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Air quality and ancillary benefits of climate change policies

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Executive summary and key messages

The Thematic Strategy on air pollution aims to improve European air pollution significantly by 2020. This report from the European Environment Agency looks a further ten years into the future, and brings together two major policy challenges — combating climate change and reducing air pollution — in an integrated way. Thus, the report analyses projected changes in European air quality up to 2030, and explores the possible benefits of climate policies on air quality and the costs of air pollution abatement.

Existing air pollution abatement policies (i.e. those without new action taken within the framework of the thematic strategy) should lead to cleaner air in 2030 compared to 2000. However, EU's objective of attaining levels of air quality that do not give rise to significant negative impacts on and risks to human health and the environment are unlikely to be met. With existing measures only, the situation is even projected to worsen after 2020. In this scenario — the baseline scenario — 311 000 premature deaths are projected in 2030, due to pollution with ground-level ozone and fine particles ($PM_{2.5}$).

EU has stated that the long-term climate objective should limit global mean temperature increase to 2 °C above pre-industrial levels. EU's contribution to meeting this target will mean climate policies which substantially reduce emissions of greenhouse gases. This, in turn, will lead to a fall in air pollutant emissions and their associated health effects, while at the same time reducing the costs of implementing existing air pollution abatement policies. In this scenario — the climate action scenario — the number of premature deaths from pollution by ozone and fine particles is projected to fall by over 20 000 to 288 000 by 2030. Moreover, the costs of implementing existing air pollution measures is projected to fall by EUR 10 billion per year. The avoided health costs could be valued at between EUR 16–46 billion per year.

These ancillary benefits of climate change policies stem from the fact that reducing EU greenhouse gas emissions in line with the 2 °C target leads to reductions of emissions of air pollutants from fossil fuel combustion. Reductions are most notable for oxides of nitrogen (10 %), sulphur dioxide (17 %), and particles (8–10 %) by 2030, as compared to the baseline. Cost savings related to the implementation of existing air pollution abatement measures are highest in the EU-15. Relative abatement cost savings for oxides of nitrogen, sulphur dioxide and particles are estimated to be 20 %, 12 % and 14 % by 2020, and more than 35 %, 25 % and 25 % respectively by 2030.

Therefore, climate change policies can make a substantial contribution to reducing air pollution. The ancillary benefits of climate policies for air pollution are expected to be greater by 2030 than 2020, since a longer period of time would be available for implementing measures and for changes to occur in the energy system.

However, it is clear that significantly greater efforts will still be necessary in the form of further targeted air pollution abatement measures in order to move closer to the EU long-term objectives. Even if the maximum feasible land-based reduction measures in relevant sectors for abatement of air pollution were combined with climate policies — the maximum feasible reduction scenario — there will still be 200 000 annual premature deaths by 2030 from ozone and fine particles. Reductions in emissions from non land-based sources, especially shipping, are necessary if the health impacts are to be brought down further.

Key messages

Action to combat climate change will deliver considerable ancillary benefits in air pollution abatement by 2030. The ancillary benefits will be:

- lower overall costs of controlling air pollutant emissions in the order of EUR 10 billion per year;
- reduced air pollutant emissions, leading to a fall in damage to public health (e.g. more than 20 000 fewer premature deaths/year) and ecosystems.

Ancillary benefits will be greater in 2030 than in 2020. However, climate change policies will reduce the overall cost of the air pollution abatement measures needed to meet the objectives of the Thematic Strategy on air pollution by 2020.

Action to reduce air pollution, including emissions from shipping, will be required to move closer to the EU long-term objectives for air quality.

Summary

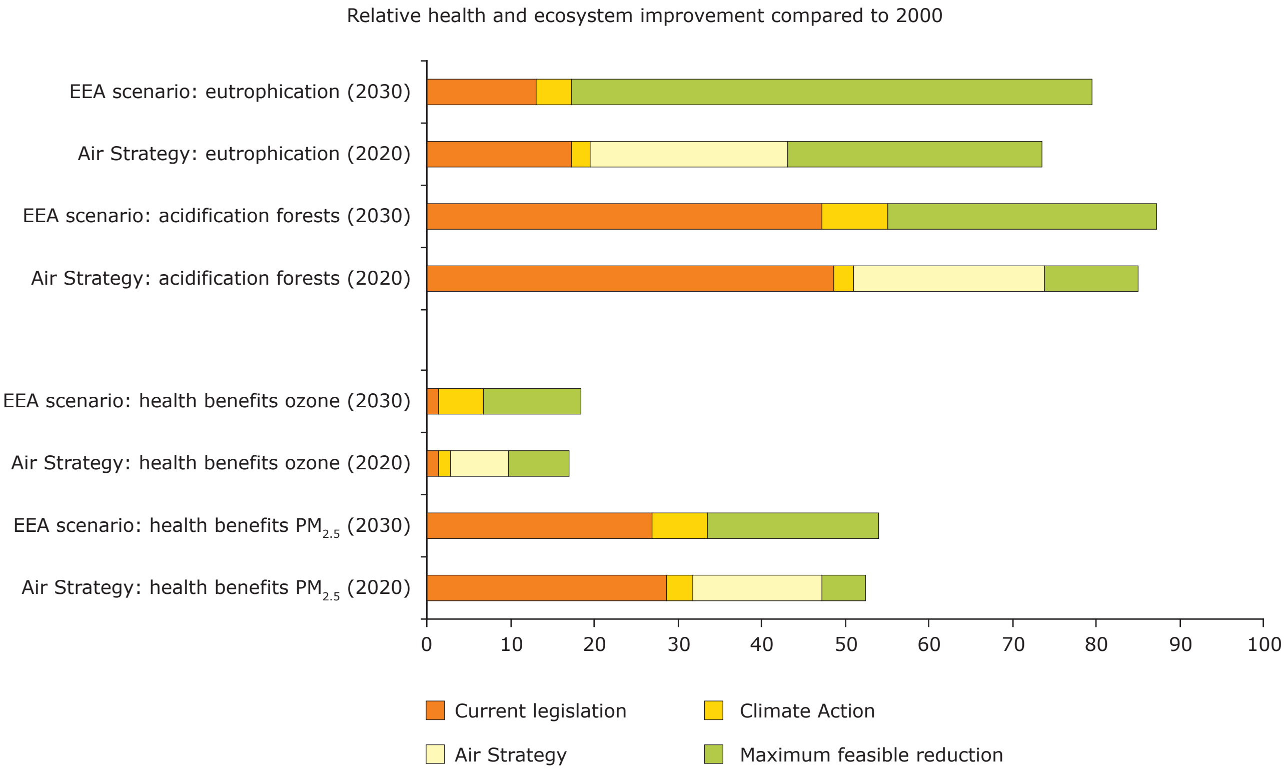
- The three scenarios for 2030 analysed and presented in this report are:
  - EEA Baseline scenario: This scenario was developed for the European Commission in the context of the CAFE programme, but extended both in time (to 2030) and geographical coverage (e.g. to cover global long-term development).
  - EEA Climate Action scenario: This scenario is consistent with the EU long-term target of limiting global temperature change to 2 °C above pre-industrial levels, assuming current legislation for air pollution (see EEA Report No 1/2005 *Climate change and a European low-carbon energy system*, published in 2005).
  - EEA Climate Action Maximum Feasible Reductions scenario (MFR): This is a Climate Action scenario that includes assumed maximum feasible reductions for air pollutants.
- Also presented is the Air Strategy, which is identical to the Thematic Strategy on air pollution and its implications for air quality and impacts for 2020, as adopted in September 2005 by the European Commission. The Thematic Strategy is based upon an energy scenario that includes policy assumptions about climate change e.g. compliance with Kyoto commitments via the imposition of a carbon tax of EUR 12 per tonne of CO_2 rising to EUR 20 per tonne by the end of the modelling period (2020).
- The EU Environment Council has not yet agreed greenhouse gas emission reduction targets for the EU beyond 2012 (Kyoto Protocol target). However, the EU Environment Council concluded that developed countries should reduce emissions to about 15–30 % below the base year (1990) level by 2020 and to 60–80 % below by 2050. This report analyses an assumed EU greenhouse gas emission reduction target of 40 % below the 1990 level by 2030.
- Climate policies aimed at reducing greenhouse gas emissions and achieving the assumed target can have significant ancillary benefits for air pollution. For example, they lower air pollutant emissions, ambient concentrations and impacts, and also reduce abatement costs of existing measures to combat air pollution. The study shows that benefits are greatest in the new Member States and other Eastern European countries.
- The effects of climate policies on air pollutant emissions mainly take place in a limited number of sectors, such as energy and transport. The share of NO_X, SO_2 and PM emissions within these sectors changes considerably in the Climate Action scenario. Emissions from shipping are not yet subject to greenhouse gas emissions controls by the European Union. As a result, there are no ancillary benefits of climate policy for air pollution from shipping.
- Climate policies are expected to have a positive effect on regional scale air pollution. In addition, positive effects will also be felt on an urban background scale and in urban hotspots (e.g. street canyons). Preliminary analyses suggest that by 2030 the number of times NO_2 and PM_{10} limit values are exceeded will drop considerably in street canyons in cities across Europe in the Climate Action scenario and even further in the Climate Action MFR scenario. The reduction in the number of times limit values are exceeded is highest for NO_2. For PM_{10}, in 9 of the 20 studied cities the assumed allowed number of exceedances of limit values is still estimated to be exceeded by 2030 in the Climate Action scenario. This number drops to 2 in the Climate Action MFR scenario.
- European air quality is significantly influenced by developments on a larger scale, notably at the hemispheric level. In the European model calculations in this report, simple assumptions for the development of the hemispheric background levels of ozone and PM have been made. For the global atmospheric model, ozone concentrations and impacts for the baseline scenario could be higher, whereas they could be lower for the climate action scenarios. Thus, the ancillary benefits of climate policy could be underestimated in this report.
- Climate policies result in considerable cost reduction for controlling air pollutant emissions. The additional costs that would be needed to reach the same impact levels as in the Climate Action scenario by 2030 (with specific air pollution abatement measures) would amount to about EUR 12 billion (i.e. 10 billion in cost savings compared to baseline and 2 billion in the cost of emission reductions beyond the baseline). Both costs and cost savings are highest in the EU-15. Relative abatement cost savings for NO_X, SO_2 and PM are estimated at 20 %, 12 % and

Table 1 Summary of air pollution effects in the scenarios

EU-25		Changes to air pollution control costs compared to baseline	Human health			Natural environment	
Year	**Scenario**	EUR bn per year	Life years lost due to $PM_{2.5}$ (millions)	Premature deaths due to $PM_{2.5}$ and ozone (Thousand)	Monetized health damage (EUR bn) ([1])	Forests with acidification (1 000 km^2)	Ecosystems with eutrophication (1 000 km^2)
2000	**2000**	*Not applicable*	3.62	370	280–790	243	733
2030	**EEA Baseline**	*Not applicable*	2.64	311	210–650	128	637
	EEA Climate Action	– 10 ([2])	2.45	288	190–600	109	606
	EEA Climate Action MFR	42	1.66	200	130–420	31	150

Source: EEA, 2006.

Figure 1 Improvement in health and environmental objectives relative to the position in 2000. The 2020 scenarios come from the Air Strategy and the 2030 scenarios are the EEA scenarios



Source: EEA, 2006 and EC, 2005b.

([1]) Truncated numbers. Lower value is based on the median of the value of a life year lost (VOLY) and higher value is based on mean value of a statistical life (VSL).

([2]) In addition to lower control costs for air pollutant emissions, there is also less air pollutants emitted in the Climate Action scenario compared to the EEA Baseline. These benefits from less air pollutant emissions can be valued at approximately EUR 2 billion per year. This corresponds to the costs that would be needed to reach the same emissions levels as in the Climate Action scenario with specific additional air pollution abatement measures in the EEA baseline scenario.

14 % respectively by 2020, and by more than 35 %, 25 % and 25 % by 2030.

- Climate policies can lead to considerable reductions in air pollution damage (i.e. to public health and ecosystems) (see Table below). In addition to savings made in controlling costs, there are also benefits to be had in terms of reduced health impact, (e.g. over 20 000 less premature deaths in the EU-25 from PM and ozone exposure. This could be valued at EUR 26–56 billion a year).
- Compared to the Air Strategy, the EEA Baseline for 2030, which assumes current legislation for air pollutants but no climate change policies, results in higher emissions of air pollutants in the range of 35 % on average compared to 2020. Air pollutant emissions are smaller in the Climate Action scenario but are still about 25 % higher on average in 2030 compared to the Air Strategy in 2020.
- The reduced emissions of $PM_{2.5}$ and ozone precursors as a result of climate policies will reduce health impacts. However, the ancillary benefits in the Climate Action scenario compared to the Baseline scenario in terms of less premature deaths, corresponds to approximately a third of the health benefits brought about by the Air Strategy. In the Climate Action scenario, the EU-25 would still experience more than 280 000 premature deaths in 2030 due to exposure to $PM_{2.5}$ and ground level ozone compared to 230 000 premature deaths in the Air Strategy for 2020. Thus, while climate change policies can contribute to reducing air pollution, targeted air pollutant policies in line with the Air Strategy on air pollution are still needed to move closer to the EU long term objective of attaining levels of air quality that do not give rise to significant impacts on and risks to human health and the environment.

1 Introduction

1.1 Main air pollution issues

Air pollution is a trans-boundary, multi-pollutant, multi-effect environmental problem. Although significant and well directed efforts over more than two decades have led to a reduction in emissions, air pollution in Europe continues to pose risks and has adverse effects on human health and the natural and man-made environment (EEA, 2003). Air pollution problems arise either from atmospheric deposition of pollutants or from direct exposure to ambient concentrations of pollutants (see Box 1).

The main policy frameworks in which air pollution issues are addressed in Europe are:

- European Community legislation and strategies;
- The United Nations Economic Commission for Europe (UN-ECE) Convention on Long-range Transboundary Air Pollution (CLRTAP).

How these policies aim to avoid and/or reduce air pollution impact is discussed in more detail in Chapter 2.

1.2 Objective and scope of this report

This report addresses the following questions:

- How will air pollution in Europe develop in the future (2000–2030)?
- How will climate change policies affect air pollution (2000–2030)?

It presents and assesses the effects of a set of scenarios on air pollution in the EU-25, notably the EEA and Air strategy baseline scenarios (expanded to 2030), the Air Strategy (to 2020) as well as the Climate Action scenario (to 2030) (see Box 2). The climate action scenario is extensively presented in the EEA report *Climate change and a European low-carbon energy system* (EEA, 2005a), which focused on possible European responses to climate change. This new report focuses on air quality in 2030. Some air quality scenario information was published earlier as a part of the European Environmental Outlook (EEA, 2005b). As explained in these earlier reports, the EEA Baseline scenario is based on previous energy scenario work for the European Commission and is the basis for the scenario analysis. Population

Box 1 Air pollution issues

Deposition of air pollutants
Emissions, atmospheric chemical reactions and subsequent deposition of NO_X, SO_2 and NH_3 are causing acidification of terrestrial and freshwater ecosystems. Eutrophication is a consequence of excess input of nitrogen nutrients (NO_X and NH_3) that disturbs the structure and function of ecosystems e.g. excessive algae blooming in surface waters. In addition to ecosystems, material damage can occur, e.g. acidifying pollutants can cause deterioration of structures and monuments.

Air quality
Ground-level ozone is a strong photochemical oxidant, which, in ambient air, can affect human health, and damage crops, vegetation and materials. Ozone is not emitted directly, but is formed in the lower atmosphere by reaction of volatile organic compounds and NO_X in the presence of sunlight.

Even more detrimental for human health can be particulate matter. Exposure to particulate matter, measured as concentrations of PM_{10} or $PM_{2.5}$ (i.e. particle diameter less than 10 and 2.5 μm respectively) in ambient air represents one of the greatest human health risks from air pollution. Short-term inhalation of high concentrations may cause increased symptoms for asthmatics, respiratory symptoms, reduced lung capacity and even increased death rates. Harmful compounds in particulate form can damage materials. Airborne particles can be emitted directly into the air (primary particles) or can be produced in the atmosphere from precursor gases (secondary particles) such as SO_2, NO_X and NH_3.

Sulphur dioxide (SO_2) and nitrogen oxides (NO_X — combinations of nitrogen monoxide, NO, and nitrogen dioxide, NO_2) can have various adverse impacts on vegetation, human health, and materials.

and GDP growth in the EU are the main driving forces. No explicit climate policies are assumed. Comments from Member States, which reflect current thinking about future developments, led to an adapted version of this scenario — the Air Strategy Baseline scenario. This scenario includes modest climate policies in line with the Kyoto Protocol targets. As discussed in (EEA, 2005a), these baseline scenarios are inconsistent with the long-term climate goal of the European Union, which is to limit global temperature change to 2 °C above pre-industrial levels. The Climate Action scenario and it variants (e.g. low economic growth, renewable, nuclear and maximum feasible reductions for air pollutants) do however include more stringent climate policies in order to meet the long-term EU climate objective.

The report addresses ancillary benefits of climate change policies in terms of reduced emissions of air pollutants, reduced impacts on ecosystems and human health, and reduced abatement costs. Ancillary benefits are also presented on a global scale. In addition, the report looks at: the development in emissions from economic sectors; effects of acidification and eutrophication; and effects on human health effects from ground-level (tropospheric) O_3 and particulate matter. The focus is mainly on the EU-25. However, due to the burden-sharing agreement under the Kyoto Protocol it also presents results for EU-15. Moreover, candidate countries and other EEA Member States are included as far as data and methods allow (3).

1.3 Outline

European air pollution policies are laid down in Protocols of the Convention on Long-range Trans-boundary Air Pollution (CLRTAP) and various EU directives. They are multi-pollutant and multi-effect-based in that they aim to protect human health and ecosystems from the impact of a variety of pollutants. Chapter 2 summarises the main current and long term European air quality objectives. Chapter 3 shows the emission of air pollutants per economic sector for the various scenarios. Reduction in emissions is expected to lead to a fall in the concentrations of air pollutants, which would reduce exposure and hence reduce impacts on health and ecosystems. Chapter 4 analyses to what extent improvements of air quality and reduced impacts may occur in the different scenarios. Chapter 5 presents the costs of air pollution policies, taking into account the ancillary benefits of climate policy for air pollution. Finally, the annexes provide detailed tables with the results of the scenario calculations, links to data, and background information about the models used.

(3) In this report scenario analyses for the European scale focus on the EU-25, and where relevant split into EU-15 (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden, United Kingdom) and the new Member States EU-10 (Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, Slovenia). In addition, the EEA member countries include: Iceland, Liechtenstein, Norway, Switzerland (EFTA) and the candidate countries Bulgaria, Romania, and Turkey. Country specific information is not presented in the main text but can be found in background documentation and the annexes.

Box 2: The scenarios

The scenarios analysed and presented in this report are:

EEA Baseline
The EEA Baseline scenario is based on the long-range energy model scenario study with socio-economic and energy projections (using the PRIMES model) for Europe. This scenario goes up to 2030 (Mantzos *et al.*, 2003). For the period up to 2100, the scenario is based on a global baseline (using POLES and IMAGE/TIMER models). This was developed as part of a study on mitigation options for climate change (Criqui *et al*., 2003). Population and economic growth are assumed similar to the CAFE scenarios. This baseline assumes implementation of current legislation for air pollutants without climate policies and equals the CAFE baseline scenario without climate change policies until 2020 (Amann *et al*., 2005).

Air Strategy
The European Commission developed for the Thematic Strategy on Air Pollution a policy scenario for 2020 that addresses various key environmental impacts (e.g. health impacts from $PM_{2.5}$, ozone, acidification and eutrophication). This scenario is a compromise between what would be desirable from the perspective of fully avoiding air pollution impacts, and the feasibility of policies and measures. The climate policies assumed in the CAFE policy scenario are the same as in the Climate Action scenario (see below) for 2008–2012 (Kyoto targets) and 2020.

Climate Action
For air pollutants, the assumptions in the Climate Action scenario are the same as in the CAFE baseline with climate change policies assumed (see above). While the emphasis of the CAFE baseline is on the period 2010–2020, the Climate Action scenario puts developments into a longer-term perspective and explores ways in which Europe can move towards a low-carbon energy system by 2030. The scenario includes policies and measures aimed at reducing emissions of all six Kyoto gases for all the relevant main emitting sectors by 2030. This is in line with an assumed EU GHG emission reduction target of 40 % below the 1990 level by 2030. It thus explicitly analyses climate policy options beyond the Kyoto Protocol targets which apply for 2008–2012. A carbon price development from EUR 20/t CO_2 in 2020 to EUR 65/t CO_2 in 2030 is assumed. Domestic GHG emission reductions in the climate action scenario would be 16–25 % below the 1990 level by 2030. International emissions trading would provide additional reductions. Substantial changes in the EU energy system are projected, which would lead to energy related CO_2 emissions of 11 % below the 1990 level by 2030, compared to 14 % above in the baseline scenario. For more details see the EEA Report *Climate change and a European low-carbon energy system* (EEA, 2005a).

Climate Action Maximum Feasible Reduction (MFR)
This scenario assesses whether longer-term objectives in the areas of air pollution and climate change would be reached. It analyses technically feasible options for reducing air pollutant emissions in all relevant sectors by 2030, while at the same time assuming the measures taken to reduce GHG emissions (see above). The MFR includes all possible technical abatement measures irrespective of their cost. This scenario is consistent with the MFR options developed in the CAFE 2020 programme.

Variants
To explore key sources of uncertainties, a number of scenario variants were developed which explore the implications of different assumptions and actions on a future energy system (EEA, 2005a). These scenarios include: one baseline scenario variant with lower economic growth; two variants with enhanced efforts to introduce renewable energy in Europe; a variant with a nuclear phase-out in Europe; and a variant with enhanced development of nuclear capacity. The current report on air pollution does not discuss these variants in detail.

2 Air quality objectives

2.1 Protection of human health

Short-term and long-term exposure to air pollution affects human health adversely. Air pollution is caused by emissions from mobile and point sources which are directly linked to energy fuel combustion and production, industrial production, transport, household, and other human activities. Often air pollution is trans-boundary, as air pollutants can travel considerable distances from their sources. In addition, emissions from sources in urban areas can have a significant local impact on human health, especially during stagnant weather conditions. Provisional estimates reveal that the extent of the health effects of the major air pollutants on life expectancy lies in the order of several tens to hundreds of thousands of premature deaths per year in Europe (WHO, 2000).

A framework of air quality guidelines (WHO Europe) and air quality standards and emission ceilings (European Union) has been put in place to improve poor air quality and to reduce major adverse health impacts. For several pollutants (e.g.PM_{10}, $PM_{2.5}$ and ground-level O_3) a safe concentration (i.e. 'no-effect level' or 'threshold'), below which health effects are unlikely to occur, does not seem to exist. Compliance with the air quality standards for these substances can reduce the human health impact but cannot prevent it. Furthermore, air quality indicators like, for example NO_2, are a proxy of traffic-related air pollution rather than the causal agent. So, even if the current air quality targets set for 2005 and 2010 are met, considerable health impacts are still likely to occur (WHO, 2003).

Long-term goals for air pollution control that can be considered to be consistent with sustainable development in Europe are:

- preventing exposure to pollutants at concentrations levels likely to cause harm;
- achieving the highest level of human protection in the most cost-effective manner.

Such goals are, however, not easy to formulate. In the long-term, it requires amendments to the current legislative framework and a strategy with new approaches, such as setting 'sustainable' targets and gap closure, to achieve the greatest standard of overall exposure reduction and health protection (NSCA, 2003), The recently proposed Thematic Strategy (EU, 2005b) is an example of this approach.

In addition, compliance in the so-called 'hot-spots' (i.e. areas with high levels of concentration, e.g. close to streets) requires prudent balancing of 'equity' (i.e. same protection level for all) versus 'efficiency' principles (i.e. the most cost-effective solutions). Quantitative assessments of exposure and health impact as well as cost-benefit and cost-effectiveness approaches are needed to support the development of effective air pollution strategies.

Other legislative areas like individual chemical substances (carcinogens), and industrial and transport safety have developed long-term goals for human health protection. These areas are quite different from those in the area of air pollution. The maximum acceptable individual risk concept (e.g. 1*10-6 for long-term mortality or morbidity, and one in a million people per year) is frequently used, and often combined with safety margins. When dealing with complex and difficult abatement measures, a risk of 1*10-5 is sometimes also acceptable. In the area of air pollution policy, however, risks are usually in the order of 1 or more people in every thousand ([4]).

2.2 Protecting ecosystems

While currently human health is considered as the main driver of air pollution policies, this has not always been the case. In the 1970s ecosystem impact was a main driver, and is still at the core of European air pollution research and policy. At the end of the 1980s, during work carried out under the Convention on Long-range Transboundary Air Pollution, critical loads were defined as:

([4]) WHO estimate a 6 % increase in mortality per 10 ug/m^3 PM, assuming an average concentration of 12 ug/m^3 and a mortality rate of 12 per 1 000 inhabitants we arrive at a risk of one person in every thousand per year.

Table 2 Current emission reduction targets for 1990–2010 (%)

	Western Europe	Central and eastern Europe	Eastern Europe, Caucasus and Central Asia
Acidification (SO_2, NO_X and NH_3)	– 56	– 40	– 40
Eutrophication (NO_X and NH_3)	– 36	– 10	– 25
Ozon precursors (NO_X, NMVOC, CO and CH_4)	– 53	– 21	– 36

Source: EEA, 2005c.

'the quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur to present knowledge'.

In support of the 1999 multi-pollutant, multi-effect Gothenburg Protocol and for the 2001 NEC-directive, critical loads were computed and mapped under the Convention on Long-range Transboundary Air Pollution by the Coordination Centre for Effects (CCE) for nutrient nitrogen. This was carried out in order to avoid eutrophication. For acidity, they defined the maximum depositions of S and N that do not lead to 'harmful effects' due to acidification (Hettelingh *et al*., 2001). Emission reductions are considered successful if non-exceedance of critical loads is attained, i.e. when actual depositions do not exceed critical loads.

Critical loads are based on a steady-state concept, namely, that they are the constant depositions which an ecosystem can tolerate in the long run (i.e. after it has equilibrated with these depositions). As such, critical loads are a measure of sustainability of air quality. However, many ecosystems are not in equilibrium with present or projected depositions, since there are processes (i.e. buffer mechanisms) at work which delay the reaching of an equilibrium or steady state for years, decades or even centuries. By definition, critical loads do not provide any information on these time scales.

2.3 Existing EU-policies

Review of emission policies

An important focus of European policy to abate air pollution is the reduction of emissions from the main sources of air pollutants. A key element of EU legislation on emissions is the national emission ceilings directive (NECD) (EC, 2001a), which sets emission ceilings for SO_2, NO_X, NH_3 and NMVOCs. These have to be achieved through EU-wide and national policies and measures aimed at specific sectors. Member States are obliged to prepare a national programme presenting their approaches to achieve the emission ceilings. EU sectoral emission legislation sets emission standards for specific source categories. There are a number of EU directives controlling emissions from vehicles (EC, 1998), large combustion plants (EC, 2001b) and industry (NMVOC directive — EC, 1999a and integrated pollution prevention and control directive — EC, 1996).

National emission ceilings for EU and non-EU countries have been agreed upon under the CLRTAP Gothenburg protocol (UNECE, 1999). Almost all European countries that are party to CLRTAP have signed protocols under this Convention. By March 2005, sixteen parties had ratified the 1999 Gothenburg protocol and therefore in May 2005 it entered into force. These ceilings represent cost-effective and simultaneous reductions of acidification, eutrophication and ground-level O_3 (see Table 2). The EU NECD ceilings were developed using either a similar approach or more stringent one. The NEC will be reviewed in 2006, and it is expected that the European Commission will propose new emission ceilings for the main air pollutants to be achieved by 2020.

Review of air quality policies

EU air quality policies have been developed in the context of the Air Quality Framework Directive (96/62/EC). The central aim of the directive is to avoid, prevent or reduce adverse effects on human health and the environment.

The framework directive has been subsequently expanded with the so-called daughter directives with limit values (e.g. for ozone, target value and long-term objectives) for specific air pollutants (SO_2, NO_X/NO_2, PM_{10}, Pb, CO, C_6H_6 and O_3,) to be realised in the period 2001–2010 (see Table 3).

If these limit values are exceeded, Member States are obliged to set up, implement and report abatement plans. EU air policy is being evaluated and new policies are being developed under CAFE, the European Commission Clean Air for Europe program, which is part of the sixth Environmental Action Programme (6EAP). This led to a proposed

Table 3 Current EU ambient air quality limit (LV) and target (T) values for the protection of human health and ecosystems

Pollutant	Value (average time)	Number of exceedances allowed/ minimum exceedance area	To be met in
Human health			
Ozone (T)	120 µg/m³ (8h average)	< 76 days/3 year	2010
PM_{10} (LV)	50 µg/m³ (24h average)	< 36 days/year	2005
PM_{10} (LV)	40 µg/m³ (annual mean)	None	2005
SO_2 (LV)	350 µg/m³ (1h average)	< 25 hours/year	2005
SO_2 (LV)	125 µg/m³ (24h average)	< 4 days /year	2005
NO_2 (LV)	200 µg/m³ (1h average)	< 19 hours/year	2010
NO_2 (LV)	40 µg/m³ (annual mean)	None	2010
Ecosystem protection			
Ozone (T)	$AOT40_c$ of 18 (mg/m³).h (5 year average)	Daylight hours May-July	2010
Ozone	$AOT40_c$ of 6 (mg/m³).h (5 year average over 22 500 km²)	Reduction >33% compared to 1990	2010
Acidification	Critical load exceedances (year, averaged over 22 500 km²)	Reduction >50% compared to 1990	2010
NO_X(LV)	30 µg/m³ (annual mean)	> 1 000 km²	2001
SO_2(LV)	20 µg/m³ (annual mean)	> 1 000 km²	2001
SO_2((LV)	20 µg/m³ (winter average)	> 1 000 km²	2001

Source: EC, 1999b; EC, 2001a; EC, 2002.

thematic strategy for air pollution in September 2005.

For the environment, achieving the 6th EAP objectives of '*levels of air quality that do not give rise to significant negative impacts on, and risks to human health and the environment*' means no exceedence of critical loads and levels. For human health, the situation is more complex as there is no known safe level of exposure to some pollutants, such as particulate matter and ground level ozone. However, there is strong evidence that measures taken to reduce these pollutants will have beneficial effects on the health of the EU population.

3 Air pollutant emissions 2000–2030

Key messages

- An assumed EU objective of 40 % greenhouse gas emission reduction by 2030 would lead to significant reductions of emissions of air pollutants from fossil fuel combustion. These reductions would be most notable for NO_X, SO_2, PM_{10} and $PM_{2.5}$ by 2030. Compared to the baseline, reduction would reach 10 %, 17 %, 10 % and 8 %, respectively). The impacts of climate policies on helping to achieve air pollution targets by 2030 is stronger than in 2020, as a longer period is available for the implementation of structural changes in the energy system and the phasing in of emissions controls.
- The effects of climate change policies on air pollutant emissions can mainly be seen in the energy and transport sector. The share of NO_X, SO_2 and PM emissions of these sectors changes considerably in those scenarios that assume climate policies but no additional air pollution policies. Emissions from shipping are not yet subject to greenhouse gas emissions controls by the European Union. As a result, shipping emissions of NO_X and SO_2 could exceed land-based emissions by 2030. However, they could be reduced by 88 % and 78 % respectively using current, best available technology.

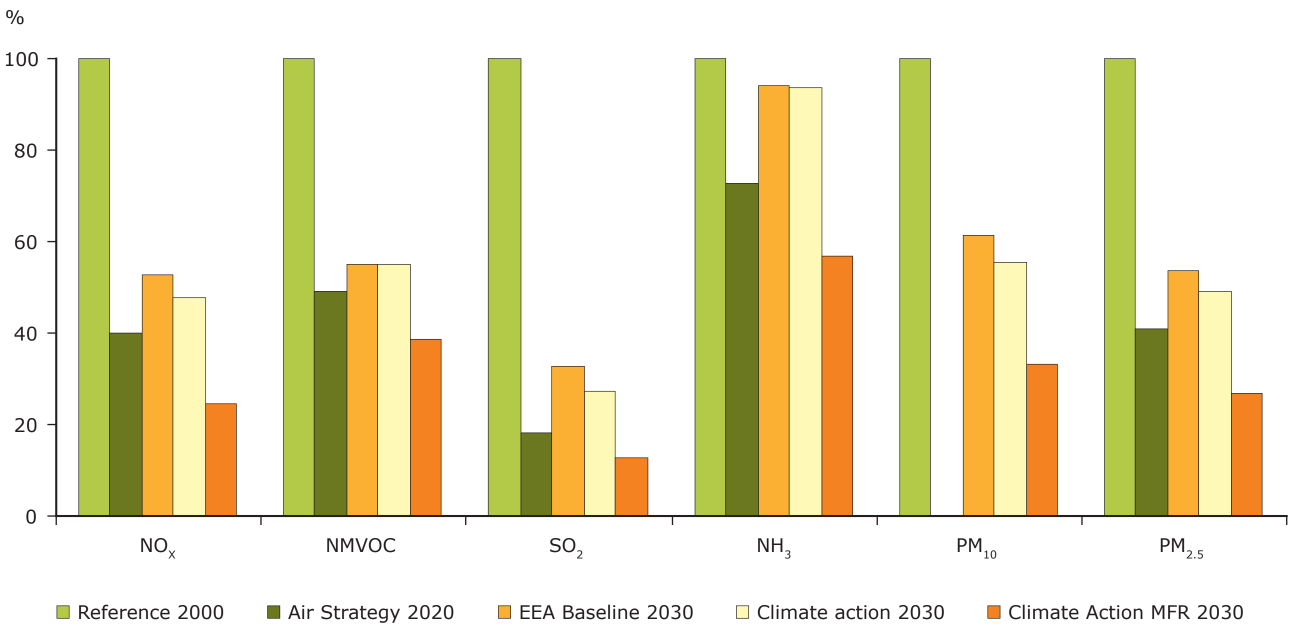
3.1 European air pollutant emissions

Figure 2 and Table 4 present an overview of the EU-25 emissions of NO_X, NMVOC, SO_2, NH_3, PM_{10}, and $PM_{2.5}$ for each scenario, including the Air Strategy (see Box 2). The emissions scenarios for the main substances for controlled sectors are discussed in more detail below.

NO_X emissions

In 2000, the emissions of NO_X in the EU-25 region were about 12 million tons. By 2030, the emissions in the EEA Base scenario are assumed to decrease by 47 % compared to the 2000 level (see Table 4). In the Climate Action Base scenario, emissions are assumed to be further reduced by 0.6 million tons compared to the EEA Base scenario. The Climate Action MFR scenario reduces the emissions in 2030 by half to 2.8 million tons. Total EU-25 emissions are clearly predominate in the 'old' EU-15 Member States.

Figure 2 Change in emissions of air pollutants in the EU-25 region in 2030 relative to 2000; excluding shipping emissions (see Table 5)



Source: EEA, 2006.

Table 4 Emissions of air pollution in Europe for the various scenarios for the EU-25, in ktonnes

	Reference 2000	NEC ceiling 2010	Climate Action 2020	Air Strategy 2020	EEA Baseline 2030	Climate Action 2030	Climate action MFR 2030
	2000	**2010**	**2020**	**2020**	**2030**	**2030**	**2030**
NO_X	11 581	8 319	5 888	4 657	6 125	5 524	2 849
NMVOC	10 654	8 150	5 915	5 251	5 863	5 877	4 101
SO_2	8 736	6 543	2 806	1 602	2 851	2 371	1 130
NH_3	3 824	3 976	3 686	2 774	3 597	3 582	2 174
PM_{10}	2 455	n.a.	1 490	n.a.	1 512	1 357	817
$PM_{2.5}$	1 748	n.a.	965	714	937	860	468

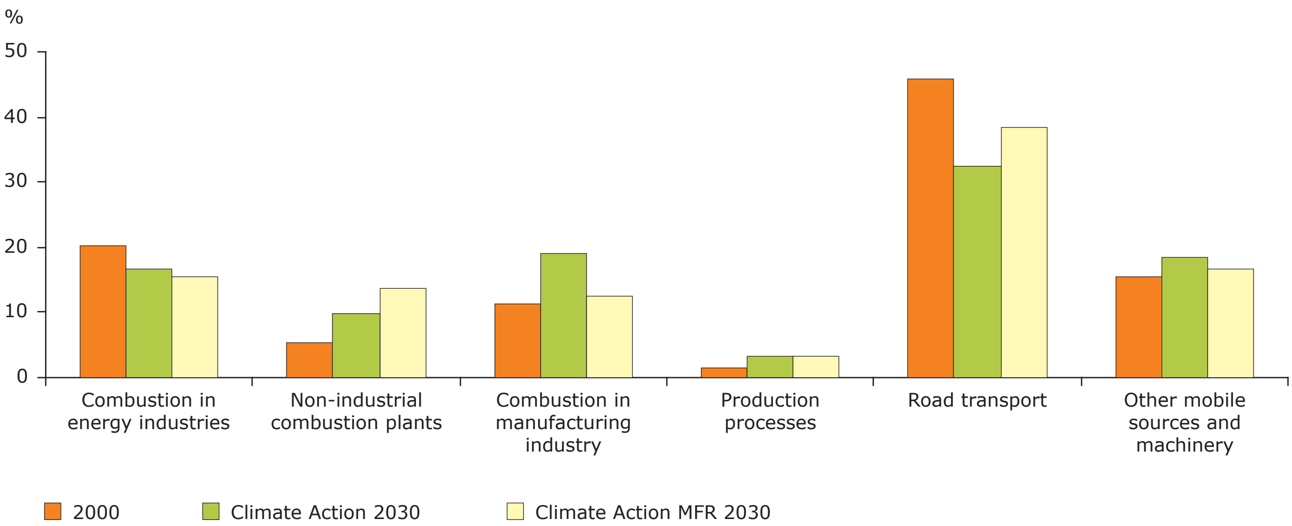
Source: EEA, 2006.

The EEA Baseline scenario assumes that the total 2010 NECD ceilings for the European Union are reached, although not all individual Member States are assumed to comply by 2010.

The largest contributor to NO_X emissions in 2000 was road transport (46 %), followed by the power plant and other fuel conversions sector (26 %). The non-road sector contributed 15 % and industrial combustion and processes another 13 %. In the Climate Action Base scenario for 2030, these proportions change. Industry and processes in the scenario would be responsible for 22 % of the emissions, road transport 32 %, power plant and fossil fuel conversion 27 % and non-road transport 18 %. Hence, the importance of road transport for NO_X emissions is projected to fall.

The reduction of NO_X emissions in the Climate Action scenario as compared to the EEA Baseline in 2030 (9.8 %) is more than double the emissions reduction by 2020 (4.6 %), The impact of climate policies on helping to achieve air pollution targets by 2030 is stronger than in 2020. This is due to the longer period available for implementation of structural changes in the energy system and for the phasing-in of emission controls. With the exception of three European countries, NEC ceilings for 2010 could be met, assuming current legislation for only air pollutants and additional policies for GHG's. Evidently, additional measures to reduce air pollution (as required under the NEC directive) will reduce emissions further and lead to compliance with the NEC directive from 2010 onwards. As compared to the Climate Action scenario, maximum feasible reductions could further cut the NO_X emissions by about half by 2030.

Figure 3 Share of NO_X emissions by sector for 2000 and 2030 for the Climate Action scenario and the Climate Action MFR scenario for the EU-25



Source: EEA, 2006.

NMVOC emissions
In 2000, the emissions of NMVOC in the EU-25 were about 11 million tons. In the EEA Baseline scenario, they decrease to 5.9 million tons or by 45 %. Total EU-25 emissions are dominated by emissions in the 'old' EU-15 Member States.

In 2000, the greatest contributor was road transport (45 %), followed by the solvent use sector (28 %). Because of stringent controls required by legislation on mobile sources, the emissions from road transport are likely to be reduced by about 90 %. By 2030 the share of emissions from solvent use is assumed to increase to 41 % in both the Climate Action and Climate Action MFR scenario.

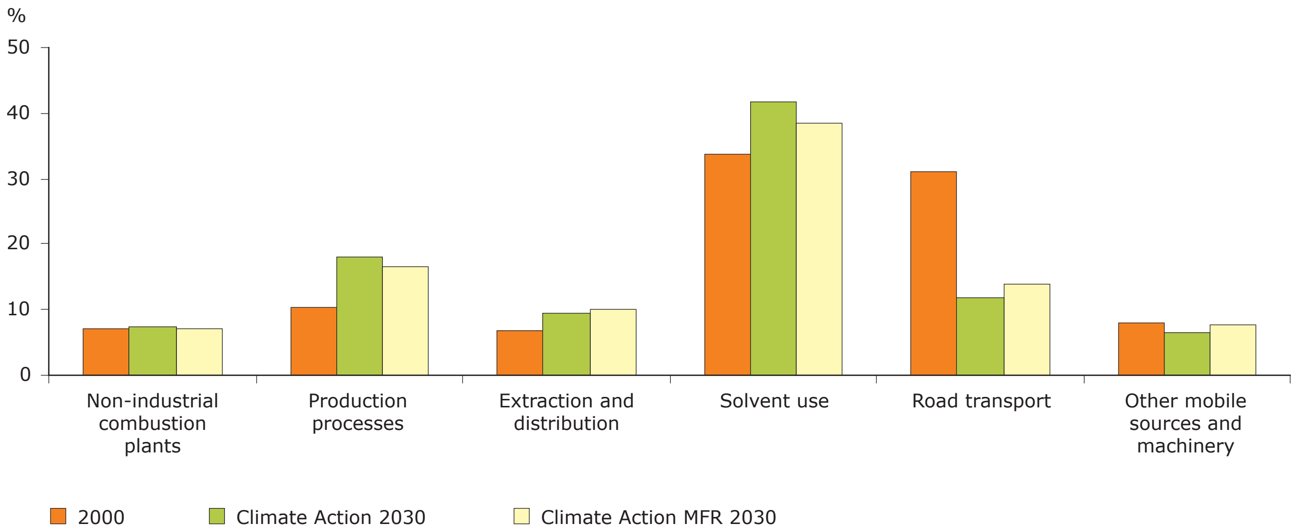
In the EEA Baseline scenario, implementation of strict controls on transport emissions reduces the share of that sector in 2030 to 12 %. Simultaneously, relative contributions of the solvent use and process sectors are assumed to increase to 40 % and 18 %, respectively.

In the EEA Baseline scenario, three Member States are not projected to comply with the 2010 national emission ceilings by 2030. However, aggregated EU-25 emissions are much lower than the sum of the ceilings. The emissions in the Climate Action scenario are about the same as in the EEA Baseline scenario. The reason for this is that additional emissions due to increased use of biomass are compensated by emissions reductions resulting from current air pollution legislation. By implementing the Air Strategy, the ceilings will be met by all countries. Implementation of the best available control technology reduces the emissions by one third to 4.1 million tonnes.

SO_2 emissions
Substantial reductions are projected for the emissions of sulphur dioxide in the EU-25 by 2030. In the EEA Baseline scenario, emissions decrease from about 8.7 million tons in 2000 to 2.9 million tons in 2030 or by 67 %. This is mainly due to stringent controls in the energy sector. The energy sector is assumed to decrease its share from 65 % in 2000 to 32 % in 2030. Total EU-25 emissions are dominated by the 'old' EU-15 Member States. Only one Member State is projected not to meet the 2010 NEC ceiling for SO_2 in the EEA Base and Climate Action scenarios by 2030.

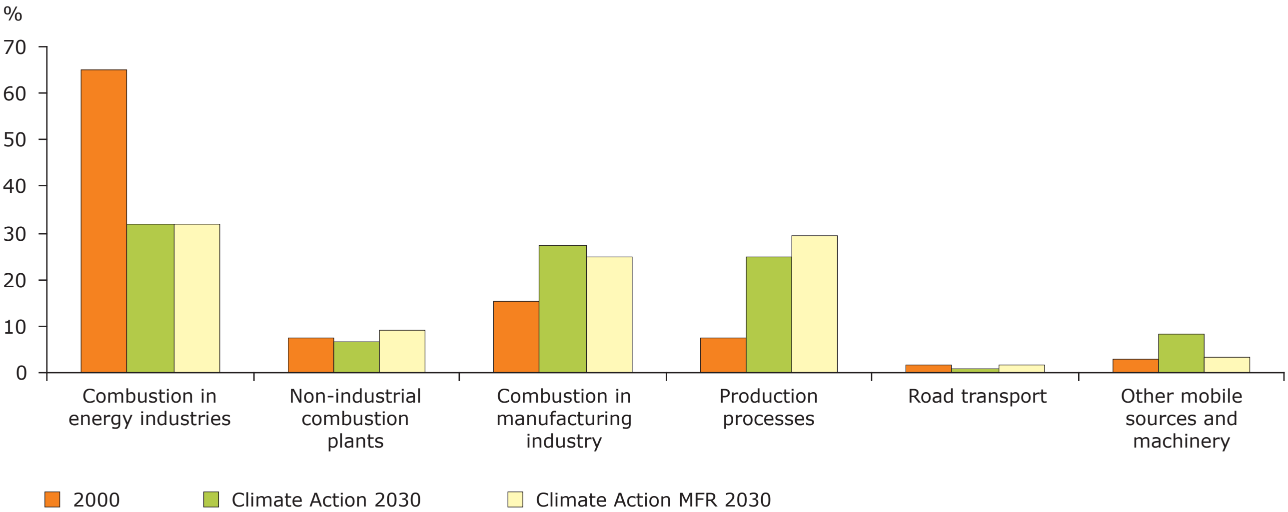
Compared with the EEA baseline, the Climate Action Base scenario reduces emissions in EU-25 by almost 500 kton or almost 17 % (more than 12 % in 2020) by 2030. In the EEA Baseline scenario, the 'new' EU-10 Member States emissions are assumed to be reduced by as much as 24 % compared to the Climate Action scenario. Thus, climate change action has a strong effect on SO_2 emissions. In 2030, the longer time available for implementation of structural changes and emission controls results in additional structural changes in the European energy supply and consumption. It also results in a higher penetration of control measures compared to the 2020 time horizon.

Figure 4 Share of NMVOC emissions by sector for 2000 and 2030 for the Climate Action scenario and the Climate Action MFR scenario for the EU-25



Source: EEA, 2006.

Figure 5 **Share of SO_2 emissions by sector for 2000 and for 2030 for the Climate Action scenario and the Climate Action MFR scenario for the EU-25**



Source: EEA, 2006.

For NO_X, the Climate Action MFR scenario indicates that despite the very high reductions achieved in the Climate Action scenario action, there is still a huge potential to reduce the emissions further. This could be done by implementing the best available techniques. Thus, in the Climate Action MFR scenario, the emissions are assumed to be reduced by another 45 % down to 1.1 million tons.

Changes in sectoral composition of SO_2 emissions are shown in Figure 5. Whereas in 2000 combustion in energy industries (e.g. power plants) was responsible for about 65 % of emissions, followed by combustion in industry (15 %), non-industrial combustion plants 8 % and production processes 7 %. In 2030 emissions from power plants will constitute only 32 % of the total emissions. In addition, a simultaneous increase in the shares of manufacturing industries and processes will take place.

NH_3

The EU-25 emissions of ammonia in 2000 were about 3.8 million tonnes and are projected to decrease only slightly to 3.6 million tons (i.e. app. 5 %) by 2030 in the EEA Baseline scenario. Thus, the projected decrease in NH_3 emission up to 2030 is far less than the projected decrease of other air pollutants. The emissions from the 'old' EU-15 Member States are projected to decrease, while the emissions from the new EU-10 are assumed to increase slightly. Total EU-25 emissions are dominated by the EU-15 and correspond to approximately 82 % of the total emissions in 2030. The Climate Action scenario indicates that emissions reduction of NH_3, as a result of climate policies, will be limited compared to the EEA Baseline scenario. Therefore, climate policies will not help substantially to reduce NH_3 emissions. The Climate Action MFR scenario assumes that the potential to reduce NH_3 emissions is 1.4 million tonnes. This corresponds to a 40 % reduction compared to baseline emissions.

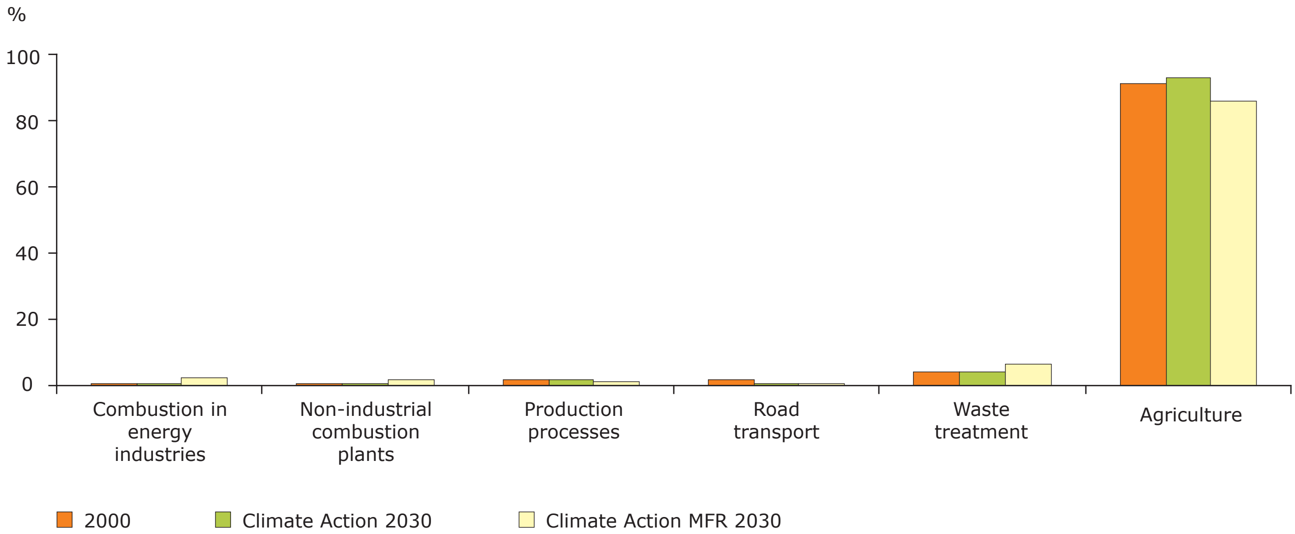
The agricultural sector dominates as an emission source. Its share in total ammonia emissions is about 91–93 % over the whole period. In agriculture, about 82 % of emissions originate from livestock farming. The remaining NH_3 emissions stem from road transport, the waste sector and industrial processes. The differences between the scenarios are marginal (Figure 6). This is due to the fact that the scenarios analysed in this study differ only in terms of activity levels for energy-related sectors and the contribution of those sectors to total national ammonia emissions is small.

In the absence of specific additional air pollution policies, five EU Member States are not projected to reach the 2010 NEC NH_3 emission ceilings in the EEA Base scenario by 2030. However, on an aggregated level the ceilings will already be met by a wide margin by as early as 2010.

Particulate emissions

Emissions of particulate matter (PM_{10} and $PM_{2.5}$) are an important indicator of the air pollution situation in Europe in relation to human health. Historically, the emissions of PM_{10} and $PM_{2.5}$ decreased in the EU-25 by approximately 50 % between 1990 and 2000. The most important drivers behind these reductions were:

Figure 6 **Share of NH_3 emissions by sector for 2000 and 2030 for the Climate Action scenario and the Climate Action MFR scenario for the EU-25**



Source: EEA, 2006.

- economic restructuring in central and eastern Europe (EU-10) and in eastern Germany, which caused a drastic decrease of emissions from the power plant, industry and process sectors;
- switch from coal to other fuels in the household sector;
- implementation of more efficient control technologies, especially on large combustion sources;
- enforcement of stringent standards on exhaust emissions from road transport sources.

The EEA Baseline scenario projects future emissions to further decrease, albeit at a much lower rate than in the last decade. By 2030, the PM_{10} and $PM_{2.5}$ emissions are projected to be reduced by 38 % and 46 % respectively, compared to the year 2000. Reduction of $PM_{2.5}$ is higher due to a smaller contribution to $PM_{2.5}$ emissions in sectors with no (or a limited number of) control options. These sectors include fugitive emissions from production processes, non-exhaust emissions from transport and agriculture.

The EU-15 countries dominate the total EU-25 emissions. They are responsible for approximately 82 % of PM_{10} and 81 % of $PM_{2.5}$ total EU-25 emissions in the EEA Baseline scenario. The Climate Action scenario involves significant additional reductions by 2030, compared to the baseline. These reductions will lie in the range of 10 % for PM_{10} and 8 % for $PM_{2.5}$ (in 2020 5 % and 4 %, respectively). However, the Climate Action MFR scenario assumes that the potential for reduction is still much larger, e.g. about 46 % for PM_{10} and 50 % for $PM_{2.5}$ compared to the EEA Baseline scenario by 2030.

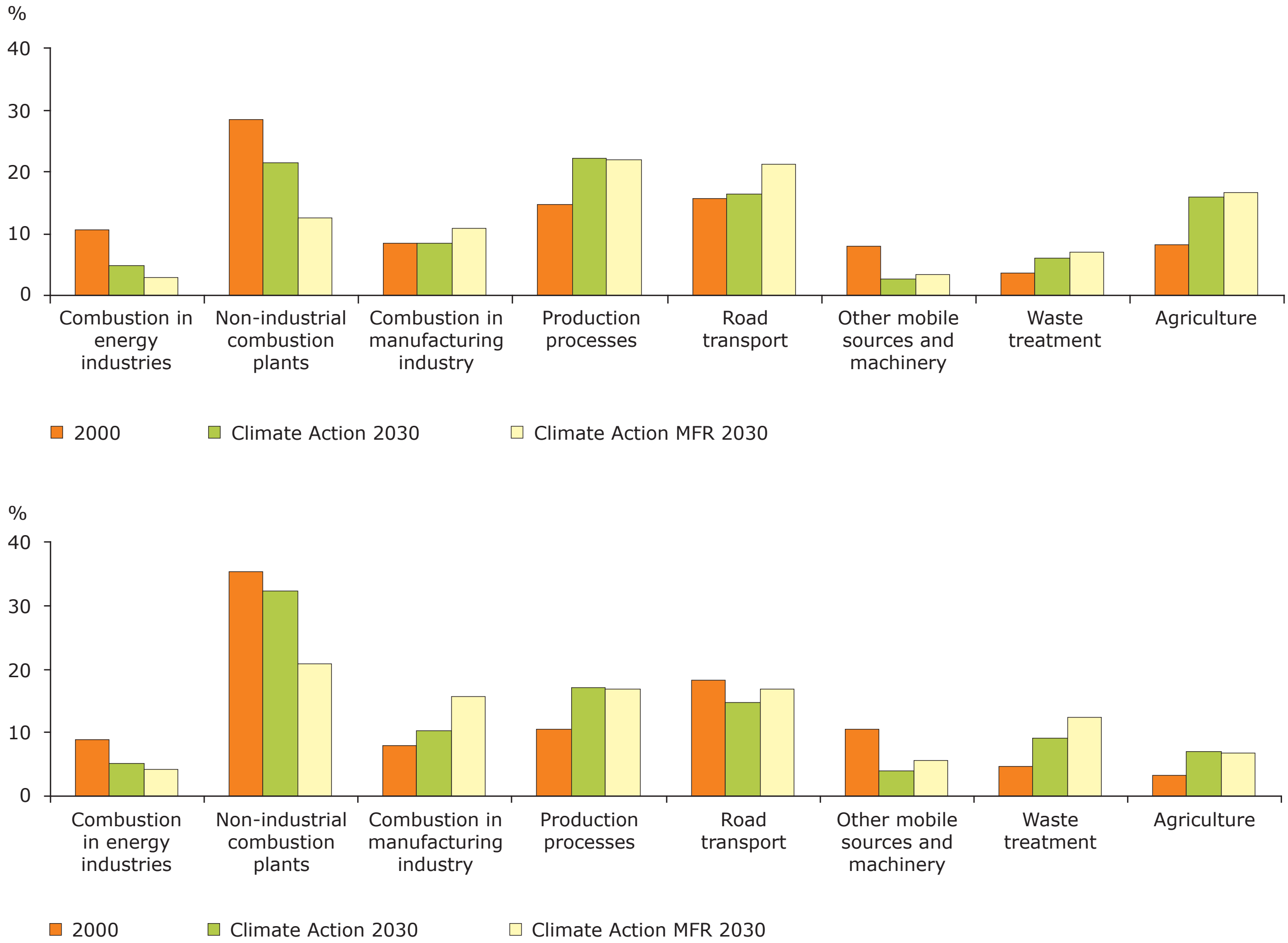
In 2000 70 % of the EU-25 emissions originated from four sectors: non-industrial combustion (28 %), road transport (16 %), production processes (15 %) and combustion in energy industries (11 %).

In the Climate Action scenario, the share of energy industries, non-industrial combustion and non-road mobile sources decreases (see Figure 7). The shares of other sectors increase. In particular, the emissions from production processes as well as from agricultural sources and waste treatment become more important. Although strict standards have been imposed on exhaust PM emissions from transport sources, the total emissions from transport will not decrease proportionally in line with the stringency of the standards. This is because non-exhaust emissions (tire and brake wear, which in our scenario remain uncontrolled) will increase proportionally to traffic volume.

3.2 Shipping emissions

Emissions from shipping and aviation are not subject to the policy controls of the Gothenburg Protocol and the NEC ceilings. Therefore, they are not included in the emissions scenarios in the previous section. However, precisely due to this lack of major policies, the share of emissions from these sectors, particularly from shipping, is increasing rapidly. Therefore, this issue deserves special attention.

Figure 7 **Share of PM_{10} (upper) and $PM_{2.5}$ (lower) emissions by sector for 2000 and 2030 for the Climate Action scenario and the Climate Action MFR scenario for the EU-25**



Source: EEA, 2006.

Table 5 **Annual emissions (106 kg) from international shipping for the European sea region**

	1990	2000	2010	2020		2030	
Pollutant			SHIP-BAU	SHIP-BAU	SHIP-MFR	SHIP-BAU	SHIP-MFR
NO_X	2 743	3 501	4 265	5 207	595	6 530	769
NMVOC	101	131	170	219	219	284	284
SO_2	1 874	2 418	2 652	3 415	752	4 406	972
PM_{10}	171	222	270	348	298	450	385
$PM_{2.5}$	162	210	255	330	282	426	364

Source: ENTEC (2002, 2005).
Note: SHIP-BAU = Shipping, business as usual.
SHIP-MFR = Shipping, maximum feasible reduction.

A baseline scenario developed by ENTEC (ENTEC, 2002, 2005) clearly shows that emissions from international shipping are likely to increase dramatically for all pollutants. Projections for 2030 suggest that NO_X emissions from shipping may increase by 87 % compared to 2000 and by 25 % between 2020 and 2030. Similarly SO_2 may increase by 82 % from 2000 and by almost 30 % between 2020 and 2030. Emissions of NMVOC, PM_{10} and $PM_{2.5}$ are projected to more than double between 2000 and 2030, with substantial increases between 2020 and 2030.

Compared to land based sources emissions it seems likely that that shipping emissions could exceed land based emissions of NO_X and SO_2 by 2030.

PM_{10} and $PM_{2.5}$ emissions are projected to be 30 % and 45 % of land-based emissions by 2030 in the scenario. The scope for reducing emissions through best available technology in the shipping sector is still great for NO_X and SO_2 — 88 % and 78 % respectively in 2030.

3.3 Global air pollutant emissions

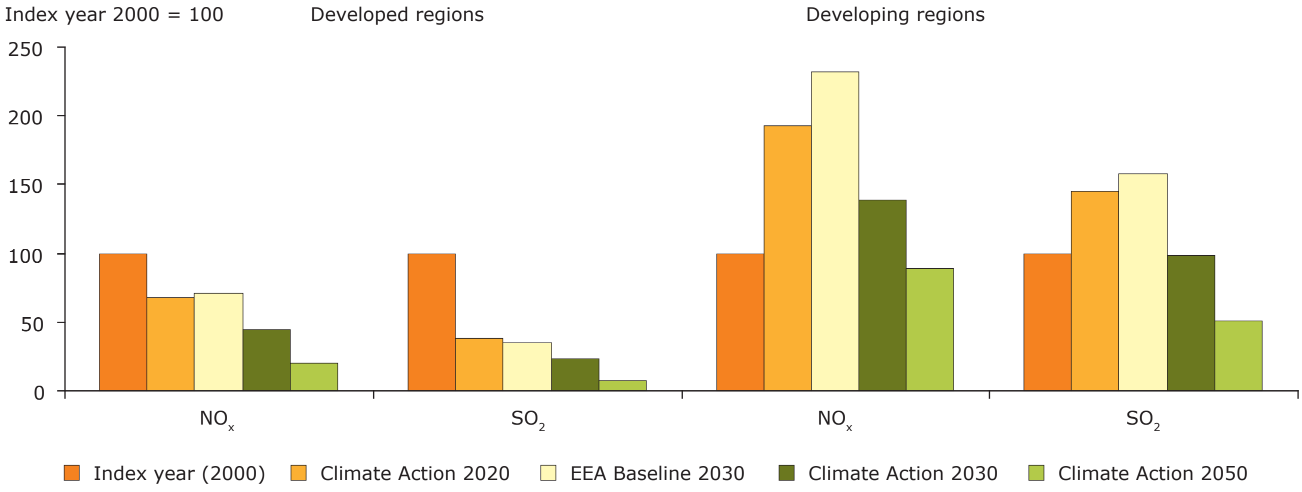
European air quality is increasingly influenced by global and more particularly hemispheric atmospheric trends (see Chapter 4). Also, regional and local environmental problems, such as air pollution, are increasing. Moreover, not only are they scientifically linked to larger scale problems, such as climate change, they are also politically linked. This report specifically includes analysis of the impact of climate policies on air pollution in Chapter 5. Therefore, global emissions of air pollutants necessary to determine the impacts of such larger scale developments on European air quality are discussed in this chapter.

The differences in the economic development status in the various world regions lead to different trends and projections of air pollutant emissions. Therefore, global anthropogenic emissions are described for two groups of regions: the developed regions ([5]) and the developing regions ([6]).

In the EEA Baseline scenario, the developed regions are projected to gradually reduce emissions of SO_2, NO_X and NMVOC over the coming decades. All the pollutant emissions exhibit a decreasing trend, but SO_2 emissions in particular would be reduced by almost 70 % by 2050 compared to 2000. These trends are mainly due to rapid efficiency improvement and technical end-of-pipe measures, induced by the need to reduce health and ecosystem impacts. The Climate Action scenario yields additional emission reductions for all pollutants, particularly beyond 2030 and particularly for SO_2 and NO_X, because these pollutants share the main sources with those of greenhouse gases (see Figure 8). The introduction of climate policies in the Climate Action scenario clearly contributes to the reduction of air pollutant emissions.

The development of emissions in developing regions is different from the projections for developed regions. In the EEA Baseline scenario, developing regions initially assume rapidly rising emissions for most pollutants — especially for NO_X emissions. These emissions will peak in 2050 at a level more than 2.5 times higher than 2000 levels. SO_2 emissions remain relatively stable until 2050. After which, they will gradually fall. As the personal income increases in developing regions and the awareness of local air quality problems grow over the years, more SO_2 controls are assumed. In the EEA Baseline scenario, NO_X emissions from developing regions are

Figure 8 Change in air pollutants emissions in developed and developing regions under the EEA Baseline and Climate Action scenarios



Source: EEA, 2006.

([5]) OECD Europe, Eastern Europe, USA, Canada, Oceania, Japan and Former Soviet Union.
([6]) South East Asia, South Asia, Africa, Central and South America, Middle East and Turkey.

projected to be twice as high (in absolute terms) as in developed regions by 2030. NMVOC emissions will be more than three times higher and SO_2 emissions from developing countries will be nine times higher than emissions in developed regions by 2030.

In the Climate Action scenario, developing countries emissions are assumed to increase at a more moderate rate with significantly reduced levels of emissions in the long-term. NO_X emissions will already peak by 2020 and then fall below 2000 levels in 2050. SO_2 emissions will peak in 2010 before starting to decline to about 50 % of the 2000 emissions by 2050. In 2030, NO_X emissions will be twice as high as developed regions in absolute terms. NMVOC emissions will remain three times higher and SO_2 emissions will be seven times higher than emissions from developed regions.

It will not be until 2100 that NO_X emissions per capita in developing regions match NO_X emissions per capita in developed regions in the Climate Action scenario. In all scenarios, SO_2 emissions are the only emission group that reach the same levels of emissions per capita in developed regions by around 2020.

3.4 Air pollutant emissions in urban areas

In urban and suburban areas all over Europe the population is exposed to conditions that exceed air quality standards set by the EU and the World Health Organisation (WHO). In this section an assessment of urban air pollution under the climate action scenario is presented and the consequences of a maximum feasible reduction scenario by 2030 are assessed. The population of the urban areas covered in this report is 53 million people or about 12 % of the EU-25 population. The cities are: Antwerp, Athens, Barcelona, Brussels, Budapest, Gdansk, Graz, Lisbon, Helsinki, Rome, Stuttgart, Thessaloniki, Copenhagen, Marseilles, Berlin, Katowice, London, Milan, Paris and Prague.

The most significant reductions with respect to the reference year can be achieved for diesel passenger cars and light-duty vehicles. These reductions progress from Euro-1 to Euro-6 standards (see Table 6 for emission standards passenger cars). This is due to the high emissions reduction factors assumed to be feasible for these vehicle categories as well as to the high replacement rates of passenger cars and light-duty vehicles. For diesel passenger cars, a 70 % decrease in NO_X emissions for the 2030 MFR-case is assumed to be feasible. This figure contrasts markedly with the 20 % decrease proposed by the European Commission for Euro V (EC, 2005a). For PM, the most marked reduction (90 %) is assumed to be possible for diesel passenger cars and light-duty vehicles equipped with diesel particle trap filters. (Note: the European Commission proposed an 80 % reduction based on the assumption that the introduction of particle trap filters is necessary).

Table 6 EU emission standards for passenger cars (mg/km)

Tier	Year	CO	HC	NO_X	PM	HC+NO_X
			Diesel			
Euro I	1992	2 720	-	-	140	970
Euro II-IDI	1996	1 000	-	-	80	700
Euro II-DI	1996–1999	1 000	-	-	100	900
Euro III	2000	640	-	500	50	560
Euro IV	2005	500	-	250	25	300
Euro V*	≥ 2008	500		200	5	250
			Petrol			
Euro II	1996	2 200	-	-	-	500
Euro III	2000	2 300	200	150	-	-
Euro IV	2005	1 000	100	80	-	-
Euro V*	≥ 2008	1 000	75	60	5**	-

* As proposed by the European Commission 21 December 2005 (EC, 2005a).
** Applies only to direct injection engines that operate- partially or fully in lean burn mode.

Source: EEA, 2006.

4 Air quality 2000–2030

Key messages

- Significant improvements in air quality are expected by 2030. However, long-term air quality objectives are unlikely to be met in all Member States by 2030. This would still be the case if maximum feasible land-based reduction measures in relevant sectors for abatement of air pollution were combined with the structural changes and measures needed to meet the EU's long-term climate objective of limiting global mean temperature increase to 2 °C above pre-industrial levels.
- The specific air quality policies of the Air Strategy for 2020 will significantly improve air quality and reduce the impact both for human health and ecosystems (see summary table below). Projected improvements are greatest for the two air pollution problems which may be considered as the most crucial, namely: the loss of life expectancy because of PM exposure, and forest damage due to exceedance of critical loads for acidification. Improvements are smaller, but still very significant for two other types of impacts, namely: premature death due to ozone exposure and damage due to excess nitrogen deposition.
- Even without the proposed targets of the Air Strategy, climate policies needed to reach an assumed EU greenhouse gas emission reduction target of 40 % below the 1990 level by 2030 go a long way towards offering the same benefits expected from achieving the Air Strategy in 2020. This does not suggest that the Air Strategy would be ineffective. However, it suggests that an approach integrating air pollution and climate policies can reach similar or more stringent air quality objectives at lower costs than air policies would by themselves.
- Climate policies are expected to have a positive effect on air pollution at regional level, on the urban background scale and in urban hotspots (Street canyons). Preliminary analyses suggest that by 2030 the number of exceedances of NO_2 and PM_{10} limit values would drop considerably in street canyons in cities across Europe in the Climate Action scenario. The decrease would be even greater in the Climate Action MFR scenario. The reduction of exceedances is highest for NO_2. For PM_{10}, the assumed allowed number of exceedances of limit values is still estimated to be exceeded in nine of the studied cities by 2030, according to the Climate Action scenario. This number drops to two in the Climate Action MFR scenario.
- European air quality is significantly influenced by developments on a greater scale, notably at the hemispheric level. In the European model calculations, simple assumptions for the development of the hemispheric background levels of ozone and PM have been made. According to calculations with a global atmospheric model, these assumptions could lead to a small underestimation of ozone concentrations; impacts for baseline scenarios; and a small overestimation for the climate action scenarios. Thus, an underestimation of the ancillary benefits of climate policy would be made.

4.1 Regional air quality: impacts on health and ecosystems

4.1.1 *Loss in statistical life expectancy attributable to anthropogenic $PM_{2.5}$*

In Section 4.2, the results from calculations performed specifically for this report for the Climate Action scenarios for 2030 are compared with the results of the Air Strategy for the year 2020 (EC, 2005) and the base year 2000. Results from tentative estimates of loss of life expectancy (i.e. in months) are presented in the Map 1 ([7]). The loss of life expectancy in 2000 is estimated at approximately nine months per capita in EU-25. The Air Strategy scenario (EC, 2005b) reduces those losses to below six months. The Climate Action scenario lowers the loss in life expectancy somewhat but does not bring about drastic changes when compared to the Air Strategy scenario. However the Climate Action MFR scenario further decreases the expected loss in life expectancy to less than two months. Obviously, these calculations are sensitive to assumptions about the meteorological conditions and other factors. While these calculations address long-term exposure to PM, there is uncertainty about the meteorological

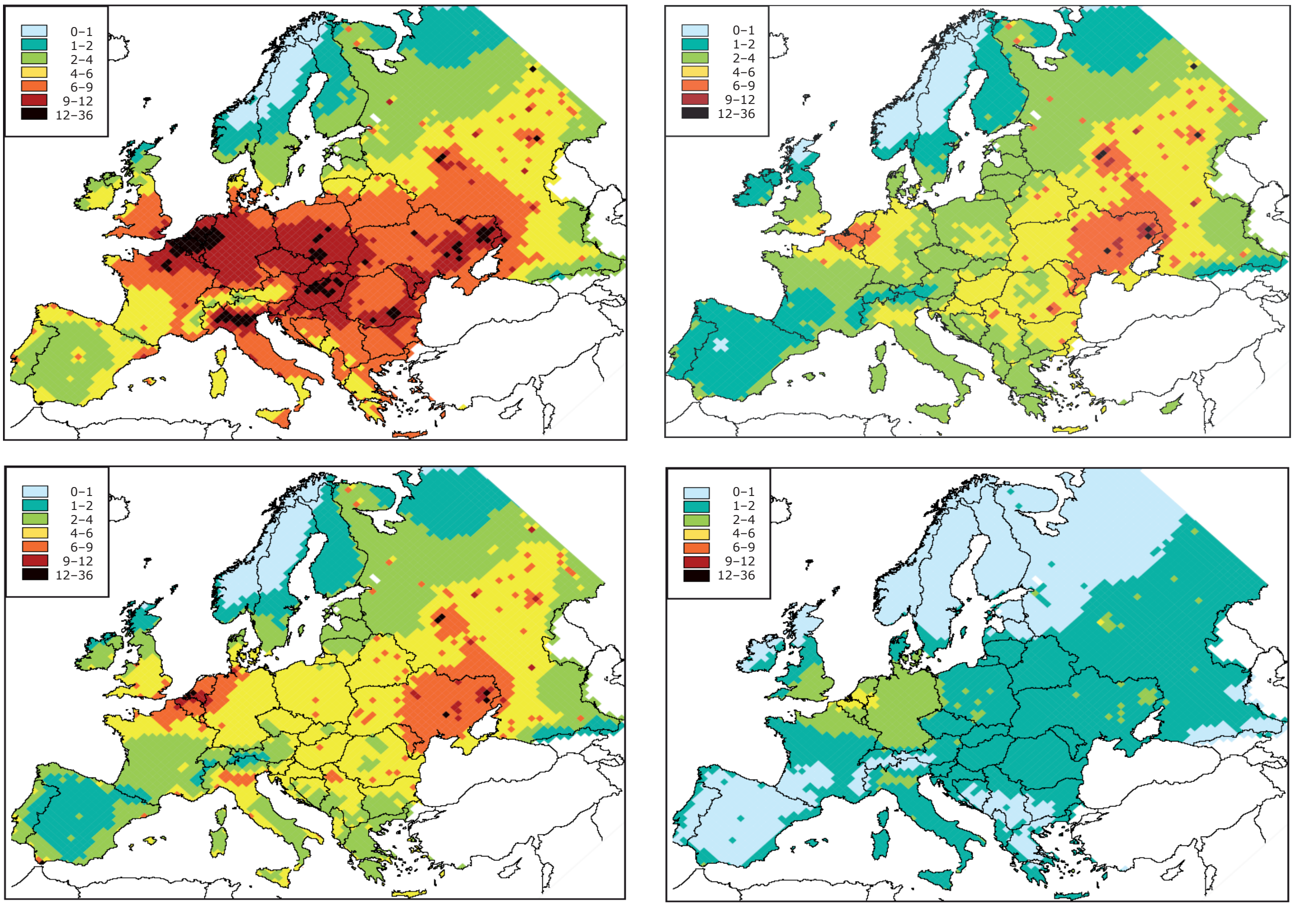
([7]) These results are derived from PM concentration changes. No specific model calculations have been performed.

Table 7 Summary of air pollution effects in the scenarios

EU-25		Changes to air pollution control costs compared to baseline	Human health			Natural environment	
Year	**Scenario**	EUR bn per year	Life years lost due to $PM_{2.5}$ (millions)	Premature deaths due to $PM_{2.5}$ and ozone (thousand)	Monetized health damage (EUR bn) (8)	Forests with acidification (1 000 km²)	Ecosystems with eutrophication (1 000 km²)
2000	**2000**	Not applicable	3.62	370	280–790	243	733
2030	**EEA Baseline**	Not applicable	2.64	311	210–650	128	637
	EEA Climate Action	– 10 (9)	2.45	288	190–600	109	606
	EEA Climate Action MFR	42	1.66	200	130–420	31	150

Source: EEA, 2006.

Map 1 Loss in statistical life expectancy that can be attributed to the identified anthropogenic contributions to $PM_{2.5}$ (in months) for the emissions of the year 2000 (top left panel), Air Strategy 2020 (top right), the Climate Action scenario 2030 (bottom left) and the Climate Action scenario MFR 2030 (bottom right panel)

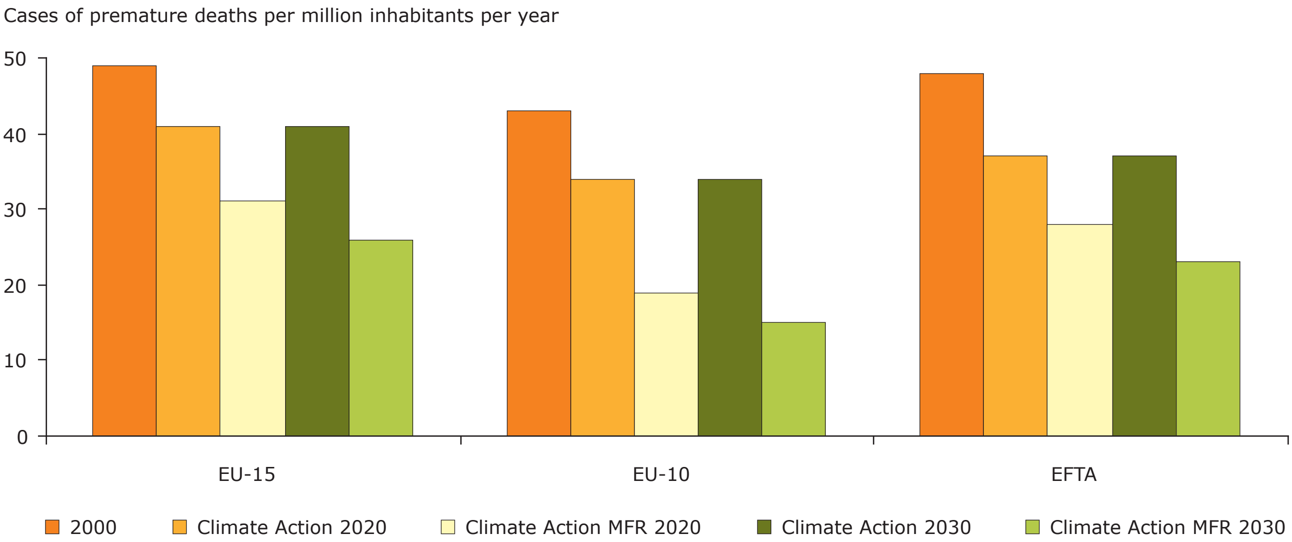


Note: Calculation results are for the meteorological conditions of 1997.
Source: EEA, 2005c.

(8) Truncated numbers. Lower value is based on the median of the value of a life year lost (VOLY) and higher value is based on mean value of a statistical life (VSL).

(9) In addition to lower control costs for air pollutant emissions, there is also less air pollutants emitted in the Climate Action scenario compared to the EEA Baseline. These benefits from less air pollutant emissions can be valued at approximately EUR 2 billion per year. This corresponds to the costs that would be needed to reach the same emissions levels as in the Climate Action scenario with specific additional air pollution abatement measures in the EEA Baseline scenario.

Figure 9 Provisional estimates of premature mortality attributable to ozone (i.e. cases of premature deaths per million inhabitants per year)



conditions that would influence the outcome. Sometimes, these conditions may influence the outcome as strongly as expected emission changes.

Trends suggested by the maps in this section are more certain than absolute numbers. The maps show that there are several hot-spots in central European where the statistical loss of life expectancy in 2000 was particularly high. Quite drastic improvements are projected in the Air Strategy scenario. Yet, the Benelux region would still be the most heavily exposed. The Climate Action scenario calculations result in small improvements notably in central Europe, while the Climate Action MFR shows a drastic decrease of losses throughout Europe.

4.1.2 Premature deaths attributable to ground-level O_3

Figure 9 shows the estimates of premature mortality due to elevated O_3 levels by country group. Whereas about 49 cases per million inhabitants are estimated to have occurred on average in the EEA region in 2000, this number is estimated to decrease to 41 by 2020 in the Air Strategy scenario. This figure would remain the same for the Climate Action scenario in 2030. In the Climate Action MFR scenario, the value of that indicator is projected to decrease to 26. EU-10 values are slightly lower than EU-15 values.

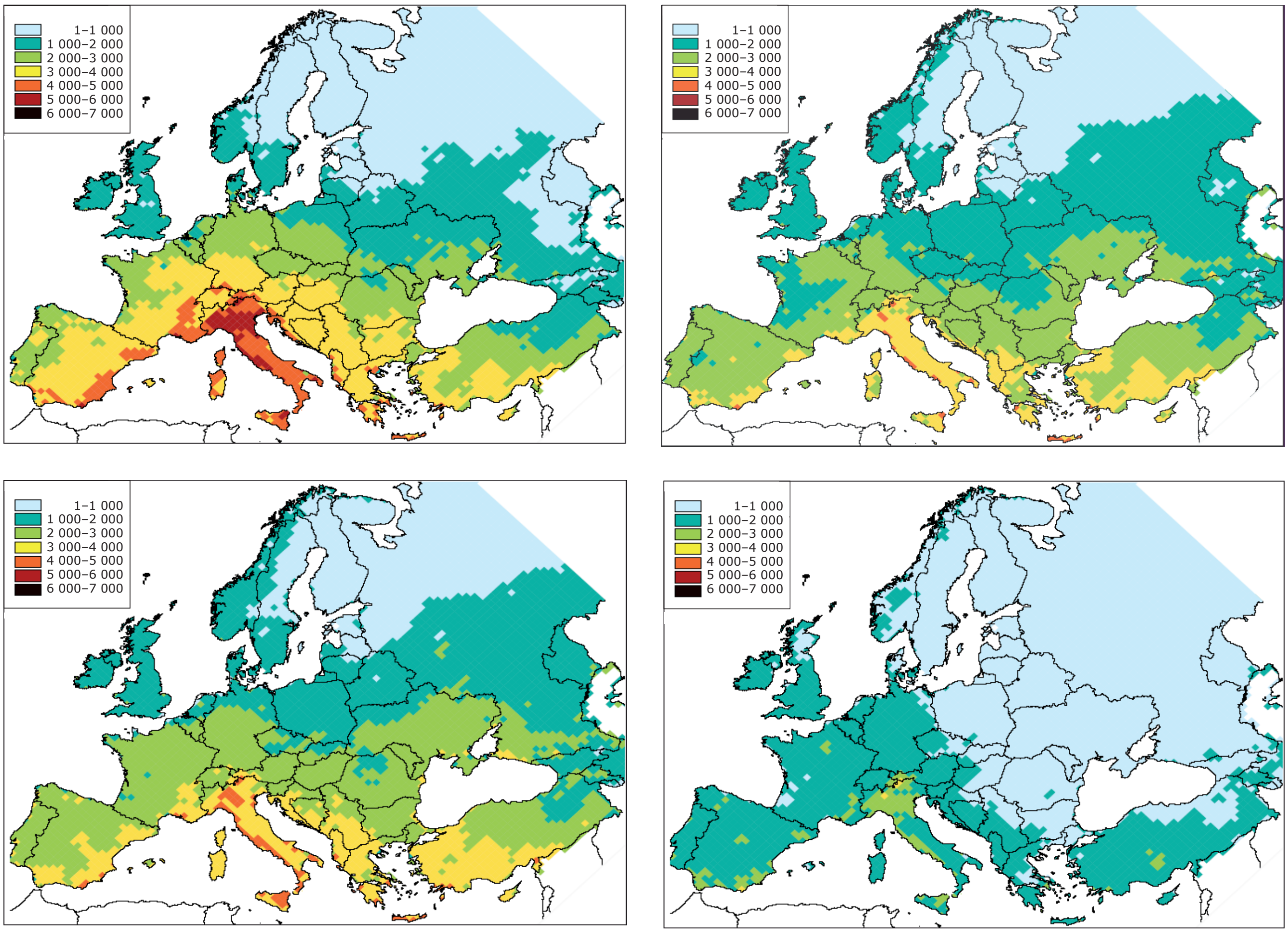
Spatial distribution of accumulated ozone levels (expressed as SOMO35) is shown in the maps of Map 2. The highest values are for southern European countries (e.g. Italy, Greece). However, hot spots also occur in countries like Luxembourg and Switzerland. Consequently, premature mortality for those countries is projected to be above average. The Air Strategy scenario shows a significant decrease of ozone levels for southern European. However, no significant changes are foreseen in the Climate Action scenario by 2030. The Climate Action MFR suggests that there is considerable scope for reducing ozone levels if best available technology is introduced on a large scale. Nevertheless, northern Italy is an area where levels would remain high.

4.1.3 Ecosystem impact

Vegetation damage from ground-level O_3
Map 3 presents the evolution of the excess O_3 which is considered to be harmful for forest trees. It uses the AOT40 (accumulated O_3 over a threshold of 40 ppb) as a metric. The updated manual for critical levels (UNECE, 2004) specifies a no-effect critical level of 5 ppm. hours for trees. Related to this quantity, significant excess O_3 is calculated for 2000 for large parts of the European Union, especially in the central and southern parts. The emission reductions assumed in the Climate Action scenario by 2030 will improve the situation, but will not be sufficient to fully eliminate the risk. Implementation of the Climate Action MFR measures limits the area affected to a select number of hot spots. These are mainly located in northern Italy.

Acid deposition to forests
According to new estimates of critical loads (database of 2004), about 18 % of forests in the EU-15 countries received deposition above their critical loads. The corresponding number for the

Map 2 **Grid-average O_3 concentrations in ppb.days expressed as SOMO35 for the emissions of the year 2000 (top left panel), Air Strategy 2020 (top right), Climate Action scenario 2030 (bottom left) and Climate Action scenario MFR 2030 (bottom right panel)**



Note: Calculation results for the meteorological conditions of 1997.
Source: EEA, 2005c.

new EU-10 was 35 %, which is thus twice the proportion compared to the EU-15. Both the Air Strategy scenario (2020) and the Climate Action scenario result in drastic decreases in the area where exceedances take place. This is especially the case in the EU-10. The Climate Action MFR leaves only less than 5 % of forested area with exceedances in the EU-15. In the EU-10 virtually no exceedances are calculated for forest areas. However, one should stress that country group averages do not reflect the situation in individual countries or regions.

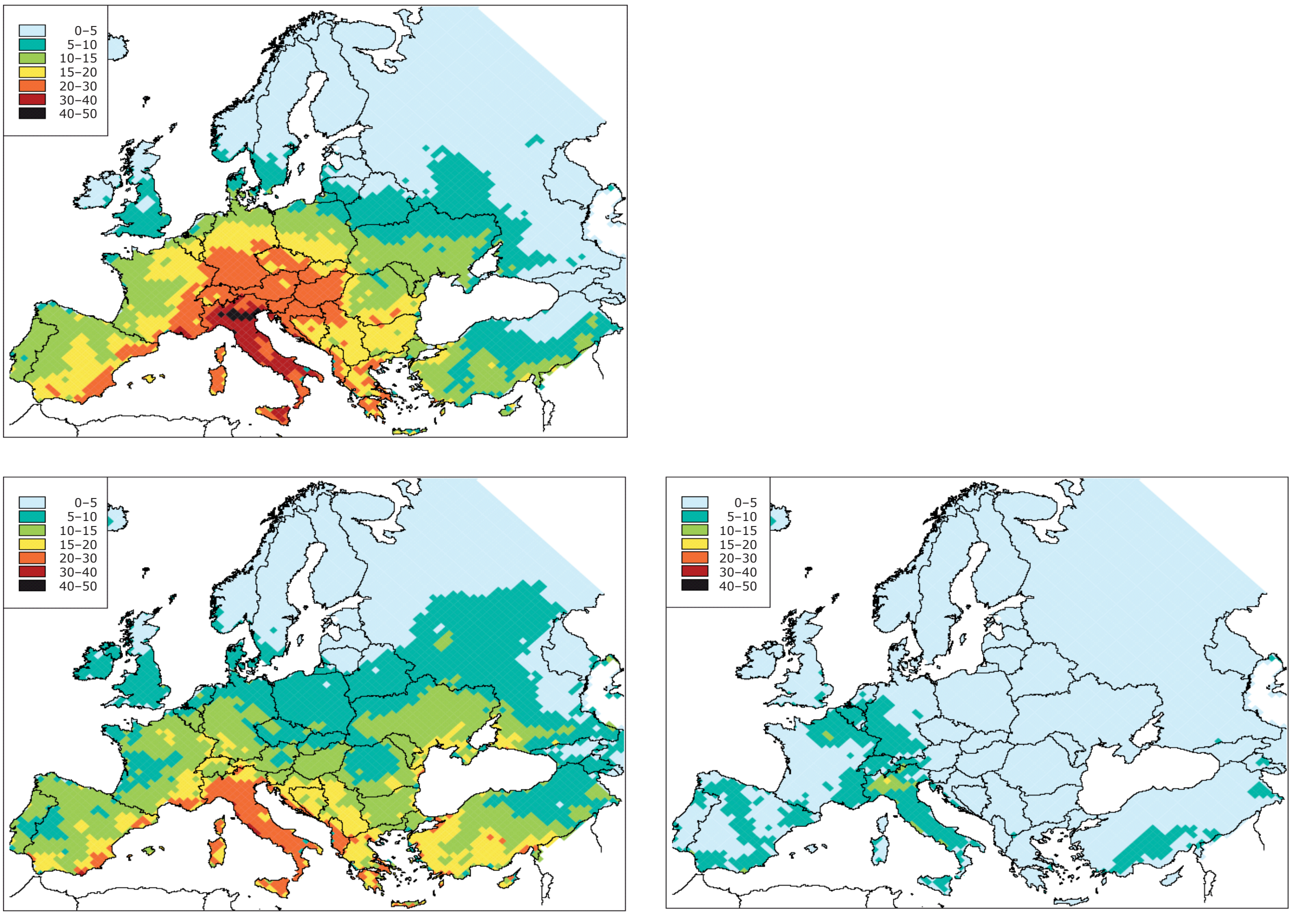
Map 4 shows the spatial distribution of forested areas subject to exceedances in critical loads. Central Europe, the United Kingdom and Scandinavia are generally the areas with most exceedances. Large improvements are visible between 2000 and the Air Strategy scenario for 2020. However, fewer improvements are estimated for 2030. This is the result of the climate policies assumed in the Climate Action scenario. In the Climate Action MFR scenario, however, only some parts of Germany and the Benelux show significant exceedances.

Excess of nitrogen deposition

Eutrophication is a wide-spread phenomenon in the EU-25. In 2000 more than 52 % of ecosystems were endangered (e.g. 54 % for EU-15, 71 % for EU-10) (see Map 5).

Although emission reductions of NO_X both in the Air Strategy (2020) and the Climate Action scenario are rather significant, the exceedances of critical nitrogen deposition levels are still high. The reason is that NH_3 emissions are only reduced to a limited extent and this contributes significantly to the excess in nitrogen deposition. In the Air Strategy (2020) and the Climate Action scenario the exceeded

Map 3 **AOT40 (in ppm.hours) for the emissions of the year 2000 (top left panel), Climate Action scenario 2030 (bottom left) and Climate Action MFR 2030 (bottom right panel)**



Note: The AOT40 is not available for the Air Strategy.
Calculation results are for the meteorological conditions of 1997.

Source: EEA, 2005c.

ecosystem area is over 40 % in the EU-15 and 60 % in the EU-10. Thus, eutrophication will remain a significant problem until 2030. This is the case both after implementation of the Air Strategy and in the scenario with additional climate policies. The Climate Action MFR scenario suggests that the areas exceeded can be reduced to approximately 10 % of the total area or below across the EU-25.

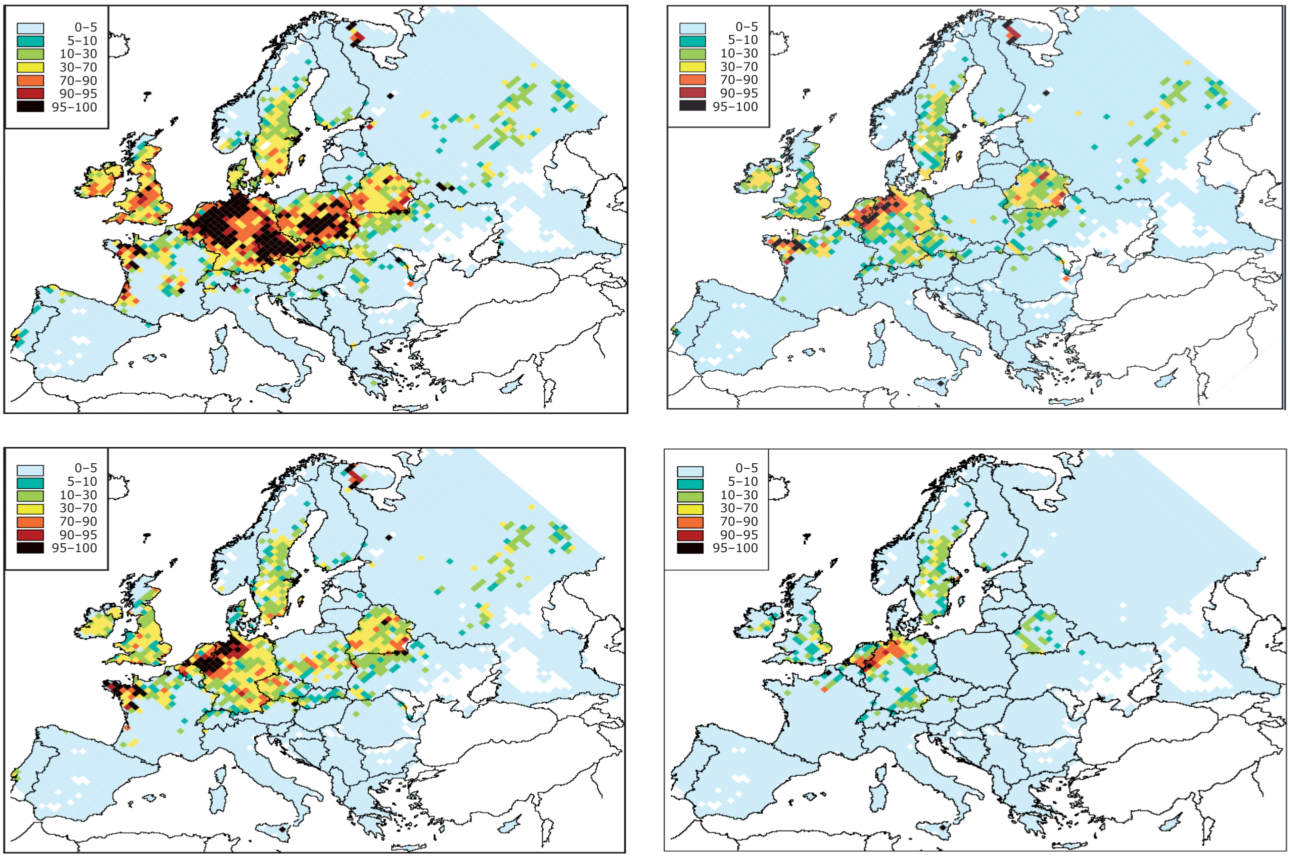
The geographical distribution of total ecosystems with excess nitrogen deposition is shown in Map 5. In 2000, virtually all countries were subject to high exceedances of nitrogen. Both the Air Strategy scenario (2020) and the Climate Action scenario show similar distributions of areas with exceedances. However, in the Climate Action MFR scenario ecosystems in Germany are still plagued by exceedances of critical nitrogen deposition levels, whereas most other countries have negligible or no exceedances.

4.2 Global level: ground level tropospheric O_3

Tropospheric ozone levels in Europe are increasingly influenced by global, or rather hemispheric transport of air pollution. The air quality and impact projections in this report are based on calculations with the EMEP ([10]). This model covers Europe, but not the rest of the world. So, it is important to evaluate how air quality in Europe is influenced by air pollution in the rest of the world, most notably the northern hemisphere. These calculations, which

([10]) The cooperative programme for monitoring and evaluation of the long-range transmission of air pollutants in Europe, linked to the Convention on Long-range Transboundary Air Pollution (CLRTAP).

Map 4 **Percentage of forest area receiving acid deposition above the critical loads for the emissions in the year 2000 (top left panel), Air Strategy 2020 (top right), Climate Action scenario 2030 (bottom left) and Climate Action scenario MFR 2030 (bottom right panel)**



Note: Calculation results for the meteorological conditions of 1997.
Source: EEA, 2005c.

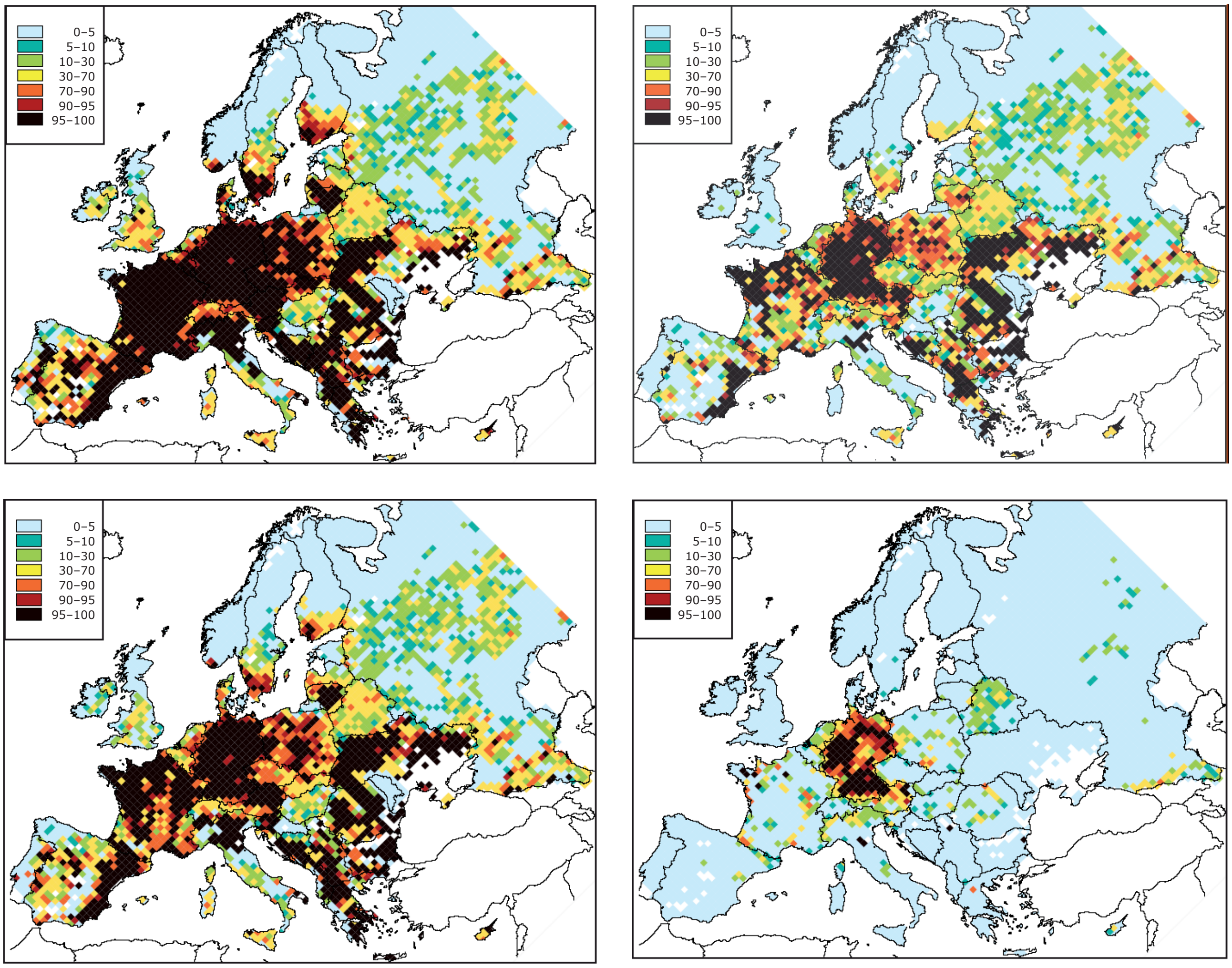
are implemented to analyse ozone levels in Europe, take the hemispheric background concentration of ozone into account by setting a boundary condition. It is expected that the hemispheric ozone levels will increase due to the global increase of the methane emissions and a steep growth in the NO_X and VOC emissions in developing regions, most notably in Asia. In the EMEP calculations this is taken into account by assuming an increase in the hemispheric background concentration of ozone to 2020–2030 of 3 ppb.

Dentener *et al.*, (2004) showed that the northern hemispheric ozone levels for a Current Legislation emission projection may increase by 3–5 ppb from the period 1990–2000 to the period 2020–2030. Dentener *et al.*, (2004) used the TM5 model and a 1990 spatial emissions distribution based on the EDGAR database.

In Map 6 the 2000 and 2030 baseline results for the ozone levels (expressed as SOMO35) are shown. The 2030 projection shows that ozone SOMO35 levels increase in most parts of Europe compared to 2000,

In a MFR-emission projection, the northern hemispheric concentration in 2020–2030 is estimated to decrease by about 5 ppb below the 1990–2000 ozone levels. A reduction in the NMVOC, NO_X and CO emissions, according to the MFR and assuming methane emissions of the baseline scenario, results in a decrease in the northern hemispheric concentration of 2–4 ppb. If the methane emissions are reduced according to the MFR scenario and the other ozone precursor emissions are kept constant at baseline level, the decrease in ozone concentration is estimated at 1–2 ppb. This shows that the main effect in the ozone reduction is due to air pollution emission reductions.

Map 5 Percentage of total ecosystems area receiving nitrogen deposition above the critical loads for the emissions in the year 2000 (top left panel), Air Strategy 2020 (top right), Climate Action scenario 2030 (bottom left) and Climate Action MFR scenario 2030 (bottom right panel)



Note: Calculation results are for the meteorological conditions of 1997, using grid-average deposition. Critical loads data base of 2004. For areas shown in white no critical loads estimates have been provided.

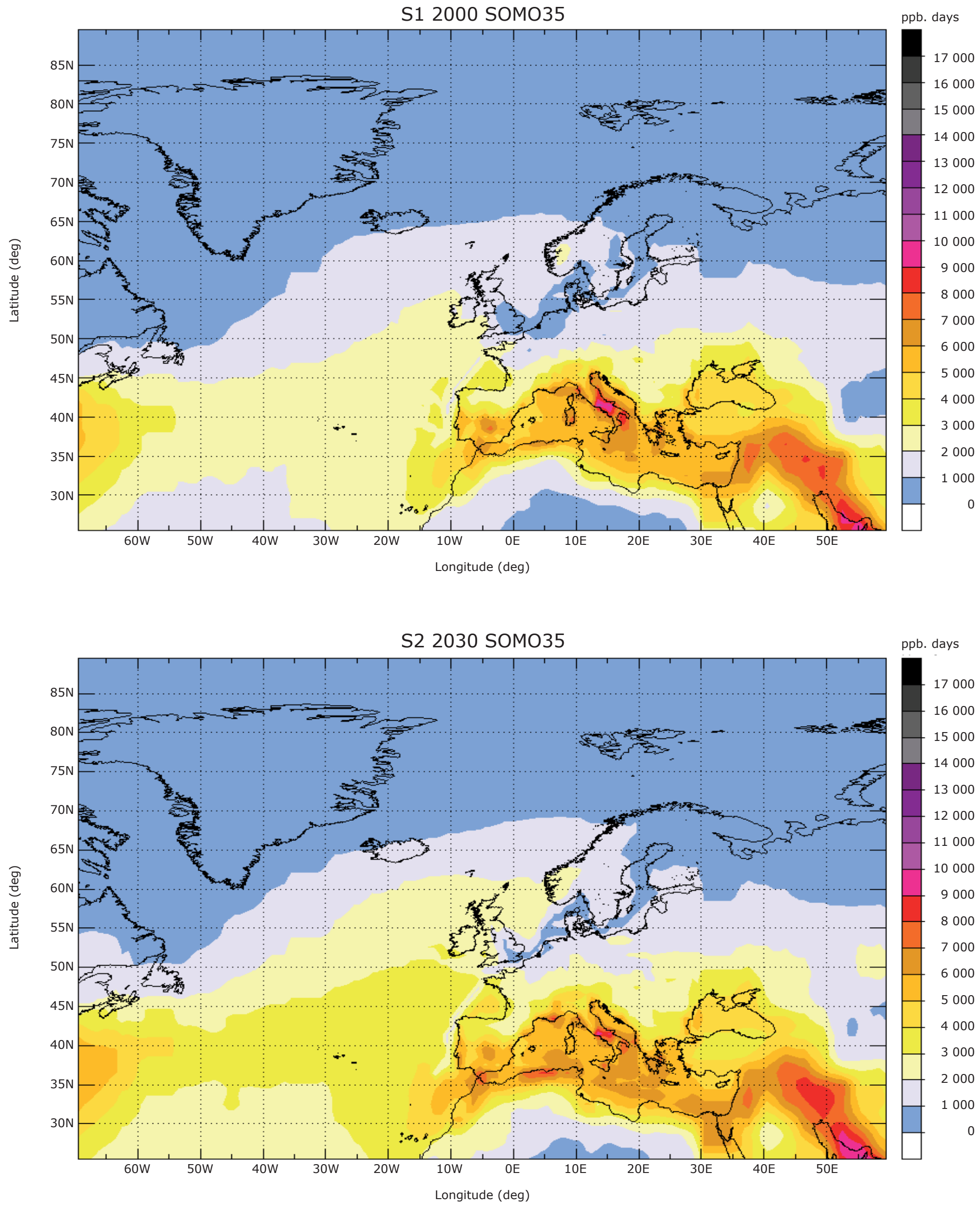
Source: EEA, 2005c.

The above-mentioned assumption about hemispheric background concentrations in the EMEP-calculations coincides with the baseline scenario of Dentener *et al*., (2004). Somewhat less growth in emissions is assumed in this baseline scenario than in the EEA Baseline scenario in this report. Therefore, the trend in the hemispheric ozone concentration in the EEA Base scenario may be somewhat higher than the assumed 3 ppb, and hence the projected ozone concentrations and associated impact for the baseline scenarios in the next section may be underestimated.

For the MFR scenario, Dentener *et al*., (2004) calculated a decrease in hemispheric ozone of about 5 ppb, compared to baseline. In this report, the Climate Action Base scenario reaches a comparable methane emission a few years earlier than in Denterner's MFR scenario. For the other air pollutant emissions, a comparable reduction is reached a few years later. An exception to this is NO_X. For NO_X, the Climate Action scenario only reaches a similar reduction by 2075. It is not clear how these differences between scenarios will affect the trend in hemispheric ozone levels.

In the Climate Action MFR scenario of this report, however, additional reductions of emissions of NMVOC, NO_X and CO are assumed. Under the assumption that other parts of the world would

Map 6 **Ozone SOMO-35 concentration calculations for the European region 2000 and 2030 baseline**



Source: Dentener *et al*., 2004.

also implement additional air pollution measures, a comparable picture of expected emissions emerges and the Climate Action MFR scenario in this report compares well to the MFR scenario of Dentener *et al*., (2004).

Therefore, the assumed increase of 3 ppb by 2030 is in approximation valid for the EEA baseline, but not equally likely for the Climate Action (MFR) scenario. The above mentioned approach is expected to result in an overestimation of the hemispheric ozone concentration. To what extent the indicators are overestimates has not been analysed, although it can be expected that the ozone SOMO35 target of zero by 2030 will still not be met in any of the scenarios.

In summary, the calculations with the JRC global atmospheric model suggest that the assumptions in the EMEP model about the development of the background concentration could lead to a slight underestimation of air pollutant concentrations and impacts for baseline scenarios. Moreover, there could be a slight overestimation for the climate action scenarios, and thus an underestimate of the ancillary benefits of climate policy. In addition, ancillary benefits through global and hemispheric air pollution is expected to be greater than estimated here, because climate policy will lead to lower summer temperature changes. Consequently, there will be lower ozone (smog) formation.

4.3 Urban air quality

In this section, preliminary findings are presented on current and future air quality on urban and street scales in 20 European cities. This is carried out in terms of the annual mean concentrations for NO_2, NO_X, PM_{10} and $PM_{2.5}$ and exceedances of the hourly and daily 2010 limit values for NO_2 and PM_{10} respectively. The model simulations were performed with the multi-scale model cascade EMEP/OFIS/OSPM (Arvanitis and Moussiopoulos, 2003; Berkowicz *et al*., 1997). This approach allows complete analysis of both the reference year situation and scenario projections, as the impact of air pollution control strategies and measures are accounted for on all relevant scales (regional, urban and street scale). More details are presented in a separate EEA technical report on air quality at street levels (EEA, 2006).

Table 8 presents the average urban background concentrations for NO_2, PM_{10} and O_3 for the reference year (2000), the Climate Action Base scenario (with current air pollution legislation) and the Climate Action MFR scenario.

The modelled concentrations follow closely the trend assumed in the emission projections for each city with significant air quality improvements in all cities.

Regarding NO_2, it is expected that in the Climate Action Base scenario the limit value currently valid for 2010 (40 μg/m^3) will be met in urban background situations by 2030. All cities except London show mean annual concentrations of less than 30 μg/m^3. Further decreases are projected in the Climate Action MFR scenario, where the concentrations reach mean annual values of less than 20μg/m^3 in all cities except London. London is calculated to have an annual mean of 23 μg/m^3.

Similar to NO_2, a reduction is observed in the PM_{10} concentrations for both the Climate Action Base scenario and the Climate Action MFR scenarios. According to the concentrations presented in Table 4.2 Climate Action scenario shows an average

Table 8 Mean annual NO_2, PM_{10} and O_3 SOMO35 index over all the cities computed using OFIS for the reference year (2000), Climate Action scenario (2030) and the Climate Action MFR (2030)

	Reference year (2000)			Climate Action (2030)			Climate Action MFR (2030)		
	NO_2	PM_{10}	O_3	NO_2	PM_{10}	O_3	NO_2	PM_{10}	O_3
	μg/m^3	μg/m^3	ppb.days	μg/m^3	μg/m^3	ppb.days	μg/m^3	μg/m^3	ppb.days
Antwerp	39	26	3 400	27	16	3 600	18	10	3 900
Athens	34	12	6 300	26	9	6 400	14	5	5 400
Barcelona	29	16	7 300	19	10	6 600	10	5	5 600
Berlin	30	10	4 300	19	7	3 500	15	4	3 000
Brussels	40	21	3 500	26	13	3 900	17	8	4 200
Budapest	30	21	6 200	18	8	4 800	10	4	3 700
Copenhagen	26	9	3 200	19	7	3 300	12	4	2 900
Gdansk	14	10	4 000	8	5	3 400	5	3	2 500
Graz	13	8	6 700	9	6	4 800	6	4	3 700
Helsinki	27	9	1 500	19	6	2 000	12	3	1 500
Katowice	48	30	3 500	28	13	3 600	16	7	3 300
Lisbon	27	11	3 900	20	9	5 100	12	5	5 000
London	50	12	1 300	32	9	2 600	23	6	2 900
Marseille	21	11	7 800	13	8	7 400	8	4	5 900
Milan	51	19	7 900	27	10	7 400	17	6	6 600
Paris	42	24	4 700	30	16	5 400	20	8	5 300
Prague	28	13	5 200	13	5	4 100	8	3	3 400
Rome	35	12	6 300	18	7	6 600	10	4	5 500
Stuttgart	26	10	7 100	15	6	5 500	12	4	4 700
Thessaloniki	20	10	6 800	17	8	6 100	7	4	4 400

Source: EEA, 2005c.

reduction of 6 μg/m^3, with maximum reductions in Katowice and Budapest and a minimum in reduction of 2 μg/m^3 observed in a number of other cities. In the Climate Action MFR scenario and in line with the additional emission reductions, the average reduction increases in 2030 to 10μg/m^3, and the maximum reduction observed is in Katowice (23 μg/m^3).

For $O_{3,}$ there is an upward trend in the Climate Action scenario for 2030 of 50 % of the cities and a downward trend fro the remaining 50 %. The 10 cities (with an average somo35 of 3 800 ppb.days in 2000) with an upward trend show an increase of 13 % (490 ppb.days) in SOMO35 concentration and the 10 cities with a downward trend (with an average SOMO35 of 6 300 ppb.days in 2000) show a decrease of 15 % (970 ppb.days) in SOMO35.

O_3 concentrations will decrease if large scale reduction in NMVOCs, methane, CO and NO_X are realised. On a local scale, however, a decrease in (high) NO_X concentrations will increase O_3 concentrations. This explains the upward trend in the 10 cities discussed above.

In the Climate Action MFR case 14 cities (with an average SOMO35 of 5 900 ppb.days in 2000) show a downward trend in O_3 concentrations, with an average reduction of 27 % (1600 ppb.days). The six cities (with an average value of 3 100 ppb.days in 2000) showing an upward trend or constant SOMO35 levels go up by an average of 25 % (750 ppb.days). In terms of impact, it is assumed that a decrease in the SOMO35 value of 600 ppb. days will reduce the number of premature deaths by approximately 13 people per million inhabitants. Compared to the gain at the regional level it can be concluded that the benefit at the impact level at the urban scale is somewhat less due to the presence of relative high NO_X levels in the urban background.

4.3.1 Air quality on a local (street) scale

The NO_2, NO_X, PM_{10} and $PM_{2.5}$ concentrations measured at urban traffic stations across Europe are higher than those at urban background stations. This is due to the increased level of local emissions from road traffic. The concentrations measured at traffic stations largely depend on: the specific street configuration; traffic characteristics; street orientation with respect to the prevailing wind direction; the location of the street; and the location of the traffic station in the street itself. Hence, it is difficult to define a representative range of values. For the same reasons, the concentrations modelled will largely depend on the specific street configurations considered and also the percentage of Heavy Duty Vehicles as well as the average vehicle speed assumed. These parameters are the most important for governing street emissions.

In the analysis that follows, the streets were assumed to be centrally located, i.e. the urban background concentrations were assumed to be adequately described by the OFIS ([11]) model results for the centre of the city. The street orientation was assumed to be east to west and wind speed and direction for each city were derived from the EMEP data. For quantifying the hotspot contributions, it is convenient to introduce street increments, i.e. the difference between the street and the urban background concentrations. Model results are presented and comparison against measurements is performed in terms of street increments.

For NO_2 in narrow street canyons, large but comparable variations are observed from city to city in both the measured and the modelled street increments (4–57 μg/m^3 and 16–53 μg/m^3 respectively).

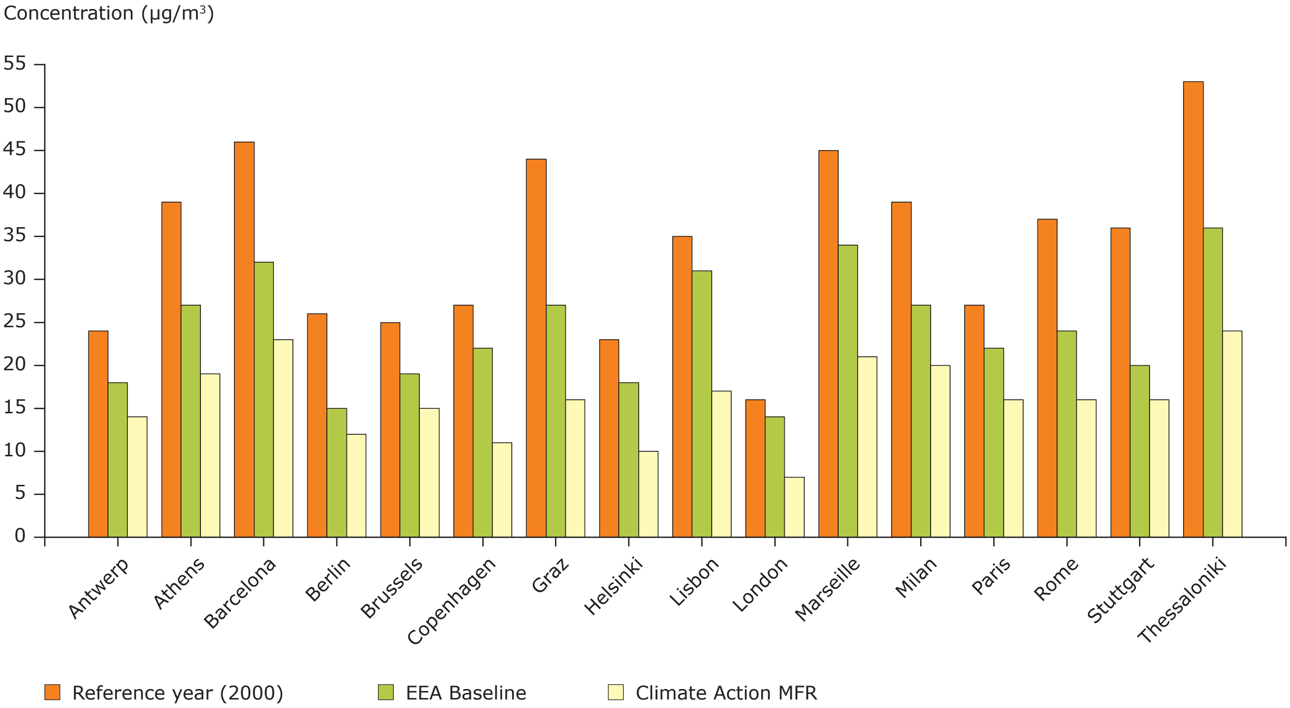
For $PM_{10,}$ the range of modelled street increments in the narrow street canyon is 5–15 μg/m^3, and the average value is 10μg/m^3. Bearing in mind all the limitations associated with the comparison between measured and modelled street increments, the modelling approach seems to reproduce the observed PM_{10} concentrations fairly well.

For $PM_{2.5,}$ the range of modelled street increments for the narrow canyon is 4–10μg/m^3.

Overall, the comparison of modelled street increments against measurements shows reasonable results, if one bears in mind all the limitations associated with this comparison, e.g. the actual distance between the location of the traffic and urban background stations, and their distance from the city centre. Moreover, the differences in the street canyon geometries must be considered. It is apparent that a measured increment exceeding the modelled increment could be associated with the use of an excessively low urban background value, whereas the opposite could well imply that the actual highest traffic concentration in the city exceeds the measured

([11]) The OFIS model (EEA, 2005c) belongs to the European Zooming Model (EZM) system, a comprehensive model system for simulations of wind flow and pollutant transport and transformation.

Figure 10 **NO_2 annual mean street increments for cities across Europe in 2000 compared to the projected street increment in 2030 according to the Climate Action and Climate Action MFR scenarios**



Note: Calculations were based on the narrow canyon case

Source: EEA, 2006.

street concentrations. Regarding the model results and assumptions, it is likely that the average vehicle speed of 26 km/h considered (following van den Hout and Teeuwisse, 2004) may be rather low. This could have led to slightly increased estimates of the exhaust PM emissions, and consequently to an overestimation of the predicted concentrations. Furthermore, it is uncertain how accurately the non-exhaust PM_{10} and re-suspension emissions were estimated. Depending on whether the PM emission sources are overestimated or underestimated, the corresponding PM_{10} street level concentrations will be affected. This would lead to a larger or smaller street increment, respectively. Finally, the comparison also reveals the restrictions of the hypothetical street canyon configurations considered in this analysis. The worst street increments may have been missed (see Rome and Thessaloniki PM_{10} street increments, Berlin, London and Thessaloniki NO_X street increments and London $PM_{2.5}$ increments) as the worst street canyon configurations in terms of street geometry and traffic characteristics have not been explicitly considered.

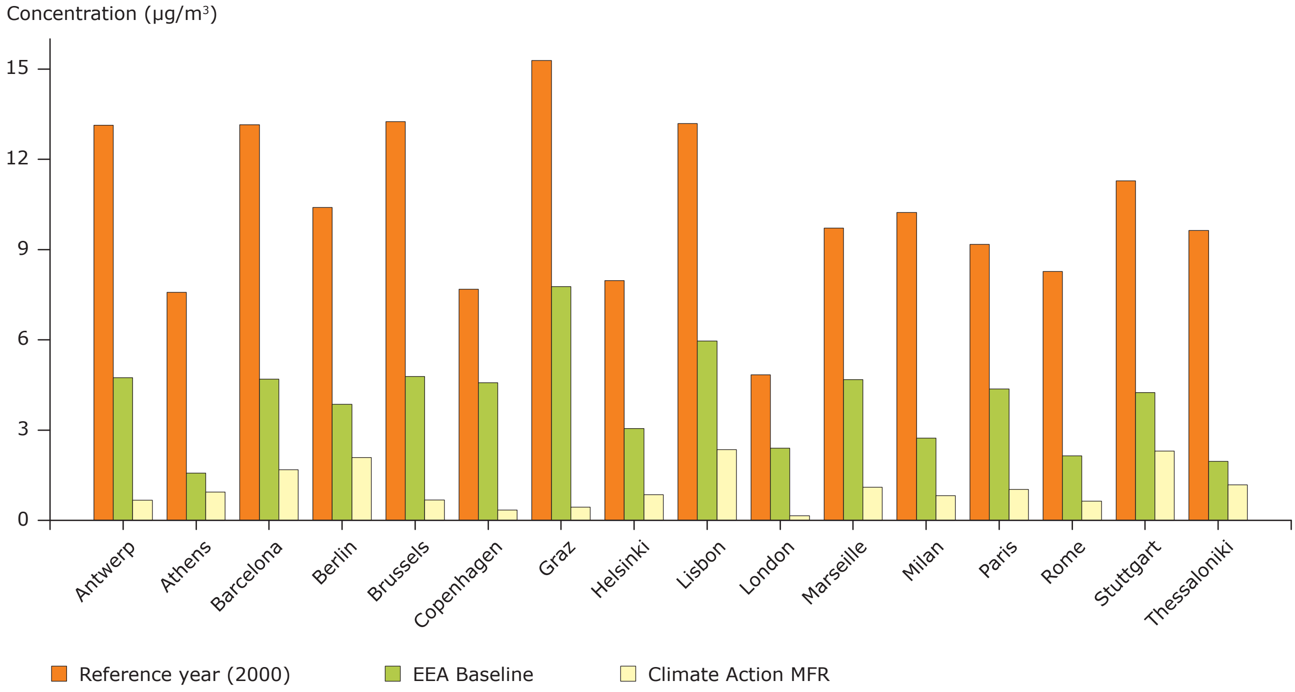
In 4–9 to 4–11, the street increments for the hypothetical narrow canyon with height 15 m and width 10 m and a traffic volume of 20 000 vehicles per day for the reference year (2000) are compared against the projected increments, according to the Climate Action Base and Climate Action MFR scenarios (see Cofala *et al.*, 2005 for details).

For the cities located in the non-EU-15 countries (e.g. Budapest, Gdansk, Katowice and Prague), the lack of reliable vehicle fleet data for 2000 leads to the calculation of unrealistic attenuation factors for the projection year 2030. A reduction of around 95 % for both scenarios, both NO_X and PM was derived (see Annex 2). As a result, the projected street increments for these countries were considered unrealistically low, unreliable and hence not included in the scenario analysis.

A reduced street increment is projected, according to both the Climate Action Base and Climate Action MFR scenarios for all pollutants. For NO_2, the modelled street increment in 2000 ranged from 16–53 µg/m³ depending on the city. In 2030 it falls to 14–36 µg/m³ for the Climate Action Base scenario and 7–24 µg/m³ for the Climate Action MFR scenario.

For NO_X, the modelled street increment in 2000 ranged from 87–154 µg/m³, whereas in the Climate Action Base and Climate Action MFR scenarios it is

Figure 11 PM_{10} annual mean street increments for cities across Europe in 2000 compared to the projected street increment in 2030 according to the Climate Action and Climate Action MFR scenarios



Note: Calculations were based on the narrow canyon case.

Source: EEA, 2006.

projected to range from 38–78 μg/m^3 and 15–44 μg/m^3, respectively.

Larger reductions are projected for PM_{10} and $PM_{2.5.}$ They ranged from 5–15 μg/m^3 for PM_{10} in 2000, and 2–8 μg/m^3 and 0.2–2.4 μg/m^3 is estimated for Climate Action Base and Climate Action MFR scenarios, respectively. For $PM_{2.5}$, the range of values from 4–10 μg/m^3 in 2000 is projected to be between 1.3–5.2 μg/m^3 and 0.1–1.6 μg/m^3. This is in line with the significant reductions in the urban scale emissions, the background concentrations and in the street scale PM emissions attributed to the EURO V and EURO VI technology vehicles.

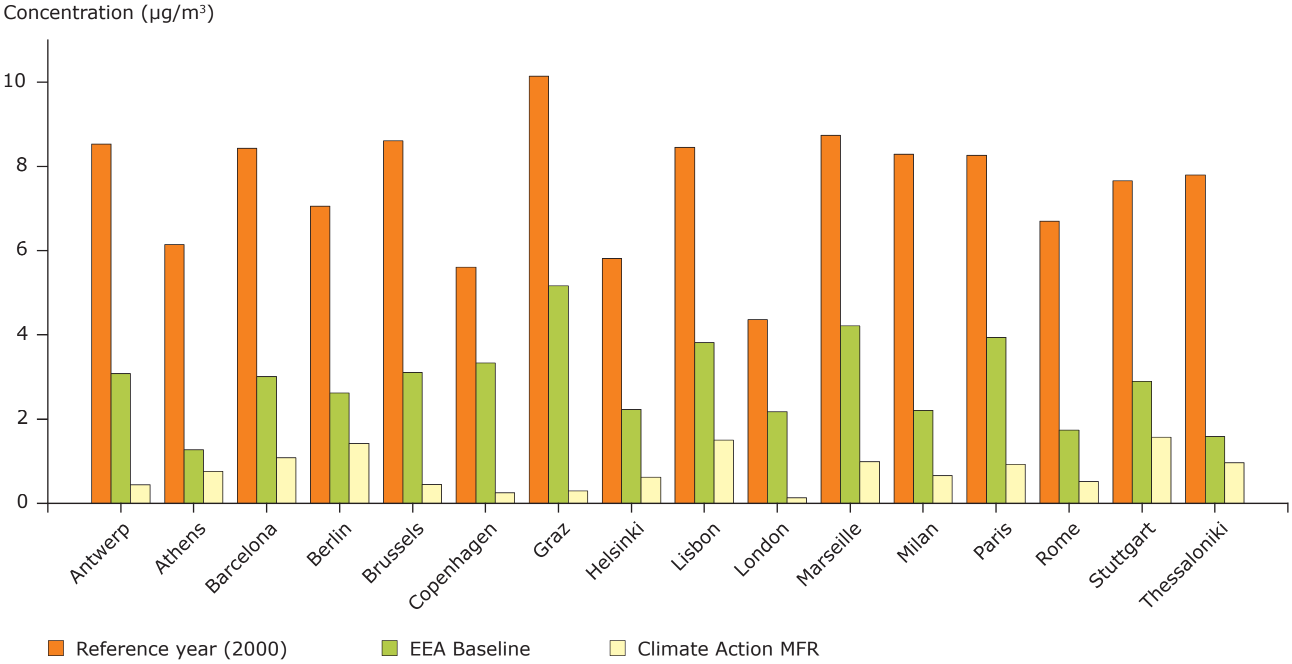
4.4 Exceedances of urban air pollution limit values in 2030

For all canyons, the number of exceedances for NO_2 and PM_{10} drop considerably in both the Climate Action Base and Climate Action MFR scenarios. For the narrow canyon and for NO_2, almost no exceedances of the 2010 limit value (200 μg/m^3) are observed in 2030, according to the Climate Action Base scenario, and no exceedances are observed in the Climate Action MFR scenario.

Despite all limitations, Figure 13 provides useful information in terms of the relative change expected in the different cities, according to the two scenarios. The situation for PM_{10} is slightly different than for NO_2. Although there is considerable reduction in the number of exceedances in the Climate Action scenario, the allowed number of exceedances (e.g. 50 μg/m^3, not to be exceeded more than seven days a year according to the 2010 indicative limit value) is still exceeded in nine cities. In the Climate Action MFR scenario all cities have close to zero exceedances except Antwerp and Paris, which are close to but not below the allowed number of exceedances (e.g. eleven and nine days a year respectively).

However, it should be noted that the worst street canyon cases have not been considered and hence the allowed number of exceedances may still be exceeded. This is especially the case for PM_{10} where in most cases compliance is marginal. In view of the fact that the natural contribution to PM_{10} concentrations has not been considered in the scenario year 2030, it is highly likely that the 2010 PM_{10} limit value will be exceeded in 2030 in a number of cities. The marked improvements in urban air quality in the Climate Action scenario are

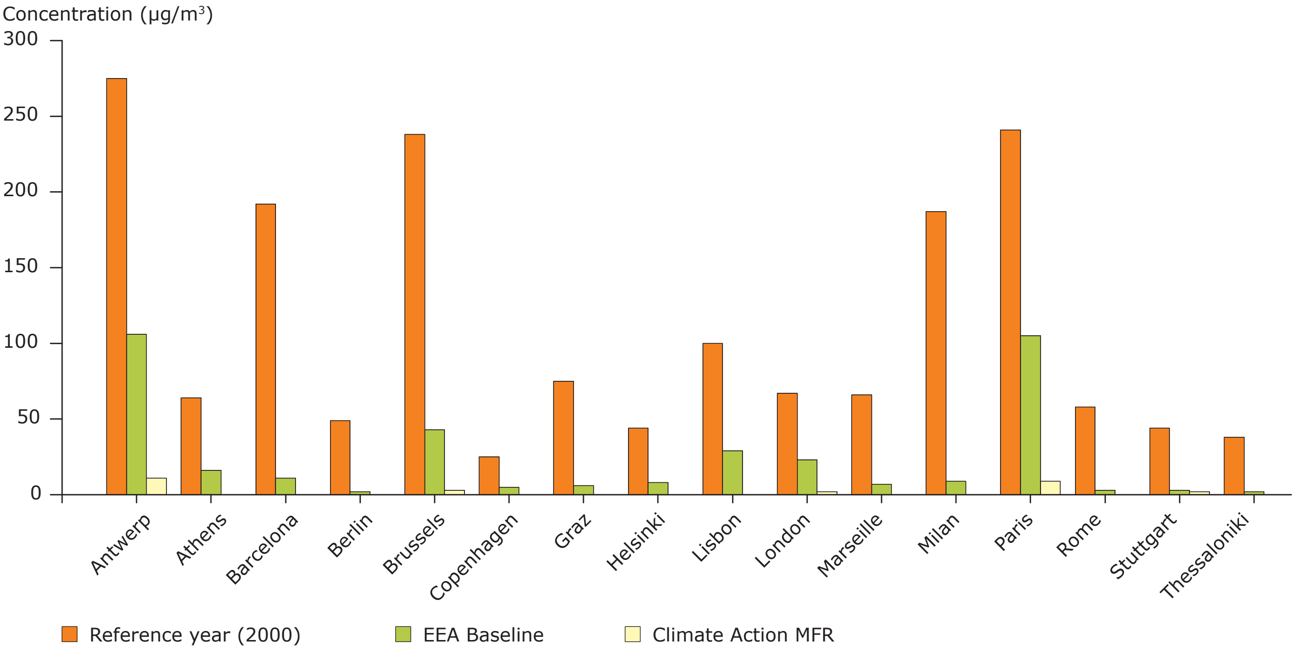
Figure 12 $PM_{2.5}$ **annual mean street increments for cities across Europe in 2000 compared to the projected street increment in 2030, according to the Climate Action and Climate Action MFR scenarios**



Note: Calculations were based on the narrow canyon case.

Source: EEA, 2006.

Figure 13 **Number of daily** PM_{10} **exceedances of the 50 µg/m³ limit value in 20 European cities for the reference year 2000 and the Climate Action and Climate Action MFR scenarios for 2030**



Note: Calculations were based on the narrow canyon case.

Source: EEA, 2006.

partly due to the effect of current legislation and partly due to the effect of climate policies (see effect of climate policies on emissions of ozone precursors in Chapter 3).

5 Ancillary benefits from climate change actions

Key findings

- Climate policies aimed at achieving an assumed target of 40 % reduction of EU GHG emissions by 2030 (from 1990 levels) have ancillary benefits for air pollution. In general, they lower air pollutant emissions, concentrations and impacts. The benefits are greatest in the new Member States and other eastern European countries.
- Climate policies make it cheaper to reach air quality targets. The costs that would be needed to reach the same impact levels as in the Climate Action scenario ([12]) by 2030 with specific air pollution abatement measures would amount to about EUR 12 billion (e.g. EUR 10 billion by direct control costs savings and an estimated value of EUR 2 billion for emission reductions beyond the baseline). Both costs and cost savings are highest in the EU-15, as compared to the rest of Europe. Relative abatement cost savings for NO_X, SO_2 and PM are estimated at 20 %, 12 % and 14 % by 2020, and more than 35 %, 25 % and 25 % by 2030.
- Climate policies can lead to considerable reductions in air pollution damage to public health and ecosystems (see Chapter 4). Besides allowing savings to be made in control costs, there are also benefits in terms of reduced health impact, e.g. over 20 000 less premature deaths in the EU-25 due to PM and ozone exposure. The health benefits of reduced air pollutant emissions due to climate action can be estimated at EUR 16 to 46 billion a year in the EU-25.
- Even within a Maximum Feasible Reduction scenario where areas with air quality targets exceedances continue to exist, climate policy is insufficient to reach air quality targets. But as shown in this report policies aimed at achieving long-term climate goals make it easier and significantly cheaper to reach long-term air quality goals. Hence, policies to address the two problems should not be considered separately.

5.1 Introduction

Many of the traditional air pollutants and greenhouse gases have common sources. Their emissions interact in the atmosphere either separately or jointly to cause a variety of environmental impacts on local, regional and global scales. Linkages work in two directions. There can either be synergies or negative trade-offs. Emission control strategies that simultaneously address air pollutants and greenhouse gases lead to a more efficient use of the resources on all scales. They have so-called 'co-benefits'. Some emissions control strategies that address only one of the two problems can have a negative effect on the other (i.e. trade-offs).

The environmental issues of which linkages are known to exist between climate change and air pollution are acidification, eutrophication, tropospheric O_3 formation and urban air pollution, (see EEA, 2004a, 2004b).

In political as well as in modelling practice, greenhouse gas emissions and air pollutants emissions reduction policies are still not usually integrated. Therefore, a full assessment of the co-benefits is beyond the scope of this report. However, the scenarios analysed for this report provide some insights into the ancillary benefits of climate policies for air pollution. Not all types of such ancillary benefits are evaluated. Moreover, the ancillary effects of air pollution abatement on greenhouse gas emissions have not been analysed in detail either. Nevertheless, some interesting conclusions can be drawn on the basis of the scenario analysis performed for the EEA reports *The European environment — State and outlook 2005* and *European environment outlook*. The next sections address costs, air pollutant emissions, air quality and impacts.

5.2 Costs

What are the costs of controlling emissions of pollutants? Table 9 compares the costs of abating air pollution in the EU-25 across scenarios.

The following categories have been included:

- Controls of SO_2 emissions;
- Controls on stationary sources of NO_X;

([12]) The Climate Action scenario has been designed to meet the long-term EU climate objective, and implies significant additional emissions reductions after the Kyoto target years. For details see Box 2.

Table 9 **Air pollutant abatement cost; EEA Baseline compared to Air Strategy, Climate Action scenario and Climate Action Maximum Feasible Reductions (MFR) scenario**

EU-25 costs in EUR billion/year	Reference	EEA Baseline	Climate Action	Climate Action MFR
	2000		2030	
SO_2	11.4	16.0	12.0	15.0
NO_X	2.0	3.1	2.0	7.9
NMVOC	0.4	1.8	1.8	4.0
NH_3	2.0	2.2	2.1	17.6
PM	6.4	7.4	5.5	17.6
Mobile	7.7	50.5	47.7	61.4
Total	30.0	81.0	71.0	123.0

Source: EEA, 2006.

- Controls on stationary sources of NMVOC;
- Controls of NH_3 emissions;
- Controls on mobile sources in the road and non-road sector.

Controls on mobile sources are treated separately, because the emission control technologies simultaneously affect the emissions of more than one pollutant. Thus, it is not possible to attribute costs separately to each of them.

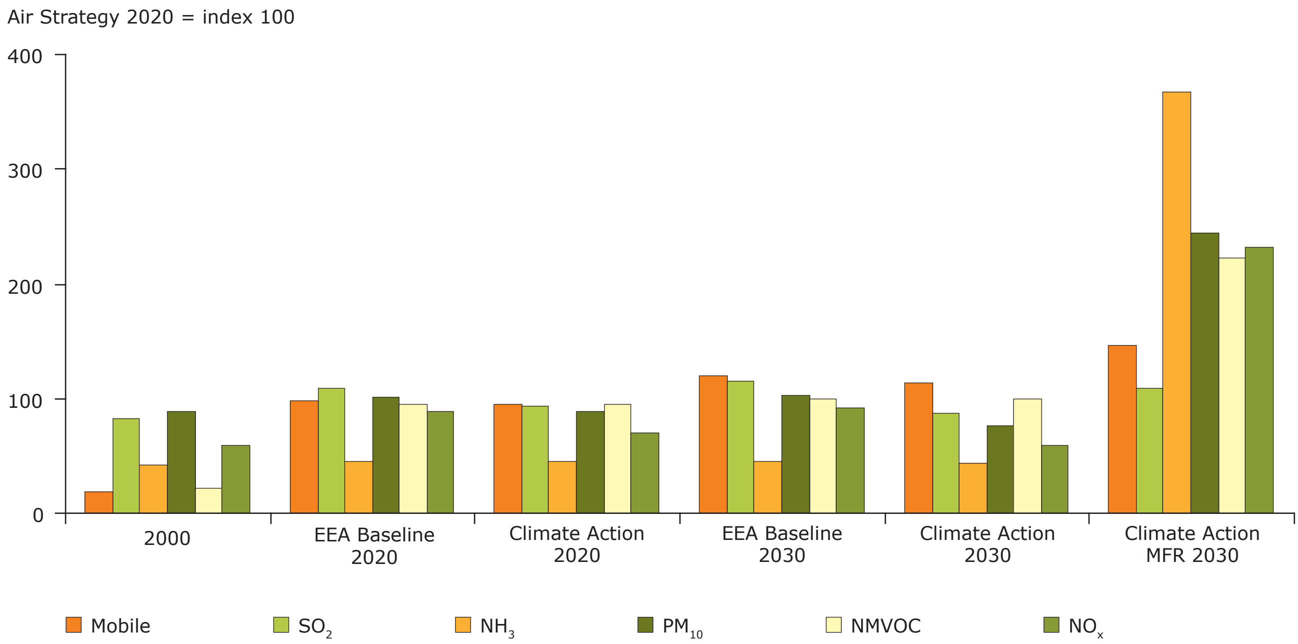
In 2000, the 'current legislation' costs in the EEA region were about EUR 32 billion (about EUR 65/capita), of which 95 % (EUR 30 billion) were costs for the EU-25. About 37 % of total expenditures went on sulphur controls, 26 % to mobile sources and 23 % on PM abatement from stationary sources.

According to these estimates, only 14 % of total abatement costs were spent on NH_3, NMVOC and NO_X from stationary sources together.

By 2020, the costs for current legislation in the EEA Baseline is expected to grow to EUR 71 billion in the EU-25 (+ 240 % compared to 2000). Using the Climate Action Base scenario with current legislation for air pollution, the total estimated costs are EUR 5 billion lower (more than 7 %), while the associated air quality is better (see next section). For some pollutants, the benefits are much larger than the average, e.g. for NO_X, there is more than a 20 % reduction.

In the Climate Action Base scenario with current legislation for air pollutants, the control costs

Figure 14 **Emission control costs by pollutant and scenario for EU-25**



Source: EEA, 2006.

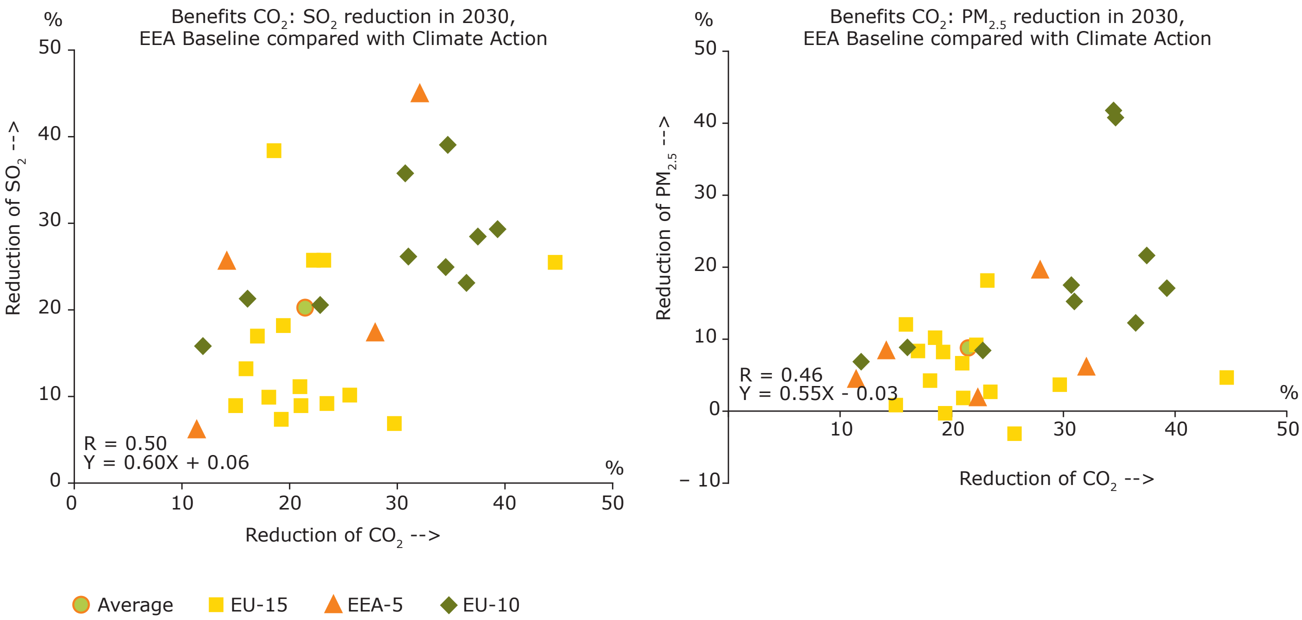
increase, to about EUR 79 billion or EUR 160/capita for the EEA region by 2030 compared to 2000, and EUR 71 billion for the EU-25 (by a factor of about 2.5). The increase is mainly due to the stringent emissions limits for mobile sources in current legislation that would have an influence after 2020. This will be due to the slow penetration of technologies, and increasing numbers of vehicles and mileage. Nevertheless, by 2030 the total costs in the Climate Action Base scenario would be almost EUR 10 billion (more than 12 %) lower than in the baseline. The costs savings would primarily be achieved in the mobile sources (all pollutants) and stationary sources (SO_2 and PM_{10}). For NO_X the savings would be more than 35 %. The Climate Action scenario also shows a 'double benefit' from climate change policies. In addition to lower control costs for air pollutant emissions, there is also less air pollutants emitted in the Climate Action scenario compared to the EEA Baseline. These benefits from less air pollutant emissions can be valued at approximately EUR 2 billion ([13]) per year. This corresponds to the costs that would be needed to reach the same emissions levels as in the Climate Action scenario with specific additional air pollution abatement measures in the EEA Baseline scenario.

The MFR costs are more than 80 % higher than the cost of 'current legislation'. In this case, the highest cost increase occurs for ammonia, stationary sources of PM and transport.

5.3 Emissions

In addition to the reduced abatement costs for air pollutants, the emissions of these pollutants under the Climate action scenarios are lower than in the baseline (Table 3.1). While the baseline emissions already go a long way to meeting the NEC ceilings, the Air Strategy and Climate Action scenarios lead to significantly lower emissions in the years after 2010. The table clearly demonstrates additional ancillary benefits of climate policies on air pollution policies. For SO_2, this figure is respectively 12 % and 17 % lower for 2020 and 2030 compared to baseline. For PM and NO_X emissions they are approximately 5 % and 10 % (2020 and 2030) below baseline values. No benefits are found again for NMVOC and ammonia emissions. The ancillary benefits in terms of reduced air pollutant emissions from climate policy vary for different pollutants and for different countries.

Figure 15 Relationship between reduction of GHG emissions and emissions of $PM_{2.5}$ and SO_2 in various European countries



Note: EEA-5 comprises of Bulgaria, Norway, Romania, Turkey and Switzerland.

Source: EEA, 2006.

([13]) The costs that would be needed to reach the same emissions levels with specific additional air pollution abatement measures in the EEA baseline scenario assuming that a reduction of 27 % of the CAFE strategy emissions can be scaled linearly to avoided control costs.

Figure 15 shows the relationship between CO_2 emissions reductions and respectively SO_2 and $PM_{2.5}$ emissions reductions compared to baseline developments for different (groups of) countries. The ancillary benefits of CO_2 reductions for PM emissions are particularly large in the 'new' Member States. The spread is large and the relationships are not very strong, but on average one could say that 1 % reduction in CO_2 is accompanied by 0.4 % reduction in $PM_{2.5}$. These relationships vary considerably from – 0.1 % in Portugal (increase due to increasing use of biomass) to 1.2 % in Slovenia (Figure 15, right panel).

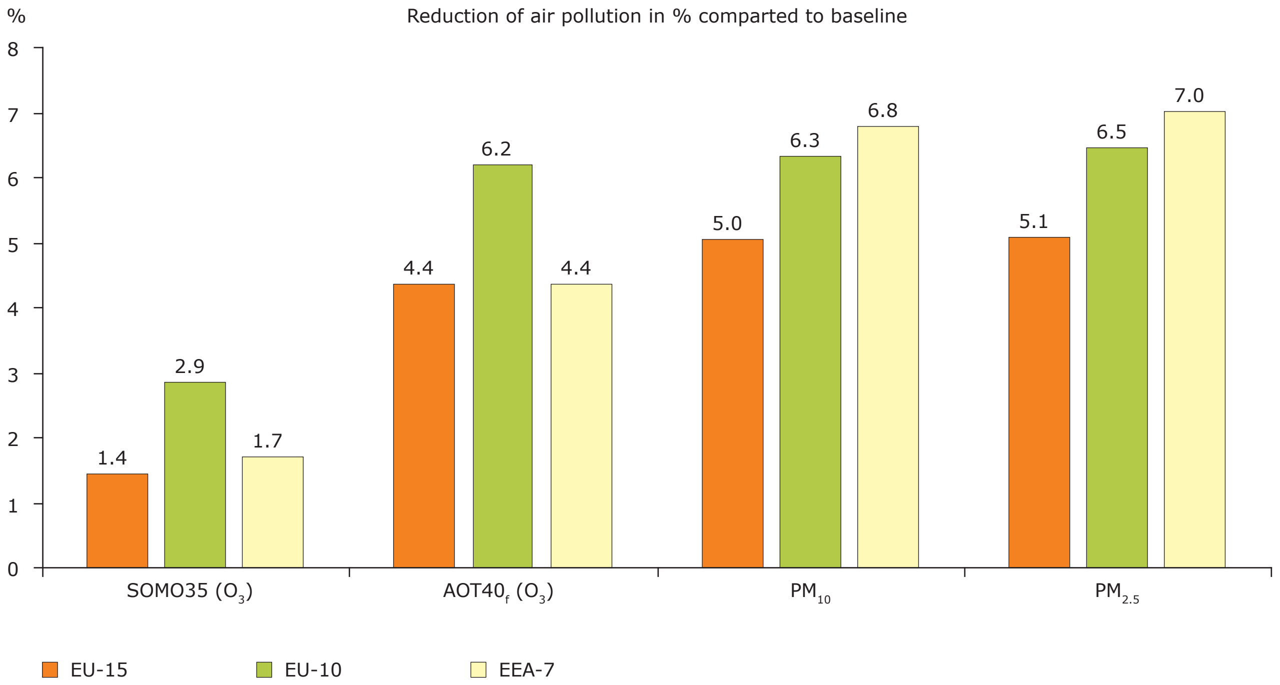
For SO_2, the emission benefits are more pronounced with on average a 1 % reduction in CO_2 accompanied by a 1 % reduction in SO_2. This relationship (Figure 15, left panel) varies considerably from 0.2 % in Finland (i.e. due to an increasing use of biomass) to 2 % in Luxemburg (see Section 3 for more detail about individual air pollutants).

5.4 Air quality and impacts

Additional emissions reductions lead to reduced concentrations. In Map 2 and Map 4 the geographic distribution of two concentration-related ozone indicators is provided: SOMO35 and AOT40 for ozone. Figure 16 shows the percentage of reduction in 2030 for these same ozone indicators and for yearly mean concentrations for $PM_{2.5}$ and PM_{10} for the Climate Action scenario compared to the baseline. The ancillary benefits for PM for individual countries are generally between 5 and 10 %, which is larger than for the ozone indicators (roughly between 1 and 6 %). The largest benefits in any individual country are in Turkey, where climate policies would reduce PM concentrations by about 15 %. In general, benefits (in percentage points) in the candidate countries are higher than in the 10 'new' Member States, which are larger than in the EU-15. This can be explained by the fact that technologies in the 'old' Member States are already cleaner than in the candidate and new Member States, where still further benefits can be obtained.

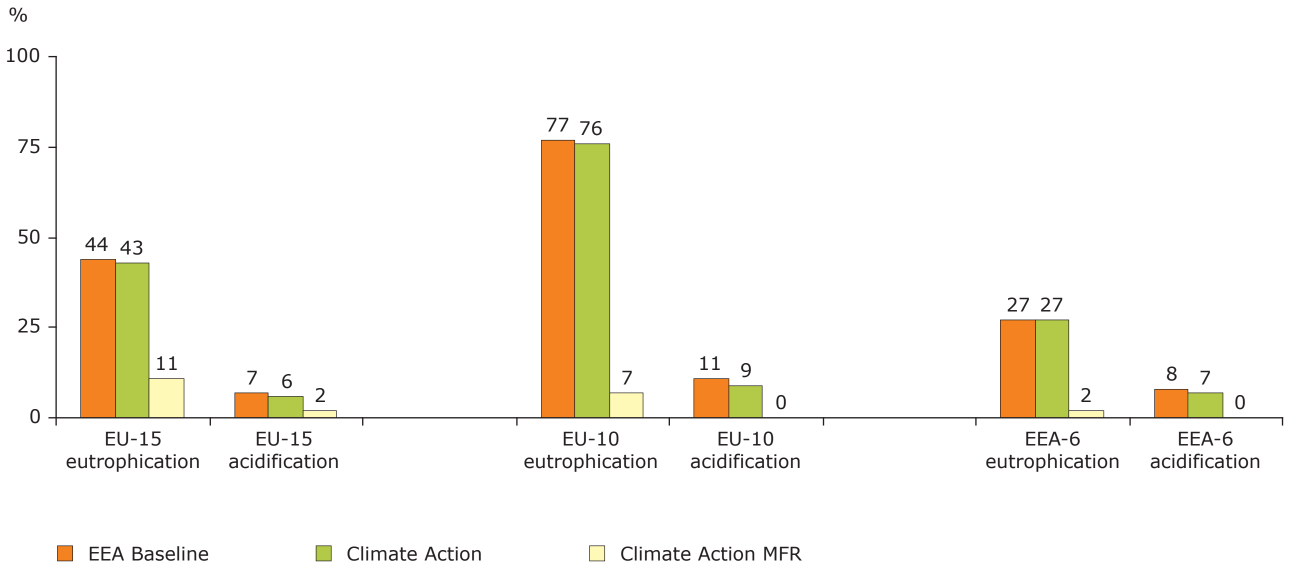
As a consequence of the above, the climate policy emissions reductions lead to reduced air pollution

Figure 16 Relative changes in concentration indicators for ozone (SOMO35, AOT40) and particulate matter (average annual concentrations of $PM_{2.5}$ and PM_{10}) as a result of climate policies in the Climate Action scenario



Note: EEA-7 comprises of Bulgaria, Iceland, Liechtenstein, Norway, Romania, Turkey and Switzerland.
Source: EEA, 2006.

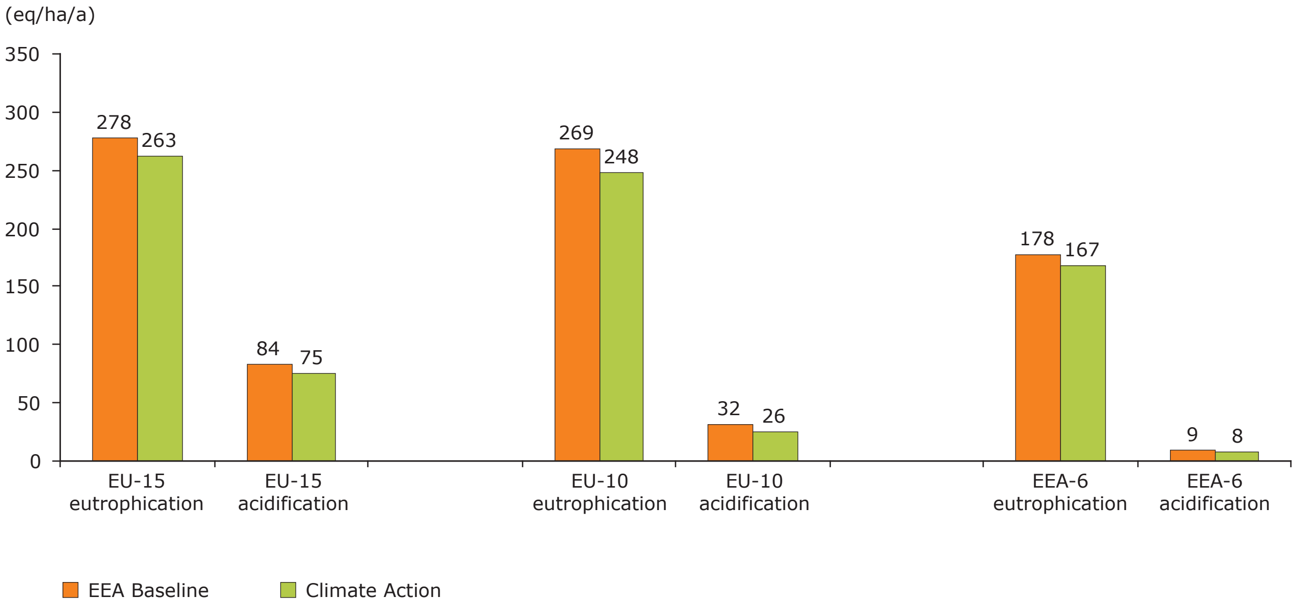
Figure 17 Changes in % of the area with exceedances of critical loads for acid deposition and eutrophication for main European regions



Note: EEA-6 comprises of Bulgaria, Iceland, Liechtenstein, Norway, Romania, and Switzerland

Source: EEA, 2006.

Figure 18 Accumulated average exceedances for acid deposition and eutrophication for various scenarios



Source: EEA, 2006.

impacts. The results are presented in the maps of Map 3 and Map 4. They show the impact on forest area with acid deposition above critical loads (SO_2 and NO_X) and on the percentage of ecosystems receiving nitrogen deposition above critical loads for eutrophication (NO_X and NH_3). Figure 17 shows the same information averaged for different country groupings. Figure 18 shows the Accumulated Average Exceedances (AAE) that quantify atmospheric depositions are higher than critical loads. According to these calculations, the benefits of climate policies for ecosystem protection expressed in accumulated exceedances are more pronounced than the benefits expressed in km^2 reduced ecosystem area where exceedances take place.

The impact on health, notably through changes in the statistical life expectancy due to $PM_{2.5}$, and on premature mortality due to O_3 (with precursors NMVOCs and NO_X), is quite significant. The number of estimated deaths due to $PM_{2.5}$ exposure decreases by 21 000 in the EU-25 and 5 300 in the non-EU-25 countries. The population in the EU-25 gains an average of 0.5 months (0.7 in the non-EU-25 EEA member countries) in life years, varying from 0.1 in Sweden to 1.1 in Luxembourg. Morbidity effects such as chronic bronchitis could be reduced by 15 000 cases in the EU-25 and 4 100 in the non-EU-25 members. Restricted activity days can be expected to be reduced by 17 million in the EU-25 and 4.7 million in the non-EU-25 members.

The reduced health impacts could be monetised. The most important would be the mortality and morbidity gains from reduced PM exposure. For the Climate Action Base scenario, gains in morbidity are estimated at EUR 4 billion a year in the EU-25 and EUR 1.2 billion a year in the non-EU-25 members. Gains in mortality range from EUR 12–43 billion in the EU-25 and EUR 4–11 billion in the non-EU-25 members. In total, the health impact gains could be estimated at around four times the emission control costs gains.

The benefits of reduced air pollutant emissions (e.g. avoided damages and reduced control costs) due to climate action policies can be estimated at EUR 26 to 56 billion a year in the EU-25. The costs of (domestic) climate action policies are estimated at EUR 100 billion a year in 2030 (EEA, 2005). The air quality ($PM_{2.5}$ only) and air pollution emission control benefits can therefore be estimated at 25 to more than 50 % of the climate change action costs.

5.5 Discussion and synthesis

Averaged over larger regions of Europe, the ancillary benefits of climate policies in terms of emissions are greater in percentage terms than those in concentrations, which are again larger than those on impacts. In general, the benefits are greater for candidate and other non-EU member countries than for the 10 'new' EU Member States, which in turn are greater than for the EU-15. However, for individual countries benefits can be significantly greater or smaller.

In other words, if one assumes that the EU makes efforts to meet its long-term climate objective regardless of air pollution, the costs for air pollution as calculated for the CAFE programme are overestimates of the real costs associated with only air pollution. Integrated analysis leads to lower cost estimates in both areas.

Under the Maximum Feasible Reductions (MFR) scenario, more than 50 % further reductions are achieved (e.g. from 30 % for NMVOC to more than 60 % for SO_2) by 2030, but at a higher cost of more than EUR 40 billion (more than 50 %). The air pollution abatement costs saved by reducing greenhouse gas emissions would thus cover a significant part of the options associated with the Maximum Feasible Reductions. This would help further improve European air quality. Conversely, Chapter 4 shows that even in the MFR scenario a number of highly polluted areas in Europe (e.g. Netherlands, Belgium, south-east United Kingdom) remain. If the European air quality goals of avoiding negative impacts are to be achieved, measures beyond technological fixes are needed. Many such options relate to changes in the driving forces, including those associated with fossil fuel consumption such as energy conservation. As a result, such measures would lead to further reductions in greenhouse gas emissions. In summary, climate policy is insufficient to reach air quality targets. Moreover, policies aimed at reaching climate goals make it easier and significantly cheaper to reach air quality goals. Hence, the two problems should not be considered in isolation.

It should be noted that various dimensions of the ancillary benefits have not been analysed. For example, the above considerations do not address the higher-scale improvements in the hemispheric background air pollution levels in the Climate Action scenario, notably for O_3 and particulate matter. This is due to the fact that many of these emissions have sources in common with direct greenhouse gas emissions. Intercontinental transport of particles and O_3 and their precursors as well as heavy metals and persistent organic pollutants have already been observed, and increase the background levels of air pollution in the northern hemisphere. These developments make it increasingly difficult to achieve air quality targets, and hence adequately protect ecosystems and public health in Europe. To respond to this development, the Executive Body of the CLRTAP recently decided to set up a new Task Force on the Hemispheric Transport of Air Pollution. This task force will report to the Steering Body of EMEP. As a result, climate and air pollution policies may be further integrated in the future.

Also, emissions of greenhouse gases from aviation and marine shipping are not included in the climate policies in the Climate Action scenario. If GHG emissions from those sources were controlled, additional benefits for air pollution would be available.

Finally, ancillary effects beyond air pollution abatement are not addressed, e.g. improved energy security, level and composition of economic growth, employment effects and other environmental implications such as for waste.

Also negative trade-offs between climate and air pollution policies have not been taken into account. For example, sulphur abatement in refineries increases energy consumption of the refining process. Therefore, this may increase greenhouse gas emissions from that process, depending on the fuel mix.

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Glossary

AOT40	The sum of the differences between hourly ozone concentration and 40 ppb during daylight hours (8.00–20.00 MET) for each hour that the concentration exceeds 40 ppb during a relevant growing season, e.g. for forest ($AOT40_f$, 6 summer months) and crops ($AOT40_c$, 3 summer months).
(C)LRTAP	(Convention on) Long-range Transboundary Air Pollution
CAFE	Clean Air For Europe (European Commission thematic strategy)
CCE	Co-ordination Centre for Effects
EAP	Environmental Action Program
ETC/ACC	European Topic Centre on Air and Climate Change
FAIR	Framework to Assess International Regimes for differentiation of commitments (model maintained by MNP)
GHG	Green House Gas
MNP	Netherlands Environment Assessment Agency
NEC(D)	National Emissions Ceilings (Directive)
NMVOC	(Non-Methane) Volatile Organic Compounds
ppm	Parts per million
ppb	Parts per billion
POLES	Long-term energy supply and demand projections (model maintained by JRC-IPTS)
PRIMES	Energy system model (model maintained by NTUA-technical University of Athens)
RAINS	Regional Air Pollution INformation and Simulation (model maintained by IIASA)
SOMO35	Sum of daily eight-hour mean ozone in excess of 35 ppb
TIMER	Targets IMage Energy Regional (model maintained by MNP)
UNECE	United Nations Economic Commission for Europe
WHO	World Health Organisation

Annex 1: Emissions of pollutants by country per component NO_X, NMVOCs, NH_3, SO_2, PM_{10} and $PM_{2.5}$

Emissions of NO_X, Kilotonnes (Kt) (10^6 kg)/year

	2000	NEC 2010	Air Strategy 2020		EEA Baseline		Climate Action 2030		
			Strategy	MFR	2020	2030	Base	Low	MFR
Austria	192	103	***108***	91	***124***	***113***	***109***	96	66
Belgium	333	176	137	112	***199***	***204***	172	155	84
Cyprus	26	23	14	10	18	20	18	17	10
Czech Republic	318	286	79	60	119	120	89	82	43
Denmark	207	127	84	65	103	98	95	91	48
Estonia	37	60	10	8	15	14	12	11	6
Finland	212	170	89	63	105	100	103	95	48
France	1 447	810	626	460	***835***	***822***	767	685	370
Germany	1 645	1 051	694	599	1 005	944	799	679	517
Greece	322	344	169	120	209	218	202	187	90
Hungary	188	198	61	42	90	96	77	73	35
Ireland	129	65	50	39	63	62	55	49	30
Italy	1 389	990	534	363	704	667	616	541	286
Latvia	35	61	11	9	17	16	14	14	8
Lithuania	49	110	21	15	28	26	24	24	13
Luxembourg	33	11	***13***	***11***	***18***	***20***	***17***	***14***	10
Malta	9	8	2	2	4	4	4	3	2
Netherlands	399	260	201	166	244	255	235	197	134
Poland	843	879	276	209	379	380	332	324	166
Portugal	263	250	127	97	171	181	159	130	81
Slovakia	106	130	45	34	50	53	48	47	26
Slovenia	58	45	20	16	27	20	16	15	9
Spain	1 335	847	519	397	674	680	634	577	314
Sweden	251	148	121	75	***161***	***179***	***151***	***152***	71
United Kingdom	1 753	1 167	646	473	797	823	775	712	384
Iceland	20	n.a	n.a.	n.a.	n.a.	n.a.	29	29	n.a.
Norway	211	156	n.a.	109	***164***	***157***	155	151	83
Switzerland	97	79	n.a.	33	56	59	55	50	30
Bulgaria	191	266	n.a.	45	107	87	81	76	35
Romania	331	437	n.a.	94	206	203	191	172	91
Turkey	942	n.a.	n.a.	369	751	830	771	675	372
EEA-31	13 371	n.a.	n.a.	n.a.	n.a.	n.a.	6 805	6 123	n.a.
EU-25	11 579	8 319	4 657	3 536	6 159	6 115	5 523	4 970	2 851
EU-15	9 910	6 519	4 118	3 131	5 413	5 366	4 889	4 360	2 533
EU-10	1 669	1 800	539	405	747	749	634	610	318
EEA-6	1 792	n.a.	n.a.	n.a.	n.a.	n.a.	1 282	1 153	n.a.

Note: Numbers higher than the NEC targets are in ***red*** and *italics.*

Emissions of NMVOC, Kilotonnes (Kt) (10^6 kg)/year

	2000	NEC 2010	Air Strategy 2020		EEA Baseline		Climate Action 2030		
			Strategy	MFR	2020	2030	Base	Low	MFR
Austria	190	159	130	92	n.a.	n.a.	133	129	88
Belgium	238	139	118	106	n.a.	n.a.	***149***	***146***	108
Cyprus	13	14	6	4	n.a.	n.a.	6	6	4
Czech Republic	241	220	97	69	n.a.	n.a.	120	119	69
Denmark	128	85	54	39	n.a.	n.a.	56	55	37
Estonia	34	49	15	11	n.a.	n.a.	15	15	9
Finland	171	130	90	61	n.a.	n.a.	89	87	58
France	1 541	1 050	846	659	n.a.	n.a.	913	881	669
Germany	1 553	995	741	637	n.a.	n.a.	787	747	641
Greece	280	261	110	79	n.a.	n.a.	147	139	78
Hungary	168	137	73	51	n.a.	n.a.	84	82	47
Ireland	88	55	37	30	n.a.	n.a.	45	43	30
Italy	1 735	1 159	691	540	n.a.	n.a.	717	698	527
Latvia	52	136	23	13	n.a.	n.a.	28	28	13
Lithuania	74	92	39	20	n.a.	n.a.	40	40	19
Luxembourg	13	9	7	6	n.a.	n.a.	8	7	6
Malta	5	12	2	1	n.a.	n.a.	2	2	1
Netherlands	264	185	161	144	n.a.	n.a.	***203***	***193***	142
Poland	581	800	296	202	n.a.	n.a.	313	309	198
Portugal	259	180	147	108	n.a.	n.a.	169	157	112
Slovakia	88	140	59	31	n.a.	n.a.	68	67	32
Slovenia	54	40	19	12	n.a.	n.a.	18	17	10
Spain	1 114	662	571	431	n.a.	n.a.	***676***	659	430
Sweden	298	241	153	118	n.a.	n.a.	206	204	118
United Kingdom	1 472	1 200	766	651	n.a.	n.a.	886	870	655
Iceland	13	n.a	n.a.	n.a.	n.a.	n.a.	7	7	n.a.
Norway	374	195	n.a.	60	n.a.	n.a.	78	77	58
Switzerland	145	144	n.a.	54	n.a.	n.a.	90	88	54
Bulgaria	134	185	n.a.	33	n.a.	n.a.	73	71	32
Romania	378	523	n.a.	102	n.a.	n.a.	227	220	105
Turkey	783	n.a.	n.a.	274	n.a.	n.a.	538	510	309
EEA-31	12 481	n.a.	n.a.	n.a.	n.a.	n.a.	6 891	6 673	n.a.
EU-25	10 654	8 150	5 251	4 115	n.a.	n.a.	5 878	5 700	4 101
EU-15	9 344	6 510	4 622	3 701	n.a.	n.a.	5 184	5 015	3 699
EU-10	1 310	1 640	629	414	n.a.	n.a.	694	685	402
EEA-6	1 827	n.a.	n.a.	n.a.	n.a.	n.a.	1 013	973	n.a.

Note: Numbers higher than the NEC targets are in ***red*** and *italics.*

Emissions of NH_3, Kilotonnes (Kt) (10^6 kg)/year

	2000	NEC 2010	Air Strategy 2020		EEA Baseline		Climate Action 2030		
			Strategy	MFR	2020	2030	Base	Low	MFR
Austria	54	66	50	28	54	53	52	52	26
Belgium	81	74	59	47	***76***	74	74	74	45
Cyprus	6	9	5	3	6	7	6	6	3
Czech Republic	74	80	43	36	66	66	65	65	36
Denmark	91	69	62	40	***78***	76	***76***	***76***	39
Estonia	10	29	8	5	12	15	15	15	5
Finland	35	31	29	22	***32***	31	31	31	21
France	728	780	521	387	703	672	671	670	364
Germany	638	550	453	481	***609***	591	***584***	***580***	470
Greece	55	73	44	35	53	50	49	49	32
Hungary	78	90	48	39	85	89	88	88	39
Ireland	127	116	108	84	***121***	112	112	112	77
Italy	432	419	300	248	399	384	383	382	235
Latvia	12	44	12	7	16	18	18	18	8
Lithuania	50	84	50	39	57	60	60	60	41
Luxembourg	7	7	5	4	6	5	5	5	4
Malta	1	3	1	1	1	1	1	1	1
Netherlands	157	128	105	103	***140***	136	***135***	***134***	99
Poland	309	468	221	150	335	337	336	336	149
Portugal	68	90	62	40	67	66	65	65	39
Slovakia	32	39	23	17	33	33	33	33	16
Slovenia	18	20	14	9	20	20	19	19	9
Spain	394	353	285	198	370	358	***357***	***357***	189
Sweden	53	57	44	33	50	49	47	47	32
United Kingdom	315	297	220	206	***311***	299	***299***	***298***	195
Iceland	3	n.a	n.a.	n.a.	n.a.	n.a.	3	3	n.a.
Norway	26	23	n.a.	15	23	23	23	23	15
Switzerland	66	63	n.a.	39	61	59	59	59	38
Bulgaria	92	108	n.a.	72	***124***	124	***124***	***124***	72
Romania	223	210	n.a.	143	***285***	285	***285***	***285***	143
Turkey	407	n.a.	n.a.	251	466	510	508	508	272
EEA-31	4 642	4 380	n.a.	n.a.	n.a.	n.a.	4 583	4 575	n.a.
EU-25	3 825	3 976	2 772	2 262	3 700	3 601	3 581	3 573	2 174
EU-15	3 235	3 110	2 347	1 956	3 068	2 956	2 940	2 932	1 867
EU-10	590	866	425	306	632	645	641	641	307
EEA-6	817	n.a.	n.a.	n.a.	n.a.	n.a.	1 002	1 002	n.a.

Note: Numbers higher than the NEC targets are in ***red*** and *italics.*

Emissions of SO_2, Kilotonnes (Kt) (10^6 kg)/year

	2000	NEC 2010	Air Strategy 2020		EEA Baseline		Climate Action 2030		
			Strategy	MFR	2020	2030	Base	Low	MFR
Austria	38	39	23	22	27	27	23	21	19
Belgium	187	99	57	51	86	89	70	64	47
Cyprus	46	39	8	3	8	8	7	6	2
Czech Republic	250	265	33	26	64	53	32	30	14
Denmark	28	55	12	10	15	14	12	11	8
Estonia	91	100	6	3	11	10	7	6	2
Finland	77	110	59	46	56	53	53	49	41
France	654	375	188	148	365	342	306	275	144
Germany	643	520	267	214	490	456	295	242	190
Greece	481	523	74	40	107	112	103	92	32
Hungary	487	500	20	19	85	82	67	55	15
Ireland	132	42	13	10	21	18	15	14	8
Italy	747	475	135	117	329	309	241	219	100
Latvia	16	101	3	2	9	8	6	6	2
Lithuania	43	145	9	5	27	28	21	21	5
Luxembourg	4	4	1	1	2	3	2	2	1
Malta	26	9	2	1	2	2	2	2	1
Netherlands	84	50	45	41	*63*	*73*	*65*	*57*	42
Poland	1 515	1 397	201	167	658	376	328	318	101
Portugal	230	160	48	33	88	96	85	75	34
Slovakia	124	110	18	11	36	30	23	21	7
Slovenia	97	27	6	5	18	18	14	13	4
Spain	1 489	746	186	155	354	375	344	315	162
Sweden	58	67	50	39	63	*69*	50	50	38
United Kingdom	1 186	585	135	115	220	223	203	185	111
Iceland	24	n.a.	n.a.	n.a.	n.a.	n.a.	27	27	n.a.
Norway	27	22	n.a.	13	19	16	16	15	12
Switzerland	20	26	n.a.	7	14	13	13	11	7
Bulgaria	1 313	856	n.a.	59	745	190	117	185	43
Romania	838	918	n.a.	32	384	132	115	105	35
Turkey	2 122	n.a.	n.a.	230	1 316	935	674	569	298
EEA-31	13 077	n.a.	n.a.	n.a.	n.a.	n.a.	3 336	3 061	n.a.
EU-25	8 733	6 543	1 599	1 284	3 205	2 875	2 374	2 149	1 130
EU-15	6 038	3 850	1 293	1 042	2 286	2 260	1 867	1 671	977
EU-10	2 695	2 693	306	242	919	615	507	478	153
EEA-6	4 344	n.a.	n.a.	n.a.	n.a.	n.a.	962	912	n.a.

Note: Numbers higher than the NEC targets are in ***red*** and *italics.*

Emissions of PM_{10}, Kilotonnes (Kt) (10^6 kg)/year

	2000	NEC 2010	Air Strategy 2020		EEA Baseline		Climate Action 2030		
			Strategy	MFR	2020	2030	Base	Low	MFR
Austria	49	n.a.	n.a.	27	39	37	36	34	24
Belgium	70	n.a.	n.a.	26	46	47	37	35	24
Cyprus	3	n.a.	n.a.	2	3	3	3	3	2
Czech Republic	104	n.a.	n.a.	20	33	31	21	20	14
Denmark	33	n.a.	n.a.	16	23	22	22	21	14
Estonia	42	n.a.	n.a.	3	10	8	6	6	2
Finland	44	n.a.	n.a.	17	32	28	29	27	15
France	375	n.a.	n.a.	136	269	257	229	204	123
Germany	261	n.a.	n.a.	147	218	210	182	168	135
Greece	66	n.a.	n.a.	31	62	59	51	44	26
Hungary	87	n.a.		14	40	44	32	32	13
Ireland	22	n.a.	n.a.	10	16	16	15	14	10
Italy	273	n.a.	n.a.	100	149	142	133	123	89
Latvia	10	n.a.	n.a.	3	7	6	5	5	3
Lithuania	21	n.a.	n.a.	6	17	15	12	12	5
Luxembourg	4	n.a.	n.a.	3	4	4	3	3	3
Malta	1	n.a.	n.a.	0	1	1	1	1	0
Netherlands	58	n.a.	n.a.	37	49	50	49	45	35
Poland	307	n.a.	n.a.	81	160	138	128	124	68
Portugal	59	n.a.	n.a.	25	49	51	50	42	25
Slovakia	29	n.a.	n.a.	10	20	20	18	17	8
Slovenia	21	n.a.	n.a.	4	10	9	5	5	3
Spain	235	n.a.	n.a.	88	144	142	131	122	79
Sweden	79	n.a.	n.a.	24	53	50	47	46	23
United Kingdom	202	n.a.	n.a.	82	118	118	110	105	76
Iceland	3	n.a.	n.a.	n.a.	n.a.	n.a.	3	3	n.a.
Norway	35	n.a.	n.a.	14	22	20	20	20	12
Switzerland	15	n.a.	n.a.	8	12	12	12	12	8
Bulgaria	94	n.a.	n.a.	18	73	60	56	55	15
Romania	171	n.a.	n.a.	31	120	119	88	85	29
Turkey	424	n.a.	n.a.	120	410	437	381	369	122
EEA-31	3 197	n.a.	n.a.	n.a.	n.a.	n.a.	1 915	1 802	n.a.
EU-25	2 455	n.a.	n.a.	912	1 571	1 507	1 355	1 258	819
EU-15	1 830	n.a.	n.a.	769	1 271	1 233	1 124	1 033	701
EU-10	625	n.a.	n.a.	143	300	274	231	225	118
EEA-6	742	n.a.	n.a.	n.a.	n.a.	n.a.	560	544	n.a.

Emissions of $PM_{2,5}$, Kilotonnes (Kt) (10^6 kg)/year

	2000	NEC 2010	Air Strategy 2020		EEA Baseline		Climate Action 2030		
			Strategy	MFR	2020	2030	Base	Low	MFR
Austria	37	n.a.	n.a.	18	27	25	25	23	15
Belgium	43	n.a.	n.a.	16	26	26	21	20	13
Cyprus	2	n.a.	n.a.	1	2	2	2	2	1
Czech Republic	66	n.a.	n.a.	11	18	17	11	11	7
Denmark	22	n.a.	n.a.	8	13	12	12	11	7
Estonia	22	n.a.	n.a.	2	7	5	4	4	1
Finland	36	n.a.	n.a.	12	26	22	22	21	10
France	290	n.a.	n.a.	84	175	159	151	134	73
Germany	171	n.a.	n.a.	82	129	120	105	95	73
Greece	49	n.a.	n.a.	21	44	41	36	30	18
Hungary	60	n.a.	n.a.	7	26	28	21	21	7
Ireland	14	n.a.	n.a.	6	9	9	9	9	5
Italy	209	n.a.	n.a.	64	98	90	84	78	55
Latvia	7	n.a.	n.a.	2	5	4	3	3	1
Lithuania	17	n.a.	n.a.	4	13	11	9	9	3
Luxembourg	3	n.a.	n.a.	2	2	3	2	2	2
Malta	1	n.a.	n.a.	0	0	0	0	0	0
Netherlands	36	n.a.	n.a.	19	26	26	25	23	17
Poland	215	n.a.	n.a.	47	107	89	81	78	37
Portugal	46	n.a.	n.a.	18	38	39	39	31	18
Slovakia	18	n.a.	n.a.	5	12	12	11	11	4
Slovenia	15	n.a.	n.a.	3	7	6	4	4	2
Spain	169	n.a.	n.a.	53	90	86	80	73	44
Sweden	67	n.a.	n.a.	16	42	39	37	36	15
United Kingdom	129	n.a.	n.a.	46	68	67	63	60	41
Iceland	3	n.a.	n.a.	n.a.	n.a.	n.a.	3	3	n.a.
Norway	29	n.a.	n.a.	10	16	15	14	14	8
Switzerland	10	n.a.	n.a.	5	7	7	6	6	4
Bulgaria	59	n.a.	n.a.	12	41	34	33	32	10
Romania	115	n.a.	n.a.	18	74	71	59	57	17
Turkey	305	n.a.	n.a.	87	276	279	254	245	85
EEA-31	2 265	n.a.	n.a.	n.a.	n.a.	n.a.	1 226	1 146	n.a.
EU-25	1 744	n.a.	n.a.	547	1 012	937	857	789	469
EU-15	1 321	n.a.	n.a.	465	814	763	711	646	406
EU-10	423	n.a.	n.a.	82	198	174	146	143	63
EEA-6	521	n.a.	n.a.	n.a.	n.a.	n.a.	369	357	n.a.

Annex 2: Emission control costs by country

Total emissions costs, EUR 2000 million/year (NO_X, NMVOC, NH_3, SO_2, PM)

Country	2000	Climate Action 2020		EEA Baseline		Climate Action 2030		
		Baseline	MFR	2020	2030	Base	Low	MFR
Austria	650	1 400	2 930	1 478	1 751	1 562	n.a.	3 180
Belgium	921	1 959	3 260	2 107	2 531	2 048	n.a.	3 510
Cyprus	16	128	231	132	143	125	n.a.	225
Czech Republic	906	1 324	2 192	1 445	1 594	1 157	n.a.	1 984
Denmark	657	1 015	2 208	1 099	1 235	1 094	n.a.	2 323
Estonia	82	187	387	196	204	163	n.a.	323
Finland	548	1 091	2 221	1 115	1 161	1 015	n.a.	2 036
France	3 231	7 796	16 558	8 182	8 940	8 179	n.a.	16 895
Germany	8 666	13 938	19 049	15 771	17 416	15 438	n.a.	21 875
Greece	600	1 941	3 155	2 171	2 553	2 195	n.a.	3 569
Hungary	286	1 017	1 796	1 107	1 314	1 056	n.a.	1 850
Ireland	234	1 035	1 794	1 071	1 182	1 009	n.a.	1 791
Italy	3 428	7 466	11 906	8 000	8 915	7 957	n.a.	12 709
Latvia	20	217	398	232	263	225	n.a.	397
Lithuania	44	384	922	388	476	393	n.a.	881
Luxembourg	90	305	390	315	370	317	n.a.	417
Malta	4	41	65	44	46	42	n.a.	68
Netherlands	1 485	3 341	5 386	3 484	4 223	3 827	n.a.	6 067
Poland	1 685	3 966	8 626	4 358	5 265	4 298	n.a.	8 866
Portugal	290	1 629	3 368	1 701	2 270	1 988	n.a.	3 986
Slovakia	164	697	1 193	665	806	628	n.a.	1 106
Slovenia	131	270	524	319	365	288	n.a.	536
Spain	1 591	5 725	11 096	5 857	7 255	6 682	n.a.	12 448
Sweden	973	1 657	3 311	1 895	2 027	1 656	n.a.	3 382
United Kingdom	3 094	7 322	11 833	7 765	8 668	7 876	n.a.	12 979
Norway	251	748	1 420	771	791	720	n.a.	1 384
Switzerland	486	889	1 362	910	976	909	n.a.	1 435
Bulgaria	243	596	1 608	640	695	587	n.a.	1 401
Romania	280	1 275	4 144	1 395	1 806	1 499	n.a.	4 073
Turkey	690	3 564	11 397	3 762	5 020	4 219	n.a.	11 585
EEA-30	31 749	72 925	134 731	78 373	90 262	79 152	n.a.	143 282
EU-25	29 799	65 853	114 800	70 895	80 972	71 218	n.a.	123 403
EU-15	26 460	57 622	98 466	62 010	70 497	62 843	n.a.	107 167
EU-10	3 339	8 231	16 334	8 885	10 475	8 375	n.a.	16 236
EEA-5	1 951	3 854	15 873	4 210	4 750	3 730	n.a.	14 136

Annex 3: Air quality projection by city

Air quality projection by city

			Emissions per capita											
		Population	Climate Action						Climate Action MFR					
Country	City	(*1 000)	SO_2	PM_{10}	$PM_{2.5}$	NO_X	VOC	NH_3	SO_2	PM_{10}	$PM_{2.5}$	NO_X	VOC	NH_3
Belgium	Antwerp	794	1 429	543	334	3 021	3 115	1 452	960	329	185	1 471	2 188	806
Greece	Athens	3 514	445	37	24	552	255	36	80	24	15	243	140	20
Spain	Barcelona	4 409	89	28	19	106	173	92	45	20	13	49	115	44
Germany	Berlin	3 351	201	74	33	263	221	99	114	51	21	164	191	78
Belgium	Brussels	1 102	1 004	472	273	1 880	2 027	1 118	674	293	158	913	1 437	621
Hungary	Budapest	1 677	1 217	100	52	689	811	1 387	302	58	26	316	544	545
Denmark	Copenhagen	1 140	114	70	42	400	368	224	80	47	24	201	230	107
Poland	Gdansk	925	249	79	42	467	634	481	98	36	19	212	396	192
Austria	Graz	261	8 945	688	388	1 985	4 050	2 995	2 131	413	212	1 202	2 738	1 303
Finland	Helsinki	1 223	592	242	158	633	389	615	463	118	69	354	255	377
Poland	Katowice	3 169	631	140	79	740	766	353	201	69	40	342	478	144
Portugal	Lisbon	2 406	126	45	32	265	260	363	50	25	16	129	171	271
United Kingdom	London	7 841	55	27	16	262	302	40	32	18	10	150	225	24
France	Marseille	1 518	328	149	68	423	600	48	148	84	34	203	458	27
Italy	Milan	3 994	119	63	38	353	566	236	60	42	24	159	299	134
France	Paris	10 610	41	40	25	127	213	58	20	21	12	65	158	31
Czech Republic	Prague	1 205	220	146	85	883	860	487	105	94	54	430	460	240
Italy	Rome	2 620	74	35	21	323	255	102	45	24	14	145	173	59
Germany	Stuttgart	2 730	65	68	37	297	364	142	45	48	24	196	293	111
Greece	Thessaloniki	918	460	82	50	859	662	493	104	53	35	363	285	284

Annex 4: Impact indicators by country

Table: PM$_{2.5}$ and eutrophication
Scenarios: 2000, Air Strategy, Climate Action Base and Climate Action MFR

Percentage of total ecosystems receiving nitrogen deposition above the critical load for eutrophication

		2000	Air Strategy 2020	Climate Action 2030	
				Base	MFR
Austria	EU-15	96	77	64	29
Belgium	EU-15	93	34	57	19
Cyprus	EU-10	48	49	99	13
Czech Republic	EU-10	95	36	92	11
Denmark	EU-15	53	11	73	1
Estonia	EU-10	12	4	32	0
Finland	EU-15	25	6	25	0
France	EU-15	96	55	69	8
Germany	EU-15	96	92	89	77
Greece	EU-15	76	51	99	1
Hungary	EU-10	31	15	25	3
Ireland	EU-15	12	0	88	0
Italy	EU-15	62	27	34	7
Latvia	EU-10	54	15	92	1
Lithuania	EU-10	85	62	100	3
Luxembourg	EU-15	96	51	98	47
Malta	EU-10				
Netherlands	EU-15	67	51	82	32
Poland	EU-10	86	64	83	11
Portugal	EU-15	30	1	61	0
Slovakia	EU-10	89	28	62	3
Slovenia	EU-10	94	75	90	12
Spain	EU-15	65	32	68	2
Sweden	EU-15	26	8	11	0
United Kingdom	EU-15	13	0	17	0

Loss in statistical life expectancy that can be attibuted to the identified anthropogenic contributions to $PM_{2.5}$ (in months)

		2000	Air Strategy 2020	Climate Action 2030	
				Base	MFR
Austria	EU-15	7.2	4.3	3.9	1.8
Belgium	EU-15	13.2	7.1	8.7	4.2
Cyprus	EU-10	4.8	4.1		
Czech Republic	EU-10	8.8	4.2	4.4	1.9
Denmark	EU-15	5.9	3.7	4.7	2.0
Estonia	EU-10	3.8	2.6	2.8	1.0
Finland	EU-15	2.6	2.1	1.9	0.8
France	EU-15	8.0	4.3	5.0	2.1
Germany	EU-15	9.2	4.8	5.9	2.8
Greece	EU-15	6.7	4.8	4.1	1.3
Hungary	EU-10	10.6	5.4	5.7	1.7
Ireland	EU-15	4.0	2.1	3.1	1.0
Italy	EU-15	9.0	4.3	4.8	1.7
Latvia	EU-10	4.5	3.3	3.1	1.0
Lithuania	EU-10	6.1	4.4	4.0	1.2
Luxembourg	EU-15	9.6	4.8	6.1	2.9
Netherlands	EU-15	11.8	6.3	8.8	4.1
Poland	EU-10	9.6	5.1	5.2	1.9
Portugal	EU-15	5.1	2.5	3.2	1.3
Slovakia	EU-10	9.1	4.7	4.8	1.7
Slovenia	EU-10	8.2	4.7	4.6	1.5
Spain	EU-15	5.2	2.7	3.1	1.1
Sweden	EU-15	3.5	2.4	2.7	1.1
United Kingdom	EU-15	6.9	3.4	4.8	2.2

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