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Introduction

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Europe has successfully tackled the most visible effects of air pollution ...

During the last decades Europe has successfully eliminated the most visible and immediate harmful effects of air pollution. Urban smog episodes like in London in the 1950s are now history, the air in industrial regions has been cleaned up since the 1960s, Scandinavian lakes are recovering from acidification in the 1970s, the large-scale forest die-back of the 1980s in central Europe has come to an end, and episodes of high ozone concentrations are less frequent than in the 1990s.

However, there is ample and robust scientific evidence that even at present rates Europe's emissions to the atmosphere pose a significant threat to human health, ecosystems and the global climate, though in a less visible and immediate way. Refined scientific methods reveal that, e.g., via the long-term exposure to fine particulate matter, current levels of air pollution shorten statistical life expectancy of the European citizens by several months. Biodiversity and Europe's genetic resource base is under threat from the excessive release of nitrogen to the atmosphere from energy combustion and intensive agriculture. Europe's greenhouse gas emissions, currently twice as high on a per-capita basis as the world average, and historically responsible for about a quarter of current concentrations in the atmosphere, make a significant contribution to global climate change.

... but solving the less visible problems constitutes serious policy challenges.

To protect the livelihood of European citizens, the sustainability of the services provided of its ecosystems and to avoid dangerous interference with the global climate system, additional efforts are required to control the release of harmful substances to the atmosphere. In principle, a host of measures is available to further reduce emissions in the future. However, as many of the 'low hanging fruits' have been harvested by now, further action will put higher demand on economic resources, especially at a time when resources are strained by the economic crisis. In addition, we gain increasing insight into the interactions and interdependencies of the various measures that could lead even to counterproductive outcomes of strategies if they are ignored. However, if put in context, informed decision making could develop strategies that maximize the synergies between different measures to safeguard environmental improvements for all relevant aspects while minimizing economic resources for their implementation.

An outlook into the likely development of future emissions and impacts

This report presents an outlook into the likely development of emissions and resulting impacts up to 2030 as can be envisaged from the current expectations on economic development and the implementation of existing legislation on air pollution controls in the European Union. It is compiled at the mid-term of the EC4MACS project cycle, and provides a first holistic perspective into the next 20 years that emerges from the new integration of the participating EC4MACS models. On that basis the report provides information for subsequent considerations of enhanced policy response strategies to protect living conditions for humans and ecosystems from atmospheric pollution at the local, regional and global scale.

Based on recent expectations on future economic growth

The future pressure on the environment from humans – and cost-effective response strategies – will be critically influenced by the types and quantities of economic activities. The recent economic crisis has clearly demonstrated how difficult it is to accurately predict economic development, and that any prediction is associated with deep uncertainties. However, this report adopts the most recent post-economic crisis projections as a central assumption, as they incorporate the economic downturn that occurred in 2008 and 2009.

Structure of the report

The remainder of the report is organized as follows: Section 1 reviews the context of the study and how the analysis aims to support future policy decisions on climate and air pollution strategies in the European Union. Section 2 summarizes assumptions on the future development of key drivers of emissions and on policies that will influence these drivers. Section 3 presents estimates of baseline emissions of greenhouse gases and air pollutants for the Member States and economic sectors. Section 4 introduces physical impacts of air pollution on human health, forests, vegetation, freshwater, agricultural crops and materials as they are modelled for 2000 and the future. Section 5 presents monetary estimates of the damage from air pollution. Conclusions are drawn in Section 6.

EC4MACS develops a holistic perspective on cost-effective response strategies

The impact of human activity on the Earth's atmosphere is critically determined by numerous linkages, interactions and feedbacks between the social, economic and environmental systems. Much, although not all, is understood about individual aspects that are involved in local air pollution and global climate change. Only an integrative perspective that brings together the relevant aspects can provide informative and accurate knowledge on the current state and the likely future development, and the scope for measures to reduce negative impacts of human activities on the atmosphere.

The European Consortium for Modelling of Air pollution and Climate Strategies (EC4MACS), a project funded under the EU LIFE programme, develops a network of well established modelling tools that enable a comprehensive integrated assessment of the policy effectiveness of emission control strategies for air pollutants and greenhouse gases.

Box 1: Objectives of the EC4MACS project

Clean air and climate change are central fields of EU environmental policy. New scientific findings demonstrate important interactions and potentially large economic synergies between air pollution control and greenhouse gas mitigation. Model analyses, based on latest scientific findings and validated data, can provide valuable information for cost-effective policy strategies. The key objectives of EC4MACS are:

- Provide scientific and economic analyses for the revision of the EU Thematic Strategy on Air Pollution and the European Climate Change Programme (ECCP)
- Improve existing models by including recent scientific findings
- Update of input data
- Achieve acceptance of modelling tools and input data by stakeholders
- Make modelling tools available to the public over the Internet

The EC4MACS approach assumes cause-effect relationships between interacting components of social, economic, and environmental systems. These include

- driving forces of environmental change (e.g., industrial production),
- pressures on the environment (e.g., discharges of pollutants to the atmosphere),
- state of the environment (e.g., air quality in different regions in Europe),
- impacts on population, economy, ecosystems (e.g., reduced life expectancy from the exposure to air pollution),
- response of society (e.g., emission control policies).

This sequence of cause-effect relationships, which is often called the DPSIR (Drivers-Pressure-State-Impact-Response) concept, is quantified in the core computer model of EC4MACS, the GAINS model (Figure 1.1). The concept allows simulation of the impacts of policy actions that influence future driving forces (e.g., energy consumption, transport demand, agricultural activities), and of dedicated measures to reduce the release of emissions to the atmosphere, along their impacts on total emissions, resulting air quality, and a basket of air quality and climate impact indicators. Furthermore, through the GAINS optimization tool, the framework allows the development of cost-effective response strategies that would meet environmental policy targets at least costs.

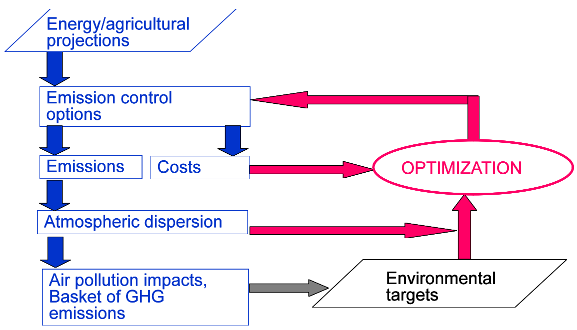

Figure 1.1: The cause-effect chain for atmospheric pollution considered in EC4MACS

Introduction

A multi-pollutant/multi-effect approach

Emissions to the atmosphere cause a variety of negative impacts on climate and air quality. In addition, pollution does not comprise a single chemical substance, but consists of a cocktail of many pollutants originating from a wide range of human activities and natural sources that can be controlled to different extents at different costs. Thus, cost-effective response strategies need to consider cause-effect relationships for multiple pollutants and multiple effects, and how they are interconnected with each other. The GAINS model, as the core integrated assessment tool of EC4MACS, represents the cause-effect chains for health impacts, vegetation damage and climate change, taking into account the sources and control potentials of five air pollutants and six greenhouse gases (Table 1.1). In particular, it describes the simultaneous effects of specific control measures on the emissions these air pollutants and greenhouse gases, and the physical and chemical interactions of these emissions in the atmosphere.

However, the GAINS model does not cover the full range of relevant driving forces that cause pollution, nor does it represent the full range of environmental and economic impacts of pollution. As these aspects cannot be ignored in the design of cost-effective response strategies, the EC4MACS project has linked existing computer modelling tools to enable a holistic and coherent assessment of policy response options.

	PM	SO_2	NO_x	VOC	NH_3	CO_2	CH_4	N_2O	HFCs PFCs SF_6
Health impacts: PM (Loss in life expectancy)	√	√	√	√	√				
O_3 (Premature mortality)			√	√			√		
Vegetation damage: O_3 (AOT40/fluxes)			√	√			√		
Acidification (Excess of critical loads)		√	√		√				
Eutrophication (Excess of critical loads)			√		√				
Climate impacts: Long-term forcing (GWP100)						√	√	√	√

Table 1.1: The multi-pollutant/multi-effect framework of EC4MACS

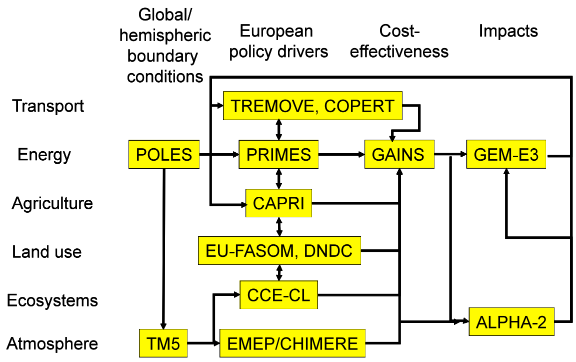

Figure 1.2: The EC4MACS model suite that describes the full range of driving forces and impacts at the local, European and global scale.

Box 2: Models participating in the EC4MACS framework

The GAINS integrated assessment model explores cost-effective multi-pollutant emission control strategies that meet environmental objectives on air quality impacts on human health and ecosystems and on total greenhouse gas emissions.

The PRIMES energy model simulates the response of energy consumers and the energy supply systems to different pathways of economic development and exogenous constraints.

The TREMOVE transport model simulates current and future transport demand, fleet structures and emissions for all European countries.

The CAPRI agricultural model describes the development of the agricultural sector in response to a wide range of policy actions.

The EUFASOM model explores welfare maximizing total land-use strategies, including greenhouses gas emission control and carbon sink strategies that meet wider environmental objectives on inter alia soil, water and biodiversity protection. The DNDC model calculates associated greenhouse gas emissions.

The EMEP and CHIMERE atmospheric dispersion models address chemical processes and the transport of pollutants in the atmosphere at the regional and local scales.

The CCE Impact Assessment module develops impact assessment methods and indicators for air pollution effects to different types of vegetation and ecosystems and collects necessary input data from all countries.

The ALPHA2 model quantifies the health and environmental benefits of emission control strategies in monetary terms.

The GEM-E3 economic model explores the macro-economic impacts of emission control strategies for all Member States of the EU by simulating the interactions between the economy, the energy system and the environment.

Box 3: Participants in the EC4MACS project

The International Institute for Applied Systems Analysis (IIASA), Austria

IIASA (www.iiasa.ac.at), an international, non-governmental research institute, has developed the GAINS integrated assessment models for air pollution and greenhouse gases. It applied the model, inter alia, for the scientific support of the CAFE programme of the European Commission (2000-2005), for the development of the EU National Emission Ceilings Directive (1998-1999), the EU Acidification Strategy (1997), and various protocols of the UNECE Convention on Long-range Transboundary Air Pollution. Under that Convention IIASA hosts the Centre for Integrated Assessment Modelling (CIAM) of the European Monitoring and Evaluation Programme (EMEP).

The Coordination Center for Effects (CCE), Bilthoven, Netherlands

The CCE (www.mnp.nl/cce), located at the Netherlands Environmental Assessment Agency (PBL), collaborates as the Programme Centre of the International Cooperative Programme on Modelling and Mapping, with 26 National Focal Centres to provide operational methodologies to support impact assessment of air pollution policies. Results of CCE's work supported effect-based UNECE protocols (1994, 1999), protocol-review (2005-2008) and EC policy processes including the Acidification Strategy (1997), the NEC Directive (1999) and the CAFE programme.

The E3M-Lab of the National Technical University (NTUA), Athens, Greece

NTUA (www.e3mlab.ntua.gr) has developed and applied several energy and economic models for all EU member states. These include the medium-term econometric engineering MIDAS model, the PRIMES energy model, and the GEM-E3 general equilibrium macro-economic model. Model applications have been carried out for the European Commission and for public authorities in many countries.

The Laboratory of Applied Thermodynamics in the Aristotle University of Thessaloniki (LAT/AUTh), Thessaloniki , Greece

LAT/A UTh (lat.eng.auth.gr) specializes in emissions control technology for mobile sources for impact assessment studies, emission standard development, monitoring policies, and inventorying. The institute is responsible for the development of the COPERT tool on behalf of EEA and UNECE, the TRENDS tool on behalf of DG TREN and EUROSTAT, and it is a member of the European Topic Centre on Air and Climate Change. In the area of transport scenarios, it has taken part in the Auto-Oil II and the CAFE programmes.

The Institute for Agricultural Policy, Market research and Economic Sociology of the University of Bonn (IAP) and EuroCARE GmbH, Bonn, Germany

IAP (www.agp.uni-bonn.de/agpo/rsrch/capri/capri_e.htm) and EuroCARE (http://www.eurocare-bonn.de) have developed the agricultural sector model CAPRI, which is used to analyse the impact of policy changes on European agriculture. CAPRI is continuously improved under a number of research projects carried out by a network of European researchers, with funds from the European Commission and EEA. The CAPRI baseline served as input into GAINS in the context of CAFE.

EMRC, AEA Technology, MetroEconomica, UK

The benefit assessment team, coordinated by EMRC, a specialist in impact assessment and cost-benefit assessment, includes AEA Technology, one of the UK's largest environmental consultancies, and MetroEconomica, a specialist in environmental economics. All three have participated extensively in Community funded work, for example the cost-benefit analysis of the CAFE programme.