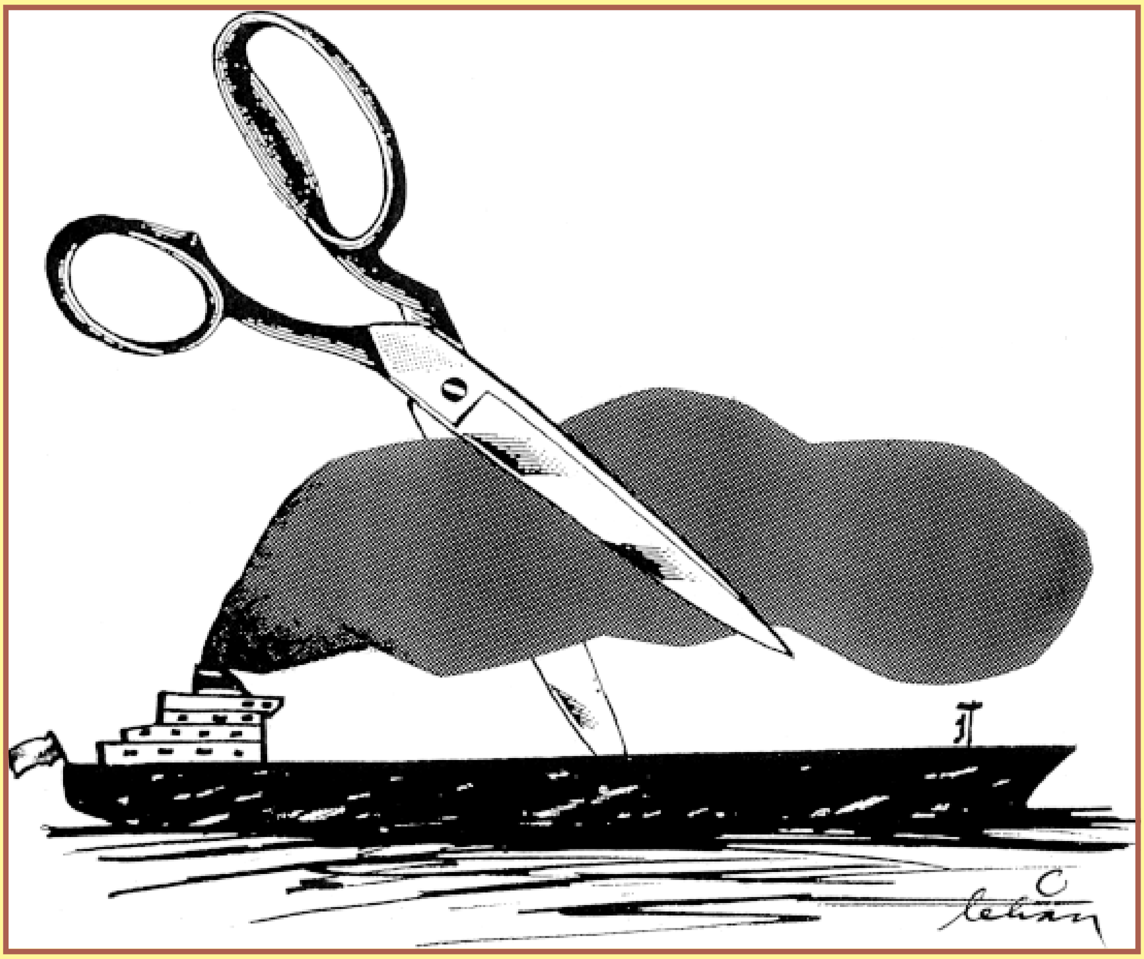
# Air pollution from ships



A briefing document by:

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# Introduction

Emissions from shipping contribute significantly to the concentrations and fallout of harmful air pollutants in Europe. There are however technical means by which these pollutants could be cut by as much as 80-90 per cent, and very cost-effectively compared with what would have to be done to achieve similar results by taking further measures on land-based sources. Such reductions are needed for protecting health and the environment, and for shipping to develop into a more sustainable mode of transport.

An EU strategy to reduce the emissions of air pollutants from sea-going ships was adopted by the Commission in November 2002. As part of this strategy the Commission also published a proposal for modifying directive 1999/32/EC as regards the sulphur content of marine fuels.

The environmental organisations welcome the Commission's declared intention to introduce measures aimed at combating emissions of air pollutants from seagoing ships. However, the action proposed by the Commission in regard to ships' emissions of sulphur dioxide ($SO_2$) will only result in total reductions from ships of less than ten per cent, as compared to their emission levels in the year 2000, which is clearly inadequate.

In order to protect human health and the environment, significant additional cuts in European air pollutants emissions are necessary.

They are also needed for the EU to attain the interim environmental targets for 2010 as stated in directive 2001/81/EC on national emission ceilings for certain atmospheric pollutants, and for achieving the Community's long-term objectives of the Fifth and Sixth Environmental Action Plans of not exceeding critical loads and levels and of effective protection of all people against recognised health risks from air pollution.

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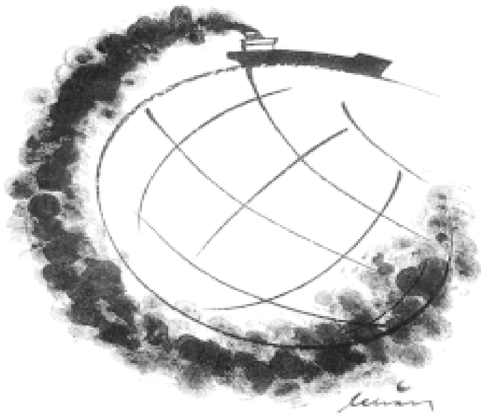


# Increasing emissions

The emissions of air pollutants from ships engaged in international trade in the seas surrounding Europe – the Baltic, the North Sea, the north-eastern part of the Atlantic, the Mediterranean, and the Black Sea – were estimated to have been 2.6 million tons of sulphur dioxide and 3.6 million tons of nitrogen oxides (expressed as $NO_2$) a year in 2000 (see Table 1).

While pollutant emissions from land-based sources are gradually coming down, those from shipping show a continuous increase. Even after accounting for enforcement of MARPOL Annex VI, which sets limits on the sulphur content of marine fuels for the Baltic Sea, the North Sea and the English Channel, emissions of $SO_2$ from international shipping are expected to increase by more than 42 per cent by 2020, and those of NOx by two-thirds. In both cases, by 2020 the emissions from international shipping around Europe will have surpassed the total from all land-based sources in the 25 member states combined (see Figures 1 and 2).

It has been estimated that about 90 per cent of the total $SO_2$ and NOx emissions from ships in the North Sea, including the English Channel, originates from a zone of approximately 50 nautic miles (approximately 90 kilometres) from the coast line. International shipping within a distance of 100 nautic miles from the seaboard was estimated to be a source of 97 per cent of the total in the North Sea (Tsyro & Berge, 1997).

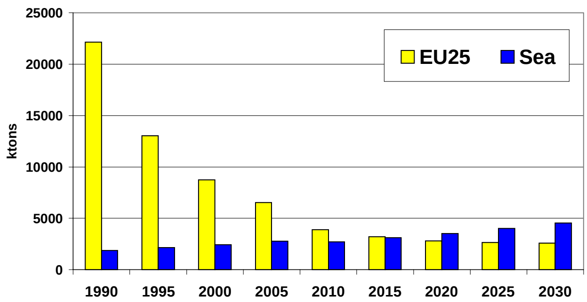
**Table 1. Emissions of $SO_2$ and NOx from international shipping in European waters (ktons).**

| | Sulphur dioxide | Nitrogen oxides |
|---|---|---|
| 1990[1] | 2,001 | 2,808 |
| 2000 | 2,578 | 3,617 |
| 2010-Low (1.5% growth/yr) | 2,845 | 4,015 |
| 2010-High (3% growth/yr) | 3,294 | 4,649 |

[1] Entec data for 1990 was estimated from 2000 data, assuming a 2.5% per annum growth 1990-2000.

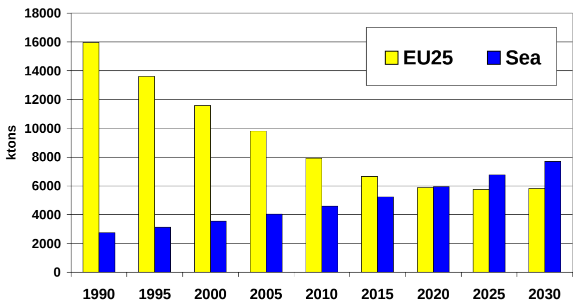
*Source*: Entec (2002).

**Figure 1. Emissions of $SO_2$ 1990 – 2030 (ktons).**




*Source*: Main baseline scenario (CP) developed by IIASA in autumn 2004 for the Commission's CAFE programme. Data from: http://www.iiasa.ac.at/rains/cafe.html (October 2004).

**Figure 2. Emissions of NOx 1990 – 2030 (ktons).**




*Source*: Main baseline scenario (CP) developed by IIASA in autumn 2004 for the Commission's CAFE programme. Data from: http://www.iiasa.ac.at/rains/cafe.html (October 2004).

# Air quality & health, acidification, eutrophication...

### *Particles*

$SO_2$ and NOx can become converted into sulphate and nitrate particles, which are very small and among the more frequent of airborne particles.

Exposure to fine particles (PM) is associated with increased mortality (especially from cardio-vascular and cardio-pulmonary diseases) and morbidity. According to the European Environment Agency, up to 45 per cent of Europe's urban population are exposed to $PM_{10}$ levels exceeding the forthcoming EU standards (EEA, 2004). It has been estimated that exposure to fine particulate matter in outdoor air leads to about 100,000 deaths (and 725,000 years of life lost) annually in Europe (WHO, 2002), and that the effect of PM on life expectancy may be in the order of one to two years (WHO, 2003).

Ship emissions are estimated to contribute between twenty and thirty per cent to the air concentrations of secondary inorganic particles in most coastal areas (CEC, 2002b).

### *Ground-level ozone*

Nitrogen oxides contribute also to the formation of ground-level ozone, which damages vegetation as well as human health.

In the second half of the 1990's, almost all of Europe's urban population were exposed to ozone concentrations above the threshold value for the protection of human health (EEA, 2002). It has been estimated that about 75 per cent of the urban population in southern Europe, and 40 per cent of that in the northern part, lived in cities where the ozone levels exceeded the EU target value of 120 microgrammes per cubic metre (mg/m$^3$) for more than 20 days (de Leeuw, F. et al, 2001).

Shipping emissions contribute notably to the formation of ground-level ozone, especially in the Mediterranean region, where increased concentrations resulting from ships' NOx emissions amount to 16-20 mg/m$^3$ (Jonson et al, 2000). The high concentrations of ozone in the Mediterranean region do not only affect human health and crop yields, but also pose a threat to the region's important tourist industry.

### *Acidification*

In 2000, the depositions of sulphur and nitrogen exceeded the critical loads for acidifying substances on more than 260,000 square kilometres (about 20 per cent) of sensitive forest ecosystems in the EU's 25 member states (Amann et al, 2004).

Emissions from ship traffic contribute to exceedances of critical loads of acidity by more than 50 per cent in most of the coastal areas along the English Channel and the North Sea, in the Baltic Sea along the coast of Germany and Poland, and also in large parts of southern Sweden and Finland. Moreover, there are a large number of grid cells in northern Europe where ship emissions are responsible for more than 90 per cent of the exceedance of critical loads for acidity (CEC, 2002a).

### *Eutrophication*

Nitrogen oxides lead moreover to eutrophication, which affects biodiversity both on land and in coastal waters.

In 2000, the depositions of nitrogen exceeded the critical loads for eutrophication on 800,000 square kilometres (about 60 per cent) of sensitive terrestrial ecosystems in EU25 (Amann et al, 2004).

Also as regards eutrophication, there are a large number of grid cells in northern Europe where ship emissions are responsible for more than 90 per cent of the exceedance of critical loads. In the Mediterranean, ship emissions contribute more than 50 per cent of exceedances of critical loads in parts of Greece, Italy, and Spain (CEC, 2002a).

Although most of the $SO_2$ and NOx emitted from ships plying in international trade gets deposited over the sea, shipping is the largest single source of acidifying and eutrophying fallout over many countries in Europe (see Table 2).

**Table 2. Examples of countries where the proportion of air pollutant depositions of sulphur and oxidized nitrogen coming from ships is most marked.**

| Sulphur | | NOx-nitrogen | |
|---|---|---|---|
| Netherlands | 16% | Portugal | 23% |
| Sweden | 15% | Greece | 22% |
| Norway | 14% | Ireland | 22% |
| UK | 12% | Spain | 18% |
| Portugal | 11% | Italy | 17% |
| Italy | 11% | UK | 16% |
| France | 11% | Sweden | 16% |
| Denmark | 11% | Norway | 16% |
| Belgium | 11% | France | 14% |
| Ireland | 10% | Netherlands | 13% |
| Finland | 9% | Denmark | 13% |

*Source*: EMEP (2003).

### Corrosion

Air pollutants, such as sulphur dioxide, nitrogen oxides, and ozone, accelerate the rate of deterioration of a large number of various materials. Buildings and monuments made of limestone and some kinds of sandstone are especially sensitive to attack from acidic substances. Also metals become corroded more quickly in an acid environment. Ozone is known to speed up the disintegration of textile materials, leather and rubber.

### Climate change

Emissions from ships also contribute to global warming. An estimate of radiative forcing due to $CO_2$ emissions from ships indicates that ships may account for 1.8 per cent of the global. Moreover, according to a study made for the IMO Marine Environment Protection Committee, the radiative forcing resulting from increased levels of ground-level ozone due to NOx from international shipping *"are highly likely to produce positive forcing effects that will contribute to global warming and that could be in the same range as (or larger than) direct forcing from $CO_2$"* (Henningsen, 2000).

# Truck versus ship emissions

Comparison of the environmental performance of different modes of transport is difficult, but by narrowing down the comparison to a few air pollutants, some conclusions can be made. In terms of today's average vehicle and fuel, a ship will let out 30-50 times more sulphur per ton-kilometre than a truck (see Table 3). When diesel becomes even cleaner in 2005, the difference will increase to 150-300 times.

The situation remains greatly to trucks advantage even if ships are run on oil with a sulphur content of 1 per cent. This comes from the fact that the highest permissible sulphur content of diesel oil for road traffic has been gradually brought down by legislation. As from 2000 it was lowered in the EU to 350 ppm (parts per million), and in 2005 it will be further reduced to 50 ppm. A further reduction to below 10 ppm is anticipated by 2009 – such fuels are already being placed on the market. In contrast, the average sulphur content of marine heavy fuel oil used in European waters is about 2.7 per cent, i.e. 27,000 ppm.

Turning to nitrogen oxides, ships release about twice as much NOx per ton-kilometre as the latest truck models today, and the difference is set to increase (again see Table 3). In 2005, the emission standards for trucks in the EU will be cut from the present 5.0 to 3.5 g/kWh, and in 2008 to 2.0 g/kWh.

According to a recent report, the burning of marine heavy fuel oil gives rise to high emissions of polycyclic aromatic hydrocarbons (PAH) (Ahlbom & Duus, 2003). Because of its high content of polycyclic aromatics, this type of fuel is classified as carcinogenic and harmful to the environment. If compared to a heavy diesel-driven truck, the PAH emissions from a ship using marine heavy fuel oil are about 30 times higher per energy unit. This means that if the energy output of a ship's engine is 40 times that of a truck engine, the PAH-emissions from a fairly large vessel entering port will correspond to those from about 1200 heavy trucks.

**Table 3. Comparison of emissions[1] from trucks on long hauls with different EU standards for emissions and cargo vessels of various sizes. Figures in grams per ton-kilometre.**

| | $CO_2$ | PM | $SO_2$ | NOx | VOCs |
|---|---|---|---|---|---|
| **Heavy truck with trailer:** | | | | | |
| Before 1990 | 50 | 0.058 | 0.0093 | 1.00 | 0.120 |
| Euro 0 (1990) | 50 | 0.019 | 0.0093 | 0.85 | 0.040 |
| Euro 1 (1993) | 50 | 0.010 | 0.0093 | 0.52 | 0.035 |
| Euro 2 (1996) | 50 | 0.007 | 0.0093 | 0.44 | 0.025 |
| Euro 3 (2000) | 50 | 0.005 | 0.0093 | 0.31 | 0.025 |
| **Cargo vessel:** | | | | | |
| large (>8000 dwt) | 15 | 0.02 | 0.26 | 0.43 | 0.017 |
| medium size (2000-8000 dwt) | 21 | 0.02 | 0.36 | 0.54 | 0.015 |
| small (<2000 dwt) | 30 | 0.02 | 0.51 | 0.72 | 0.016 |
| RoRo (2-30 dwt) | 24 | 0.03 | 0.42 | 0.66 | 0.029 |

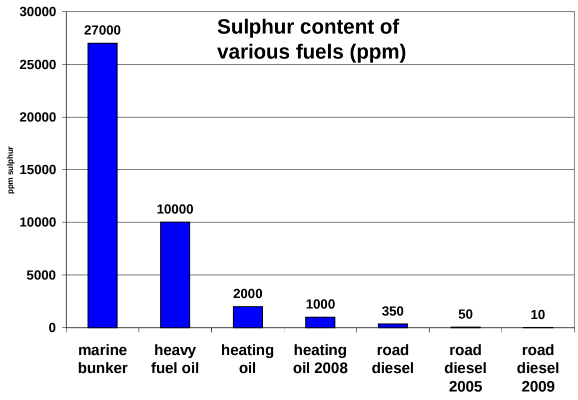
[1] Emissions are average in each case. **Trucks**: maximum overall weight 40 tons, loading 70 per cent, operating on diesel with a sulphur content of 300 ppm. **Cargo vessel**: bunker oil with and average sulphur content of 2.6 per cent, no cleaning of NOx. *Source*: www.ntm.a.se.

# Stationary sources vs ships

Sulphur emissions from land-based stationary sources are in the EU regulated by several directives, such directive 1999/32 on the sulphur content of liquid fuels, directive 2001/80 on the limitation of emissions from large combustion plants, and directive 1996/61 concerning integrated pollution prevention and control.

According to directive 1999/32, the maximum allowed emissions from all oil-fired plants must not exceed the equivalent of using heavy fuel oil with a sulphur content of 1 per cent. (Larger plants are subject to stricter emission standards in directive 2001/80, see below.) For gas oils, including for marine use, the limit is set stricter, at a maximum of 0.2 per cent, and it will be further reduced to 0.1 per cent as from January 2008 (see Figure 3). Any new large combustion plants (i.e. with a thermal capacity of more than 50 megawatts) built after 2003 must, according to directive 2001/80, keep their $SO_2$-emissions below levels equivalent to maximum sulphur contents in fuel oil of between 0.1 and 0.5 per cent. The bigger the plant, the stricter the emission limit value will apply.

**Figure 3. The sulphur content of various types of fuel.**




# International action so far

Although some countries, such as Sweden and Norway, have taken steps to attack the problem of ships' emissions independently, on the whole little has been done about it.

Shipping being largely an international business, it would be logical to try and bring about global agreement for control of its emissions, and an attempt has been made in the Marine Environment Protection Committee of the UN International Maritime Organization (IMO). After years of negotiation, agreement was reached in 1997 on an air-pollution annex to the MARPOL 73/78 Convention. But this agreement was so weak that it was obvious it would have little effect. Annex VI establishes a global sulphur cap of 4.5 per cent for bunker fuel, and it designates two so-called sulphur emission control areas (the Baltic Sea and the North Sea), where fuel used by ships must be below 1.5 per cent. It also prescribes emission standards for NOx for diesel engines with a power output greater than 130 kilowatts, but these standards are so weak that virtually all new engines are already in compliance.

Following its ratification by 15 countries representing 50 per cent of the gross tonnage of the world's merchant fleet, Annex VI will come into force in May 2005. In practise this will mean that the 1.5-per-cent sulphur limit will apply to all ships in the Baltic Sea as from May 2006, while the corresponding requirement for the North Sea will be delayed until 2007. To date (November 2004) only seven EU member states have ratified – Cyprus, Denmark, Germany, Greece, Spain, Sweden, and the United Kingdom.

The voting rules of the MARPOL convention, as well as experience to date, make it unlikely that possible further moves by the IMO will result in any significant emission reductions in the near future.

Protocols for reducing emissions under the Convention on Long-Range Transboundary Air Pollution (LRTAP) do not cover those from international shipping. Moreover, the emissions of greenhouse gases from international shipping are not covered by the Framework Convention on Climate Change or its Kyoto protocol.

Although it has long been held within the European Union that shipping is a matter for the IMO, the Commission has recently been investigating the economic, legal, environmental, and practical implications of coordinated EU action for reducing the emissions of air pollutants from ships. This initiative has been spurred among others because the EU directive on national emission ceilings required the Commission to present a program of action for reducing emissions from international maritime traffic before the end of 2002 (CEC, 2001b).

# Lower sulphur content in fuel

Emissions of $SO_2$ are directly proportional to the sulphur content of the fuel. The simplest and least expensive way of reducing them is to go over to using fuel oil with a low sulphur content.

In shipping matters it is usual to distinguish two main categories of fuel: heavy bunker fuel oil (HFO), with high viscosity and often a high sulphur content, and the light marine distillates. The latter are divided into two groups: marine diesel oil (MDO) and marine gas oil (MGO). Of these MGO is the "lightest", that is, it has the lowest viscosity and often the lowest sulphur content. Large vessels usually have HFO as standard fuel, but often switch to a lighter fuel for their auxiliary engines when manoeuvring or lying in port. Marine distillates are then used, as they are also for the main engines of small vessels.

The average sulphur content of marine HFO (so-called bunker fuel) is now between 2.5 and 3 per cent, but low-sulphur HFO can also be had. They usually require no engine modification, and the additional cost is to some extent compensated by cost savings. Because of its higher quality, low-su1phur fuel oil has the advantage of resulting in less wear on the machinery, with less need too for lubricating oil and less maintenance work, thus making for smoother engine running, with less risk of operating problems (Kågeson, 1999). High-sulphur marine HFO costs around $100-130 per ton, while marine gas oils costs around $150-190 per ton (Beicip-Franlab, 2002).

Since there are marine HFO with varying sulphur content available on the market, there is also information on the current "price premium" for low-sulphur HFO. Between 1990 and 2001, the price differential between low sulphur marine HFO – with a sulphur content of 1 per cent or less – and high sulphur HFO (3.5% S) averaged around $19 per ton (Beicip-Franlab, 2002). This would mean a cost of about 400 euro per ton for reduced emission of sulphur dioxide.

To meet an increased demand of low-sulphur HFO, there are three ways in which additional quantities of such fuels can be produced. The first and lowest-cost option is re-blending (10-16 euro per ton), which could make available in the EU some 5 million tons of HFO with less than 1.5 per cent sulphur, but is however not expected to be able to deliver any significant quantities of fuel with less than 0.5 per cent sulphur. The next option in order of cost is the processing of lower-sulphur crude oils, with an estimated incremental cost of 40-45 euro per ton of fuel.

The third and most expensive option is to desulphurize the HFO. This would require new investment in refinery desulphurization (combined with residue conversion to lighter products), and the resulting price premium has been estimated to between 50 and 90 euro per ton. (All cost estimates are taken from Beicip-Franlab, 2002 & 2003.)

As can be seen from Table 4, the extra cost of producing marine HFO with 0.5 per cent sulphur is calculated to lie between 47 and 93 euros a ton. To produce it with 1.5 per cent sulphur would, it is thought, cost 22-83 euros per ton.

Referring to these estimates, the Commission has assumed the average price premium for supplying 11 million tons of low sulphur (1.5%) bunker fuel in the Sulphur Emission Control Areas to be around 50 euro per ton (CEC 2002b). According to Beicip-Franlab, the total demand for marine heavy bunker fuel in the EU in the year 2000 was about 35 million tons. (See also section on cost-effectiveness, below.)

The use of low-sulphur marine fuels can be promoted e.g. by economic instruments. A system with fairway and harbour dues differentiated for environmental effect was introduced in Sweden in January 1998. Here ship-owners who state and verify that they are using fuel oil with a sulphur content of less than 0.5 per cent for ferries and 1.0 per cent for cargo vessels get a discount on the due. A rapid increase in the number of ships operating on low-sulphur oil, spurred to some extent by the demands for environmentally friendly transport from some of the big shippers, has come about since 1998, and close on 80 per cent of the entries to Swedish ports are now of ships using low-sulphur fuel.

**Table 4. Estimated price premium of supplying low sulphur marine heavy fuel oil versus current quality (euro/ton fuel).**

| | Quantity supplied | | | |
|---|---|---|---|---|
| **Sulphur** | **8.5 Mt** | **17 Mt** | **25.5 Mt** | **34 Mt** |
| 1.5% | 22-52 | 32-73 | 35-80 | 37-83 |
| 1.0% | 35-81 | 39-87 | 40-90 | 41-92 |
| 0.5% | 47-92 | 50-92 | 51-93 | 52-93 |

*Source*: Beicip-Franlab (2003).

# Seawater scrubbing

Seawater scrubbing is another possible means of reducing the emissions of sulphur from ships. The scrubber transfers the oxides of sulphur from the exhaust gas to the water. After scrubbing, the water is filtered to remove particulates, which are trapped and collected for disposal. The filtered water is recirculated back into the sea, where the sulphur goes into solution as sulphate, which is a natural component of sea water.

Trials using this technology indicate that it can cut sulphur emissions by up to 95 per cent and those of particulates by about 80 per cent. There is still uncertainty as to the possible negative effects on the sea of releasing waste water containing sulphate from the scrubbers. According to Annex VI of the MARPOL, such cleaning systems must be approved, and "waste streams from the use of such equipment shall not be discharged into enclosed ports, harbours and estuaries unless it can be thoroughly documented by the ship that such waste streams have no adverse impact on the ecosystems of such enclosed ports, harbours and estuaries based upon criteria provided by the authorities of the port state." (IMO, 1998) Such criteria have as yet not been developed.

# Reducing emissions of NOx

There are various methods for reducing NOx emissions, differing somewhat in cost and effectiveness.

### *Water injection and water emulsion.*

Water is injected into the combustion chamber or mixed with the fuel in order to lower the temperature of combustion and hence reduce NOx formation. The potential for emission reduction is at most around 50 per cent, but at the cost of increased fuel consumption (Kågeson, 1999). The installation cost is however lower than for either of the following methods.

### *HAM, Humid Air Motor*

A technique for preventing the formation of NOx during combustion by adding water vapour to the combustion air. Performance is unaffected either by the quality of the bunker oil or by engine workload. By reducing the consumption of fuel and lubricating oil, HAM has the advantage over SCR of somewhat lowering operating costs instead of increasing them. The method is able to reduce NOx by 70-80 per cent at a cost apparently similar to that of SCR (Kågeson, 1999).

### *Selective Catalytic Reduction, SCR*

A system for after-treatment of the exhaust gases. It can reduce the emissions of NOx by more than 90 per cent, but may require the use of low-sulphur fuel. When retrofitted it replaces the exhaust silencers. Nitrogen oxides are reduced to nitrogen gas by spraying urea or ammonia into the gases before they pass through a catalytic converter. Reduction costs are generally below 600 euro per ton NOx reduced, lower if the equipment can be installed while the ship is being built (Kågeson 1999, Davies et al, 2000). There are now more than fifty ships fitted for SCR. About half of them are Swedish, and most of the others are frequent callers at Swedish ports. This is largely a result of the environmentally differentiated fairway charges and port dues that has been used in Sweden in since 1998.

# Shore-side electricity

While docked at the port, ships shut off their propulsion engines, but they use their auxiliary engines to power refrigeration, lights, pumps and other equipment. These auxiliary engines are usually powered by high-sulphur marine heavy fuel oil, or in some cases by lower-sulphur marine gas oil, resulting in significant emissions of air pollutants. One possible alternative measure that specifically aims to reduce emissions from vessels in port is to hook them up to shore-side electricity so that they no longer need to run their auxiliary engines.

This solution is not entirely without problems however – for example it requires investments and certain modifications to be made in the ports and onboard vessels. Systems for supplying shore-side electricity are in themselves nothing new – they have been in use for decades in a few ports and for certain types of vessel. Experience from the Port of Göteborg, among others, has shown that the practicalities of handling shore-side electricity systems are simple, if modern high-voltage systems are used. The entire procedure for switching from onboard generated power to shore-side electricity is done in less than ten minutes, including the phasing-in of the new electricity supply and closing down of the onboard auxiliaries.

In a recent Swedish study (MariTerm, 2004), the direct costs for shore-side electricity were found to be two to four times higher than the direct cost of generating electricity onboard by auxiliary engines running on heavy fuel oil. However, the study also evaluated the external costs that emissions of air pollutants give rise to through damage to health and the environment, and these are considerably lower for vessels that are connected to a shore-side electricity supply. Depending on the fuel (HFO or MGO) and the type of shipping service investigated, the external costs for onboard generation of electricity were found to be between 15 and 75 times higher than those for shore-side electricity connection. (The shore-side electricity was assumed to be generated by modern coal-fired power plants.)

A comparison between direct electricity generation costs and estimated external costs of onboard generation and shore-side electricity, respectively, showed that the benefits associated with shore-side electricity supplies clearly outweigh the costs.

MariTerm concludes that shore-side electricity can effectively reduce air pollutant emissions and noise from vessels in port, thus providing environmental and health benefits. It is also recommended that if a wide-scale application of shore-side electricity systems were to be envisaged, it would be useful to develop a common international practice, or international standards, for such systems.

# Cost-effective to do it at sea

The costs of typical measures for reducing ships' emissions of sulphur dioxide range from 250 to 600 euro per ton, and for nitrogen oxides from 350 to 600 euro per ton. The measures required for reducing the emissions from sources on land more than envisaged by current legislation would usually cost still more, and in some cases much more (Kågeson, 1999).

For example, the retrofitting of SCR on large combustion plants usually costs between 1000 and 2000 euro per ton NOx removed, and the cost of reducing NOx in order to comply with the Euro 4 standards for diesel trucks is estimated by IIASA (the International Institute for Applied Systems Analysis) at about 2000-3000 euro per ton. Regarding sulphur dioxide, a switch from high-sulphur to low-sulphur (0.6%) heavy fuel oil is estimated to cost less than 500 euro per ton $SO_2$ removed. The cost for retrofitting flue-gas desulphurization to existing coal-fired large combustion plants can vary a lot depending on the specific plant, but typically range between 400 and 800 euro per ton. (Already adopted EU legislation will make this mandatory for most such plants as from 2008.) To retrofit that same technology on smaller boilers is more expensive – about 1500-2000 euro per ton $SO_2$. A main reason for the costs at sea generally being lower is that the easiest and least expensive measures have already been taken ashore in most EU countries, but not yet at sea.

Referring to Beicip-Franlab's estimates, the Commission has chosen to take 50 euro per ton fuel as the additional cost for lowering the sulphur content of European marine HFO from the present 2.9 to 1.5 per cent. That would correspond to 1800 euro per ton of eliminated $SO_2$ emissions, a figure that appears exaggerated, as it is more than four times the cost resulting from the present market price difference between high and low sulphur heavy bunker fuel.

A report of 1993 from the European oil industry's environmental organisation Concawe gives $46-69 per ton as the extra cost of producing oil with a sulphur content of 1.5 per cent – largely the same as Beicip-Franlab's figures. It should be noted that Concawe's estimate is mainly based on data from the mid-eighties referring to a desulphurizing plant in Rotterdam, although with some updating to 1991. Concawe has moreover added a "capital charge" of 25 per cent, which has meant that capital costs have come to dominate in its estimates (Concawe, 1993).

For the purposes of the Convention on Long-Range Transboundary Air Pollution, as well as the EU's NEC directive, the RAINS computer model developed by IIASA has been used for analyzing the cost-effectiveness of various measures for reducing emissions.

Those analyses took no account of the write-off periods desired by the oil industry, substituting instead an interest rate of 4 per cent on the capital costs. Given these conditions, the cost of lowering ships' emissions of sulphur by reducing the sulphur content of bunker oils turns out to be about 500 euro per ton of $SO_2$, which consequently is the figure used in the RAINS model. In 1998 for the analysis of the NEC directive, Concawe accepted that figure. It is also generally conceded that the same cost – 500 euro per ton of $SO_2$ – would be applicable for reductions down to about 0.6 per cent sulphur.

The cost-effectiveness of abatements at sea was studied by IIASA, while examining the EU strategy for combating acidification (CEC, 1997). The analysis showed that if the interim target for environmental quality proposed for the EU were to be attained solely by the use of technical measures on land, the annual cost by 2010 would be around 7 billion euro. The overall cost could however be brought down by 2.1 billion euro, or about 30 per cent, if cost-effective measures to limit the emissions of $SO_2$ and NOx from ships were applied in the Baltic, North Sea, and waters of the north-eastern Atlantic. (No account was at that time taken of emissions in the Mediterranean.)

With measures for shipping added to those for land-based sources, the environmental target could thus be attained at a considerably reduced cost. Alternatively, still more could be achieved at the same cost.

# A Community strategy to reduce air pollution from ships

Article 12 of directive 2001/81 on national emission ceilings commits the Commission to report to the European Parliament and the Council by the end of 2002 "*on the extent to which emissions from international maritime traffic contribute to acidification, eutrophication and the formation of ground-level ozone within the Community*".

The report "*shall specify a programme of actions which could be taken at international and Community level as appropriate to reduce emissions from the sector concerned*" (CEC, 2001b).

In January 2002 the Commission presented a discussion paper, intended to inform the development of a "Community strategy on air pollution from seagoing ships". The paper contained a series of questions, which member states and stakeholders were invited to respond to. The discussion paper as well as the responses can be found at the Commission's website: www.europa.eu.int/comm/environment/air/background.htm#transport

Work on the strategy has also been informed by a number of studies prepared by consultants, e.g. one by BMT Murray Fenton Edon Liddiard Vince Ltd on the implications of an EU system to reduce ship emissions (Davies et al, 2000). Two studies on the costs of reducing the level of sulphur in marine fuels were published in April 2002 and October 2003 (Beicip-Franlab, 2002 and 2003). Another study, by Entec UK Ltd, which among others quantified ship emission levels for the year 2000 and in-port emissions, as well as carried out a market survey of marine fuel oils, was published in August 2002 (Entec, 2002).

The EU strategy to reduce the emissions of air pollutants from sea-going ships was adopted by the Commission in November 2002 (CEC, 2002a). It contains a broad series of objectives, proposed actions and recommendations for bringing about such reductions over the next 5-10 years. According to the Commission, the cost of reducing emissions from ships is considerably lower than that of further abatement on land. The strategy document includes a list of actions that the Commission itself intends to take, as well as those it recommends to other parties. Here are some examples:

**International action**. Within the International Maritime Organization the Commission will continue to press for tougher measures to reduce ships' emissions. It recommends member states to ratify MARPOL Annex VI as soon as possible, and to support a co-ordinated EU position pressing for tighter international standards in regard to the global sulphur cap and NOx emissions.

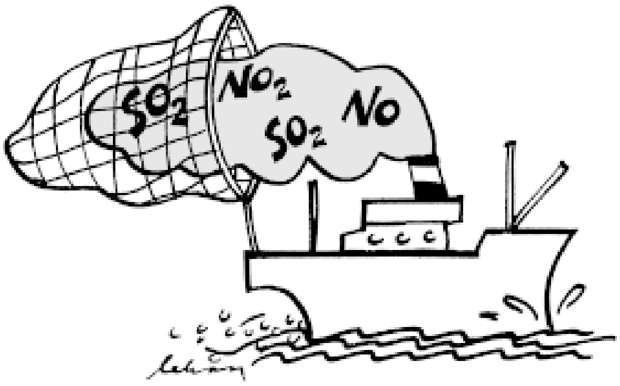
**EU regulation on emission standards**. Also on November 20, the Commission published a proposal to amend directive 1999/32/EC so as to limit the sulphur content of marine fuels marketed and used in the EU (see more below). The recently adopted directive 2004/26/EC (amending directive 1997/68/EC) sets standards for emissions of NOx, PM and CO for new non-road engines marketed in the EU, including engines for use aboard vessels operating on inland waterways. These new standards are gradually strengthened over the time period 2006-2014.

As concerns global emission standards for ships' engines, if the IMO has not proposed tighter international standards for NOx by the end of 2006, the Commission will consider bringing forward a proposal for reducing such emissions from seagoing vessels, in line with the proposed US standards put forward by the US Environment Protection Agency.

**EU regulation on economic instruments**. The Commission has yet to come up with proposals, in the context of an EU framework for infrastructure charging, for the development of an EU system of differentiated charges for all modes of transportation. A charging scheme for maritime transportation will be part of that framework, and be developed on the basis of ships' environmental performance, including atmospheric emissions.

Later, the Commission will be considering the possibility of developing an emissions trading regime (or regimes) to achieve incremental reductions in ships' emissions in EU sea areas, particularly for NOx. The feasibility of trading in ships' emissions will however first have to be demonstrated.

**Voluntary measures**. The Commission urges the international bunker industry to make available significant quantities of marine heavy fuel oil with a maximum sulphur content of 1.5 per cent in states bordering on SOx Emission Control Areas, and also to make available at least some marine fuel of any grade with a sulphur content of 1.5 per cent in all world bunkering ports, so as to be able to supply ships destined for an SOx Emission Control Area. The Commission urges port authorities to consider introducing voluntary speed reductions, and to require, facilitate, or provide incentives for ships to use land-based electricity or clean onboard power while in port.




# Proposal to limit the sulphur content of marine fuels

As part of its strategy to reduce the atmospheric emissions from seagoing ships, the Commission has published a proposal for modifying the provisions of directive 1999/32/EC as regards the sulphur content of marine fuels (CEC, 2002b). The aim of the Commission's proposal is to reduce the emissions of sulphur dioxide and particulates, thus lowering the extent to which ships contribute to problems of air quality and acidification. The main items are to:

❑ **1.5% in the Baltic and North Sea**. Introduce a 1.5-per-cent sulphur limit on marine fuels used by all sea-going vessels in the Baltic, the North Sea, and the English Channel, in line with the sulphur limits of MARPOL Annex VI. This internationally agreed limit is intended to be implemented 12 months after the entry into force of the revised directive, or one year after that of Annex VI, whichever should be the earlier.

❑ **1.5% for ferries**. Introduce a 1.5-per-cent sulphur limit on marine fuels used by passenger vessels in regular service to or from any Community port. To ease the effect on operators, it is proposed to allow a transition period ending July 2007.

❑ **0.2% in ports**. Amend the existing provisions for marine distillates used by sea-going and inland vessels by introducing an 0.2-per-cent sulphur limit on fuel used by ships at berth in ports within the EU. This limit should be lowered to 0.1 per cent by 2008. To this end, it is suggested firstly to ban the sale if marine gas oils with more than 0.2 per cent sulphur (0.1 per cent from 2008), secondly to remove the 0.2-per-cent sulphur limit on marine diesel oil, and then ban the sale of marine diesel oil with more than 1.5 per cent sulphur.

It is estimated that the combined costs, when all these measures have to be implemented (by 2006-08), will amount to about 1.1 billion euro a year. Taken together, by 2008 the proposed measures are expected to reduce the annual emissions of $SO_2$ from shipping by about 10 per cent, as compared to the emission level in 2000. The improvement in fuel quality will also result in lowered emissions of particulates and nitrogen oxides.

According to the Commission's analysis, only some of the benefits of reduced emissions can be expressed in terms of money. Methodologies are as yet unavailable for monetizing for instance the effects on ecosystems of exceeding the critical loads for acidification, but where the benefits have been estimated, the Commission has taken into account the effects on human health as well as on crops and modern building materials. Added up, they are estimated to amount to 2.7 billion euros a year. It is in any case clear from the analyses that the benefits will significantly outweigh the costs in all aspects.

# Parliament calls for tougher action

At its first reading in June 2003, the European Parliament voted almost unanimously to demand stricter standards on the sulphur content in marine fuels – the intention being to bring about a reduction of 80 per cent in ships' emissions. Put briefly, this means that the parliament is urging the introduction of gradually tighter measures, as follows:

**Stage 1: 1.5% in all European sea areas**. The introduction of the limit of 1.5 per cent sulphur in marine fuels is to be brought forward to six months after the entry into force of the directive for northern European sea areas (the Baltic and the North Sea with the inclusion of the English Channel), and the limit is also to apply to ferries in all EU waters. As from December 31, 2010, it is to apply, too, in southern sea areas (the Mediterranean and the NE Atlantic).

**Stage 2: 0.5% in all European sea areas**. Lowering the limit, from December 31, 2008, to 0.5 per cent sulphur for all ships in northern European waters and for ferries in all EU sea areas, and from December 31, 2012, in the remaining European sea areas. These limits would apply to ships registered anywhere in the world, regardless of what port they start from.

The text also allows the possibility of carrying out pilot trials to assess and eventually develop new technologies for abatement (such as sea-water scrubbing of the exhausts). There would be no requirement to use low-sulphur fuels during the trials. The Commission shall then consider which, if any, of the abatement methods might be permissible as an alternative or complement to low-sulphur fuels.

If any of these abatement methods are shown to be successful and acceptable, the Commission should – before December 31, 2007 – make proposals for a further revision of the directive, with the possible inclusion of economic instruments.

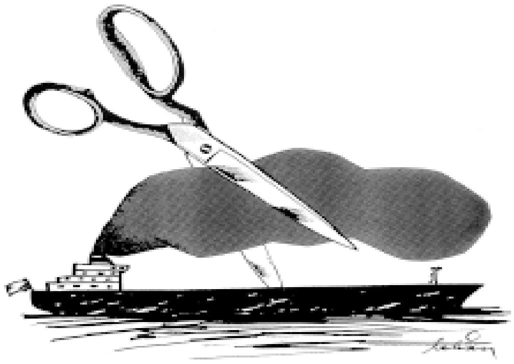
# Commission and Council reject proposals from Parliament

In August 2003, the Commission presented its views on the amendments that had been passed by the Parliament. Of the Parliament's 40 or so amendments, the Commission was willing to agree, by and large, with all but six. Among those that the Commission did not accept were those that would further lower the sulphur content (from 1.5 to 0.5 per cent) in a second stage, and also extend the region in which these requirements shall apply to the southern sea areas.

On June 28, 2004, the EU environment ministers reached political agreement on the draft directive aimed at reducing sulphur emissions from ships. In doing so, the Council expressed its general support of the Commission's original proposal – a position that was not supported by Sweden, which argued that the Council should instead back the proposal of the Parliament.

The only substantive change introduced by the Council, is to require ships at berth in EU ports as well as inland vessels to use fuel containing no more than 0.1 per cent sulphur, to apply from January 2010. In the Commission's original text, the proposed deadline for this measure was January 2008.

The next step will be for the European Parliament to arrive at their second reading, which is expected by April 2005. The fact that the Parliament at its first reading had reached such a high degree of unanimity on the matter is a strong signal that it will maintain its attitude also at the second reading. Should this happen, there will have to be recourse to conciliation negotiations between the Parliament and the Council, before the directive can finally be adopted.



# What the EU and its member states should do

Four environmental organisations – the European Environmental Bureau, the European Federation for Transport and Environment, Seas At Risk, and the Swedish NGO Secretariat on Acid Rain – have jointly worked out a series of recommendations for action to be taken:

❑ The best approach would be to combine regulation with market-based instruments that apply Community fair and efficient pricing principles to the marine sector.

❑ The EU should introduce legislation for reducing emissions of $SO_2$ from ships by setting limits on the sulphur content of fuel used by ships in the Exclusive Economic Zones (or at least in the territorial waters). The maximum permitted sulphur content for marine fuel should initially be set at 0.5 per cent, and should be applied in all Community sea areas. This would reduce annual $SO_2$ emissions from ships by about 80 per cent, as compared to year 2000.

❑ Since the EU legislative process is likely to take some years, and most probably will cover only parts of the problem, charges should be imposed that are differentiated for environmental effect and apply impartially to all vessels. Because methods of charging shipping vary, it would be useful to adopt an EU directive that makes all member states as well as candidate countries introduce charges. Charges should be related to the amounts of pollutants emitted, and set so as to make it financially worthwhile – at least for ships that regularly frequent the area – to use lower sulphur fuels and to invest in techniques needed to ensure a distinct reduction of NOx emissions.

❑ The EU and its member states should make every effort to markedly strengthen the weak emission standards for NOx, as well as the standards on maximum allowed sulphur content of bunker fuels of the Annex VI to the MARPOL Convention. The EU should introduce NOx emission standards that are significantly stricter than those of Annex VI to the MARPOL Convention.

❑ Stricter standards should also be introduced for control of emissions in inland waterways.

❑ Any measure needs to be accompanied with monitoring of compliance, not only at sea going vessels, but also on bunker fuel trading boats and at onshore selling points.

It is important to differentiate between measures that are – or can be expected to be – effective in the short term (i.e. within the next few years), in the medium term (up to 2010), and in the longer term (after 2010). Some examples:

– Some economic instruments (such as environmentally differentiated fairway and/or port dues) have the advantage of being able both to be quickly introduced and to bring quick results. EU legislation can also bring quick results, but may need about two years to reach political agreement. Developing and introducing more elaborated economic instruments (such as infrastructure charges that apply full marginal social costs pricing) is likely to need even more time. Global agreements under the IMO have shown to need relatively long time to agree, and additional time for ratification and entry into force.

– Measures such as lowering of the sulphur content of fuels will bring immediate emission reductions, as will the retrofitting of SCR or HAM. On the other hand, measures that will apply only to new vessels, such as stricter NOx emission standards exclusively for new ships, will only gradually reduce emissions over a longer time period (depending on the fleet turnover rate).

The Commission's White Paper on the Common Transport Policy (CEC, 2001c) proposed the development of EU-wide charging systems for the infrastructure used by the maritime sector and the application of fair and efficient pricing principles that internalise external costs applied to all transport modes. Such infrastructure charges on a kilometre basis should therefore be introduced throughout the Exclusive Economic Zones of the member states, and they should apply marginal social costs pricing via the methodology to be elaborated in the framework directive that the Commission is to put forward.

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# Annex: Emission scenario calculations

Based primarily on annual fuel consumption data for the different sea areas and ship types for 2006, as estimated by the Commission's consultant Entec, the emissions for three different scenarios have been calculated.

**Scenario A. Business as usual (BAU):** Total annual emissions in 2006 if adding all a-alternatives below will be **2.96 million tons** (Mt), which is slightly higher than the Entec 2006 BAU figure of 2.72 Mt. This is explained by the fact that here a sulphur content of 2.9% in marine bunker fuel has been assumed, while Entec assumed 2.7%. If using the fuel consumption figures below and a sulphur content of 2.7%, the sum will be 2.76 Mt.

**Scenario B. Commission proposal:** Combines 1b + 2b + 3b + 4a below, which adds up to **2,36 Mt** total emissions, i.e. a reduction by about 600 kton/year compared to BAU 2006, as from July 2007. (The Commission's own estimate is a 500 kton annual reduction, but this is based on a starting point of 2.7% S in the fuel.) Compared to the ship emission level in year 2000, this scenario would reduce annual emissions by **less than 10%.**

**Scenario C. NGO proposal:** This combines 1c + 2c + 3b + 4c below, resulting in **0.50 Mt** total emissions, i.e. a reduction of about 2,458 kton/year compared to BAU 2006, as from mid-2005. Compared to the 2000 level of ship emissions, this is a reduction in annual emissions of about **80%.**

Ships and Ferries in the SECA (North Sea & Baltic Sea) 2006 assuming 1.5% annual growth

a) Fuel use 14.3 Mt x 2.9% S => 829 kton $SO_2$

b) Fuel use 14.3 Mt x 1.5% S => 429 kton $SO_2$

c) Fuel use 14.3 Mt x 0.5% S => 143 kton $SO_2$

Ferries in the NE Atlantic and Mediterranean (about 2006)

a) Fuel use 4 Mt x 2.9% S => 232 kton $SO_2$

b) Fuel use 4 Mt x 1.5% S => 120 kton $SO_2$

c) Fuel use 4 Mt x 0.5% S => 40 kton $SO_2$

Vessels at berth (2006) assuming 1.5% growth

a) Fuel use 2.3 Mt x average 2.2% S (half 2.9% S and half 1.5% S) => 101 kton $SO_2$

b) Fuel use 2.3 Mt x 0.2% S => 9.2 kton $SO_2$

**Ships in the NE Atlantic and Mediterranean (about 2006) assuming 1.5% annual growth**

(Fuel use figure from the Commission's Explanatory Memorandum, where it is said that some 35 Mt is consumed in EU sea areas outside the SECA. As the 4 Mt used by ferries are included in that figure, this has been deducted.)

a) Fuel use 31 Mt x 2.9% S => 1,798 kton $SO_2$

b) Fuel use 31 Mt x 1.5% S => 930 kton $SO_2$

c) Fuel use 31 Mt x 0.5% S => 310 kton $SO_2$