ESF EXPLORATORY WORKSHOP (co-sponsored by the Research Council of Norway and the Norwegian Agency for Development Co-operation):

Atmospheric pollution effects on local, regional and global scales – an integrated approach.

Norwegian Academy of Science and Letters, Oslo
September 26 – 28, 2002

Scientific Report

The Norwegian Academy of Science and Letters

Organizers:
Hans Martin Seip (Department of Chemistry, University of Oslo & Center for International Climate and Environmental Research – Oslo (CICERO)
Kristin Aunan (CICERO)
Haakon Vennemo (ECON Centre for Economic Analysis)

1. Executive summary

An integrated approach to mitigating climate change and local and regional environmental problems may have important advantages, but it also poses methodological challenges. Relevant issues were discussed by 25 scientists from China, USA, Chile and several European countries at a recent workshop in Oslo.

After an opening welcome speech by the Director of CICERO, Paal Prestrud, and an orientation about ESF activities by Milena Horvat, there were 5 sessions with altogether 18 plenary presentations (see attached workshop program). In each session there was time for discussion. A final session with discussions and summary concluded the workshop. To allocate ample time for discussions proved successful; the debate was lively and fruitful.

Effects of human-made emissions to air may be on very different scales, from indoor to global. One may distinguish between air quality policy and climate policy, the former referring to effects of pollutants (particles, SO_2, NOx, ozone) on health, vegetation and materials. Climate is affected by greenhouse gasses (GHGs, in particular CO_2 and CH_4) and particles. Reduced emissions of greenhouse gasses may be co-benefits (or ancillary benefits) of air quality measures while less pollution and thus less damage to health, vegetation and materials, may be co-benefits of measures to mitigate climate change.

Several speakers emphasized that since many measures affect emissions of several compounds (often unintentionally) and each compound may have several effects, there is clearly a need to investigate potential advantages of an integrated approach, aiming at maximizing potential benefits. Advantages of an integrated perspective of local and global pollution control include possibilities for:

- identifying positive synergetic effects between air pollution abatement and climate policies, and thus reducing the overall costs by prioritizing measures that reduce more than one pollution problem;
- preventing perverse effects of specific policies on other pollution problems;
- giving support for more ambitious commitments with respect to GHG mitigation.

These advantages are likely to outweigh possible drawbacks from methodological or administrative complications of considering several compounds in the decision process which implies a weighting of quite different effects.

The presentations covered a broad range of issues from emissions and dispersion of pollutants, through effect estimation to costs and social issues. Harmful effects of particles on human health and damage of ground-level ozone to vegetation were among emphasized topics. Present stage of knowledge in some areas (acid rain, health effects, ground-level ozone) was summarized, showing clearly that in many areas the uncertainties are formidable. Several speakers also discussed problems related to valuation of effects in monetary terms. Ethical questions are pertinent in monetizing health effects and "natural" environment. While damage to agricultural crops and building materials can be estimated using market prices, non-market benefits are very important in valuation of damage to (more or less) wild nature and health outcomes.

Results were presented from case studies (e.g. in China and Chile) using detailed analyses of specific projects or macroeconomic models for large regions.

Most case studies and scenario analyses presented showed that measures to mitigate climate change often have large co-benefits especially in terms of reduced health damage. The public health benefits of carbon reduction measures can often offset most of the cost of GHG reduction. Also, measures to reduce local pollution have co-benefits in terms of reduced emissions of GHGs.

However, there are complications in improving local air pollution and reducing GHG emissions with the same measures. Several participants pointed to the fact that it was necessary to push on for better local air quality. To obtain improvements quickly most measures are likely to be of a technical end-of-pipe nature that will not necessarily have large effects on GHG emissions. Participants particularly concerned with climate change warned against selling air quality policy as climate policy, since this might turn focus away from the need for GHG reductions.

The role of co-benefits in relation to the flexibility mechanisms in the Kyoto protocol was also discussed, especially whether climate change measures with large local benefits are good candidates for the Clean Development Mechanism (CDM). (CDM allows industrial countries to fulfil part of their obligations through investing in climate measures in developing countries.) The greatest asset of projects with large co-benefits is likely to be that many stakeholders will tend to be positive. For example, the co-benefits may fend off NGO skepticism to CDM in the industrial country and attract some stakeholders in the host country by possibilities for technology transfer.

At present integrated benefit-cost analyses are useful, but in an early state of development. There are still large uncertainties both regarding climate change effects and effects of air pollutants, thus results of such analyses are only one contribution in the decision process, albeit an important one. There is a need for improved knowledge in a number of areas, including:

- exposure estimates
- dose-response relationships
- valuation
- social effects

The participants expressed great interest in establishing formal cooperation for example through establishing a Network of scientists. If a network is established on the basis of the workshop, the overall goal might be
to understand the interactions between the various pollutants and their effects and the implications these have for different mitigation strategies and best policy instruments.

Sub-goals might include:

- Develop guidelines for integrated analyses to facilitate comparison
- Develop recommendations for monitoring programs so that the observations are well suited for integrated analyses.
- Contribute to improved communication with decision makers so that all important aspects of mitigation measures are included in the decision process.
- Perform a common case study.

In combination, or as an alternative to a network, it was suggested to join the Forward Look activities on Urban Science, where issues of air pollution are very important.

The scientific content (next section) will be published in essentially the same form in Newsletter of the European Geosciences Union, Vol.1, Issue 2, January 2003, available online at www.the-eggs.org.

.

The participants outside the academy.

2. Scientific content

Common causes – common solutions

Until a few years ago environmental problems were usually dealt with one at a time. Thus acid rain, with precursors SO_2 and NOx, was discussed without much consideration of other effects of these compounds such as health effects of SO_2 or the contribution of NOx to formation of tropospheric ozone. However, since many measures affect emissions of several compounds (often unintentionally) and each compound may have several effects (see Tables 1and 2), there is clearly a need to investigate potential advantages of an integrated approach, aiming at maximizing potential benefits. Recently there have been many publications and much discussion about possible advantages of considering several environmental and health problems at local and global scales in an integrated way (see for example Ekins, 1996; Aaheim et al., 1999; Krewitt et al., 1999; Cifuentes et al., 2001; Aunan et al., 2002). An example of integrated policy on local and regional scales is the Gothenburg protocol (UN/ECE, 2000) which addresses three different air pollution problems, i. e. acidification, eutrophication and ground level ozone. The protocol covers SO_2, NOx, NH_3 and volatile organic compounds (VOCs), but not particles (PM) or greenhouse gasses (GHGs).

Advantages of an integrated perspective of local and global pollution control include possibilities for:

- identifying positive synergetic effects between air pollution abatement and climate policies, and thus reducing the overall costs by prioritizing measures that reduce more than one pollution problem;
- preventing perverse effects of specific policies on other pollution problems;
- giving support for more ambitious commitments with respect to GHG mitigation.

These advantages are likely to outweigh possible drawbacks due to methodological or administrative complications by considering several compounds in the decision process which implies a weighting of quite different effects.

In some cases it is reasonable to consider reduction of greenhouse gasses (GHGs) as the main objective. Possible advantages on local and regional scales may then be called co-benefits (ancillary or secondary benefits are also used.) These may include effects on human health, natural and human-made ecosystems, the economy and social effects (safety, congestion, employment, income). In other cases the local or regional issue may be the main one and reduction of GHGs may then be regarded as a co-benefit. (The Intergovernmental Panel on Global Change (IPCC, 2000a) reserves the term co-benefits for cases where the aim is reductions of both local and global benefits. This distinction is not used in this paper.)

Advantages and problems related to integrating mitigation of local/regional pollution and climate change were discussed at a workshop in Oslo in September 2002, held at the Norske Videnskaps-Akademi (Norwegian Academy of Sciences and Letters). The participants covered a broad range of issues from the emissions and dispersion of pollutants, through effect estimation to costs and social issues. Results were presented from case studies using detailed analyses of specific projects and obtained by macroeconomic models for large regions.

Methods of an integrated approach

Analyses may be carried out by *Bottom-up* (B-U) or *Top-down* (T-D) methods. Examples of both methods were presented at the workshop. B-U methods are often used to analyse specific projects on a fairly small scale while T-D models focus the overall macroeconomic effect of measures and are suited to analyse options such as carbon taxes or non-price policies (market reforms, information, capacity building).

Main steps in a B-U analysis are given in Figure 1. Estimation of co-benefits of measures implies finding the change in physical/biological damage from changed exposure to various pollutants (exposure-response curves) and often to monetize the changes. Some important co-benefits are discussed in following sections.

Table 1. Impacts of different substances emitted to air.

	Climate change	Transboundary[1]		Local air pollution		
		Acidification	Tropospheric ozone	Health	Vegetation	Materials
CO_2	x					
CH_4	x		x			
N_2O	x					
SO_2	x	x		x[2]	x	x
NOx	x	x	x	x[2]	x	x
NH_3	x	x		x[2]	x	x
NMVOC[3]	x		x	x	x	?
CO	x		x	x		
PM[4]	x	x		x		x

1. For effects see text
2. In part due to formation of secondary particles
3. Non-methane volatile organic compounds
4. Particulate matter

Table 2. Some measures and their effects. (+ implies that the effect is beneficial, – that it is harmful, 0 implies no significant effect.

Type of measure	**Local/ Regional**	**Global (Climate)**
Removal of SO_2 and/or particles*	+	(–)
Removal of black carbon emissions	+	+
Change to unleaded gasoline	+	0
Fuel substitution: Coal → Oil → Gas	+	+
Increased energy efficiency	+	+
Renewable energy- biomass	–	+
Renewable energy- sun/wind/wave	+	+
CO_2 deposition	0	+

* except black carbon (soot)

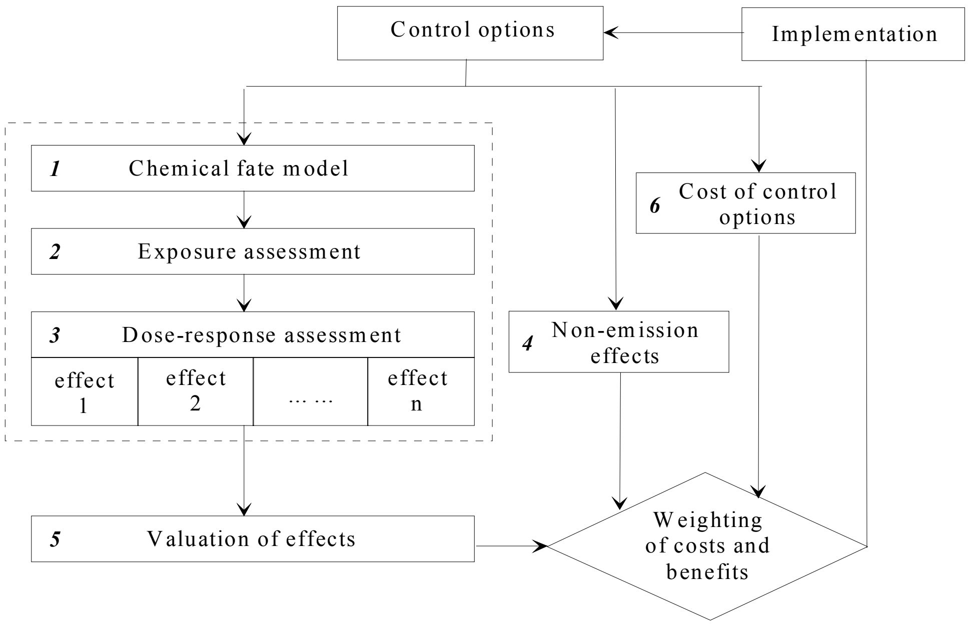


Fig. 1. Main steps in a bottom up analysis. To calculate the net benefits, it is necessary to know:
1. how the measures affect the emissions
2. how the exposure of humans and the environment changes
3. changes in the effects due to changed exposure (exposure-response or dose-response functions)
4. size of non-emission effects
5. the economic values of the changes
5. costs of the measure

Effects on different geographic scales

Several speakers (e.g K. Hicks from *Stockholm Environment Institute at York*, R. Maas from *RIVM, the Netherlands* and H.M. Seip from *University of Oslo and Cicero*) stressed the importance of an integrated approach covering scales from indoor pollution to global issues.

Local effects.

Local effects include indoor, urban, and peri-urban scales, i.e. effects occurring mainly within some tenths of kilometers from the emission source. Humans, vegetation and materials may be affected. Although indoor pollution was recognized as very important and indoor air quality improvement may be an important co-benefit of GHG mitigation in developing countries (e.g. Wang and Smith, 1999), it was not addressed in detail at the workshop.

Regarding local effects, most emphasis at the Workshop was on human health. Particulates were considered to be the main factor causing pollution-related health effects although SO_2, NOx and ozone may also be important. In most case studies change in mortality due to changed pollution levels is the most important effect of mitigation measures. Changed mortality may be estimated as reduced excess deaths due to changes in daily pollutant concentrations (acute mortality) or long-term effects of high pollution levels on mortality rate (chronic mortality). It may be more appropriate to estimate the number of life years saved than the number of deaths avoided. Smaller particles are the most important in estimating health effects. The correlation between excess mortality and concentration of particles increases going from TSP (total suspended particlulates) to PM_{10} (particles with diameter < 10 μm) to $PM_{2.5}$ (diameter < 2.5 μm). In addition to size, composition and surface properties may be important but it was pointed out that too little is known about this to allow for a reasonable effect estimation effort. Most of the information on health effects is from industrialized countries; there are few epidemiological studies in developing countries, although this is likely to change in the future.

Regional effects

Regional effects stretch hundreds of kilometers from the emission source; the most important ones are due to acid deposition, tropospheric (ground level) ozone and fine particles.

Acid deposition may affect freshwater and terrestrial ecosystems. Large reductions in SO_2 emissions in Europe have reduced acid deposition substantially with clear improvements in freshwater quality in some regions, particularly in Scandinavia (Stoddard et al., 1999). In the 1980s possible forest dieback due to acid deposition was probably the most discussed environmental problem in Europe. More recently it has become an important issue in China (Feng et al., 2002). Fortunately the massive forest damage in Europe predicted by some researchers never materialized (UN/EC, 2002). In spite of extensive studies no reliable exposure-response relationship between acid deposition and forest damage has been established. The reduced SO_2 emissions in Europe seem to have resulted in some improvement in forest conditions, most clearly in southern Poland (UN/EC, 2002). This may, however, be more due to reduced direct damage from gas-phase SO_2 than to reduced acidification.

At the meeting tropospheric ozone was an important issue. J.N.B. Bell (*Imperial College, London*) summarized the knowledge base and presented some unpublished material from case studies in the developing world. A number of studies on effects of ozone on crops have been carried out in the USA and some in Europe. Little has so far been done in developing countries although it is suspected that there may be reduction in yields in large areas and the problems are likely to increase in the years to come. Bell stated further that effects of air pollutants on crops are also a serious, although indirect, threat to human health in developing countries, since the yield reduction is substantial and the nutrient content is also reduced. He argued that air quality standards need to be established for developing country crops and cultivars grown under local agricultural conditions. This will inevitably lead to more stringent standards than those that currently address direct effects on human health. The benefits will be felt by both the population of developing countries, particularly the poor, and by the world as a whole.

Kostas Kourtidis (*University of Thessaloniki, Greece*) illustrated that by reducing one problem another may become worse. While reduction of tropospheric ozone in south-eastern Europe is likely to have a positive effect on vegetation and some diseases, it will also increase the UV-radiation resulting in increased skin-cancer frequency. The latter effect, however, can be alleviated by population information campaigns.

Climate

There was no dispute about the main conclusions from the IPCC third assessment (IPCC, 2001b) including the indicated uncertainties. The importance of particles as climate agents was focused in the presentation of Frank Raes (*Joint Research Centre, European Commission, Italy*). It was shown that current models give reasonably good agreement with observed spatial distribution of temperature increase in recent years when emissions both of GHGs and particles were included. However, different types of particles have different properties; while sulfate aerosols generally cause a cooling, "black carbon" (BC) or soot will contribute to global warming due to absorption of solar irradiation (Hansen and Sato, 2001). Since particles are so important both regarding local pollution effects and in climate change, they play a key role in integrated assessment as discussed further below.

Valuation

Difficulties in valuing effects on health and environment were generally recognized and discussed in several presentations. Terry Barker (*University of Cambridge)* compared valuation of primary benefits (i.e. related to climate change) and co-benefits. The following is essentially from his presentation.

Considerable effects have been made to estimate primary benefits in the context of the cost-benefit analysis of climate change, adaptation and mitigation. However, the estimates are controversial:

- the valuation of human morbidity and mortality across countries and generations involves social and political judgements
- many damages are unknown and far into the future and involve the earth's ecosystems
- uncertainty is rife and the possibility of unpleasant surprises is high.

Although in principle the problems of valuing co-benefits are the same as those of the primary benefits, there are significant differences:

- reductions in air pollution are more local (the pollutants return to the land rather than being globally dispersed)
- reductions in air pollution are more immediate (many GHGs are very long-lived compared to air pollutants, so the damages accrue over human generations). The choice of discount rate in valuing local effects is therefore not a critical issue, but different discount rates give very different costs for climate change.
- there is more knowledge about the effects of air pollution than about those of climate change (major programs of air pollutant abatement have been justified by assessment of air pollution damages).

Other speakers discussed the use of VSL (value of statistical life) and VOLY (value of a life year lost). Most western studies base monetization on willingness-to-pay (WTP). Since there are few WTP studies in developing countries, transfer of values from western studies is often necessary. In some developing countries the so-called human capital approach (HCA) is applied. HCA is based on production loss from premature death. In a World Bank study of health effects in China, the WTP estimate for VSL was nearly 7 times higher than that obtained using HCA (World Bank, 1997). Paul Metz (*Integerconsult, the Netherlands*) presented the concept of equal per capita user rights of the global commons, which offers a fair starting point for e.g. emissions trade and creates income for the non-polluters, especially in developing countries.

While damage to agricultural crops and building materials can be estimated using market prices, non-market benefits are very important in valuation of damage to (more or less) wild nature. These include esthetical and cultural values, ecological benefits such as soil formation and climate regulation, and harvest of wild species for food, fuel and pharmaceuticals.

Case studies

Several case studies were presented.

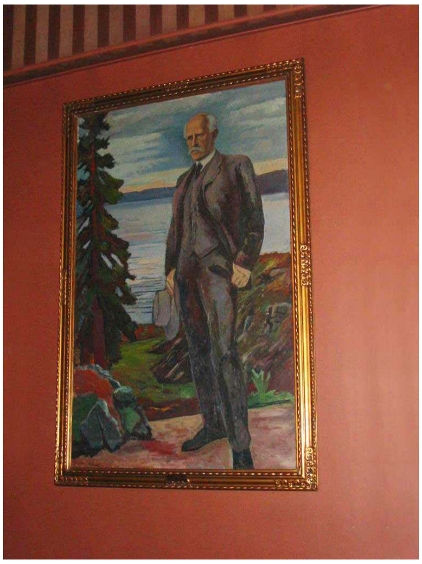
Two case studies of possible measures in Shanxi Province in China were described, one of a proposed industrial boiler efficiency program (by Jinghua Fang from *Taiyuan University of Technology, China*) and one of six Clean Development Projects in Taiyuan, the capital of Shanxi (by Kristin Aunan from *Cicero*). In these studies the co-benefits were essentially those related to human health. Several projects had large co-benefits, but if emission reduction of pollutants occurred at high stacks, the local health benefits were minor. When the health benefits are considered, the ranking of measures becomes dramatically different from a ranking based solely on cost-effectiveness of GHG abatement.

A case study of the interaction of measures to abate air pollution and measures to mitigate GHG emissions in Chile was presented by Luis Cifuentes *(Universidad Católica de Chile)*. The local pollution health benefits of GHG reduction measures were found to be significant. Actually, the public health benefits of such measures can offset most of the cost of GHG reduction. However, for most measures analyzed, the public health benefits are an order of magnitude greater than the benefits from carbon reduction. Also, the cost offsets due to potential carbon credits are limited from a few per cent up to 36% in the best case. This suggests that the main driver for air pollution policy is likely to continue to be local concerns, like public health issues. Studies of projects in Zimbabwe, Botswana, Mauritius and Thailand presented by Kirsten Halsnaes (*Risoe National Laboratory, Denmark*) also showed that the cost-effectiveness ranking of the GHG emission projects is considerably different when based on social costs from that based on financial costs. In almost all project cases social costs were lower than financial costs indicating that the projects have co-benefits seen in a national development perspective.

Two studies applying macroeconomic models to China were described. One study presented by Mun S. Ho (*Resources for the Future*, *Washington)* included only health effects as co-benefit, but two tax systems were investigated. One was a tax on sectoral output, where the tax rate is proportional to the health damage caused by the production of the commodity. The second policy was a tax on primary fuels, where the tax rate is proportional to the average damage per unit of fuel and applied equally to all users. The other study presented by Fan Zhai from *Ministry of Finance, China*, included both reduced health damage and increased crop yields. For moderate tax levels the social costs of such tax policies were found to be much lower than the direct economic costs.

Janusz Cofala described work at *International Institute for Applied Systems Analysis (IIASA)* to extend methodologies that have been used for development of strategies for reducing acidifying emissions and ozone precursors (the RAINS model) to include more air pollution effects and climate change. Major linkages and interactions between emissions and mitigation strategies for pollutants contributing to regional air pollution (SO_2, NO_x, VOC, NH_3, PM) and greenhouse gases were discussed. Costs of reaching targets for air quality in Europe vary under different assumptions about simultaneous climate policies and utilization of the flexibility mechanisms in the Kyoto Protocol. It was concluded that the targets were likely to be reached at the lowest costs if Kyoto commitments are met without CO_2–trading.

The studies presented showed that co-benefits for CO_2 mitigation depend on the sectoral breakdown of the relevant emission sources. For example, in Chile mobile sources contributed 50% of the emissions and resulted in smaller ancillary benefits for GHG mitigation as compared to the Chinese examples where the heavy reliance on coal creates larger potential for ancillary benefits.



Nobel peace prize laureate Fridtjof Nansen was a member of the Academy and his picture has a prominent place in the main lecture room.

From integrated studies to policies
According to Audun Rosland (*The Norwegian Pollution Control Authority*) the development in Europe from a narrow approach, where different pollutants were treated separately, to the more integrated approach in the Gothenburg protocol, is to a large extent a function of the development of model tools and maturing scientific knowledge. Hence, one might draw the conclusion that a further development of integrated model tools could be instrumental in facilitating international treaties and policies that address climate change and air pollution in a holistic way. However, this may not actually happen, because whereas the negotiations under the *Convention on Long-range Transboundary Air Pollution (CLRTAP)* has been very much guided by model based assumptions, the Kyoto process is much more policy driven.

Most case studies and scenario analyses presented showed that measures to mitigate climate change often have large co-benefits especially in terms of reduced health damage. The public health benefits can often offset most of the cost of GHG reduction. Also measures to reduce local pollution have co-benefits in terms of reduced emissions of GHGs.

However, there are complications in improving local air pollution and reduce GHG emissions with the same measures. Several participants pointed to the fact that it was necessary to push on for better local air quality. To obtain improvements quickly most measures are likely to be of a technical nature and will not necessarily have large effects on GHG emissions. Participants particularly concerned with climate change warned against selling air quality policy as climate policy, since this might turn focus away from the need for GHG reductions. It was pointed out that decreased particle concentrations following large reductions in emissions of SO_2 and NOx, should be accompanied by especially large reductions in GHGs to compensate for the lost cooling effect. More focus on non-technical measures, e.g. more public transport to reduce car transport, may have several advantages compared to simple technical improvements, although this requires a change in attitudes that may be difficult to achieve.

The role of co-benefits in relation to the flexibility mechanisms in the Kyoto protocol was also discussed, especially if climate change measures with large local benefits are good candidates for the Clean Development Mechanism (CDM).

CDM projects shall contribute to sustainability in the host country and should be additional to projects that the host country is likely to implement anyway. Important questions concerning the projects are therefore:

- Are they additional?
- Do they contribute to sustainable development?
- What will stakeholders say?

Criteria for additionality were discussed in 2001 at the Marrakesh meeting of the Parties (COP7). If the technology is more expensive than alternatives, the project is considered additional. A number of other barriers to implementation may also make the project qualified. These include

- Less financially viable compared to alternative
- Technologically advanced compared to alternative
- Prevailing practice blocks the technology

- Regulatory barriers to the technology
- Low managerial resources to introduce technology

Haakon Vennemo (*ECON Centre for Economic Analysis, Oslo*) drew the following conclusions that seemed to get general support:

- Large co-benefits may not make the project more likely to pass the additionality test, but are not disqualifying
- Co-benefits may be an advantage when contribution to sustainability is assessed.
- The greatest asset of projects with large co-benefits is likely to be that many stakeholders will tend to be positive. (Useful to fend off NGO skepticism, possible technology transfer may attract stakeholders etc.)

Asbjorn Aaheim from *Cicero* stated that efficiency of an integrated environmental policy requires:

- The policy is revised regularly as the relative values of measures change and new information becomes available.
- Flexibility with respect to the priority of measures.

He was concerned that these requirements may turn out to be obstacles for implementing the policy.

The question "Who owns Nature" was also raised and discussed by Paul Metz (*Integerconsult, the Netherlands*). It was argued that each world citizen owns an equal share of Nature, especially the Global Commons and that this principle should guide policy considerations. It offers an alternative for the currently practiced 'grandfathering' of the rights in emissions trade, which disadvantages the developing countries and is an obstacle for their entry into the Kyoto Protocol. This 'equity'-based "fair" emissions trade can generate a modest annual income for non-emitting citizens and thus give a strong impetus to sustainable development.

Knowledge gaps – Future work

At present integrated benefit-cost analyses are useful, but in an early state of development. There are still large uncertainties both regarding climate change effects and effects of air pollutants, thus results of such analyses are only one contribution in the decision process, albeit an important one.

There is a need for improved knowledge in a number of areas, including:

- Exposure estimates
    - Improvements are necessary on all scales - from indoor to regional; importance of site and height of emission should be emphasized
- Dose-response relationships
    - Includes effects on humans, vegetation and materials. There is a particular lack of information from developing countries.
    - Effects of particles, including black carbon, both as part of the climate system and as air pollutant, are particularly important
- Valuation
    - Valuation of health effects and natural ecosystems should be focused. Willingness-to-pay studies in developing countries are highly needed.

The question who pays – where is the polluter – should be part of such studies.

- Social effects
    - Property rights on global commons and ecological debts are new concepts to bring more justice into the new market-based instruments for environmental protection and modern social systems.

The participants expressed great interest in establishing formal cooperation for example through establishing a Network of scientists. If a network is established on the basis of the workshop, the overall goal might be
to understand the interactions between the various pollutants and their effects and the implications these have for different mitigation strategies and best policy instruments.

Sub-goals might include:

- Develop guidelines for integrated analyses to facilitate comparison
    - As a part of this, contribute to standardization of cost-benefit analysis of air pollution benefits for projects in the Clean Development Mechanism (CDM).
    - The methodological framework should facilitate integration of economic, social, and environmental sustainability dimensions.
- Develop recommendations for monitoring programs so that the observations are well suited for integrated analyses.
- Contribute to improved communication with decision makers so that all important aspects of mitigation measures are included in the decision process.
    - Ensure that the users' requirements are considered in the analyses.
    - Improved description and communication of uncertainties are essential (cf. Giles, 2002).
- Perform a common case study.

In combination, or as an alternative to a network, it was suggested to join the Forward Look activities on Urban Science, where air pollution issues are very important.

References

Aaheim, H.A., Aunan, K., and Seip, H.M., 1999. Climate change and local pollution effects - An integrated approach. *Mitigation and Adaptation Strategies for Global Change*, **4**, 61-81.

Aunan, K., Fang, J., Vennemo, H., Oye, K. and Seip, H. M. , 2002. Co-benefits of climate policy - lessons learned from a study in Shanxi, China. *Energy Policy*, in press.

Cifuentes, L., Borja-Aburto, V. H., Gouveia, N., Thurston, G. and Lee Davis, D., 2001. Hidden health benefits of greenhouse gas mitigation. *Science* **293**, 1257-1259.

Ekins, P., 1996. How large a carbon tax is justified by the secondary benefits of CO_2 abatement? *Resource and Energy Economics*, **18**, 161-187.

Feng, Z., Miao, H., Zhang, F. and Huang, Y., 2002. Effects of acid deposition on terrestrial ecosystems and their rehabilitation strategies. *J. Environ. Sci*., **14**, 227-233.

Giles, J., 2002. When doubt is a sure thing. *Nature*, **418**, 476-478.

Hansen, J.E. and Sato, M., 2001. Trends in measured climate forcing agents. PNAS, Dec., 18, 2001, 14778-14783.
http://www.pnas.org/cgi/reprint/98/26/14778.pdf

IPCC, 2001a. Climate change 2001. Mitigation. Contribution of Working Group III to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

IPCC, 2001b. Climate change 2001. The scientific basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

Krewitt, W., Heck, T., Trukenmüller, A., and Friedrich, R., 1999. Environmental damage costs from fossil fuel generation in Germany and Europe, *Energy Policy*, **27**, 179-183.

Stoddard, J.L. et al., 1999. Regional trends in aquatic recovery from acidification in North America and Europe. *Nature*, **401**, 575-578.

UN/EC, 2002. Forest condition in Europe. Prepared by "Federal Research Centre for Forestry and Forest Products", Hamburg, Germany for The United Nations Economic Commission for Europe and the European Commission, Geneva and Brussels.

UN/ECE, 2000. Protocol to abate acidification, eutrophication and ground-level ozone. Secretariat for the Convention on Long-range Transboundary Air Pollution, UN/ECE, Geneva, Switzerland.
http://www.unece.org/press/99env11e.htm**,** http://www.unece.org/env/lrtap/

Wang, X. and Smith, K. R., 1999. Secondary benefits of greenhouse gas control: Health impacts in China. *Environmental Science and Technology,* **33** 3056-3061

World Bank, 1997. Clear water, blue skies. China's environment in the new century. The World Bank, Washington D.C.

3. Final Program

Thursday (26.09.02)

09 00 – 09 15	***Coffee in the Academy***
Chair: Bell, Aunan	
09 15 – 09 30	**Welcome** (**Paal Prestrud**, Director at CICERO)
09 30 – 09 45	**Milena Horvat** Welcome on behalf of the ESF
09 45 – 10 15	**Audun Rosland:** *From Acid Rain to Greenhouse Gasses – International Progress in Prevention of Emissions*
10 15 - 1030	*Break*
10 30 – 11 00	**Hans Martin Seip:** *Why is an Integrated Approach Necessary?*
11 00 – 11 15	Discussion
11 15 – 11 30	*Coffee/Tea*
11 30 – 12 00	Markus Amann and **Janusz Cofala:** *Linkages Between Air Pollution and Climate: Towards an Integrated Assessment*
12 00 – 12 30	**Terry Barker:** *The Problems of Valuing the Ancillary Benefits of GHG Mitigation*
12 30 – 12 45	Discussion
12 45 – 13 45	***Lunch***
Chair: Cifuentes, Angell	
13 45 – 14 15	**K. Hicks** and J. C. I. Kuylenstierna: *Integrating Air Pollution Impacts from Household Scales to the South Asian Sub-continent for the Policy Process*
14 15 – 14 45	**Kirsten Halsnaes:** *Climate Change and Sustainable Development – Case Studies from Developing countries*
14 45 – 15 00	Discussion
15 00 – 15 15	*Coffee/Tea*
15 15 – 15 45	**H. Asbjorn Aaheim:** *Challenges in Integrating Environmental Policies*
15 45 –	Discussion

Friday (27.09.02)

Chair: Barker, Vennemo	
09 00 – 09 30	**Kostas Kourtidis**: *An Effect Study of Tropospheric Ozone Controls for the Area of Eastern Mediterranean*
09 30 – 10 00	**J.N.B. Bell** & F.M. Marshall**:** *Air Pollution in Developing Countries - The Case for Control Policy Based on Vegetation Impacts*
10 00 – 10 30	Discussion
10 30 – 11 00	*Coffee/Tea*
11 00 – 11 30	**Jinghua Fang**, Guanghai Li, Kristin Aunan, Haakon Vennemo, Hans M. Seip, Kenneth A. Oye, Janos M. Beer: *Potential CO_2 Mitigation and Associated Costs and Health Benefits of a Proposed Industrial Boiler Efficiency Program in Shanxi*
11 30 – 12 00	**Mun S. Ho**, Dale W. Jorgenson, and Wenhua Di: *The Health Benefits and Costs of Controlling Air Pollution in China*
12 00 – 12 30	Discussion
12 30 – 13 30	*Lunch*
Chair: Hicks, Cofala	
13 30 – 14 00	Heidi E. Staff Mestl, **Kristin Aunan**, Jinghua Fang, Hans Martin Seip, John Magne Skjelvik and Haakon Vennemo**:** *Cleaner Production as Climate Investment - Integrated Assessment in Taiyuan City, China*
14 00 – 14 30	Kristin Aunan, Terje Berntsen, Maurizio Bussolo, David O'Connor, Haakon Vennemo and **Fan Zhai**: *Agricultural and Human Health Impacts of Climate Policy in China: A General Equilibrium Analysis with Special Reference to Guangdong*
14 30 – 14 45	Discussion
14 45 – 15 00	*Coffee/Tea*
15 00 – 15 30	**Luis Cifuentes:** *Air Pollution Health Benefits and Greenhouse Gas Reductions: A Case Study in Chile*
15 30 –	Discussion
19 00	*Dinner in the Academy*

Saturday (28.09.02)

Chair: Zhai, Aaheim	
09 30 – 10 00	**R. Maas:** *Linking Air Pollution Scales, Models and Negotiations*
10 00 – 10 30	**Frank Raes**, Julian Wilson, Jean-Philippe Putaud, Frank Dentener, Rita Van Dingenen: *Connections between Conventional Air Pollution and Climate Change and their Consequences for Policy Making: the Case of Particulate Matter*
10 30 – 10 45	Discussion
10 45 – 11 00	*Coffee/Tea*
11 00 – 11 30	**Haakon Vennemo:** *How Integrated? Integrated Assessment and the Clean Development Mechanism*
11 30 – 12 00	**P. Metz:** *Global Climate Policy: Tools for Sustainable Innovation*
12 00 – 12 30	Discussion
12 30 – 13 30	*Lunch*

Conclusions and plans for further cooperation

Chair: Zhang (will also give a final summary), Seip	
13 30 – 15 00	Discussion
15 00 – 15 30	*Coffee/Tea*
15 30 – 18	Discussion continues

4. Participants

Aaheim, Asbjørn, Senior Researcher
CICERO (Center for International Climate and Energy Research – Oslo), P.O. Box 1129 Blindern, 0318 Oslo, Norway
Phone: 47 22858761, Fax: 47 22858751
asbjorn.aaheim@cicero.uio.no

Angell, Valter, Senior researcher
Norwegian Institute of International Affairs
Pb.8159 Dep.,0033 Oslo, Norway
Phone: 47 22056539, Fax: 47 22177015
Valter.Angell@nupi.no

Aunan, Kristin, Senior Researcher
CICERO (Center for International Climate and Energy Research – Oslo), P.O. Box 1129 Blindern, 0318 Oslo, Norway
Phone: 47 22858763, Fax: 47 22858751
kristin.aunan@cicero.uio.no

Barker, Terry, Senior Research Associate
Dept. of Applied Economics, University of Cambridge,
Sidgwick Avenue, Cambridge CB3 9DE UK
Phone: 44-(0) 1223-335289, Fax: 44-(0) 1223-335299
Terry.Barker@econ.cam.ac.uk

Bell, Nigel, Professor
T H Huxley School, Imperial College of Science, Technology and Medicine
London SW7 2PE, UK.
Phone: 44(0)207-594 9288/+44(0)207 594 2312
Fax: 44(0)207-581 0245/+44(0)207 594 2339
n.bell@ic.ac.uk

Bjerkholt, Olav, Professor
Department of Economics
University of Oslo
P. O. Box. 1095 – Blindern, 0317 Oslo, Norway
Phone: 47 22855138, Fax: 47 22855035
olav.bjerkholt@econ.uio.no

Cifuentes, Luis, Professor
Pontificia, Universidad Católica de Chile,
Vicuña Mackenna 4860
Santiago, Chile
Phone: 56 2 354-4836, Fax: 56 2 552 1608
lac@ing.puc.cl

Cofala, Janusz, Dr.
International Institute for Applied Systems Analysis (IIASA)
A-2361 Laxenburg, Austria
Phone: +43 2236 807 416 Fax: +43 2236 807 533
cofala@iiasa.ac.at

Fang, Jinghua, Professor
Taiyuan University of Technology, 79 West YinZhe St.
Taiyuan, Shanxi, 030024 China
Phone: 86 351 6010051, Fax: 86 351 6042457
fjh@tyut.edu.cn

Halsnaes, Kirsten, Senior Research Specialist
UNEP Collaborating Centre on Energy and Environment,
Risoe National Laboratory, P.O. Box 49, DK 4000 Roskilde, Denmark
Phone: 45 46 77 51 12 Fax: 45 46 32 19 99
kirsten.halsnaes@risoe.dk

Hertzberg Karine
The Norwegian Pollution Control Authority (SFT)
P..O. Box 8100 Dep, 0032 Oslo, Norway
Phone: 47 22573427, Fax: 47 22676706
karine.hertzberg@sft.no

Hicks, Kevin, Research Associate
Stockholm Environment Institute at York
Biology Dept. Box 373, University of York, York, YO1 5YW, UK
Phone: 44 (0)1904 432896, Fax: 44(0)1904 432898
wkh1@york.ac.uk

Ho, Mun S, Dr
Resources for the Future, Washington, DC, USA
and
Kennedy School of Government, Room B402
79 JFK St., Cambridge, MA 02138
Phone: 1 617 495-0833, Fax: 1 617 495-1635
HO@rff.org

Horvat Milena, Dr
Jožef Stefan Institute, Department of Environmental Sciences, Jamova 39, 1111
Ljubljana, Slovenia
Phone: +386 (0)1 588 52 87, Fax: +386 (0)1 588 53 46
milena.horvat@ijs.si

Kourtidis, Kostas, Dr
Aristotle University of Thessaloniki, Physics Department
Laboratory of Atmospheric Physics, P.O. Box 149, 54006, Thessaloniki, Greece
New address: Demokritos University of Thrace
Phone: +30-25410-63035
kourtidi@env.duth.gr

Larssen, Thorjorn, Researcher
Norwegian Institute for Water Research (NIVA)
P.O. Box 173 Kjelsas
0411 Oslo
Phone: 47 22185194, Fax: 47 22185200
thorjorn.larssen@niva.no

Maas, Rob, Dr
RIVM, National Institute of Public Health and the Environment
Postbus 1
3720 BA Bilthoven
The Netherlands
Phone: 31 30 274 3704, Fax: 31 30 274 4435
Rob.Maas@rivm.nl

Metz, Paul, Dr.
INTEGeR... consult
and
European Business Council for a Sustainable Energy Future - e5
Stalen Enk 45
NL-6881 BN Velp
The Netherlands
Phone: 31 26 362 04 50, Fax: 31 (84) 222 41 38
Metz@Integerconsult.org

Raes, Frank, Dr
Institute for Environment and Sustainability
Joint Research Centre, European Commission
I-21020 Ispra, Italy
Phone: 39 0332 789958, Fax: 39 0332 785704
frank.raes@jrc.it

Rosland, Audun
The Norwegian Pollution Control Authority (SFT)
P..O. Box 8100 Dep, 0032 Oslo, Norway
Phone 47 22573547, Fax: 47 22676706
audun.rosland@sft.no

Seip, Hans Martin, Professor
CICERO
and
Department of Chemistry, University of Oslo,
P.O. Box 1033 Blindern, 0315 Oslo, Norway
Phone: 47 22855401, Fax: 47 22855441
h.m.seip@kjemi.uio.no

Vennemo, Haakon, Senior Researcher
ECON (Centre for Economic Analysis),
P.O.Box 6823 St Olavs plass, 0130 Oslo, Norway
Phone: 47 22989849, Fax: 47 22110080
haakon.vennemo@econ.no

Vogt, Rolf D., Dr
Department of Chemistry
University of Oslo
P O. Box 1033 Blindern
0315 Oslo, Norway
Phone: 47 22855696, Fax: 47 22855441
r.d.vogt@kjemi.uio.no

Zhai Fan, DR
Policy and Fiscal Affairs Dept., Ministry of Finance
P.R China
Phone: 86-10-6855-1573, Fax: 86-10-6855-1523
fzhai_99@yahoo.com

Zhang ZhongXiang, Professor
East-West Center
1601 East-West Road
Honolulu, HI 96848-1601
USA
Phone: 1 808 944 7265, Fax: 1 808 944 7298
ZhangZ@EastWestCenter.org