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A model framework for ranking of measures to reduce air pollution with a focus on damage assessment

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A MODEL FRAMEWORK FOR RANKING OF MEASURES TO REDUCE AIR POLLUTION WITH A FOCUS ON DAMAGE ASSESSMENT

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ABSTRACT

Different pollution problems are often due to the same sources. For instance road traffic causes health and noise problems locally, contributes to ozone formation and acidic deposition regionally and is an important emission source for greenhouse gases. This fact calls for an integrated approach considering several pollution problems and components when developing abatement strategies. This paper discusses the advantages of a "bottom-up approach", based on primarily microeconomic information, when the focus is on the complexity of relations between emissions of different components and their associated damages. The importance of knowledge concerning dose-response relations is emphasized and the status of today's knowledge is briefly discussed. A methodology for damage assessment and ranking of measures according to their cost-benefit ratio, planned to be applied in a case study in Hungary, is briefly outlined.

CONTENTS

1. INTRODUCTION

Both nationally and internationally there is a growing interest in decision-support tools to assist decision-makers in defining optimal combinations of abatement measures concerning a wide range of pollutants and their adverse effects. The claim for cost-effectiveness and optimization has strengthened as the size of the investments needed to reduce environmental deterioration has been realized. Usually each abatement measure influences the emissions of a number of pollutants and some components are closely related in terms of abatement measures. This fact requires that different pollutants and abatement measures as far as possible are considered in an integrated way.

The project presented here is part of a comprehensive study planned to be carried out during 1994 and 1995: "Climate, Air Pollution and Energy: Cost-Effective Strategies for Reduction of Emissions", or the CAPE project for short. Two areas in Hungary will serve as cases for application of the model, Budapest and Miskolc, as examples of large cities and industry areas, respectively. The damage types that probably are the main problems due to air pollution in Hungary and that will be focused in the study, are effects on human health, deterioration of forests and forest soils and corrosion of materials. Global warming will be dealt with by estimating the reductions in greenhouse gases (GHGs) given in Global Warming Potential units (GWP) as defined by the IPCC (Houghton et al., 1990). An introductory workshop with the Norwegian and Hungarian counterparts was held in Budapest in September 1993.

The project will be directed by Center for International Climate and Energy Research - Oslo (CICERO) and be performed by researchers at a number of Norwegian and Hungarian institutions.

The overall objective of the CAPE project is to establish a comprehensive methodology and a decision-support tool for ranking of abatement measures regarding air pollutants and greenhouse gases (GHGs). Global, regional as well as local environmental effects will be addressed.

The approach builds on cost/benefit analysis (CBA). CBA proceeds by assessing, as far as possible, the social costs and benefits of a policy or action (e.g. abatement measure). Theoretically, all measures with a positive present value of the net benefit should be realized. However, a ranking is usually desirable, mainly because the budgetary frames may be lower than what is necessary for realizing all these measures and because some measures may be interdependent. The basic value judgement of CBA is that people act according to their individual preferences and the goal is, in economic terms, to maximize social utility (OECD, 1989).

A number of objections have been raised as to whether monetary reductionism is feasible for all environmental attributes (for discussions see Schrader-Frechette, 1991 and OECD, 1992). In our view it is crucial that also a physical description is presented in connection to the monetized environmental attributes. We will, however,

however, point out that monetization of health and environmental attributes, when pursued with integrity, has the advantage that implicit judgements are made explicit and subject to analysis and open discussion. As will be described in the following, we intend to integrate some features of other decision-frameworks into our CBA approach. (For a systematized description of decision-frameworks, see OECD, 1989).

An important element of the project will be performed by political scientists and involves analyses of the socio-economic and institutional environment, within which alternative response measures may be chosen. In addition to contributing to development of methodology, the case studies in this project will hopefully also contribute to the development of cost-effective strategies concerning environmental and energy policy in Hungary.

2. THE OSLO AIR STUDY

The CAPE project will partly draw upon experiences from a project carried out in Norway - the Oslo Air Study. In this study, initiated and organized by the Norwegian State Pollution Control Authority, an analysis of air pollution abatement measures related to the city of Oslo was conducted (SFT, 1987; Trønnes and Seip, 1988). The principle steps in studies of this kind (see fig.1) include models for the fate of the emitted pollutants and the resulting exposure of humans, materials and environment. Combining this information with quantitative knowledge of effects of the pollutants, the damages may be estimated. One control measure may affect a number of pollutants and each compound may affect the population/recipient in several ways.

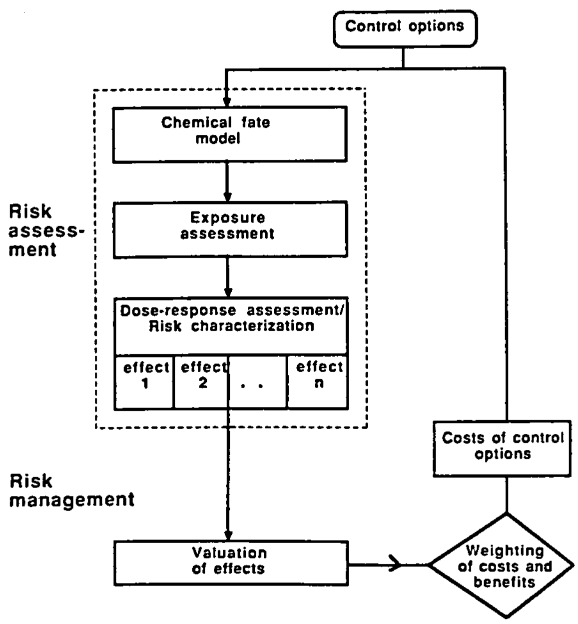

Figure 1. Components of an analysis of pollution control (from Trønnes and Seip, 1988)

Altogether 38 measures (control options) were considered including for example emission standards for busses, better maintenance of diesel vehicles and substitution of oil by electricity in domestic heating. While most of the measures were applicable on a local scale, some were inherently national scale measures (i.e. emission standards for road vehicles).

The analysis was restricted to comparing the benefits (monetized effects of the measures) to the direct costs of implementation. Implementation costs for the state, the municipality and the private sector were estimated. Other social effects were calculated as "side effects".

The primary motivation for the work on measures to curtail air pollution in Oslo was considerations of human exposure to air pollution and effects on health and well-being. Additionally, benefits concerning some other impacts were also included in the analysis. The objectives were structured in the following way:

1. Reduce human exposure to SO_2, NO_x, CO and suspended particulate matter.
2. Increase well-being in the sense of reducing affliction by dust and/or odour.
3. Reduce contribution to acidification by reducing emissions of SO_2 and NO_x in Oslo.
4. Increase positive and reduce negative "side effects" (e.g. changes in number of traffic accidents, changes in travel times due to changed passableness on the roads, reduced corrosion of buildings and metals and changes in heating expenses).
5. Reduce implementation, operation and maintenance costs of abatement measures.

The attributes (the variables in the analysis) according to each of these objectives were estimated in different units:

- "Number of persons exposed to concentration levels above the guideline" (for SO_2, NO_2, CO and particles respectively). Considering effects on human health, the attributes were thus not based on dose-response functions, due to the lack of satisfactory models in the literature at that time. (4 attributes, X_1-X_4).
- "Number of persons afflicted" (by dust and odour respectively). (2 attr., X_5, X_6).
- "Tons emitted per year" (of SO_2 and NO_x respectively). (2 attr., X_7, X_8)
- "Annualized present value of net change in side effects". (X_9).
- "Annualized present value of implementation costs". (X_{10}).

Only the two last attributes were given directly in monetary units. In order to bring the different effects onto a common scale for internal comparison and be able to make trade-offs with abatement costs and thereby ranking the measures, a simplified Multi Criteria Decision Analysis (MCDA) was applied (Trønnes and Seip, 1988). This method will also be applied in the CAPE study (see later).

The benefit/cost ratio for each measure was calculated simply as

$$\frac{B}{C} = \sum_{i=1}^{9} \frac{k_i \cdot X_i}{k_{10} \cdot X_{10}}$$

where the k_i's (i = 1-10) are the weights bringing the attributes onto a common scale and the X_i's are the attributes.

When putting together a ranked selection of measures, dependency between measures was accounted for. An example of mutual dependency between measures is the relationship between the following measures; a) reducing the sulphur content in oils used in domestic heating, and b) partly substituting oil in domestic heating by electricity. The environmental effect of implementing both is lower than the sum of the isolated effects of implementing one of them. The cost-benefit ratio of the measures will therefore depend on the order they were entered.

The uncertainties in the attribute values for the measures are often large. The effect was studied by subjective estimation of probability distributions for the attributes and performing "Monte Carlo simulations": A large number of calculations were carried out by drawing values for the uncertain variables according to their probability distributions (stochastic simulation). The uncertainties are thus carried through the calculations and displayed in the result as a probability distribution of the B/C ratio.

The methodology developed in the Oslo Air Study has been further elaborated in other studies conducted by the State Pollution Control Authority in Norway, i.a. the analysis of measures to fulfill the commitments according to the North Sea Declaration on discharges of nutrients to the North Sea basin (SFT, 1992a). Although it is usually difficult to state with certainty what is actually decisive for a policy being chosen, it is a fact that in Norway these kinds of analyses are used in the official argumentation for political decisions (Strand, 1990).

3. FURTHER METHODOLOGICAL DEVELOPMENT

In this project we will attempt to take some further steps towards a more comprehensive model tool regarding the ranking of abatement measures. The basic philosophy is that one must take an integrated approach comprising various environmental problems in order to sort out cost-effective measures. An underlying motive is also that the incentive for responding to the climate change issue may be strengthened by connecting it more closely to regional and local problems.

The approach taken in the CAPE study includes some interrelations between emissions, environmental impacts and economic activities that are vital to the evaluation of measures. However, many relations that indeed exist between these variables will have to be excluded. For instance, the social benefits obtained from a more healthy population cannot be derived from the reductions in the costs of health care alone. Productivity will increase, for instance because of reductions in days off from work due to illness. A lower need for health care means that one can release some of the economic resources to other economic activities and so on. Indirect effects of this type will be excluded from the study. Neither do we intend to include all types of pollutants, but rather focus, at least as a starting point, on some of the main air pollutants in addition to GHGs. Thus the model outcome will only partly deserve the term "integrated assessment" as it will not include e.g. effects of hazardous waste and effects of discharges to water. If our concept turns out to be successful, the model might be extended to include such issues.

Methodological development is desirable for several reasons, and some of the items that will be dealt with in our study are outlined in the following.

3.1 Extension of the "bottom-up" approach

The approach applied in the Oslo Air Study and related studies is based on information on the micro-level, often referred to as the "bottom-up approach" (B/U). This implies that a number of abatement measures considered appropriate for fulfilling the objectives of concern are explored in detail. The emission reduction potentials (based on empirical evidence) and potentials for damage reductions (based partly on empirical studies, partly on theoretical assumptions) are estimated. Assessments of the values of the costs and benefits are then made according to observed or estimated market prices. The social net benefit from each alternative, found by adding up all costs and benefits, provides the basis for the evaluation of measures.

An alternative to the "bottom-up"-approach is the "top-down approach" (T/D), where the effects of an abatement strategy is assessed by the use of a macroeconomic model. These models enable in principle analysis of direct and indirect economic effects of abatement measures on main macroeconomic variables. From the predicted changes in economic activity, the effects on emissions are deduced. In principle, the damage caused by the effects on emissions could be assessed similarly to the estimation of damage in the CAPE study and then be implemented in the macroeconomic model in order to make a simultaneous assessment of economic and environmental effects. However, this requires that the model distinguishes between different sources of emissions and different recipients of importance. For instance, if a given level of pollution affects health according to population density, the model will have to include a geographical dimension. This turns out to be a major problem in establishing integrative macroeconomic model tools.

A major weakness of B/U calculations is, on the other hand, that macroeconomic effects are generally left out. If the measures under consideration require a vast amount of economic resources, for instance large investments, they will displace activities which would have been carried out if the measure in question was not implemented. The short-term effect of this might be unemployment or increased pressure in the labour market. The long-term effect might be reallocation of resources and changes in relative prices. Thus, the reliance on observed market prices would no longer apply. However, some macroeconomic effects, e.g. unemployment, may be approximated as "side effects".

The properties of the T/D and B/U approaches are also crucial for their usefulness in making an evaluation of alternative policy instruments. The general framework of macroeconomic models makes them particularly suitable for analyzing general measures, such as taxes, and less suitable for the analysis of individual physical measures such as investments in abatement activities, for which a B/U approach would be preferable. Taxes appear to have some optimizing properties if there is a close correlation between economic activity and environmental effects. They do not, however, always provide the most cost-effective alternative. There may be many factors that complicate the relation between the taxed commodity (e.g. fossil fuel) and the environmental deterioration, as for instance patterns of dispersion, the mechanisms of formation of the pollutant and atmospheric interactions with other pollutants. A tax may thus "overpunish" parts of the consumption that actually have only a small environmental impact.

In our view the T/D approach is especially difficult to apply when effects of a number of components with different chemical features are considered. When the focus is on the complexity of relations between emissions and damage, macroeconomic models may not provide enough relevant information for the ranking of measures.

In the CAPE study the intention is to take the B/U approach as the point of departure, but to extend the approach with some new elements that widen the scope. This will be done by analyzing the socio-economic and institutional environment, which is decisive for defining feasible measures to be analyzed. However, a complete macroeconomic analysis will not be performed. In addition to the problems mentioned above the special transient economic situation in Hungary and other post-communist countries at present would be extremely difficult to model.

Our primary goal is to contribute with some novel ideas about how to perform damage assessment and how to evaluate the related costs and benefits. For the ranking of measures, special attention will be paid to the evaluation of uncertain outcomes of the alternatives. The damage assessments will be indicated by probability distributions. Accordingly, the net benefit of measures will also have to be expressed in terms of distributions. However, because of non-linear cost functions and/or risk aversion, the relation between the marginal damage and the marginal net benefit is unlikely to be linear. If it is non-linear, the net benefit will depend partly on the distribution of the assessment of the damage, not only on its expected level. Since the interval of probable damage may be large, and vary significantly between alternative measures, it is vital to take account for the uncertainty of the outcomes when evaluating the measures. As mentioned above, the probability distribution of damage will depend on several factors taken as assumptions. Sensitivity analysis on these assumptions enables evaluation of cost-effectiveness not only according to parametres of a given distribution, but also according to alternative distributions.

3.2 Application of dose-response functions

A dose-response function gives the relationship between the concentration level and the prevalence of a certain effect in the recipient. The scientific basis for applying the dose-response approach has improved significantly since the Oslo Air Study was conducted, although there are still many unknowns and uncertainties as illustrated by examples given below.

In the CAPE study we will draw upon other studies on damage assessment. A major study has been conducted jointly by the Commission of the European Community (CEC) and US Department of Energy on external costs of different fuel cycles (i.a. Markandya and Rhodes 1992). International expert groups were convened to discuss methodologies and make recommendations concerning the most applicable dose-response functions and models and the basis for monetizing damages. Although the study made an effort to estimate damages on a marginal basis, it was realized that often average figures have to be used and that these are an approximation to the marginal damage. When it came to impacts on forestry, for instance, it was not considered possible to use the dose-response approach and it was recommended to estimate average damage in a country per ton of SO_2 deposited. Concerning global warming, estimates of contribution to total global warming potential (GWP) were calculated.

A literature study with regard to present methods and knowledge concerning damage assessment will be the basis for selecting the dose-response functions and other types of assessment tools to be included in our model. The attributes which will be subject to monetization should be easily understood by decision-makers (the user) and this objective must be pragmatically weighted against considerations of i.a. precision.

Concerning *health effects* it is a problem that most studies report only the immediate consequences and not the possible delayed effects. It appears, however, that cumulative exposure of air pollutants also provides a significant risk. For instance, experiments with animals indicate that prolonged exposure to ozone may induce effects which seem to be irreversible, while most human studies cover relatively short periods (up to a few weeks in epidemiological studies) reporting impaired pulmonary function, cough and other reversible effects (for an overview, see SFT, 1992b). Epidemiological studies show that elderly people are more vulnerable to air pollution in general, but it is hard to say whether this is due to increased vulnerability to short-term rises in the concentration level or if it is caused by a cumulative effect of long-term exposure (Gottinger, 1983).

Concerning *effects on forests* a large number of variables, in the air, water and soil, will be affected by emissions of air pollutants. The effects may be caused either directly when gasses are taken up through the stomata or indirectly when deposition alters the soil chemistry. Resilience of trees are recognized through the estimation of critical levels and loads. A number of models of tree response to acidic deposition have been developed, e.g. the forest module of the RAINS model and a growth response model by Sverdrup et al. (both assessed in the CEC/US study, 1993). The first one identifies areas of increased risk of forest decline due to excess of a critical dose of SO_2, which in principle is the same as comparing the concentration levels with *critical levels* (although the model additionally includes considerations of the effects of altitude on tree health). The second one predicts growth response as a function of soil acidification expressed by the (Ca+Mg)/Al ratio (*critical load* approach).

The main problem for the modelers is the lack of dose-response functions for acidic deposition and forest decline, which i.a. is due to lack of knowledge of basic growth processes and more technical problems in experimental studies of long-term response of mature trees. The fact that forest decline probably is caused by different pollutants and different mechanisms in various regions makes it extremely difficult to make models for larger areas.

Impacts of sulphur dioxide and ozone on *materials* provide some of the clearest examples of damage related to air pollution. The detrimental effect depends on the material properties, concentration levels of the agents and, for acid precursors, the presence of water. According to a survey undertaken in the CEC/US study (Markandya and Rhodes, 1992) reliable estimates of damage from acidic deposition (based on dose-response functions) can be made for stone, mortar, concrete, paint, steel, zinc and aluminium. In Norway several attempts have been made to estimate maintenance and replacement costs of material damage and the total social costs of these damages (see e.g. Henriksen et al., 1993; Glomsrød and Rosland, 1988). In addition to costs of maintenance, monetization can also involve estimates of existence value (for instance for historical monuments).

Concerning *global warming* there are some formidable problems with the benefit-cost approach. Quantitative insights (i.a. response functions) concerning physical impact are still rudimentary, monetary assessment is accordingly difficult, the uncertainties are huge and worst case scenarios predict extensive irreversible damage, which has made the precautionary principle a governing rule in global environmental policy processes. Advocates of the cost-benefit approach point out that the drastic measures that are needed to curb greenhouse gas emissions should not be implemented without any serious attempt to weight the economic costs and benefits of alternative control strategies (see Pearce et al. 1992 for a discussion). Since the potential effect of global warming will affect different regions in the world very differently, national or regional cost-benefit analyses might, however, tend to have a too narrow perspective for taking properly care of the climate change issue.

3.3 The process of weighting and evaluating health and environmental attributes

The purpose of this part of the study is the monetization of damage to health and environment and other side effects that are considered in the analysis. These are external costs, defined as costs which fall on one group of people due to the social or economic activities of another group, and where the latter group does not take these costs into account.

When trying to monetize these effects it is necessary to distinguish between costs in terms of a change in the trade of goods and services with observed market prices, and attempts to relate a market price to effects on variables that are not traded in the market but indeed count for the social welfare, such as environmental amenities. The first category relates to so-called indirect economic effects which include loss of worker productivity due to illness, medical expenses, and repair and replacement costs for material damage. The second category relates to a broader welfare concept than usually applied in cost-benefit analysis. Nevertheless, such elements may have a significant influence on the choice of policy, especially when evaluating environmental measures (see e.g. Sen, 1979). However, when monetizing these effects, several methodological problems arise. In the CAPE project attempts will be made to include the value of environmental amenities, but a clear distinction between "real" economic effects and estimated value of environmental amenities will be made when presenting the results.

There are different methods for monetization of environmental amenities. The issue is subject to extensive research and implies considerations of fundamental questions of values. In the Oslo Air Study an expert panel arrived at values by using results from other studies, based on different methods, including Contingent Valuation assessments[1]. Here we will restrict ourselves to give a brief introduction to one method we intend to apply to bring attributes that are not directly commensurable onto a common scale, the Multi Criteria Decision Analysis (MCDA). Recently, this method has been applied for the purpose of estimating the Norwegian society's willingness to pay for environmental goods (Wenstøp et al., 1993).

The theoretical foundation for MCDA was laid down already in 1944 by von Neumann and Morgenstern (1944) through their work on the basis for utility theory. The theory was generalized by Keeney and Raiffa (1976) and made suitable for treating several conflicting objectives. Application of MCDA has increased significantly the last years, specifically in areas where it is necessary to make trade-offs between health and environment versus economic criteria (Carlsen and Wenstøp, 1992).

In a MCDA the criteria, or attributes, are given weights by expert panels. These panels may consist of persons who have special knowledge of the topics of concern and/or have a specific profession or belong to a particular type of organization.. The members of the panels are encouraged to aim at acting as general members of the society, and not act tactically in order to promote sectional interests. The process of weighting different attributes is heuristic and helps the members of the panels, through discussions and assisted by interactive data software, to reveal their preferences in a consistent way (Carlsen and Wenstøp, 1992). The results from different panels will differ to a varying extent.

[1] Contingent Valuation includes asking for willingness to pay or willingness to accept - a measure of personal valuation of the respondent for increases or decreases in quantity of some good, contingent upon an hypothetical market. The method is only meaningful if the respondent is properly aware of the effects of concern (OECD, 1989).

3.4 Time limits and transferability

Questions of time limits and comparability of events at different points of time for the estimations of long-term effects are essential, i.a. because of varying time profiles of different effects. Discounting monetary estimates of future environmental effects has been extensively discussed (Cline, 1992), but several problems remain to be solved before one can say there is consensus about how to treat the problem of discounting, see e.g. Machina (1989).

In studies where long-term environmental effects with uncertain outcomes are as important as in the CAPE-study, a comparison between different ways of discounting is of particular interest. The problem relates partly to that of welfare comparisons mentioned above. In a long-term perspective one may encounter considerable changes in the distribution of welfare between countries, and between welfare components within one country. Generally, there is little knowledge of the income elasticity of demand for different environmental goods (Markandya, 1993). From damage estimates in the US PACE study on Environmental Costs of Electricity (Ottinger, 1990), the income elasticities of health damages and material damages were estimated to 1.15 and 0.72, respectively. This implies that if the income increases over time, the importance of health increases relative to material damages (see Markandya, 1993). Since the value of health is expected to comprise more than the direct economic value of it, these non-economic aspects of a future change in income should be reflected in the discount rate. The longer the time perspective, the more important is the inclusion of non-economic aspects.

Concerning global warming the output of our model will probably be limited to GWP units. GWPs for the important green house gases have been estimated for various time horizons. However, this does of course not describe the time profiles of environmental effects.

Similar problems are related to transferability of dose-response functions from one region to another. National boundaries are in themselves not of any relevance to how people and environment respond to pollution, but cultural differences may be. Easier to deal with, but equally important, are differences for instance in age distribution and overall health status in the population and in vulnerability of vegetation due to e.g. climatic conditions.

4. OUTLINE OF A DAMAGE ASSESSMENT MODEL

In the CEC/US study mentioned above well over 200 impacts (considered as externalities) were identified for the coal fuel cycle. However, detailed analysis was restricted to those believed to be most important. This indicates the importance of identifying *priority impacts* at an early stage. The damage types that are pointed out as probably the main problems due to air pollution in Hungary are effects on human health, deterioration of forests and forest soils and corrosion of materials (Gajzago, 1992; Pais and Horváth 1990; KTM, 1992).

Interdependency between measures calls for arranging the damage assessment model in such a way that for every measure that are fed into the model, the exposure status is adjusted before entering a new measure. The cost-benefit ratio of the measures will therefore depend on the order it was entered.

Four main modules have been outlined as necessary elements in the damage assessment model:

Data base modules:
- Emission data (source specification)
- Recipient data (people, crops, forests, materials/buildings)

Model base modules:
- Atmospheric chemistry, dispersion and deposition
- Damage assessment (based on dose-response functions and other approaches)

1. *Emission database.* The input to this database is the results of the inventories of GHGs and other air pollutants according to different source categories (i.a. stationary combustion, industrial processes and mobile combustion). It will include CO_2 SO_2, NO_x, particulates (TSP/PM10 [2]), CO, organic compounds and metals.

2. *"Chemical fate" model(s).* The input to this module will be emissions from different sources and the output should give estimates of how dispersion and deposition of the different chemical species influence concentration levels and deposition loads in different areas. The different measures that are analyzed will result in changes in these quantities and the status should be recalculated for every measure introduced. The formate of the output has to be in accordance with the damage attributes in module 4. For instance one has to decide whether the concentration levels should be given as hourly, daily and/or yearly means.

3. *Population database.* This database will contain data concerning the geographical distribution of people, agriculture production and forests within the areas of concern. We will also include data on buildings and materials (including historical/cultural objects) that are vulnerable to corrosion due to air pollution. This database will be built up in close association with the following module (damage assessment) in order to ensure accordance between the two.

4. *Damage assessment module.* The output of the two former modules will be an exposure assessment for people, vegetation and materials and this will be input to the damage assessment module which should provide estimates of potential damage (risk) to the populations/recipients of concern. When possible, dose-response functions will be used to calculate changed damage due to reductions in the emissions of air pollutant. Concerning global warming, estimates of indirect effects of other gases (NO_x, CO and VOCs) on climate, as calculated by Fuglestvedt et al.

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[2] Suspended particles with diameter <10μm

(1993), will also be included in the GWP figures.

CONCLUSIONS

An integrated approach considering several pollution problems is generally necessary in cost-benefit analyses of abatement measures. When the focus is on the complexity of relations between emissions of different components and their associated damages (local, regional and global) the microeconomic approach (often referred to as "bottom-up approach") seems to have advantages compared to macroeconomic methods ("top-down") which are often applied for evaluation of environmental policy instruments.

The assessment of impacts on health and environment, a crucial step in the analysis, requires knowledge concerning exposure and the mechanisms responsible for chemical and biological effects. Dose-response relationships give information which is very useful when it comes to analyzing the effects of reducing emissions.

Inherently, there will be uncertainties in every step in the calculations, and these should be reflected in the results.

The process of carrying out an analysis may in itself be valuable in terms of clarifying the main objectives of an abatement policy and explicitly describing adverse impacts and their assumed relative importance. This gives excellent opportunities for communication with those affected by the decisions. It also reveals the areas where the need for more insight is strongest. In our view it is crucial that also a physical description is presented in connection with monetized environmental damages.

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