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PREPARATORY WORK FOR THE NEGOCIATION OF A REVISED
GOTHENBURG PROTOCOL

INTEGRATED ASSESSMENT MODELLING

## WORKSHOP ON INTEGRATED MODELLING OF NITROGEN

Report by the Chair of the Task Force on Integrated Assessment Modelling[3]

1 ECE/EB.AIR/GE.1/2008/1.
2 ECE/EB.AIR/WG.5/89.
3 This document was submitted late due to delayed inputs from other sources

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## WORKSHOP ON INTEGRATED MODELLING OF NITROGEN

1. This report was prepared by the Chair of the Task Force on Integrated Assessment Modelling in cooperation with the organizers of the workshop. The workshop on the integrated modelling of nitrogen took place from 28 to 30 November 2007 in Laxenburg, Austria, and is reported in accordance with item 2.3 of the 2008 workplan (ECE/EB.AIR/91/Add.2) adopted by the Executive Body at its twenty-fifth session (ECE/EB.AIR/91). It was organized by the Task Force on Integrated Assessment Modelling, the European Cooperation in the Field of Scientific and Technical research (COST) Action 729, and the research networking programme “Nitrogen in Europe” (NinE) of the European Science Foundation (ESF). The International Institute for Applied Systems Analysis (IIASA) hosted the meeting.

2. Eighty-two experts attended the workshop. The following Parties to the Convention were represented: Austria, Belgium, Croatia, Cyprus, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, the Netherlands, Norway, Serbia, the Slovak Republic, Spain, Sweden, and the United Kingdom of Great Britain and Northern Ireland, as well as by the European Community. Also present were representatives of the Expert Group on Techno-economic Issues and representatives of the Working Group on Effects’ International Cooperative Programmes (ICP) on Waters, Integrated Monitoring, and Modelling and Mapping as well as the Coordination Centre for Effects (CCE), the Centre for Integrated Assessment Modelling (CIAM) and the Meteorological Synthesizing Centre-West (MSC-West) of EMEP. The European Environment Agency (EEA), the European Commission and its Joint Research Centre (JRC), the European Environmental Bureau (EEB), the European Fertilizer Manufacturers Association (EFMA), and the Oil Companies’ European Organization for Environment, Health and Safety in Refining and Distribution (CONCAWE) were also represented. A member of the UNECE secretariat also attended.

3. Mr. R. Maas (Netherlands), Mr. M. Amann (Austria), Mr. J. W. Erisman (Netherlands), Mr. M. Sutton (United Kingdom) and Mr. J. Sliggers (Netherlands) chaired the meeting.

## I. AIMS OF THE WORKSHOP

4. The objectives of the workshop were to:

(a) Explore the possibilities for a holistic approach of nitrogen;
(b) Design the framework that was needed for such an approach;

(c) Review the integrated assessment modelling approaches that were available to include nitrogen;

(d) Define necessary future developments;

(e) Prepare a proposal for a possible integrated nitrogen approach within the review and possible revision of the 1999 Gothenburg Protocol.

5. Mr. L. Hordijk welcomed the participants on behalf of IIASA. During the workshop, several assessments covering the European, the national or the regional scales were presented (www.iiasa.ac.at/rains/meetings/IAM_Nitrogen/Presentations.html).

## II. CONCLUSIONS

### A. Nitrogen-related policies

6. The workshop noted that nitrogen played an important role in several policy areas. Especially with respect to policies on biodiversity, climate change, air pollution, surface waters, groundwater and marine areas the losses of nitrogen to the environment in its different forms were addressed. In agricultural policy, the availability of nitrogen was important to produce food or biomass. The coherence and consistency of the policy actions involved were points of concern, as the awareness seemed often insufficient of nitrogen flows across the societal and natural systems. Policy decisions at all levels for different forms of reactive nitrogen (ammonia ($NH_4$), nitrogen oxides (NOx), nitrous oxide ($N_2O$) and nitrates ($NO_3$)) have quite often been stand-alone decisions. This has led to the risk of swapping nitrogen in potentially more harmful directions. The workshop noted the need for an integrated approach to manage reactive nitrogen and make full use of existing tools.

7. Nitrogen is linked with several environmental problems. $NO_3$ is a threat for drinking water and can lead to eutrophication problems, including increased algal growth and bloom with possible changes in coastal ecosystem structure and functioning. $N_2O$ contributes to global warming. NOx in air contributes to ozone formation together with volatile organic compounds. NOx and $NH_4$ contribute to exposure of the population to fine particulate matter and the exceedance of critical loads of nutrient nitrogen for ecosystems. The latter will eventually lead to a loss of biodiversity: e.g. species or functional groups like blueberries, heather and rare forest flowers being replaced by grasses and nettle, which could then also reduce the diversity of butterflies, birds and mammals in nature areas; the diversity of ecosystem types is reduced; and the stability and economic value of ecosystems functions is endangered.

8. The workshop took note of nitrogen-related work under the Working Group on Effects of the Convention, as well as the forthcoming European Nitrogen Assessment (ENA) and many international activities such as the Nitro-Europe Integrated Project under the sixth framework programme of the European Union (EU), COST Action 729, NinE of ESF and the global Integrated Nitrogen Initiative (INI). It was noted that effects-based policies on air quality, aquatic and terrestrial ecosystems, and climate could benefit from an integrated approach. Such an approach could improve the consistency and cost-effectiveness for the different policies. There appeared to be several possibilities for synergy, but also trade-offs, e.g. between policies aimed at $NO_3$ in groundwater and marine areas, $NH_4$ and $N_2O$.

9. The workshop was informed that the Thematic Strategy on Air Pollution, launched by the European Commission in September 2005, also addressed the need for a coherent and integrated approach to nitrogen management. The revision of the EU National Emission Ceilings (NEC) Directive aims to support this need and to prioritize measures and policies to reduce excessive nitrogen use in agriculture, and to simultaneously address $NO_3$ in water and $NH_4$ and $N_2O$ emissions to air (ec.europa.eu/environment/air/cafe/activities/ammonia_en.htm).

## B. Availability of data

10. The workshop noted that science could improve the linkages between policy areas by providing consistent data. The consistency in nitrogen data could be improved via nitrogen budget calculations at different scales. Such budget (or balance) calculations could show how reactive forms of nitrogen entered the system, what sectors contributed to the nitrogen losses to the environment and how certain policy measures would influence the flow of nitrogen. The workshop also noted that budget calculations could prove to be a powerful communication tool for decision makers at international, national and regional levels. Even at the farm level, nitrogen budget calculations could contribute to the awareness of farmers of the losses of nitrogen and promote a more efficient use of nitrogen by providing the right amount at the right place at the right time.

11. Nitrogen budget calculations have been made for several countries and/or regions. However, there was a need for harmonizing the methodology.

12. Nitrogen budget calculations could be a good method to detect weaknesses in activity data and in nitrogen emission estimates, and to set policy priorities. Preliminary results indicated that in particular data on $N_2O$ emissions of from soils, wetlands and aquatic systems revealed gaps in knowledge. Preliminary nitrogen budget calculations for Germany showed that reactive nitrogen losses were primarily to air and they consisted of roughly 40 per cent $NO_3$ losses to

water, and of 30 per cent $NH_4$ emissions, 25 per cent NOx emissions and 5 per cent $N_2O$ emissions to air. Agriculture contributed almost 60 per cent to the total reactive nitrogen losses. Industry, energy production, transport (including ships) and waste treatment were also significant. Almost 10 per cent of the total nitrogen balance could presently not be accounted for.

### C. Integrated nitrogen modelling

13. The workshop noted that current assessment models usually addressed only single effects of nitrogen and did not always take into account costs. Assessment models needed to be broadened to address the multiple effects of nitrogen simultaneously and to deliver fully cost-effective policy advice while decreasing the risk of pollutant swapping. Assessments with agricultural models showed that structural changes in human diets, livestock numbers, animal feed and mineral use could reduce all types of nitrogen loss at the same time.

14. Different forms of reactive nitrogen lead to different environmental impacts at different timescales and at different geographical scales. An effects-based approach including dynamic modelling is required to consider the cascading effects of nitrogen in an appropriate way. In addition, substantial work is needed to better quantify the environmental damage of different forms of nitrogen and to determine which policy measures should have priority.

15. The workshop noted that it was doubtful whether a single comprehensive optimization model was useful, feasible or explainable. It seemed more useful to be able to clarify the trade-offs and potential synergies between policy choices. This would not require a new comprehensive optimization model, but could be done by linking existing models. The workshop noted the need to make environmental constraints for different timescales and geographical scales comparable. For example, national targets for the $N_2O$ and $NH_4$ emissions could be translated into regional targets to improve its coherence with regional constraints for $NO_3$ in groundwater and regional targets for biodiversity.

16. The nitrogen cycle is interconnected with other biogeochemical cycles such as the carbon, the phosphorus, the sulphur and the water cycles. Changes in other cycles will affect the nitrogen cycle. All cycles will influence biodiversity and interact with climate change.

17. At the European level, existing models for the projection of agricultural production, future land use, air pollution, water pollution and biodiversity impacts could be linked. This could enable the analysis of the consequences of European strategies such as the reform of the common agricultural policy of the EU and the production of biofuels for the losses of nitrogen and its impacts on biodiversity, climate change and health. The first steps in linking models have

been made, e.g. in the “Consortium for the modelling of air pollution and climate strategies” (the EU/LIFE project EC4MACS), the linking of the common agricultural policy regionalised impact analysis with a model on denitrification and decomposition of soil carbon and nitrogen in agricultural ecosystems (the CAPRI-DNDC framework), the comprehensive approach to study the fate and impacts of nutrients on the European environment (the EU project FATE) and the scenario study framework on future of rural areas in the EU (Eururalis). Further improvements still have to be made to guarantee consistency. The workshop noted the results of such linked models, e.g. indicating that the use of rapeseed as a biofuel would increase emissions of $N_2O$ and lead to a net increase in greenhouse gas emissions. Biomass production would require additional inputs of nitrogen and this could lead to a loss of biodiversity. Linkages with the global trade analysis project model (GTAP) indicated that increased demand for biofuels in Europe would increase deforestation and biodiversity loss, e.g. in Brazil. Also, the influence on food prices was a reason for concern.

18. It is currently possible to add restrictions for $N_2O$ emissions and $NO_3$ leaching to the GAINS model of IIASA to optimize national emission ceilings for $NH_4$ and NOx without violating decisions taken in the framework of climate policy and water policy.

19. The workshop deemed it possible to use air quality policy scenarios which addressed nitrogen deposition and $NO_3$ leaching from nature areas in water quality models which captured river catchments areas and coastal waters. However, models linking exposure and response for selected effects on some environmental compartments were still lacking, e.g. for marine areas.

20. The workshop considered biogeochemical models, such as those developed in Sweden, Netherlands and Germany, capable of simulating regional nitrogen turnover. It appeared possible to assess the long-term impacts of nitrogen in forest ecosystems when linked with biodiversity models. Biogeochemical models could also evaluate the effects of whole-tree harvesting, which is becoming a current practice in many countries to increase the use of biomass in power generation. Monitoring was needed to complement the knowledge on the nitrogen balance to further improve these assessments.

21. The workshop acknowledged the need for regional and landscape scale assessments of the various nitrogen impacts. Such models could take into account the sensitivity of Natura 2000 areas of the EU, the protection of vulnerable groundwater layers, and the contribution to the water quality of river basins and coastal zones. Regional assessments could show the trade-offs between these impact indicators and the economic indicators such as soil productivity, food production costs and agricultural employment. Though it was deemed sensible to keep the use of

these more detailed regional models for national purposes, the European scale work could benefit from the findings of such assessments.

22. The workshop deemed it possible to optimize nitrogen use at the farm or regional and landscape level, once constraints for the various types of nitrogen losses were translated to these levels. Further analysis was required to show whether a regional cap on the total loss of nitrogen could be used instead of specific caps for $NH_4$ or $NO_3$ losses, without unacceptable effects for health, biodiversity or climate. Such a total cap might improve the cost-effectiveness of environmental policy. The workshop noted that the different types of reactive nitrogen were not completely interchangeable, that aquifers and river basins not always matched with regions, and that for an optimal result each emission cap should have a responsible institution or policy framework, which could be difficult to achieve at the regional level.

23. Complex models might be needed to find right answers to certain policy questions. The identified challenge was to simplify as much as possible the relationship between inputs and outputs of models and to use these simplified presentation for policy analyses, while maintaining complex approaches for scientific review. The nitrogen visualization tool (www.initrogen.org/visualization) could be considered as a good example for communicating complex modelling systems in a comprehensible way to policymakers.

24. The critical load concept, which is instrumental for the effects-based approach under the Convention, needs to improve the quantification of specific policy-relevant nitrogen effects to biodiversity. The importance of knowledge of nitrogen effects to biodiversity has been acknowledged in the workplan of the Working Group on Effects.

## III. RECOMMENDATIONS FOR FUTURE WORK

25. The workshop recommended that the proposed new task force on reactive nitrogen under the Convention identify the timing and information requirements of the various policy processes, raise awareness of the linkages between them, and give practical advice on how the policy consistency can be improved. Integrated nitrogen modelling should not be seen as the prime goal, but as a means to solve policy problems in a more cost-effective way. A firm link with environmental policy problems as well as economic concerns (e.g. better regulation, use of economic instruments) should remain the focus of attention.

26. Modellers should carry on developing modelling tools for an integrated nitrogen approach at various spatial and temporal scales, with a strong incorporation of effects and costs, and to validate them and to proactively communicate their usefulness to policymakers.

27. The workshop deemed that enhanced data were required to improve the quality of models. Nitrogen budget calculations could prove to be an important means to better underpin the reliability and consistency of emission data. The workshop therefore recommended that the proposed new task force develop a common methodology for nitrogen budget calculations. Findings that were relevant for the quality of emission estimates could be reflected in the work on emission inventories under the Convention. The proposed new task force could further list benefits and drawbacks of integrating nitrogen budget calculations in the reporting requirements of the Convention.

28. The workshop recommended that integrated assessment modellers in the work of the Convention should review the feasibility and usefulness of linking models, which would incorporate in the analyses the policy decisions for water pollution, greenhouse gas reduction, biomass production and revision of the European agricultural policy. An operational combination of models might be more efficient than the development of new comprehensive models.

29. European biodiversity indicators of the EU project “Streamlining European biodiversity indicators for 2010” (SEBI 2010) included indicators developed under the Working Group of Effects, in particular critical load exceedance. The workshop recommended that effects modellers in the work of the Convention continue the collaboration with SEBI 2010 in developing persuasive, nitrogen-relevant impact indicators for natural and, to the extent possible, non-natural areas, as appropriate, under the workplan of the Working Group.

30. The workshop recommended that the proposed new task force should evaluate the integrated assessment models and their applicability for policy purposes and advise how different nitrogen-related environmental targets could be efficiently met in an integrated way. It was further recommended that the task force should adopt an effects-based approach to identify synergies and trade-offs between policy measures and related environmental targets. The task force should also, in cooperation with agricultural economists, identify the trade-offs between environmental targets and economic goals such as agricultural production costs.

31. The proposed new task force should make full use of existing work by the Working Group on Effects, the EMEP Steering Body and their subsidiary bodies.

32. The workshop noted that policy analysts could further study the effects of various sequences in policy decisions on the overall cost-effectiveness of nitrogen-related policies. Currently, it was not clear whether and when global constraints for $N_2O$ should be determined

first or whether regional constraints for $NO_3$ leaching or $NH_4$ emissions should be considered as mitigation priorities.

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