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IIASA Working Paper

WP-93-069

November 1993

Klaassen, G. (1993) Sulfur Emission Trading and Regulation in Europe. IIASA Working Paper. WP-93-069 Copyright © 1993 by the author(s). http://pure.iiasa.ac.at/3745/

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Preface

Initiatives to reduce emissions of acidifying air pollutants, such as the new 'sulfur protocol' presently discussed under the Convention on Long-range Transboundary Air Pollution, are important steps to reduce acid deposition in Europe. It is always useful, however, to examine whether there might not be more cost-effective means of achieving environmental protection. Or stated conversely, if the same amount of money could not be spent differently to achieve more environmental protection.

This paper explores the use of relative simple emission trading schemes, such as the ones currently applied for sulfur in the USA under the 1990 Clean Air Act Amendments, as complements to existing and proposed regulations to control sulfur emission in Europe. Making use of IIASA's Regional Acidification INformation and Simulation (RAINS) model, the paper explores the costs, environmental impacts as well as the distributional consequences of emission trading.

Abstract

How to implement emission trading is only one question in the current negotiations on a new sulfur protocol in Europe. Whereas the current protocol stipulates a 30 per cent uniform reduction, national emission ceilings included in the proposed new protocol imply differentiated reductions. In addition, emission and fuel standards are proposed. This paper examines the costs and environmental impacts of emission trading. A new element is that emission trading is combined with regulations. Calculations, using the RAINS (Regional Acidification INformation and Simulation) model, suggest that overlaying emission trading on regulations does reduce the cost savings but has beneficial impacts as well: ecosystem protection is not changed and significant decreases in environmental benefits for countries are largely avoided. Emission trading can also be used to decrease emissions and increase ecosystem protection. If combined with existing legislation, this minimizes losses in expected environmental benefits for some countries since most countries gain. The initial distribution of emission ceilings, however, has to be used to avoid that some countries are confronted with higher costs. Trade-offs thus appear to exist between using emission trading to achieve cost savings on the one hand and ecosystem protection and distributional equity on the other hand.

Key words: emission trading, sulfur, acid rain, costs, Europe

1 Introduction[1]

In the ongoing negotiations on a new sulfur protocol in Europe the possibility of joint implementation of agreed emission ceilings is addressed. Whereas the current protocol stipulates a 30 per cent uniform reduction, national emission ceilings included in the proposed new protocol imply differentiated reductions. In addition, emission and fuel standards are proposed. On top of this an emission trading system is point of discussion as well. The major question appears how to design emission trading so as to avoid negative environmental effects for third parties. In theory, a system of deposition permits (Montgomery, 1972) or pollution offset trading would be ideal (Krupnick et al., 1983). Model simulations generally confirm this (Tietenberg, 1985). In practice, however, these systems either have not been applied or excessive transaction costs have limited the number of external trades (Hahn and Hester, 1989). Moreover, in practice emission trading has always been applied in combination with existing regulations, especially emission standards (Hahn and Hester, 1989). This is also true for the most radical approach to emission trading taken so far: allowance trading for sulfur emissions in the USA (Kete, 1992). The US system simply allows trading in one zone. It is based on the assumption that, given the size of the emission reduction and the expected distribution of marginal control costs of power plants in different US states, emission reductions would take place where they are necessary to protect the environment anyway.

The aim of this paper is to examine the costs and environmental impacts of emission trading in Europe, similar to that of the USA. This implies trading in one zone in combination with existing emission and fuel standards in Europe and alternatively also combined with the standards proposed in the new sulfur protocol.

In the remainder, Section 2 describes existing regulations in Europe and Section 3 the draft sulfur protocol. In Section 4 the method and data to simulate emission trading are clarified. Section 5 gives the simulation results and Section 6 draws the major conclusions.

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[1] This is a slightly revised version of a paper prepared for the conference "Economic Instruments for Air Pollution Control", October 18-20, 1993, IIASA, Laxenburg.

2 Existing Regulations

2.1 The European Community

The European Community's policy to control air pollution takes two forms. First, 'environment action programs' formulate the broad, mid term strategic framework. Secondly, specific measures are adopted as legislation. In the field of air pollution these have usually taken the form of Directives (Bennett, 1991). A Directive being an item of EC legislation, proposed by the European Commission and adopted by the Council of Ministers. It places binding obligations on the member states (Haigh, 1989).

The legislation regarding the control of air pollution falls into the following categories (Bennet, 1991):

1. air quality standards,
2. product standards for fuels
3. product or emission standards for motor vehicles
4. emissions from industrial plants
5. information and monitoring
6. atmospheric change (greenhouse gases and ozone layer).

This section will be confined to product standards for fuels and emissions from industrial plants in as far as they affect sulfur dioxide emissions in Europe. Two types of regulations influence sulfur dioxide emissions substantially: directives regulating the sulfur content in fuels and directives on industrial, in particular large combustion, plants.

The fuel directives regulating the sulfur content of gas oil originate in large part from the concern to prevent barriers in trade caused by different national standards. It was not before the 1980s that environmental considerations came to play a more dominant role (Bennet, 1991). In 1975 a directive was adopted to arrive at reductions in sulfur dioxide emissions caused by gas oil fuels (Johnson and Corcelle, 1989, p.122). Gas oil includes heating oil for domestic, commercial or industrial use as well as diesel fuel (for motor vehicles). The directive stipulates that only two types of gas oil would be allowed in the internal market of the EC: type A low sulfur gas oil (sulfur content below 0.3 per cent as of 1980) and type B with a higher sulfur content to be used in specific zones only. In 1987 a directive was accepted to further reduce the sulfur content in gas oil (Johnson and Corcelle, 1989, p.122). To avoid important specific air quality problems especially in urban centers, the limit value was further reduced to 0.3 per cent sulfur everywhere in each member state. Furthermore, member states were allowed to enforce the use of gas oils with a sulfur content below 0.3 per cent but not below 0.2 per cent. On 23 March 1993 the EC accepted a Directive (93/12/EEC) to further limit the sulfur content in gas oil to 0.2 per cent and if used as diesel oil in vehicles of not more than 0.05 per cent (Dumas, 1993). Background was the wish to further standardize the sulfur content in gas oils, to improve air quality and to improve fuel quality in order to enable further reduction (by means of a catalyst) in exhaust gas emissions from diesel engines. The 0.2 per cent standard has to be met in 1994 and the 0.05 per cent standard in 1996. Greece is granted a derogation. It has to meet the standards ultimately on 31 December 1999.

The directive of 1984 on the combatting of air pollution from industrial plants is a framework directive in the sense that it foresees that specific emission standards are set in subsequent directives (Bennett, 1991). The directive requires that new, or significantly modified, industrial plants are given prior authorization before starting operation. Before issuing authorization the following conditions have to be met:

1. the best available technology not entailing excessive costs (BATNEEC) has to be applied to prevent air pollution;
2. emissions must not cause significant air pollution;
3. emission limit values have to be met and air quality limit values must be taken into account.

The plants covered by the directive are to be found in the following sectors: energy, metal production and processing, non-metallic mineral production, chemicals, waste disposal and paper pulp manufacturing. Eight substances are seen as the most polluting among which sulfur dioxide, nitrogen oxides, asbestos and fluorine. The Council of Ministers is empowered to fix emission limit values on the basis of BATNEEC.

In 1983, the Commission presented a directive proposal on the limitation of emissions of pollutants into the air from large combustion plants (Johnson and Corcelle, 1989). Concern for air pollution and significant forest damage observed in Northern Europe triggered the proposal. The proposal accounted for the different laws already existing (Germany) or about to be accepted (the Netherlands), the associated costs as well as the desire to harmonize national provisions in this area. Initial drafts were modeled on German legislation and included only technology based emission standards, reflecting the German approach to pollution control under the name "Vorsorgeprinzip" or the principle of prevention. This implies the use of the best technology to prevent pollution (Haigh, 1989). Acceptance of the directive implied that, for the first time, the EC fixed common emission standards. When finally adopted in November 1988 (OJ, 1988), the Directive on the limitation of pollutants in the air from large combustion plants, however, consisted of two main elements:

1. emission standards for new, large combustion plants, depending on the size of the plant;
2. emission ceilings or bubbles, limiting the national sulfur- and nitrogen oxides emissions from existing large combustion plants in three phases: 1993, 1998 and 2000.

The emission standards for sulfur dioxide for new, large combustion plants are shown in Figures 1 and 2. The directive applies to combustion plants with a rated heat input greater than 50 MW, irrespective of the type of fuel used. A new plant is a plant for which the operating license was granted on or after 1 July 1987. Figures 1 and 2 show that the standards depend on the type of fuel and the size of the plant. The bigger the size the more stringent the standards. If the standards cannot be met, which is sometimes difficult with indigenous fuels of poor quality, a minimum degree of desulfurization has to be achieved. The standards for the biggest plants (over 500 MWth) can only be achieved by flue gas desulfurization with a removal efficiency of 90 per cent. For the medium size type of plants (100-300) combustion modification, partial application of flue gas desulfurization or low sulfur fuels (for heavy fuel oil) is sufficient. There is only one exception to these emission standards. Up till the end of 1999, Spain may authorize new thermal power plants greater than 500 MWth, which have to meet less stringent standards. In the case of imported solid fuels the emission limit value is only 800 mg/m3 and in the case of indigenous solid fuels at least a 60 per cent (instead of a 90 per cent) desulfurization rate is required (OJ, 1988). Provided, however, that the new capacity does not exceed 2000 MWe (indigenous solid fuels) and 7500 MWe or 50 per cent of all new capacity (whichever is lower) for imported solid fuels.

Table 1 shows the overall emission ceilings for sulfur dioxide for existing large combustion plants. Clearly, emission reductions required from the member states differ considerably, according to their environmental, economic and energy situation. Belgium, France, Germany (West) and the Netherlands are aiming at 40 per cent, 60 per cent and 70 per cent cutbacks while the UK is aiming at 20 per cent, 40 per cent and 60 per cent reductions and Greece, Ireland and Portugal are allowed to increase emissions compared to 1980.

2.2 National legislation

A number of countries in Europe have accepted national legislation to reduce sulfur dioxide emissions (UN/ECE, 1991; UN/ECE, 1987). Chiefly, this legislation consists of emission standards for combustion installations, fuel standards and the regulation of industrial process emissions. In a number of countries (Denmark and the Netherlands), however, the bubble concept is applied to cap the emissions from power plants, and in other countries (Norway and Sweden) sulfur taxes are also being used.

Table 2 gives an overview of the emission standards for combustion plants in place in a number of countries in Europe. Countries that have adopted similar standards as the EC Directive on large combustion plants are not explicitly mentioned unless their standards are more stringent. The table shows that a large number of countries have accepted regulations to limit the emission from combustion. Only a few countries limit these emission standards to new installations. Most countries have set emission standards for both new and existing installations. Existing installations usually have to comply with these standards within a certain period of time (Austria, Germany, CSFR, the Netherlands) and/or are faced with more lenient standards (Austria, Poland). In all but one country (Poland) the emission standards depend on the size of the installation. In comparing the emission standards among different countries, one should be aware of the fact that standards are sometimes set in different units (Sweden, Finland, Poland). They may also differ per coal type (Poland) and conversion of these standards in gram SO_2/m3 flue gas depends on the heat value and the flue gas volume of the fuel under consideration (Vernon, 1988).

Fuel standards are in place in a number of countries as well (Table 3). In various EC-countries the sulfur content in gas oil was already restricted to 0.2 per cent S before acceptance of the comparable EC Directive. Furthermore, a number of countries limited the sulfur content in heavy fuel oil, usually to 1.0 per cent S, and have put an upper limit in the sulfur content in hard coal (0.5-1.0 per cent S).

On top of this, various countries have regulated the non-combustion emissions from industrial processes such as smelters, refineries, iron and steel plants, cement plants, paper mills and gas plants: Austria, Finland, Germany, the Netherlands and Norway (UN/ECE, 1991).

Both the Netherlands and Denmark have set a cap on the total annual emissions from power plants. In the Netherlands the cap is set at 18 kton SO_2 to be attained in the year 2000 (Vlieg, 1993). The cap is agreed upon in a covenant between the state, provincial authorities and the electricity production board (SEP). In Denmark the cap has been set at 125 kton SO_2 to be attained in 1995 and at 85 kiloton for the year 2000 (UN/ECE, 1991).

In Norway and Sweden fuel taxes are being used to promote the use of low sulfur fuels. In Norway the sulfur content in gas oil is less than 0.15 per cent S as a result of the sulfur tax. In the northern parts of Norway, were the maximum allowable sulfur content in fuel oil is 0.25 per cent S, 1 per cent S is used to a greater extent due to the sulfur tax. In the thirteen southern and southwestern countries the maximum allowable sulfur content is 1.0 per cent, in Oslo and Drammen the maximum allowable level is 0.8 per cent S. The tax structure is as follows. There is no tax for sulfur contents below 0.05 per cent. In the range 0.05-0.25 per cent S, the tax is 0.07 NOK (0.01 ECU). For sulfur contents exceeding 0.25 per cent S, there is an additional tax of 0.07 NOK (0.01 ECU) per liter per 0.25 per cent S. For example the sulfur tax for residual oil with 0.95 per cent S is 0.28 NOK (0.03 ECU) liter (Borge, 1992).

In Sweden a sulfur tax came into force in January 1991 corresponding to SEK 30000 per ton of sulfur emitted (3500 ECU per ton). It is imposed on coal, peat and oil. Technically, the sulfur tax takes the form of a fuel tax. There exists also a differentiation in the tax on diesel fuel to stimulate the use of environmentally superior grades of diesel oil. As a result of the taxes diesel fuels with less than 0.01 per cent S have a market share of 10 per cent and diesel fuels with less than 0.05 per cent S a market share of 60 per cent. For heavy fuel oils, the average sulfur content has decreased from 0.65 per cent to 0.4-0.5 per cent S (Bergman et al., 1993).

3 The UN/ECE and the Making of a New Sulfur Protocol

Currently, within the framework of the UN/ECE (the United Nations Economic Commission for Europe) Convention on Long-Range Transboundary Air Pollution, negotiations are in progress on a new protocol to control sulfur dioxide emissions in Europe. The present protocol calls for all signatories to uniformly reduce their SO_2 emissions by 30 per cent compared to the year 1980 by 1993. A major new element of the current negotiations is the intention to apply an effect-oriented approach by basing the extent of emission reductions on the susceptibility of natural ecosystems to acid deposition. Hence, emission reduction strategies should account for the so called 'critical loads': Critical loads being defined as the maximum levels of deposition (sulfur, nitrogen or total acidity) below which, according to current scientific knowledge, no damage to sensitive ecosystems occurs (Hettelingh et al., 1991). The paper restricts calculations to sulfur only. The (net) deposition of base cations may neutralize the acidifying impact of sulfur emissions. A net base cation balance is used to derive so-called critical sulfur deposition values. Critical sulfur deposition values are equal to the critical loads for sulfur corrected for the net base cation balance. Figure 3 displays the map of the 5-percentile values for critical sulfur deposition provided by the Coordination Center for Effects (CCE) at the National Institute of Public Health and Environmental Protection (RIVM), the Netherlands. This is the map being used in the ongoing negotiations. Obviously, the map shows that the sensitivity of soils and ecosystems differs within Europe and highly sensitive areas are to be found especially in Northern Europe.

Since these critical loads are hard to achieve on the short run, compromises have been discussed in the course of the negotiations. A compromise that has been used as the latest (August 1993) reference point accepts that, although critical loads remain the long term objective, the new sulfur protocol makes a gradual move towards these goals only. The difference (the gap) between the sulfur deposition in 1990 and the 5 percentile critical loads (protecting 95 per cent of all ecosystems for excessive sulfur deposition) has to be reduced by at least 60 per cent. In grids where the 1990 deposition was already below the 5 percentile values (especially in parts of Portugal, Spain and Russia), the 5 percentile values were chosen as deposition targets (being the long-term objective). The resulting targets for the deposition of sulfur have to be attained in a cost-effective way minimizing total European costs. This cost minimization takes into account that countries at least will do what they were planning to do anyway: the Current Reduction Plans (CRP). It also accounts for the fact that the sulfur content in the fuel oil used by ships, in the Baltic Sea, the North Sea and the Atlantic Ocean, will not be reduced although this would be cost-effective. The resulting scenario is called A5 and formed the basis for further negotiations (see Amann et al., 1993). Although A5 still serves as reference point, further negotiations assessing the countries' willingness to reduce emissions lead to a provisional schedule for emission ceilings. Main result is that countries, especially in eastern Europe, are allowed to delay their reduction until the year 2010, although some countries will not meet the reductions required under A5 at all.

In addition to the above ceilings, derived from a receptor oriented policy, the second tier of the protocol is formed by a source oriented, preventive approach. More specifically, emission standards and fuel standards are proposed, similar to the ones adopted by the EC, or already adopted by some European countries (Germany, the Netherlands, Austria, Switzerland). Parties are to make use of the best available technologies and control options (not entailing excessive costs) and encourage the use of low sulfur fuels (UN/ECE, 1993). The proposed emission and fuel standards state that:

1. no later than one year after entry into force of the new protocol, countries shall apply emission standards similar to the EC (see Table 4) for all major, stationary sources;
2. no later than five/ten years after entry into force, apply national emission standards (as Table 4) to all major existing combustion sources;
3. no later than two/five years apply standards for the sulfur content of fuels, especially a reduction in the sulfur content of gas oil to 0.2 per cent S but for diesel (for on-road vehicles) to 0.05 per cent S.

Finally, a proposal is included in the draft protocol on joint implementation (UN/ECE, 1993). The proposal states that two or more parties may jointly fulfil the obligations in terms of annual emission ceilings, subject to rules and conditions to be specified, ensuring that the overall environmental objectives are fulfilled and that the calculated environmental improvements for third parties are not compromised.

4 The Trade Simulation: Method and Data

4.1 Introduction

This section describes the method used to simulate emission trading. In addition, data on the costs and transfer coefficients used for the example simulation runs are briefly summarized. Use is made of the optimization module in the RAINS (Regional Acidification INformation and Simulation) model (Alcamo et al., 1990). This model simulates the flow of acidifying pollutants (sulfur and nitrogen species) from source regions in Europe to environmental receptors. The current model (version 6.1) covers 38 source regions in Europe: 26 countries, 7 regions in the former USSR and 5 sea regions (ship emissions). Analysis of deposition is performed for 547 land-based receptor sites with a regular grid size of 150*150 km. First, the control costs options and atmospheric transport data are described. Then the optimization and emission trading method is elucidated.

4.2 Data on costs and atmospheric transport

The RAINS model contains a sub-module to assess the feasibility and costs of alternative emission abatement technologies. The evaluation is based on internationally reported performance and cost data of control devices. Cost estimates for specific technologies are extrapolated by the model to reflect country-specific conditions such as operating hours, boiler size, and fuel price. The following technical options are available:

1. Use of low sulfur fuels and fuel desulfurization. This pertains to the use of fuels with a reduced sulfur content, such as fuels with a lower natural sulfur content or fuels that have undergone a desulfurization process. For low sulfur hard coal, the sulfur content is set at 1.6 per cent. Desulfurization of gas oil and diesel oil can reduce the sulfur content in two steps: down to 0.3 per cent and down to 0.05 per cent. The desulfurization of heavy fuel oil is assumed to be possible up to a level of 0.6 per cent.

2. Desulfurization of flue gases during or after combustion. This set of measures requires investments at the plant site. Three techniques are considered: desulfurization during combustion with removal efficiencies of 50 per cent at relatively low costs, flue gas desulfurization with a removal efficiency of 95 per cent at moderate costs, and the use of

advanced flue gas purification with emission reduction of 98 per cent at high costs.

Not all abatement technologies are applicable for all fuel types and energy sectors. Moreover, a distinction is made between new and existing plants to account for the additional costs of retrofitting existing plants.

For the optimization RAINS creates 'national cost functions' for controlling emissions. National circumstances (such as sulfur content and operating hours) result in variations in the costs for applying the same technology in different countries in Europe. Another difference is the structural variation of energy systems, especially in the amount and structure of energy use, which determines the potential for application of individual control options. One way to combine these factors is to compile national cost functions. These functions display the lowest costs for achieving various emission levels by applying the cost optimal combination of abatement options. The cost curves used in this paper are based on official energy use projections for the year 2000 (Amann et al., 1993).

Source-receptor transfer coefficients, which relate (country) emissions in the diffusion model to deposition at receptor points (for each grid), are based on the acid deposition model developed within the European Monitoring and Evaluation Program (EMEP) (Sandnes and Styve, 1992). The model calculates transboundary fluxes of oxidized sulfur and nitrogen as well as reduced nitrogen (ammonia and its product ammonium). For the trade simulations presented in this paper, EMEP model results have been applied that reflect the meteorological average of the years 1985, 1987, 1988, 1989 and 1990.

4.3 The optimization approach implemented in the RAINS model

The optimization mode of the RAINS model allows the user:

1. to identify the cost-minimal international allocation emission reduction measures to attain a set of deposition levels for each receptor site in Europe;
2. to determine the lowest costs to attain a target level of total European emissions.

The optimization modules formulate possible strategies to minimize the costs of achieving deposition targets at certain receptors as a linear optimization problem that can be solved with LP packages. The cost-effective solution requires that the total costs of emission reductions are minimized, subject to the constraint that the desired depositions are met at every receptor. Cost functions of emission reductions are expressed as piecewise linear curves denoting cost-minimal combination of measures within each country to achieve certain levels of national total emissions. The reduction in each of the segments is limited. Total deposition (wet and dry) at each receptor j is calculated as the sum of the contributions of each source region plus the background deposition using linear source-receptor relationship from region i to receptor j, as based on the atmospheric transport model. The background deposition which is not attributable to specific sources is considered as not reducible. Furthermore, limits or targets can be set on the sulfur deposition for each receptor j (j=1,...,J). Alternatively, so-called policy constraints can be added on the maximum or minimum emissions remaining after abatement in each region i to reflect e.g. abatement devices already in place.

If the objective is the attainment of a certain level of Europe-wide emissions the optimization problem is simpler:

$$Min\ C = \Sigma_i\ C'_{i,l} * R_{i,l} \tag{1}$$

subject to the condition:

$$\Sigma_i\ E_i - \Sigma_i\ \Sigma\ R_{i,l} \leq \Sigma_i\ E_i^{max} \tag{2}$$

With $R_{i,l}$ being the emission reduction in region i at the l th level. E_i are the emissions remaining after abatement. $C'_{i,l}$ are the marginal costs, determined as the slope of the cost curve in region i at level l. Again, the reductions in each of the segments l are limited to the technically feasible reductions (E_i^{max}). The solution to the problem is relatively easy. The segments of all the regional cost curves are ranked according to increasing marginal costs to form the so-called continental cost function. The associated emission reductions of each of the segments are added and subtracted from the unabated emissions. What remains are the total European-wide emissions after abatement. The cost minimum is easily determined since the point is sought where the emissions remaining after abatement equal the desired target. Again one can build in policy constraints on the reductions in some countries. As an alternative one can maximize the volume of emission reduction, given a certain cost budget.

4.4 Simulating emission trading and regulations

The RAINS model allows the user to specify any control strategy in the so-called simulation mode. This option has been used to estimate the emissions and costs of existing and proposed regulations on national emissions. Since the emission standards depend on the size of the installation and on whether the plant is new or existing, assumptions were made on the size distribution of combustion plants and the replacement of old by new plants. The size distribution data is based on CITEPA (1986) and Klaassen et al. (1988). The capacity of new plants is based on Klaassen et al. (1988) and data in the RAINS model.

To clarify how one could combine emission trading and regulations the concept of the national cost function is illustrated. Figure 4 gives an example cost function for Italy for the year 2000. The step function depicts the marginal costs and the other line depicts the total annual costs. The Figure shows that without control SO_2 emissions in Italy would amount to around 3000 kiloton. Applying all emission reduction measures would bring emission to below 500 kilotons at costs of around 5000 million DM/year. This cost function represents what would happen with a perfect emission trading scheme. If one would set a limit of 1000 kiloton on the Italian emissions, a perfect permit market would result in an equilibrium permit price of around 1500 DM/ton SO_2 and reach the cap at minimum costs (around 1000 million DM/year). If one combines regulations with emission trading, part of the abatement options are and remain implemented, irrespective of their costs. This is shown in Figure 5. Figure 5 shows that, given the existing regulation in Italy, emissions would already come down to some 2250 kiloton SO_2. If one would apply a ceiling of 1000 kiloton in this case the market equilibrium price would only be 1000 DM/ton SO_2 and annual costs would be around 500 million DM. To obtain total annual costs we have to add the costs of the existing regulation since part of the abatement options where already taken before.

In this paper this part of the optimization routine was used to simulate the result of a perfectly functioning permit market. In this case the result of emission trading would be equal to the cost minimization option for a given emission ceiling. To simulate the case in which emission trading is combined with regulations the "shrunk" cost functions, with simply less segments or control options, such as the one in Figure 5, have been employed.

5 Simulation Results

Current negotiations on a new sulfur protocol not having reached final agreement yet, this section will assume that countries agree on the national emission ceilings as they have been proposed in August 1993 (UN/ECE, 1993). Calculations in this section are for the year 2000 only. Furthermore, it is assumed that: the protocol will include the envisaged emission standards for new plants, that emission standards for existing standards will not be accepted or their implementation is postponed beyond the year 2000, and that the proposed fuel standards are accepted.

Bearing the above in mind, this section examines the cost-efficiency, environmental impacts and distributional impacts of emission trading in Europe, combined or not combined with existing legislation and the proposed emission and fuel standards in the draft protocol. More specifically the following scenarios are analyzed:

1. The proposed protocol including existing legislation and the proposed standards
2. Trading plus existing legislation and proposed standards to achieve emissions of scenario 1
3. Trading plus existing legislation for emissions of scenario 1
4. Trading for the same emissions as scenario 1
5. Trading plus existing legislation and proposed standards given the same cost as the protocol (scenario 1)
6. Trading plus existing legislation given the same costs as the protocol
7. Trading for the same costs as the protocol.

Scenarios 1 to 4 have one objective in common: A Europe wide emission ceiling of 30063 kiloton SO_2 to be attained in the year 2000. This is the level of emissions that is expected to result from the national ceilings in the protocol proposal plus existing legislation plus the proposed emission and fuel standards. Scenario 1, 5 to 7 have in common that the same budget of 25480 DM/year is spent as under the protocol. The main results of the analysis are presented before the country level details are discussed.

Table 5 shows the main results. The protocol plus existing legislation and the protocol standards would cost 25480 million DM/yr (scenario 1). As a result 84 per cent of all ecosystems would be protected against excessive sulfur loads, above the critical loads. If one would allow emission trading in Europe on top of the existing legislation and the proposed standards (scenario 2) cost savings would be small; only 4 per cent of the costs could be saved. A positive aspect is that the same Europe wide level of ecosystem protection would be achieved. A potential problem is indicated under the heading equity. This column shows the extent to which ecosystem protection in countries is altered, compared to scenario 1. The column shows that for scenario 2 the country with the highest gain in term of ecosystem improvement would see its percentage of ecosystem protection increase by 37 per cent points (e.g from 40 to 77 per cent). The highest loss would be 9 per cent points. Trading on top of the existing legislation only, without the proposed protocol standards (scenario 3), would save more costs (17 per cent compared to scenario 1), would not change the overall percentage of ecosystem protection, and have similar distributional impacts as scenario 2. Allowing one Europe wide trading without the existing legislation could (in theory) result in enormous cost savings, with a perfect market, and bring costs down to only 43 per cent. The price for this is being paid in terms of less ecosystem protection (only 81 per cent) and more equity problems; in this case the biggest loser might be confronted with a loss in ecosystem protection of 27 per cent points. Apparently, there appears to be a trade-off between costs savings on the one hand, and environmental protection and distributional equity on the other hand.

The latter conclusion is only partly true, however, since the potential costs savings of emission trading can also be used to reduce emissions further and to increase ecosystem protection compared to the protocol. This is based on the notion that for the same budget to be spent under the protocol, more emission reduction could be achieved by emission trading. This is shown in Table 5. If the potential cost savings of emission trading would be spent to achieve more emission reduction, emission trading with existing and proposed legislation (scenario 5) could reduce emissions down to 28970 kton, combined with existing regulation (scenario 6) achieves a reduction to 24643 kton and (hypothetical) emission trading only (scenario 7) would even reduce emissions to 17132 kton. As a result, ecosystem protection would also improve to respectively 86 per cent (scenario 5), 87 per cent (scenario 6) and even 90 per cent (scenario 7). In the latter case, however, some countries would be confronted with significant losses in ecosystem protection (up to 14 per cent points) although some might gain considerably (+ 54 per cent point). Overlaying trading on existing legislation (scenario 6) and proposed standards (scenario 5) would minimize these equity problems; expected highest losses in terms of ecosystem protection would be 6 per cent point (scenario 5) or only 3 per cent points (scenario 6). In conclusion, emission trading could be used to increase ecosystem protection without significant negative impacts on the distribution of ecosystem protection.

Before drawing firm conclusions, however, one might as well examine what would exactly happen under the Europe wide trading systems. Which countries would increase emissions and buy permits? Which ones would sell permits and reduce emissions? Which countries would save costs? And what would happen to environmental protection?

Table 6 shows the shifts in emissions that would occur. With scenario 2 trading would be restricted. The most active buyers in this case would be: Belgium, CSFR, Denmark, Finland, FRG-E, Poland and the UK. On the seller side especially Hungary, Romania, Spain, and the Ukraine would reduce emissions further. Under scenario 3 this picture is not drastically altered. On the supply side, some of the Eastern European countries would be more active since the proposed standards would not restrict them in reducing emissions further in a cost-effective way. On the demand side Western European countries would remain just as inactive since the existing legislation in place restricts their demand. Under scenarios 5 and 6, significantly less emission reduction than the sulfur protocol (scenario 1) would take place in Belgium, CSFR, FRG-E and Italy. More reduction would occur in: France, Hungary, Poland, Rumania, Spain, the Ukraine, and Moldavia. Russia, Turkey and the UK would only reduce more under scenario 6. Remarkably, scenario 6 would cut back the protocol emissions down to 24643 kton. This is an additional cut-back of 18 per cent at no extra costs.

Costs in this case consist of two elements: abatement costs and the costs c.q. revenues of buying or selling permits (Table 7). If one would allow trading on top of existing legislation and proposed standards (scenario 2), or existing legislation only (scenario 3), the price of an emission permit is expected to range between 500 and 2200 DM/ton SO_2. The median would be 700 DM/ton SO_2. Taking the median as the equilibrium price of a permit the revenues and costs of buying permits are calculated in Table 7. The Table shows that nearly all countries would save costs but some countries would save more costs than others. Under scenario 2, relatively high cost savings (more than 100 million DM/year) are expected in: Belgium, FRG-E, Romania, and Spain. Some countries would not save costs at all since they would not trade: Bulgaria, France, FRG-W, Luxembourg, Portugal, Switzerland, Turkey (due to the standards), Kola-Karelia and Byelorussia. Under scenario 3 (existing legislation only) cost savings would be high especially in: Belgium, FRG-E, Hungary (net savings), Poland, Romania, Spain, Turkey, Yugoslavia, the Baltic states, Ukraine and Russia.

Table 7 shows what would happen to the costs if emission trading would be used to reduce emission further (scenario 5 and 6). Although total abatement costs would remain the same, the distribution would be altered significantly. Some countries (e.g Hungary, Rumania and Ukraine) would have more abatement costs with emission trading than under the protocol (scenario 1). The eventual costs, however, consist of two items: the abatement costs in sensu stricto and the costs/revenues from buying/selling emission permits. These countries would have to be allocated more emission permits (lower initial ceilings) before trading to give them an incentive to agree to the emission trading scheme. To give an example: Under trading scenario 6, Hungary would reduce emissions to 504 kiloton and the costs would be 397 million DM. Before protocol trading, emission would be 894 kiloton at costs of 186 million DM. Since the equilibrium permit price is around 700 DM/ton $S0_2$, Hungary's initial permit allocation should be 805 kiloton (301 kiloton higher than after trading) to ensure that the expected costs are the same as under the protocol. Clearly, the initial distribution of emission permits has to be used as instrument to induce countries to reduce emissions further than under the protocol.

Table 8 shows that under emission trading (scenario 2 or 3) ecosystem protection would improve significantly in Bulgaria and Hungary. In other countries the improvements would be much smaller or ecosystem protection would generally be reduced slightly. With a few exceptions this is since in some countries ecosystem protection would be reduced by 8 to 9 per cent points (Germany, Denmark). Under trading scenarios 5 and 6 ecosystem protection, generally, would improve compared to the protocol and it would improve considerably in some countries (Hungary and Bulgaria). However, some countries might have less ecosystem protection (Germany and Luxembourg). Under scenario 5 the extent of the losses would be higher since accepting the proposed standards would restrict the additional emission reductions emission trading could achieve. Under scenario 6, the expected losses in ecosystem protection would be small (below 3 per cent points) and most countries would have more protection.

Going back to square one, it is now time to put the pieces together and compare the cost and benefits of emission trading in Europe. Table 9 shows the cost-benefit configuration for scenario 3 (Europe wide trading on top of the existing legislation) and Table 10 for scenario 6 (Europe wide plus existing legislation). Table 9 suggests that some countries (e.g Bulgaria) would have less costs and more ecosystem protection in this schedule. Some have equal protection and equal or less costs (e.g. Albania). Problems occur with countries that have less protection and less costs since these countries might oppose. Most problematic are countries like France that are confronted with equal costs and less protection since they would have nothing to gain. Using emission trading to curb emissions further would be less problematic. Although some countries would have less ecosystem protection (Germany e.g.) the extent would be limited and they would also have less costs. Only one country (Italy) would have less protection and more abatement costs. In this case, however, the initial distribution might be used to compensate Italy for the ecosystem losses. The same applies to Spain and Turkey and possibly France, Poland, Romania, Switzerland, UK and Ukraine.

In summary, using emission trading on top of the existing legislation to curb emissions further seems an attractive possibility to achieve more ecosystem protection. Clearly, however, the initial distribution of emission permits would have to be used to compensate potential losers and to determine which country would have to reduce emissions to what extent on top of the initial protocol proposal.

6 Conclusions and Discussion

The aim of this paper was to examine the costs and environmental impacts of emission trading in Europe in one zone given the emission ceilings and emission and fuel standards proposed for a new sulfur protocol. A new element in the paper was the combination of emission trading in Europe with existing emission and fuel standards and standards proposed in the new sulfur protocol. The results suggest the following conclusions:

1. overlaying emission trading on regulations to achieve the same emission level as the sulfur protocol reduces cost savings but has beneficial impacts as well since average ecosystem protection is not altered;
2. combining trading with regulation, to achieve the same emission level, limits the negative impacts on ecosystem protection but some countries would still have less ecosystem protection than without trading;

3. the cost savings of emission trading can also be used to reduce emissions further and to increase ecosystem protection. If combined with existing legislation, significant negative environmental impacts for countries are then avoided;
4. if trading is used to increase ecosystem protection, the initial distribution of emission reduction has to be used as instrument to redistribute costs to avoid that some countries are confronted with higher costs than under the protocol.

In conclusion, there appears to be a trade-off between the use of emission trading to save costs on the one hand and to increase ecosystem protection and also political acceptability on the other hand.

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Figure 1. EC emission standards for SO_2 for solid fuels

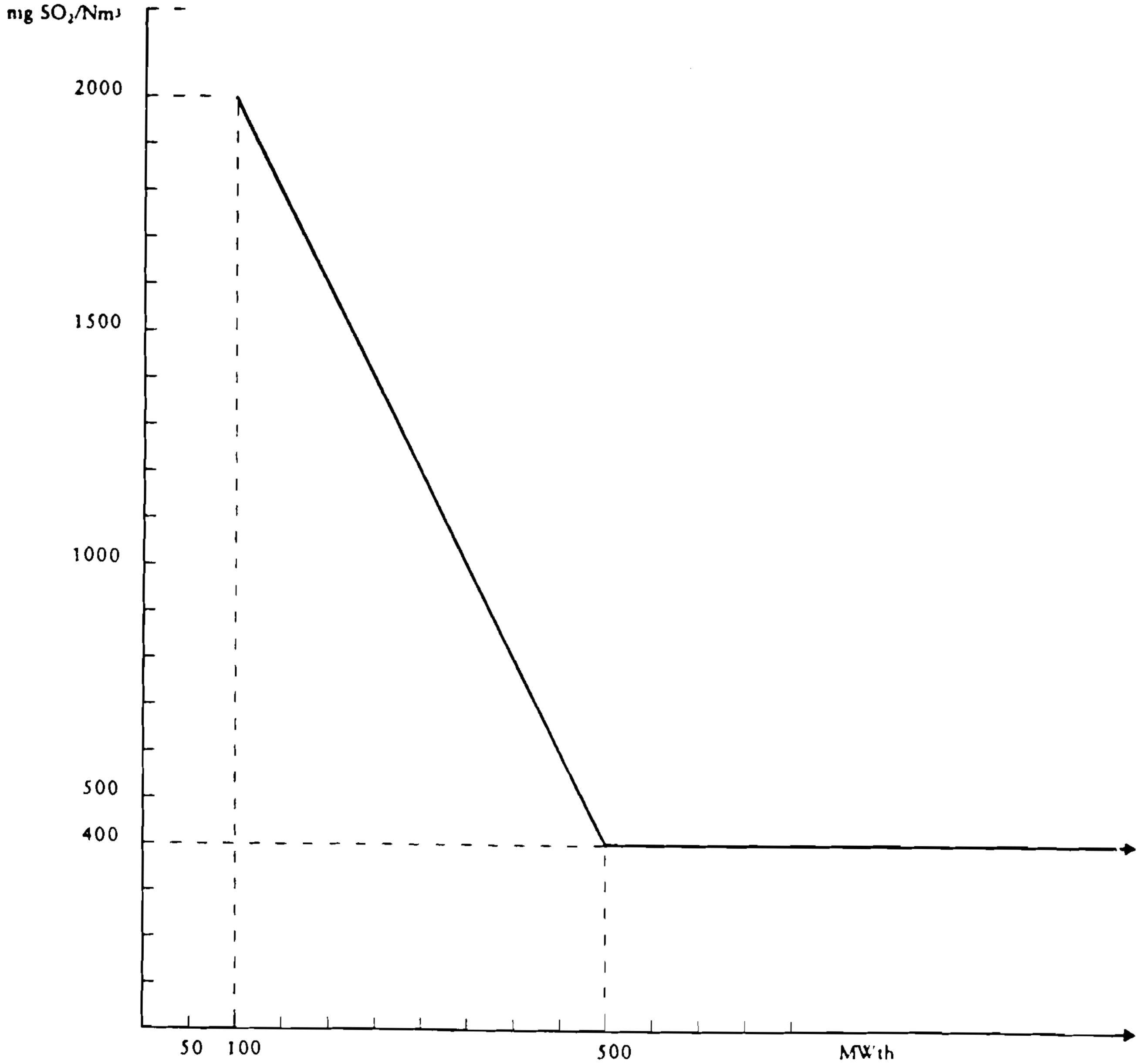

Figure 2. EC emission standards for SO_2 for liquid fuels

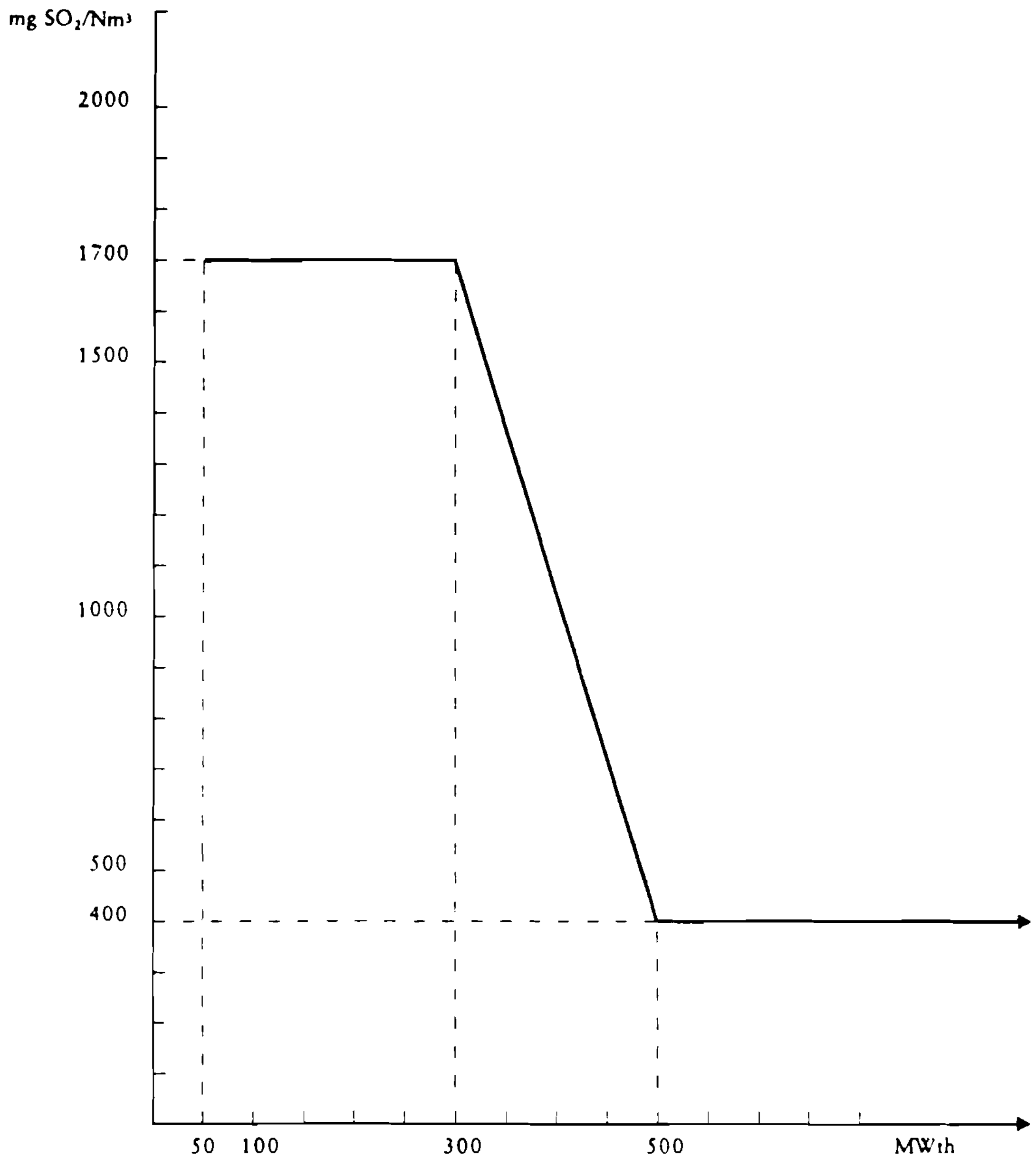

Figure 3. Critical sulfur deposition values (g S/m2/yr)

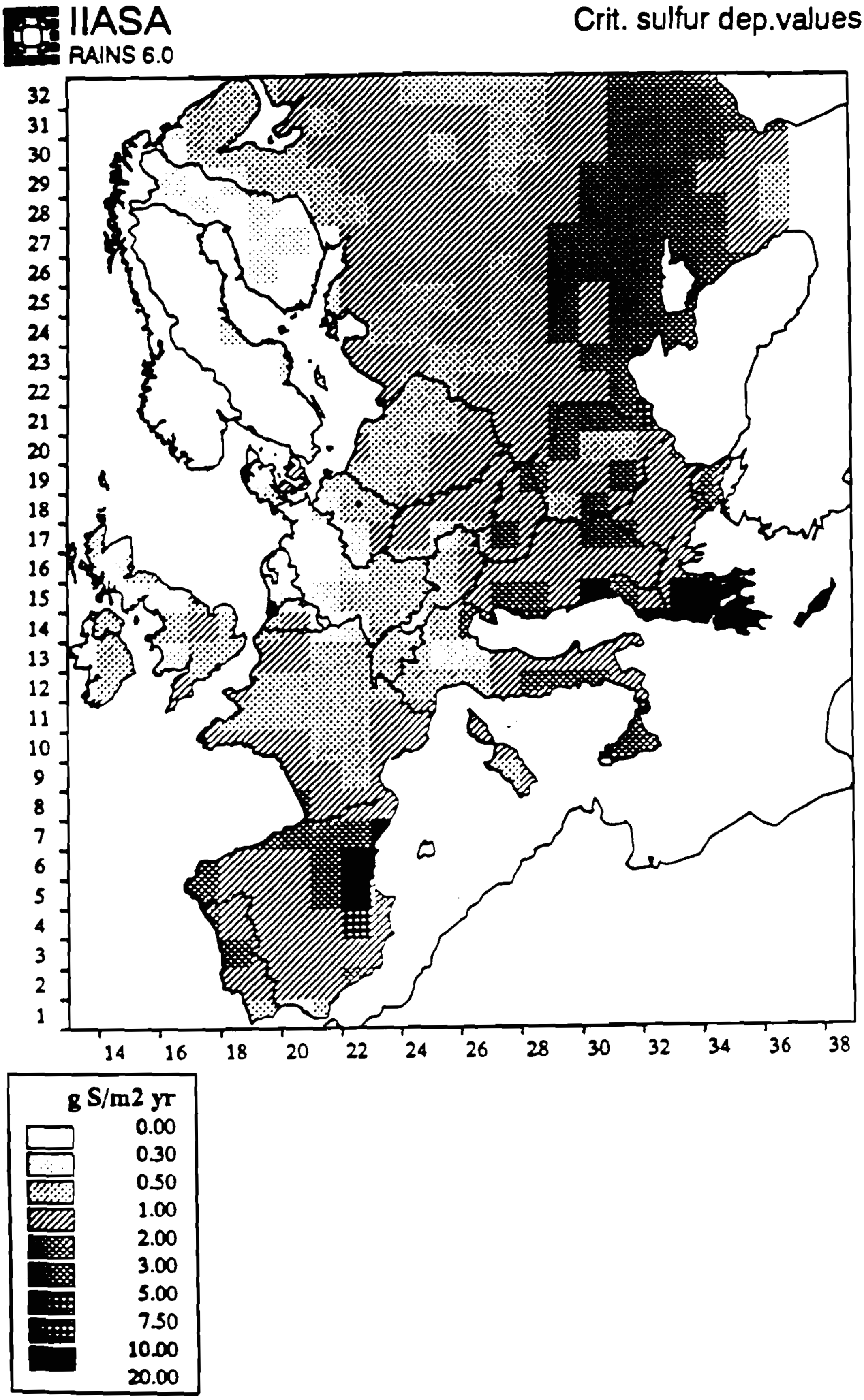

Figure 4. National cost function

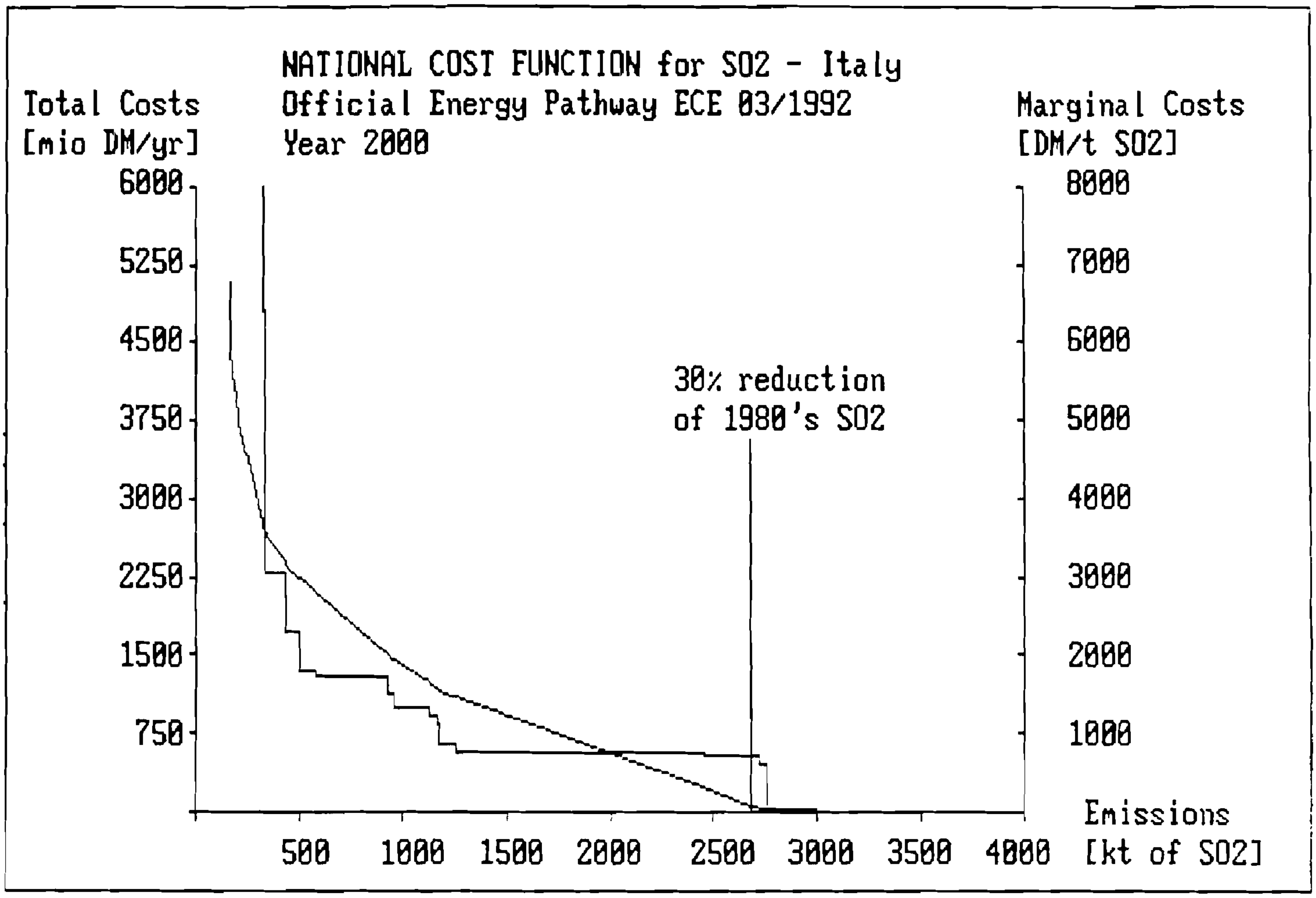

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Figure 5. National cost function on top of existing legislation

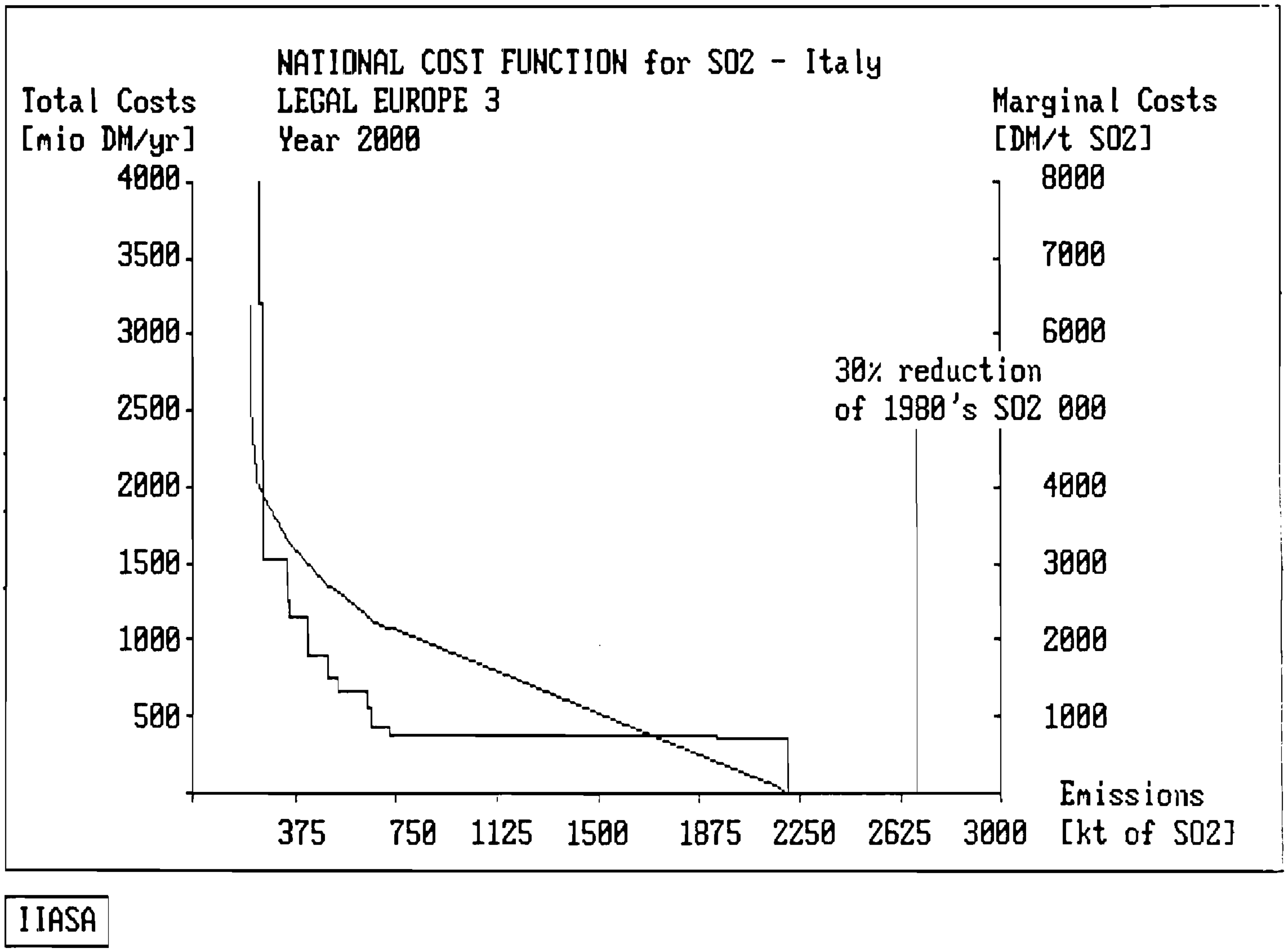

Table 1. EC Emission ceilings for SO_2 for existing large combustion plants (LCP).

Member State	Emission by LCP 1980 (kton)	Emission ceiling (kton/year)			% Reduction over 1980		
		1993	1998	2003	1993	1998	2003
Belgium	530	318	212	159	-40	-60	-70
Denmark	323	213	141	106	-34	-56	-67
Germany	2225	1335	890	668	-40	-60	-70
Greece	303	320	320	320	+6	+6	+6
Spain	2290	2290	1730	1440	0	-24	-37
France	1910	1146	764	573	-40	-60	-70
Ireland	99	124	124	124	+25	+25	+25
Italy	2450	1800	1500	1900	-27	-39	-63
Luxembourg	3	1.8	1.5	1.5	-40	-50	-60
Netherlands	299	180	120	90	-40	-60	-70
Portugal	115	232	270	206	+102	+135	+79
United Kingdom	3883	3106	2330	1553	-20	-40	-60

Table 2. National emission standards (g SO_2/m^3)[a]

Capacity (MWth)	Austria		Belgium	CSFR	Finland	FRG
Solid	New	Exist	New	New/Exist	New [b]	New/exist
<50	0.4	1-2		2.5		2.0
50-100	0.2-0.4	1.0	2.0	1.7	0.65	2.0
100-300	0.2-0.4	0.2-1	1.2	1.7	0.4-0.65	2.0
>300	0.2-0.4	0.2-0.4	0.25-0.4	0.5	0.4	0.4
Liquid					New/exist	New/exist
<50	1.7	1.7		1.7	1.7	1.7
50-100	0.35	1.1	1.7	1.7	1.7	1.7
100-300	0.35	0.35-1.1	1.7	1.7	1.7	1.7
>300	0.2	0.2	0.25-0.4	0.5	1.7	0.4
Capacity (MWth)	Netherlands		Poland[c]		Sweden	Switzerland
Solid	New	Exist	New	Exist	New/exist	New/exist
<50			All sizes 0.6-1.9	All sizes 1.2-4.4 After 1997 0.7-3.0	<400t S/y 0.57; >400t S/y 0.29 (from 1993)	2.0
50-100	0.7	0.8%S				2.0
100-300	0.7	0.8%S				0.4
>300	0.4	0.4				0.4
Liquid					New/exist	New/exist
<50			4.5	4.5	<400tS/y 0.72; >400tS/y 0.36 (from 1993)	1.7
50-100	1.7	1.7	0.6	0.6		1.7
100-300	1.7	1.7	0.6	0.6		0.4
>300	0.4	1.7	0.6	0.6		0.4

a) Conversion factors used for hard coal: 1 mg/Nm3 = 0.35 gr/GJ; for HFO: 1 mg/NM3 = 0.28 gr/GJ.
b) for existing > 200 MWth: 0.65 (230 gr/GJ)
c) standard depends on coal type

References: UN/ECE (1991), Federal Committee for the Environment (1991), Vernon (1988), Cofala (1991), Rentz et al. (1990), MOSZNIL (1990).

Table 3. National fuel standards (% S)

Fuel type	Austria	CSFR	Denmark	Finland	France	FRG	Hungary
Fuel oil							
light	0.15-0.3	2.0	0.2	0.2	0.3	0.2	0.3
medium	0.6	2.2	1				3.5
heavy	1.0	3	1		3		5.5
Solid fuels							
hard coal	0.4-0.6	0.6-1.5	0.9	1			
lignite		0.9-4.1					
	Netherlands	Norway	Portugal	Sweden	Switzerland	USSR	Former Yugoslavia
Fuel oil							
light	0.2	0.2	0.3-1	0.2	0.05	0.5-2	1-1.5
medium	1	0.5	2		1	0.5-3.5	1-3
heavy	1	1	3-3.5		1	0.5-3.5	1-4
Solid fuels							
hard coal	1.2	0.8			0.8		
lignite							

References: UN/ECE (1991), UN/ECE (1987), Federal Committee for the Environment (1991), Vernon (1988), MOSZNIL (1990).

Table 4. Proposed emission standards for sulfur dioxide

Thermal power input	SO_2 Standard (mg/m^3)		
(MWth)	Solids	Liquid	Gaseous
50-100	a)	1700	35
100-300	2400-4x b)	1700	35
300-500	2400-4x b)	3600-6.5x b)	35
>500	400	400	35

a) 2000 suggested.

b) x is the thermal power input. E.g if the thermal power input is 300 MW the standard equals 2400-4.300=1200.

Table 5. Main results

Scenario	1	2	3	4	5	6	7
	Protocol	bubble + legal + standards	bubble + legal	bubble	budget + legal + standards	budget + legal	budget
Emissions (kton)	30063	30063	30063	30063	28970	24643	17132
Annual Costs (10^9 DM)	25.5	24.3	21.2	10.9	25.5	25.5	25.5
Annual Costs (%)	100	96	83	43	100	100	100
Ecosystem protection (%)	84	84	84	81	86	87	90
Equity (% eco + / %eco-)	0/0	+37/-9	+37/-9	+36/-27	+37/-6	+40/-3	+54/-14

Table 6. Emissions

	EMISSIONS (kton SO_2)				
Scenario	1	2	3	5	6
Country	Protocol	bubble+ legal+ standards	bubble + legal	budget+ legal+ standards	budget+ legal
Albania	128	129	132	129	124
Austria	78	81	81	81	81
Belgium	248	584	584	584	540
Bulgaria	747	747	794	747	776
CSFR	1465	1748	1768	1713	1706
Denmark	112	164	164	164	164
Finland	116	165	179	165	179
France	1127	1127	1127	1054	1054
FRG, West	612	612	612	612	591
FRG, East	280	497	497	497	456
Greece	595	687	687	687	676
Hungary	894	504	521	504	521
Ireland	166	187	187	187	186
Italy	1976	2242	2242	2242	1313
Luxembourg	10	10	10	10	10
Netherlands	106	120	120	120	120
Norway	34	84	84	84	84
Poland	2583	2774	2807	2060	2093
Portugal	294	308	308	308	296
Romania	2463	1095	1128	1095	1128
Spain	2153	1614	1614	1614	1614
Sweden	100	160	160	160	160
Switzerland	60	61	61	61	52
Turkey	2642	2642	2752	2642	1605
UK	2449	2827	2827	2459	1548
Yugoslavia	1374	1479	1498	1452	1498
Kola-Karelia	396	536	478	466	478
St. Petersburg	301	302	319	302	239
Baltic[2]	435	577	502	478	502
Belarus	456	509	542	477	478
Ukraine	1696	998	804	998	804
Moldavia	231	341	161	91	100
Russia[1]	3736	4162	4324	4162	2902
EUROPE	30063	30063	30063	28970	24643

Notes:

[1] Russian Federation within the EMEP area, Kola-Karelia, St. Petersburg and Kaliningrad regions excluded.

[2] Includes Estonia, Latvia, Lithuania and Kaliningrad (part of Russian Federation).

Table 7. Abatement and permit costs

	COSTS				
Scenario	1	2	3	5	6[3]
Country	Protocol	bubble+ legal+ standards	bubble+ legal	budget+ legal+ standards	budget+ legal
Albania	15	15	3	15	6
Austria	602	598	598	596	596
Belgium	787	638	638	505	434
Bulgaria	166	166	33	166	13
CSFR	822	789	774	615	515
Denmark	517	510	510	472	474
Finland	694	667	558	633	514
France	707	707	707	790	759
FRG, West	4419	4419	4419	4384	4434
FRG, East	1814	1645	1645	1494	1523
Greece	381	381	381	313	317
Hungary	186	106	-94	397	279
Ireland	136	133	133	126	119
Italy	1697	1673	1673	1495	2150
Luxembourg	18	18	18	13	18
Netherlands	809	806	806	798	796
Norway	278	200	200	165	165
Poland	1358	1358	1105	1715	1433
Portugal	223	222	222	210	221
Romania	215	-18	-195	940	740
Spain	1044	831	831	1262	1209
Sweden	608	512	512	470	470
Switzerland	109	109	109	109	115
Turkey	787	787	80	787	834
UK	1569	1561	1561	1543	2210
Yugoslavia	299	279	113	223	26
Kola-Karelia	270	270	212	64	155
St. Petersburg	105	105	13	105	58
Baltic[2]	262	252	114	219	67
Belarus	207	207	63	192	46
Ukraine	2262	2257	2027	2746	2651
Moldavia	149	149	89	245	179
Russia[1]	1954	1948	1301	1650	1946
EUROPE	25480	24338	21174	25480	25480

Notes:

[1] Russian Federation within the EMEP area, Kola-Karelia, St. Petersburg and Kaliningrad regions excluded.

[2] Includes Estonia, Latvia, Lithuania and Kaliningrad (part of Russian Federation).

[3] Abatement costs only.

Table 8. Environmental protection

	ECOSYSTEM PROTECTION (%)				
Scenario	1	2	3	5	6
Country	Protocol	bubble+ legal+ standards	bubble+ legal	budget+ legal+ standards	budget +legal
Albania	100	100	100	0	0
Austria	73	67	67	67	74
Belgium	8	6	6	6	6
Bulgaria	45	82	82	82	82
CSFR	29	30	30	33	33
Denmark	77	68	68	74	77
Finland	91	87	87	89	89
France	91	89	89	92	93
FRG, West	48	40	40	43	45
FRG, East	48	40	40	43	45
Greece	99	99	99	99	99
Hungary	53	82	82	83	83
Ireland	95	92	92	94	94
Italy	78	76	76	76	87
Luxembourg	20	15	15	15	20
Netherlands	24	21	21	21	24
Norway	70	66	66	68	70
Poland	30	27	27	34	35
Portugal	98	98	98	98	98
Romania	85	92	91	91	91
Spain	98	98	98	98	98
Sweden	85	79	79	81	83
Switzerland	72	70	70	71	77
Turkey	99	99	99	99	99
UK	79	71	71	79	85
Yugoslavia	89	89	89	89	90
Kola-Karelia	97	97	98	99	99
St. Petersburg	97	97	98	99	99
Baltic[2)]	93	85	87	94	94
Belarus	97	97	97	99	99
Ukraine	97	97	98	99	99
Moldavia	97	97	98	99	99
Russia[1)]	97	97	98	99	99
EUROPE	84	84	84	86	87

Notes:

[1)] Russian Federation within the EMEP area, Kola-Karelia, St. Petersburg and Kaliningrad regions excluded.

[2)] Includes Estonia, Latvia, Lithuania and Kaliningrad (part of Russian Federation).

Table 9. Cost/benefit configuration Europe wide trading plus existing regulations from same emissions (scenario 3)

		Costs	
		less	equal
Ecosystem Protection	more	Bulgaria, CSFR, Hungary, Romania, Russia[1], Ukraine	
	equal	Albania, Belarus, Spain, Yugoslavia, Turkey	Greece, Moldavia, Portugal
	less	Austria, Baltic, Belgium, Denmark, Finland, Germany, Ireland, Italy, Netherlands, Norway, Poland, Sweden, UK	France, Luxembourg, Switzerland

1) Includes St. Petersburg and Kola-Karelia.

Table 10. Cost/benefit configuration Europe wide trading plus existing and proposed regulations from same budget (scenario 6)

		Costs		
		less	equal	more
Ecosystem Protection	more	Baltic, CSFR, Hungary, Yugoslavia, Russia	Austria, Bulgaria	France, Poland, Romania, Switzerland, UK, Ukraine
	equal	Netherlands	Denmark, Greece, Luxembourg, Portugal	Spain, Turkey
	less	Belgium, Finland, Germany, Ireland, Norway, Sweden		Italy

1) Includes St. Petersburg and Kola-Karelia.