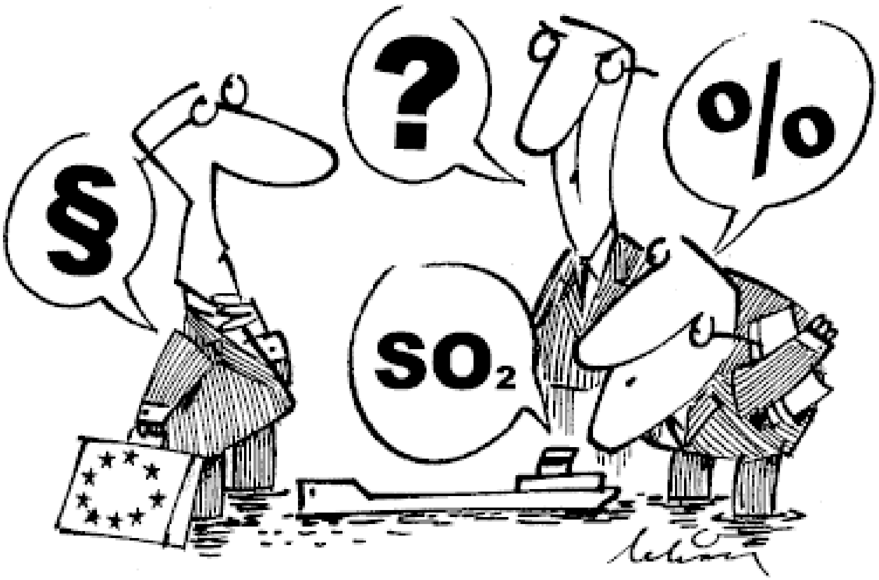

Cost-benefit analysis of using 0.5% marine heavy fuel oil in European sea areas

THE SWEDISH NGO SECRETARIAT ON ACID RAIN

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A briefing from the Swedish NGO Secretariat on Acid Rain, January 2005

For more information, contact:
Christer Ågren
The Swedish NGO Secretariat on Acid Rain, Box 7005, S-40231 Göteborg, Sweden
Phone: +46-31-7114515
E-mail: cagren@acidrain.org
Internet: www.acidrain.org

Cover illustration by Lars-Erik Håkansson (Lehån).

Summary and main results

A lowering of the sulphur content of marine heavy fuel oil from the current average of about 2.7 per cent down to 0.5 per cent in all European sea areas, would reduce total sulphur dioxide emissions from international shipping around Europe by more than three quarters by 2010, as compared to the emission levels of 2000.

Estimates of the cost of lowering the sulphur content of marine heavy fuel oil vary significantly. As there appears to be no obvious explanation for the big differences in cost estimates, three different figures have been applied for this analysis. The lowest cost figure (580 euro/tonne reduction in sulphur dioxide) is taken from the International Institute for Applied Systems Analysis (IIASA). The medium figure (1,083 euro/tonne SO_2) and the high cost figure (1,938 euro/tonne SO_2) are both taken from Beicip-Franlab.

Figures on the estimated economic benefits of reducing SO_2 emissions were taken from a study prepared for the European Commission by AEA Technology. These benefit figures vary between sea areas, from 1,600 to 5,900 euro/tonne SO_2 depending primarily on the differences in population exposure resulting from the emissions. The benefit estimates include the impact on health due to fine particles and SO_2 and the effects of SO_2 and acidity on modern buildings and structures. Damage to ecosystems and cultural heritage, and impact on visibility are however not accounted for, which means that the benefits are underestimated.

A comparison of the benefits and the costs for **all European sea areas combined**, show that the benefits clearly outweigh the costs. For the year 2020, the annual benefits are estimated to amount to nearly 12 billion euro, while the costs are estimated to amount to between 1.6 and 5.4 billion euro per year. The resulting net benefits would be between 6.6 and 10.4 billion euro per year.

The benefit-to-cost ratio varies significantly depending on the cost figure used. If assuming the highest cost estimate, the benefits are calculated to exceed the costs by about 2.2 times, and if assuming the lowest cost estimate, the benefits are calculated to be 7.5 times higher than the costs.

Regarding the various sea areas, the **Mediterranean** shows the highest benefit-to-cost ratios, with benefits exceeding costs by up to 8.1 times, as well as the highest benefits in absolute terms. This is then followed by the **NE Atlantic** and the **North Sea**, showing benefit-to-cost ratios of up to 7.8 and 7.4 times, respectively. The **Baltic Sea** shows the lowest benefit-to-cost ratios, with at most 2.8 times, and it is the only sea area which – when assuming the highest cost figure – comes out with a negative benefit-to-cost ratio (0.8).

Background

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 45 per cent between 2000 and 2020. As a result, 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 Figure 1).

Projections of future ship emissions have been taken from the so-called baseline scenario of the Clean Air For Europe (CAFE) programme (IIASA, 2004b), in which the introduction of a limit value of 1.5 per cent sulphur for marine heavy fuel oil in line with the forthcoming entry into force of MARPOL Annex VI, has been accounted for.

As part of its strategy to reduce atmospheric emissions from seagoing ships, in 2002 the European Commission published a proposal for modifying the provisions of directive 1999/32/EC regarding the sulphur content of marine fuels (CEC, 2002). However, the action proposed by the Commission in regard to ships' emissions of SO_2 will 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.

A lowering of the sulphur content of marine heavy fuel oil to 0.5 per cent in all European sea areas would result in a fall in total SO_2 emissions from international shipping around Europe from more than 2.4 million tonnes in 2000 to less than 0.6 million tonnes in 2010, i.e. a reduction of about 76 per cent (see Table 1).

Sulphur dioxide can become converted into sulphate aerosols, which are very fine and among the more frequent of airborne particles. Exposure to fine particles (PM) is associated with increased mortality (especially from cardiovascular and cardiopulmonary diseases) and morbidity. It has been estimated that exposure to PM 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 of the order of one to two years (WHO, 2003). Ship emissions

Figure 1. Emissions of SO_2 from land-based sources in the 25 EU countries and from international shipping in European sea areas 2000-2030 (ktonnes).

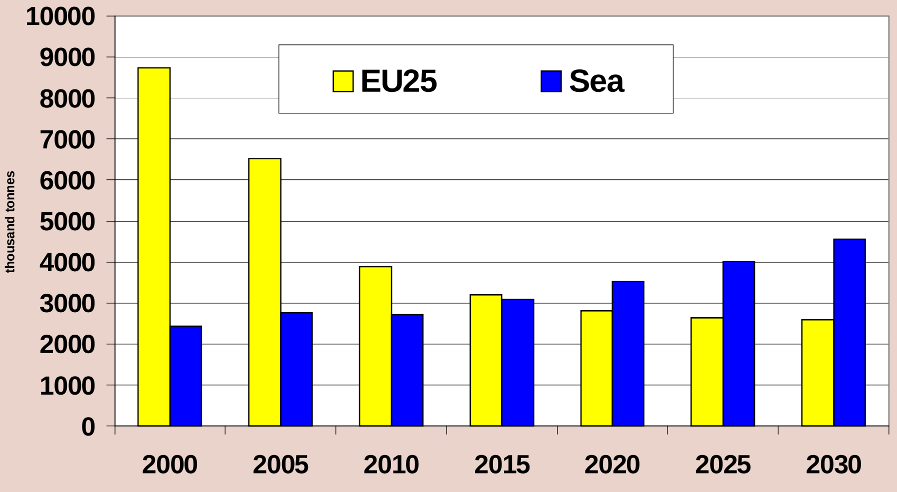


Table 1. Emissions of SO_2 from international shipping 2000-2020 (kilotonnes).

	2000 2.7%	2010 2.7/1.5%	2010 0.5%	2015 2.7/1.5%	2015 0.5%	2020 2.7/1.5%	2020 0.5%
Baltic Sea	242	174	58	198	66	225	75
North Sea	459	328	109	373	124	423	141
NE Atlantic	395	509	94	578	107	656	121
Mediterranean	1232	1599	296	1823	338	2078	385
Black Sea	83	107	20	122	23	138	26
Sum	**2411**	**2717**	**577**	**3094**	**658**	**3520**	**748**

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

In 2000, the depositions of acidifying air pollutants (sulphur and nitrogen) exceeded the critical loads for acidifying substances over more than 260,000 square kilometres (about 23 per cent) of sensitive forest ecosystems in the EU's 25 member states (IIASA, 2004b). 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 many 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, 2002).

Input data and results

This paper compares the estimated economic benefits and costs of cutting back from the current average of about 2.7 per cent sulphur content in marine heavy fuel oil to an average sulphur content of 0.5 per cent, for ships engaged in international traffic in the sea areas around Europe.

Figure 2. Comparison of benefits and costs of using 0.5% sulphur fuel in all European sea areas (billion euro/year).

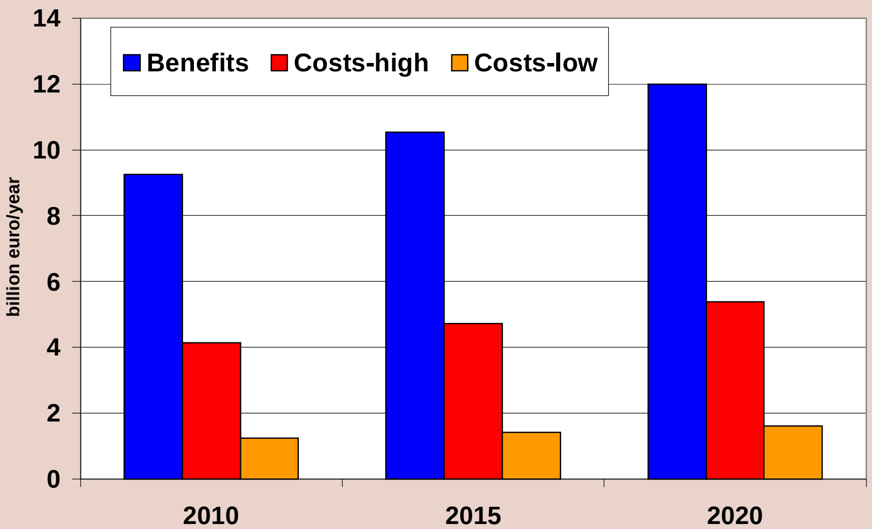
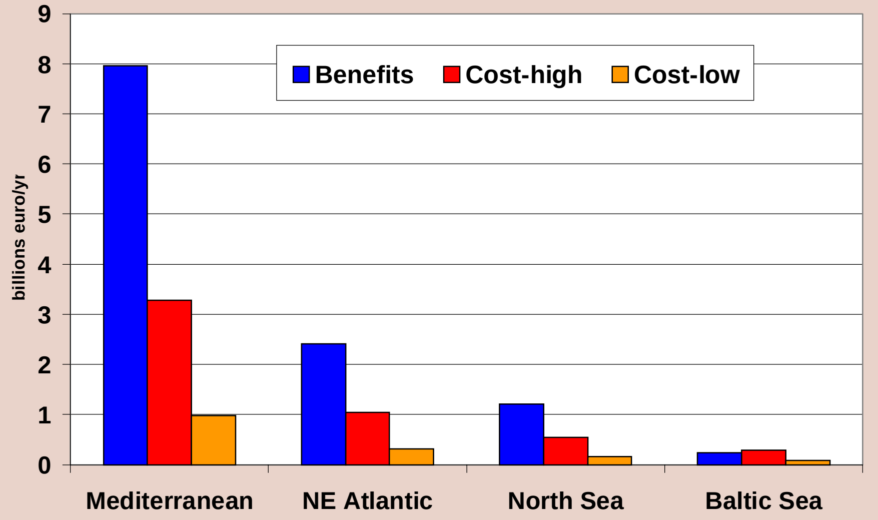


Figure 3. Comparison of benefits and costs of using 0.5% sulphur fuel in the different European sea areas (billion euro/year).



Estimates of the costs of lowering the sulphur content of marine heavy fuel oil vary significantly. As there appears to be no obvious explanation for the big differences in cost estimates, three different figures have been used – one from IIASA, and two from Beicip-Franlab (IIASA, 2004a and Beicip-Franlab, 2003). The lowest cost is set at 580 euro/tonne reduction in SO_2, the medium cost at 1,083 euro/tonne, and the highest cost at 1,938 euro/tonne reduction in SO_2.

Figures on the estimated economic benefits of reducing SO_2 emissions were taken from a study prepared for the European Commission by AEA Technology (AEA, 2002). These benefit figures vary between sea areas, from 1,600 to 5,900 euro/tonne SO_2 depending primarily on the differences in population exposure resulting from the emissions. The benefit estimates include the impact on health of fine particles and SO_2 and the effects of SO_2 and acidity on modern buildings and structures. Damage to ecosystems and cultural heritage, and impact on visibility are however not accounted for, which means that the benefits are underestimated.

Looking at the result for **all European sea areas combined**, the benefits clearly outweigh the costs (see Figure 2 and Table 2). The benefit-to-cost ratio varies significantly however, depending on the cost figure used. If assuming the highest cost estimate, the benefits are calculated to exceed the costs by about 2.2 times, and if assuming the lowest cost estimate, the benefits are calculated to be 7.5 times higher than the costs.

For the year 2020, the annual benefits are estimated to amount to nearly 12 billion euro, while the costs are estimated to amount to between 1.6 and 5.4 billion euro/year. The resulting net benefits would be between 6.6 and 10.4 billion euro.

Regarding the various sea areas, the **Mediterranean** shows the highest benefit-to-cost ratios, with benefits exceeding costs by up to 8.1 times, as well as the highest benefits in absolute terms (see Figure 3 and Table 6). This is then followed by the **NE Atlantic** (Table 5) and the **North Sea** (Table 4), showing benefit-to-cost ratios of up to 7.8 and 7.4 times, respectively. The **Baltic Sea** (Table 3) shows the lowest benefit-to-cost ratios, with at most 2.8 times, and is the only sea area which – when assuming the highest cost figure – comes out showing a negative benefit-to-cost ratio (0.8).

Table 2. Estimate of costs and benefits of 0.5% marine HFO, combined for all European sea areas (million euro).

	2010			2015			2020		
	RAINS	B-F low	B-F high	RAINS	B-F low	B-F high	RAINS	B-F low	B-F high
Benefits	9258	9258	9258	10539	10539	10539	11996	11996	11996
Costs	1241	2318	4147	1413	2638	4721	1608	3002	5372
NetBenefits	**8287**	**6940**	**5111**	**9126**	**7901**	**5818**	**10388**	**8994**	**6624**
RatioBe/Co	7.5	4	2.2	7.5	4	2.2	7.5	4	2.2

Table 3. Estimate of costs and benefits of 0.5% marine HFO (million euro), for the Baltic Sea.

	2010			2015			2020		
	RAINS	B-F low	B-F high	RAINS	B-F low	B-F high	RAINS	B-F low	B-F high
Benefits	186	186	186	211	211	211	240	240	240
Costs	67	126	225	76	143	256	87	162	291
NetBenefits	**119**	**60**	**-39**	**135**	**68**	**-45**	**153**	**78**	**-51**
RatioBe/Co	2.8	1.5	0.8	2.8	1.5	0.8	2.8	1.5	0.8

Table 4. Estimate of costs and benefits of 0.5% marine HFO (million euro), for the North Sea.

	2010			2015			2020		
	RAINS	B-F low	B-F high	RAINS	B-F low	B-F high	RAINS	B-F low	B-F high
Benefits	942	942	942	1071	1071	1071	1213	1213	1213
Costs	127	237	424	144	270	483	164	305	547
NetBenefits	**815**	**705**	**518**	**927**	**801**	**588**	**1049**	**908**	**666**
RatioBe/Co	7.4	4.0	2.2	7.4	4.0	2.2	7.4	4.0	2.2

Table 5. Estimate of costs and benefits of 0.5% marine HFO (million euro), for the NE Atlantic.

	2010			2015			2020		
	RAINS	B-F low	B-F high	RAINS	B-F low	B-F high	RAINS	B-F low	B-F high
Benefits	1868	1868	1868	2120	2120	2120	2408	2408	2408
Costs	241	449	804	273	510	913	310	579	1037
NetBenefits	**1627**	**1419**	**1064**	**1847**	**1610**	**1207**	**2098**	**1829**	**1371**
RatioBe/Co	7.8	4.2	2.3	7.8	4.2	2.3	7.8	4.2	2.3

Table 6. Estimate of costs and benefits of 0.5% marine HFO (million euro), for the Mediterranean.

	2010			2015			2020		
	RAINS	B-F low	B-F high	RAINS	B-F low	B-F high	RAINS	B-F low	B-F high
Benefits	6124	6124	6124	6980	6980	6980	7957	7957	7957
Costs	756	1411	2525	861	1608	2878	982	1834	3281
NetBenefits	**5368**	**4713**	**3599**	**6119**	**5372**	**4102**	**6975**	**6123**	**4676**
RatioBe/Co	8.1	4.3	2.4	8.1	4.3	2.4	8.1	4.3	2.4

Estimates of the costs

The cost data from the IIASA's (the International Institute for Applied Systems Analysis) RAINS model is based – as with all cost data used for the RAINS model – on a so-called societal interest rate of 4 per cent. The cost data used for the RAINS model has repeatedly been screened and accepted by member states and stakeholders (including industry) – the latest consultation process was conducted in 2004 for the purpose of the ongoing modelling activities carried out for the EU Clean Air For Europe (CAFE) programme. For heavy fuel oil (HFO) in particular, the RAINS cost figure of 580 euro/tonne reduction in SO_2 is valid for desulphurizing fuels down to 0.6 per cent sulphur content.

The Beicip-Franlab (B-F) cost estimates are taken from a report to the European Commission from October 2003, providing estimates of the costs of reducing the sulphur content of marine HFO from an assumed current average sulphur content of 2.9 per cent down to 0.5 per cent sulphur (Beicip-Franlab, 2003). B-F cost figures are given as costs per tonne of fuel, and vary, for instance, depending on the overall amount of low-sulphur HFO to be produced. To produce 34 million tonnes of 0.5 per cent HFO was estimated to cost between 52 and 93 euro per tonne of fuel. The B-F report concludes that the cost estimates for residue desulphurization at refineries have a considerable amount of uncertainty, for example the assumed investment costs are stated to have an accuracy of plus or minus 40 per cent. B-F estimates for the higher range of the costs are said to try to reflect the "maximum likely price premium".

For the purpose of this comparison, the B-F cost figures have been converted to cost per tonne of SO_2 reduction, based on the following assumptions: Burning 1 tonne of HFO with a sulphur content of 2.9 per cent results in 58 kg of SO_2 emissions, and burning 1 tonne of HFO with a sulphur content of 0.5 per cent results in 10 kg of SO_2 emissions. Thus, switching from 2.9% S fuel to 0.5% S fuel results in reduced SO_2 emissions of 48 kg (=0.048 tonnes) per tonne of fuel burned. If the desulphurization cost is set at 52 euro/tonne of fuel, the cost for reducing 1 tonne of SO_2 will be 52 euro divided by 0.048 tonnes of SO_2, i.e. 1,083 euro/tonne SO_2. Similarly, if the desulphurization cost is set at 93 euro/tonne of fuel, the cost for reducing 1 tonne of SO_2 will be 1,938 euro/tonne SO_2.

Estimates of the benefits

Estimates of the benefits of reducing SO_2 emissions in various parts of Europe have been taken from the "BeTa Benefits Table database", prepared for the European Commission in autumn 2002, by AEA Technology (AEA, 2002). This is the same source of data that the Commission used for the cost-benefits calculations in its Explanatory Memorandum to the proposed amendment of Directive 1999/32/EC as regards the sulphur content of marine fuels (COM (2002) 595 final).

The BeTa report provides a "benefits table database", and includes a table on "marginal external costs from emissions at sea (year 2000 prices)". The table gives varying benefit figures for emissions in the different sea areas (Baltic Sea:

1,600 euro/tonne SO_2; North Sea: 4,300 euro; English Channel: 5,900 euro; NE Atlantic: 4,500 euro; and, the Mediterranean: 4,700 euro/tonne SO_2).

For emissions close to shore, the report recommends the use of national rural benefit figures, and regarding emissions in ports, it recommends the use of urban benefit figures for cities of the same size as the port city, with the addition of rural externality figures for the country in question. For reasons of simplicity, the CBA calculations carried out here for marine HFO with 0.5 per sulphur content have used only the figures given in the table for offshore emissions, even though this procedure is likely to result in an underestimate of the benefits.

The highest benefit figure of 5,900 euro/tonne SO_2 (for the English Channel) has not been used here because of lack of emission projections for this specific sea area – instead the benefit figure for the North Sea (of 4,300 euro) was also used for the English Channel. Since no benefits data was available for the Black Sea, the lowest figure (i.e. for the Baltic Sea) was also applied for the Black Sea.

The benefit estimates include impacts on health by fine particles and SO_2 and effects of SO_2 and acidity on modern buildings and structures. Due to lack of information, however, some types of damage have been omitted. Among them are effects on ecosystems, cultural heritage, and visibility. Consequently, these benefit figures do not account for all the benefits, and particularly not for the significant potential to reduce acidification damage to ecosystems in northern Europe. This helps explain why the benefit figures are relatively low for the Baltic Sea, and also underlines the fact that the benefits generally are underestimated. (It should be noted that the BeTa numbers are in the process of being updated as part of the ongoing CAFE programme.)

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