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Item 2 of the provisional agenda

INTEGRATED ASSESSMENT MODELLING

Progress report by the Chairman of the Task Force

Introduction

1. This report presents the results of the sensitivity analysis for the guiding scenario for the multi-pollutant, multi-effect protocol, including the results of the twenty-third meeting of the Task Force on Integrated Assessment Modelling, held in Les Diablerets (Switzerland) from 10 to 12 March 1999. Experts from Austria, Belgium, the Czech Republic, Denmark, Finland, France, Germany, Italy, the Netherlands, Norway, Poland, Spain, Sweden, Switzerland, the United Kingdom and the European Community (EC) participated in the meeting. Representatives from the Coordination Center for Effects (CCE) and the European Environment Agency, as well as from the International Institute for Applied Systems Analysis (IIASA), the International Union of Producers and Distributors of Electrical Energy (UNIPEDE), the Oil Companies' European Organization for Environmental and Health Protection (CONCAWE) and the World Conservation Union (IUCN) were also present. Mr. Rob MAAS (Netherlands) chaired the meeting.

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2. At its twenty-eighth session, the Working Group on Strategies requested the Task Force to examine the uncertainties in the data used for modelling and analyse the sensitivity of the guiding scenario (EB.AIR/WG.5/58, para. 15(h)). This report summarizes work done at IIASA and Imperial College (London) in response to this request. The work by IIASA was made possible through funding from France and the Netherlands. The report also summarizes a number of contributions by national experts discussed by the Task Force. The reports and notes presented that were electronically available to the secretariat can be obtained via the Internet (www.unece.org/env/tfiam).

I. SENSITIVITY ANALYSIS

A. Changes to the input data

3. The previous report on integrated assessment modelling (EB.AIR/WG.5/1998/3 and Add.1) presented an overview of the basic assumptions and data used for modelling and described some of the fundamental scenarios, such as the reference (REF) scenario and the maximum feasible reduction (MFR) scenario, as well as a range of optimized scenarios. Such a detailed description is not repeated in this report.

4. Since the previous report, the following changes have been made to the input data used for the IIASA RAINS model:

- Change for the member States of the European Community to reflect Directive 98/70/EC, adopted by the European Parliament and the Council on 13 October 1998, relating to the quality of petrol and diesel and amending Council Directive 93/12/EEC (OJ, 1998);

- Change for the member States of the European Community to reflect Directive 98/69/EC, adopted by the European Parliament and the Council on 13 October 1998, relating to measures to be taken against air pollution from motor vehicles and amending Council Directive 70/220/EEC (OJ, 1998);

- Implementation for the member States of the European Community of standards for heavy-duty vehicles for the period after 2005 in the REF scenario reflecting the common position reached in December 1998 by the European Parliament and the Council on amending Directive 88/77/EEC (on the approximation of laws of the EC member states relating to the measures to be taken against the emissions of gaseous and particulate pollutants from diesel engines for use in vehicles). For the REF scenario, the stricter standards were implemented in two stages (2005/2006 and 2008/2009), and the removal efficiencies have been changed according to the standards in the above document;

- Change for the member States of the European Community to limit the sulphur content of gas oil for stationary sources to 0.1% (Directive on sulphur in liquid fuels);

- Updates of the current reduction plans according to recent information provided to the secretariat by December 1998;

- Based on detailed discussion with French experts, a revision of the emission factors for France for off-road sources and maritime activities (seagoing ships) for 2010;

- Modifications to the VOC databases for France, Germany, Ireland, Sweden and the United Kingdom taking into account the latest national information.

These changes, in particular the incorporation of the recent traffic-related decisions, lead generally to lower NO_x emissions for the REF scenario, but, due to the later implementation date, they reduce the overall NO_x reduction potential in the year 2010.

5. The work by Imperial College uses the Abatement Strategies Assessment Model (ASAM), which is an integrated assessment model focusing on acidification and eutrophication. It was updated in December 1998 to incorporate the most recent cost curves developed by IIASA and changes in emission data.

B. The revised G5/2 scenario

6. At its twenty-eighth session, the Working Group on Strategies decided to adopt scenario G5/2 as a guiding scenario, on the understanding that this decision did not bind the Parties to the ambition level or the level of emission ceilings to be set in the protocol (EB.AIR/WG.5/58, para. 17 (a)). Scenario G5/2 has the following environmental targets:

Acidification	
Gap closure on accumulated excess acidity	95%
Gap closure on accumulated excess acidity for some grid cells in southern Norway	85%
Health-related ozone	
Gap closure on AOT60	67%
Maximum AOT60, to be achieved in four out of five years	2.9 ppm.h
Vegetation-related ozone	
Gap closure on AOT40	33%
Maximum excess AOT40, mean over five years	10 ppm.h
Eutrophication	
Gap closure on accumulated excess nitrogen deposition	60%

7. IIASA repeated the optimization for the G5/2 scenario using the most recent data incorporating changes described in section A above. The results are presented in tables 1-8.

C. Assessment of uncertainties

8. As requested by the Working Group on Strategies (EB.AIR/WG.5/58, para. 15(h)), collaboration with the Chairman of the Working Group on Effects, the Meteorological Synthesizing Centre-West of EMEP, the Chairman of the Working Group on Abatement Techniques and the Chairman of the Task Force on Emission Inventories. While this work continues, some preliminary findings can already be presented.

9. Uncertainties exist in almost all parts of the model framework, including in the emission inventories, the estimates of emission control potentials, the atmospheric dispersion calculations and in the estimate of environmental sensitivities. However, a systematic analysis of the importance of these

uncertainties requires a full quantification of the uncertainties of all the input data. At present, such information is not available for most of the input elements of the model. In addition, the modelling work for a full uncertainty analysis would require many years just for computing. Consequently, an overall uncertainty analysis can only explore the theoretical influence of the individual uncertainties on the final model output, without actually quantifying the importance of the individual elements and the confidence range of model results.

10. It is useful to distinguish between symmetric uncertainties and specific biases in the data and model assumptions. If the probability distribution of input data is symmetric around the central value, then the output variable is also likely to be in the centre of the distribution. This may not apply to ozone modelling due to the non-linearities involved. An exact quantification of the confidence intervals cannot be provided without a time-consuming and resource-intensive uncertainty analysis and such a quantified uncertainty band around a central value may only be of limited use to negotiators.

11. This does not hold, however, in case of unsymmetrical probability distributions, i.e. if estimates are associated with a systematic bias. In such a case, a bias might feed through the entire chain from environmental targets via dispersion calculations to emission control potentials and costs, so that the optimization result might also be biased. Many of these biases point in one direction and indicate that the emission reductions calculated by the RAINS model are at the minimum level required to really meet the environmental targets. A more conservative approach would then call for stricter measures, but it is also possible to conclude that none of the measures taken on the basis of the scenario is likely to turn out as being unnecessary for reducing the environmental effects in a cost-effective manner.

12. Some of these potential biases are:

- The steady-state approach for estimating critical loads may overestimate the current impacts when compared with a dynamic analysis. However, recovery of ecosystems may be slow when excess deposition is removed;

- The spatial scale of critical load mapping influences the distribution of critical load estimates. Higher spatial resolution captures smaller ecosystems with extreme (low or high) sensitivities, which are not considered if the analysis is done on a highly aggregated level. As a consequence, higher spatial resolution of the mapping exercise decreases the critical loads of the low percentiles and increases the critical loads for the high percentiles, if compared to a more aggregated analysis;

- A similar effect occurs for the atmospheric dispersion calculations, which are at present carried out with a 150 km x 150 km resolution. The atmospheric models try to capture the average conditions for each grid, which implies that there are some areas with a lower deposition, but also some areas with a higher deposition than predicted by the model. For ground-level ozone, the EMEP model is designed to estimate rural ozone concentrations. It is clear from the model design that it necessarily overestimates ozone concentrations in city centres, but at the same time it systematically underestimates ozone levels in the suburbs. A finer resolution of the atmospheric calculations would yield certain areas with higher ozone than currently estimated;

- Furthermore, the model calculations presented in this report assume a constant level of background concentration originating from hemispheric scale emissions. The analysis ignores the hemispheric feedback of European emission reductions on background concentrations in Europe, but perhaps more important, it also ignores the potential for large increases in emissions, for instance, in south-east Asia;

- There is also a demonstrated bias in the estimates of the emission control potentials and costs. Numerous studies show that excluding non-technical measures and the possibility for technological progress from the analysis underestimates the existing reduction potential and systematically overestimates the costs. This phenomenon is also confirmed by the results of the work done by the French-German Institute for Environmental Research (IFARE) to calculate VOC abatement costs for France and Germany (see para. 54 below)).

13. In the modelling work, several measures were taken to limit the influence of the most uncertain model elements in the optimization results. The environmental targets were selected in such a way that the confidence ranges in model performance were taken into account. Furthermore, extreme values in critical load estimates (the very low percentiles) were disregarded when setting the environmental targets, and the revised cost-curve routine excludes measures with questionable cost-effectiveness (e.g. retrofits of already controlled plants).

14. A note presented by an expert from Belgium highlighted a potential bias towards higher emission reduction requirements in smaller countries in the optimization. At the same time there is a potential bias that may increase the reduction requirements calculated by the model for large countries, as measures that are local for certain border areas may lead to calculated reductions for the whole country, because the emission patterns within a country cannot be changed in the current model methodology.

15. An expert from France presented a note on the uncertainty of the RAINS model results calling for caution in its use. The uncertainties identified included the lack of dynamic elements, such as structural and technological change in the cost functions, differences in observed and modelled ozone exposure, differences in atmospheric modelling between the Lagrangian and the Eulerian models, and differences in methodologies used in different countries for assessing critical loads. Model biases were also considered to result from the chosen spatial distribution. While the expert regarded it enlightening to study the outcome of simulations using the RAINS model, he expressed doubts about the use of optimization results. In particular, in view of the uncertainties, he criticized the choice of gap closure targets at the country level, which he considered arbitrary and too stringent to leave any reasonable room for variations. He emphasized that uncertainties should be clearly communicated when presenting model results.

16. Several experts disagreed with the assessment by the expert from France and noted that some of the evidence presented relied on outdated information. Given the political agreement to follow an effects-based approach and aim for the achievement of critical loads and levels, the model provided the best basis possible, in view of present scientific knowledge, to set emission reductions for a stepwise approach towards the ultimate targets. Any policy decision taken now on the basis of the modelling work should be reviewed

within the next five years or so, but uncertainties should not be used to postpone necessary measures.

D. Sensitivity to changes in the energy scenario

17. The level and the composition of energy use are important parameters determining the internationally optimized allocation of emission reductions. In this context, the results of negotiations concerning emissions of CO2 as laid down in the Kyoto Protocol have particular relevance. They will lead to modifications to the 'business as usual' energy policies. Energy projections underlying the G5/2 scenario fail by far to meet the Kyoto targets.

18. Since the RAINS model is not an energy model, it cannot provide the realistic or desirable energy strategies to meet the Kyoto targets, but has to rely on exogenous energy pathways. There are a number of alternative energy projections implemented in the RAINS database that could be used for such an analysis:

- The 'Official Energy Pathway' as reported in the UN/ECE database;

- For all EC member countries, the 'Business as usual' energy scenario of the European Commission (DG XVII);

- Also for the EC countries, the 'Low CO_2' energy scenario derived from an earlier DG XVII scenario;

- For ten Parties, the national energy scenarios submitted for the purpose of modelling;

- For three Parties, 'Energy efficiency' scenarios; and

- For countries in central and eastern Europe, the 'Economic and Environmental Convergence' scenario developed by IIASA for a study for the European Environment Agency.

19. To conduct a provisional assessment of the possible impact of the Kyoto Protocol agreed in December 1997, an illustrative 'post-Kyoto scenario' (scenario J2) has been compiled on the basis of these data. For the EC member States, this was done by selecting for each country, out of the available energy scenarios, the projection which in terms of CO_2 emissions comes the closest (but is not always identical) to the targets agreed by the EC Council in June 1998. For the other countries (except Norway and Switzerland), an illustrative 'post-Kyoto' scenario was derived from the IIASA study.

20. The scenario assumes that the reductions for the three greenhouse gases would also hold for CO_2 emissions alone. Obviously, such an approach is not necessarily cost-effective, and countries might actually implement the Kyoto Protocol in different ways. The scenario can thus give only a rough indication of the possible impact of the Kyoto Protocol on the G5/2 scenario.

21. The results of the analysis are presented in the summary tables 1-8. Most striking is that the total emission control costs decline from 8.5 to 4.8 billion euros per year, i.e. by about 45%. Due to the less carbon-intensive energy structure of the post-Kyoto case, 60% less would be spent on SO_2 control, 44% less on NO_x and VOC reductions, and also the most expensive

ammonia measures would not be necessary, so that in the agricultural sector control costs would also be 35% lower. For Europe as a whole, the remaining SO_2 emissions optimized for the post-Kyoto energy scenario are 3% lower than the G5/2 level, NO_x emissions 6% lower, VOC emissions 2% lower and ammonia emissions 2% higher. Due to the preliminary structure of the illustrative post-Kyoto energy projection, no firm conclusions about results for individual countries can be drawn. However, it is interesting to note that there are some cases where a low CO_2 energy strategy emphasizing the use of renewable energy, such as wood burning, may result in higher VOC emissions.

22. A further sensitivity analysis was carried out to examine the effects of higher SO_2 emissions on the optimized allocation of emission reductions (scenario J3). Higher SO_2 emissions could result from higher combustion of sulphur-containing fuels than foreseen in the baseline energy projection (although this would widen the gap with the Kyoto target), or from less efficient emission controls for SO_2 emissions than applied in the RAINS analysis. The sensitivity study applied for all countries modified sulphur abatement cost curves, which were derived by scaling up the costs by a factor of 1.05, so that both the REF and the MFR levels would be 5% higher than in the original case.

23. The optimization results, presented in tables 1-8, show that there would be only little impact on optimized emission levels. For the EC countries, overall SO_2 reductions would be relieved by about 1%, compensated to some extent by slightly higher reductions in non-EC countries, where a potential for less expensive measures remains. Changes for other pollutants are very small. It is in the nature of the set-up of this scenario that costs for SO_2 control would be higher than in G5/2.

E. <u>Sensitivity to changes in the agricultural scenario</u>

24. Agricultural policy has important implications for the achievement of the environmental targets of the G5/2 scenario. For the analysis of the potential impacts of such policies and of the uncertainties associated with the forecasts of livestock, a 'low NH_3' scenario was developed (scenario J4). This illustrative scenario is based on the simple assumption that, across all countries and all animal categories, the total livestock numbers would be 10% lower than in the baseline forecast. Due to differences in livestock composition and emission factors among countries, total ammonia emissions would decline between 7 and 9%. This ‘low NH_3' scenario has not been based on reviewed data and serves only as a tool for the sensitivity analysis.

25. The optimization (see tables 1-8) shows a response similar to the 'post-Kyoto’ (in this specific case -27%), with cost savings for all pollutants. Costs for ammonia control are cut by about 50%, and for SO_2 and NO_x/VOC control by 14 and 12%, respectively.

26. A further sensitivity analysis explores the response to higher NH_3 emissions, caused either by larger livestock numbers than assumed for the G5/2 scenario, or by less efficient emission control options (scenario J5). As in the ‘high sulphur’ case (J3), the ammonia cost curves were scaled up by 5% for all countries.

27. The basic conclusions drawn from the high SO_2 case also hold for a high NH_3 situation (see tables 1-8). Despite the higher costs implied by the

modified cost curves, NH_3 emissions for all of Europe increase by only 56 kt or 0.74%, which is compensated by minor additional reductions in SO_2 and NO_x.

28. Imperial College also performed a sensitivity analysis to examine the robustness of optimal NO_x and sulphur abatement strategies to uncertainties concerning ammonia emissions, in particular uncertainties in the emission estimates, in the future development of agriculture and the possible influence of a reform of the EC common agricultural policy, and the effectiveness of ammonia abatement measures. These uncertainties were examined using the Model for the Assessment of Regional Ammonia Cost Curves for Abatement Strategies (MARACCAS), developed at Imperial College.

29. Taking the REF scenario as an upper limit for future ammonia emissions, and a scenario with the implementation of the most efficient ammonia abatement measures in all countries as a 'low NH_3', ASAM was applied to derive the optimal abatement strategy for a certain investment (4 billion euros per year) to reduce NO_x and sulphur emissions. The pattern of NO_x reductions was found to be very robust to such large changes in ammonia emissions and depositions. This also held for countries with large ammonia abatement, such as Germany and the Netherlands. Generally, larger sulphur emission reductions are required when less ammonia is abated.

F. <u>Uniform emission reduction scenarios</u>

30. The Task Force has shown in many examples that cost-effectiveness implies differentiated requirements for emission reductions, taking into account regional differences in environmental sensitivities, differences in the potential for and the cost of further emission controls, and in meteorological conditions. The variations of these factors in Europe imply, however, that the burden of additional emission control measures imposed by least-cost strategies on individual countries might be quite different. In order to illustrate the gains in cost-effectiveness achieved by the optimization approach for the G5/2 scenario, two alternative scenarios are constructed:

(a) Scenario J7 constructs a 'flat-rate' emission control scenario in which the average reduction rates for the four pollutants of the revised G5/2 scenario are applied uniformly to all countries;

(b) Scenario J11 is a 'flat-rate' per capita emission scenario in which the average per capita emission rates for the four pollutants of the revised G5/2 scenario are applied uniformly.

31. The rationale for the illustrative 'flat-rate' J7 scenario is to fix - as far as possible - each country's emissions to the value corresponding to the average percentage reduction across all countries for the G5/2 scenario. The average reductions compared to the 1990 emission levels for each pollutant for the G5/2 scenario are:

Sulphur	-73%
NO_x	-45%
VOC	-45%
NH_3	-24%

For some combinations of countries or pollutants the average emission reduction would lead to emission values that lie outside the range available for control. In such cases the emissions for this sensitivity scenario were set to the relevant bound, i.e. the maximum feasible reduction (MFR) or the REF level, as appropriate.

32. In scenario J11, each country's emissions are fixed - as far as possible - to the value corresponding to the average per capita emission rates for the G5/2 scenario. These average per capita emission rates are:

Sulphur	15.5 kg/capita/year
NO_x	19.1 kg/capita/year
VOC	18.3 kg/capita/year
NH_3	8.5 kg/capita/year

As in scenario J7, for some countries or pollutants these rates would lead to emission values that lie outside the range available for control options and the MFR or REF emission level was used, as appropriate.

33. The emissions, costs and exposure indices obtained for the non-optimized flat-rate J7 and J11 scenarios are summarized in tables 9-16. Compared to the revised G5/2 scenario, the flat-rate per capita J11 scenario would require increased control measures in most non-EC countries, as well as in Denmark, Finland, France, Greece, Ireland, Luxembourg, Spain and Sweden. Austria, Belgium, Croatia, Germany, Hungary, Italy, Netherlands, Portugal and Yugoslavia would enjoy reduced emission control costs. For Europe as a whole, the flat-rate per capita J11 scenario would cost 6.4 billion euros more than the revised G5/2 scenario, which is an increase of 76%.

34. Increased exposure to ozone throughout Europe would result from the J11 scenario. The area unprotected against acidification generally increases within the EC, while there would be some improvements in parts of eastern Europe. Health-related ozone exposure, in terms of the cumulative population exposure index, would increase by 32%, particularly in the high-ozone area of Belgium, France, Germany, the Netherlands and the United Kingdom. For vegetation-related ozone exposure, the largest increases would be found in France, Germany and Italy (in that order). For acidification, 4.3 instead of 3.5 million hectares in the EC countries would remain unprotected (an increase of 23%), while additional measures in the eastern part of Europe would achieve some additional environmental benefits there. On the whole, the flat-rate per capita emission reductions of the J11 scenario would result in a significantly lower cost-effectiveness for vegetation- and health-related ozone exposure.

G. <u>Limiting marginal abatement costs</u>

35. There are concerns regarding the high marginal abatement costs resulting for some countries from the G5/2 scenario. An expert from Belgium drew attention to the large dispersion in marginal reduction costs between countries indicating that, in some extreme cases, these marginal costs might exceed the marginal benefits. Such unacceptable situations could be avoided by setting an upper bound on the marginal reduction costs of measures chosen by the model for the optimal solution.

36. Several experts noted that the benefit assessment conducted by the Task Force on Economic Aspects of Abatement Strategies (EB.AIR/WG.5/1998/4/Add.1) did not make it possible to determine whether marginal costs exceeded marginal benefits or not. It is, therefore, not possible to determine the optimal ambition level through modelling work. The benefit analysis conducted leaves

out many damage categories and follows a scenario approach that shows that total benefits for the whole of Europe exceeded total costs. For some countries the situation may be different due to the transboundary impact of pollution.

37. At the previous Task Force meeting, CONCAWE had presented the results of some sensitivity analysis covering the EC countries and relating to acidification using a method which capped the national marginal cost curves (EB.AIR/WG.5/1998/3/Add.1, para. 40). The Task Force had agreed to examine such scenarios further.

38. The approach chosen for integrated assessment modelling, which was endorsed by the Working Group on Strategies, is that of cost-effectiveness analysis. The integrated assessment model determines the least-cost abatement strategy for Europe to ensure that a given set of environmental targets is met everywhere. Under such an approach the marginal costs for different countries and emission sources at different locations in Europe should differ in an abatement strategy that is optimal for Europe. The optimal differences in marginal costs reflect the different impacts that emissions from various parts of Europe have on human health and the environment. The model will choose more expensive measures for sources whose emissions have greater adverse effects than for sources that contribute less to environmental impacts, especially in areas with high emission densities and/or sensitive ecosystems.

39. Imperial College (London) examined the impacts of limits on the marginal abatement costs for acidification and eutrophication using the ASAM model. Three ways of introducing such limits in the model were examined:

(a) Removing high marginal cost measures from the least-cost solution, allowing a violation of the environmental targets set for optimization. The results are important cost savings on the one hand and limited reductions in the overall level of protection on the other. While the decrease in the overall protection level is relatively small, significant exceedances occur at certain locations, in particular of the European-wide maximum excess levels;

(b) Deriving the least-cost solution with a cap on marginal costs, ensuring that original environmental targets are met. The overall costs increase significantly, while the protection level will also rise;

(c) Capping total expenditure for Europe at a level equivalent to the total cost under the original scenario, while redistributing the expenditure from high-cost measures to the most effective measure below the marginal cost limit. In this case the overall protection level will not be as high as in the base case and there will be substantial shifts in abatement requirements and benefits between countries.

In all cases, shifts in costs and environmental benefits between countries will occur. Generally, abatement efforts will decrease in Belgium and surrounding countries and increase in northern Europe. Limiting the abatement costs for ammonia specifically will lead to increased reduction requirements for sulphur and NOx. A balanced set of limits can avoid such shifts.

40. IIASA developed two scenarios to examine limits on marginal costs. Emission controls were limited to measures having marginal costs below a

certain threshold. This was examined in two ways. In scenario J9, emission reduction requirements of the revised G5/2 scenario were reduced for countries or pollutants exceeding the imposed limit on marginal costs to the level corresponding to the cost limit. In scenario J10, the optimization with the environmental target of the G5/2 scenario was repeated with the limits on marginal costs. The following limits were selected in both cases:

Sulphur:	4000 euros/ton
NO_x:	7000 euros/ton
VOC:	5000 euros/ton
NH_3:	25000 euros/ton

The selected levels restrict sulphur control in Belgium, Germany and Hungary, NO_x and VOC control in Belgium and ammonia control in the Netherlands.

41. The revised emission levels for scenario J9 are presented in tables 9-16. Overall, European emissions of sulphur are 33 kt higher; NO_x increases by 15 kt, VOCs by 20 kt and ammonia by 9 kt compared to the revised G5/2 scenario. Total costs decline by 777 million euros/year, i.e. by 9%. The environmental targets of the G5/2 scenario are violated, including the AOT60 level of 2.9 ppm.h, though overall reductions in the protection level are not very large. They may be considered to be significant for some parts, especially in the north-west of Europe.

42. The J10 scenario uses the same limits on marginal costs, but violations of the environmental targets of the G5/2 scenario are not allowed. The optimization done for the G5/2 scenario was repeated with lower bounds on emissions which were derived from the marginal cost limits, using only abatement measures with marginal costs below the limits. Excess exposure resulting from the restricted emission reduction potential had to be compensated by additional reductions at other sources. The results are presented in tables 9-16.

43. Maintaining the environmental targets while excluding the most expensive emission controls from an optimized solution requires additional emission controls at other emission sources. The 17 kt increase in NO_x emissions in Belgium (close to the ozone problem area) requires additional NO_x reductions of 419 kt at more distant locations. 19 kt of extra VOC emissions in Belgium have to be compensated by additional reductions of 149 kt in other countries. Relaxing reduction requirements for sulphur emissions in Belgium, Germany and Hungary by a total of 32 kt has to be compensated by additional reductions of 813 kt at other places. Although the costs of the relaxed emission controls are high, the increase in control volume at sources more distant from the environmental problem area increases total emission control costs by almost 40%. Major cost savings occur in Belgium, the Netherlands and Hungary, while many other countries experience significantly higher costs. The environmental performance of scenario J10 is better than that of G5/2. In some countries additional measures will also lead to higher protection levels.

H. <u>Other sensitivity studies</u>

44. After the final approval of the critical load data by the Working Group on Effects in August 1998, experts from Slovakia indicated that they had revised the critical load database, resulting in higher estimates for the most sensitive ecosystems in Slovakia. Since in the G5/2 scenario, which uses the

officially approved critical load data, exceedances in Slovakia are driving emission reductions in some parts of central and eastern Europe, a sensitivity analysis explored the implications of the proposed revisions to the critical load data.

45. The modelling done by IIASA with the RAINS model indicate that higher critical loads in Slovakia would mainly relax sulphur control requirements in Poland (a 65% instead of a 76% reduction), in the south-eastern part of Europe (Bosnia and Herzegovina, Croatia, and Slovenia) and to a lesser extent in Austria, Hungary, Italy and Slovakia. Lower reductions in Polish sulphur emissions impact sensitive ecosystems in Germany and the Netherlands and higher sulphur depositions in this area from Polish sources would have to be compensated by additional sulphur controls in Denmark. Impacts on other pollutants are very small. Total emission control costs would decline by about 3%.

46. Similar results were derived at Imperial College (London). Examining the revised critical loads data for Slovakia with ASAM showed a cost saving of 0.3 billion euros/year for the attainment of targets for acidification and eutrophication, due to a relaxation of sulphur emission reductions in central and eastern Europe.

47. In addition, Imperial College conducted specific sensitivity analysis regarding the inclusion of shipping emissions in the European abatement strategies. In scenarios aiming at the attainment of the acidification and eutrophication targets of the G5/2 scenario, the impacts of limiting the sulphur content in bunker fuel and applying selective catalytic reduction (SCR) for ships in the North Sea and the North Atlantic were examined. The introduction of these measures led to a decrease in costs of almost 10%, due to a decrease in emission reduction requirements from land-based sources, in particular sulphur for the United Kingdom, ammonia for Germany and all pollutants for France, the Netherlands and Poland.

I. Conclusions about the robustness of model results

48. The emission reduction requirements for the four pollutants as calculated for the two basic scenarios, REF and the revised G5/2, and for the sensitivity runs J2, J3, J4 and J5, are presented in summary tables 1-4. The figure (a)-(d) gives a graphic representation of these emission data and show that the differences in optimized emission reduction requirements between G5/2 and the sensitivity runs are surprisingly small, or, where there are bigger differences, generally tend to indicate that G5/2 reduction requirements constitute an upper bound. The chances of overachieving environmental targets seem small. It is more likely that in a future review of the protocol higher emission reductions will be required. In view of this general picture, the Task Force concluded that:

(a) Optimized emission reduction requirements in the revised G5/2 scenario appear generally to be robust for higher activity rates, but would increase for scenarios with lower rates of economic activity. This is particularly important for the energy scenario, which, at present, is based on a pre-Kyoto scenario, which is incompatible with the obligations under the Kyoto Protocol, but it is also relevant for the agricultural scenario, where a policy shift could have similar effects. Abatement costs fall significantly in a scenario assuming low-energy consumption, such as the post-Kyoto scenario;

(b) Uniform emission reduction scenarios studied so far, whether a flat-rate approach or an equal per capita emissions scenario, are not cost-effective. They are more expensive or less effective in reducing environmental impacts than optimized scenarios;

(c) Three ways of limiting marginal costs by excluding some of the most expensive abatement options from the analysis have been studied. The measures can be excluded after the optimization, in which case there will be cost-savings, but also lower environmental protection levels. The measures can be redistributed so that the environmental targets are met everywhere. In this case, the costs of the strategy will turn out to be higher, but environmental benefits will also increase. There will be a major redistribution of costs and benefits. Finally, total expenditure can be fixed, leading to a redistribution of abatement efforts and limited reductions in the environmental protection levels. In general, limits on the marginal costs tend to move efforts away from the most polluted areas because these areas are associated with the high marginal costs;

(d) The impacts of changes in critical loads for Slovakia are restricted to neighbouring countries. Measures to reduce shipping emissions turn out to be cost-effective and reduce the overall cost of reaching the environmental targets in Europe.

II. PRESENTATION OF MODEL RESULTS

49. Explanations of the critical load exceedance and the evolution of the gap closure methodology had been prepared by CCE. The note was distributed to the Task Force and experts found it very useful. The Task Force will make it available via the Internet (www.unece.org/env/tfiam).

50. In addition, the previous report on integrated assessment modelling (EB.AIR/WG.5/1998/3), also available via the Internet, gives a complete introduction to the methodology, the input data used and single and joint scenarios around the G5/2 scenario. A note on the multi-effect, multi-pollutant protocol is also available on the Internet (www.unece.org/env/multipro.htm).

51. IIASA has prepared a series of slides that explain in simple terms the integrated assessment modelling work, including its results and some background information. IIASA will also make available a simple tool to examine the environmental effects of scenarios of abatement strategies for the four pollutants or groups of pollutants covered. This information is available via the Internet (www.iiasa.ac.at/~rains).

52. The Chairman called upon experts to publish work related to integrated assessment modelling in scientific journals in order to inform the wider scientific community about this work.

III. MODELLING ACTIVITIES UNDER WAY OR PLANNED FOR THE PERIOD AFTER THE PROTOCOL PREPARATIONS

A. Modelling exposure to particulate matter

53. Imperial College (London) has started work on the contribution of long-range transported primary particulate matter to concentrations of airborne particulates. It used an emission inventory prepared by the Netherlands institute TNO and mapped these to the EMEP grid using the distribution of NOx emissions as a basis. A simple model was applied to simulate the atmospheric transport of primary particulate matter across Europe. The model indicates that contributions in some central parts of Europe can be significant during episodes. Further work will include the development of abatement cost curves to allow analysis in integrated assessment models.

B. Dynamic modelling of VOC abatement costs

54. The French-German Institute for Environmental Research (IFARE) at the University of Karlsruhe (Germany) presented the results of a research project on VOC cost functions. The results for Germany had been presented to the Task Force earlier (EB.AIR/WG.5/1998/1, para. 50). VOC cost functions for France were prepared in collaboration with the Centre interprofessionel technique d'études de la pollution atmosphérique (CITEPA) and supported by the French Agency for Environment and Energy Management (ADEME). Based on the data sheets developed by the Task Force on the Assessment of Abatement Options/Techniques for VOCs, a detailed database on the structure of emission sources and on sectoral activities was built. The data were used in the dynamic mass flow model ARGUS to determine VOC cost functions for various scenarios analysing different implementation periods for emission reductions and different discount rates. The ARGUS model takes into account all relevant emission reduction options including technical measures (primary and secondary) and structural changes related to changes in activities, replacement of installations at the end of their lifetime, etc. The results show that the costs strongly decrease and the maximum feasible emission reduction (MFR) increases when the implementation period is increased from the year 2000 (short term) to 2010 (long term). For instance, the cost of reducing the emissions in 2010 by 47% compared to 1995 level is reduced by a factor of 10 when the implementation period is extended. The MFR increases by about 27% in this case. This difference is mainly due to the influence of considered structural options.

C. Life-cycle analysis

55. Ms. J. POTTING, Chairperson of the scientific task group on acidification, eutrophication and nutrient enrichment of the Society of Environmental Chemistry and Toxicology (SETAC), introduced the work of her task group on life-cycle analysis and the use of integrated assessment modelling in this context. The objective of the work is to develop a life-cycle analysis methodology to be used by national authorities for product regulations. Ms. Potting invited experts to participate in the work of SETAC and proposed to the Task Force to hold a joint workshop in the year 2000 on

the use of integrated assessment modelling in life-cycle analysis.

56. The Task Force expressed its interest in the work, especially with a view to products that may lead to VOC emissions. It agreed to keep this topic in mind when developing its work plan at the next meeting.

D. Elements for a long-term work programme on integrated assessment modelling

57. The Chairman introduced an open-ended discussion on the long-term programme on integrated assessment modelling under the Convention. The Task Force decided to note the ideas presented as a basis for further discussion at its next meeting.

58. Once this stage in integrated assessment modelling with the preparation of the multi-effect, multi-pollutant protocol is completed, a review of the past may be useful. Such a review could be conducted by the Task Force itself or by an external expert.

59. A number of elements could be added to the integrated assessment modelling activities or their scope could be extended to cover, for instance:

(a) Other substances, such as particulate matter, heavy metals and persistent organic pollutants;

(b) Areas outside Europe, possibly covering the whole northern hemisphere;

(c) The period beyond the year 2010;

(d) Policy instruments used for the implementation of strategies, including product regulation and the impacts of trade;

(e) Other areas of environmental policy through closer links with other conventions, such as those on climate change and on the regional seas.

60. A review of existing models to be ready for a review of protocol obligations in some five years’ time should include updates of:

(a) The forecasts of sectoral activities;

(b) The modelling of abatement techniques, including their costs and potential;

(c) The modelling of legislation (current legislation scenario);

(d) Improvements of effects (critical loads and levels), emission data and atmospheric transport data;

(e) Methodologies, such as the coverage of monetary benefits, the model resolution, dynamic modelling, etc.

61. Integrated assessment modelling work could play a more prominent role in accompanying the implementation of protocols, for instance by assisting the Implementation Committee in evaluating the impacts of legislation on

compliance, by identifying policy gaps and proposing additional measures to fill those gaps.

62. It is of the utmost importance to ensure that the scientific network that has developed should remain as active as it is at present, once the protocol is in place. A wider exchange of national modelling experience and topical workshops may support this objective.

E. Next meeting

63. The next meeting will be held in Rome, on 8-9 June 1999. It will be preceded by a workshop on 7 June organized under the project coordinated by the Finnish Environment Institute and supported by the EC LIFE programme. Its aim is to apply and develop tools at the national level to assess cost-effective emission reductions and impacts with a high spatial and temporal resolution (EB.AIR/WG.5/1998/3, para. 4).

Table 1. NO_x emissions in 1990, the reference and the revised G5/2 scenarios and the sensitivity cases (J2-J5). Percentage changes related to the year 1990 (RAINS estimates)

	1990 RAINS	REF		G5/2 (revised)		J2 (Post Kyoto)		J3 (High SO_2)		J4 (Low ammonia)		J5 (High ammonia)	
	kt	kt	change	kt	change	kt	change	kt	change	kt	change	kt	change
Albania	24	36	50%	36	50%	32	33%	36	50%	36	50%	35	46%
Austria	192	103	-46%	91	-53%	97	-49%	91	-53%	91	-53%	91	-53%
Belarus	402	316	-21%	290	-28%	235	-42%	290	-28%	290	-28%	269	-33%
Belgium	351	191	-46%	127	-64%	113	-68%	127	-64%	133	-62%	127	-64%
Bosnia and Herzegovina	80	60	-25%	53	-34%	43	-46%	53	-34%	54	-33%	51	-36%
Bulgaria	355	297	-16%	266	-25%	211	-41%	266	-25%	249	-30%	260	-27%
Croatia	82	91	11%	87	6%	74	-10%	84	2%	91	11%	81	-1%
Czech Republic	546	296	-46%	188	-66%	168	-69%	188	-66%	197	-64%	172	-68%
Denmark	274	128	-53%	113	-59%	122	-55%	113	-59%	113	-59%	113	-59%
Estonia	84	73	-13%	73	-13%	56	-33%	73	-13%	73	-13%	73	-13%
Finland	276	152	-45%	152	-45%	134	-51%	152	-45%	152	-45%	152	-45%
France	1867	858	-54%	704	-62%	641	-66%	704	-62%	706	-62%	703	-62%
Germany	2662	1184	-56%	1081	-59%	952	-64%	1080	-59%	1115	-58%	1080	-59%
Greece	345	344	0%	344	0%	306	-11%	344	0%	344	0%	344	0%
Hungary	219	198	-10%	137	-37%	138	-37%	131	-40%	141	-36%	131	-40%
Ireland	2037	70	-38%	55	-51%	45	-60%	55	-51%	60	-47%	43	-62%
Italy	113	1130	-45%	901	-56%	899	-56%	901	-56%	902	-56%	901	-56%
Latvia	117	118	1%	118	1%	78	-33%	118	1%	118	1%	117	0%
Lithuania	153	138	-10%	134	-12%	94	-39%	134	-12%	134	-12%	132	-14%
Luxembourg	22	10	-55%	8	-64%	7	-68%	8	-64%	9	-59%	8	-64%
Netherlands	542	280	-48%	266	-51%	179	-67%	250	-54%	280	-48%	240	-56%
Norway	220	178	-19%	142	-35%	173	-21%	142	-35%	142	-35%	166	-25%
Poland	1217	879	-28%	654	-46%	694	-43%	654	-46%	803	-34%	654	-46%
Portugal	208	177	-15%	144	-31%	137	-34%	144	-31%	177	-15%	177	-15%
Republic of Moldova	87	66	-24%	64	-26%	53	-39%	64	-26%	65	-25%	63	-28%
Romania	518	458	-12%	328	-37%	297	-43%	332	-36%	355	-31%	308	-41%
Russian Federation	3486	2653	-24%	2653	-24%	2255	-35%	2653	-24%	2653	-24%	2653	-24%
Slovakia	219	132	-40%	115	-47%	84	-62%	115	-47%	118	-46%	108	-51%
Slovenia	60	36	-40%	34	-43%	33	-45%	33	-45%	34	-43%	33	-45%
Spain	1162	847	-27%	726	-38%	717	-38%	726	-38%	758	-35%	726	-38%
Sweden	338	190	-44%	159	-53%	190	-44%	159	-53%	158	-53%	163	-52%
Switzerland	163	79	-52%	76	-53%	76	-53%	76	-53%	76	-53%	76	-53%
The FYR of Macedonia	39	29	-26%	29	-26%	24	-38%	29	-26%	29	-26%	29	-26%
Ukraine	1888	1433	-24%	1222	-35%	981	-48%	1222	-35%	1242	-34%	1222	-35%
United Kingdom	2839	1186	-58%	1181	-58%	1051	-63%	1176	-59%	1181	-58%	1075	-62%
Yugoslavia	211	152	-28%	132	-37%	119	-44%	132	-37%	136	-36%	118	-44%
European Community	13226	6849	-48%	6054	-54%	5589	-58%	6032	-54%	6179	-53%	5944	-55%
Total	23398	14568	-38%	12883	-45%	11508	-51%	12855	-45%	13215	-44%	12694	-46%

Table 2. VOC emissions in 1990, the reference and the revised G5/2 scenarios and the sensitivity cases (J2-J5). Percentage changes related to the year 1990 (RAINS estimates)

	1990 RAINS	REF		G5/2 (revised)		J2 (Post Kyoto)		J3 (High SO_2)		J4 (Low ammonia)		J5 (High ammonia)	
	kt	kt	change	kt	change	kt	change	kt	change	kt	change	kt	change
Albania	31	41	32%	41	*32%*	34	10%	41	32%	41	32%	41	32%
Austria	352	205	-42%	142	-60%	200	-43%	142	-60%	142	-60%	151	-57%
Belarus	371	309	-17%	298	-20%	263	-29%	298	-20%	298	-20%	298	-20%
Belgium	374	193	-48%	103	-72%	95	-75%	103	-72%	103	-72%	103	-72%
Bosnia and Herzegovina	51	48	-6%	48	-6%	47	-8%	48	-6%	48	-6%	48	-6%
Bulgaria	195	190	-3%	185	-5%	177	-9%	184	-6%	182	-7%	188	-4%
Croatia	103	111	8%	86	-17%	100	-3%	86	-17%	86	-17%	86	-17%
Czech Republic	442	305	-31%	156	-65%	216	-51%	163	-63%	157	-64%	174	-61%
Denmark	182	85	-53%	85	-53%	85	-53%	85	-53%	85	-53%	85	-53%
Estonia	45	49	9%	49	9%	45	0%	49	9%	49	9%	49	9%
Finland	213	110	-48%	110	-48%	125	-41%	110	-48%	110	-48%	110	-48%
France	2382	1223	-49%	989	-58%	907	-62%	939	-61%	1014	-57%	933	-61%
Germany	3122	1137	-64%	995	-68%	1031	-67%	995	-68%	997	-68%	995	-68%
Greece	336	267	-21%	261	-22%	249	-26%	261	-22%	263	-22%	261	-22%
Hungary	204	160	-22%	137	-33%	159	-22%	136	-33%	138	-32%	137	-33%
Ireland	110	55	-50%	55	-50%	48	-56%	55	-50%	55	-50%	54	-51%
Italy	2055	1159	-44%	1030	-50%	1069	-48%	1048	-49%	1003	-51%	1055	-49%
Latvia	63	56	-11%	56	-11%	49	-22%	56	-11%	56	-11%	56	-11%
Lithuania	111	105	-5%	105	-5%	90	-19%	105	-5%	105	-5%	105	-5%
Luxembourg	19	7	-63%	7	-63%	6	-68%	7	-63%	7	-63%	7	-63%
Netherlands	490	233	-52%	157	-68%	151	-69%	157	-68%	158	-68%	157	-68%
Norway	297	195	-34%	195	-34%	195	-34%	195	-34%	195	-34%	195	-34%
Poland	797	807	1%	475	-40%	472	-41%	475	-40%	475	-40%	475	-40%
Portugal	212	144	-32%	102	-52%	106	-50%	102	-52%	100	-53%	100	-53%
Republic of Moldova	50	42	-16%	42	-16%	39	-22%	42	-16%	42	-16%	42	-16%
Romania	503	504	0%	500	-1%	474	-6%	500	-1%	487	-3%	499	-1%
Russian Federation	3542	2787	-21%	2723	-23%	2398	-32%	2723	-23%	2706	-24%	2723	-23%
Slovakia	151	140	-7%	140	-7%	126	-17%	140	-7%	140	-7%	140	-7%
Slovenia	55	40	-27%	40	-27%	40	-27%	40	-27%	40	-27%	40	-27%
Spain	1008	669	-34%	648	-36%	669	-34%	653	-35%	632	-37%	645	-36%
Sweden	511	290	-43%	241	-53%	290	-43%	241	-53%	239	-53%	241	-53%
Switzerland	278	144	-48%	144	-48%	144	-48%	144	-48%	144	-48%	143	-49%
The FYR of Macedonia	19	19	0%	19	0%	19	0%	19	0%	19	0%	19	0%
Ukraine	1161	851	-27%	770	-34%	715	-38%	768	-34%	756	-35%	797	-31%
United Kingdom	2667	1351	-49%	1101	-59%	1108	-58%	1105	-59%	1068	-60%	1052	-61%
Yugoslavia	142	139	-2%	138	-3%	134	-6%	138	-3%	136	-4%	136	-4%
European Community	14031	7128	-49%	6024	-57%	6138	-56%	6001	-57%	5974	-57%	5949	-58%
Total	22644	14170	-37%	12373	-45%	12075	-47%	12353	-45%	12276	-46%	12340	-46%

Table 3. SO_2 emissions in 1990, the reference and the revised G5/2 scenarios and the sensitivity cases (J2-J5). Percentage changes related to the year 1990 (RAINS estimates)

	1990 RAINS	REF		G5/2 (revised)		J2 (Post Kyoto)		J3 (High SO_2)		J4 (Low ammonia)		J5 (High ammonia)	
		kt	change	kt	change	kt	change	kt	change	kt	change	kt	change
Albania	72	55	-24%	55	-24%	47	-35%	55	-24%	55	-24%	55	-24%
Austria	93	40	-57%	35	-62%	42	-55%	35	-62%	38	-59%	35	-62%
Belarus	843	494	-41%	494	-41%	262	-69%	494	-41%	494	-41%	494	-41%
Belgium	336	193	-43%	76	-77%	75	-78%	80	-76%	77	-77%	76	-77%
Bosnia and Herzegovina	487	415	-15%	162	-67%	277	-43%	94	-81%	216	-56%	161	-67%
Bulgaria	1842	846	-54%	378	-79%	776	-58%	397	-78%	378	-79%	378	-79%
Croatia	180	70	-61%	23	-87%	59	-67%	21	-88%	23	-87%	23	-87%
Czech Republic	1873	366	-80%	283	-85%	184	-90%	296	-84%	283	-85%	282	-85%
Denmark	182	90	-51%	60	-67%	66	-64%	39	-79%	58	-68%	60	-67%
Estonia	275	175	-36%	175	-36%	107	-61%	175	-36%	175	-36%	175	-36%
Finland	226	116	-49%	116	-49%	103	-54%	116	-49%	116	-49%	116	-49%
France	1250	448	-64%	219	-82%	252	-80%	222	-82%	252	-80%	193	-85%
Germany	5280	581	-89%	463	-91%	442	-92%	480	-91%	474	-91%	457	-91%
Greece	504	546	8%	546	8%	363	-28%	546	8%	546	8%	546	8%
Hungary	913	546	-40%	296	-68%	187	-80%	311	-66%	296	-68%	296	-68%
Ireland	178	66	-63%	36	-80%	72	-60%	38	-79%	46	-74%	36	-80%
Italy	1679	567	-66%	290	-83%	277	-84%	289	-83%	316	-81%	261	-84%
Latvia	121	104	-14%	104	-14%	49	-60%	104	-14%	104	-14%	104	-14%
Lithuania	213	107	-50%	107	-50%	51	-76%	107	-50%	107	-50%	107	-50%
Luxembourg	14	4	-71%	3	-79%	4	-71%	3	-79%	4	-71%	3	-79%
Netherlands	201	73	-64%	50	-75%	42	-79%	53	-74%	50	-75%	50	-75%
Norway	52	32	-38%	18	-65%	32	-38%	19	-63%	18	-65%	25	-52%
Poland	3001	1397	-53%	722	-76%	1392	-54%	757	-75%	723	-76%	722	-76%
Portugal	284	141	-50%	141	-50%	138	-51%	141	-50%	141	-50%	141	-50%
Republic of Moldova	197	117	-41%	38	-81%	77	-61%	40	-80%	38	-81%	38	-81%
Romania	1331	594	-55%	148	-89%	354	-73%	155	-88%	148	-89%	148	-89%
Russian Federation	5012	2344	-53%	2186	-56%	1184	-76%	2185	-56%	2155	-57%	2201	-56%
Slovakia	548	137	-75%	92	-83%	47	-91%	97	-82%	92	-83%	92	-83%
Slovenia	200	71	-65%	14	-93%	71	-65%	15	-93%	14	-93%	14	-93%
Spain	2189	774	-65%	747	-66%	747	-66%	747	-66%	746	-66%	747	-66%
Sweden	119	67	-44%	67	-44%	67	-44%	67	-44%	66	-45%	67	-44%
Switzerland	43	26	-40%	23	-47%	24	-44%	24	-44%	26	-40%	22	-49%
The FYR of Macedonia	107	81	-24%	81	-24%	75	-30%	81	-24%	81	-24%	81	-24%
Ukraine	3706	1488	-60%	1457	-61%	621	-83%	1449	-61%	1445	-61%	1460	-61%
United Kingdom	3805	980	-74%	499	-87%	429	-89%	520	-86%	582	-85%	497	-87%
Yugoslavia	585	269	-54%	217	-63%	250	-57%	65	-89%	230	-61%	211	-64%
European Community	16339	4687	-71%	3349	-80%	3118	-81%	3376	-79%	3514	-78%	3286	-80%
Total	37941	14420	-62%	10421	-73%	9245	-76%	10317	-73%	10613	-72%	10374	-73%

Table 4. NH_3 emissions in 1990, the reference and the revised G5/2 scenarios and sensitivity cases (J2-J5). Percentage changes related to the year 1990 (RAINS estimates)

	1990 RAINS	REF		G5/2 (revised)		J2 (Post Kyoto)		J3 (High SO_2)		J4 (Low ammonia)		J5 (High ammonia)	
		kt	change	kt	change	kt	change	kt	change	kt	change	kt	change
Albania	32	35	9%	32	0%	32	0%	32	0%	30	-6%	31	-3%
Austria	77	67	-13%	66	-14%	66	-14%	66	-14%	61	-21%	67	-13%
Belarus	219	163	-26%	140	-36%	157	-28%	140	-36%	143	-35%	147	-33%
Belgium	97	96	-1%	60	-38%	69	-29%	57	-41%	63	-35%	59	-39%
Bosnia and Herzegovina	31	23	-26%	22	-29%	22	-29%	22	-29%	20	-35%	23	-26%
Bulgaria	141	126	-11%	105	-26%	108	-23%	105	-26%	102	-28%	110	-22%
Croatia	40	37	-8%	29	-28%	29	-28%	29	-28%	27	-33%	30	-25%
Czech Republic	107	108	1%	101	-6%	105	-2%	101	-6%	96	-10%	107	0%
Denmark	77	72	-6%	69	-10%	71	-8%	69	-10%	63	-18%	72	-6%
Estonia	29	29	0%	29	0%	29	0%	29	0%	27	-7%	29	0%
Finland	40	31	-23%	31	-23%	31	-23%	31	-23%	28	-30%	31	-23%
France	807	777	-4%	642	-20%	657	-19%	643	-20%	627	-22%	645	-20%
Germany	757	571	-25%	413	-45%	460	-39%	412	-46%	418	-45%	416	-45%
Greece	80	74	-8%	73	-9%	73	-9%	73	-9%	67	-16%	74	-8%
Hungary	120	137	14%	77	-36%	83	-31%	77	-36%	73	-39%	79	-34%
Ireland	127	126	-1%	116	-9%	117	-8%	116	-9%	115	-9%	117	-8%
Italy	462	432	-6%	356	-23%	356	-23%	356	-23%	347	-25%	360	-22%
Latvia	43	35	-19%	35	-19%	35	-19%	35	-19%	33	-23%	35	-19%
Lithuania	80	81	1%	72	-10%	77	-4%	72	-10%	72	-10%	74	-8%
Luxembourg	7	7	0%	7	0%	7	0%	7	0%	6	-14%	7	0%
Netherlands	233	136	-42%	105	-55%	105	-55%	104	-55%	96	-59%	109	-53%
Norway	23	21	-9%	21	-9%	21	-9%	21	-9%	18	-22%	21	-9%
Poland	505	541	7%	468	-7%	477	-6%	469	-7%	454	-10%	468	-7%
Portugal	71	67	-6%	65	-8%	66	-7%	65	-8%	61	-14%	62	-13%
Republic of Moldova	47	48	2%	41	-13%	45	-4%	41	-13%	40	-15%	42	-11%
Romania	292	304	4%	227	-22%	240	-18%	227	-22%	225	-23%	231	-21%
Russian Federation	1282	894	-30%	894	-30%	894	-30%	894	-30%	819	-36%	894	-30%
Slovakia	60	47	-22%	39	-35%	39	-35%	39	-35%	38	-37%	41	-32%
Slovenia	23	21	-9%	16	-30%	18	-22%	16	-30%	16	-30%	17	-26%
Spain	352	353	0%	353	0%	353	0%	353	0%	353	0%	353	0%
Sweden	61	48	-21%	48	-21%	48	-21%	48	-21%	48	-21%	48	-21%
Switzerland	72	66	-8%	63	-13%	63	-13%	63	-13%	60	-17%	66	-8%
The FYR of Macedonia	17	16	-6%	15	-12%	15	-12%	15	-12%	13	-24%	14	-18%
Ukraine	729	649	-11%	588	-19%	589	-19%	588	-19%	536	-26%	592	-19%
United Kingdom	329	297	-10%	264	-20%	264	-20%	264	-20%	244	-26%	264	-20%
Yugoslavia	90	82	-9%	64	-29%	69	-23%	65	-28%	64	-29%	66	-27%
European Community	3578	3154	-12%	2668	-25%	2743	-23%	2663	-26%	2596	-27%	2683	-25%
Total	7559	6617	-12%	5746	-24%	5890	-22%	5744	-24%	5503	-27%	5801	-23%

Table 5. Control costs for the (revised) G5/2 scenario and sensitivity runs compared to the REF case (in million euros/year)

Party	NO_x and VOCs - Cost above REF						SO_2 - Cost above REF					
	REF	G5/2 revised	J2 Post Kyoto	J3 High SO_2	J4 Low NH_3	J5 High NH_3	REF	G5/2 revised	J2 Post Kyoto	J3 High SO_2	J4 Low NH_3	J5 High NH_3
Albania	0	0	0	0	0	0	0	0	0	1	0	0
Austria	902	70	2	70	70	48	191	5	0	7	1	5
Belarus	0	3	1	3	3	8	0	0	0	6	0	0
Belgium	1278	452	325	452	380	452	426	122	122	125	118	127
Bosnia and Herzegovina	1	2	1	2	1	4	0	55	0	78	38	55
Bulgaria	4	10	4	10	27	16	153	58	0	58	58	58
Croatia	1	5	4	6	3	10	52	18	0	22	18	18
Czech Republic	568	235	85	220	213	240	411	36	0	36	35	36
Denmark	484	8	0	8	8	8	138	13	0	33	15	13
Estonia	0	0	0	0	0	0	0	0	0	3	0	0
Finland	642	0	0	0	0	0	247	0	0	8	0	0
France	7383	437	449	537	373	555	1276	132	91	155	83	209
Germany	10549	484	315	487	387	493	3264	240	134	250	191	251
Greece	1048	2	1	2	1	2	434	0	0	4	0	0
Hungary	420	112	29	136	97	136	166	113	51	113	113	113
Ireland	477	10	4	10	3	52	132	12	9	12	7	12
Italy	7868	245	35	228	271	222	1776	87	9	97	77	107
Latvia	0	0	0	0	0	0	0	0	0	1	0	0
Lithuania	0	0	0	0	0	1	0	0	0	2	0	0
Luxembourg	71	2	13	2	1	5	13	0	0	0	0	0
Netherlands	1731	112	63	156	87	196	340	19	49	19	19	19
Norway	567	12	0	12	12	2	56	10	0	10	10	2
Poland	2487	373	77	373	178	373	855	283	0	284	283	284
Portugal	1349	57	37	57	62	58	181	0	0	2	0	0
Republic of Moldova	0	0	0	0	0	0	0	30	1	30	30	30
Romania	2	100	40	91	48	140	155	137	46	137	137	137
Russian Federation	21	0	0	0	0	0	694	54	9	81	65	49
Slovakia	331	11	5	11	5	27	91	25	0	25	25	25
Slovenia	93	1	1	1	1	1	35	23	0	23	23	23
Spain	5658	42	12	39	42	44	809	9	70	21	9	9
Sweden	1125	45	0	45	50	40	316	0	0	4	0	0
Switzerland	831	2	2	2	2	2	118	1	0	1	0	2
The FYR of Macedonia	1	0	0	0	0	0	0	0	0	2	0	0
Ukraine	0	44	3	44	39	42	328	8	0	31	11	7
United Kingdom	6695	353	326	342	478	653	1269	295	135	303	168	300
Yugoslavia	3	6	6	6	4	31	88	27	0	150	17	32
European Community	47258	2318	1583	2435	2212	2827	10813	935	619	1042	689	1053
Total	52590	3235	1840	3352	2846	3861	14014	1812	726	2134	1551	1923

Table 6. Control costs for the (revised) G5/2 scenario and sensitivity runs compared to the REF case (in million euros/year)

	NH_3 - Cost above REF						Total - Cost above REF					
	REF	G5/2 revised	J2 Post Kyoto	J3 High SO_2	J4 Low NH_3	J5 High NH_3	REF	G5/2 revised	J2 Post Kyoto	J3 High SO_2	J4 Low NH_3	J5 High NH_3
Albania	0	1	1	1	1	2	0	1	1	2	1	2
Austria	0	1	0	1	0	12	1093	76	3	78	71	65
Belarus	0	9	2	9	3	9	0	12	4	18	6	18
Belgium	0	312	147	467	133	467	1704	886	595	1044	631	1046
Bosnia and Herzegovina	0	1	1	1	0	1	1	58	2	82	39	60
Bulgaria	0	13	7	13	7	13	157	81	12	81	92	86
Croatia	0	3	3	3	3	4	52	26	8	32	25	32
Czech Republic	0	9	3	9	2	9	979	280	88	265	251	285
Denmark	0	2	0	2	1	4	623	22	0	42	24	25
Estonia	0	0	0	0	0	1	0	0	0	3	0	1
Finland	0	0	0	0	0	4	889	0	0	8	0	4
France	0	367	261	359	125	581	8659	936	801	1052	581	1345
Germany	0	842	322	853	299	1219	13813	1567	771	1591	877	1963
Greece	0	0	0	0	0	4	1482	2	1	6	1	6
Hungary	0	319	191	320	255	378	586	545	270	569	464	627
Ireland	9	146	122	145	7	356	618	168	134	167	17	421
Italy	0	85	84	84	58	120	9644	417	128	409	406	450
Latvia	0	0	0	0	0	1	0	0	0	1	0	1
Lithuania	0	4	2	4	2	4	0	4	2	6	2	5
Luxembourg	15	0	0	0	0	0	98	2	13	2	1	5
Netherlands	517	672	632	741	616	741	2588	803	744	917	722	957
Norway	0	3	0	3	18	9	623	25	0	25	40	14
Poland	0	182	115	173	45	342	3342	838	192	830	505	999
Portugal	0	2	1	2	0	18	1530	59	38	61	62	76
Republic of Moldova	0	3	1	3	2	3	0	33	2	33	32	34
Romania	0	304	187	304	111	417	157	541	273	533	295	695
Russian Federation	0	0	0	0	0	17	715	54	9	81	65	66
Slovakia	0	7	7	7	3	8	423	43	13	44	33	61
Slovenia	0	2	1	2	1	2	128	25	2	25	24	26
Spain	28	0	0	0	0	30	6495	51	82	60	51	83
Sweden	113	0	0	0	0	48	1554	45	0	49	50	88
Switzerland	0	6	6	6	1	6	949	9	8	9	2	10
The FYR of Macedonia	0	1	1	1	1	2	1	1	1	2	1	2
Ukraine	0	30	27	29	27	96	328	82	30	104	78	145
United Kingdom	0	23	23	23	22	87	7964	671	484	669	668	1040
Yugoslavia	0	94	52	93	25	114	92	128	58	249	46	177
European Community	682	2450	1592	2677	1261	3692	58754	5704	3794	6154	4163	7573
Total	682	3443	2199	3658	1768	5129	67287	8491	4769	9149	6163	10920

Table 7. Population and vegetation exposure indices for the (revised) G5/2 scenario and the sensitivity runs (J2-J5) compared with 1990 and the REF scenario

	Cumulative population exposure index (million persons.ppm.hours)							Cumulative vegetation exposure index (1000 km² excess. ppm.hours)						
	1990	REF	G5/2 revised	J2 post Kyoto	J3 High SO_2	J4 Low NH_3	J5 High NH_3	1990	REF	G5/2 revised	J2 post Kyoto	J3 High SO_2	J4 Low NH_3	J5 High NH_3
Albania	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Austria	16	3	1	1	1	2	1	468	257	194	191	193	198	192
Belarus	4	1	0	0	0	0	0	186	78	44	22	44	49	39
Belgium	71	34	22	22	22	23	22	177	141	115	115	115	115	115
Bosnia and Herzegovina	3	0	0	0	0	0	0	244	162	126	122	126	129	124
Bulgaria	4	1	0	0	0	0	0	357	281	228	196	229	229	225
Croatia	8	3	1	1	1	2	1	347	214	173	170	173	176	171
Czech Republic	34	11	5	5	5	6	5	570	311	218	210	217	226	214
Denmark	9	3	1	1	1	1	1	160	53	30	30	30	32	29
Estonia	0	0	0	0	0	0	0	2	0	0	0	0	0	0
Finland	0	0	0	0	0	0	0	0	0	0	0	0	0	0
France	311	89	54	50	53	54	53	4168	2345	1865	1755	1853	1881	1845
Germany	404	140	91	84	90	94	89	2341	1204	901	871	899	920	894
Greece	7	4	3	3	3	3	3	245	170	146	129	146	146	145
Hungary	27	12	6	6	6	7	6	631	404	290	275	287	302	282
Ireland	3	1	0	0	0	0	0	29	8	3	3	3	3	3
Italy	183	63	40	41	40	39	40	1852	1186	993	994	994	992	994
Latvia	1	0	0	0	0	0	0	42	6	2	1	2	3	2
Lithuania	2	0	0	0	0	0	0	77	23	9	2	9	11	7
Luxembourg	3	1	1	1	1	1	1	25	14	11	10	11	11	11
Netherlands	73	38	26	25	26	26	26	110	79	63	65	63	62	63
Norway	1	0	0	0	0	0	0	4	1	1	1	1	1	1
Poland	91	36	18	17	18	20	17	1510	829	529	498	527	584	518
Portugal	16	8	6	6	6	6	6	383	274	229	226	230	241	240
Republic of Moldova	3	1	0	0	0	0	0	83	56	43	34	43	44	42
Romania	17	6	1	0	1	1	1	845	623	458	402	458	480	443
Russian Federation	21	7	5	2	5	5	4	1764	983	861	611	860	868	857
Slovakia	15	6	3	3	3	4	3	341	215	153	140	151	159	148
Slovenia	4	1	1	1	1	1	1	139	94	78	77	78	78	77
Spain	35	7	3	3	3	4	3	2088	1281	1046	1022	1045	1097	1064
Sweden	4	0	0	0	0	0	0	163	18	7	8	7	7	7
Switzerland	14	2	1	0	1	1	0	155	85	70	68	70	70	69
The FYR of Macedonia	0	0	0	0	0	0	0	52	40	33	30	33	33	33
Ukraine	45	14	6	3	6	6	6	1776	1206	971	774	970	997	957
United Kingdom	125	77	49	50	49	49	48	204	153	111	116	111	108	110
Yugoslavia	8	3	1	1	1	1	1	327	248	195	184	194	199	191
European Community	1260	466	298	286	297	302	294	12412	7183	5714	5536	5699	5815	5710
Total	1563	572	345	326	343	356	338	21865	13042	10196	9352	10172	10451	10112

Table 8. Ecosystems with acid and nitrogen deposition above their critical loads for the revised G5/2 scenario and sensitivity runs (J2-J5) compared with 1990 and the REF scenario

	Acid deposition above critical loads (1000 hectares)							Nitrogen deposition above critical loads (1000 hectares)						
	1990	REF	G5/2 revised	J2 Post Kyoto	J3 High SO_2	J4 Low NH_3	J5 High NH_3	1990	REF	G5/2 revised	J2 Post Kyoto	J3 High SO_2	J4 Low NH_3	J5 High NH_3
Albania	0	0	0	0	0	0	0	240	200	160	147	160	133	155
Austria	2376	162	68	78	69	74	67	5392	3441	2477	2504	2471	2397	2491
Belarus	2709	1048	686	116	688	687	565	2049	1293	924	940	924	937	937
Belgium	410	155	52	52	51	52	51	700	677	572	581	558	577	564
Bosnia and Herzegovina	132	131	0	0	0	0	0	1104	725	460	440	458	438	483
Bulgaria	0	0	0	0	0	0	0	3964	3396	1263	1228	1263	1232	1615
Croatia	7	0	0	0	0	0	0	70	18	10	9	10	9	10
Czech Republic	2394	474	81	67	93	80	83	2608	2312	1983	1997	1977	1947	2019
Denmark	54	9	5	5	5	5	5	197	119	85	84	84	72	86
Estonia	314	11	8	5	8	8	8	1296	738	598	585	598	592	598
Finland	4725	1183	756	673	757	644	775	7386	2538	1738	1486	1729	1613	1733
France	8191	218	84	85	84	85	83	29320	25160	21632	21632	21627	21578	21885
Germany	8158	1617	567	585	588	604	558	10157	9184	7312	7504	7272	7464	7267
Greece	0	0	0	0	0	0	0	295	236	85	60	85	52	97
Hungary	144	65	37	36	37	37	37	166	150	125	125	125	125	126
Ireland	97	12	8	9	8	9	8	91	58	29	29	29	29	29
Italy	2065	74	51	51	51	51	50	5921	3795	2508	2498	2506	2360	2571
Latvia	128	0	0	0	0	0	0	2260	1553	1417	1387	1415	1404	1418
Lithuania	817	78	5	0	5	5	0	1462	1357	894	894	894	895	899
Luxembourg	58	5	1	1	1	1	1	88	80	63	63	63	63	63
Netherlands	285	193	76	75	76	76	76	312	291	278	276	278	276	278
Norway	5314	2573	1928	1950	1931	1900	1936	2053	281	35	36	35	27	36
Poland	12634	1357	173	476	181	172	173	16875	16218	14894	14907	14895	14896	14906
Portugal	1	1	1	1	1	1	1	913	709	580	580	580	578	581
Republic of Moldova	84	29	10	10	10	10	10	1	0	0	0	0	0	0
Romania	231	51	17	17	17	17	17	3450	2495	1770	1770	1770	1769	1773
Russian Federation	27105	4073	1026	1037	1027	636	1155	47704	26263	23123	20066	23121	21365	23094
Slovakia	1033	295	149	138	151	151	149	1874	1507	939	916	935	937	952
Slovenia	363	19	4	4	4	4	4	489	156	87	87	87	85	87
Spain	78	17	17	17	17	17	17	2390	1158	850	812	849	917	872
Sweden	6348	1605	1166	1142	1148	1170	1174	2588	891	620	606	617	609	619
Switzerland	508	57	35	36	35	36	35	2105	1887	1468	1472	1467	1445	1561
The FYR of Macedonia	0	0	0	0	0	0	0	242	158	108	101	108	93	106
Ukraine	2397	643	237	303	242	238	238	6181	5331	3859	3763	3859	3736	3863
United Kingdom	4117	1182	636	547	650	639	604	1030	126	62	58	62	55	58
Yugoslavia	2	2	0	0	0	0	0	2306	1994	1280	1276	1280	1272	1287
European Community	36963	6433	3486	3320	3504	3425	3469	66778	48461	38890	38775	38810	38641	39194
Total	93279	17339	7884	7516	7935	7409	7880	165279	116495	94288	90919	94191	91977	95119

Table 9. NO_x emissions in the reference, the revised G5/2 and the uniform emission reduction scenarios and the scenarios to limit marginal abatement costs (J9-J10)

Party	REF		G5/2 (revised)		J7 Uniform		J11 Uniform		J9 Violation		J10 Non-violation	
	kt	Change	kt	Change	kt	Change	kt	Change	kt	Change	kt	Change
Albania	36	50%	36	50%	16	-33%	16	-33%	36	50%	36	50%
Austria	103	-46%	91	-53%	103	-46%	103	-46%	91	-53%	91	-53%
Belarus	316	-21%	290	-28%	221	-45%	221	-45%	290	-28%	290	-28%
Belgium	191	-46%	144	-59%	191	-46%	191	-46%	144	-59%	127	-64%
Bosnia and Herzegovina	60	-25%	53	-34%	44	-45%	44	-45%	54	-33%	53	-34%
Bulgaria	297	-16%	266	-25%	195	-45%	195	-45%	266	-25%	266	-25%
Croatia	91	11%	87	6%	45	-45%	45	-45%	84	2%	87	6%
Czech Republic	296	-46%	188	-66%	296	-46%	296	-46%	149	-73%	188	-66%
Denmark	128	-53%	113	-59%	128	-53%	128	-53%	107	-61%	113	-59%
Estonia	73	-13%	73	-13%	46	-45%	46	-45%	73	-13%	73	-13%
Finland	152	-45%	152	-45%	152	-45%	152	-45%	152	-45%	152	-45%
France	858	-54%	704	-62%	858	-54%	858	-54%	705	-62%	704	-62%
Germany	1184	-56%	1081	-59%	1184	-56%	1184	-56%	1014	-62%	1081	-59%
Greece	344	0%	344	0%	248	-28%	248	-28%	344	0%	344	0%
Hungary	198	-10%	137	-37%	120	-45%	120	-45%	141	-36%	137	-37%
Ireland	70	-38%	55	-51%	62	-45%	62	-45%	49	-57%	55	-51%
Italy	1130	-45%	901	-56%	1122	-45%	1122	-45%	903	-56%	901	-56%
Latvia	118	1%	118	1%	65	-44%	65	-44%	118	1%	118	1%
Lithuania	138	-10%	134	-12%	84	-45%	84	-45%	134	-12%	134	-12%
Luxembourg	10	-55%	8	-64%	10	-55%	10	-55%	8	-64%	8	-64%
Netherlands	280	-48%	266	-51%	280	-48%	280	-48%	237	-56%	266	-51%
Norway	178	-19%	142	-35%	125	-43%	125	-43%	173	-21%	142	-35%
Poland	879	-28%	654	-46%	670	-45%	670	-45%	649	-47%	654	-46%
Portugal	177	-15%	144	-31%	114	-45%	114	-45%	177	-15%	144	-31%
Republic of Moldova	66	-24%	64	-26%	48	-45%	48	-45%	64	-26%	64	-26%
Romania	458	-12%	328	-37%	286	-45%	286	-45%	334	-36%	328	-37%
Russian Federation	2653	-24%	2653	-24%	1920	-45%	1920	-45%	2653	-24%	2653	-24%
Slovakia	132	-40%	115	-47%	121	-45%	121	-45%	115	-47%	115	-47%
Slovenia	36	-40%	34	-43%	33	-45%	33	-45%	34	-43%	34	-43%
Spain	847	-27%	726	-38%	640	-45%	640	-45%	660	-43%	726	-38%
Sweden	190	-44%	159	-53%	186	-45%	186	-45%	158	-53%	159	-53%
Switzerland	79	-52%	76	-53%	79	-52%	79	-52%	75	-54%	76	-53%
The FYR of Macedonia	29	-26%	29	-26%	21	-46%	21	-46%	29	-26%	29	-26%
Ukraine	1433	-24%	1222	-35%	1039	-45%	1039	-45%	1222	-35%	1222	-35%
United Kingdom	1186	-58%	1181	-58%	1186	-58%	1186	-58%	907	-68%	1181	-58%
Yugoslavia	152	-28%	132	-37%	116	-45%	116	-45%	132	-37%	132	-37%
European Community	6849	-48%	6069	-54%	6464	-51%	6464	-51%	5656	-57%	6054	-54%
Total		-35%	14528	-42%	13685	-45%	13685	-45%	14111	-44%	14513	-42%

Table 10. VOC emissions in the reference, the revised G5/2 and the uniform emission reduction scenarios and the scenarios to limit marginal abatement costs (J9-J10)

Party	REF		G5/2 (revised)		J7 Uniform		J11 Uniform		J9 Violation		J10 Non-violation	
	kt	Change	kt	Change	kt	Change	kt	Change	kt	Change	kt	Change
Albania	41	32%	41	32%	17	-45%	41	32%	41	32%	41	32%
Austria	205	-42%	142	-60%	192	-45%	142	-60%	142	-60%	142	-60%
Belarus	309	-17%	298	-20%	203	-45%	188	-49%	298	-20%	298	-20%
Belgium	193	-48%	103	-72%	193	-48%	193	-48%	122	-67%	122	-67%
Bosnia and Herzegovina	48	-6%	48	-6%	28	-45%	48	-6%	48	-6%	48	-6%
Bulgaria	190	-3%	185	-5%	107	-45%	165	-15%	185	-5%	186	-5%
Croatia	111	8%	86	-17%	56	-46%	86	-17%	86	-17%	100	-3%
Czech Republic	305	-31%	156	-65%	241	-45%	190	-57%	156	-65%	133	-70%
Denmark	85	-53%	85	-53%	85	-53%	85	-53%	85	-53%	85	-53%
Estonia	49	9%	49	9%	25	-44%	29	-36%	49	9%	49	9%
Finland	110	-48%	110	-48%	110	-48%	92	-57%	110	-48%	110	-48%
France	1223	-49%	989	-58%	1223	-49%	1038	-56%	989	-58%	849	-64%
Germany	1137	-64%	995	-68%	1137	-64%	1137	-64%	995	-68%	986	-68%
Greece	267	-21%	261	-22%	184	-45%	184	-45%	261	-22%	261	-22%
Hungary	160	-22%	137	-33%	111	-46%	160	-22%	137	-33%	158	-23%
Ireland	55	-50%	55	-50%	55	-50%	55	-50%	55	-50%	54	-51%
Italy	1159	-44%	1030	-50%	1123	-45%	1056	-49%	1030	-50%	1116	-46%
Latvia	56	-11%	56	-11%	34	-46%	42	-33%	56	-11%	56	-11%
Lithuania	105	-5%	105	-5%	61	-45%	68	-39%	105	-5%	105	-5%
Luxembourg	7	-63%	7	-63%	7	-63%	7	-63%	7	-63%	5	-74%
Netherlands	233	-52%	157	-68%	233	-52%	233	-52%	157	-68%	156	-68%
Norway	195	-34%	195	-34%	162	-45%	135	-55%	195	-34%	195	-34%
Poland	807	1%	475	-40%	436	-45%	700	-12%	475	-40%	446	-44%
Portugal	144	-32%	102	-52%	116	-45%	144	-32%	102	-52%	102	-52%
Republic of Moldova	42	-16%	42	-16%	27	-46%	42	-16%	42	-16%	42	-16%
Romania	504	0%	500	-1%	275	-45%	426	-15%	500	-1%	501	0%
Russian Federation	2787	-21%	2723	-23%	1935	-45%	1861	-47%	2723	-23%	2723	-23%
Slovakia	140	-7%	140	-7%	82	-46%	97	-36%	140	-7%	140	-7%
Slovenia	40	-27%	40	-27%	30	-45%	36	-35%	40	-27%	40	-27%
Spain	669	-34%	648	-36%	551	-45%	669	-34%	648	-36%	655	-35%
Sweden	290	-43%	241	-53%	279	-45%	174	-66%	241	-53%	227	-56%
Switzerland	144	-48%	144	-48%	144	-48%	124	-55%	144	-48%	143	-49%
The FYR of Macedonia	19	0%	19	0%	10	-47%	19	0%	19	0%	19	0%
Ukraine	851	-27%	770	-34%	634	-45%	836	-28%	770	-34%	787	-32%
United Kingdom	1351	-49%	1101	-59%	1351	-49%	1051	-61%	1101	-59%	1021	-62%
Yugoslavia	139	-2%	138	-3%	77	-46%	139	-2%	138	-3%	138	-3%
European Community	7128	-49%	6024	-57%	6838	-51%	6260	-55%	6045	-57%	5893	-58%
Total	14168	-37%	12370	-45%	11534	-49%	11691	-48%	12390	-45%	12240	-46%

Table 11. SO_2 emissions in the reference, the revised G5/2 and the uniform emission reduction scenarios and the scenarios to limit marginal abatement costs (J9-J10)

Party	REF		G5/2 revised		J7 Uniform		J11 Uniform		J9 Violation		J10 Non-violation	
	kt	Change	kt	Change	kt	Change	kt	Change	kt	Change	kt	Change
Albania	55	-24%	55	-24%	20	-72%	50	-31%	55	-24%	55	-24%
Austria	40	-57%	35	-62%	31	-67%	40	-57%	35	-62%	35	-62%
Belarus	494	-41%	494	-41%	232	-72%	158	-81%	494	-41%	494	-41%
Belgium	193	-43%	76	-77%	92	-73%	169	-50%	82	-76%	82	-76%
Bosnia and Herzegovina	415	-15%	162	-67%	134	-72%	70	-86%	162	-67%	216	-56%
Bulgaria	846	-54%	378	-79%	506	-73%	145	-92%	378	-79%	378	-79%
Croatia	70	-61%	23	-87%	49	-73%	70	-61%	23	-87%	23	-87%
Czech Republic	366	-80%	283	-85%	366	-80%	267	-86%	283	-85%	275	-85%
Denmark	90	-51%	60	-67%	50	-73%	79	-57%	60	-67%	32	-82%
Estonia	175	-36%	175	-36%	75	-73%	24	-91%	175	-36%	175	-36%
Finland	116	-49%	116	-49%	71	-69%	77	-66%	116	-49%	116	-49%
France	448	-64%	219	-82%	343	-73%	448	-64%	219	-82%	193	-85%
Germany	581	-89%	463	-91%	29	-73%	581	-89%	484	-91%	484	-91%
Greece	546	8%	546	8%	468	-91%	155	-69%	546	8%	546	8%
Hungary	546	-40%	296	-68%	138	-73%	296	-68%	301	-67%	301	-67%
Ireland	66	-63%	36	-80%	296	-68%	54	-70%	36	-80%	25	-86%
Italy	567	-66%	290	-83%	49	-72%	566	-66%	290	-83%	295	-82%
Latvia	104	-14%	104	-14%	461	-73%	42	-65%	104	-14%	104	-14%
Lithuania	107	-50%	107	-50%	33	-73%	58	-73%	107	-50%	107	-50%
Luxembourg	4	-71%	3	-79%	59	-72%	4	-71%	3	-79%	3	-79%
Netherlands	73	-64%	50	-75%	4	-71%	73	-64%	50	-75%	50	-75%
Norway	32	-38%	18	-65%	55	-73%	32	-38%	18	-65%	32	-38%
Poland	1397	-53%	722	-76%	17	-67%	590	-80%	722	-76%	432	-86%
Portugal	141	-50%	141	-50%	824	-73%	141	-50%	141	-50%	141	-50%
Republic of Moldova	117	-41%	38	-81%	78	-73%	67	-66%	38	-81%	44	-78%
Romania	594	-55%	148	-89%	54	-73%	359	-73%	148	-89%	148	-89%
Russian Federation	2344	-53%	2186	-56%	366	-73%	1632	-67%	2186	-56%	2202	-56%
Slovakia	137	-75%	92	-83%	1377	-73%	91	-83%	92	-83%	92	-83%
Slovenia	71	-65%	14	-93%	137	-75%	30	-85%	14	-93%	14	-93%
Spain	774	-65%	747	-66%	55	-73%	577	-74%	747	-66%	260	-88%
Sweden	67	-44%	67	-44%	601	-73%	67	-44%	67	-44%	67	-44%
Switzerland	26	-40%	23	-47%	53	-55%	26	-40%	23	-47%	26	-40%
The FYR of Macedonia	81	-24%	81	-24%	12	-72%	33	-69%	81	-24%	81	-24%
Ukraine	1488	-60%	1457	-61%	1018	-73%	782	-79%	1457	-61%	1435	-61%
United Kingdom	980	-74%	499	-87%	980	-74%	886	-77%	499	-87%	446	-88%
Yugoslavia	269	-54%	217	-63%	161	-72%	162	-72%	217	-63%	230	-61%
European Community	4687	-71%	3349	-80%	3475	-79%	3918	-76%	3375	-79%	2775	-83%
Total	15571	-60%	11572	-70%	10446	-73%	10053	-74%	11605	-70%	10791	-72%

Table 12. NH_3 emissions in the reference, revised G5/2 and the uniform emission reduction scenarios and the scenarios to limit marginal abatement costs (J9-J10)

Party	REF		G5/2 (revised)		J7 Uniform		J11 Uniform		J9 Violation		J10 Non-violation	
	kt	Change	kt	Change	kt	Change	kt	Change	kt	Change	kt	Change
Albania	35	9%	32	0%	25	-22%	28	-13%	32	0%	32	0%
Austria	67	-13%	66	-14%	59	-23%	66	-14%	66	-14%	66	-14%
Belarus	163	-26%	140	-36%	163	-26%	103	-53%	140	-36%	140	-36%
Belgium	96	-1%	60	-38%	74	-24%	93	-4%	60	-38%	60	-38%
Bosnia and Herzegovina	23	-26%	22	-29%	23	-26%	23	-26%	22	-29%	22	-29%
Bulgaria	126	-11%	105	-26%	107	-24%	86	-39%	105	-26%	105	-26%
Croatia	37	-8%	29	-28%	30	-25%	37	-8%	29	-28%	29	-28%
Czech Republic	108	1%	101	-6%	81	-24%	88	-18%	101	-6%	101	-6%
Denmark	72	-6%	69	-10%	58	-25%	44	-43%	69	-10%	69	-10%
Estonia	29	0%	29	0%	22	-24%	16	-45%	29	0%	29	0%
Finland	31	-23%	31	-23%	31	-23%	31	-23%	31	-23%	31	-23%
France	777	-4%	642	-20%	613	-24%	526	-35%	642	-20%	566	-30%
Germany	571	-25%	413	-45%	570	-25%	571	-25%	413	-45%	394	-48%
Greece	74	-8%	73	-9%	61	-24%	74	-8%	73	-9%	73	-9%
Hungary	137	14%	77	-36%	91	-24%	88	-27%	77	-36%	80	-33%
Ireland	126	-1%	116	-9%	111	-13%	111	-13%	116	-9%	118	-7%
Italy	432	-6%	356	-23%	351	-24%	432	-6%	356	-23%	356	-23%
Latvia	35	-19%	35	-19%	33	-23%	23	-47%	35	-19%	35	-19%
Lithuania	81	1%	72	-10%	61	-24%	49	-39%	72	-10%	75	-6%
Luxembourg	7	0%	7	0%	7	0%	7	0%	7	0%	7	0%
Netherlands	136	-42%	105	-55%	136	-42%	127	-45%	114	-51%	114	-51%
Norway	21	-9%	21	-9%	18	-22%	21	-9%	21	-9%	21	-9%
Poland	541	7%	468	-7%	384	-24%	368	-27%	468	-7%	477	-6%
Portugal	67	-6%	65	-8%	54	-24%	67	-6%	65	-8%	63	-11%
Republic of Moldova	48	2%	41	-13%	36	-23%	37	-21%	41	-13%	41	-13%
Romania	304	4%	227	-22%	222	-24%	206	-29%	227	-22%	227	-22%
Russian Federation	894	-30%	894	-30%	891	-30%	836	-35%	894	-30%	894	-30%
Slovakia	47	-22%	39	-35%	45	-25%	45	-25%	39	-35%	40	-33%
Slovenia	21	-9%	16	-30%	17	-26%	17	-26%	16	-30%	18	-22%
Spain	353	0%	353	0%	268	-24%	318	-10%	353	0%	353	0%
Sweden	48	-21%	48	-21%	46	-25%	48	-21%	48	-21%	48	-21%
Switzerland	66	-8%	63	-13%	55	-24%	58	-19%	63	-13%	66	-8%
The FYR of Macedonia	16	-6%	15	-12%	13	-24%	16	-6%	15	-12%	15	-12%
Ukraine	649	-11%	588	-19%	554	-24%	431	-41%	588	-19%	589	-19%
United Kingdom	297	-10%	264	-20%	250	-24%	297	-10%	264	-20%	238	-28%
Yugoslavia	82	-9%	64	-29%	68	-24%	82	-9%	64	-29%	65	-28%
European Community	3154	-12%	2668	-25%	2689	-25%	2811	-21%	2677	-25%	2556	-29%
Total	6616	-12%	5745	-24%	5627	-26%	5470	-28%	5754	-24%	5658	-25%

Table 13. Control costs for the (revised) G5/2 and the uniform emission reduction scenarios and the scenarios to limit marginal abatement costs (in million euros/year)

Party	NO_x and VOCs						SO_2					
	REF	J1	J7 Uniform	J11 Uniform	J9 Violation	J10 Non-violation	REF	J1	J7 Uniform	J11 Uniform	J9 Violation	J10 Non-violation
Albania	0	0	89	0	0	0	0	0	15	1	0	0
Austria	902	70	3	51	70	70	191	5	18	0	5	5
Belarus	0	3	96	172	3	3	0	0	93	125	0	0
Belgium	1278	452	0	0	179	179	426	122	68	9	93	93
Bosnia and Herzegovina	1	2	26	0	2	1	0	55	64	85	55	38
Bulgaria	4	10	181	229	10	10	153	58	42	182	58	58
Croatia	1	5	146	4	5	3	52	18	6	0	18	18
Czech Republic	568	235	23	141	235	523	411	36	0	86	36	47
Denmark	484	8	0	32	8	16	138	13	22	5	13	37
Estonia	0	0	54	114	0	0	0	0	42	73	0	0
Finland	642	0	0	98	0	0	247	0	106	74	0	0
France	7383	437	0	127	437	819	1276	132	38	0	132	211
Germany	10549	484	0	0	484	874	3264	240	282	0	113	113
Greece	1048	2	490	489	2	2	434	0	203	164	0	0
Hungary	420	112	231	0	112	91	166	113	113	113	92	92
Ireland	477	10	2	0	10	25	132	12	6	4	12	29
Italy	7868	245	21	74	245	173	1776	87	30	0	87	83
Latvia	0	0	128	192	0	0	0	0	33	22	0	0
Lithuania	0	0	129	170	0	0	0	0	20	21	0	0
Luxembourg	71	2	0	9	2	7	13	0	0	0	0	1
Netherlands	1731	112	0	0	112	208	340	19	11	0	19	19
Norway	567	12	198	310	12	0	56	10	16	0	10	0
Poland	2487	373	492	131	373	466	855	283	232	422	283	588
Portugal	1349	57	141	0	57	45	181	0	27	0	0	0
Republic of Moldova	0	0	16	0	0	0	0	30	23	18	30	27
Romania	2	100	340	12	100	88	155	137	52	53	137	137
Russian Federation	21	0	1133	1021	0	0	694	54	333	286	54	48
Slovakia	331	11	57	89	11	11	91	25	0	32	25	25
Slovenia	93	1	8	2	1	1	35	23	6	16	23	23
Spain	5658	42	288	44	42	109	809	9	57	65	9	255
Sweden	1125	45	4	397	45	63	316	0	80	0	0	0
Switzerland	831	2	0	21	2	5	118	1	34	0	1	0
The FYR of Macedonia	1	0	15	0	0	0	0	0	28	26	0	0
Ukraine	0	44	283	408	44	43	328	8	155	256	8	14
United Kingdom	6695	353	0	625	353	1304	1269	295	0	33	295	464
Yugoslavia	3	6	60	0	6	6	88	27	72	71	27	17
European Community	47258	2318	949	1946	2046	3895	10813	935	948	354	778	1311
Total	52590	3235	4654	4959	2963	5145	14016	1814	2327	2240	1635	2442

Table 14. Control costs for the (revised) G5/2 and the uniform emission reduction scenarios and the scenarios to limit marginal abatement costs (in million euros/year)

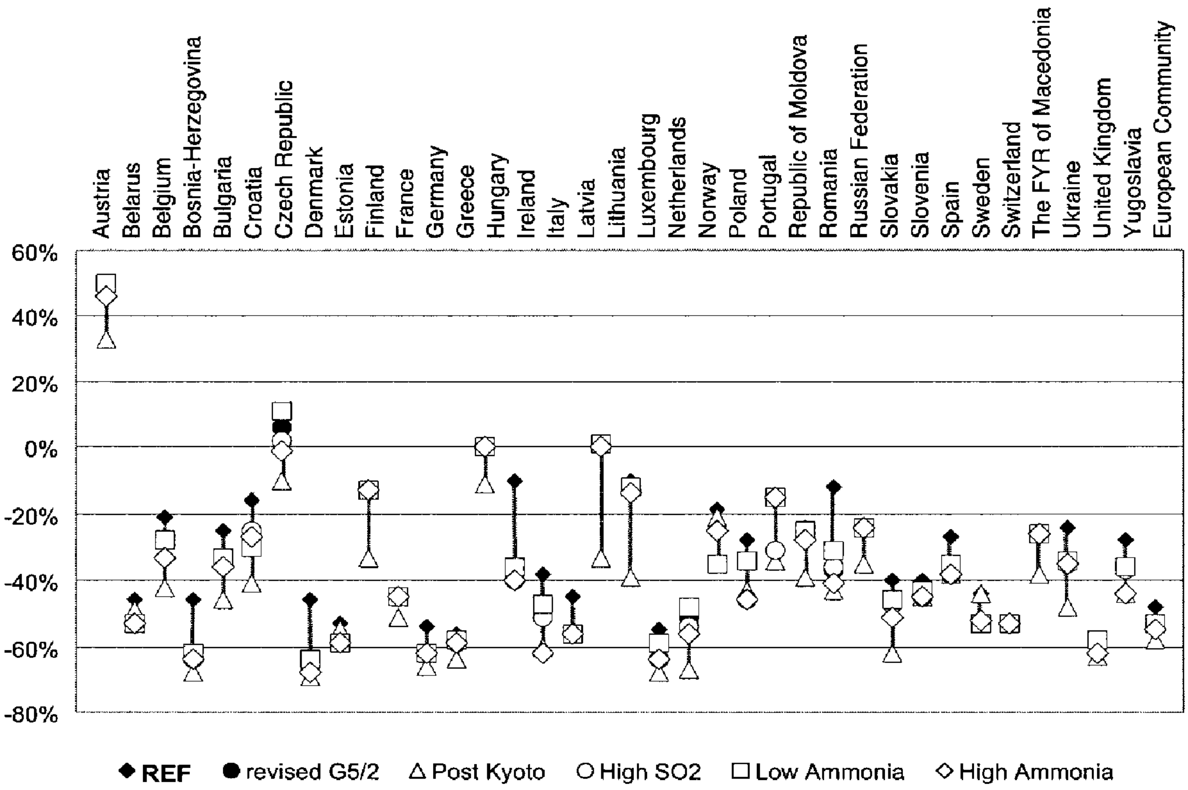
Party	NH_3						Total					
	REF	J1	J7 Uniform	J11 Uniform	J9 Violation	J10 Non-violation	REF	J1	J7 Uniform	J11 Uniform	J9 Violation	J10 Non-violation
Albania	0	1	56	10	1	1	0	1	160	11	1	1
Austria	0	1	38	2	1	1	1093	76	60	53	76	76
Belarus	0	9	0	433	9	9	0	12	189	729	12	12
Belgium	0	312	95	4	312	310	1704	886	163	12	584	583
Bosnia and Herzegovina	0	1	0	0	1	1	1	58	90	85	58	40
Bulgaria	0	13	10	262	13	13	157	81	232	673	81	81
Croatia	0	3	3	0	3	3	52	26	154	4	26	25
Czech Republic	0	9	160	86	9	9	979	280	184	312	280	578
Denmark	0	2	120	539	2	2	623	22	142	575	22	54
Estonia	0	0	6	83	0	0	0	0	103	270	0	0
Finland	0	0	0	0	0	0	889	0	106	173	0	0
France	0	367	586	1592	367	947	8659	936	624	1719	936	1977
Germany	0	842	1	0	842	1262	13813	1567	283	0	1439	2249
Greece	0	0	95	0	0	0	1482	2	788	654	2	2
Hungary	0	319	94	124	319	245	586	545	438	237	523	428
Ireland	9	146	455	455	146	107	618	168	463	460	168	161
Italy	0	85	96	0	85	84	9644	417	147	74	417	341
Latvia	0	0	1	33	0	0	0	0	162	247	0	0
Lithuania	0	4	58	246	4	3	0	4	207	437	4	3
Luxembourg	15	0	0	0	0	0	98	2	0	9	2	9
Netherlands	517	672	0	108	345	345	2588	803	11	108	476	572
Norway	0	3	74	0	3	0	623	25	287	310	25	0
Poland	0	182	1056	1455	182	115	3342	838	1779	2007	838	1168
Portugal	0	2	51	0	2	6	1530	59	220	0	59	51
Republic of Moldova	0	3	21	12	3	3	0	33	60	29	33	30
Romania	0	304	385	764	304	305	157	541	777	829	541	529
Russian Federation	0	0	5	34	0	0	715	54	1472	1340	54	48
Slovakia	0	7	1	1	7	3	423	43	58	122	43	39
Slovenia	0	2	1	2	2	1	128	25	15	20	25	24
Spain	28	0	497	101	0	0	6495	51	841	210	51	364
Sweden	113	0	33	0	0	0	1554	45	117	397	45	63
Switzerland	0	6	105	45	6	0	949	9	139	66	9	5
The FYR of Macedonia	0	1	7	0	1	1	1	1	50	26	1	1
Ukraine	0	30	134	1334	30	27	328	82	572	1998	82	85
United Kingdom	0	23	95	0	23	195	7964	671	95	658	671	1963
Yugoslavia	0	94	57	0	94	90	92	128	189	71	128	113
European Community	682	2450	2164	2801	2125	3259	58754	5704	4061	5100	4949	8465
Total	682	3442	4398	7723	3116	4089	67288	8490	11380	14922	7713	11676

Table 15. Population and vegetation exposure indices for the REF, the revised G5/2, the uniform emission reduction scenarios and the scenarios to limit marginal abatement costs

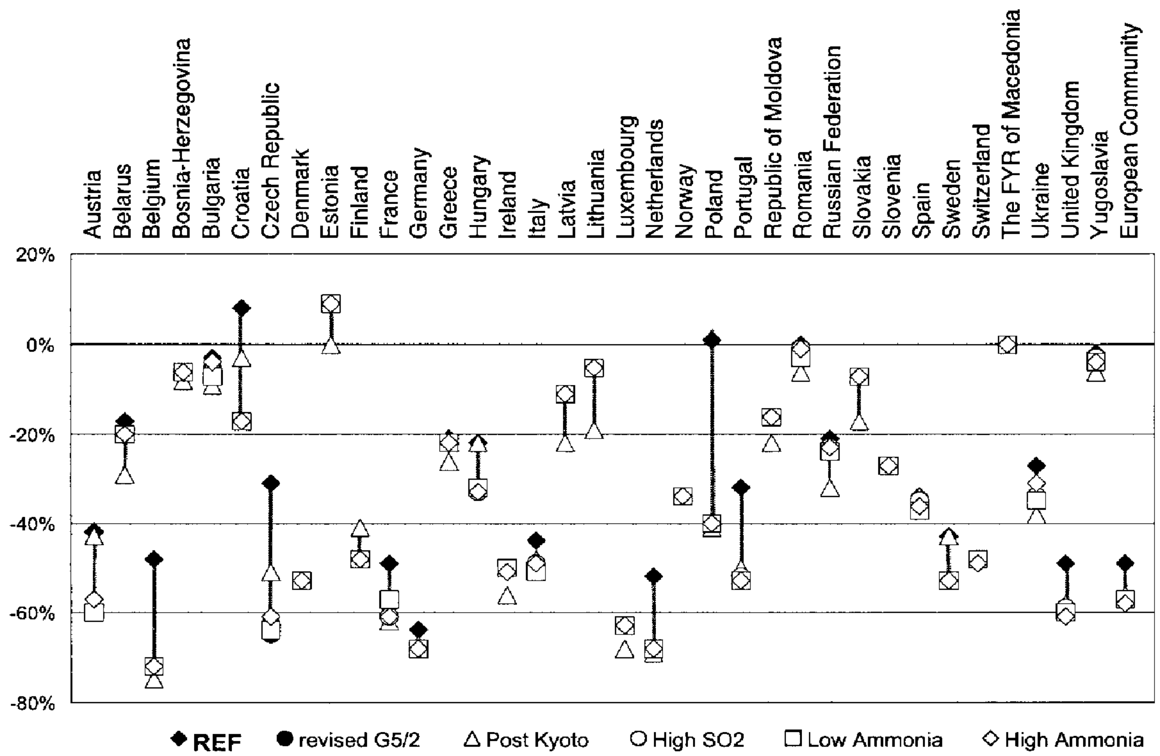
Party	Population exposure index						Vegetation exposure index					
	REF	G5/2 Revised	J7 Uniform	J11 Uniform	J9 Violation	J10 Non-violation	REF	G5/2 Revised	J7 Uniform	J11 Uniform	J9 Violation	J10 Non-violation
Albania	0	0	0	0	0	0	0	0	0	0	0	0
Austria	3	1	2	2	0	0	257	194	232	227	+1	-7
Belarus	1	0	0	0	0	0	78	44	22	20	0	-3
Belgium	34	22	32	30	+1	0	141	115	138	133	+1	0
Bosnia and Herzegovina	0	0	0	0	0	0	162	126	125	148	0	0
Bulgaria	1	0	0	0	0	0	281	228	178	205	0	-1
Croatia	3	1	2	2	0	1	214	173	175	197	0	-1
Czech Republic	11	5	9	7	0	-2	311	218	269	260	+1	-15
Denmark	3	1	2	2	0	0	53	30	45	38	0	-4
Estonia	0	0	0	0	0	0	0	0	0	0	0	0
Finland	0	0	0	0	0	0	0	0	0	0	0	0
France	89	54	83	76	+1	-3	2345	1865	2278	2195	+12	-55
Germany	140	91	130	121	+2	-7	1204	901	1133	1085	+7	-44
Greece	4	3	2	2	0	0	170	146	110	122	0	1
Hungary	12	6	6	9	0	0	404	290	292	348	0	-4
Ireland	1	0	1	1	0	0	8	3	7	5	0	0
Italy	63	40	55	52	0	+2	1186	993	1107	1098	0	10
Latvia	0	0	0	0	0	0	6	2	1	0	0	-1
Lithuania	0	0	0	0	0	0	23	9	2	2	0	-2
Luxembourg	1	1	1	1	0	0	14	11	14	13	0	0
Netherlands	38	26	36	34	+1	0	79	63	76	73	+1	0
Norway	0	0	0	0	0	0	1	1	1	1	0	0
Poland	36	18	24	25	0	-2	829	529	593	622	+1	-41
Portugal	8	6	5	7	0	0	274	229	210	262	0	6
Republic of Moldova	1	0	0	0	0	0	56	43	32	40	0	-1
Romania	6	1	0	3	0	0	623	458	399	512	0	-3
Russian Federation	7	5	2	2	0	0	983	861	460	484	0	-5
Slovakia	6	3	4	4	0	0	215	153	161	175	0	-5
Slovenia	1	1	1	1	0	0	94	78	85	86	0	-1
Spain	7	3	4	5	0	0	1281	1046	963	1133	2	-49
Sweden	0	0	0	0	0	0	18	7	12	8	0	-1
Switzerland	2	1	2	1	0	-1	85	70	83	78	0	-2
The FYR of Macedonia	0	0	0	0	0	0	40	33	25	32	0	0
Ukraine	14	6	2	4	0	0	1206	971	747	805	0	-12
United Kingdom	77	49	73	61	+1	-3	153	111	152	123	+1	+1
Yugoslavia	3	1	1	2	0	0	248	195	183	218	0	-2
European Community	466	298	426	394	+6	-12	7183	5714	6476	6516	+25	-142
Total	570	346	479	456	+6	-17	13043	10196	10310	10750	+27	-238

Table 16. Ecosystems with acid and nitrogen deposition above their critical loads for the REF, the revised G5/2, the uniform emission reduction scenarios and the scenarios to limit marginal abatement costs

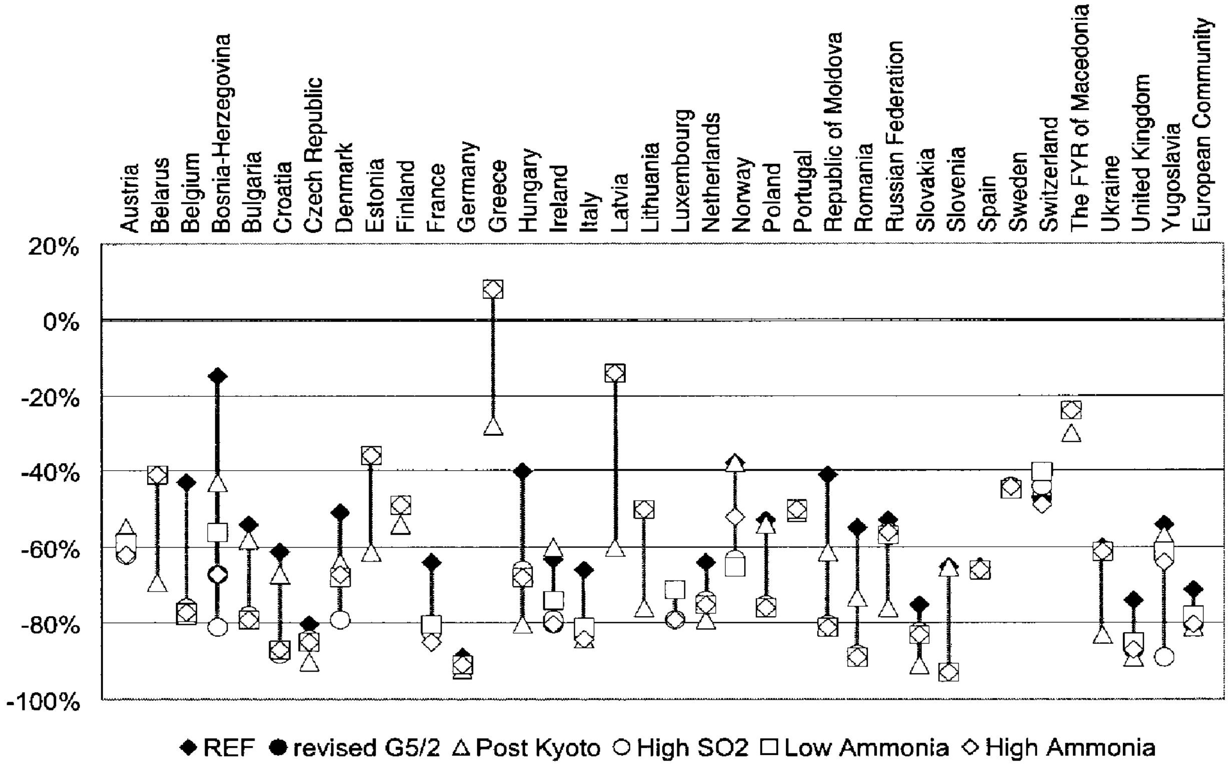
Party	Acid deposition above critical loads (1000 hectares)						Nitrogen deposition above critical loads (1000 hectares)					
	REF	G5/2 revised	J7 Uniform	J11 Uniform	J9 Violation	J10 Non-violation	REF	J1	J7 Uniform	J11 Uniform	J9 Violation	J10 Non-violation
Albania	0	0	0	0	0	0	200	160	109	130	0	0
Austria	162	68	108	117	+2	-5	3441	2477	2860	2989	+5	-126
Belarus	1048	686	72	2	+1	-200	1293	924	894	597	+1	-5
Belgium	155	52	106	118	+4	-1	677	572	628	633	+7	-50
Bosnia and Herzegovina	131	0	0	0	0	0	725	460	496	590	0	-6
Bulgaria	0	0	0	0	0	0	3396	1263	1114	1200	0	-1
Croatia	0	0	0	0	0	0	18	10	10	17	0	0
Czech Republic	474	81	170	125	+5	-23	2312	1983	2016	2028	+6	-100
Denmark	9	5	6	6	0	-1	119	85	72	18	0	-9
Estonia	11	8	3	2	0	0	738	598	560	479	0	-3
Finland	1183	756	360	289	+1	2	2538	1738	1457	1164	+9	-84
France	218	84	105	108	+1	-5	25160	21632	21182	19658	+6	-1830
Germany	1617	567	1142	1227	+40	-86	9184	7312	8763	8676	+53	-566
Greece	0	0	0	0	0	0	236	85	47	48	0	0
Hungary	65	37	38	38	0	0	150	125	129	130	0	+1
Ireland	12	8	9	9	0	0	58	29	28	28	0	0
Italy	74	51	56	62	0	-1	3795	2508	2671	3566	+2	-14
Latvia	0	0	0	0	0	0	1553	1417	1230	719	+1	-11
Lithuania	78	5	0	0	0	-5	1357	894	850	594	0	3
Luxembourg	5	1	4	4	0	0	80	63	70	69	+1	-4
Netherlands	193	76	163	177	+11	0	291	278	287	286	+2	-1
Norway	2573	1928	2015	2055	+9	-88	281	35	43	33	0	-2
Poland	1357	173	208	161	+3	-58	16218	14894	13925	13449	+10	-36
Portugal	1	1	0	1	0	0	709	580	349	691	0	0
Republic of Moldova	29	10	10	10	0	0	0	0	0	0	0	0
Romania	51	17	17	17	0	0	2495	1770	1730	1706	0	-1
Russian Federation	4073	1026	111	54	+1	+96	26263	23123	18565	16534	+7	-85
Slovakia	295	149	173	156	+1	-5	1507	939	1031	1037	+1	-4
Slovenia	19	4	4	4	0	0	156	87	89	98	0	0
Spain	17	17	10	9	0	-17	1158	850	204	477	+1	-118
Sweden	1605	1166	1124	1126	+9	-128	891	620	667	574	+3	-35
Switzerland	57	35	39	44	0	-1	1887	1468	1522	1615	+3	-20
The FYR of Macedonia	0	0	0	0	0	0	158	108	83	93	0	0
Ukraine	643	237	221	16	+1	-92	5331	3859	3663	3249	+1	-5
United Kingdom	1182	636	944	1029	+2	-256	126	62	58	95	+1	-61
Yugoslavia	2	0	0	0	0	0	1994	1280	1269	1818	0	-1
European Community	6433	3486	4136	4281	+72	-497	48461	38890	39344	38972	+91	-2899
Total	17341	7883	7220	6967	+94	-873	116494	94287	88672	85087	+121	-3172



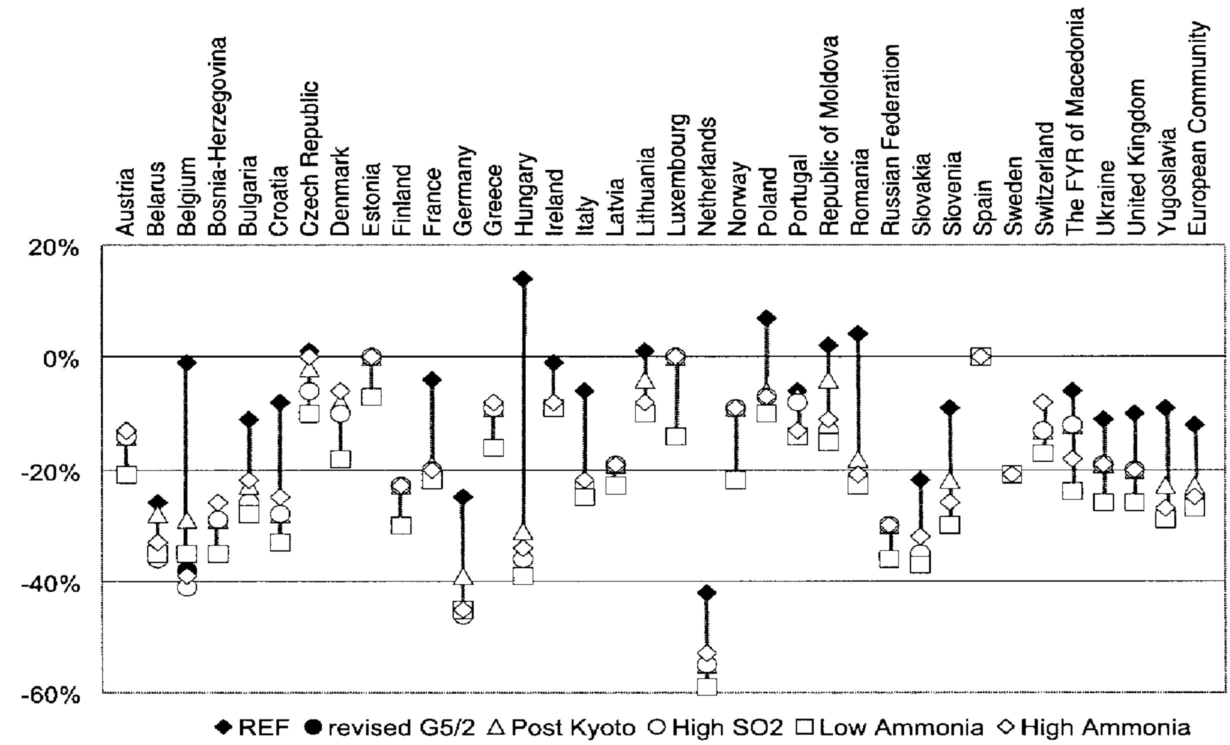
(a) Changes in NO_x emissions compared to 1990



(b) Changes in VOC emissions compared to 1990



(c) Changes in SO_2 emissions compared to 1990



(d) Changes in NH_3 emissions compared to 1990