3. Climate change

Global mean temperature has increased by 0.6 °C (in Europe by about 1.2 °C) over the past 100 years, and the 1990s was the warmest decade for 150 years. Global and European mean temperatures are projected to increase by 1.4–5.8 °C between 1990 and 2100 with larger increases in eastern and southern Europe in most projections. The proposed European Union target to limit temperature increase to a maximum of 2 °C above pre-industrial levels will therefore be exceeded during this century.

Sea level rose by 0.1–0.2 meters, globally and in Europe, during the last century. It is projected to rise by an additional 0.1–0.9 meters by 2100. Global precipitation increased by about 2 % during the last century, with northern Europe and the western part of the Russian Federation getting 10–40 % wetter with a further projected increase of 1–2 % per decade. In southern Europe and most of the countries of eastern Europe, the Caucasus and central Asia, precipitation in summer is projected to decrease by up to 5 % per decade, while the winters may become wetter. In summer 2002, heavy rainfall caused floods in central Europe, which cannot be attributed to climatic change alone, but can be considered an example of what may happen if climate change continues. The risk of floods is projected to increase, but river management and urban planning are also contributory factors. Droughts are likely to become more frequent in other areas of Europe such as southern Europe.

Greenhouse gas emissions in the EU fell by 3.5 % between 1990 and 2000, about halfway to the Kyoto target for 2008–12, assuming the use of domestic measures alone. Decreases from energy industries, the industry sector, agriculture and waste were partly offset by increases from transport. Substantial further reductions are needed to reach the national (burden-sharing) targets. Emissions in central and eastern European countries fell by 35 % between the base year 1990 (or earlier years for five countries) and 2000; most of these countries are on track to reach their Kyoto targets. Emissions in some countries, however, have started to increase again as their economies recover. Emissions in eastern Europe, the Caucasus and central Asia fell by about 38 %, mainly due to economic and structural change.

Many European countries have adopted national programmes that address climate change. Key policies and measures include carbon dioxide taxes, renewable energy for electricity production (wind, solar, biomass) combined heat and power, domestic emissions trading schemes, abatement measures in industry and measures for reducing emissions from landfills. A key policy is the directive on an EU-wide emissions trading scheme, which is expected to lower the compliance costs of the Kyoto protocol.

The costs of climate mitigation in western Europe can be reduced significantly through the use of the Kyoto mechanisms (joint implementation, clean development mechanism and emissions trading). In many economies in transition in eastern Europe, the Caucasus and central Asia investments in the energy sector are needed, and greenhouse gas mitigation costs in eastern Europe are expected to be lower than in western Europe. The Russian Federation, which is likely to have a significant surplus of emission allowances by 2010, could have a central role in the future market for greenhouse gas allowances. The costs of domestic measures in western Europe have been estimated in a recent study to be about EUR 12 billion per year. Assuming optimal banking of allowances by the Russian Federation would decrease the costs to a total of about EUR 4 billion per year, but lead to higher global greenhouse gas emissions by 2008–12 due to the use of surplus allowances. Climate change policies can have significant positive effects ('co-benefits') by also reducing emissions of air pollutants and thus the costs of abating air pollution.

Sequestration through land-use change and forestry ('carbon sinks') can be used to meet Kyoto targets, under some circumstances, with additional allowances amounting to about 1–4 % of 1990 emissions for some EU countries.

3.1. Introduction

Global and European average temperatures are increasing, sea levels are rising, glaciers are melting, and the frequencies of extreme weather events and precipitation are changing. Most of the warming can be attributed to emissions of greenhouse gases from human activities. Climate change is expected to have widespread consequences including an increased risk of floods, and impacts on natural ecosystems, biodiversity, human health and water resources as well as on economic sectors such as forestry, agriculture (food productivity), tourism and the insurance industry.

Climate change is addressed by the United Nations Framework Convention on Climate Change (UNFCCC), and the Kyoto protocol set binding targets for industrialised countries to reduce their greenhouse gas emissions. The protocol is a first step towards the more substantial global reductions (about 50 % by the middle of the 21st century) that will be needed to reach the long-term objective of achieving 'sustainable' atmospheric greenhouse gas concentrations.

Many countries have adopted national programmes that focus on reducing greenhouse gas emissions. However, even immediate large reductions in emissions will not prevent some climate change, and environmental and economic impacts, because there is a considerable time delay between the reduction of emissions and the stabilisation of greenhouse gas concentrations. Measures in various socio-economic sectors will therefore be necessary to adapt to the consequences of climate change in addition to emission reduction measures.

Although there have been some successes in reducing emissions, with some countries on track to achieving their Kyoto protocol targets, many of the improvements have resulted from one-off changes. Further action at all levels, affecting all economic sectors, will be needed if national Kyoto targets are to be met. Beyond Kyoto, the challenges of achieving 'sustainable' greenhouse gas concentrations are large, particularly if the economies and lifestyles of the countries of central and eastern Europe, the Caucasus and central Asia (EECCA) move towards the levels currently enjoyed by most western European (WE) countries.

3.2. Climate change and sustainability

Signs of a changing climate have been observed at global and European levels. The clearest indicator is the considerable increase in temperature over the past 150 years (ECA, 2002). A rise in sea level and changes in precipitation and extreme weather and climate events have also been observed in Europe during the past 50 years. Other signs include a retreat of mountain glaciers and a decrease of snow cover (IPCC, 2001a) (see also Box 3.1).

3.2.1. Sustainable targets for climate change

The ultimate objective of the UNFCCC is to reach atmospheric concentrations of greenhouse gases that prevent dangerous anthropogenic interference with the climate system, but allow sustainable economic development. Achieving such 'sustainable' levels would require substantial (about 50 % by the mid-21st century) reductions of global greenhouse gas emissions (IPCC, 2001a). The European Union (EU), in its sixth environment action programme (6EAP), has proposed that global temperatures should not exceed 2 °C above pre-industrial levels, which means 1.4 °C above current global mean temperature (European Parliament and Council, 2002). A study (Leemans and Hootsmans, 1998) proposed additional 'sustainable' targets: to limit anthropogenic warming to 0.1 °C per decade and sea level rise globally to 20 mm per decade.

Comparing these proposed indicative targets with projections of temperature increase and sea level rise shows that it is likely that these targets will be exceeded during the next 50-100 years if no further steps to mitigate climate change are taken. Achieving 'sustainable' levels of greenhouse gas concentrations and related climate change is likely to be one of the most difficult environmental challenges of the century.

3.2.2. Temperature increase

Globally, surface air temperatures have been recorded systematically since the middle of the 19th century. There is new and stronger evidence that most of the warming observed over the past 50 years is attributable to human activities. Confidence in climate models has increased: when fed with data on past anthropogenic emissions they calculate changes similar to those that have actually been observed (IPCC, 2001a).

Over the past 100 years, global mean temperature has increased by 0.6 °C with land areas warming more than oceans (Figure 3.1). Of the past 150 years, 1998 was the warmest, and 2002 the second warmest (WMO, 2002). The 1990s was the warmest decade since the middle of the 19th century, and probably also the warmest decade of the millennium. It is likely that the increase in northern hemisphere surface temperatures in the 20th century was greater than during any other century in the last 1 000 years (IPCC, 2001a).

The data for Europe (including Siberia) show that the temperature increase up to

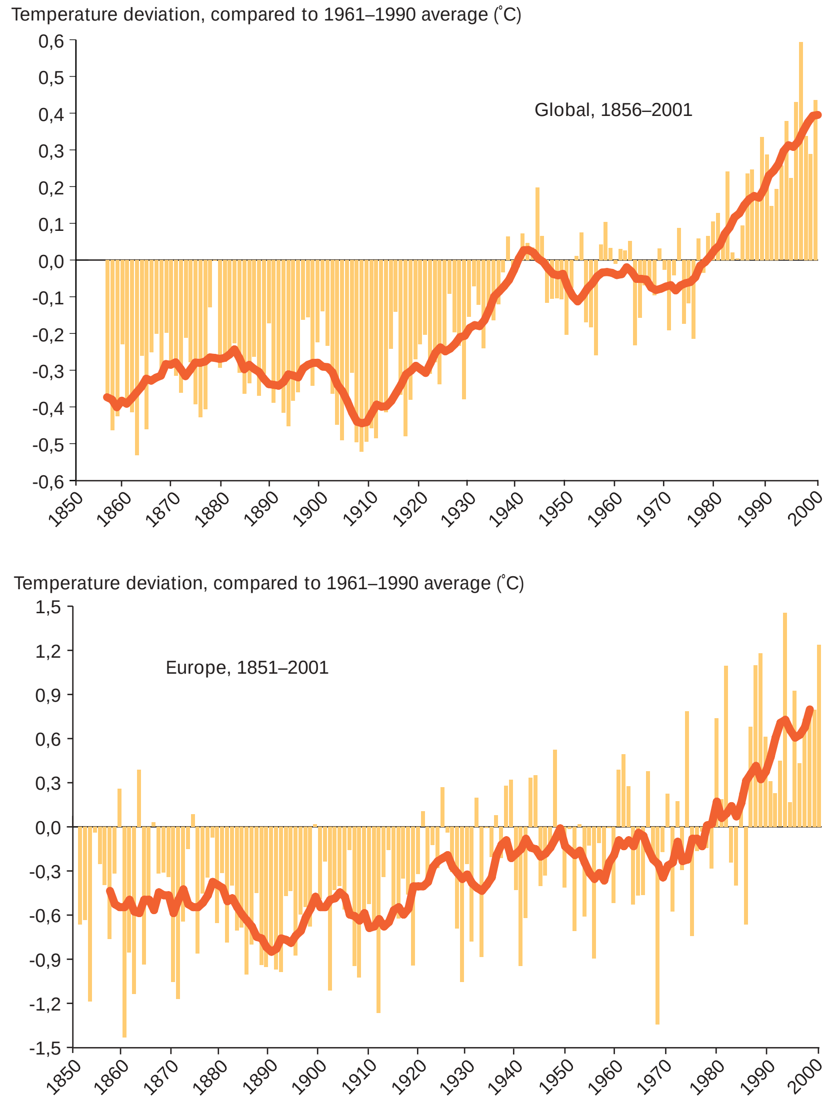
2002 is consistent with the global trend and amounts to about 1.3 °C over the past 100 years. The increase in the countries of EECCA was up to 1.3 °C with the increase in Siberia amongst the highest in Europe (IPCC, 2001c; UNFCCC, 2002a). Observations show that 2002 was also the second warmest year in Europe (including Siberia). The temperature was 1.25 °C higher than the average (from 1961 to 1990) and only 1995 was warmer (1.46 °C above the average). Especially the beginning of 2002 was warm (3.9 °C above the average), while 2002 had the coldest December month in the last 100 years (3.1 °C below the average).

The warming in Europe has been largest over the Russian Federation and the Iberian Peninsula and least along the Atlantic coastline. The temperature changes are larger in the winter season in line with the global trend. In the summer season, southern Europe warms at twice the rate of northern Europe. Cold winters are expected to nearly disappear during the next century, and hot summers are expected to become much more frequent (Parry, 2000).

According to the Intergovernmental Panel on Climate Change (IPCC), global mean temperature is projected to increase by 1.4–5.8 °C from 1990 until 2100 (IPCC, 2001a). The range reflects not only the uncertainty of climate change models, but also the differences in scenarios for greenhouse gas and sulphur dioxide emissions over the next 100 years based on different assumptions on population growth and socio-economic development. These scenarios imply an increase in average temperature in Europe of 0.1–0.4 °C per decade over the next 100 years. The largest increase is projected for southern Europe (Spain, Italy, Greece), northeast Europe (Finland and the western Russian Federation) and some of EECCA, and the smallest increase along the Atlantic coastline. The projected increase in the annual average temperature in EECCA varies, with an average of about 4.5 °C by 2080 (IPCC, 2001c). In the winter season, the continental interior of eastern Europe, the western Russian Federation and some other areas in EECCA warms more rapidly than elsewhere (Parry, 2000; IPCC, 2001a; UNFCCC, 2002a).

Comparing these projections with the proposed 'sustainable' targets suggests that the EU target for absolute global temperature increase might be exceeded by about 2050, and the proposed target of not more than 0.1 °C increase per decade might be exceeded even earlier.

Observed annual average temperature deviations (global and European) — Figure 3.1.



Notes: The bars show the annual average and the line the 10-year smoothed trend. Europe includes Siberia.

Source: Climatic Research Centre (CRU)

> Over the past 100 years, global mean temperature has increased by 0.6 °C (in Europe about 1.2 °C). Global and European mean temperatures are projected to increase by 1.4–5.8 °C between 1990 and 2100.

3.2.3. Sea level rise

The sea level, globally and for Europe, rose between 0.1 m and 0.2 m during the 20th century (IPCC, 2001a; Parry, 2000). Global sea level is projected to rise by 0.09–0.88 m between 1990 and 2100, taking into account the full range of emission scenarios (IPCC, 2001a). Future sea level rise in Europe is expected to be similar (Parry, 2000). Due to long-term movements in the Earth's crust, there are regional differences, because most of southern and central Europe is slowly sinking (typically by 5 cm by the 2080s) and much of northern Europe is rising out of the ocean (Parry, 2000).

Comparing this projection with the proposed 'sustainable' target suggests that the target will be exceeded during the next 100 years.

3.2.4. Precipitation change

Global precipitation increased by about 2 % during the last century (IPCC, 2001a) with large variations between continents and also within Europe. Northern Europe and the western Russian Federation are getting wetter with an increase of 10–40 % over the last century; southern Europe and many EECCA countries are changing little or getting dryer by up to 20 % in some parts (IPCC, 2001a; IPCC, 2001c; ECA, 2002).

The intensity of precipitation has also changed. Several indicators show that more intense precipitation events are occurring over many areas in Europe whereas other areas are experiencing more droughts (ECA, 2002). In Kazakhstan, for example, rainfall intensities increased although annual precipitation decreased (IPCC, 2001c). In addition, increasing intensities may result in extreme events like floods (see Chapter 10). In the United Kingdom, for example, the contribution of short-duration precipitation events has increased significantly during the past 40 years (Hulme *et al.*, 2002).

A third factor related to precipitation is its seasonal variation. Precipitation in winter has changed most (IPCC, 2001a). As a result, water losses in summer, due to increasing temperatures, are compensated for by precipitation increases in winter, but may lead to more severe summer droughts.

Climate models project a further increase in precipitation of 1–2 % per decade in northern Europe during this century. In southern Europe, especially in parts of Spain, Greece and Turkey, precipitation in the summer is projected to decrease by up to 5 % per decade (depending on the region and the climate model used), while the winters may become wetter (Parry, 2000, IPCC, 2001c). In most EECCA countries, precipitation is also projected to decrease in summer, for example with a 5–10 % decrease in Kazakhstan by 2080 whereas the winters are projected to become wetter. The annual decrease is projected to be 1–4 % by 2050 (IPCC, 2001c).

> Global and European sea level rose by 0.1–0.2 m during the last century and is projected to rise by an additional 0.1–0.9 m by 2100.

3.2.5. Extreme weather and climate events

Changes in the frequency and characteristics of extreme weather and climate events were observed in the second half of the 20th century. These extreme events cannot be attributed to long-term climate change, but may provide a picture of the future since climate models predict that the frequency and intensity of extreme events are very likely to increase as a result of climate change. Climate change models project that further changes are likely in this century (IPCC, 2001a). In Europe, extremely cold winters have become less frequent in recent decades and may become rare by the 2020s, whereas hot summers are likely to become more frequent (Parry, 2000). An increase in maximum temperatures and the number of hot days was observed during the second half of the 20th century in various locations in Europe (e.g. the United Kingdom, Scandinavia and the Russian Federation). In the northern hemisphere, the proportion of total annual precipitation derived from heavy and extreme precipitation events has increased (IPCC, 2001a). In 1995, for example, large parts of northwest Europe became flooded. Likewise, in summer 2002 heavy rainfall in the Erz Mountains in central Europe caused a 'flood of the century' in Germany, the Czech Republic and Austria.

3.2.6. Uncertainties

There has been significant progress in the scientific understanding of climate change, its impacts and the human response to it (IPCC, 2001d). Many of the available robust findings relate to the existence of climate change, while uncertainties are concerned with quantifying the magnitude and the timing of these changes. Important areas for further scientific work, aimed at reducing uncertainties and increasing knowledge, are (IPCC, 2001d):

- detection and attribution of climate change;
- understanding and prediction of regional changes in climate and climate extremes;
- quantification of climate change impacts at the global, regional and local levels;

- analysis of adaptation and mitigation activities;
- integration of all aspects of the climate change issue into strategies for sustainable development;
- investigations to support the judgement of what constitutes 'dangerous anthropogenic interference with the climate system'.

3.3. Impacts and adaptation

Climate change is expected to have significant impacts in Europe. Generally, the south and the European Arctic are the most vulnerable areas (IPCC, 2001c; Parry, 2000; IPCC, 1997). Impacts can be expected in particular with respect to:

- hydrology and water resources (see also Chapter 8);
- mountain regions and coastal zones;
- land and soil resources (see also Chapter 9);
- forestry and agriculture (see also Chapter 2.4 and Chapter 2.3);
- natural ecosystems and biodiversity (see also Chapter 11);
- economic sectors (see also Chapter 10);
- human health (see also Chapter 12).

3.3.1. Hydrology and water resources

Total annual flow and its variations through the year are likely to be affected by climate change. Changes in precipitation are projected to increase annual flow in northern Europe and decrease it in the countries around the Mediterranean Sea. Decreasing flows are also projected for the EECCA countries (see Box 3.1). In mountainous and continental regions more precipitation will fall as rain instead of snow. These effects will also increase the risk of floods and summer droughts in the downstream areas of rivers. More intense precipitation events may affect large areas as in the 'flood of the century' mentioned above. Many large towns and industrial areas are in the catchments of large rivers. For example in Germany about 17 000 people were evacuated and many cities along the rivers were severely damaged, with estimated costs of about EUR 15 billion (Die Zeit, 2002). The demand for water for irrigation will increase, but availability will be reduced during the summer.

Adaptation will involve measures on both the demand and the supply side, and will require the development of management systems that allow short-term actions as well as measures affecting urban planning and building standards.

3.3.2. Mountain regions and coastal zones

Mountain regions and coastal zones are particularly vulnerable to climate change. Changes in rain and snow precipitation in mountain areas will also have significant impacts on more lowland populations (see Section 3.3.1). Landslides, rockslides and avalanches are likely to increase due to sudden and strong precipitation and endanger human settlements (as occurred in Italy in 2000). Furthermore, the area covered by European glaciers has decreased in recent decades (e.g. already by 50 % in the Alps). Projections show that as much as 50–90 % of alpine glaciers could disappear by the end of the 21st century, and the snowline is expected to rise by 100–150 m for every degree of warming (Parry, 2000). Coastal zones already face several pressures such as flood risk and coastal erosion. Climate change will increase the risk of floods and the erosion of coasts due to the rising sea level, a higher frequency of storms (especially in northwest Europe) and increased precipitation intensity. In both mountain regions and coastal zones, human settlements, important sectors of the economy (e.g. tourism) and natural areas (e.g. wetlands, especially in the Baltic and Mediterranean regions) will be affected.

There are various policy options for limiting the potential impacts and adapting to the adverse effects of climate change in coastal areas. The policies implemented depend on local and national circumstances, recognising the economic and ecological importance of coastal zones and taking account of technical capabilities (Parry, 2000). Fewer policies have as yet been implemented in mountain regions. One option often mentioned is to change the approach to forest management to 'support' mountain forests and enable them to adapt to climate change resulting in conservation of the soil and improved water storage and land protection (Parry, 2000).

3.3.3. Land and soil

Climate change will affect land and soil directly as well as indirectly through impacts on land use. Changes in the use and management of land are likely to have bigger effects on soils than climate change itself. Nevertheless, climate change is likely to result in the deterioration of soil quality. Likely effects include salinisation, peat loss and erosion by wind or water (see Chapter

Box 3.1. Climate change impacts in some eastern European, Caucasus and central Asian countries

Many of the countries in eastern Europe, the Caucasus and central Asia (EECCA) are vulnerable to climate change especially in relation to water resources and agriculture. The agriculture sector is important in most of EECCA because of the significant contribution to gross domestic product (GDP) (e.g. about one third in Tajikistan). Agriculture and livestock production depend significantly on the availability of water for irrigation. Water is already a scarce resource in many EECCA countries, and small decreases in water availability can have severe effects.

Periods with significant changes in annual river flow and flood events are occurring, for example in Tajikistan. These are caused by a combination of effects including decreased precipitation in summer and increased precipitation in winter. Further, reduced snowfall in winter, due to increased temperature, results in increased runoff in winter and reduced runoff in summer. Rapid snowmelt was one of the main causes of the disastrous floods in Tajikistan in the 1990s. Finally, significant retreat of glaciers affects annual river flows and flood events.

In some EECCA countries, glaciers play a crucial role in the hydrological cycle. In Tajikistan, for example, glaciers occupy about 6 % of the total land, providing about a quarter of Tajikistan's annual water flow. Increasing temperatures have already caused significant retreat of glaciers in several EECCA countries with various impacts on water availability, flood risk, agriculture and livestock production. Some glaciers are projected to retreat further, which is thought initially to increase water availability and to contribute to increasing flood risks. The increase in runoff will, however, be followed by a strong decrease after the disappearance of the glacier, which can take decades or centuries for large glaciers. This is projected to reduce the water availability in downstream areas with considerable consequences. Grassland production in many EECCA countries, for example, might decrease 40-90 % by 2080, mainly due to high water stress in summer. Considerable impacts are also projected for the power supply in Tajikistan, which relies largely on hydropower.

Observed and projected changes in temperature also have direct negative effects on particular sectors in some of the EECCA countries. Kazakhstan, for example, reported decreasing trends in grassland production, mainly due to unfavourable temperature conditions in summer. The projected temperature increases might lead to an additional 30–90 % loss by 2050.

An example of a combined effect of temperature and precipitation change is the recent rise in the Caspian Sea level by 2.5 m, which resulted in severe floods. By 2020–40 an additional 1.2–1.5 m increase is projected, which could result in about US$ 4 billion damage.

Source: UNFCCC, 2002a; IPCC, 1997 and 2001c; national communications

9). Mediterranean forest soils are already facing a loss of carbon through wildfires, which are likely to increase.

Adaptation will require the development of policies to preserve the quality of land and soil and promote a sustainable use of land, for example through afforestation.

3.3.4. Forestry and agriculture

A higher carbon dioxide (CO_2) concentration in the atmosphere may lead to an increase in net productivity in most European forests and agricultural systems, though there will be regional differences depending mainly on water availability. For example, productivity in the forestry sector in Germany may fall (by up to 9 %) at forest sites where drought stress increases. However, where precipitation is not the limiting growth factor, forest productivity may increase by 5 % (Lindner *et al.*, 2002). The risks of climate change will be considerably higher and less manageable in countries that already suffer significantly from drought stress such as the Mediterranean countries. In agriculture, increasing temperatures are likely to result in a reduction in the growing period of crops like cereals. In contrast, warming could lead to a lengthening of the growing season for root crops like sugar beet. An unclear, but important issue is how pests and diseases will be affected by climate change. Both are expected to increase, but it is not yet known to what extent. Agricultural systems and forests are vulnerable to extreme weather events such as droughts, storms or fires which are likely to increase with climate change.

Adaptation measures will require more flexibility of land use, crop production and farming systems.

3.3.5. Natural ecosystems and biodiversity

Climate change is expected to affect ecosystems and biodiversity, though it is difficult to attribute changes that have already occurred to climate change alone. The impacts may threaten the habitats of some plant and animal species, which may lead to their extinction if they are not able to adapt or migrate. For example, wintering shorebird and marine fish diversity are seriously endangered by a loss of coastal wetlands. Ecosystems that thrive in the warm humid conditions of northern Iberia may appear in northern France and the southern British Isles. The tree line has already moved upwards and this is projected to continue in many mountainous regions.

Adaptation measures will have to protect endangered species, and include monitoring the productivity of other species, as changes in these may disrupt ecological balances.

3.3.6. Economic and health-related impacts

Economic activities in coastal areas

The increased risk of flooding, erosion and wetland loss in coastal areas will have impacts on human settlements, industry, tourism and agriculture. Southern Europe appears most vulnerable (Parry, 2000). Management systems which safeguard human activities and preserve coastal ecosystems will need to be developed; these should include measures to lessen flood peaks and keep floods away from properties.

Insurance

The insurance industry is already facing claims for growing property damage due to more extreme weather events such as windstorms and flooding. Worldwide, economic losses from catastrophic events have increased more than 10-fold during the past 50 years although only a part of this increase can be linked to climatic factors (IPCC, 2001c). Properties at risk in some regions of Europe may become uninsurable. Adaptation measures include risk transfer into wider financial markets and generally better cooperation between stakeholders.

Tourism

Climate change is likely to have significant consequences, both positive and negative, for tourism. Higher temperatures are likely to change summer destination preferences since outdoor activities in northern Europe may be stimulated, while summer heat waves in the Mediterranean region may lead to a shift of tourism to spring and autumn. Higher temperatures will also result in less reliable snow conditions and affect winter tourism. Regional policies will have to respond to changes in tourism patterns, for example new destinations may need specific infrastructure (Parry, 2000).

Human health

Climate change is likely to have considerable effects on the spread of vector-, food- and water-borne infections. Some vector-borne diseases may expand their range northwards. For example, there is some evidence that the northward migration of tick vectors in Sweden is due to the observed warming. An increase in heat waves, accompanied by a rise in urban air pollution, can cause an increase in heat-related deaths and periods of illness, but winter mortality is likely to be reduced. Adaptation measures should include specific public health programmes and the development of pan-European surveillance systems which allow the early detection of infectious diseases (Parry, 2000).

3.4. Greenhouse gas emissions

3.4.1. Overview

For international comparisons purposes, 1996 is the latest year which provides complete data. On this basis, total greenhouse gas emissions in the EU (excluding land use change and forestry) are about 4 160 million tonnes of CO_2 equivalent per year (24 % of the total for industrialised countries). In EFTA countries they are about 110 million tonnes (less than 1 % of the total of industrialised countries) and in the EU accession countries about 1 070 million tonnes (6 % of the total of industrialised countries). In the EECCA countries they are about 2 900 million tonnes (17 % of the total of industrialised countries, out of which 12 % for the Russian Federation). Other industrialised countries in the world contribute as follows to the total greenhouse gas emissions of industrialised countries (excluding land use change and forestry): US (39 %), Japan (8 %) and Canada (4 %).

Significant reductions in total greenhouse gas emissions occured during the 1990s, ranging from 3.5 % in the EU, to 34 % in CEE and 38 % in EECCA (Figure 3.2).

CO_2, the most important greenhouse gas, contributes about 82 % of total greenhouse gas emissions in WE, about 84 % in the accession countries and about 75 % in EECCA.

Figure 3.3 shows that:

- Combustion in the energy industries, industry, transport and 'other' sectors (mainly heating in commercial and residential areas) is the dominant source of greenhouse gas emissions in all of Europe.
- Emissions from energy industries (electricity and heat production) are more important in the accession countries (including Cyprus, Malta and Turkey) and the EECCA countries than in WE, partly because of the lower share of other sources such as road transport. In the European Free Trade Association (EFTA) countries, emissions from energy industries are relatively low due to a high

Figure 3.2. **Greenhouse gas emissions by gas in Europe, 2000**

Source: UNFCCC, 2002a

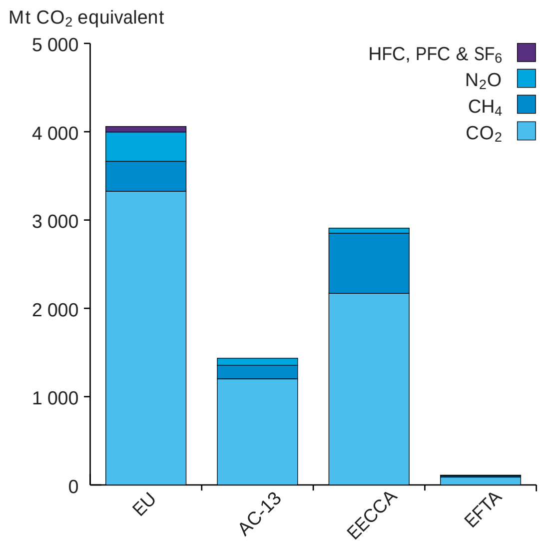
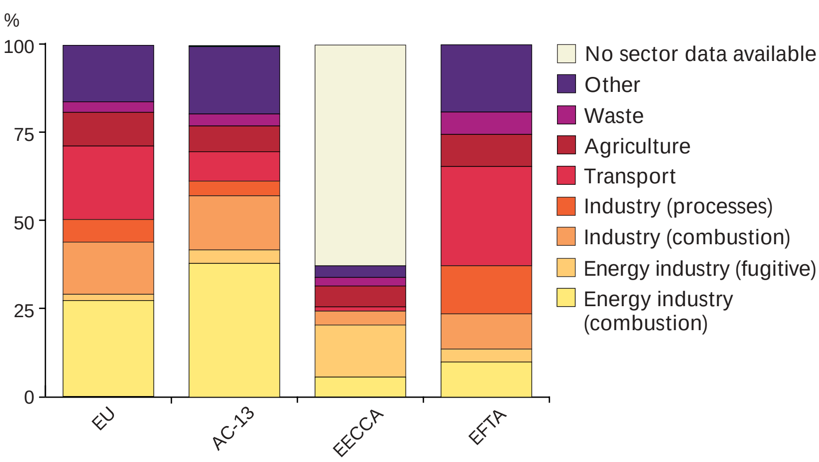


Figure 3.3. **Greenhouse gas emissions by sector in Europe, 2000**



Note: Data for EECCA countries are incomplete: for 63 % of the reported emissions the sectors are not known.

Source: UNFCCC, 2002a

share of electricity from hydropower plants.

- In the EU, transport contributes to about 20 % of total greenhouse gas emissions, whereas in the EU accession countries, the contribution is considerably less since there is less road transport.
- Emissions from industry contribute to about 20 % of total greenhouse gas emissions in most of Europe. Fuel combustion for power and heat generation is the main source. Process emissions are more important in the EFTA countries.
- Although data for the EECCA countries are limited, fugitive emissions from energy industries appear to contribute significantly to total emissions. This is caused mainly by methane leakages in natural gas transport systems.

> 😐 In the EU, decreases in emissions from energy industries, the industry sector, agriculture and waste management have been partly offset by increases from transport.
>
> 😐 In the accession countries, emissions from energy industries, the industry sector, agriculture and waste management also decreased; emissions from transport fell between 1990 and 1995, but increased significantly thereafter.

3.4.2. Energy industries

Energy industries (electricity and heat production, refineries, mining and distribution of energy carriers) are the most important sources of greenhouse gases in Europe, contributing 29 % of total emissions in WE; 42 % in the accession countries and about 20 % in the EECCA countries.

In the EU, CO_2 emissions from electricity supply fell by 5 % between 1990 and 2000, corresponding to 55 million tonnes, mainly due to switching from coal to gas in the United Kingdom and efficiency improvements in Germany, while consumption of electricity increased by 19 % (EEA, 2002a). The increase in combined heat and power generation in several Member States, as well as increasing wind power generation in Denmark and Germany, also contributed to the reductions. Significant reductions of fugitive emissions from methane (by 34 %) were a result of reduced coal production, better control of coalmines and reduction of leaks in the natural gas distribution system.

In the EU accession countries, emissions from energy industries fell by about 8 %, corresponding to 50 million tonnes of CO_2 equivalent, between 1990 and 2000. This was due to economic restructuring, an associated decrease or stabilisation of electricity consumption, changes in fuel use (less coal, more nuclear) and considerable efficiency improvements in power plants. Fugitive methane emissions also decreased significantly by 23 %, corresponding to 64 million tonnes of CO_2 equivalent.

Greenhouse gas emissions from energy industries also fell significantly in the EECCA countries between 1990 and 2000 resulting mainly from reduced electricity generation due to economic restructuring.

3.4.3. Industry

The industry sector is the second largest source of greenhouse gas emissions in western and central Europe. Combustion of fossil fuels is the most important industrial source: about 70 % of emissions from industry in the EU and about 75 % in the accession countries. Information for the EECCA countries is not available. CO_2 emissions from the production or use of mineral products (e.g. cement production) is the other main source, followed by nitrous oxide (N_2O) emissions from the chemical industry, mostly from adipic and nitric acid production and the use of fluorinated gases used for various purposes in industry as substitutes for ozone-depleting substances banned by the Montreal protocol.

In the EU, annual CO_2 emissions from industry fell by 8 % between 1990 and 2000, corresponding to 55 million tonnes, mainly as a result of improvements in industrial processes, economic restructuring and efficiency improvements in German manufacturing industry after reunification. Large reductions of 56 % between 1990 and 2000, corresponding to 59 million tonnes, were achieved in nitrous oxide emissions from the chemical industry, because of specific measures at adipic acid production plants in Germany, the United Kingdom and France (EEA, 2002a). Emissions of fluorinated gases increased by 36 % between 1990 and 2000. Emissions of hydrofluorocarbons (HFCs) increased by 94 % over the same period, although during recent years large reductions of HFC emissions were achieved in the United Kingdom. It is expected that emissions of fluorinated gases will increase further by a significant amount (EEA, 2002b).

CO_2 emissions from industry in the EU accession countries fell by 25 %, corresponding to 60 million tonnes, between 1990 and 2000. Some countries reduced industrial nitrous oxide emissions from chemical plants. However, there was no overall reduction in emissions from industry in the accession countries. No information is available on emissions of fluorinated gases. No data are available on trends in emissions from industry in the whole of the EECCA region.

3.4.4. Transport

The transport sector contributed more than 20 % of overall greenhouse gas emissions in the EU in 2000. In the accession countries, emissions from transport are the third largest contributor (about 8 %), with a far smaller share in the EECCA countries. Road transport is the largest source. CO_2 from fuel combustion is by far the most important greenhouse gas, followed by nitrous oxide, mostly generated as a by-product in catalytic converters.

Of particular concern in the EU is the 18 % increase in CO_2 emissions from transport between 1990 and 2000, corresponding to 128 million tonnes. This was due to a growing volume of traffic, both passenger car and freight transport, and no substantial improvement in energy use per vehicle-km for the whole vehicle fleet. However, recent years show a decreasing trend in CO_2 emissions per vehicle-km for new passenger cars, due to an agreement to reduce such emissions with European and other car manufacturers (see Chapter 2.6, Section 2.6.4.5). Only Finland achieved slight emission reductions and the United Kingdom and Sweden managed to limit growth to less than 10 % from 1990 to 2000. Although only responsible for 0.6 % of greenhouse gas emissions, nitrous oxide emissions from transport increased after the introduction of the catalytic converters in most WE countries. CO_2 emissions are expected to increase by about 25-30 % between 2000 and 2010 (EEA, 2002b).

Emissions in the 10 accession countries fell by 19 % between 1990 and 1995, but increased significantly thereafter. Emissions in 2000 were only about 5 % below the 1990 level. Economic growth and the continued shift towards road transport will further significantly increase emissions. Although CO_2 is currently the main greenhouse gas emission from the sector (98 %), nitrous oxide emissions are expected to increase rapidly due to the growing penetration of cars with catalytic converters.

Transport is a smaller contributor to greenhouse gas emissions in the EECCA countries. However, large increases are expected as the number of cars and transport demand rise (see Chapter 2.6).

3.4.5. Agriculture

Agriculture contributed about 10 % of overall greenhouse gas emissions in all three groups of countries in 2000. Nitrous oxide emissions from agricultural soils (mainly due to the application of mineral nitrogen fertilisers) and methane emissions from enteric fermentation (mainly from cattle) are the largest sources.

In the EU, nitrous oxide emissions fell by 4 % from 1990 to 2000 mainly as a result of a decrease in the use of nitrogen fertilisers. Methane emissions from ruminant animals fell by 9 % between 1990 and 2000 due to falling cattle numbers and changes in manure management (EEA, 2002a). Methane emissions may fall by 18–40 % by 2010 compared with 1990 due to a further reduction in livestock numbers and changes in manure management (EEA, 2002b).

In the 10 accession countries, relatively large reductions in methane emissions from enteric fermentation were achieved (46 %) due to falling cattle numbers. Nitrous oxide emissions do not show a clear trend, and in 2000 were at about the same level as in 1990. No data are available on trends in emissions from agriculture in EECCA.

3.4.6. Waste

The waste sector contributes only about 3–5 % of total greenhouse gas emissions in the different country groups within Europe. The main source is methane resulting from solid waste disposal on land.

Table 3.1. EU Member States' burden-sharing targets (EU Council Decision 2002/358/EC)

Member State	Commitment (% change in emissions for 2008-12 relative to base-year levels)
Austria	-13
Belgium	-7.5
Denmark	-21
Finland	0
France	0
Germany	-21
Greece	+25
Ireland	+13
Italy	-6.5
Luxembourg	-28
Netherlands	-6
Portugal	+27
Spain	+15
Sweden	+4
United Kingdom	-12.5

In the EU, substantial reductions (26 %) in methane emissions were achieved (from 1990 to 2000) as a result of landfill emission control measures (EEA, 2002a) through early implementation of the landfill directive. Similar trends can be observed in the 10 accession countries, where methane emissions fell substantially (by 27 %) between 1990 and 2000. Methane emissions from the waste sector may decline much further by increasing use of methane and energy recovery and the diversion of biodegradable waste from incineration to composting or anaerobic treatment.

3.5. Kyoto protocol targets

3.5.1. Kyoto protocol targets

Negotiations on an international convention addressing climate change resulted in the adoption of the UNFCCC in 1992. The Kyoto protocol, adopted in 1997, sets binding targets for industrialised countries (Annex I Parties) to reduce their collective greenhouse gas emissions by about 5 % by 2008–12 compared with 1990. This is generally seen as a first step towards the ultimate objective of the UNFCCC. The Kyoto protocol covers the greenhouse gases carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6).

Most of the detailed provisions of the Kyoto protocol were finally agreed in 2001 with the Marrakech accords. These contain concrete rules for the use of the flexible mechanisms — joint implementation, clean development mechanism and emissions trading — and on the extent to which carbon sequestered by land-use change and forestry activities ('carbon sinks') can be accounted for the fulfilment of reduction commitments.

Under the Kyoto protocol, the EU has an emission reduction target of 8 % from 1990 levels for 2008–12. According to Council Decision 2002/358/EC, the EU and its Member States agreed on different emission limitation and/or reduction targets for each Member State according to economic circumstances — the 'burden-sharing' agreement. According to this, some Member States have to cut their emissions, while others may increase them (Table 3.1).

The Russian Federation and Ukraine are committed to keeping their emissions at the 1990 level by 2008-12, Norway may increase its emissions by 1 %, Iceland by 10 %. Switzerland and eight accession countries (Bulgaria, Czech Republic, Estonia, Latvia, Lithuania, Romania, Slovakia and Slovenia) have to reduce their emissions by 8 %; Hungary and Poland by 6 %, and Croatia by 5 %. Other European countries do not have binding targets. Non-European countries with a commitment under the Kyoto protocol are Australia (+8 %), Canada (-6 %), Japan (-6 %) and New Zealand (0 %). The US has a target of -7 %, but announced in 2001 that it does not intend to ratify.

By January 2003, more than 100 countries (28 from Annex I industrialised countries), responsible for 44 % of the emissions of industrialised countries in 1990, had ratified the protocol (UNFCCC, 2002a). The Kyoto protocol will enter into force when it has been ratified by at least 55 countries including industrialised developed countries that together accounted for at least 55 % of CO_2 emissions from this group in 1990. In practice, this means that the United States or the Russian Federation would need to ratify for the protocol to enter into force.

3.5.2. Progress towards targets

European Union

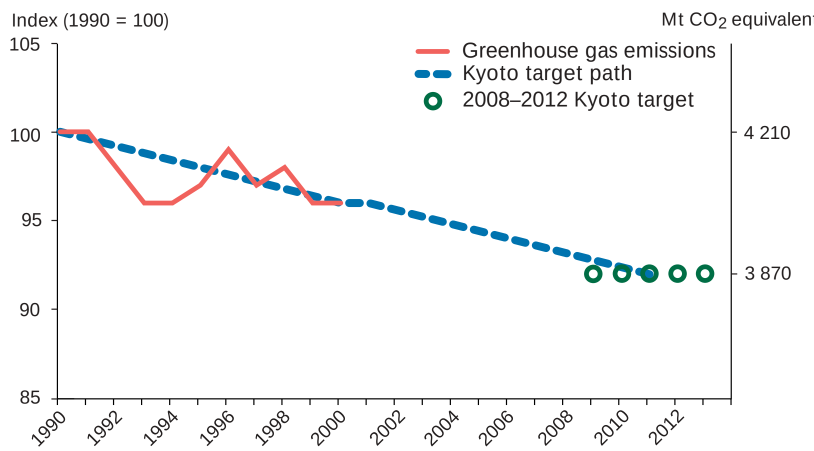
Greenhouse gas emissions in the EU fell by 3.5 % between 1990 and 2000. The EU is about halfway towards reaching its Kyoto target (see EEA, 2002a) assuming that this will be reached through domestic policies and measures in the EU alone (Figure 3.4). The possible use of the Kyoto mechanisms and carbon sinks to meet the EU Member States' burden-sharing targets is discussed in Section 3.6.4.

> EU greenhouse gas emissions fell by 3.5 % between 1990 and 2000, about halfway to the Kyoto target for 2008–12. Emissions were reduced partly due to favourable circumstances in Germany and the United Kingdom. Projections show that substantial further action is needed to reach many national (burden-sharing) targets.

During the past 10 years, considerable cuts in emissions were achieved, mainly in Germany (by 19.1 %) and the United Kingdom (by 12.9 %), while emissions increased in eight Member States. About half of the emission reductions in Germany and the United Kingdom were due to one-off factors (Eichhammer *et al.*, 2001; Schleich *et al.*, 2001). In Germany, economic restructuring of the five new Länder after reunification resulted in significant emission reductions, particularly in the electricity production sector due to energy efficiency improvements. In the United Kingdom, energy markets were liberalised and electricity utilities switched from oil and coal to gas.

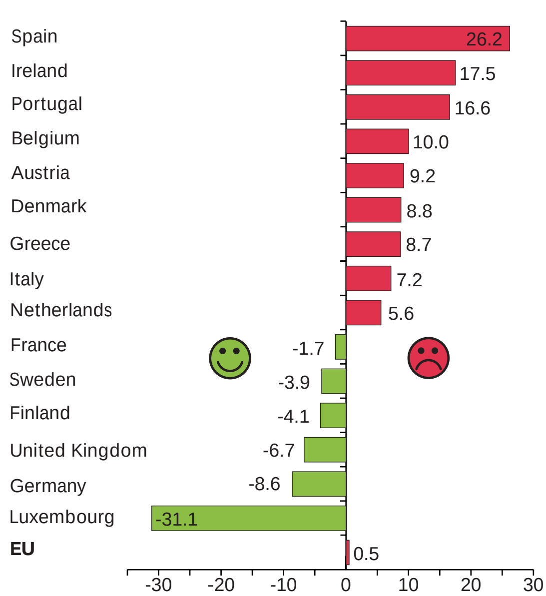
Figure 3.5 compares greenhouse gas emissions of EU Member States in 2000 with their linear target path for 2008–12. Nine Member States are well above their Kyoto target path and six are below.

European Union greenhouse gas emissions compared with target for 2008-12 (excluding land-use change and forestry) — Figure 3.4.



Source: EEA, 2002a

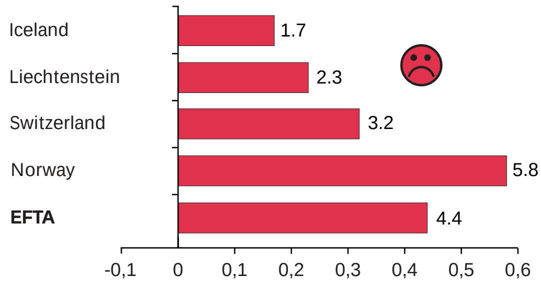
Distance to target indicators (in index points) in 2000 for the Kyoto protocol and burden-sharing targets of EU Member States — Figure 3.5.



Notes: The distance-to-target indicator (DTI) measures the deviation of actual emissions in 2000 from the (hypothetical) linear target path between 1990 and 2010. The DTI gives an indication of progress towards the Kyoto and Member States' burden-sharing targets. It assumes that the Member States meet their target entirely on the basis of domestic measures. However, Member States may also use the flexible mechanisms and sinks to fulfil their commitments (see Sections 3.6.3 and 3.6.4).

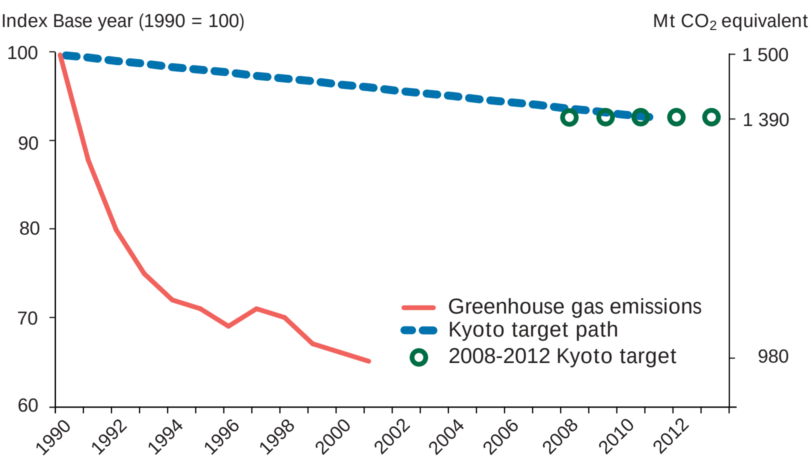
Source: EEA , 2002a

Figure 3.6. **Distance-to-target indicators (in index points) in 2000 for the Kyoto protocol of EFTA countries**



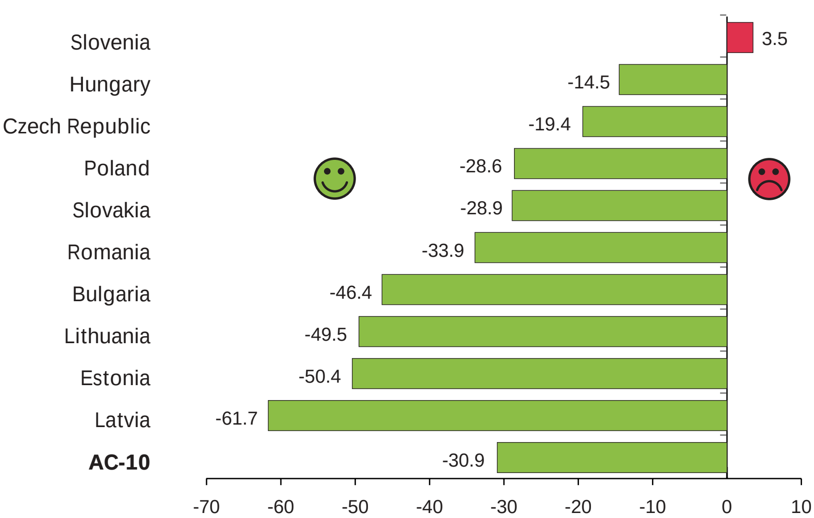
Notes: The distance-to-target indicator (DTI) measures the deviation of actual emissions in 2000 from the (hypothetical) linear target path between 1990 and 2010. The DTI gives an indication of progress towards the Kyoto targets. It assumes that countries meet their target entirely on the basis of domestic measures. However, countries may also use the flexible mechanisms and sinks to fulfil their commitments (see Sections 3.6.3 and 3.6.4).
Source: UNFCCC, 2002a

Figure 3.7. **Greenhouse gas emissions in 10 EU accession countries compared with Kyoto target for 2008–12 (excluding fluorinated gases and land-use change and forestry)**



Note: Article 4.6 of the UNFCCC allows countries undergoing the process of transition to a market economy some flexibility in choosing the base year. For Bulgaria the base year is 1988, for Hungary the average of 1985-87, for Poland 1988, for Romania 1989 and for Slovenia 1986.
Source: UNFCCC, 2002a

Figure 3.8. **Distance-to-target indicators (in index points) in 2000 for the Kyoto protocol of 10 EU accession countries**



Note: See note to Figure 3.6. For countries with other base years than 1990 (Bulgaria, Hungary, Poland, Romania and Slovenia), base-year emissions have been taken into account.
Source: UNFCCC, 2002a

According to the latest EU projections, total greenhouse gas emissions in the EU are expected to fall by 4.7 % from the 1990 level by 2010 assuming adoption and implementation of current, but no additional, policies and measures (EEA, 2002a). This leaves a shortfall of 3.3 % to the target of an 8 % reduction. Only the United Kingdom, Germany and Sweden are projected to achieve their Kyoto burden-sharing targets without additional policies or measures or the use of the flexible mechanisms. The transport sector is of particular concern with emissions projected to increase by more than 25–30 % between 1990 and 2010 (EEA, 2002a). Substantial further action is therefore needed if the EU is to reach its Kyoto target.

EFTA countries

Greenhouse gas emissions in Iceland, Liechtenstein, Norway and Switzerland fell slightly during the first half of the 1990s. During the second half, emissions increased significantly in Iceland and Norway, but hardly changed in Switzerland and Liechtenstein. In total, between 1990 and 2000, greenhouse gas emissions increased in Iceland (by 6.7 %) and Norway (by 6.3 %) and decreased in Switzerland (by 0.9 %) and Liechtenstein (by 1.7 %). All these countries are some percentage points above their linear Kyoto target (Figure 3.6).

EU accession countries

In the accession countries, greenhouse gas emissions fell altogether by 34.7 % between the base year and 2000 (Figure 3.7). The reductions were mainly due to the transition to a market economy and economic restructuring during the first half of the 1990s. During the second half, emissions in Slovenia, the Czech Republic, Poland and Hungary increased, while those in the other countries stabilised or continued to fall.

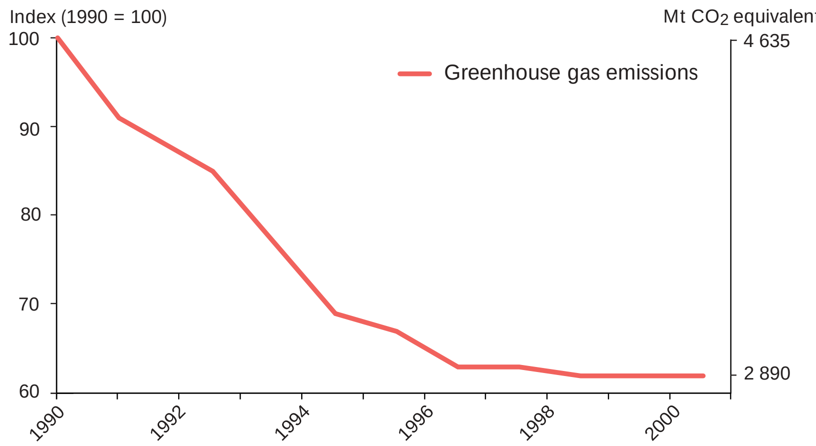
Total accession country greenhouse gas emissions in 2000 were far (30.9 %) below their linear Kyoto targets, except for Slovenia which is above (Figure 3.8.).

Greenhouse gas emissions in the accession countries fell by 35 % between the base year (1990, or earlier years for five countries) and 2000, and most countries are well on track to reach their Kyoto targets. However, in some countries emissions have started to increase again.

Eastern Europe, the Caucasus and central Asia
Greenhouse gas emissions in the EECCA countries fell by about 38 % between 1990 and 2000 (Figure 3.9). As in the accession countries, this was mainly due to economic and structural changes following the collapse of the former USSR.

Within EECCA, only the Russian Federation and Ukraine currently have Kyoto targets. Both countries are far below their linear Kyoto target path, and emissions are expected to be substantially below their Kyoto target by 2010. This will generate significant surpluses of emission allowances (see also Section 3.6.3).

Greenhouse gas emissions in eastern Europe, Caucasus and central Asia (excluding fluorinated gases and land-use change and forestry) Figure 3.9.



Source: UNFCCC, 2002a

3.6. Policy responses

Most WE countries will need additional efforts to fulfil their commitments under the Kyoto protocol, while most accession countries and the EECCA countries expect to be below their Kyoto targets. Most European countries will need to prepare for climate change by selecting and implementing appropriate adaptation strategies. WE countries are expected to reduce greenhouse gas emissions primarily by domestic action, policies and measures, although the Kyoto protocol gives Parties additional flexibility in fulfilling their commitments by the use of flexible mechanisms and 'carbon sinks'.

Programmes, policies and measures addressing climate change, mainly for the period up to 2008–12, are described in the next section while the possible use of the flexible mechanisms and sinks is analysed separately. In addition, the costs and benefits of climate change policies are analysed.

A long-term climate change strategy for the period after 2012 will also be needed.

> Many European countries have adopted national programmes addressing climate change. Key policies and measures include carbon dioxide or energy taxes, promotion of renewable energy (wind, solar, biomass) and combined heat and power, abatement measures in industry and measures to reduce emissions from landfills. A new policy instrument is emissions trading which has been put in place in a few countries.

Projections show that emissions are expected to increase, particularly in the transport sector, if no additional efforts are undertaken. Also the massive nuclear decommissioning which is anticipated to take place after 2010 will challenge climate policy responses. Future climate change policy will require structural changes of the economy to bring down emissions in the long term. Expansion of the use of renewable energy and increase in energy efficiency will need to be a focus of such a future climate change policy, along with adaptation measures in a wide range of socio-economic sectors.

3.6.1. National programmes
Many European countries have adopted and partly implemented programmes that address climate change. The energy sector, the largest contributor to greenhouse gas emissions, is a focus of policies and measures in many countries.

- *Energy and CO_2 taxes*. Several countries (Denmark, Finland, Germany, Italy, the Netherlands, Norway, Slovenia, Sweden and the United Kingdom) have introduced or increased taxes on energy use and/or CO_2 emissions.
- *Promotion of renewable energy*. In WE, many countries have adopted legislation to further increase the share of renewables. The rapid expansion of wind power (38 % per year in the EU between 1990 and 1999), driven by Denmark, Germany and Spain, was the result of support measures including 'feed-in' arrangements that guarantee a fixed

favourable price for renewable electricity producers. Germany and Spain are leading countries in the growth of solar (photovoltaic) electricity, mainly as a result of a combination of 'feed-in' arrangements and high subsidies (EEA, 2002c). Biomass for electricity and heat production has also expanded significantly in some countries, especially in Finland, Sweden, Austria and the Baltic countries (EEA, 2002c).
- *Promotion of combined heat and power (CHP).* Several countries have promoted the use of CHP plants by regulatory, economic and fiscal policies. A particularly high penetration of CHP was achieved by 1998 in Denmark (62.3 %), the Netherlands (52.6 %) and Finland (35.8 %) (European Commission, 2002).
- *Carbon dioxide emissions trading schemes in the United Kingdom and Denmark.* The United Kingdom is the first country in the world to set up a domestic emissions trading scheme for the basket of six Kyoto gases. Companies may voluntarily take on legally binding obligations to reduce their emissions from 1998–2000 levels. The government is making up to USD 340 million available over five years to participating companies. Denmark is experimenting with emissions trading on a pilot basis in the electricity generation sector. This system is expected to cover approximately 30 % of the country's CO_2 emissions.

Regarding transport, with emissions projected to rise significantly, some policies and measures are in place in several countries. For example, in Denmark, the Netherlands and the United Kingdom, the use of less fuel-consuming cars is promoted through tax-differentiation schemes (in Sweden such a system is under consideration). The promotion and development of inter-modal transport, rail transport and public transport are an important part of Finnish transport policy.

Few policies and measures are in place to reduce greenhouse gas emissions in the agricultural sector. Some policies and measures may help to reduce emissions as a side effect rather than directly. For example, in Finland, an agri-environmental support programme aimed at decreasing nutrient inputs to surface waters and groundwaters is being implemented by about 90 % of farmers, which is also expected to reduce nitrous oxide emissions as a side effect.

In industry, large reductions of nitrous oxide emissions can be achieved by measures in the manufacture of adipic and nitric acid. Emission reductions ranging from 45 % to 75 % are projected in the United Kingdom, Germany and France from such measures.

Large reductions may be achieved in the waste sector by implementing the landfill directive, leading to reductions of methane emissions of up to 80 %.

3.6.2. European Union

In the EU, several common and coordinated policies and measures have been developed including an agreement with car manufacturers to limit emissions of CO_2 from new passenger cars and a directive on an EU-wide emissions trading scheme.

In the EU, common and coordinated policies and measures have been developed in several sectors, for example the Green Paper on the security of energy supply (see Chapter 2.1) and the White Paper on a common transport policy (see Chapter 2.6) (see also European Commission, 2001a; European Commission, 2001b; European Parliament and Council, 2002).

In June 2000, the EU established the European climate change programme (ECCP) to help identify the most cost-effective additional measures to meet the Kyoto target and national burden-sharing targets. Several measures are at an advanced stage of preparation, including directives on:

- an EU emissions trading scheme;
- promotion of renewable energy;
- combined heat and power;
- biofuels;
- energy performance of buildings;
- energy efficient public procurement;
- fluorinated gases.

In the transport sector, the 1999 agreement with the European car manufacturers association (ACEA agreement) is expected to significantly limit the increase of CO_2 emissions from road passenger transport.

An important new EU policy instrument for the mitigation of climate change is a greenhouse gas emissions trading scheme, which was agreed in December 2002 (European Commission, 2001c). The scheme is limited to CO_2 and to energy-intensive sectors. The proposal covers about 46 % of the EU CO_2 emissions. A first phase will be established for the period 2005–07. The scheme is expected to lower the compliance costs of the Kyoto protocol for the EU significantly (by 35 %) compared with Member States meeting their commitments without trading across borders. The price for allowances for 1 tonne of CO_2 is estimated to fall in the range of EUR 20–33 (European Commission, 2001c).

3.6.3. Emissions trading and joint implementation

The Kyoto protocol and the Marrakech accords provide for three flexible mechanisms, which Parties may use to supplement domestic measures to facilitate compliance with their commitments:

- By *joint implementation*, industrialised countries (Annex I countries) may conduct joint projects to reduce greenhouse gas emissions or to increase take-up by sinks (including soils and forests). The mechanism invites western economies especially to invest in projects to reduce greenhouse gas emissions in countries in transition in eastern Europe and the Russian Federation. The achieved emission reduction units, or parts of them, are transferred to the investing Party, which can use them to fulfil its reduction commitments.
- The *clean development mechanism* invites industrialised countries (Annex I countries) to invest in projects to reduce greenhouse gas emissions in developing countries (non-Annex I countries). According to the reduction achieved, certified emission reduction units are issued which industrialised countries can use to fulfil their commitments. Projects that enhance the uptake of carbon are limited to afforestation and reforestation activities and may not exceed 1 % (annually) of a Party's base-year emissions.
- *Emissions trading* allows industrialised countries to trade emission allowances among each other.

The three flexible mechanisms are expected to become important instruments for reducing compliance costs by channelling investments into cost-effective greenhouse gas mitigation options. Joint implementation is particularly interesting for cooperation between western and eastern European countries. In many countries in transition in eastern Europe, investments in the energy sector are needed. At the same time, greenhouse gas mitigation costs in eastern Europe are mostly expected to be lower than in western Europe. Such projects could also help accession countries to integrate into the EU (Fernandez and Michaelowa, 2002). During a pilot phase for project-based activities to reduce greenhouse gas emissions under the UNFCCC, more than 80 projects under 'activities implemented jointly' have been reported in eastern Europe, including many cooperative projects between Sweden and Latvia, Estonia and Lithuania. The Netherlands has also implemented many projects in eastern Europe and EECCA (UNFCCC, 2002b).

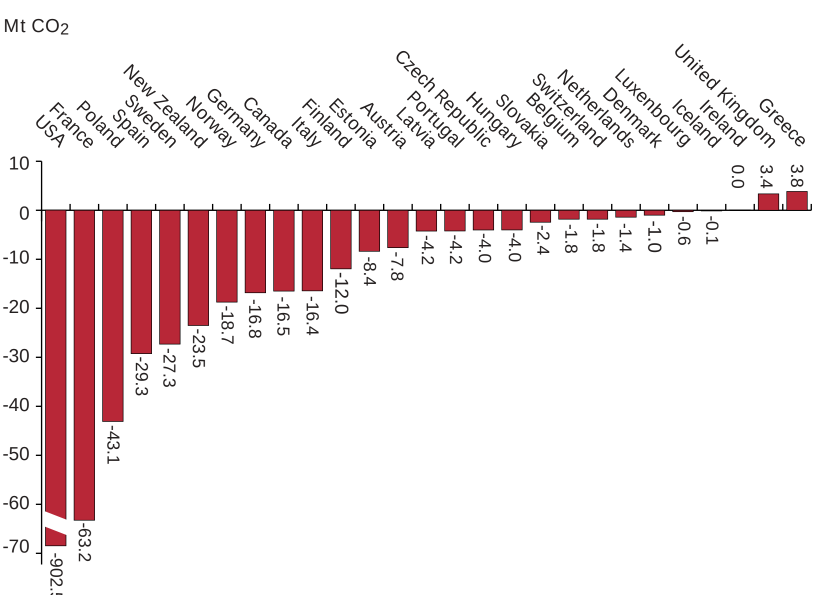
The Russian Federation and Ukraine could have a central role in the future market for greenhouse gas allowances. Both had relatively large emissions (the Russian Federation about 3 040 million tonnes of CO_2 equivalent in 1990), which fell until 1996 due to economic restructuring and a decrease in economic activity (Russian emissions fell by approximately 35 % (DIW, 2002)). By 2010, Russian emissions are projected to be far below the Kyoto target, which is to keep emissions at the 1990 level. Consequently, the Russian Federation and also some other eastern EECCA countries are likely to have a surplus of emission allowances in 2008-12, which is estimated to range from 750 to 1 340 million tonnes of CO_2 equivalent annually by 2010 (Grüttner, 2001a). In addition, if Kazakhstan agrees a Kyoto protocol commitment, this could lead to substantial additional surplus emission allowances. Following negotiation in Marrakech, the Russian Federation is allowed to account up to an additional 121 million tonnes of CO_2 annually during the first commitment period (or a total of 605 million tonnes of CO_2 during the five years from 2008 to 2012) for forest management activities. This may lead to an increase in the amount of surplus emission allowances available from the Russian Federation.

Trading of surplus allowances would increase physical greenhouse gas emissions during the first commitment period. However, there is a substantial potential in many EECCA countries for further emission reduction through improvements in energy efficiency, which may be facilitated through joint implementation projects. The 'green investment scheme' which is currently being developed aims to use funds from the flexible mechanisms to invest in reforming the Russian energy sector. It could create a framework to make Russian surplus emission allowances both economically effective and environmentally legitimate by ensuring investment in real emission-reduction projects (Moe *et al.*, 2001).

Following the United States withdrawal from the Kyoto protocol and with the additional flexibility of accounting for carbon sinks, projected prices in the future greenhouse gas market have dropped from a range of USD 3-27 to a range of USD 0–8 per tonne of CO_2 (Grüttner, 2001b; den Elzen and de Moor, 2001; Vrolijk, 2002). The Russian Federation, as a potential main supplier of greenhouse gas allowances, has an economic interest in reducing the supply of its allowances by banking them to the next commitment period after 2012, which would lead to a reasonable price in the first commitment period (see also Chapter 5). However, prices would be difficult to control, because they will depend on economic growth, on the amount of allowances banked and on the extent to which countries use domestic policies and measures, flexible mechanisms and carbon sinks to meet their targets.

Altogether, the effect of the Kyoto protocol after Marrakech is estimated to bring emissions of Annex I countries (without the United States) to 0–3 % under the base-year levels (den Elzen and de Moor, 2001).

Figure 3.10 **Reported emissions/removals of greenhouse gases from land use, land-use change and forestry for the year 2000, Annex 1 Parties to UNFCCC**



Notes: Positive values indicate a net emission, negative values a net uptake of CO_2. Several Annex I Parties have not reported inventories on land-use change and forestry or not complete inventory data.

Source: UNFCCC, submitted greenhouse gas inventories by Annex I Parties for the year 2000

3.6.4. Carbon sinks

Sequestration in land-use change and forestry ('carbon sinks') can be used to meet Kyoto targets, under some circumstances, with additional allowances amounting to about 1–4 % of 1990 emissions for EU countries (with an EU average of 2 %).

Terrestrial ecosystems contain large carbon stocks, amounting to about 2 500 000 million tonnes of carbon globally (IPCC, 2001b). In the past, land management has often resulted in the depletion of carbon pools, but in many regions, like WE, carbon pools are now recovering (IPCC, 2001b). Recent calculations indicate that terrestrial carbon sinks may turn into a source of CO_2 in the second half of the 21st century (Cox *et al.*, 2000).

Management of land may also lead to considerable carbon uptake and consequently mitigate climate change by lowering CO_2 concentrations in the atmosphere. However, the effectiveness and security of such sequestration may be only temporary.

Under the Kyoto protocol, carbon sequestration from human-induced afforestation, reforestation and deforestation (ARD) as well as from other land use, land-use change and forestry activities (revegetation, forest management, cropland management and grazing land management) since 1990 can be used to meet the targets. The extent to which Parties can account for carbon sequestration by specific land use, land-use change and forestry activities is limited to the first commitment period (2008–12). Accounting of forest management activities is subject to an individual cap for each Party.

There are large differences between countries' emission/removal estimates from land-use change and forestry for the year 2000 (Figure 3.10). The United States shows the largest uptake of about 900 million tonnes of CO_2. Within the EU, the largest CO_2 uptake occurs in France (about 36 million tonnes), followed by Spain (29 million tonnes). The United Kingdom and Greece have net emissions from land-use change and forestry. The amount of removals which can be accounted for under the protocol will be lower than the removals currently reported, because of the limits agreed for several activities and because only activities initiated after 1990 can be accounted for.

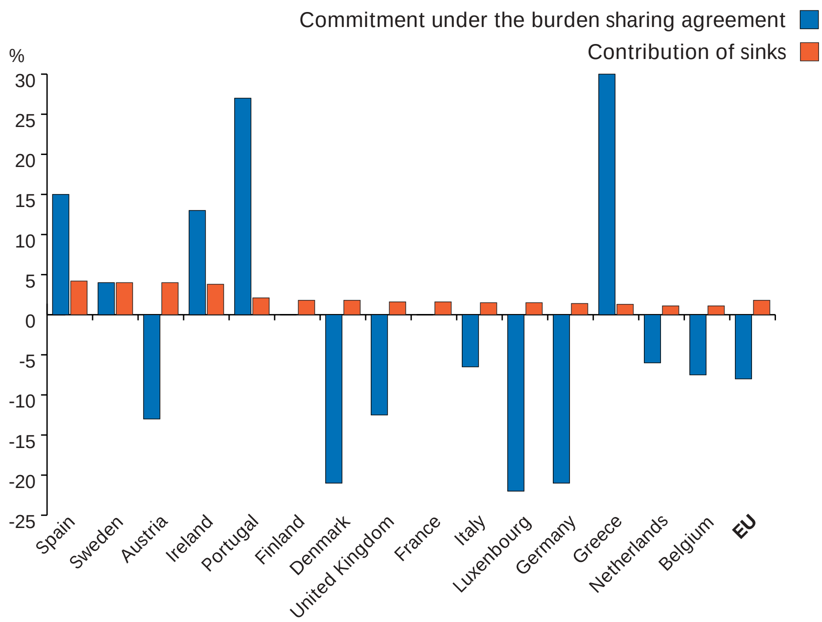
Comprehensive methods for estimating changes of carbon pools under the protocol are currently being developed by IPCC. Projections for the relevant carbon pool changes during the first commitment period are therefore difficult to perform with the existing inventory data.

The maximum potential of the contribution of sinks may be estimated. However, this does not imply that Parties will actually use the maximum potential, some countries have even indicated that they expect not to use their maximum (Petroula, 2002).

Figure 3.11 compares the maximum contributions from the potential carbon removal activities with the EU Member States targets under the burden-sharing agreement. With the use of carbon sinks, Spain can increase its emissions target of an allowed increase of 15 % by approximately 4.2 %. Similarly, Sweden can increase its emissions target of an allowed increase of 4 % to 8 % by using all of its potential for sinks. In Austria and Ireland, sinks could contribute about 4 % (of base-year emissions) to the achievement of their burden-sharing target. For the rest of the EU, the sink potential is less than 2 % of base-year emissions. The EU average is about 2 % of base-year emissions (Petroula, 2002). Most EU countries have not yet provided final estimates for the carbon sink potential of their agriculture activities, which are therefore not included in Figure 3.11. This could further increase the contribution of sinks to the achievement of the Kyoto targets.

For some non-EU Parties, sinks could contribute to a much larger extent to the achievement of the Kyoto targets (Figure 3.12). In New Zealand, sinks would allow for an emission growth by 40 % above the stabilising target if maximum potentials were used. For Canada, potential effects from removals are considerably larger (11 %) than the reduction target (-6 %). For Iceland and Norway, potential credits from sinks can also considerably increase the allowed emission growth, but Norway has indicated that it will not use sink credits from agricultural activities and forest management (Petroula, 2002). Japan, Switzerland and the Russian

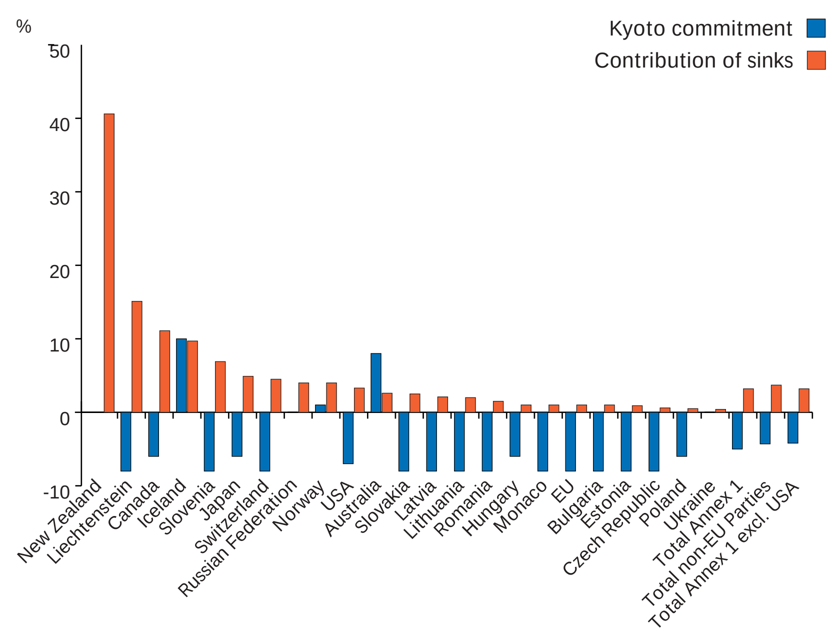
Comparison of potential contributions from land use, land-use change and forestry with burden-sharing targets for EU (percentage change from the base year) — Figure 3.11.



Notes: Agreed caps were considered. Estimates include the maximum contribution of sink clean development mechanism projects. This contribution was calculated on the basis of base-year data from 2002 inventory submission.

Sources: Data for ARD activities, forest management and additional activities were taken from Parties' submissions to UNFCCC; FAO data and country specific data were used for calculation of the debit compensation

Comparison of potential contributions from land use, land-use change and forestry with targets for non-EU industrialised countries (percentage change from the base year) — Figure 3.12.



Notes: See note in Figure 3.11. For clean development mechanism potential it was assumed that CEE and EECCA countries will not use the mechanism.

Sources: id. Figure 3.11.

Federation can potentially increase their emissions by 4–5 percentage points. For most accession countries (with the exception of Slovenia) sinks will not contribute significantly to achieving emission targets.

3.6.5. Costs and benefits of climate change policies

Costs

In general, there is still a considerable range in the estimated cost of implementing the Kyoto protocol. The estimates for the EU range from about EUR 4 to EUR 30 billion per year. Important factors that influence the estimates include differences in cost definitions and baseline scenarios, the assumed effectiveness of policies and measures for reduction of emissions, and the greenhouse gases that have been taken into account (only carbon dioxide or all gases). A further important factor is different assumptions about using the Kyoto mechanisms: joint implementation, clean development mechanism, emissions trading and the EU internal emissions trading scheme. Using these mechanisms can significantly reduce the costs of climate change mitigation.

In a detailed study (Blok *et al.*, 2001), the costs of domestic implementation of the Kyoto protocol in the EU were estimated to vary between EUR 4 and EUR 8 billion per year with the lower estimate assuming EU-wide emissions trading. The study covered all greenhouse gases, which generally leads to a somewhat lower cost estimate than studies that only take CO_2 into account.

Another relevant study, which analysed European environmental priorities (RIVM *et al.*, 2001) and used the EU-wide PRIMES energy model, estimated costs for the EU for domestic implementation of the Kyoto protocol at EUR 13.5 billion per year. The study also included a cost estimate, taking into account the use of Kyoto mechanisms, of EUR 6.3 billion per year. This study also included macro-economic cost estimates (welfare loss), which are higher due to impacts on foreign trade and the competitive position of EU industries, and which could lead to displacement of industries to countries outside the EU. These macro-economic costs of domestic implementation of the Kyoto protocol in the EU were estimated to be about EUR 30 billion per year.

Another more recent study (EEA, 2003) has estimated the costs of achieving the Kyoto targets for WE, taking into account only CO_2, and analysed the ancillary benefits of climate change policies on air pollution (see also Chapter 5). This study uses a similar cost estimation method to RIVM *et al.* (2001) and leads to similar cost estimates (Table 3.2). In one scenario within the study, it is assumed that the Kyoto targets would be achieved by using only domestic action in WE. This baseline scenario results in an 8 % increase in CO_2 emissions compared to the 1990 level, which implies, assuming domestic action only, a 13 % decrease in energy-related CO_2 emissions by 2010 from 1990 levels (including 2 % for sinks). Measures would include a number of the policies and measures mentioned above, including the improvement of energy efficiency, the substitution of coal by gas in electricity production and measures in some end-use sectors. Measures in the transport sector would be limited. The costs of these measures in WE would be about EUR 12 billion (1995) per year. The study also analysed two additional scenarios of use of the Kyoto mechanisms; more details on the assumptions are given in Chapter 5.

One of these additional scenarios ('optimal banking') assumes that it is beneficial for the Russian Federation and Ukraine to 'bank' a large share of their available surplus emission allowances and supply only 25 % of their potential to the market. In such a scenario, the use of all flexible instruments (emissions trading, joint implementation and clean development mechanism) would result in a 3 % emission reduction (instead of 13 %) compared with the baseline in WE, a 5 % reduction in central Europe and a 5 % reduction in the EECCA countries. This implies that about 80 % of the reductions in WE would be met by the use of flexible mechanisms, resulting in significantly reduced implementation costs. Costs for domestic policies and measures in WE would decrease to EUR 1 billion per year. However, at the same time about EUR 3 billion per year would be spent on permits (both emissions trading and joint implementation), giving a total of EUR 4 billion per year.

In a second scenario, the maximum potential for ancillary benefits, in terms of reduced emissions of air pollutants, was explored by excluding trading of surplus emission allowances. In this scenario, 55 % of the total emission reduction of CO_2 does not take place in WE but in central Europe and EECCA. The total expenditure for WE then is about EUR 7 billion per year.

Climate mitigation costs in western Europe can be reduced significantly through the use of cost-effective policies and measures and the use of the Kyoto mechanisms (joint implementation, clean development mechanism and emissions trading).

Total annual costs for implementation of the Kyoto protocol in western Europe (EUR billion/year) — Table 3.2.

Scenario	Domestic policies and measures	Kyoto mechanisms	Total
Domestic action only	12	0	12
Kyoto mechanisms with optimal banking	1	3	4
Kyoto mechanisms without trading of surplus emission allowances	2	5	7

Note: Costs in central and eastern Europe and EECCA are zero in all scenarios.
Source: EEA, 2003

Benefits
Policies and measures to abate greenhouse gas emissions result in lower emissions and lower concentrations in the atmosphere, which is expected to slow down climate change. However, there is a considerable time delay between the reduction in emissions and stabilisation of the concentrations. Many impacts of the greenhouse gases emitted during the past 150 years will only become apparent during the second part of this century or even beyond. Assessment of the benefits (or the avoided costs of damages) of abatement policies is therefore difficult. Furthermore, today's costs of reducing greenhouse gases are difficult to compare with the future costs of adaptation to climate change. Because of uncertainties in the quantification of climate change impacts and difficulties in expressing these in monetary terms it is not possible to compare benefits (now and in future) directly with mitigation costs with sufficient degree of accuracy.

Climate change policies can have significant positive effects on other environmental issues, in particular acidification, tropospheric ozone and urban air quality (primary particulate matter) in terms of reduced emissions of air pollutants (nitrogen oxides, sulphur dioxide, particulate matter) and reduced costs (see also Chapter 5). Climate change policies in the EU may lower the cost of reaching acidification and ozone targets by EUR 2–7 billion per year.

Climate change policies can have significant positive effects (ancillary benefits) by also reducing emissions of air pollutants and thus the costs of abating air pollution.

3.7. References

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