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Item 4 (f) of the provisional agenda

INTEGRATED ASSESSMENT MODELLING

Addendum

LINKAGES AND SYNERGIES OF REGIONAL AND GLOBAL EMISSION CONTROL

Summary report and conclusions of the workshop

Introduction

1. The workshop on linkages and synergies of regional and global emission control took place on 27-29 January 2003 at the EMEP Centre for Integrated Assessment Modelling (CIAM) at the International Institute for Applied Systems Analysis (IIASA) in Laxenburg (Austria). It was organized by the Task Force on Integrated Assessment Modelling and CIAM and supported by the Topic Centre on Air and Climate Change (ETC/ACC) of the European Environment Agency (EEA).

2. The workshop was attended by 75 experts from Austria, Belgium, Denmark, Finland, France, Germany, Italy, the Netherlands, Norway, Poland, Portugal, Sweden, Switzerland, the

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United Kingdom, the United States of America and the European Community, as well as representatives of the Coordination Center for Effects (CCE), the UNECE secretariat, the World Health Organization European Centre for Environment and Health, the European Environment Agency, the European Community Joint Research Centre (Institute for Environment Sustainability), the European Chemical Industry Council (CEFIC); the Union of the Electricity Industry (EURELECTRIC) and the World Conservation Union (IUCN).

3. An informal report with extended abstracts will be prepared by IIASA. The presentations of the workshop can be found on the Internet at: www.iiasa.ac.at/rains/meetings/AP&GHG-Jan2003/announcement.html.

4. Many of the traditional air pollutants and greenhouse gases have common sources, their emissions interact in the atmosphere, and separately or jointly they cause a variety of environmental effects at the local, regional and global scales. Thus, emission control strategies that simultaneously address air pollutants and greenhouse gases could be beneficial at all scales. The Executive Body at its twentieth session noted with interest the plans of the Task Force on Integrated Assessment Modelling to examine the links and synergies between regional air pollution and climate change, and recognized the importance of these links. Welcoming the work initiated to explore such links, it requested EMEP to address all relevant aspects of these links in its future work.

5. Through a series of brief overview presentations the workshop reviewed, from the air pollution perspective, the scientific knowledge on the physical linkages between the control of air pollution and greenhouse gases (e.g. atmospheric chemistry, impacts, emission control options) and examined possible synergies addressing sectoral emission control options, multi-pollutant strategies and economic instruments. The objective was to identify future directions for integrated assessment modelling under the Convention so that the policy-relevant linkages and synergies could be systematically explored. While the focus of the workshop was on the linkages and synergies from a scientific perspective, the discussion also covered aspects relevant for policy-making in developing air pollution control strategies.

6. The workshop recognized that the numerous linkages and synergies provided a strong argument for developing programmes that addressed air pollution and climate change simultaneously or at least in parallel. The first step was to encourage the development of analytical tools in order to be able to analyse such comprehensive programmes. At the same time, policy analyses of air pollution control should consider the air pollution effects on climate change and vice versa.

I. THE PHYSICAL LINKAGES

A. Atmospheric chemistry

7. The impact of gases and aerosols on climate is usefully expressed as radiative forcing. Radiative forcing is a measure (expressed in Watts per square metre) to estimate, to a first order, the relative impact on climate due to radiatively induced perturbations. The concept assumes a general relationship between global mean forcing and the global mean equivalent temperature response. While the concept of radiative forcing is useful, it does not encompass all the important impacts of changing atmospheric composition on climate, especially at the regional scale and in relation to variables other than surface temperature, such as precipitation.

8. Radiative forcings of the six long-lived trace gases covered by the United Nations Framework Convention on Climate Change (greenhouse gases (GHGs)) have received much attention. Also some short-lived air pollutants, notably ozone and fine particles exert climate impacts. While GHGs are uniformly distributed at the global level, for ozone and fine particles there are some high concentration regions, which are not necessarily close to the sources of the precursor emissions. In some parts of the world, traditional air pollutants have been significantly reduced, which is not the case for GHGs.

9. The radiative forcings of ozone and fine particles are different, both in space and in time, from those of GHGs. Model simulations have shown that short-lived air pollutants can lead to significant regional climate perturbations, especially affecting seasonal precipitation patterns, which may contribute regionally to floods and droughts. Climate control strategies are usually examined at long time horizons, sometimes up to 100 years or more. Air pollutants may affect climate much more quickly and such impacts can also be addressed by policy on shorter time scales.

10. Particulate matter (PM) is a diverse group of substances with different physico-chemical properties and with different impacts on climate. The effects of aerosol forcing on precipitation patterns may be very important. Some of these effects are very uncertain, in particular the indirect effects of aerosols (via cloud coverage and cloud optical properties).

11. Sulphate, nitrate and organic carbon particles in the atmosphere affect the climate in the opposite direction to GHGs, i.e. they tend to have a cooling effect and can lead to reduced precipitation. Other carbonaceous particles (black carbon, soot) are thought to have a positive forcing on the climate though the magnitude of this effect is uncertain. Hence, while the reduction of black carbon will be beneficial in reducing climate change, this is not the case for the reduction of other aerosols.

12. In Europe, black carbon constitutes only a small share (10-15%) of total PM2.5 (PM<2.5μ) emissions. Emission reductions necessary to reduce the health effects of PM will have to reduce not only black carbon but also other components of PM. The net effect of a PM reduction strategy to cut health effects substantially may therefore be an increase in radiative forcing. To reach any given climate targets, such PM reductions will have to be compensated by further measures on other climate gases. At the same time, strategies to reduce PM should be developed so that they place more emphasis on bringing down black carbon emissions than measures do at present. Such strategies will target diesel emissions, biomass burning as well as residential combustion of solid fuels, and should place greater emphasis on non-road mobile sources. Preliminary estimates suggest that ships especially contribute increasingly to black carbon concentrations.

13. Tropospheric ozone has a relatively strong radiative forcing and, therefore, measures to reduce it will be beneficial in reducing climate change. The influence of tropospheric ozone on climate change is better understood than the role of aerosols. Regional ozone levels build up on top of a considerable hemispheric background ozone baseline. Hemispheric ozone baseline concentrations have been increasing by about 0.5 ppb per year and are projected, in some scenarios, to increase in the future. One of the important factors contributing to this increase is the rise in global methane emissions.

14. Methane is important both in building up the hemispheric background of ozone and in increasing intercontinental ozone transport. Methane also exerts direct radiative forcing and is a GHG with a relatively short atmospheric lifetime (12 years). A methane emission reduction strategy will therefore be very effective in reducing both climate change and ozone concentrations. While natural methane emissions are important, the larger (and growing) share is anthropogenic. Preliminary results of work on introducing methane into the RAINS model[1/] show that there is significant potential for controlling methane emissions.

15. Climate change is likely to affect regional circulation and wind patterns. This may affect the accuracy of source-receptor relationships developed on the basis of historic meteorological data. For a relatively short time horizon, such as up to 2020, this effect is not likely to be important and it would be very difficult to quantify.

B. Environmental impacts

16. There are a number of linkages between climate change and air pollution effects, but they can go into different directions and are not yet fully understood. Model results suggest, for example, that: (1) a temperature increase through climate change may reduce ecosystem sensitivity to acidification damage and tends to change deposition patterns so that there will

[1/] The Regional Acidification Information and Simulation (RAINS) model is the integrated assessment model developed by IIASA under the guidance of the Task Force on Integrated Assessment Modelling.

generally be less critical load exceedance; (2) an increase in nitrogen deposition (through air pollution) may raise the ability of plants to store carbon counteracting CO_2 accumulation in the atmosphere; (3) many air pollutants tend to weaken plant growth thereby reducing carbon storage capacity; (4) both climate change and air pollution may adversely affect biodiversity.

II. SYNERGIES OF MULTI-OBJECTIVE STRATEGIES

17. Many measures to cut air pollution also benefit the climate by reducing GHG emissions and vice versa. Understanding these synergies in emission controls and addressing local, regional and global objectives simultaneously, rather than separately, is needed to achieve overall cost-effectiveness. As marginal costs of further air pollution abatement measures tend to increase rapidly once a certain reduction level has been achieved, any potential for cost-savings for strategies to reach air quality objectives must be explored. Synergies may free resources that allow reaching more ambitious targets. Many of the driving forces underlying air pollution and climate change are identical: economic growth, consumption and production processes, and demography. A sustainable development strategy must address these issues in an integrated manner.

18. While there are many synergies in emission control for air pollution and climate change, there are also trade-offs. Some air pollution abatement measures tend to increase energy consumption thereby causing increases in CO_2 emissions. Nitrous oxide (N_2O) emissions may increase through nitrogen oxide (NO_x) reducing catalytic converters.

19. At the global level, stabilizing GHG emissions will lead to a decrease in SO_2 emissions. The extent of this depends on the type of CO_2 measures applied, on SO_2 control measures in place and on the energy scenario assumed. Single sector measures may lead to an increase in SO_2 or PM emissions; for instance, moving out of coal into renewables in the electricity sector in Asia may lead to higher use of coal in some other sectors hence increasing SO_2/PM emissions. Also a regional strategy to enhance the natural gas infrastructure may reduce global CO_2 while increasing SO_2 emissions regionally, due to the risk of switching to coal in gas-exporting countries. The use of biomass (e.g. fuel wood) has been promoted in the European Union (EU). While decreasing CO_2, this has tended to increase PM, CO and volatile organic compound (VOC) emissions in the domestic sector. In the industry and power sector this does not apply, as such emissions can be effectively controlled.

20. The regulatory structure can facilitate multi-emission strategies in the power sector. Multi-pollutant approaches can provide more certainty and reduce costs. For instance, a power company may decide to apply different emission control measures (e.g. a switch in fuel or process instead of some end-of-pipe technology) when addressing multiple substances simultaneously than it would if it addressed emitted substances sequentially.

21. IIASA calculated that the costs of reaching the Gothenburg Protocol emission ceilings could be reduced by more than €5 billion per year by implementing the changes in the energy system necessary to achieve the reductions required by the Kyoto Protocol domestically (i.e. without international CO_2 emission trading).

22. For China, it has been estimated that the cost of cutting CO_2 emissions by 5-10% would be offset by the benefits resulting from reduced health effects of air pollution. Including the effects on crop yield (via decreasing NO_x) increases the “no-regret” level of CO_2 emission cuts to 15-20%.

23. Synergies and trade-offs are also present in agriculture. For instance, certain ammonia abatement measures related to manure application can increase emissions of N_2O, which is an important GHG also covered by the Kyoto Protocol. There are, however, abatement techniques that can reduce this negative impact. Scenario analysis has shown that it is possible to cut ammonia emissions significantly and at the same time reduce nitrous oxide and methane emissions. An integrated approach tends to achieve such synergies at much lower cost.

24. Change in agricultural policy may be an efficient structural measure to reduce the environmental effects of agriculture, although not all structural changes will reduce ammonia emissions. Air pollution may not be a major driving force to bring about such structural change, but knowledge of the air pollution and climate impacts of agriculture has influenced the political process. For integrated assessment modelling, a clear political signal on feasible policy options is important to determine the boundaries of the modelling work.

III. STRATEGIC ASPECTS – THE WAY FORWARD

A. National emission ceilings and international carbon trading

25. GHG emission trading systems can have significant effects on the distribution and levels of air pollution emissions. International emission trading, joint implementation and the clean development mechanism under the Kyoto Protocol have the potential to reduce the overall costs of emission reductions for given targets. As, however, Western Europe is likely to be a net buyer of CO_2 permits from other parts of the world, it is expected to reduce its domestic CO_2 emission less than without trading. This will also tend to shift the significant co-benefits of CO_2 abatement measures from Western Europe to other regions. Unconstrained trading of GHG may not be cost-effective if air quality objectives were to be taken into account. In some countries, GHG trading may prevent the structural measures for CO_2 abatement required to achieve the emission reduction (e.g. for NO_x) necessary to meet the national emission ceilings for air pollutants.

26. In practice, the effects of carbon trading are uncertain. Regional air pollution studies should therefore use different assumptions about the baseline energy consumption (as affected by the Kyoto Protocol) including different assumptions on scope and order of

magnitude of international carbon trading and, possibly, as an extreme case, a situation without the Kyoto Protocol.

27. In developing GHG emission trading, the effects on regional air pollutants (NO_x, SO_2, PM) should be taken into account so as to give realistic estimates of the net cost and the net environmental impacts of trading. Also further research on the effects of GHG emission trading on regional air pollution would be useful.

B. Modelling linkages and synergies of regional and global strategies

28. A combined analysis of air pollution and climate change requires bridging different temporal (from a 10- to a 100-year perspective) and spatial (from local/urban to global) scales. To capture the feedbacks from climate change, air pollution modelling needs to take sufficiently long time horizons in order to take account of the inertia in climate change and the time required for structural measures and technology development to take effect. At the same time, climate research should examine changes that may occur over the next 10-20 years.

29. The linkages between air pollution and climate change are manifold and not homogeneous. Modelling such effects that go in different directions is possible, as long as they can be quantified. Including these effects in integrated assessment models makes it possible to determine strategies that minimize the cost of reaching a given set of objectives.

30. It may be challenging to bring together very different targets, such as health targets expressed in terms of years of lost life expectancy and targets related to climate change, but integrated assessment modelling can assist the policy process in this task. This has already been done in a multi-effect framework before, using a gap closure approach. Approaches that can be extended to link to climate change targets should be examined.

31. By incorporating the most important linkages and synergies with climate change, air pollution-focused integrated assessment modelling will have to be extended to incorporate some aspects of sustainable development strategies, in particular to model structural change. This might, for instance, require general equilibrium macroeconomic modelling. The Task Force on Integrated Assessment Modelling may have to discuss whether new criteria, possibly going beyond a simple cost-effectiveness approach, should be pursued and how to address equity considerations.

32. In further developing integrated assessment modelling to cover these issues, it is important not to lose focus. Rather than incorporating all into one unmanageable modelling framework, other ways of linking results should be explored. The growing complexity of models poses challenges for quality assurance and quality control (QA/QC). This will require an active approach to uncertainty analysis and management. As an increased level of complexity makes the use of

model optimization more difficult, the emphasis should be on finding robust results and communicating them.

33. CIAM should conduct this work, closely following discussions of the Intergovernmental Panel on Climate Change (IPCC) to make appropriate assumptions about the parts of the world and the issues not covered by the RAINS model. At the same time, efforts should be made to inform IPCC about the EMEP work and to encourage global modelling work to adequately cover air pollution related issues.

C. The way forward

34. Focusing on the abatement synergies, CIAM will develop cost curves for the six GHGs (CO_2, CH_4, N_2O, PFC, HFC, SF6) included in the Kyoto Protocol and incorporate them into the RAINS model. In the same way as for the air pollutants included in RAINS, this work will be done country by country for the EMEP region with a time horizon of 2030. In parallel, CIAM will develop methodologies for introducing structural change into the model and for addressing the physical linkages. This work will be completed in 2004.

35. The objective of the work on linkages and synergies between regional air pollution and climate change should be to provide policy makers with the information necessary to make the right choices: (1) to cut pollutant emissions maximizing the positive linkages and minimizing the negative ones; and (2) to take those measures that are the most cost-effective in view of the objectives in both policy areas.

36. At this stage, work should first concentrate on the scientific issues of linkages before addressing the policy process. This will be to the benefit of both policy processes. The Gothenburg Protocol review can take some of the abatement synergies into account, while just addressing the air pollutants responsible for acidification, eutrophication, ground-level ozone and PM pollution. The direct benefits of climate change policies tend to be far away. Highlighting the additional benefits of certain climate mitigation measures on air pollution will make such policies more attractive in bringing the benefits closer both in space (e.g. to the local scale) and in time.

37. Contacts between experts in air pollution and climate change should be enhanced. The approach of EEA in linking climate change and air pollution in one framework (the European Topic Centre on Air and Climate Change) is a good example. There is a need for further workshops to bring the different scientific communities closer together. Also at the policy level, closer contacts between those responsible for air pollution and climate change, both at the national and international levels, would be beneficial. In this connection it is interesting to note that the Directorate-General Environment of the European Commission decided to bring its air quality and

climate change units together under the same directorate from March 2003 onwards to make policy more coherent.

38. In pursuing the work, EMEP should cooperate with IPCC. The linkages and synergies between air pollution and climate change should be examined both from the air pollution and the climate change perspectives. While EMEP should cover the work from the air pollution side based on relevant findings of IPCC, IPCC could address the relevant scientific questions from the climate change perspective. The secretariat and national experts, including the National Focal Points for Integrated Assessment Modelling, should establish the necessary contacts so that relevant IPCC bodies are informed about this suggestion prior to deciding on the topics to be covered by the fourth assessment report.

D. Further research

39. Further research on how air pollutants (ozone and PM) affect the climate is important in view of the significant uncertainties. More research is especially needed to get a better understanding of how the different components of PM have an impact on climate, and this is also important for their effects on human health. Part of this research must aim at improving the observational basis. Measurements are also required to improve emission inventories.

40. The relevant aspects of the effects of air pollution on the regional climate should be further examined and this should be considered in connection with the work on hemispheric air pollution. As far as possible, this should also involve scientists from Asia.

41. Concerning the options to reduce emissions (of air pollutants and GHG), the workshop presentations and discussions focused on structural measures and energy saving. Further work should also explore technical measures for multi-pollutant abatement.

42. IPCC has established a Task Group on Scenarios for Climate Impact Assessment that operates a data distribution centre (website: http://ipcc-ddc.cru.uea.ac.uk/). This centre provides a broad set of climatic, socio-economic and other environmental data that are consistent with published IPCC scenarios and are intended for use in assessing the impacts of climate change. These data may be useful to air pollution modellers.