5. Air pollution

Emissions of acidifying and eutrophying substances and ground-level ozone precursors have fallen substantially since 1990 — in particular in central and eastern Europe and the 12 countries of eastern Europe, the Caucasus and central Asia (EECCA) as a result of economic restructuring. Reductions in western Europe have resulted mainly from fuel switching, flue-gas treatment and the introduction of three way catalysts for cars.

In consequence, most of Europe's ecosystems are now protected against further acidification but a number of hot-spot areas remain at risk especially in central Europe. Eutrophication remains a substantial problem with large areas unprotected throughout Europe especially in western Europe and central and eastern Europe. Furthermore, most of the monitored vegetation and agricultural crops in western Europe and central and eastern Europe are exposed to ozone concentrations above the long-term European Union target.

Air pollution remains a problem in most cities. Long-term average ground-level ozone concentrations continue to increase although short-term peak concentrations are falling. Exposure to particulate matter may be the largest potential health problem from air pollution in most cities. Although concentrations have been falling since monitoring began, a significant proportion of the urban population experiences concentrations above limit values. Exposures to concentrations of nitrogen dioxide and sulphur dioxide above limit values have fallen since 1990 and further notable reductions are expected. These reductions will focus attention to a greater extent on cities in the EECCA countries where air pollution remains a serious problem, and where implementation of better policies, monitoring and assessment are needed.

Baseline projections to 2010 suggest that while exposure to ground-level ozone at concentrations in excess of the EU threshold will fall in almost all western European and central and eastern European cities, the target levels are nevertheless unlikely to be attained. Similarly, concentrations of particulates will remain above the limit values. The fraction of the urban population exposed to air concentrations in excess of the most stringent of the nitrogen dioxide limit values will fall to about half compared to 1995, and exceedance of sulphur dioxide threshold will be observed only in EECCA.

Baseline projections for 2010 also suggest that economic restructuring and switching to cleaner fuels should enable the Russian Federation and the western countries of EECCA to fulfil their emission ceilings targets. Implementation of EU legislation in central and eastern Europe should result in countries attaining their national emission ceilings for all air pollutants except ammonia. In western Europe, additional measures beyond current legislation will be needed to reach the national emission ceilings of nitrogen oxides, volatile organic compounds and ammonia.

The same projections suggest that the total area of ecosystems protected from further acidification will increase to cover nearly all the ecosystem area. Recovery from past impacts, however, cannot be expected so rapidly. Protection from further eutrophication will also improve but still leave about half of the area in western, and central and eastern Europe unprotected. Regional ground-level ozone concentrations will fall below the threshold for vegetation.

Assuming a reduction of carbon dioxide emissions to comply with the Kyoto protocol, there will be significant ancillary benefits in terms of additional reduced emissions of air pollutants and reduced costs of air pollution abatement. The use of flexible mechanisms to implement the Kyoto protocol, compared to implementation primarily by means of domestic measures, will shift the additional reductions of air pollutant emissions from western to central and eastern Europe, the Russian Federation and the western countries of EECCA. It will also reduce the ancillary benefits in terms of control costs for air pollution in Europe and result in higher ecosystem protection in the whole of Europe. Using surplus emission allowances will reduce ancillary benefits in particular for central and eastern Europe, the Russian Federation and the western countries of EECCA.

5.1. Introduction

5.1.1. The issue

Air pollution is a transboundary, 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 have adverse effects on human health and on natural and man-made environments.

Box 5.1 summarises various important air pollution issues. These arise either from atmospheric deposition of pollutants or from direct exposure to ambient concentrations of pollutants i.e. from air quality.

The main deposition issues for this chapter are:

- acidification of soils and freshwater through the deposition of sulphur and nitrogen compounds;
- eutrophication of terrestrial, freshwater and marine ecosystems through the deposition of nitrogenous nutrients.

The main air quality issues addressed are:

- human health effects resulting from ground-level (tropospheric) ozone, particulate matter and other pollutants, including nitrogen oxides, benzene and sulphur dioxide;
- adverse effects on vegetation and crops resulting from ground-level ozone, nitrogen oxides and sulphur dioxide.

Ground-level ozone, acidification and eutrophication are issues of European scale because of atmospheric transboundary transport of pollutants. Air quality issues such as nitrogen dioxide and benzene are more subregional or local. Particulate matter and ozone have both local and transboundary aspects. Policy measures must be targeted accordingly at European, national and local levels.

The issues of stratospheric ozone depletion and dispersion of chemicals such as organic compounds or heavy metals are addressed in Chapters 4 and 6 respectively.

> Emissions of acidifying and eutrophying substances and ground-level ozone precursors have fallen substantially since 1990, but these pollutants continue to pose risks to health and the environment.

5.1.2. The policy framework

Air pollution issues are addressed by:

- European Community legislation and strategies;
- the United Nations Economic Commission for Europe (UNECE) Convention on Long-Range Transboundary Air Pollution (CLRTAP).

A key element of EU legislation on emissions is the national emission ceilings directive (NECD) (European Community, 2001a), which sets emission ceilings for sulphur dioxide (SO_2), nitrogen oxides (NO_X), and ammonia (NH_3) and volatile organic compounds (VOCs). 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 achieving 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 (European Community, 1998), large combustion plants (European Community, 2001b) and industry (VOC directive — European Community, 1999 and integrated pollution prevention and control directive — European Community, 1996).

National emission ceilings for non-EU countries have been agreed under the CLRTAP Gothenburg protocol (UNECE, 1999). These ceilings represent cost-effective and simultaneous reductions of acidification, eutrophication and ground-level ozone. The EU NECD ceilings were developed using a similar approach.

The EU air quality framework directive (Directive 96/62/EC) and daughter

Box 5.1. Air pollution issues

Deposition of air pollutants

Ecosystem acidification and eutrophication: Emissions, atmospheric chemical reactions and subsequent deposition of nitrogen oxides (NO_X) sulphur dioxide (SO_2), and ammonia (NH_3) are causing acidification of terrestrial and freshwater ecosystems. Eutrophication is a consequence of excess input of nitrogen nutrients (nitrogen oxides and ammonia), which disturbs the structure and function of ecosystems e.g. excessive algae blooming in surface waters.

Materials damage: Acidifying pollutants also 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.

Exposure of *particulate matter*, measured as concentrations of PM_{10} or $PM_{2.5}$ (particle diameter less than 10 and 2.5 µm respectively) in ambient air represents one of the largest 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 to air (primary particles) or can be produced in the atmosphere from precursor gases (secondary particles) such as SO_2, NO_X and ammonia.

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.

directives (SO_2, NO_X/NO_2, PM_{10}, Pb, CO, C_6H_6 and O_3) set concentration limit values to protect human health and the environment. If these limit values are exceeded, Member States are obliged to set up, implement and report abatement plans.

EU air policy is evaluated and new policies are being developed under CAFE, the European Commission's clean air for Europe programme, which is part of the sixth environment action programme (6EAP). This should lead to a thematic strategy for air pollution in 2005.

Almost all European countries that are parties to CLRTAP have signed protocols under this convention. However, in many countries the protocols await ratification. By January 2003, only four parties had ratified the 1999 Gothenburg protocol (31 signatures), and 14 parties the 1998 heavy metal protocol (36 signatures) and the 1998 protocol on persistent organic pollutants (36 signatures).

Long-term environmental targets within the EU and the CLRTAP policy frameworks are derived from an effect-oriented approach based on critical thresholds that define the extent to which deposition and ambient concentrations should be reduced to maintain the structure and function of ecosystems. The level of protection afforded to ecosystems may therefore be expressed in terms of the fraction of total ecosystem areas where critical thresholds are not exceeded and hence protected from further impact (this does not reflect recovery from past damage, which typically only occurs over an extended time period) (see CCE, 2001; 1999).

The emission targets set in the EU NECD and Gothenburg protocol correspond to interim environmental targets where ecosystem protection will be improved but critical thresholds will still be exceeded in some areas (Table 5.1).

5.2. Current status and trends of regional air pollution

5.2.1. Acidification — emission reductions and ecosystem protection

Agriculture, energy production and transport are the main sectors that contribute to acidification (Table 5.2).

Emissions of acidifying compounds in Europe have decreased significantly since 1990 (Figure 5.1). In particular, emissions in

Emission reduction targets for 1990–2010 (%) — Table 5.1.

	Western Europe	Central and eastern Europe	Eastern Europe, Caucasus and central Asia
Acidification	-56	-40	-40
Eutrophication	-36	-10	-25
Ozone precursors	-53	-21	-36

Notes: Percentage change between the emissions in the base year 1990 and the emission ceilings of the EU NECD or the CLRTAP protocols. The following weighting factors to convert to acid equivalents: sulphur dioxide * 1/32, nitrogen oxide * 1/46 and ammonia * 1/17. These factors represent a simplified approach to complex atmospheric processes. Western Europe: excluding Iceland. Central and eastern Europe: excluding Cyprus, Malta, and Turkey. Eastern Europe, Caucasus and central Asia: the targets refer to Belarus, Republic of Moldova, the Russian Federation and Ukraine.

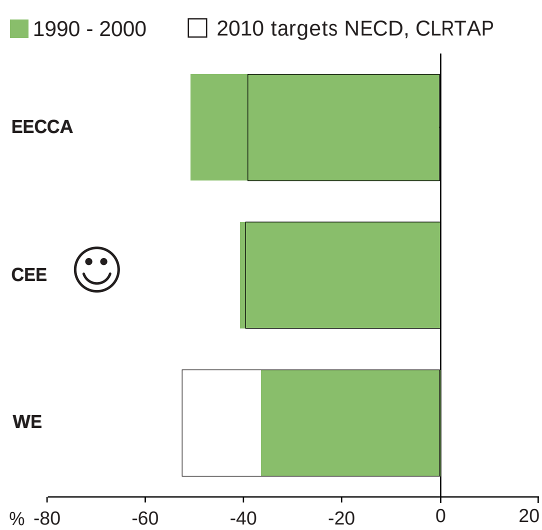
Sources: EMEP/MSC-W, 2002; EEA-ETC/ACC

Contribution to emissions of acidifying pollutants in 2000 (% of total emissions from all sectors) — Table 5.2.

	Western Europe	Central and eastern Europe	Eastern Europe, Caucasus and central Asia
Agriculture	31	13	17
Energy industries	25	48	41
Transport	24	12	21

Sources: EMEP/MSC-W, 2002; EEA-ETC/ACC

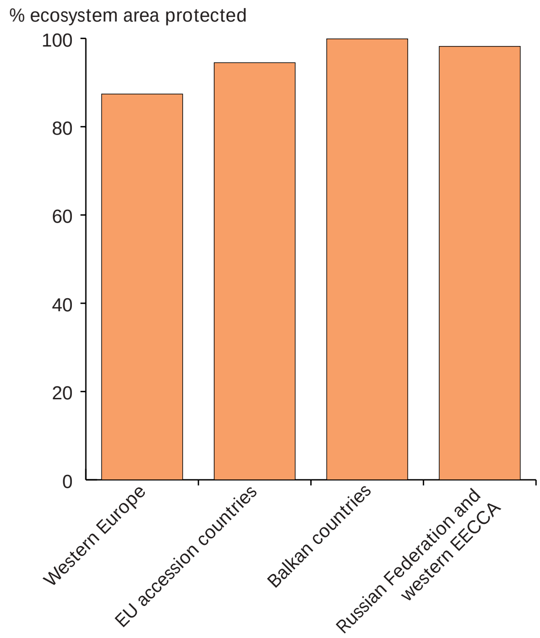
Change in emissions of acidifying substances for 1990–2000 compared to EU NECD and CLRTAP targets for 2010 — Figure 5.1.



Source: EMEP/CLRTAP and EEA-ETC/ACC

Figure 5.2. **Calculated estimates of ecosystem protection against further acidification in 2000**

Sources: CCE, 2001; EMEP/MSC-W, 2002



central and eastern Europe (CEE) and the countries of eastern Europe, the Caucasus and central Europe (EECCA) fell, by 39 % and 52 % respectively, mainly as a result of economic restructuring, switching from coal to gas and more desulphurisation of emissions from power plants. At present, EECCA and CEE emissions are below targets whereas western Europe (WE) will need to reduce emissions further to reach the 2010 targets.

In 2000, more than 90 % of the ecosystems in CEE and EECCA were estimated to be protected against further acidification (Figure 5.2). In WE, more than 10 % of the ecosystem area remains unprotected — i.e. acidifying deposition exceeds the thresholds for these ecosystems.

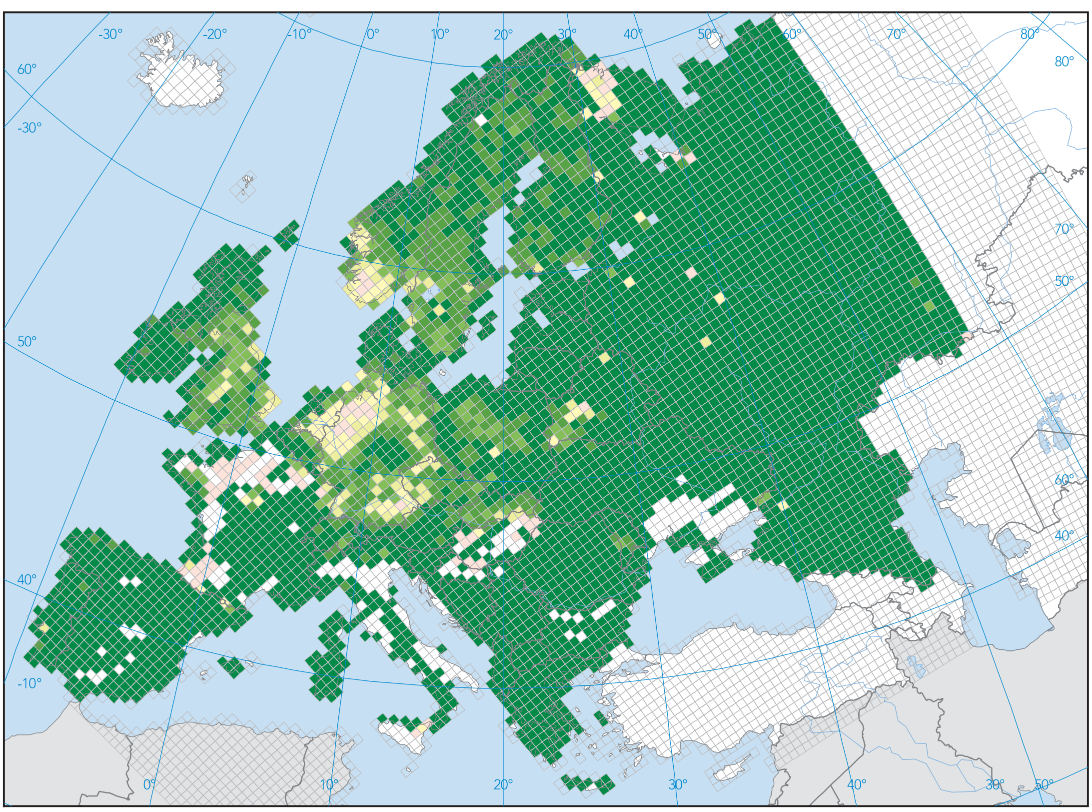
The geographical distribution of ecosystem protection suggests significant differences between areas (Map 5.1). Areas in southern Scandinavia, central Europe and the United Kingdom are believed to have relatively low ecosystem protection whereas ecosystem protection in southern WE and the EECCA countries is relatively high. Central Asian soils are less sensitive than those in Siberia, but acidification in these areas is still believed to be worsening as a result of rising emissions.

Map 5.1. **Calculated estimate of the distribution of ecosystem protection against further acidification in 2000**

% of ecosystem area protected

Acidity

- 0 - 5
- 5 - 30
- 30 - 50
- 50 - 70
- 70 - 95
- 95 - 100
- No data
- Outside data coverage



Sources: CCE, 2001; EMEP/MSC-W, 2002

More than 90 % of the ecosystem areas of Europe overall are calculated to have been protected against further acidification as a result of general emission control. However, many hot-spot areas remain at risk especially in central Europe.

5.2.2. Eutrophication — emission reductions and ecosystem protection

Emissions of eutrophying substances originate mainly from the energy, transport and agriculture sectors (Table 5.3).

Emissions of nitrogen compounds that cause eutrophication have fallen since 1990 (Figure 5.3). Reductions in nitrogen oxide emissions resulted from the introduction of three-way catalysts in passenger cars, fuel switching from coal to gas, and measures to improve energy efficiency in industry and power plants. In CEE and EECCA, the main underlying factor was economic restructuring. Reductions in emissions of ammonia from the agriculture sector in WE and CEE are the result of falling animal numbers rather than abatement measures. Although now stabilising, these emissions have generally proved difficult to control. The reduction of nitrogen oxide emissions from the transport sector has to some extent been offset by increased road traffic.

In WE, substantial further reductions of nitrogen emissions are believed necessary to reach the 2010 Gothenburg protocol and NECD targets. In 2000, ecosystem protection against eutrophication was below 50 % in WE and below 30 % in CEE. In EECCA, however, ecosystem protection was high above 80 % (Figure 5.4). Thus the area calculated to be unprotected against eutrophication is larger than that unprotected against acidification. Ecosystems are therefore exposed to a higher long-term risk of eutrophication than of acidification. Areas of low protection levels against eutrophication are more widespread and extend over most of WE and CEE (Map 5.2).

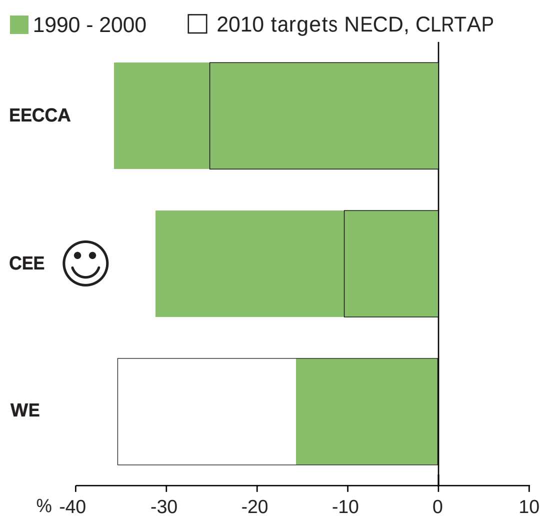
Eutrophication of ecosystems remains a significant problem with large areas throughout Europe unprotected especially in western Europe and central and eastern Europe.

Contribution to emission of eutrophying compounds in 2000 (%) — Table 5.3.

	Western Europe	Central and eastern Europe	Eastern Europe, Caucasus and central Asia
Agriculture	24	20	21
Energy industries	13	22	41
Transport	47	33	16

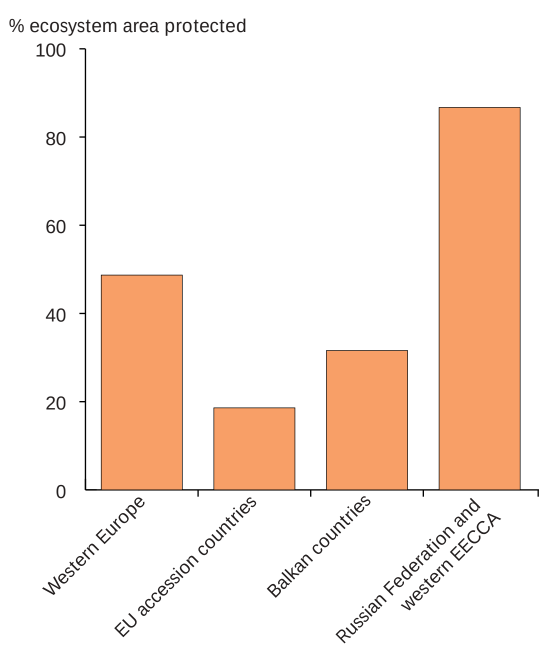
Sources: EMEP/MSC-W, 2002; EEA-ETC/ACC

Change in emission of eutrophying substances for 1990–2000 compared to EU NECD and CLRTAP targets for 2010 — Figure 5.3.



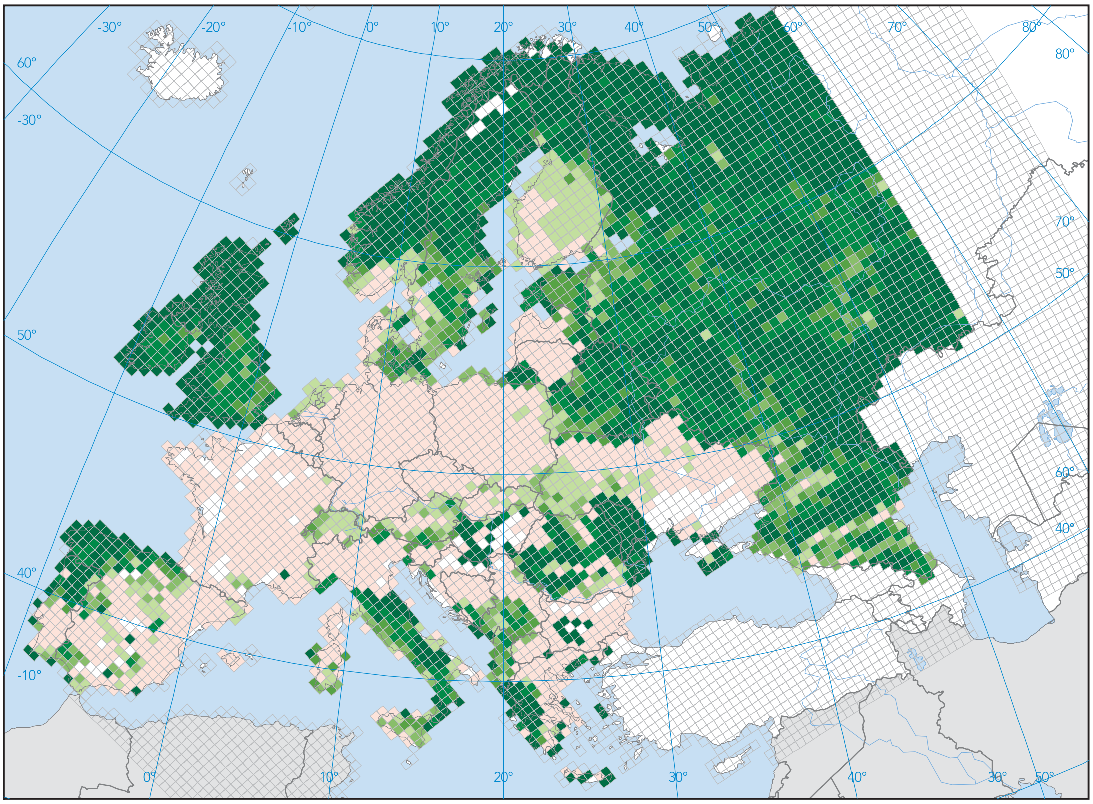
Source: EMEP/MSC-W, 2002; EEA-ETC/ACC

Calculated estimates of ecosystem protection against eutrophication in 2000 — Figure 5.4.



Sources: CCE, 2001; EMEP/MSC-W, 2002

Map 5.2. **Calculated estimate of the distribution of ecosystem protection against eutrophication in 2000**



Sources: CCE, 2001; EMEP/MSC-W, 2002

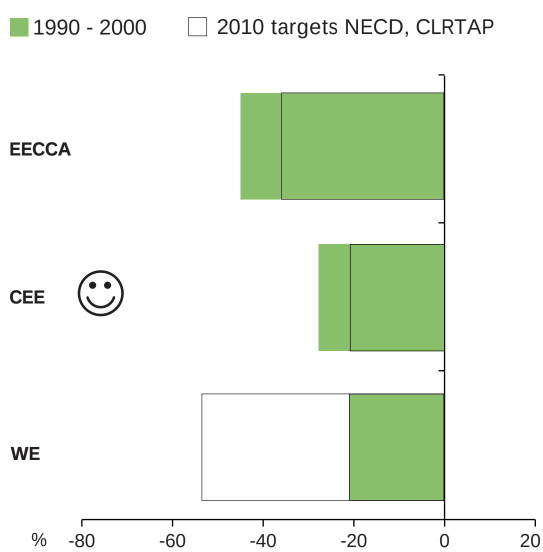
5.2.3. Ground-level ozone — emissions and exposure

Emissions of ozone precursors come mainly from the transport sector and constitute for EECCA 38 %, for CEE 37 % and for WE 52 % of the total emissions in these regions.

In CEE, and particularly EECCA, emissions of ozone precursors have fallen mainly as a result of economic restructuring (Figure 5.5). In WE, the reductions resulted mainly from the introduction of catalysts on new cars, and implementation of the solvents directive in industrial processes and other uses of solvents.

Figure 5.5. **Change in emission of ozone precursors for 1990–2000 compared to EU and CLRTAP targets for 2010**

Source: EMEP/MSC-W, 2002; EEA-ETC/ACC



In WE, substantial further reductions of emissions of ozone precursors, particularly NO_x and non-methane volatile organic compounds (NMVOC), are expected to be needed to reach the 2010 Gothenburg protocol and NECD targets.

In 1999, almost 90 % of agricultural crops covered by monitoring in WE and CEE were subject to ground-level ozone concentrations above the EU long-term critical level (Figure 5.6). In 1999, the monitored area covered

Almost 90 % of the monitored vegetation and agricultural crops in western Europe and central and eastern Europe are exposed to ozone concentrations above the long-term EU target.

more than 50 % of the total arable area, compared with about 30–35 % in previous years. In addition, a significant fraction of crops were exposed to concentrations in excess of the less strict EU interim target for 2010 — especially in WE. No data are available for EECCA.

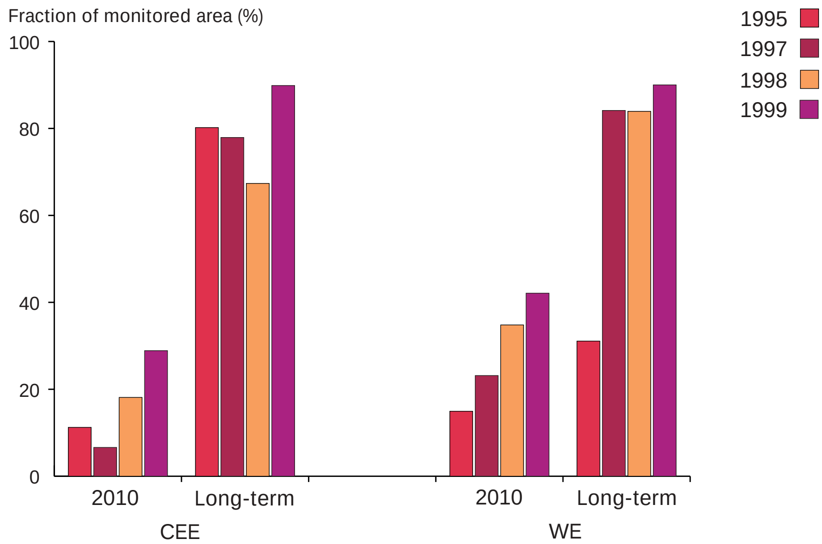
5.3. Urban air pollution

The information in this section is derived from the Auto-Oil II air quality study (European Commission, 2000; EEA, 2001). Urban air quality across Europe is managed at different levels — European, national and local. EU Member States and accession countries have to comply with air quality limit values for the protection of human health and the environment as set in daughter directives to the air quality framework directive. These are based on the World Health Organization air quality guidelines for Europe. Where limit values are exceeded, countries must prepare abatement programmes. These generally include local, essentially urban and sometimes industrial, measures, since national emission ceilings, policies and measures should be included in the national programmes required under the EU NECD and CLRTAP Gothenburg protocol. No national emission ceilings have been set for particulate matter.

Figure 5.7 shows the fraction of urban population in WE and CEE exposed to peak air pollution in excess of short-term EU limit values. The fraction is estimated from calculating the total population of those cities experiencing days of exceedance of the limits divided by the total population of all cities with monitoring stations. Problems from sulphur dioxide (SO_2) and nitrogen dioxide (NO_2) affect 10 % or less of the urban population. During occasional years exceedance of short-term limits is not observed (as for NO_2 in 1996). About half of the urban population is exposed to elevated particulate concentrations, and more than 95 % to excess ozone concentrations (all in terms of the threshold in the old ozone directive (Directive 92/72/EEC)).

Coverage of monitoring stations from which data are reported at European level increased considerably between 1990 and 1995 partly because of the establishment of the EuroAirNet network (EEA, 2002a). Monitoring coverage in EECCA is probably less.

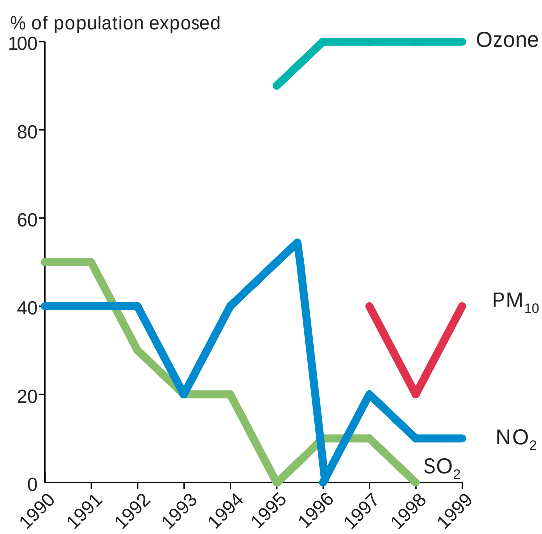
Calculated estimated fraction of monitored arable land above 2010 and long-term ground-level ozone concentrations targets for crops — Figure 5.6.



Notes: 2010 = AOT40 18mg/m³.h. Long term = AOT40 6mg/m³.h. AOT40 stands for accumulated exposure to ozone above 40 ppb.

Source: EEA

Urban population fraction in western Europe and central and eastern Europe exposed to short-period air quality above limit values — Figure 5.7.



Notes: Based on an estimate from data in 21 western European and central and eastern European countries. Limit values referred to are: ozone 110 µg/m³ 8-hour average not to be exceeded; PM_{10} 50 µg/m³ 24-hour average not to be exceeded on more than 35 days; NO_2 200 µg/m³ 1-hour average not to be exceeded more than 18 times a year; SO_2 125 µg/m³ 24-hour average not to be exceeded more than 3 times a year.

Source: EEA

5.3.1. Ground-level ozone

The new EU target of 120 µg/m³ (8-hour average to be exceeded on no more than 25 days per year) (Directive 2002/3/EC) has seldom been met in recent years. In 1999, a third of the urban population was exposed to over 30 exceedances a year, and about 30 % of cities exceeded the target (rural concentrations are generally higher than urban - see Section 5.2.3). Most exceedances are in central and southern European countries. There appear to be decreasing short-term peak concentrations across WE but increasing long-term averages. This would reduce the effects of acute ozone exposure, which the limit values address, but increase low-level chronic exposure.

In the Auto-Oil II air quality project, projections of ozone concentrations have been estimated for major conurbations across the EU, accession and EFTA countries under a scenario developed for 2010. These estimates indicate that reductions in the emissions of ozone precursors between 1990 and 2010 could be expected to result in significant improvement in health protection. Exceedances of the 8-hour 120 µg/m^3 threshold should decrease by 20–85 % between 1990 and 2010 in almost all cities as a result of reductions in emissions of ozone precursors. However, these reductions are unlikely to be enough to reach target concentrations over the whole of Europe. The limit value is expected to be exceeded on about 25 days per year in 2010 in northwest Europe (see Section 5.4).

5.3.2. Particulate matter

Exposure to particulate matter may be the largest potential health problem from air pollution in all areas (see Chapter 12). The EU has set the following limit values for PM_{10} (particle diameter less than 10 µm): an annual mean of 40 µg/m^3 by 2005, to fall to 20 µg/m^3 by 2010, and exceedances of a 24-hour peak value of 50 µg/m^3 on no more than 35 days per year, to fall to 7 days per year by 2010.

A significant fraction of the urban population in WE is currently exposed to PM_{10} concentrations in excess of the limit value of 50 µg/m^3 24-hour average not to be exceeded on more than 35 days (Figure 5.7).

Analysis of the PM_{10} data in AIRBASE, the European air quality information system (van Aalst, 2002), suggests that concentrations at almost all stations have been falling in recent years (Figure 5.9).

Nevertheless, projections carried out under the Auto-Oil II programme suggest that concentrations of PM_{10} in most urban areas in the EU will remain well above limit values up to 2010.

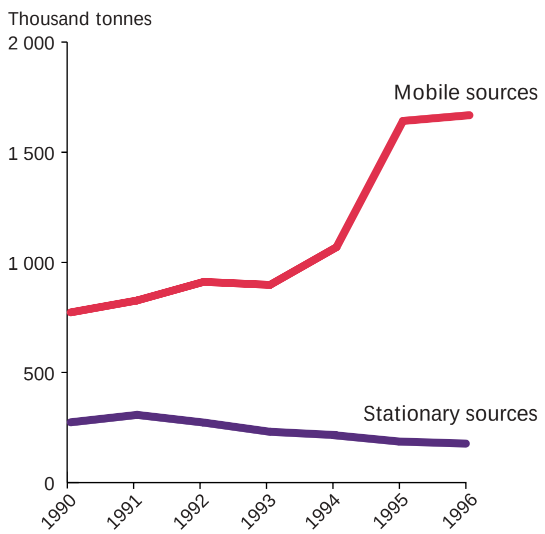
5.3.3. Nitrogen dioxide

The most stringent of the EU limit values for NO_2 proves to be the annual average concentration of 40 µg/m^3 as its attainment will generally also mean achievement of short-term limits. Concentrations at urban street hot spots have declined since the end of the 1980s as a result of the growing penetration of catalysts in the car fleet. Exposure to NO_2 has decreased and may now be stable. Nevertheless, at present the annual limit is exceeded in about 30 European cities which report data, and substantial numbers of people are exposed to NO_2 concentrations above health protection-based limit values. According to

Box 5.2. Air emissions in cities of eastern Europe, the Caucasus and central Asia

Rapidly increasing private transport is a major problem for the urban environment in EECCA. In capital cities such as Ashgabat, Dushanbe, Moscow, Tbilisi and Tashkent transport is the dominant source of air pollutants — more than 80 % of the total (Figure 5.8). Mobile sources are also a major source of emissions in other large cities in eastern Europe, the Caucasus and central Asia including Baku, Bishkek, Chisinau, Kiev, Minsk and Yerevan. The main causative factors include the age of the vehicle fleet, low quality and high sulphur content fuel, and declining public transport. Industrial sources have declined in importance, but remain relevant and difficult to address.

Figure 5.8. **Development of total emissions of air pollutants in Moscow, 1990-96**



Source: WHO, 2002

Abatement measures
The level of implementation of abatement measures in eastern Europe, the Caucasus and central Asia varies greatly. Mobile source abatement began in Moscow in 1996 with control of the technical condition of cars more than 15 years old. In Dushanbe, emission permits are given to vehicles that meet required standards. Turkmenistan has set a reduction by 2005 for emissions from mobile sources. In Kiev, however, it is expected that air pollution from road transport will continue to be a problem for at least 10–15 years due to the slow change in the car fleet. For stationary sources, the aim is reconstruction and modernisation, often with international assistance, but environmental control under conditions of intermittent operation is complicated. Lack of finance and a focus on energy issues has meant that no environmental programme exists in Tbilisi.

Economic growth, which is now expected, will not immediately bring in new technology for industrial sources. Growth in transport and a greater proportion of new vehicles can be expected, but improvements in air quality will take many years. In some countries, serious economic problems will preclude strong abatement measures. Emissions can therefore be expected to rise, with consequent effects on air quality.

the Auto-Oil II study, NO_2 concentrations are expected to fall considerably by 2010. The fraction of the urban population affected is estimated to be 45-60 % below its 1995 value by 2010 (EEA, 2001).

5.3.4. Sulphur dioxide
Increased use of low-sulphur fuel and successful implementation of abatement measures have reduced concentrations in WE considerably since the 1980s. Limit values in the EU have more than halved to 125 µg/m^3 (98^{th} percentile of daily values). Since 1995, less than 20 % of the population has been exposed to SO_2 concentrations above the limit value, and the number of exceedance days continues to fall. Similar reductions have occurred more recently in CEE and EECCA as a result of economic restructuring and abatement measures; though information is scarce, World Health Organization (WHO) guideline values appear to be widely exceeded.

Further reductions in urban SO_2 exposure in WE by 2010 will shift attention to CEE and EECCA. In some cities, air quality may deteriorate between 2010 and 2020 if emissions from traffic and heating increase as expected.

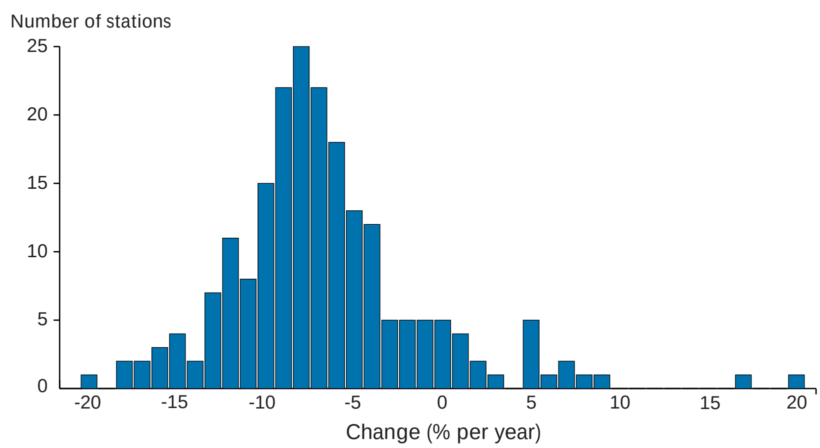
National reduction plans may not have a large impact on local air quality, since the major industrial emissions from high stacks have little influence on urban concentrations.


The EU target value for ground-level ozone is exceeded in many European cities. Average ozone concentrations have continued to increase since 1995, but short-term peak values have fallen.


A significant proportion of Europe's urban population is exposed to concentrations of fine particulates, PM_{10}, above limit values. However, concentrations have fallen since monitoring began.


Exposures of urban citizens in western Europe and central and eastern Europe to concentrations of nitrogen dioxide and sulphur dioxide above the EU limit values have fallen since 1990.

Distribution of change coefficients for 210 stations monitoring PM_{10} in 12 western European and central and eastern European countries Figure 5.9.



Note: Time series of daily data from 1999 or before to 2000.
Source: EEA

5.4. Air pollution in Europe in 2010

5.4.1. Regional air pollution in 2010 — a baseline scenario
This section presents a baseline scenario for 2010, which has been derived to assess the effects of the implementation of current legislation. It includes policies as decided by December 2001, national emission ceilings on future emissions of air pollutants and ecosystem protection. The section is based on a study performed by the European Environment Agency (EEA, 2003). The baseline scenario covers WE, CEE, the Russian Federation and the western countries of EECCA.

The scenario includes emission control policies and measures, including fuel standards, according to current legislation, and emission ceilings from the EU NECD and the Gothenburg protocol. For each country the more stringent value of current legislation or national ceiling was used. The baseline scenario does not assume implementation of any recent adopted or foreseen climate change policies after 1999 (this is addressed in Section 5.4.2).

Main assumptions
The baseline scenario is characterized by a continuation of the dominant 1990s trends: increasing globalisation, further liberalisation and average assumptions regarding population growth, economic growth and technology development (EEA, 2002b). The baseline was developed to ensure consistent CO_2 projections at the EU level with previous energy projections developed for the European Commission

Box 5.3. Urban air quality in eastern Europe, the Caucasus and central Asia

Air pollution is among the most serious of the environmental problems faced by cities in eastern Europe, the Caucasus and central Asia.

Lack of monitoring data precludes in-depth assessment of the state of air quality in this region though air quality has been monitored in all the countries for many years. After decentralization, the countries redesigned their monitoring systems, but lack of funds has inhibited any major progress. Obsolete measuring methods are therefore still widely in use. Monitoring is under the control of different authorities with often poorly defined responsibilities (WHO, 2002) and/or quite different functional competences.

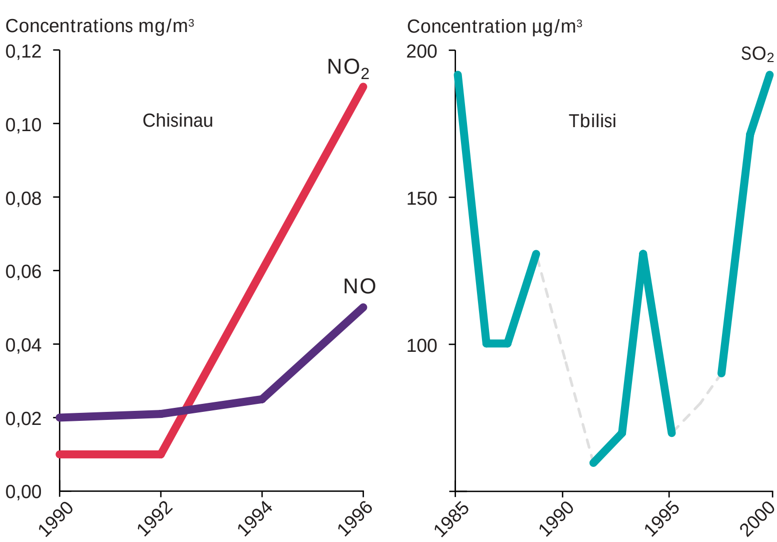
During the 1990s, pollutant concentrations fell in many states before rising again with economic growth and related increased road transport. By 1998 in the Russian Federation, 72 of the observed cities exceeded annual average concentration limits for at least one pollutant and more than 24 exceeded annual limits for three or more pollutants. Acute exposure was extensive. Up to 95 cities exceeded short-term limits for at least one substance. Elsewhere the picture is similar. Concentrations several times above limit values have been observed in a number of cities, examples being Tbilisi and Dushanbe (SO_2 and PM_{10}), Bishkek (NO_X and PM), Kiev and Chisinau (NO_X), Almaty (formaldehyde) and Ashgabat (formaldehyde and PM) (Figure 5.10). Large industrial centres regularly exceed limits, e.g. Ust-Kamenogorsk, Ridder and Temirtau in Kazakhstan, and Donetsk, Lutsk, Odessa in Ukraine. Ozone smog events are reported from Georgia, but a lack of monitoring data means that the scale of the problem is unknown.

Effects on health cannot currently be quantified partly because of the lack of monitoring data, e.g. for PM_{10} and $PM_{2.5}$. There are some indications that respiratory disease occurs in cities such as Kiev at twice the rate found in other monitored cities. The link with air pollution, however, can only be assumed, not demonstrated. Tbilisi reports increased illness as the major impact of air pollution.

Approximately 30 % of Russian cities exceeded limits for particulate matter in 1998. In Ukraine in 2000 over 40 % of monitored cities exceeded PM limits. Limits were exceeded in the central Asian Republics, where elevated natural concentrations from desertification, desert dust and the dried Aral Sea bed enhance the impact of particulates from cheap low-quality coal used for power generation and from road transport . Emissions of PM in central Asia are expected to increase with growing energy use as control measures for low-quality coal burning or road transport are not expected to reduce emissions sufficiently.

Sources: State of environment reports, various dates

Figure 5.10. **Ambient air quality in Chisinau, Moldova, and Tbilisi, Georgia**



Sources: 'State of the environment in Tbilisi', 2000 (Tbilisi); 'Summary environment state in the Republic of Moldova', 1998 (Chisinau)

and used in several other scenarios for European assessments (EEA, 2002c; Capros, 1999; Criqui and Kouvaritakis, 2000; IMAGE-team, 2001). The baseline projection shows somewhat higher CO_2 emissions than the most recent projections that include the latest measures adopted by Member States.

The most important changes in primary energy consumption and emission control legislation in individual regions included in this baseline are:

Western Europe: Between 2000 and 2010, energy use will continue to increase in absolute and per capita terms. Natural gas shows the fastest growth rates but oil remains the most important fuel. The share of coal declines further. Implementing current legislation (including the large combustion plant directive adopted in 2001) allows the national emission ceilings for SO_2 to be reached. In the case of other pollutants (NO_X, VOC and NH_3), additional measures are needed and assumed to be implemented.

Central and eastern Europe: Total energy use is expected to grow considerably after 2000 but not to reach the levels of the late 1980s. Coal is replaced by natural gas in the residential sector and power plants. Oil consumption increases due to rapid growth of road transport. The region will adopt EU emission and fuel standards for mobile and stationary sources in 2006-08.

The Russian Federation and western countries of EECCA: Natural gas has become by far the most important energy carrier since the early 1990s. From 2000 to 2010, coal use decreases further and natural gas and oil grow modestly. Total energy use in 2010 remains more than one third below the 1990 level. Regarding SO_2 emission, standards for new sources and low sulphur gas oil are assumed to be implemented (second sulphur protocol — CLTRAP). The Gothenburg protocol does not specify any national emission ceilings for the Russian Federation but only the control of emissions in the pollution emissions management areas (PEMA). Emissions ceilings will be reached mainly through economic restructuring and switching to cleaner fuels. Emission volumes from transport remain uncontrolled.

Emissions and ecosystem exposure in 2010

The baseline scenario indicates that emissions of air pollutants will fall significantly throughout Europe (Table 5.4), a continuation of the recent trend. In particular, SO_2 emissions will fall to 25 % of the 1990 level, mostly as a result of emission control policies. Emissions of NO_X and VOC will fall by more than 40 % and fine particulates by more than 35 %. Reduction of ammonia emissions is much more limited (around 15 %) and will result mainly from the decrease in livestock farming. In contrast to regional air pollution, CO_2 emissions will increase in all regions compared to 2000, but in CEE, the Russian Federation and western countries of EECCA their levels will not (yet) return to their 1990 levels. CO_2 emissions from WE will increase by 8 % compared to 1990.

For Europe as a whole, implementation of national emission ceilings (in addition to the current legislation controls) decreases the emissions of NO_X and SO_2 by 2 % and emissions of VOC by 7 %.

The emission controls implemented up to 2010 will significantly increase the area of ecosystem protected against acidification and eutrophication. Protection against acidification will be high throughout Europe in 2010 leaving 1.5 % of the ecosystem area unprotected. However, relatively large areas (more than 57 %) will remain unprotected against eutrophication in particular in CEE. Realisation of the baseline scenario will also reduce vegetation and population exposure to elevated regional ozone levels by 50 % and 74 % respectively.

Emission control costs

The emission control costs for each region (Table 5.5) include the costs of measures necessary to reach the emission reductions displayed in Table 5.4. The costs of controlling all air pollutants in the baseline scenario will increase to about EUR 89 billion/year in 2010. The high costs of NO_X and VOC controls are due to relatively expensive measures for mobile sources (57 % of the total costs). Fine particulates control costs for stationary sources contribute about 11 % and for SO_2 21 %. The policies and emission ceilings for ammonia are still relatively liberal and the costs of controlling ammonia are only 2 % of the total cost.

Western Europe bears 81 % of total European costs. This is because of more stringent emission ceilings than in other parts of Europe and high emissions in the base year. The marginal reduction costs in WE are higher than in CEE and the Russian Federation and western countries of EECCA.

Emissions changes in 2010 as compared with 1990 (%) Table 5.4.

	CO_2	NO_X	SO_2	NH_3	VOC	PM_{10}
Western Europe	+8	-52	-81	-15	-54	-56
Central and eastern Europe	-10	-42	-68	-15	-22	-67
The Russian Federation and EECCA	-32	-32	-71	-36	-26	-68
Total	-7	-45	-74	-18	-44	-64

Notes: Western Europe includes EU, Norway and Switzerland and excludes Iceland, Liechtenstein, Andorra, Monaco and San Marino. Central and eastern Europe does not include Cyprus, Malta and Turkey. The Russian Federation includes the European part within the EMEP region. The energy projections were generated with the PRIMES energy model. PRIMES results as well as TIMER/RAINS results (used in this study) compared fairly well with country estimates. For details see EEA, 2003.

Sources: IIASA, RIVM

Annual emission control costs for the baseline scenario (1995 prices) Table 5.5.

		Distribution of control cost (%)				
	Cost EUR billion (1995)/year	NO_X + VOC (stationary sources only)	SO_2	NH_3	PM_{10}	Mobile sources
Western Europe	72	11	22	1	8	59
Central and eastern Europe	14	2	14	7	15	61
The Russian Federation and EECCA	3	2	35	1	63	0
Total	89	9	21	2	11	57

Notes: Control costs (as calculated by the RAINS model) may be compared with the costs of complying with the Kyoto protocol in Chapter 3, but with care. The latter were calculated by the TIMER model and include the costs of energy system measures such as energy efficiency improvement and fuel switching. The RAINS model includes only the costs of add-on technologies. Since TIMER and RAINS use different technology databases, the assumptions and methodologies may not be fully comparable.

Source: IIASA (RAINS model)

Implementing EU legislation, mainly for NO_X and VOC emissions from mobile sources, will drive the control costs in CEE. The control costs more than double compared with the legislation from the mid-1990s (i.e. with emission and fuel standards adopted before the accession negotiations began). Costs for the Russian Federation and western countries of EECCA are driven by the need to comply with the emission and fuel standards specified in the second sulphur protocol.

5.4.2. Exploring ancillary benefits of implementing the Kyoto protocol

This section presents the way that different use of Kyoto mechanisms could affect emissions of air pollutants, their associated control costs and ecosystem protection in 2010. It focuses solely on CO_2 emissions, and does not consider the other greenhouse gasses. As a result, the actual ancillary benefits can change when the other greenhouse gasses (especially methane — CH_4 and nitrous oxide — N_2O) are considered.

It should be noted that the results are of a descriptive 'what-if' character and are not intended to be prescriptive for any future implementation of the Kyoto protocol and air pollution policies. The purpose is to explore the possible ancillary benefits in larger European regions. This section is based on a study performed by the European Environment Agency (EEA, 2003).

There are potential ancillary benefits of climate policies for regional air pollution in Europe in 2010. In particular, reducing CO_2 emissions through structural changes in the energy sector or energy efficiency measures are likely to have beneficial spill-over effects on emissions of air pollutants. Different ways of meeting the Kyoto targets (in terms of the use of flexible instruments) will affect the potential for these ancillary benefits. In principle, reaching some of the required greenhouse gas emission reductions in WE by using emissions trading and/or joint implementation with CEE or the Russian Federation and western countries of EECCA would shift the ancillary benefits (additional reduction of air pollutants or reduced control costs) to these regions.

There are important differences between abatement strategies for climate change and regional air pollution that affect the actual ancillary benefits. In principle, the effects of climate change policies on global temperature and other climate change indicators do not depend on where emissions are reduced. Climate change policies therefore aim for the most cost-effective reductions worldwide. Policies to combat regional/local air pollution have to address the location of the emission sources. In a European context, it is mainly WE which needs to implement policies to meet its Kyoto target, the other two regions already meet their target under the baseline scenario. There are several options available for meeting the WE target (see Chapter 3). These include reduction of CO_2 emissions from the energy sectors, reducing other greenhouse gases (methane, nitrous oxide and gases with a high global warming potential), sinks enhancement and the use of Kyoto mechanisms such as emissions trading, joint implementation and the clean development mechanism. The use of the Kyoto mechanisms can lead to emission reductions in the selling regions, but can also involve trade of so-called surplus emission allowances.

Below, three different climate change policy regimes are compared with the baseline scenario (see Section 5.4.1). The scenarios involve the same assumptions regarding air pollution control as the baseline scenario. Implementation of the Kyoto target is limited to addressing CO_2 emissions and does not consider the other greenhouse gases.

The following trading scenarios are explored and compared with the baseline:

1. Scenario: *Domestic action only (DAO).* All Annex 1 Parties (countries from western and central Europe as well as EECCA, Canada, Australia, New Zealand and Japan) implement their Kyoto targets domestically, i.e. without use of the Kyoto mechanisms. The exception is trade within the regions considered, for example among the current EU Member States.
2. Scenario: *Trade — no use of surplus emission allowances (TNS).* This scenario assumes full use of Kyoto mechanisms among Annex 1 Parties, but without any use of the 'surplus emission allowances'. This scenario explores the maximum ancillary benefits that can be obtained under a trade case.
3. Scenario: *Trade with surplus emission allowances (TWS).* This scenario assumes full use of Kyoto mechanisms among Annex 1 Parties and includes the use of 'surplus emission allowances'. However, the supply of these allowances is limited to the level that maximizes the profits of the Russian Federation and Ukraine from selling the emission permits. According to calculations performed by the FAIR model, the supply of tradable permits on the basis of the 'surplus emission allowances' of some of the CEE countries and EECCA is 25 % of the total available potential.

In summary, the DAO scenario requires physical policies and measures at the domestic level whereas the TNS also involves physical policies and measures abroad, mainly through joint implementation (in CEE, the Russian Federation and western countries of EECCA) and the clean development mechanism (in developing countries). The TWS scenario reduces the need to use joint implementation/clean development mechanisms compared to the TNS scenario, and increases the use of emission trading.

Table 5.6 shows that climate policies, irrespectively of the scenario, can have important ancillary benefits by reducing emissions of air pollutants in Europe. In the DAO scenario, climate policies are implemented only in WE, so all ancillary benefits in terms of emissions are restricted to this region.

For the trading scenarios (TNS and TWS), the ancillary benefits of climate policies are partly shifted to CEE and the Russian Federation and western countries of EECCA. The main reason for this is that WE as well as other industrialised countries will use cost-effective emission reduction options by means of joint implementation in CEE, the Russian Federation and western countries of EECCA. The resulting CO_2 reduction will have consequences for air pollutant emissions and particularly for SO_2. Parts of the ancillary benefits are a result of a fuel switch from coal to gas, which reduces both CO_2 and SO_2 emissions. Fuel savings will also result in a decrease of emissions of NO_X and fine particulates, although smaller than for SO_2. Ancillary benefits for VOC emissions are low.

The emission reductions of atmospheric pollutants are more strongly coupled to the reduction of CO_2 in CEE than in WE (because of less strict environmental policies and more coal use). The net result of the trading scenarios is that the ancillary benefits in terms of emission reductions for Europe

Change in 2010 emissions and energy mix compared to the baseline scenario (%) Table 5.6.

		Emissions					Energy use			
Scenario	Region	CO_2	SO_2	NO_X	VOC	PM_{10}	Coal	Oil	Gas	Total
Domestic action only	WE	-12	-15	-7	-1	-5	-38	-9	-2	-7
	CEE	0	0	0	0	0	0	0	0	0
	Russian Federation and EECCA	0	0	0	0	0	0	0	0	0
	Total	**-7**	**-5**	**-4**	**-1**	**-2**	**-20**	**-7**	**-1**	**-5**
Trade — no use of surplus emission allowances	WE	-4	-7	-3	0	-3	-21	-3	3	-2
	CEE	-8	-16	-7	-2	-9	-23	-2	7	-4
	Russian Federation and EECCA	-11	-19	-12	-6	-7	-32	-9	-7	-9
	Total	**-6**	**-14**	**-6**	**-2**	**-6**	**-23**	**-4**	**0**	**-4**
Trade with surplus emission allowances	WE	-3	-4	-1	0	-2	-14	-2	3	-1
	CEE	-5	-11	-4	-1	-7	-17	0	6	-2
	Russian Federation and EECCA	-5	-15	-8	-4	-6	-26	-6	-3	-5
	Total	**-4**	**-10**	**-4**	**-2**	**-4**	**-17**	**-2**	**1**	**-2**

Notes: The scenarios assume full use of land use, land-use change and forestry activities and clean development mechanisms for achieving carbon credits for sinks as agreed in Marrakech in 2001. This means that the Annex 1 countries could use a total amount of sink credits of 440 million tonnes CO_2, of which 270 million tonnes CO_2 could be used by the regions included in our study. The remaining total emission reduction obligation in Europe, after taking into account these sink credits, is about 500 million tonnes CO_2 (see also den Elzen and Both, 2002). We have assumed that the United States will implement the targets indicated in the Bush climate change initiative, which does not result in any improvement over our baseline scenario. At the time of the analysis, Australia had not indicated that it was not going to implement the Kyoto protocol. The rejection of the Kyoto protocol by Australia, however, has only a very small impact on the international permit market and thus on the analysis presented here (see Lucas *et al.*, 2002). It should be noted that the total available 'surplus emission allowances' is larger than the required emissions reductions by Annex 1 Parties (from the baseline), a scenario that would assume trade with full use of 'surplus emission allowances' would simply equal the baseline.

Source: RIVM, IIASA

as a whole are higher than in the DAO scenario.

The difference in ancillary benefits between the trading scenarios TNS and TWS is a reduction of the emissions of SO_2 by 10 % instead of 14 % (see Table 5.6). Thus the introduction of a limited amount of surplus emission allowance on the market, based on maximizing profits, reduces the ancillary benefits by around one third. The trading scenarios increase ecosystem protection against acidification and eutrophication throughout Europe. The transboundary character of air pollution is reflected in the DAO scenario, where ecosystem protection increases in CEE and the Russian Federation and western countries of EECCA, and in the trading scenarios where most of the emission reductions take place outside WE but which still yield substantial increased ecosystem protection in WE.

In the scenarios with constraints on CO_2 emissions, the costs of controlling emissions that contribute to regional air pollution are clearly lower than in the baseline scenario (Table 5.7). The reductions in air pollution control costs again illustrate the synergistic effects of global and regional air pollution control policies. In the DAO scenario, which requires the strongest domestic climate policies, the costs of controlling CO_2 emissions are estimated at approximately EUR 12 billion/year. Expenditure on regional air pollution mitigation in WE decreases at the same time by approximately 9 % (EUR 7 billion/year in 2010). As expected, the trading scenarios involve less cost for controlling CO_2 emissions. Costs are EUR 7 billion/year (of which EUR 2 billion/year is for domestic action) in the TNS scenario and EUR 4 billion/year (of which EUR 1 billion/year is for domestic action) in the TWS trading scenario. This is EUR 5–8 billion/year less than calculated for the DAO scenario. At the same time, the reduction in costs of controlling air pollution emissions reduces: EUR 2.5 billion/year less is saved by going from DAO to TNS scenario, and a further 1.6 billion less by going to TWS scenario.

The main conclusions of the analysis show that:

- Implementation of climate change policies to comply with the Kyoto protocol is likely to yield substantial ancillary benefits for air pollution in Europe. The ancillary benefits are expected to result in a decrease in air pollution emissions and control costs but also an increase in environmental protection. The realization of ancillary benefits depends on how the flexible mechanisms and surplus emission allowances are used to reach the Kyoto targets.
- The use of the flexible mechanism and surplus emission allowance is intended to, and will, reduce the costs of implementing the Kyoto protocol. However, using flexible mechanisms will also reduce the ancillary benefits in terms of control costs for air pollution in Europe.
- Using flexible mechanisms will shift ancillary benefits in terms of emissions reductions of air pollutants from WE to CEE and the Russian Federation and

Table 5.7. Change in air pollutant emission control costs in 2010 compared to the baseline scenario

	(EUR billion/year)			(%)		
	Domestic action only	Trade — no use of surplus emission allowances	Trade with surplus emission allowances	Domestic action only	Trade — no use of surplus emission allowances	Trade with surplus emission allowances
WE	-6.6	-2.9	-1.7	-9	-4	-2
CEE	0.0	-0.9	-0.6	0	-7	-5
Russian Federation and EECCA	0.0	-0.2	-0.2	0	-9	-7
Total	**-6.6**	**-4.0**	**-2.5**	**-7**	**-5**	**-3**

Source: IIASA

western countries of EECCA. For Europe, emission trading could lead to further emission reductions of regional air pollutants, which will also increase ecosystem protection in WE. Using surplus emission allowances will reduce these ancillary benefits, in particular for CEE and the Russian Federation and western countries of EECCA.

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