled since the latest port call (or since entering east of a line from, say, Brest via Ireland to the Faroe Islands), and refrain from giving frequent visitors favourable treatment. However, before deciding on a distance-based scheme it is necessary to look more closely at the administrative cost of taking distance into consideration.

Another problem with the current Swedish scheme is that high speed craft moved by, for instance, gas turbine engines may get a low due despite having large emissions of NO_x per passenger or tonne-kilometre. Turbine engines have low specific emissions of NO_x per kWh. High speed ships, however, generally have large engines and use plenty of fuel. Total emissions of NO_x may therefore be a great deal higher than from a conventional vessel of equal capacity. Being relatively light, high speed craft also benefit in an unjustified way from charging systems based on gross-tonnage. To avoid giving high speed ships a competitive advantage, a European scheme could alternatively relate the NO_x discount to gram per kW installed engine shaft output.

The only way of establishing a scheme that would not have an impact on inter-port competition would be to make the charge part of national (or regional) systems of fairway dues. The revenue would in this case reduce the need for raising funds by other elements of fairway charging. The system would also have the advantage over differentiated port dues of being non-negotiable and completely transparent.

A system based on voluntary participation by ports is more problematic. To base part of the charge on a differentiation of port dues would affect inter-port competition. Assuming “user pays” principles, ports will have to make up for any shortfall in revenue one way or another. It might be possible to raise ship dues for those outside the scheme, but this could have a serious effect on a port’s trade. Harbours where most calls are made by vessels in dedicated trade might lose to ports with many long-distance visitors, as ships in the latter category will often prefer to pay the higher due rather than take costly measures for reducing emissions. Lack of transparency is also a problem in this context. Will ports trust that other ports are not giving up part of the nominated differentiation when they negotiate harbour fees with shipowners?

In a common European (or north European) scheme for charging sea vessels for emissions of nitrogen oxides and sulphur, the rates should ideally be based on the marginal cost of reducing the emissions to substantially lower levels than those of today. Retrofitting existing ships with SCR costs Euro 0.35-0.60 per kg NO_x when the investment is written off over eight years. A fee of Euro 0.60 /kg on emissions of NO_x would in this case provide a correct incentive. Ships used solely in the north east Atlantic and with an expected remaining lifetime of at least eight years would find it beneficial to invest in NO_x abating measures. Others would not. Similarly the sulphur fee should reflect the incremental cost of shifting to low sulphur bunker oils. It should be possible to base the fee on the ships’ engine capacity and average engine load. The rate could be based either on the incremental cost of running on a bunker oil containing less than 1 per cent sulphur or on the cost of shifting to a fuel with less than 0.5 per cent sulphur. All ships used entirely in short sea shipping can be expected to shift to fuels containing less sulphur than the limit on which the incentive is based. The revenue will therefore be limited to fees paid by ships involved in long distance traffic.

If there is a fear that limiting sulphur and NO_x charges to ports north-east of a certain line would distort competition between ports located close to that “border”, it may be worth considering a geographical differentiation of the fee. Such negative border effects could presumably be avoided by reducing the level of the charge stepwise in a south-westerly direction.

A fast introduction of a differentiated fairway due that provides incentives for an immediate shift to low sulphur bunker fuels might lead to a shift in demand for different types of heavy fuel oils that is too fast for refineries and/or for other users to cope with. A stepwise introduction (geographically

or in terms of incentive) may be needed in order to avoid market problems. The NO_x element of the differentiated due, on the other hand, need not be gradually phased in as there is hardly any likelihood that all shipowners will make immediate orders for SCR or the HAM technique.

Where revenue neutrality is concerned it should be recognised that a national maritime authority (or its local or regional equivalent) may under certain conditions raise more money from the due than corresponds to its expenditure on fairways. This could above all be expected to occur in ports with a large share of overseas traffic and low annual costs. Such surplus revenue could be directed towards common purposes such as the IMO or the European Commission, in the latter case for expenditure related to maritime transport. After a few years of existence the revenue of the scheme will fall to substantially lower levels as a result of more and more ships shifting to low sulphur bunker fuels and techniques for NO_x reduction.

Where sulphur is concerned an alternative option to differentiated fairway dues would be to enforce a green tax on high sulphur bunkers taken on in European ports. The tax rates then have to equal the price differential between bunker fuels with a content of no more than 1 per cent sulphur and bunker fuel containing more than 1 per cent. This means all ships will have an incentive to choose low sulphur bunkers, including those that are involved in transatlantic trade. This model has the advantage of being more easily enforceable than a system of differentiated dues levied in all ports. The drawback, however, is that some ships may choose to bunker up in ports outside the region covered by the green tax.

The second-best solution to a common European model would be for other coastal countries to introduce differentiated fairway and port dues analogous to those used in Sweden. The fact that these do not reflect distance and that they include different kinds of basic or negotiable discounts erodes somewhat the cost-effectiveness of the scheme. However, if other countries adopted the Swedish approach, the combined effect on emissions from shipping would nevertheless be significant. If this model is preferred, it is important to choose a construction that is sustainable and robust for changes in port ownership structure and port dues.

It should be kept in mind that fairway and/or port dues might in future also have to include an element of charging for emissions of carbon dioxide. Bunker fuel oils are currently exempt from energy taxation in the EU. However, in the long term all modes of transport must do their utmost to improve energy efficiency. Charging for carbon dioxide emissions will be necessary for providing approximately the same incentive to all modes. For road and rail transport the charge can be part of the fuel tax. Taxing fuels in the aviation and maritime sectors is more complicated because some aircraft and sea vessels may choose to fill up in countries outside the EU. Making the charge part of landing charges and port or fairway dues might then be the second best solution.

Legal issues

Coastal States enjoy sovereignty over their internal waters, and international law does not restrict their competence to regulate foreign flag vessels voluntarily entering into their ports. Entry to European ports could thus, in principle, be made conditional upon the vessel's use of bunker fuel with a specified sulphur content, or upon the payment of fairway and/or port dues that are differentiated according to specific emissions of sulphur and/or nitrogen oxides. There is thus no reason for the European Union to hesitate about establishing a port related EC ship emissions regime that goes further than the requirements set out in MARPOL Annex VI. The EU will be able to

demonstrate strong environmental and economic reasons for doing so that outweigh other flag States' interest in uniformity of shipping standards. It should also be noted that other states have not protested against the Swedish system of differentiated dues or the EU's directive on differentiation of port dues with respect to segregated ballast tanks.

However, applying national or EU regulations to ships plying international waters is hardly in line with the international maritime conventions and treaties. To do so would require the consent of the IMO.

Matters of enforcement and monitoring will not be discussed in this paper. However, it should be noted that there might be cause to contemplate a somewhat higher rebate for the use of prime movers and exhaust gas treatment systems that are inherently incapable of producing high emissions of NO_x. The HAM technique has in this sense the advantage over SCR of not needing any input of chemicals that cause additional running costs and may tempt shipowners not to use the installation at sea.

14. The commercial value of clean shipping

Several large companies in Scandinavia and Germany have started making environmental demands in the procurement of freight services. Attention is so far mostly on road and rail transport but a few major corporations, notably some of Sweden's large forest companies, have begun to ask for cleaner shipping. This practice is expected to grow rapidly as more companies certify their environment management systems to ISO 14001 and EMAS, and learn that a large part of their impact on the environment comes from the transport of raw materials and finished goods.

In this new field of competition, shipping is potentially in a good position to improve its market share. Today's sea transport causes considerable damage to the environment due to large emissions (also per tonnekm) of sulphur and nitrogen oxides. The cost of reducing these emissions, however, is small compared with the incremental cost of making road transport less polluting. In addition, short sea shipping has an advantage over rail and road transport, because the latter are facing much higher costs when all modes in future have to pay for their infrastructure.

Kågeson (1998) studied the impact on competition and modal split from internalising all major costs caused by transport by 2010. An underlying assumption was that transport enterprises and vehicle owners would try to adjust to the new situation as inexpensively as possible. A complete internalisation of external costs (including the fixed costs of the infrastructure) would significantly affect freight prices, which would probably rise by 40 to 60 per cent, except in the case when customers can shift to short sea shipping. In a case where only short-term marginal costs are internalised, the price rise would only be between 10 and 20 per cent. Treating all four modes of transport in an equal manner, means in the latter case that governments will have to start to subsidise the fixed part of the costs of fairways and ports (which in Sweden are currently paid for by the shipowners). Therefore the overall costs of shipping would fall by between 3 and 23 per cent depending on circumstances. Short sea shipping would also in this case gain in market share, in particular from rail transport.

However, it should be recognised that the competitiveness of shipping and other modes of transport depends on a multiplicity of factors. Many enterprises have integrated their logistics and transport operations and are looking for reliable transport solutions which will reduce aggregate costs. The ongoing process of structural change is another important factor. The branches generating large flows of low-value goods will probably continue to decline in relative importance, which will work to the advantage of road haulage and air freight and most likely reduce the market shares of railways and short sea shipping.

15. Short note on the Mediterranean and inland waterways

This report discusses emissions emitted from ships plying the waters of the Baltic Sea, the North Sea and the north east Atlantic. There may also be cause to consider measures on ships used in parts of the Mediterranean and on barges on inland waterways. The latter usually run on gas oil with a low content of sulphur (in the EU limited to 0.2 per cent as of July 2000). However, emissions of NO_x are high and could be reduced by SCR or the HAM technique. Yet another alternative is EGR (Exhaust Gas Recirculation) which, however, requires very low levels of particulate matter in the exhaust stream. For barges used in densely populated areas it may be cost-effective to reduce particles (by 90 per cent) by a filter such as CRT (Continuously Regenerating Trap). EGR would then in combination with CRT reduce NO_x by around 50 per cent. One reason for not including shipping in the Mediterranean in this report is the fact that there are not yet any emission inventories for that sea area. A first emission inventory is expected to be finalised next year.

16. Conclusions and recommendations

In 1990, international shipping was responsible for 4 per cent of Europe's emissions of sulphur and 9 per cent of the total emissions of nitrogen oxides (NO_x). These shares are expected to grow to 11 and 15 per cent respectively in 2010, if no additional measures are taken at sea.

Calculations by IIASA show that if the proposed interim environmental quality target for acidification in Europe is to be achieved solely by relying on additional technical measures on land-based sources of emissions, the annual cost would amount to about 7 billion Euro by the year 2010. However, that cost could be reduced by more than 2 billion a year, if cost-effective measures limiting shipping emissions of sulphur and nitrogen oxides in the Baltic, North Sea and north east Atlantic are used (Amann et al, 1996). This means a saving of eight Euro for each Euro spent on emission abatement at sea.

Coastal States enjoy sovereignty over their internal waters, and international law does not restrict their or the European Union's competence to regulate foreign flag vessels voluntarily entering into their ports. However, in the case of controlling emissions from shipping, regulation does not appear to be the best option. Ships in long distance traffic would not always be able to find low sulphur bunker fuels in other parts of the world and may therefore have to be allowed a derogation. Investing in NO_x abatement technologies would not be cost-effective in cases when, say, 90 per cent of the journey takes place in waters where the emissions do not do much harm. Another problem with regulation is that installing techniques for NO_x abatement on ships with few remaining years in operation is not cost effective. For these reasons a more flexible policy instrument is to be preferred.

The Swedish system of environmentally differentiated fairway and port dues have proved to be a powerful instrument for making shipowners shift to low sulphur bunker fuels and start investing in NO_x abatement techniques. Existing technologies such as Selective Catalytic Reduction (SCR) and Humid Air Motor (HAM) can reduce NO_x emissions by as much as 80 to 90 per cent. However, inter-port competition and lack of transparency make it difficult to rely solely on differentiated port dues set by privately owned ports and harbours. One way of making sure of avoiding a negative impact on inter-port competition would be to make the differentiated charge part of national (or regional) systems of fairway dues.

According to the European Commission's White Paper on infrastructure charging, all four modes of transport ought to pay for their short term social marginal costs, including damage caused by emissions. This means that charging for sulphur and NO_x emissions is something that should be done in addition to charges for fairway and port costs rather than through a differentiation that does not raise the average fee. However, so long as competing modes do not pay their environmental costs through special charges, enforcing such a liability on shipping would not be fair. Differentiating port

and/or fairway dues in a revenue neutral manner then appears to be the best short-term solution.

The White Paper says that charges should reflect true costs as much as possible. The Swedish system for environmental differentiation clearly does not meet this requirement as neither port dues nor fairway dues reflect distance. The distance travelled is important as the amount of pollutants emitted is roughly proportional to the length of the haul.

Another problem with the current Swedish scheme is that high speed craft may get a low due despite having large emissions of NO_x per passenger or tonne-kilometre. High speed ships generally have large engines and use plenty of fuel. Total emissions of NO_x may therefore be a great deal higher than from a conventional vessel of equal capacity. Being relatively light, high speed craft also benefit from charging systems based on gross-tonnage. To avoid giving high speed ships a competitive advantage, a European scheme could alternatively relate the NO_x discount to gram per kW installed engine shaft output.

The proposal then is for the European Community to adopt a Directive that makes all Member States and accession countries, that have not already done so, introduce fairway dues that, if possible, take account of the distance travelled. The revenue from the connected environmental charges would in this case reduce the need for raising funds by other elements of fairway charging. Such a system would have the advantage over differentiated port dues of being non-negotiable and completely transparent.

In a common European (or north European) scheme for charging sea vessels for emissions of nitrogen oxides and sulphur, the rates should ideally be based on the marginal cost of reducing the emissions to substantially lower levels than those of today. Retrofitting existing ships with SCR costs Euro 0.35 to 0.60 per kg NO_x reduced when the investment is written off over a period of eight years. A fee of Euro 0.60 on emissions of NO_x would in this case provide a correct incentive. Ships used solely in the north east Atlantic, the North Sea, and the Baltic Sea, and with an expected remaining lifetime of at least eight years would find it beneficial to invest in NO_x-abating measures. Others would not. Similarly the sulphur fee should reflect the incremental cost of shifting to low sulphur bunker oils.

If there is a fear that limiting sulphur and NO_x charges to ports north-east of a certain line would distort competition between ports located close to that "border", it may be worth considering a geographical differentiation of the fee. Such negative border effects could presumably be avoided by reducing the level of the charge stepwise in a south-westerly direction.

A fast introduction of a differentiated fairway due that provides an incentive for an immediate shift to low sulphur bunker fuels might lead to a shift in demand for different types of heavy fuel oils that is too fast for refineries and/or for other users to cope with. A stepwise introduction (geographically or in terms of incentive) may be needed in order to avoid market problems. The NO_x element of the differentiated due, on the other hand, need not be gradually phased in as there is hardly any risk that all shipowners will make immediate orders for NO_x-reducing technologies.

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The essential aim of the Swedish NGO Secretariat on Acid Rain is to promote awareness of the problems associated with air pollution, and thus, in part as a result of public pressure, to bring about the required reduction of the emissions of air pollutants. The eventual aim is to have those emissions brought down to levels – the so-called critical loads – that the environment can tolerate without suffering damage.

The work of the secretariat is largely directed on the one hand towards eastern Europe, and on the other towards the European Union and its member countries. By emitting large amounts of sulphur and nitrogen compounds, all these countries add significantly to acid depositions over Sweden.



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The European Federation for Transport and Environment (T&E) 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.



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The European Environmental Bureau is the largest environmental citizens organisation, comprised currently of 132 member organisations. Its main mission is to improve EU's environmental policies and promote sustainable development. Its priority areas include environmental policy integration, the environmental consequences of enlargement, pro-active industry policies (environmental liability, extended producer responsibility, eco-label, standardisation), agriculture, and policies on water, air and waste. EEB is also coordinator of the Transatlantic Environmental Dialogue. It has a number of working groups and produces several publications a year, including a magazine called "Metamorphosis" (4 times a year).



Shipping has clear environmental advantages. An important drawback, however, is the high emissions of sulphur and nitrogen oxides.

From a technical point of view there would be no difficulty in reducing these by 80–90 per cent. In comparison with additional measures taken on land, reducing emissions at sea would be very cost effective.

This report presents the problems, as well as the technical and political opportunities to solve them. Environmentally differentiated fairway dues is promoted as the best solution.