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EXECUTIVE BODY FOR THE CONVENTION ON
LONG-RANGE TRANSBOUNDARY AIR POLLUTION

Steering Body to the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission for Air Pollutants in Europe (EMEP)
(Twenty-fifth session, Geneva, 3-5 September 2001)
Working Group on Strategies and Review
(Thirty-third session, Geneva, 24-27 September 2001)

INTEGRATED ASSESSMENT MODELLING

Progress report prepared by the Chairman of the
Task Force on Integrated Assessment Modelling in collaboration with the secretariat

Introduction

1. This report presents progress in integrated assessment modelling and the preparation of model inputs, with a focus on particulate matter (PM) pollution. It includes the results of the twenty-sixth meeting of the Task Force on Integrated Assessment Modelling, held in Brussels on 14-16 May 2001.

2. Experts from Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Italy, Netherlands, Norway, Poland, Slovakia, Sweden, Switzerland, the United Kingdom, and the European Community (EC) participated in the meeting. Representatives from the Centre for Integrated Assessment Modelling (CIAM), the Chemical Coordinating Centre (CCC), the Meteorological Synthesizing Centre-West of EMEP (MSC-W), the Coordinating Center for Effects (CCE), the European Environment Agency (EEA), the Technical Support Unit of Working

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Group III of the Intergovernmental Panel on Climate Change (IPCC), as well as from the International Union of Air Pollution Prevention and Environmental Protection Associations (IUAPPA), the Oil Companies' European Organization for Environment, Health and Safety (CONCAWE), the Union of the Electricity Industry (EURELECTRIC) and the World Conservation Union (IUCN), were present. Mr. Rob MAAS (Netherlands) chaired the meeting.

3. The secretariat summarized the developments under the Convention since the twenty-fifth meeting of the Task Force. It highlighted the tentative long-term timetable for work to be done in preparation for the review of the Gothenburg Protocol drawn up by the EMEP Steering Body (EB.AIR/GE.1/2000/2, annex) and approved in principle by the Executive Body. The timetable was geared towards preparing models so that negotiations on the Gothenburg Protocol review could take place in 2004. The secretariat also drew the attention of the Task Force to discussions to secure long-term financing for all core activities under the Convention. In this context the Task Force was advised to draw up a budget proposal for CIAM.

4. The European Commission informed the Task Force about the progress in drawing up the Clean Air for Europe (CAFE) Programme. The European Commission had adopted a communication on CAFE and a first meeting of the CAFE Steering Group would be held on 18 May. The work was aimed at preparing a thematic strategy covering all relevant issues by 2004. It was intended to link the integrated assessment modelling work under CAFE closely to the work of the Task Force to ensure consistency in methodologies and data, but there might be a need for a separate working group under CAFE to discuss issues specifically related to its work.

5. The European Environment Agency (EEA) presented an overview of its activities related to integrated assessment modelling. It highlighted the useful link between its European Environment Information and Observation Network (EIONET) and the other two task forces under EMEP. EEA intended to intensify work on integrated assessment modelling also through its newly established European Topic Centre for Air and Climate Change with a view to supporting CAFE. It did not want to duplicate any work done elsewhere and was hoping that it could cooperate with the Task Force on Integrated Assessment Modelling and the newly established national focal points.

I. EMISSION PROJECTIONS AND TRENDS

6. CIAM reported that it had extended its modelling to 2020. In contrast to the calculations for the Gothenburg Protocol, which were based on energy projections for the year 2010 provided by Parties, CIAM used data from the “shared analysis” energy scenario developed by the Euroepan Commission’s Directorate General for Transport and Energy for the extension to 2020. Under this scenario, 23 countries would have to take additional measures to current legislation in order to reach their Gothenburg Protocol emission ceilings for sulphur and NOx by 2010. To maintain sulphur and NOx emissions below their ceilings upto 2020, nine countries would have to take further measures after 2010.

7. The scenario shows that after 2010, the turnover of capital stock, in particular the renewal of the vehicle fleet and the construction of new power stations with stricter emission controls, will lead to a deeper penetration of the abatement measures taken to achieve the Gothenburg Protocol ceilings. This will result in further emission reductions after 2010, offsetting to some extent the emission increases from higher energy demand. Overall between 2010 and 2020, SO_2 emissions are expected to decrease by 25%, NOx emissions by 12% and VOC emissions by 2%.

8. The analysis of the environmental effects shows, however, that the emission reductions triggered by the measures necessary to meet the Gothenburg Protocol ceilings would not lead to full environmental protection even by 2020. Calculations indicate that the environmental protection levels initially proposed during the Gothenburg Protocol negotiations for 2010 will only be reached by the year 2020.

9. A study was conducted at CIAM to examine the determinants of changes of emissions of SO_2 and NOx between 1960 and 2020. The study shows that for the whole of Europe after 1980, more than two thirds of SO_2 reductions resulted from structural change and a reduction in the overall consumption of energy (see fig. I). There are significant differences between individual countries. Abatement measures are expected to become more important to reach the emission ceilings of the Gothenburg Protocol, but structural change will continue to play an important role. For NOx, structural change has caused an increase or prevented further reduction of emissions in the 1990s and is expected, together with growing energy consumption, to counterbalance some of the emission reductions due to control measures in the future.

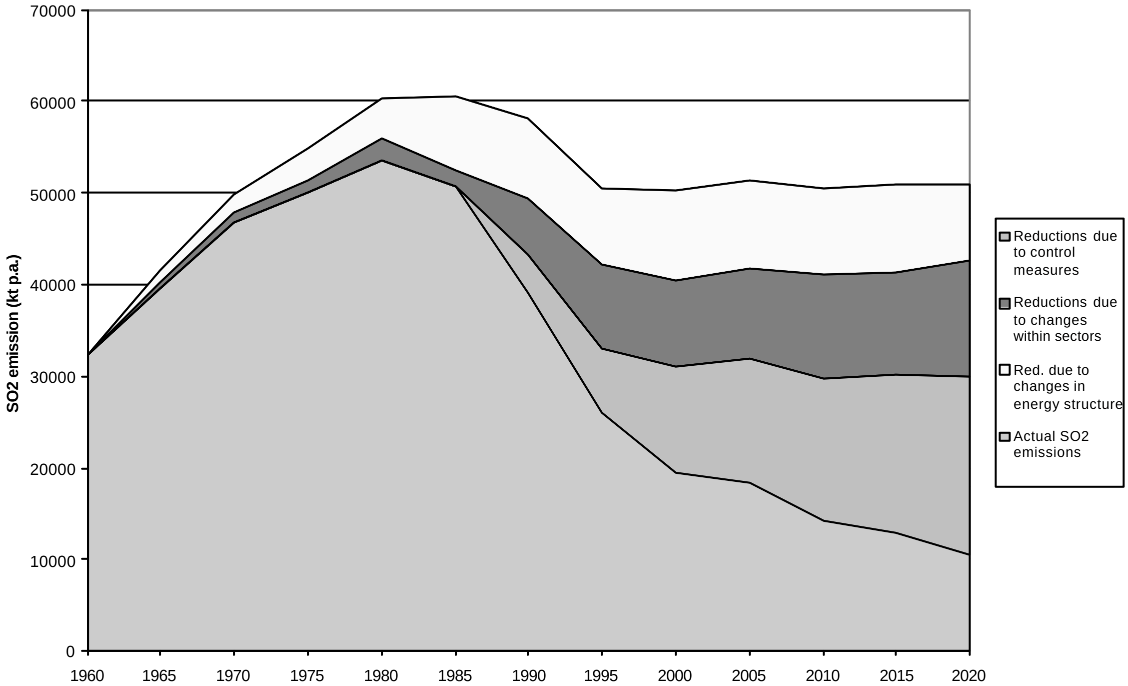

Figure I. European SO_2 emissions from 1960 to 2020 showing avoided emissions compared to hypothetical levels due to energy consumption growth

10. The Task Force noted that these results would be important for the review of the Gothenburg Protocol. To get a realistic picture of projected emissions, it would be crucial to better understand the driving forces for structural change.

11. The Task Force on Emission Inventories and Projections, at its meeting in May 2001, had agreed in principle to a new set of emission reporting guidelines. These would be used for emission data reporting by the end of this year and finalized, taking into account the experience gained, in 2002. They aimed at harmonising the reporting formats with those of the United Nations Framework Convention on Climate Change. The guidelines will also, for the first time, cover reporting on activity data in five-yearly intervals, including projected activity data. This change was intended to provide the tools for better verification of emissions data by linking emissions estimates to reported activity data. These data would be of great importance to CIAM, enabling it to base its modelling upon nationally reported projections. The Task Force reiterated its support, expressed in its previous report (EB.AIR/GE.1/2000/11 – EB.AIR/WG.5/2000/2, para. 10 (c)), for the inclusion of projected activity data in the annual data reporting under EMEP.

12. A new PM emission inventory for 1995 has been prepared by Netherlands Consultancy TNO under the Coordinated European Programme on Particulate Matter Emission Inventory’s

Projections and Guidance (CEPMEIP) project. The data are under review by experts at MSC-W and CIAM. A fully documented version of the inventory will be available on the Internet, accessible via the EMEP homepage (www.emep.int). The objective is to present these data to national experts for review and to assist them in preparing their national PM inventory on emissions in the year 2000 for submission in the beginning of 2002.

13. Recent findings on non-agricultural ammonia emissions in the United Kingdom indicate that such emissions may constitute up to 20% of total national emissions instead of 5% as previously estimated. Emissions that had not previously been included in estimates are those from horses and from the catalytic converters fitted to vehicles. Further work is necessary to assess the consequence of these findings.

II. MODELLING PARTICULATE MATTER POLLUTION

14. The Task Force adopted the report on the workshop on the potential and costs for controlling fine particle emissions in Europe and decided to annex it to this report.

A. Integrated assessment model developments

15. Since the workshop, CIAM has further developed the RAINS model. For primary emissions of particulate matter (PM), all data related to the abatement potential and the cost of control measures for the countries in Europe are now available on the Internet (www.iiasa.ac.at/~rains). National experts are encouraged to review the data and present comments and corrections to CIAM. Experts at CIAM are ready to assist Parties in this task if necessary.

16. The PM module of RAINS is designed to fit a range of possible health impact hypotheses. At present, RAINS distinguishes three size classes: the fine fraction (diameter < 2.5 ìm, i.e. PM2.5), the coarse fraction (diameter between 2.5 and 10 ìm) and particles with a diameter larger than 10 ìm. The model provides specific emission factors and removal efficiencies for each of these classes. Work is under way to examine specific types of PM, such as soot and other carbonaceous particles.

17. Further work has also been done to examine areas of uncertainty concerning the emission factors. This concerns, in particular, PM emissions from wood burning, re-suspension (road and rail) and material handling. In all three areas, more recent findings indicate that earlier studies overestimated the importance of such emissions. Further work is warranted to better understand the importance of agricultural emissions.

18. In all countries many abatement measures are already in place and some of these control technologies have very high removal efficiencies (see fig. II). Assumptions about the implementation of control measures in a country therefore have a strong impact on the calculated emissions for a current legislation (CLE) scenario. To obtain a reliable starting point for further analysis, it is crucial to use accurate information on the control measures in place in each country.

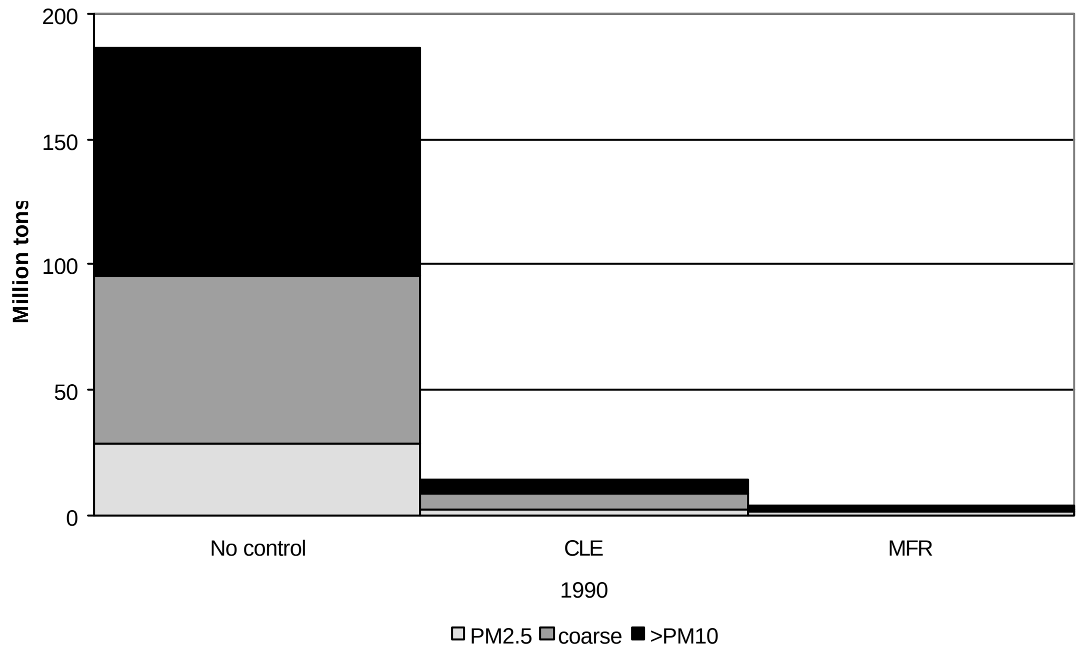

Figure II: Hypothetical primary emissions of particulate matter in 1990 without any end-of-pipe emission controls (left bar); actual emissions in 1990 (centre bar) and hypothetically maximum technically feasible reductions (right bar).

19. CCC will assist CIAM with extending the PM module to cover heavy metals emissions. This work is expected to be ready by the end of 2001 and would provide the basis for modelling heavy metals exposure in Europe.

20. Imperial College has further developed its integrated assessment model to cover primary PM (either as PM2.5 or as PM10). The new model, ASAM-P, uses a simplified source-receptor relationship developed by Imperial College. It applies the cost function prepared by CIAM. The model allows the development of cost-effective abatement strategies for Europe to reach either a defined reduction of human exposure to PM or a defined reduction in PM concentrations. First illustrative results are available.

21. ASAM-P has also been used to explore options for target-setting and for defining exceedance functions in assessing strategies to reduce long-range transported PM. Modelling results differ depending on the choice made. The results will have an impact on the cost-effective choice between regional and local measures and place different burdens on countries.

B. Further results on the assessment of health impacts

22. The World Health Organization (WHO) convened a working group in Bilthoven (Netherlands) in November 2000 to develop guidelines for methods to quantify health impacts and their application. The conclusions and recommendations for future health impact studies have to be taken into account in future integrated assessment modelling work. Long-term cohort studies deliver the most complete estimates of health impacts (e.g. attributable numbers of deaths and reductions in lifespans). Since, however, only few such studies are available, their results have to be transferred to other countries. Such a transfer has to be done carefully. There is a need for careful definition of health end-points to avoid double counting. Health studies should present sufficient levels of detail to give a complete picture. The exposure characterization should mirror overall exposure and not only focus on single pollutants, as summing the results of single-pollutant studies might lead to double counting. It is important to present a full sensitivity analysis to give useful information for decision makers. There is a need for further research, in particular for further cohort studies.

23. The Network of Experts on Benefits and Economic Instruments (NEBEI) conducted a workshop on the measurement and valuation of health impacts, in London on 19-20 February 2001. The results confirm most of the conclusions of the WHO meeting. They are presented in a report to the Working Group on Strategies and Review (EB.AIR/WG.5/2001/4). Presentations made at the workshop are available on the Internet (www.unece.org/env/nebei).

24. A study conducted at Finnish Environment Institute in cooperation with Imperial College London and CIAM estimated the relative importance of exposure of urban populations in Europe to primary PM10 and PM2.5. The study developed a methodology to determine human exposure to PM and the related risks for health impacts based on European emission data, atmospheric transfer information and a rural/urban population map on a 50 km x 50 km grid scale. Calculations were conducted for the years 1990 and 2010 using the current legislation scenario. The results can help identify areas in Europe where a large urban populations are exposed to high primary particulate concentration levels due to emissions of local origin.

25. A research note prepared by France’s National Institute for Industrial Environment and Risks (INERIS) presented background information for a proposal to include other PM effects

in the assessment work and not only health impacts. PM pollution contributes to, or interacts with, a wide range of health and environmental effects, including photochemical pollution, visibility, climate change and the perturbation of the hydrological cycle. This wide range of effects calls for a careful assessment of all implications of strategies to abate primary PM and the precursors of secondary PM. The note argues that this broader perspective of the PM problem should be taken into account when developing cost-effective abatement strategies. INERIS offered to contribute to this task.

C. Progress in atmospheric modelling and measurement of PM

26. CCC announced that a report on PM measurements and source allocations would be finalized by the end of June. A joint EMEP report by three EMEP centres (CCC, MSC-W, CIAM) on measurements, modelling and emissions of PM will be presented to the EMEP Steering Body.

27. MSC-W reported on progress with the verification of the aerosol dynamic module (MULTIMONO) developed in cooperation with the University of Helsinki. First steps have also been initiated to include aerosol dynamic processes in the description of transport of primary particles and results will be presented to the Steering Body of EMEP.

28. Progress is also under way in the calculation of source-receptor relationships. MSC-W, in collaboration with CIAM, is examining four sample countries in order to identify whether there are significant non-linearities in the air concentrations of atmospheric aerosols with respect to envisaged emission changes in 2010. On the basis of this study, CIAM will develop a statistical model that will update and extend the transport coefficients to be used in the RAINS model.

D. Urban modelling

29. The Ministry for Urban Development of Berlin has investigated the sources of particulate matter in the Greater Berlin area based on measurements of particle components. Results indicate that at a busy traffic spot 27% of PM10 concentrations originate from local transport sources, 37% from other local sources and 36% from sources outside the Greater Berlin area and that in the urban background almost half of PM10 is secondary aerosol. As PM10 accumulates in urban areas in addition to a significant large-scale particle background load, urban areas should be expected to exceed the environmental targets for particulate matter.

30. The results from Berlin indicate that, in extending the integrated assessment modelling tools for particulate matter, coverage of the urban scale will be vital for assessing the measures

necessary to meet the air quality objective for PM. A full year of measurements of PM components was planned in Berlin inter alia for model validation purposes. A model tool is being developed by the German Federal Environment Agency allowing simulation of ozone and PM on a regional and urban scale with Berlin as a test area. A similar activity is being conducted for the Rhine-Ruhr area by the State Agency in North-Rhine Westphalia. The Federal Agency and the Ministry for Urban Development of Berlin also offered to contribute to the joint project by MSC-W, CIAM and the EC Environment Institute at the Joint Research Centre (JRC) referred to in paras 33 and 35 below.

31. Imperial College has developed an urban-scale integrated assessment model (USIAM) applied to London and based on principles similar to those of the ASAM model. This model considers PM10 in relation to urban air quality standards, combining long-range transport, urban scale and local street contributions. Source apportionment is combined with scenarios incorporating both technical measures (e.g. particulate traps and fuel switching) and non-technical measures (e.g. public transport, economic instruments, low emission zones). The ranking order according to the costs of such measures can vary greatly depending on whether the gross costs or net costs are considered.

32. Within the EEA ShAIR project, the urban air quality models used for the EC Auto Oil II Programme have been improved and linked to the output of the RAINS model (see also para. 39). The generalized empirical approach (GEA) describes in a simplified way SO_2, NO_2, ozone and PM10 concentrations in over 300 cities covering 30% of the European population. Analyses show that by 2020 EC air quality limit values for SO_2 will still be breached in urban areas of eastern Europe. EEA offered to share the results of its Kiev 2002 report on urban air quality and to assist in analysing the urban air quality consequences of new abatement strategies. EEA intends to update its empirical approach of PM urban modelling as soon as reviewed PM data become available.

33. A joint project by MSC-W, CIAM and JRC at Ispra (Italy) has been drawn up to address urban air pollution (ozone, PM10, and PM2.5) and its linkage to regional background pollution. A comparison of urban and regional dispersion will be conducted with the objectives of exploring the importance of local and regional emissions for urban air quality and assessing the response of the various models towards changes in local and regional precursor emissions. The findings of the model intercomparison, i.e. the ranges of model responses towards urban and regional emission reductions, will then be used in the RAINS model to evaluate the balance between international and local measures.

34. A series of model intercomparison workshops open to all interested urban modelling groups will be conducted covering different urban models that apply the same emission data and meteorological assumptions. Four cities (Berlin, London, Marseilles, France, and Milan, Italy) have been selected so far, but the project will be open to participation from other modelling groups. The intercomparison workshops will be coordinated by JRC (Mr. Frank Raes). The work will start in 2002 with ozone. Five scenarios are envisaged: 1998 (as the base year), 2010 CLE, 2010 Maximum Feasible Reductions (MFR), CLE with a 10% NOx reduction and CLE with a 10% reduction in volatile organic compounds (VOCs). PM will be addressed in 2003, but depending on the availability of additional resources that would help advance the work on the operational PM transfer model, the PM part of the project may already start in 2002.

35. A preparatory EMEP workshop to cover the atmospheric part of the project will be held near Helsinki on 10-12 October 2001. A workshop, together with EUROTRAC, on NOx/VOC limitations to ozone formation will be held in Gerzensee (Switzerland) in December 2001.

36. The Task Force had a preliminary discussion on the scope of urban modelling in the context of regional integrated assessment modelling. There was general agreement that the integrated assessment models could make a contribution to:

(a) Perform health impact assessment for the review of the Gothenburg Protocol and CAFE; and

(b) Determine the cost-effective balance between regional policies and local abatement policies (for the review of the Gothenburg Protocol and for CAFE).

Further research will assess the appropriate spatial and temporal resolutions of urban models to address these issues, also taking into account the results and limitations of epidemiological studies. It was debated whether integrated assessment models should be geared towards assessing whether short-term air quality limit values as established by the EC air quality daughter directives would be complied with. A further question was related to the need to include concentrations of NO_2 in such models. Such modelling required more detailed models, for instance nested regional/national/local/street-canyon models.

37. In considering these questions, it should be understood that one regional integrated assessment model cannot efficiently serve many different purposes. As urban-scale features will be dealt with in the future work for the review of the Gothenburg Protocol and under the CAFE programme, there is an increasing need for involving experts at the local levels. It remains to be examined how this could best be achieved.

38. The Task Force agreed to bring these questions to the attention of the Working Group on Strategies and Review and the CAFE Steering Group and seek guidance concerning the exact purpose of this work and on the priorities for the different tasks. It also agreed to devote the Task Force workshop in the autumn 2001 to the issue of urban modelling.

III. INTEGRATED ASSESSMENT ON THE GLOBAL SCALE

39. EEA presented an evaluation of the projections in the report 'European Environment at the Turn of the Century', linking global-regional-urban integrated assessment modelling scenarios. The study identifies a number of remaining problems:

- Inconsistency between the scenarios at different scales (global-regional-local);
- Missing connections between models used for assessment at different scales;
- Lacking information on geographical, sectoral or thematic issues.

EEA offered to assist in the further development of a baseline scenario for specific sectors in cooperation with Environment and other directorates (Transport and Energy, Agriculture) of the European Commission.

40. The International Union of Air Pollution Prevention and Environmental Protection Associations (IUAPPA) initiated work to examine the feasibility for extending the experience of the Convention to other regions of the world, as had been requested at the Rio Conference. The study will feed into the follow-up conference (Rio +10) scheduled for September 2002. The study shows that there are no apparent theoretical obstacles to extending regional modelling work to the global level. The quality of emission data at the global level is improving rapidly. Given the globalization of the economy, abatement techniques available in the UNECE region can be assumed to be available worldwide. Atmospheric transport is relatively well understood, with several models already working on the global scale. Most problematic is the estimation of ecosystem sensitivity, which is less developed in other regions.

41. Among the main advantages to performing integrated assessment on a global scale is the possibility of establishing interlinkages between different environmental stresses, such as climate change and particulates. A global integrated assessment would have to adapt to the different necessities in the different regions, and would probably benefit from the aggregation of several integrated assessment studies on different scales. There is a need for political support to make such work acceptable in the different regions and the initiative for work should preferably come from those regions. Much of the support for air pollution policies is driven by health concerns with some focus on the large "mega-cities". This is likely to

determine the priority given to different issues and work in other regions may start with PM and ozone before moving to the other regional pollutants.

42. The International Institute for Applied Systems Analysis (IIASA) has finalized a new version of its RAINS-Asia model. Due to recent economic changes, emission projections for SO_2 and NOx up to the year 2020 are much more favourable than estimated in the mid-1990s. A decoupling of energy consumption growth from economic growth and the growing share of gas are among the main reason for this shift, but also some abatement measures are being implemented and are taking effect. Nevertheless, the levels of environmental protection are expected to continue to deteriorate up to 2020. RAINS-Asia now includes an optimization tool and results show that there is a large potential for cost-savings.

43. Integrated assessment modelling is an important analysis tool for IPCC. The work of IPCC also covers SO_2, NOx, VOCs and ammonia. A special report on emission scenarios (SRES) that includes these pollutants was published in 2000. In most SRES scenarios, after an initial increase, sulphur emissions are assumed to decrease worldwide after a few decades, due to concerted policy action. This is one of the main reasons that in the third assessment report the projected climate effects (temperature, sea level) exceed those in earlier IPCC reports. Recent results of Working Group III of IPCC show the importance of synergies between global, regional and local pollution abatement efforts. Greenhouse gas mitigation can have very important ancillary benefits for regional and local air pollution, and vice versa. For instance, reducing tropospheric ozone has been shown to yield important benefits for climate change. Such synergies have a large potential that should be exploited more actively. More detailed analysis at the regional level is needed, especially to improve knowledge on future emissions of NO_x and other ozone precursors, and on options for abatement synergy. The Chairman will continue to strengthen the exchange of information between the Task Force and IPPC modelling work. He will explore the possibility of exchanging information on scenarios between modelling groups under the two forums.

IV. INTEGRATED ASSESSMENT MODELLING ACTIVITIES BY PARTIES

44. The secretariat informed the Task Force about progress in setting up national focal points for integrated assessment modelling. Twenty-two Parties had nominated such focal points. Those Parties that have not yet nominated experts are encouraged to do so.

45. A collaborative project (MERLIN) conducted by six institutes in different European countries, coordinated by the University of Stuttgart (Germany) and funded by the European Commission’s Directorate General for Research, aims at developing an integrated assessment model for European air pollution. The model will cover regional air pollution, global warming

and urban air quality. It will be able to perform cost-effectiveness and cost-benefit analyses of European abatement strategies. Benefit assessment uses the results of the EC ExternE project. MERLIN consists of linked models covering emissions, atmospheric transport (using the EMEP MSC-W model), urban air quality models and a macroeconomic model. The modelling tool is expected to be ready by the end of 2002.

46. In Poland an integrated assessment model has been developed extending the IIASA RAINS software to adapt it to national purposes. Previous modelling had focused on energy and macroeconomic modelling to support national environmental policy development. This work was extended to cover also the ecosystem effects. Nested with the continental scale EMEP model, but using a national Eulerian model, depositions in Poland are modelled at a resolution of 12.5 km x 12.5 km. The model includes a detailed inventory of sources and available abatement techniques. The model has been tested to examine a number of scenarios targeted to reach specified emission ceilings and protection levels. Further work is planned in order to include other air pollutants, e.g. PM. The model is also intended to be used to develop the national strategy to implement the Gothenburg Protocol.

47. The Swedish Parliament adopted 15 environmental quality objectives for Sweden to reach sustainability by 2020. Four of these are directly linked to regional air pollution. A study at the Swedish Environmental Research Institute (IVL) developed alternative cost curves to estimate the cost of reaching these targets. The approach followed differed from the RAINS model notably by including structural change e.g. in energy and transport. Results demonstrate that there is significant potential for structural change that is not taken into account in the RAINS model. Therefore, estimated emission control costs estimated are much lower than those used in RAINS for the negotiations of the Gothenburg Protocol. Work on this approach will continue.

48. The Chairman reported on information received from the United States Environmental Protection Agency (US EPA) on the results of recent cost-benefit assessments in the United States that show that structural changes due to climate change policies would create sufficient secondary benefits by reducing acidification, eutrophication and exposure to ozone and fine particles to offset their costs. Climate change measures were identified as the most cost-effective measures to abate acidification and fine particles. These findings are consistent with comparable studies in Asia and Europe.

V. UNCERTAINTY ANALYSIS

49. CIAM conducted a study funded by the Department of the Environment, Transport and the Regions of the United Kingdom (DETR) on uncertainty analysis for integrated assessment modelling results focusing on two specific RAINS model scenarios. An analytical method to propagate errors through the calculation chain of the RAINS model was developed combining uncertainty parameters for all individual model input parameters. Work so far has concentrated on scenario analysis and has not covered model optimization. For the analysis, data for countries covered by the model were classed into three categories. The following uncertainty ranges, based on expert judgement, were used in the analysis:

	SO_2	NO_X	Ammonia
Activity rates: 1990 2010	0.06-0.20 0.12-0.30		0.05-0.50 0.10-1.00
Emission factors	0.05-0.10	0.075-0.15	0.15-0.40
Removal efficiencies	0.005-0.05		0.015-0.10
Transfer coefficients	0.10-0.15		
Critical loads	0.22	0.12	

50. To estimate the overall uncertainty of emission estimates used in the model, uncertainty ranges were assumed for the emission factors and all other relevant input parameters for emissions. Using error propagation, the overall uncertainties of emission estimates, both for 1990 and for 2010, were estimated. It was found that the error compensation potential has crucial influence on the overall uncertainties for emissions data. SO_2 emissions data may turn out to be more uncertain than ammonia data if individual source categories dominate overall estimates. The results of this work can be used to determine the sensitivity of emission estimates to variations in different input parameters.

51. The following table is an example of the type of information that the method can produce. It shows the results of a sensitivity analysis: 95% confidence intervals for estimates of national SO_2 and NO_x emissions in the United Kingdom. Values describe the 95% confidence interval in national total emissions only if the uncertainties of the particular parameter are considered and the uncertainties for all other parameters are excluded.

	SO_2		NO_x	
	1990	2010	1990	2010
Activity data	±8 %	±14 %	±5 %	±8 %
Emission factors	±7 %	±6 %	±9 %	±7 %
Removal efficiency	±0 %	±3 %	±0 %	±3 %
All factors considered	±11 %	±15 %	±10 %	±11 %

52. A preliminary analysis assesses uncertainties in the deposition estimates. Preliminary results show that uncertainty ranges tend to be large in areas where single sources or individual source categories dominate the deposition.

53. The analysis of the uncertainties in critical load data - and thus the overall uncertainties in ecosystem protection - was based on data collected by CCE and derived from a detailed analysis of input parameters used for German critical loads calculations. The analysis has to be regarded as preliminary since: (i) data for the whole of Europe are not yet available, and (ii) the propagation of uncertainties from individual critical loads to cumulative distribution functions within a grid square has not yet been modelled satisfactorily.

54. For estimates of ecosystem protection, the spread of critical loads within a grid cell appears to have a stronger impact on the resulting uncertainties than possible error compensation (as long as perfect correlation is assumed). This means that in cases where countries report only few critical loads for grid cells or where these critical loads are in a similar range, estimates of ecosystem protection are rather uncertain since, for example, a small change in these data or in deposition might change the protection status for many ecosystems. The traditional deterministic calculations of the RAINS model represent the median of the probability distribution and thereby assume a 50% probability of the achievement of the environmental targets. It is clear from the calculations that there is a significant uncertainty interval around the median and, depending on the level of confidence one puts into the calculations, the achievement of the original policy target might appear in a different light.

55. The deterministic calculations suggest 4.1% of ecosystems in the EC remain unprotected from acidification with the emissions of the basic scenario (‘revised G5/2’) used for the Gothenburg Protocol negotiations. However, the preliminary analysis reveals a confidence interval ranging from 1.8% of ecosystems remaining unprotected to 12.4% of ecosystem area with acid deposition above the critical loads. As a conclusion, the setting of interim or long-term environmental policy targets should not only address the desired level of protection but at the same time also consider the certainty with which this level should be achieved. As shown above, the uncertainty range is considerable, and it needs to be explored

how different confidence levels will influence the economic efforts that are needed to attain targets.

56. A difficulty for such analyses is obtaining the uncertainties of the input parameters. It is very demanding to estimate uncertainty distributions, especially their correlation structure, for all model input parameters. The work of CIAM does not cover the full range of potential factors that contribute to the uncertainties in the estimates of atmospheric dispersion of pollutants. Further insight could be gained by additional analysis, for instance with the EMEP dispersion model. Further work is hence necessary and should be done in cooperation with experts from different fields. The Chairman will explore the possibility of organizing a workshop on this topic.

VI. PLANNING FURTHER WORK

57. The Task Force discussed the budget requirements of CIAM. It recognized that CIAM would receive funding through the EMEP Protocol of US$ 66 000, for temporary external assistance to MSC-W. The Executive Body had budgeted for 2001 an additional US$ 180 000 and for 2002 and 2003 US$ 240 000 for CIAM in its decision 2000/3 (ECE/EB.AIR/71, annex III). Decision 2000/3 included a recommendation to Parties to contribute to the cost of core activities. However, by May 2001 not many Parties had followed that recommendation.

58. CIAM explained that due to the uncertain funding situation it depended on other sources of funding. The International Institute for Applied Systems Analysis (IIASA) covered some core funding of its scientific research work. Additional resources came from specific research contracts with Parties (Netherlands, Switzerland, United Kingdom, EC) and with the EEA. The table below gives an estimate of budgeted resource use for 2002 and 2003, also listing the areas of work that would not be covered by the funding through the Convention’s trust fund and would therefore require additional resources from research contracts.

Table. Budgeted resource requirements of CIAM covered by the Convention, 2002 and 2003 (thousands of US$)

Tasks	2002	2003
1. Dynamic modelling:		
Acid models	60	-
Cost curves	-	-
Optimization	-	60
2. Particulate matter cost curves	60	30
2020 projections and baseline emissions	-	60
Update of cost curves for other pollutants	60	30
Urban scale cost curves	-	-
3. Health impacts		
- Methodology	30	-
- Data	-	30
- Urban scale	-	-
4. Source-receptor relations	66	66
5. Optimizations PM and urban	-	-
6. Uncertainty management	-	-
7. Scenarios	-	-
8. Public access (Internet)	-	-
Cooperation with National Focal Points	30	30
Proposed funding through EMEP and decision 2000/3	**66+240**	**66+240**

59. Updates to the critical load data used for the Gothenburg Protocol have been received by CCE from about 70% of the Parties. The emphasis has been on: (i) eliminating shortcomings from the old data set; and (ii) compiling separate data sets for each ecosystem category (forest soils, surface waters, semi-natural vegetation, etc.). This would make it possible to differentiate exceedance and protection per centages for these ecosystem categories, both in scenario analyses and in optimization. It is planned to include the results of this work into integrated assessment models in autumn 2001.

60. Dynamic modelling work under the Task Force on Mapping aims at developing a methodology that will allow an assessment of ecosystem recovery processes, once depositions are reduced below critical loads. Work on dynamic modelling is progressing, but results for inclusion into integrated assessment models are not expected before 2004. However, sufficient information to conduct some scenario analyses is expected to be available by 2003.

61. The next meeting of the Task Force on Integrated Assessment Modelling is scheduled for May 2002. The venue has not yet been chosen. In November 2001 a workshop will be held at CIAM at IIASA in Laxenburg (Austria) to follow up the discussion on the requirements

for urban modelling within the context of integrated assessment modelling. In January 2002 a workshop is scheduled on uncertainty management.

Annex

POTENTIAL AND COSTS FOR CONTROLLING FINE PARTICULATE EMISSIONS IN EUROPE

Conclusions from a workshop held at IIASA in Laxenburg (Austria), 23-24 November 2000

Introduction

1. The workshop was attended by 64 experts from Austria, Belgium, the Czech Republic, Finland, France, Germany, Hungary, Italy, Netherlands, Norway, Poland, Slovakia, Spain, Sweden, Switzerland, the United Kingdom, and the European Commission, as well as the UN/ECE secretariat, the European Environment Agency, IUCN, the International Union of Producers and Distributors of Electrical Energy (UNIPEDE), CONCAWE and ACEA. It was organised by the Task Force on Integrated Assessment Modelling and the EMEP Centre on Integrated Assessment Modelling (CIAM). The German Federal Environment Agency supported the workshop.

2. The RAINS model has now been extended to include primary emissions of particulate matter. The purpose of the workshop was to check the completeness of the new RAINS model framework and its databases and to establish a procedure for data quality control for the next few years. The findings of the workshop will be presented at the twenty-sixth meeting of the Task Force on Integrated Assessment Modelling, which will take place on 14-16 May 2001 in Brussels.

Background

3. Particulate matter found in ambient air is composed of a wide range of substances originating from many different emission sources. Primary aerosols are emitted directly into the atmosphere by numerous anthropogenic and natural processes. Secondary aerosols formed in the atmosphere from precursor gaseous emissions, such as SO_2, NO_x, NH_3 and VOC, also contribute to total particle concentrations in the ambient air.

4. The sizes of particles found in the atmosphere range from a few nanometres to well above 10 micrometres. Small particles (diameter < 2.5 ìm, i.e. PM2.5) travel further than the coarse fraction (diameter between 2.5 and 10 ìm) and thus contribute significantly to long-range transboundary pollution of atmospheric aerosol.

Health effects

5. It is important to acknowledge that the toxicological mechanisms of PM are still not fully understood and that this scientific uncertainty will probably not be solved within the coming four years. Based on epidemiological surveys a statistical association is found between PM10 concentrations and both mortality and respiratory diseases, but several (yet unproven) hypotheses exist on the causal toxicological mechanisms focusing either on the mass of PM2.5, ultra-fine particles (smaller than 0.1 ìm), PM with special chemical characteristics (acid, carbonaceous or particles containing heavy metals or biological components) or numbers of particles. There are also potential carcinogenic effects from diesel exhaust particles (due to carbonaceous soot).

PM concentrations in Europe

6. Ambient concentrations of PM10 vary in Europe from 10 ìg/m^3 (annual average) in remote areas to about 100 ìg/m^3 in heavily polluted areas. At most rural monitoring stations about 80 to 90 per cent of total suspended particle matter (TSP) is constituted of PM10, and typically about 60 per cent of monitored PM10 consists of PM 2.5. Measurements in Europe and North America indicate that 30-40 per cent of the PM2.5 concentrations might be carbonaceous.

7. Higher PM concentrations occur in urban areas, mainly caused by local emissions of larger particles (PM>2.5). However, for particles smaller than 2.5 ìm, studies show that even in central urban areas between 30 and 70 per cent of observed PM2.5 concentrations might be attributed to long-range transport.

8. The air quality directive of the European Community (1999/30/EC) stipulates for PM10 a limit value of 40 ìg/m^3 as an annual average from 2005 on and sets an indicative limit of 20 ìg/m^3 for the year 2010. The United States has set a limit on the annual mean for PM10 of 50 ìg/m^3 and for PM2.5 of 15 ìg/m^3. The European Commission will revisit its PM legislation in 2003 to review the indicative PM10 limit value for 2010 and possibly decide about alternative size fractions of PM concentrations (e.g. PM2.5) to more effectively safeguard human health.

Particulate matter emissions in RAINS

9. The design of effective emission control strategies will crucially depend upon the particle properties that are believed to cause health damage. The current version of the RAINS

model considers PM emissions in three size classes: the fine fraction (diameter < 2.5 ìm, i.e. PM2.5), the coarse fraction (diameter between 2.5 and 10 ìm) and particles with a diameter larger than 10 ìm. The last fraction is considered because several countries measure and report TSP.

10. Additional work is envisaged to include the chemical composition of particulate matter (e.g. carbonaceous, heavy metals, alkaline) and, eventually, if necessary from the requirements from the study of health effects, the number concentration of the aerosol.

11. The RAINS PM model should ultimately assist in identifying cost-effective balances between control measures for primary emissions of particles (distinguishing the various size classes) and further controls of the precursors of secondary aerosols, taking into account that stringent emission controls are already applied in several sectors.

12. The model framework should also help to put persistent uncertainties into context and to identify robust emission control strategies. It should become possible to compare practical implications of alternative concepts, e.g. the precautionary principle with no-regret strategies.

Sources of primary PM emissions

13. Based on the statistical information available in the RAINS model and on the literature, IIASA conducted a preliminary estimate of PM emissions for the year 1990 for all European countries. These data are well documented and can be used as additional reference material by national experts when compiling their official primary particulate matter emission estimates in 2001 (see para. 28 below).

14. According to these preliminary estimates, the largest contribution (34 per cent) to overall emissions of the fine fraction (PM2.5) comes from domestic sources (including wood stoves), followed by boilers in power plants and industry (28 per cent) and industrial production processes (25 per cent). The share from traffic is estimated at 13 per cent. For the coarse fraction, about 50 per cent of emissions are estimated to result from large boilers, 30 per cent from domestic combustion and 16 per cent from industrial processes. Larger particles (> 10 ìm) originate in almost equal shares from domestic combustion (coal stoves), large boilers and industrial production processes.

15. RAINS estimates also allow aggregation of the coarse and fine fractions to PM10 emissions, if this is of interest. Combustion in large boilers is the dominant source for PM10 (38 per cent), followed by combustion in small stoves (33 per cent) and industrial processes (20 per cent). Eight per cent originate from traffic. Non-exhaust emissions from mobile sources

(tyre and brake wear, road abrasion) represent about 2 per cent of the emissions of the coarse fraction (PM10 - PM2.5).

16. As indicated above, combustion of wood in residential stoves emerge as one of the most important contributors to total PM2.5 emissions from the preliminary analysis. However, there are significant uncertainties about the emission factors from wood-burning as reported in the literature.

Options for reducing primary PM emissions

17. There is a wide range of measures to control primary emissions of particulate matter from stationary and mobile sources. Most prominently, particle filters (cyclones, baghouses, electrostatic precipitators) which are widely applied in practice, can reduce PM concentrations in flue gases from stationary sources by up to 99.9 per cent. It is, however, important to note that these technologies are usually more efficient for large-size fractions, but capture only a small share of the fine particles (e.g. PM2.5). Also for mobile sources, combinations of engine technology and fuel specifications achieve large reductions in PM emissions.

18. No control measures are at present foreseen for inclusion in the model for non-exhaust emissions (tyre and brake wear, road abrasion) from mobile sources.

19. Dominant abatement techniques are primarily used to reduce the mass of particulate matter emissions. In some cases, there is information available on the control efficiencies for different aerosol sizes but there is little information on potential and control costs related to the chemical composition or number distribution of the aerosol.

20. According to 1990 estimates, diesel vehicles contributed 5-10 per cent to the total mass of PM2.5 emissions in Europe. However, their contribution to total population exposure might be considerably higher since they are directly emitted in cities close to where people live. There is a need for further urban-scale modelling to fully assess the cost-effectiveness of additional vehicle measures in terms of health protection. Further research into urban PM exposure is expected to be covered under the Clean Air for Europe (CAFE) Programme of the European Commission.

Emission projections

21. At least for large stationary sources, particle control is now common practice throughout Europe. Primary emissions of TSP and PM10 have been reduced dramatically

since the 1950s. It is estimated for all of Europe that in 1990 about 95 per cent of large particles (>10 ìm) in the raw gases were removed by abatement measures. However, for PM2.5 only 82 per cent of particles in raw gases were eliminated.

22. The historic decline in primary emissions of TSP and PM10 is also relevant for the dynamic modelling of ecosystem effects of acidification because the deposition of acidifying compounds has long been partly compensated by a high base cation deposition.

23. For 2010, preliminary RAINS estimates suggest that with the current legislation for controlling particle emissions Europe's total primary emissions of the coarse fraction could decline further by about 66 per cent, while for PM2.5 only a 40 per cent decline could be expected. PM10 would be 50 per cent lower. Major factors contributing to this decline are control measures for large stationary sources (cyclones, wet scrubbers, fabric filters and especially electrostatic precipitators), changes in vehicle fuel quality (decrease in lead and sulphur content), changes in vehicle engine design and exhaust treatment, and fuel switches in domestic heating.

Potential and costs of additional control

24. CIAM presented a framework to estimate the potential and the costs for the control of fine particulate emissions (accessible on the Internet at www.iiasa.ac.at/~rains). Accurate estimates of the potential and costs for further controlling PM emissions depend crucially on solid information about abatement measures already in place, the size distribution of emission sources, the vintage (or remaining lifetime) of installations, and the applicability of control options. Verification by national experts of these assumptions will be essential.

25. Assumptions about the possibilities for retrofitting emission sources which are already fitted with PM control devices will be crucial for estimating the remaining potential for further controlling PM emissions in the future. Technically, retrofitting heavy-duty vehicles and already-controlled large point sources is possible, but will be expensive.

26. Such retrofits to existing control devices will be an important issue when limit values should be met by a certain date. In order to develop a cost-effective multi-sectoral approach fuel switches (especially for domestic heating and district heating and the fuel used in urban captive fleets such as buses and taxis) should be incorporated in the RAINS model.

Data quality verification by national experts

27. All assumptions and data that are used in the RAINS model are made available on the Internet (www.iiasa.ac.at/~rains). National experts are invited to analyse these data thoroughly, compare them with national data and report their findings to CIAM at IIASA. Differences will be discussed bilaterally with CIAM. The review of data in the RAINS model (related to emission-generating activities and costs) will be an ongoing process that should be finalized by 2003.

28. At the beginning of 2001, TNO will provide its PM-emission estimates for 1995, which are prepared within the framework of the joint CEPMEIP project of EEA and EMEP. Also based on CEPMEIP, the Task Force on Emission Inventories and Projections will update the emission inventory guidelines in 2001. Subsequently, by the end of 2001, Parties will be requested to submit officially their emission estimates (for the primary PM as well as SO_2, NO_x, NH_3 and VOC) for the year 2000 to EMEP. These data will then be available as base year estimates for the review of the Gothenburg Protocol in 2004.

Improvements and uncertainties

29. Communication of uncertainties to policy makers and stakeholders will be crucial for the acceptance of the scientific contribution to the policy process. Continued interaction between national and international atmospheric scientists and integrated assessment modelling experts is recommended in order to cross-verify the scientific findings. In the coming years, improvements are expected on: (i) the definition of health impact indicators that can be linked to the different species of PM; (ii) the emission estimates of PM; (iii) modelling of abatement strategies, including fuel switches; (iv) the modelling of atmospheric transport and monitoring of PM concentrations; (v) the estimation of urban population exposure; (vi) the verification by national experts of potential and control costs data introduced in RAINS; and (vii) sensitivity analysis of those elements in the framework that remain highly uncertain.

30. The work to be done requires effective cooperation between experts in Europe and North America, as well as interaction between work under the CAFE Programme of EC and work under the Convention.