03

Climate change

3 Climate change

Photo: Glacier, Norway © George Buttner

Key messages

- New scientific insight and new research have confirmed that global climate change is taking place and is projected to continue. Impacts of climate change on society and natural resources are already occurring worldwide and are projected to become even more pronounced. Much of the recent global warming can be attributed to greenhouse gas (GHG) emissions from human activities.

- Many European countries have adopted national programmes including policies and measures to reduce GHG emissions. However, they have increased in recent years in most countries and are projected to continue to do so in the future. Many WCE countries will have difficulties in meeting their Kyoto commitments, while those EECCA countries with a Kyoto commitment are projected to meet them.

- The Kyoto Protocol under the UN Framework Convention on Climate Change and its first commitment period is only a first step in addressing climate change. To avoid unacceptable future impacts, further substantial global GHG emission reductions are needed and strong mitigation measures must be implemented. The EU has proposed a target of limiting temperature increase to a maximum of 2 °C above pre-industrial levels. To achieve this, a global emission reduction of up to 50 % by 2050 is necessary.

- Even if global emissions of greenhouse gases are drastically reduced, some unavoidable climate change impacts are still projected to occur in most sectors of the economy and on natural resources. It is therefore also urgent to adapt to those impacts in developing and implementing policies and measures in all sectors of society.

- Climate change and depletion of the ozone layer are two separate issues, but with interactions related to the emissions of compounds as well as the physical and chemical changes in the atmosphere. Ozone-depleting substances and their replacement compounds are GHGs with long atmospheric lifetimes and they will, therefore, contribute to climate change for many years to come.

3.1 The challenge: tackling climate change

The earth's climate is changing. The average temperature — globally and in Europe — continues to increase. Globally it has increased 0.74 °C between 1906–2005. In Europe the temperature is about 1.4 °C higher than pre-industrial levels with the last decade the warmest for 150 years, and 1998 and 2005 warmer than any year on record (CRU, 2006; GISS/NASA, 2006; IPCC, 2007). Global mean temperatures are projected to increase by 1.8–4.0 °C, during this century, with some studies suggesting a wider possible range of 1.1–6.4 °C (IPCC, 2007). Europe is likely to become warmest in the eastern and southern parts of the continent.

Sea levels are rising and the melting of glaciers is accelerating. The global mean sea-level rose by more than 1.7 mm/year during the 20th century and is projected to rise by 0.18 m to 0.59 m during the 21st century (IPCC, 2007).

The impacts of climate change, including those on natural ecosystems, biodiversity, human health and water resources such as floods and droughts, are already being observed and are projected to become more pronounced. The least developed countries, such as some of those in EECCA, are among the most vulnerable, having the least financial and technical capacity to adapt, for example, to droughts or increased flooding.

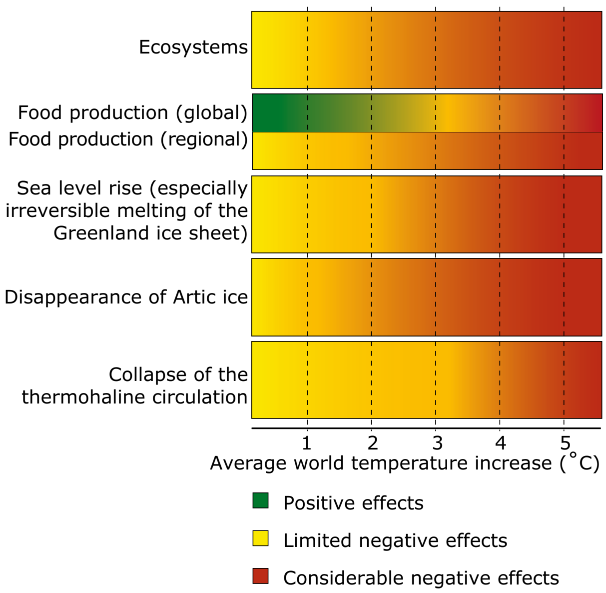
The impacts are affecting many economic sectors including forestry, agriculture, tourism and the insurance industry. In recent years, for example through the summer of 2005, heavy rains have led to destructive flooding in eastern parts of Europe, particularly in Romania, Bulgaria, Hungary and the Former Yugoslav Republic of Macedonia, causing damage to property, infrastructure and agriculture. Such individual episodes cannot be attributed to global climate change alone, but illustrate what may become more frequent as climate change continues. Not all current and projected effects of climate change are adverse: for example in some parts of Europe the agricultural sector may benefit from a temperature rise.

There is increasing scientific and political concern that climate change may be more rapid and pronounced than suggested in previous projections (e.g. IPCC). In addition to gradual changes, a number of non-linear, abrupt changes may occur. Although uncertainties still surround this possibility, were they to occur they might have severe consequences, such as shifting the climate system from one state to another in a relatively short time. One such change could be the melting of the large ice sheets in Greenland and in western Antarctica, which would release enough water to increase sea levels by 13 metres, something that could happen over the next 1 000 years.

Even if global warming is to some extent the result of natural factors, the latest scientific insight shows that over recent decades much of it can be attributed to greenhouse gas (GHG) emissions from human activities (IPCC, 2007): carbon dioxide (CO_2) is the largest contributor at about 80 % of total GHG emissions. Substantial reductions in GHG emissions are needed if the impacts of climate change are to be kept at manageable levels.

At the global level, the threat of climate change is being addressed by the United Nations Framework

Figure 3.1 The vulnerability of various sectors to changes in global average temperature



Source: MNP, 2005a.

Convention on Climate Change (UNFCCC), and the Kyoto Protocol under that convention. The Kyoto Protocol, which entered into force on 16 February 2005, sets binding emission targets for a basket of six GHGs ([1]) for those industrialised/developed countries (Kyoto Annex B countries) that have ratified it.

The targets in the Kyoto Protocol are only a first step towards the more substantial global emission reductions that will be needed to reach the UNFCCC's long-term objective 'to stabilise atmospheric greenhouse gas concentrations at a level that would prevent dangerous anthropogenic interference with the climate system'. The EU has pointed to the need to reduce global emissions by about 50 % by the middle of the 21st century (Environment Council conclusions, 20 February 2007) which implies the reduction or limiting of emissions by countries other than those that are already included in Annex B. New targets for industrialised countries and possible new emission reduction strategies for other countries have been discussed within the UNFCCC since 2005, but no agreement has been reached.

Many European countries have adopted national programmes aimed at reducing emissions. Key policies and measures include national taxes on CO_2 emissions: the EU carbon dioxide Emission Trading Scheme (EU ETS); increased use of renewable energy (wind, solar, biomass) and combined heat and power installations; improvements in energy efficiency across the spectrum from buildings and industry to household appliances; abatement measures in transport, households and industry; and measures to reduce emissions from landfills.

In the EU, GHG emissions fell by about 5 % between 1990 and 2004: decreases from energy generation and from the industrial, agriculture and waste sectors all played a part, but were partly offset by increases from transport. The joint EU-15 Kyoto target will only be attained when all planned measures, including the use of such Kyoto instruments as the Clean Development Mechanism (CDM, see below) and the removal by sinks are taken into account. The other EU Member States will meet their targets with already implemented measures, except Slovenia which is in the same situation as EU-15.

Between 1990 and 2003, emissions in EECCA countries fell by about 27 % mainly as a result of economic and structural change, but most emissions have started to increase again as economies recover. Nonetheless, those EECCA countries with Kyoto commitments, the Russian Federation and Ukraine, are projected to meet them. Over the same period, emissions in SEE increased by about 2 % after a strong decrease during the first half of the 1990s. In EFTA they increased about 4 %.

In order to reduce the cost of mitigation, Kyoto mechanisms can be used (clean development mechanism, joint implementation and trading with Assigned Amount Units (AAUs) ([2]). In addition investments can be made in so-called green investment schemes, which can be set up by Annex 1 (developed) countries of the convention that have a surplus of assigned amount units. These include the EECCA countries, the Russian Federation, Ukraine and the SEE countries Romania and Bulgaria. Internally in the EU, industries can trade emission allowances within the EU ETS to find more cost-effective measures.

In many of the economies in transition and developing countries in SEE and EECCA, investment in the energy sector is urgently needed. The CDM, and indeed green investment schemes (GIS), could provide an opportunity to boost energy efficiency or the production of renewable energy, while providing win-win situations: the host country benefits from cleaner energy and from new infrastructure, while investing countries and corporations benefit by offsetting their excess emissions often at a lower cost than introducing internal reduction measures.

([1]) Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and the F-gases hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6).

([2]) The allowable level of emissions for a party over the commitment period (2008–2012) is called its assigned amount. This quality is denominated in individual units or AAUS, each of which represents an allowance to emit one metric tonne of carbon dioxide equivalent.

However, even immediate and large reductions in GHG emissions will not halt climate change, due to time lags in the climate system: some impacts of climate change — both environmental and economic — are now, inevitable. Thus, in addition to emission reductions, measures across a wide range of sectors will be needed to adapt to the consequences of climate change. In parallel to mitigation programmes, more and more countries have therefore started investigations into and development of national adaptation programmes to deal with current and future impacts.

3.2 Climate change and its impact

3.2.1 Temperature

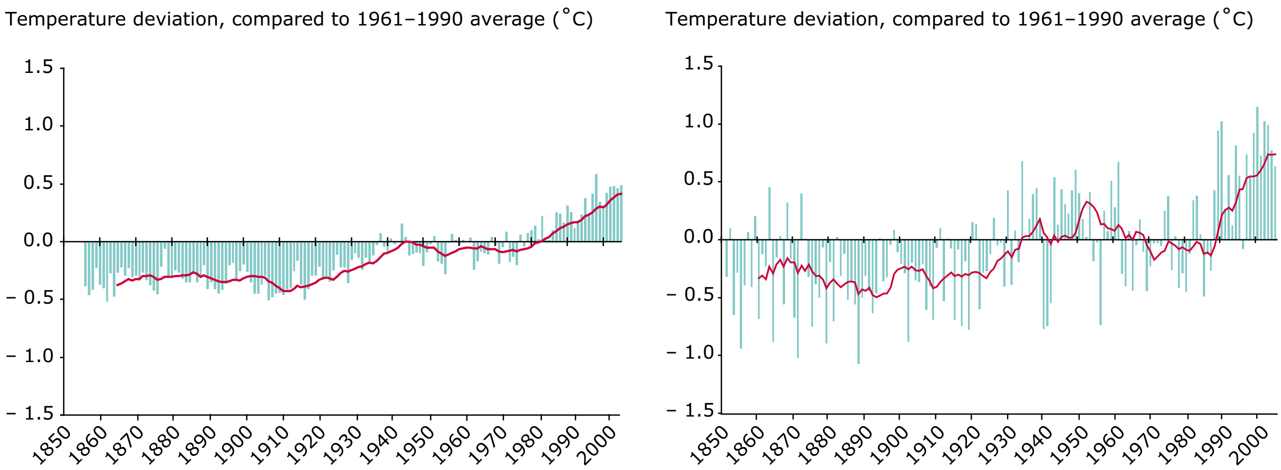
Global temperature has been recorded systematically since the early 19th century, and using indirect methods, global average temperatures have been reconstructed for more than the past 400 millennia. The gradual changes over time in global average temperature provide an indicator of the vulnerability of different sectors to climate change (e.g. IPCC, 2007; EEA, 2004, 2005).

The increase in global temperature, particularly in recent decades, is one of the clear signs that the climate is changing (Figure 3.2). The global average temperature is now 0.8 °C higher than in pre-industrial times (CRU, 2006; GISS/NASA, 2006). On average, 2005 and 1998 are among the warmest years on record. Note that there was a strong El Niño in 1998, which generally results in more warming, whereas 2005 was about as warm but without such an event.

Up to 2005, data for Europe, including all EECCA countries, show a 1.4 °C increase in the annual average temperature over land, compared with pre-industrial levels ([3]) (Figure 3.2). As such Europe has warmed more quickly than the global average. Particularly significant warming has been observed over the Iberian Peninsula; south-eastern Europe, including Turkey; north-western Russia; and the Baltic states. The largest warming, however, has been in the Arctic regions of the Russian Federation, where temperatures have increased 3 °C over the past 90 years (Russian Third National Communication (NC3), 2002; ACIA, 2004).

The global average temperature is projected to increase 1.8–4.0 °C, with some studies suggesting

Figure 3.2 Observed annual average temperature — global (left) and UNECE Europe (right)



Source: CRU, 2006.

([3]) Pre-industrial means the average of the 1850–1919 averages, based on IPCC standards.

a wider possible range of 1.1–6.4 °C (IPCC, 2007). Europe, excluding the EECCA countries, is likely to warm 2.1–4.4 °C by 2080, or possibly 2.0–6.3 ([4]) (Schröter *et al.,* 2005), with the largest increases projected for northern and eastern Europe. Projections for the Russian Federation indicate an average increase of 1–3 °C by 2020 and 3–6 °C by 2080, with the largest increases, 5–9 °C by 2080, in eastern Siberia and the Far East (Alcamo *et al.,* 2003; Ruosteenoja *et al.,* 2003). In other EECCA countries the annual temperature may increase by 1–6.9 °C by 2050, and 4–6.6 °C by 2080/2100 (Table 3.1).

Models project greater warming in winter than in summer in northern Europe, up to 8–10 °C by 2080 in Arctic regions (ACIA, 2004), whereas in central and southern Europe warming is projected to peak in summer, with local increases of 6 °C (Räisänen *et al.*, 2004; Giannakopoulos *et al.,* 2005).

3.2.2 Precipitation

The amount of annual precipitation in Europe varies widely, depending on geographical location (IPCC, 2001; Klein Tank *et al.*, 2002). In the 20th century, it has increased in northern Europe (by 10–40 %), in the Arctic region (by 8 % (ACIA, 2004)), and in the Russian Federation, while southern Europe became up to 20 % dryer. Most EECCA countries show no clear trend (Peterson *et al.,* 2002).

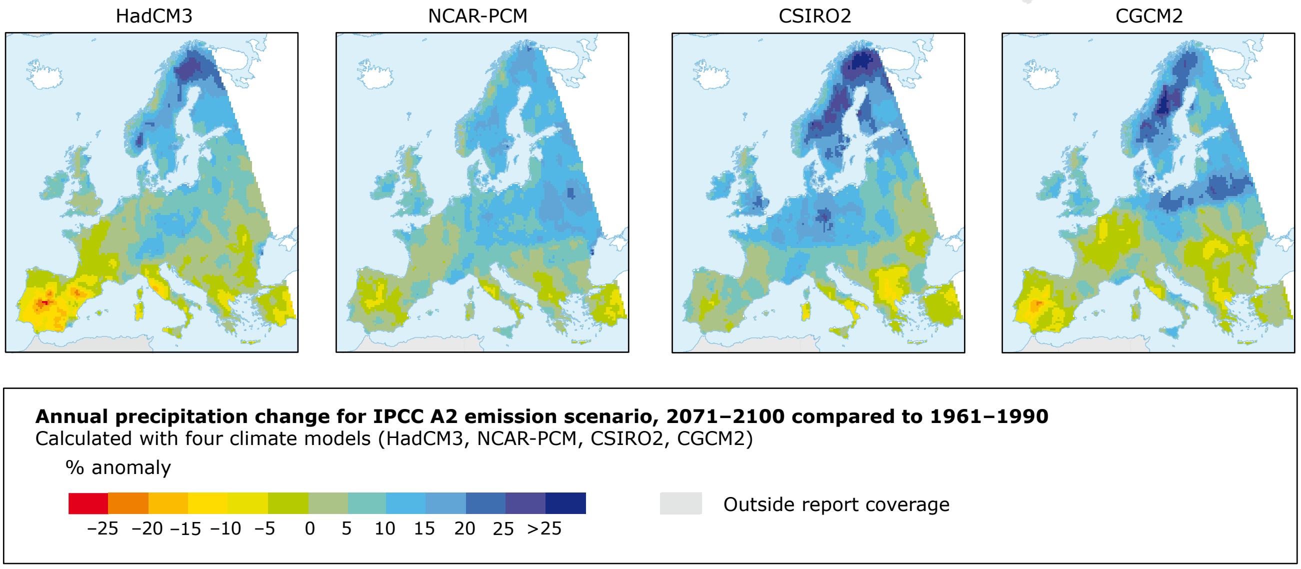
Table 3.1 Climate projections in EECCA and SEE countries (based on national communications (NC))

EECCA and SEE countries	Observed temperature	Temperature increase (in °C)		Observed precipitation (mm yr-1)	Precipitation change (in %)		Source
		2050	2080/2100		2050	2080/2100	
Albania	7.0–6.0	1.2–1.8	2.1–3.6	1 485	– 6.1 to – 3.8	– 12.5 to – 6.0	NC1, 2002
Armenia*			1.7	569	– 5.4	– 10.3	NC1, 1998
Azerbaijan*	0–14		4.3–5.1	200–1 400		– 15 to 7	NC1, 2000
Belarus*	4.5–7.0	1	1.9	600–700	3	4	NC1, 2000
Bulgaria		1.6–3.1	2.9–4.1	630		Winter >, summer <	NC4, 2006
Croatia	– 3 to 22	1.0–2.1	2.4–3.2	600–3 500	2.4–6.5	6–10	NC1, 2001
Georgia*	0–14	1.0–1.5		400–1 600			NC1, 1999
Kazakhstan*	– 18 to 26		4.5–6.9	150–1 500		1–3	NC1, 1998
Kyrgyzstan*	– 17.1 to 25.4	1.4–2.2	1.8–4.4	100–500	3–37		NC1, 2003
FYR of Macedonia*	11–14	1.3–1.7	1.7–3.2	500–1 000	– 1.8 to – 2.4	– 2,4 to – 4.4	NC1, 2003
Republic of Moldova*	8–10	2.3–2.4	3.3–4.6	450–620	– 2.7 to 11.8	0.1–11.0	NC1, 2000
Romania	2.6–11.7	2.7–3.4		400–600			NC4, 2006
Russian Federation*	– 40 to 25		3–6				NC3, 2002
Tajikistan*	– 6 to 17	1.8–2.9		70–1 800	3–26		NC1, 2002
Turkey		1.8–2.0	3.2–4.4		35	50	
Turkmenistan*	16		4.6–6.1	76–398		– 56 to 0	
Ukraine*	– 4 to 20			500–700			NC1, 1998
Uzbekistan*	– 8 to 30	1.5–3.0		80–200			NC1, 1999

Note: * = EECCA countries.

([4]) The range is smaller because the used models and scenarios are a sub-set of the ones used to define the IPCC range.

Map 3.1 Changes in annual precipitation for the IPCC A2 scenario (2071–2100 compared with 1961–1990) for four different climate models



Note: The spatial pattern projected by each climate model remains the same for different emission scenarios, only the size of the changes varies.

Source: Schröter *et al.*, 2005.

Over the last decades, western and central Europe and the Arctic experienced additional rainfall in winter, whereas southern and south-eastern Europe became dryer (Giorgi, 2004b). In contrast, during the summer, most parts of central and northern Europe experienced less precipitation over the last decades (Klein Tank *et al.*, 2002).

Precipitation projections for Europe vary between climate models and scenarios (Table 3.1, Map 3.1). In general, annual mean precipitation is projected to increase continuously in northern Europe, for example by 20 % in Arctic regions (ACIA, 2004), and decrease further south (Schröter *et al.*, 2005). Decreasing precipitation is projected for most EECCA countries, by about 3 % by 2080 (Table 3.1). For most but not all of the Russian Federation, precipitation is projected to increase, with the largest projected increases in the range of 20–30 % in north-eastern Russia, but decreases in south-western Russia/northern Caucasus.

In winter, Europe may experience more precipitation except in the Mediterranean region; for example 15–30 % in central and northern Europe (Giorgi *et al.*, 2004). In general, models project a decrease in summer precipitation (June–August) in most of Europe.

3.2.3 Temperature and precipitation extremes

Climate change is experienced most intensively through the impacts of extremes, rather than gradual changes. Impacts include river floods, droughts, forest fires, and human health problems due to heat waves. Even areas that benefit from changes in average climate are still likely to suffer from more intense and more frequent climate extremes. For example, agriculture in northern Europe is projected to benefit from increasing temperatures and atmospheric CO_2 levels, but the gain could be nullified by more frequent heavy rainfall events (IPCC, 2007).

In recent decades Europe has experienced hotter summers than ever before and extremes of high temperatures — the 2003 heat wave in Europe and the 2005 heat wave in the Russian Federation were the most extreme summers since observations started — and more frequent and intense droughts, whereas the number of cold extremes has fallen significantly (Giorgi, 2004b; Klein Tank, 2004). The trend in temperature extremes is consistent across Europe, including the EECCA countries.

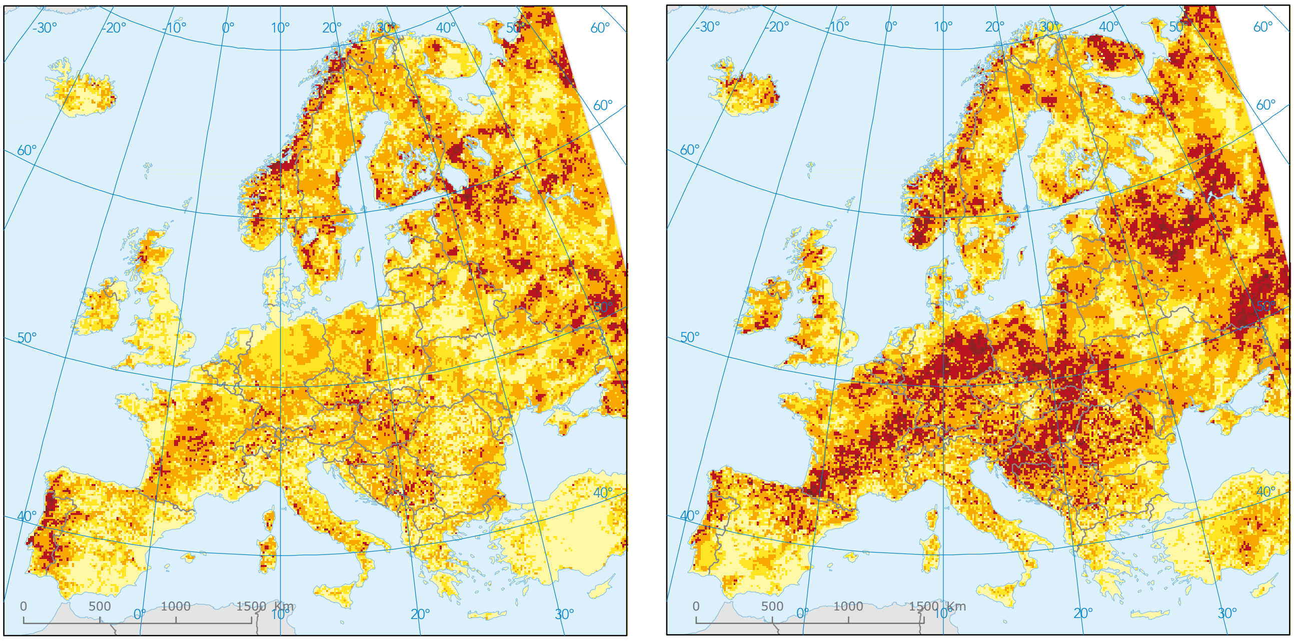
There has also been an increase in the number of wet days and heavy rainfall events in central and northern Europe and in western Russia, and a decrease in southern Europe (Klein Tank *et al.*, 2002) and Siberia (Ruosteenoja *et al.*, 2003).

Projections for temperature and precipitation extremes are highly uncertain. Nonetheless, warm periods, including heat waves, are expected to be more intense, more frequent and longer-lasting. These changes are projected to occur especially in the Mediterranean and eastern Europe. Indeed, by 2050–2060 the Mediterranean region may experience one additional month per year of 'summer days' with temperatures above 25 °C, and the number of 'hot days', those with temperatures above 30 °C, may increase in other regions (Map 3.2) (Beniston, 2004; Giannakopoulos *et al.*, 2005). Since the yearly minimum temperature is projected to increase even faster, cold winters, which occurred once every ten years from 1961–1990, are projected to disappear almost entirely from Europe by the end of the century.

The probability of extreme precipitation events is projected to increase in western and northern Europe (Palmer and Raisanen, 2002), while many parts of Mediterranean Europe may experience further reduced rainfall and longer periods of drought (Klein Tank, 2004; Good, 2004; Holt and Palutikof, 2004).

Higher temperatures and less precipitation can increase the risk of salinisation, land degradation and

Map 3.2 Occurrence of heat wave events with a duration of 7 days (left: 1961–1990 average; right: 2071–2100 average)



Heat wave frequency for the periods 1961–1990 (left) and 2071–2100 (right)
Based on the IPCC-SRES A2 emission scenario and the DMI climate model

< 1 | 1 | 2–3 | 4–5 | 6–7 | 8–9 | ≥ 10 | Outside report coverage

Note: The A2 baseline scenario in combination with the Danish regional climate model.

Source: Indicator elaboration: R. Hiederer, European Commission DG Joint Research Centre, Institute for Environment and Sustainability, 2007. Data: PRUDENCE Project 12km HIRHAM4, Danish Climate Centre, 2006.

desertification ([5]). These impacts, which can cause serious social and economic problems, are already major concerns for many SEE and EECCA countries, for example Kazakhstan, Kyrgyzstan and Tajikistan, where agriculture — particularly vulnerable to all three — is an important sector (see also Section 3.2.7). For example, there is already a severe drying out of large areas of Kazakhstan, mainly the Aral Sea. Although only partly for climatic reasons, climate change is expected to accelerate this trend. The main problems in mitigating this trend are insufficient financing, absence of monitoring, non-sustainable use of natural resources, sometimes a lack of coordination between the bodies involved and insufficient support from international organisations.

3.2.4 Sea-level rise

Sea-level rise is highly relevant to coastal countries. One third of the EU population lives within 50 km of the coast. Impacts of sea-level rise include inundation and displacement of wetlands, coastal erosion, increased salinity, and impeded drainage.

Global mean sea-level rise is distinct from local or relative sea-level rise, which depends on regional variations in ocean temperature and salinity — variations can be up to 100 % — and vertical movements of the land surface — for example, caused by tectonics or land subsidence due to water extraction. For the 20th century the average global mean sea-level rise was 1.7 mm/yr (IPCC, 2007). This increased to 1.8 ± 0.5 mm/yr for the period 1961–2003 and to 3.1 ± 0.7 mm/yr for 1993–2003 (IPCC, 2007). These increases were mainly the result of thermal expansion of the sea water due to higher temperatures, and additional freshwater from the melting of glaciers and the Antarctic and Greenland ice sheets (IPCC, 2007). Local increases along the European coasts between 1896 and 1996 were between 80 mm and 300 mm (Liebsch *et al.*, 2002).

By 2100 global sea level is projected to rise by 0.18–0.59 m (IPCC, 2007). Relatively large sea-level rises are projected for the Arctic region (ACIA, 2004). These projections do not incorporate the melting of the Antarctic (WAIS) and Greenland ice sheets, which may add 0.1–0.2 m during this century. Larger values cannot be excluded, but estimates cannot be given due to a limited understanding of some factors (IPCC, 2007). In the long term, further rises of several metres are possible, since these ice sheets contain enough water for a sea-level rise of up to 13 m — about 7 m from Greenland alone. Recent research indicates that a process of irreversible melting of the Greenland ice sheet may start at a local temperature increase of 3 °C which corresponds to a global mean temperature rise of about 1.5 °C (Gregory *et al.*, 2004; Lowe *et al.*, 2006). This, however, has a very high uncertainty.

Even the projected gradual sea-level rise of 0.18–0.59 m by 2100, combined with possible increases in the frequency and/or intensity of extreme weather events, can have a variety of impacts for Europe's coastal areas. Coastal ecosystems appear to be threatened, especially those in the Baltic, Mediterranean and Black Seas (Johansson *et al.*, 2004; Meier *et al.*, 2004). These habitats could be severely reduced or even disappear during the 21st century because of the low tidal range in these areas; the limited scope for onshore migration, due to the intense human use of the coastal zone; and coastal subsidence (Gregory *et al.*, 2001; Nicholls and Klein, 2003).

3.2.5 Glaciers and Artic sea ice

Changes in mountain glaciers provide some of the clearest signals of climate change (IPCC, 2001). Effects of the melting and even disappearance of glaciers are an increase in the number of natural hazards such as falling ice and land slides; a reduced supply of drinking water; weakened irrigation facilities; and reduced generation of hydropower. Until recently, data for 19 glaciers in the EECCA countries were reported to the World Glacier Monitoring Service (WGMS). However, for various reasons only six of them, all of which are retreating though to different degrees, are currently being observed and data reported (Table 3.2 and Figure 3.3). Restarting the observations of the other

([5]) Much of the information presented is derived from the review of the reports on implementation of the United Nations Convention to Combat Desertification (UNCCD), as input to their Fifth Conference of the Parties, held 12–21 March 2007 in Buenos Aires.

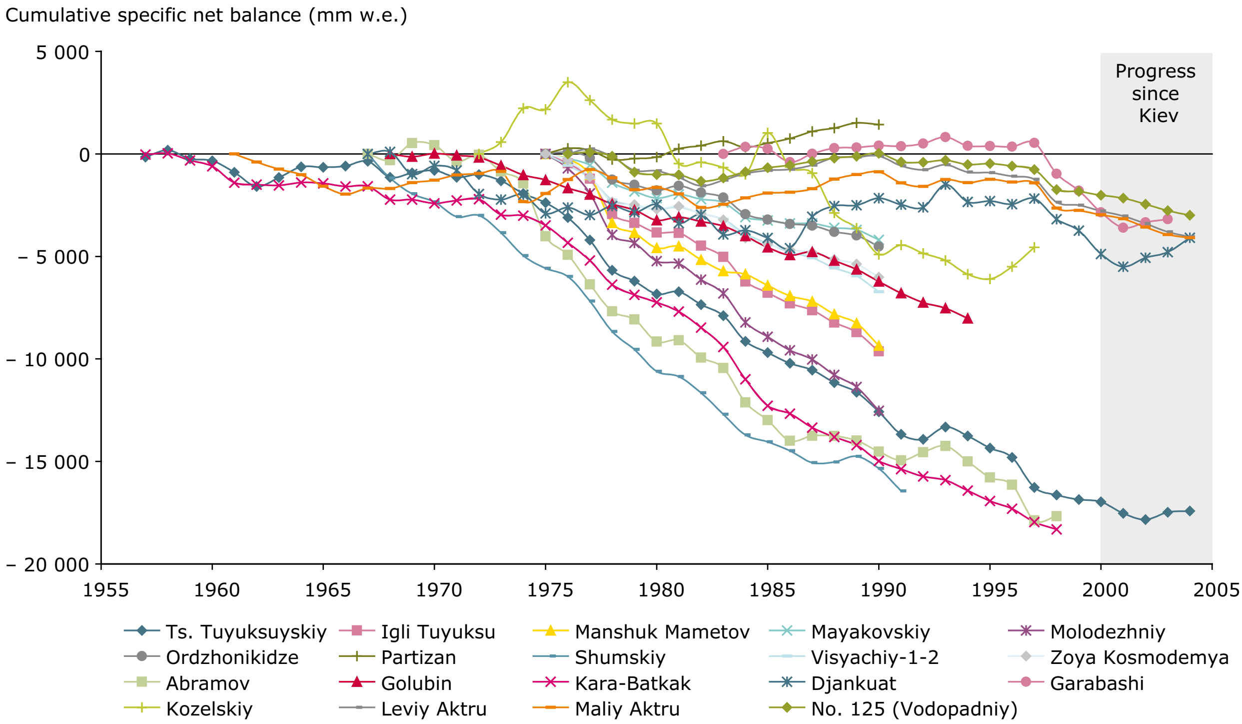
Table 3.2 Observed and reported glaciers in EECCA countries

Glacier name	1st survey year	Last survey year	Country	Location
Abramov	1968	1998	Kyrgyzstan	Pamir Alai
Djankuat	1968	2004	Russian Federation	Caucasus
Garabashi	1984	2003	Russian Federation	Caucasus
Golubin	1969	1994	Kyrgyzstan	Tien Shan
Igli Tuyuksu	1976	1990	Kazakhstan	Tien Shan
Kara-Batkak	1957	1998	Kyrgyzstan	Tien Shan
Kozelskiy	1973	1997	Russian Federation	Kamchatka
Leviy Aktru	1977	2004	Russian Federation	Altay
Maliy Aktru	1962	2004	Russian Federation	Altay
Manshuk Mametov	1976	1990	Kazakhstan	Tien Shan
Mayakovskiy	1976	1990	Kazakhstan	Tien Shan
Molodezhniy	1976	1990	Kazakhstan	Tien Shan
No. 125 (Vodopadniy)	1977	2004	Russian Federation	Altay
Ordzhonikidze	1976	1990	Kazakhstan	Tien Shan
Partizan	1976	1990	Kazakhstan	Tien Shan
Shumskiy	1967	1991	Kazakhstan	Dzhungarskiy
Ts. Tuyuksuyskiy	1957	2004	Kazakhstan	Tien Shan
Visyachiy-1-2	1976	1990	Kazakhstan	Tien Shan
Zoya Kosmodemya	1976	1990	Kazakhstan	Tien Shan

Note: Lines in blue: continued; not coloured: interrupted due to different reasons.

Source: Zemp, M., 2006.

Figure 3.3 Changes in cumulative net balance of glaciers for EECCA countries



Note: mm w.e.: mm water equivalent.

Source: Zemp, M., 2006.

glaciers would give important information on the impacts of climate change.

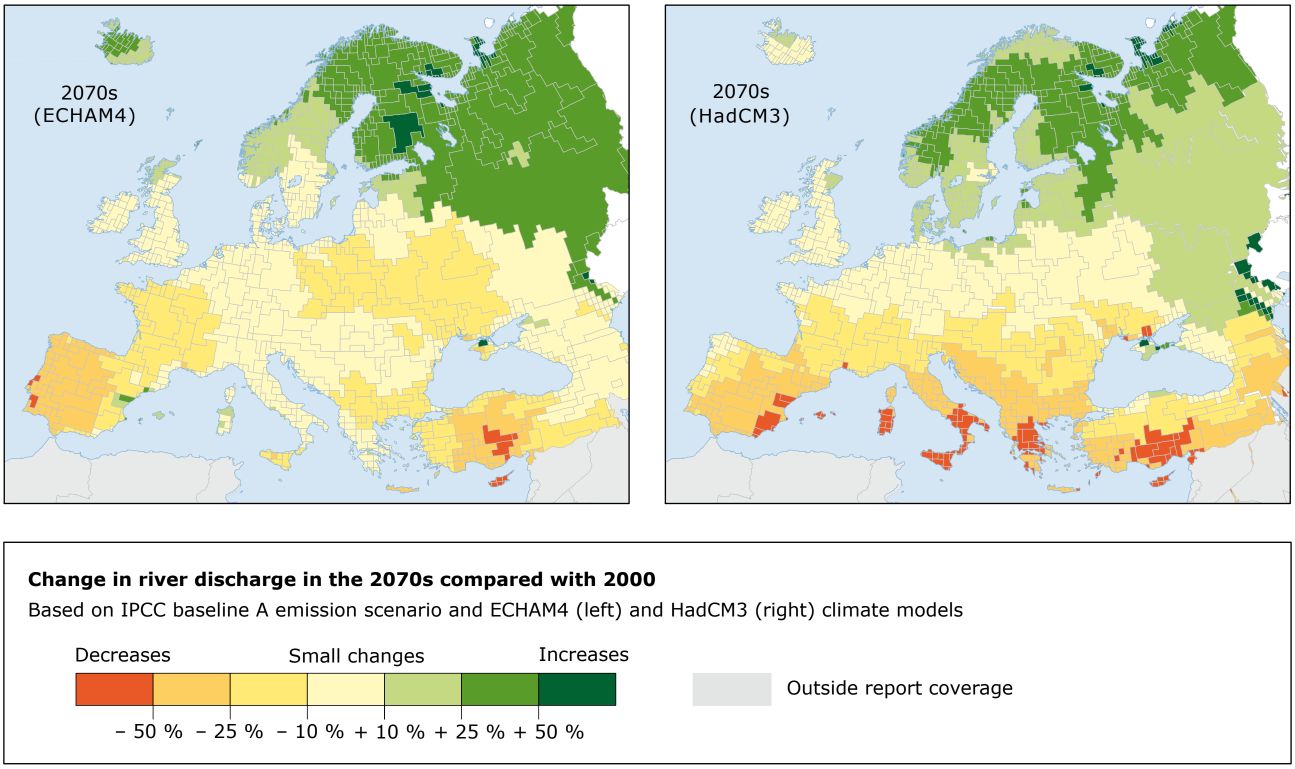
Summer Arctic sea ice is projected to almost disappear by the end of this century, but its winter extent will shrink less. Reduced ice coverage will increase the absorption of heat from the sun and therefore contribute to further global warming (ACIA, 2004). Further, the shrinking of the sea ice will endanger the habitats of the highly diverse ice-associated flora and fauna and threaten the traditional lifestyles of indigenous peoples (see also Section 5.3.7).

3.2.6 Water resources

Climate change is often an additional pressure on water resources. Annual discharges of many rivers have decreased significantly in recent decades including, in southern Europe — from the river Adige in Italy and from parts of the Russian Federation — the inflow to the Aral Sea (Clarke and King, 2004). Increased discharge is observed in the rivers flowing from the Russian Federation into the Arctic Ocean (see Section 2.3). Seasonally, across Europe river discharges have decreased in summer and increased in winter. These changes in seasonal discharge have probably increased the risks of droughts in some periods and floods at other times, although floods are not just the result of climate change, they are also partly caused by mismanagement and inappropriate land use.

The projected changes in climate during the 21st century may further intensify the hydrological cycle. Annual river discharge and the resulting water availability is projected to increase in northern and north-western Europe and decrease in parts of Mediterranean Europe especially (Map 3.3, Lehner *et al.*, 2005). In many parts of EECCA, water scarcity is likely to increase due to a combination of increasing demand, temperature increase and precipitation decrease (national

Map 3.3 Projected changes in annual river discharge in Europe for 2070, using different climate models



Source: Lehner *et al.*, 2005.

communications). Important agricultural areas of the Russian Federation may experience a larger variability in water availability, with higher risk of water scarcity during the growing season (Peterson *et al.*, 2002).

3.2.7 Agriculture

Agricultural production, important for the economies of many SEE and EECCA countries, is sensitive to climate change. However the impacts of climate change should be seen against continuously increasing production over recent decades, due mainly to technological development.

Agriculture in some parts of Europe might benefit directly from increasing CO_2 levels in the atmosphere (IPCC, 2007). Changes in precipitation will also affect crop production, because the balance between precipitation and evaporation is the main factor that governs production. Temperature increases can reduce yields under already dry conditions, and this could become worse if precipitation declines. Despite stimulating growth, warming and increased CO_2 levels can have negative effects on the feed quality of pasture areas, due to their effect on species composition, shifting it towards less preferable plant species (IPCC, 2007). Temperature increases may also lead to a northwards and upwards, in terms of altitude, expansion of crop types currently grown in southern Europe, including sunflower, soybeans, and sugar maize (European Commssion, 2003). For example, a 30–50 % expansion of the sugar maize area in Europe has been projected by 2100 for the range of IPCC scenarios.

Models project increased crop yields in middle and, especially, northern Europe, and large reductions in the Mediterranean and south-eastern Europe (Schröter *et al.*, 2005). The main causes of increased yields are increasing CO_2 levels, and northwards and upwards movement of agricultural potential. The decrease in southern and south-eastern Europe is related particularly to the extent and severity of drought periods.

A critical issue is climate variability, since this is a major determinant of inter-annual variations in agricultural productivity. This can be illustrated by the remarkable heatwave of 2003 which led to yield losses of up to 30 % in some European regions (European Commssion, 2003). Similarly, various extreme weather events caused the loss of about one third of agricultural production in Tajikistan during 1991–2000 (NC1, 2002). If such events become more frequent and/or more intense, many areas that stand to benefit from changes in average climate may be adversely affected. This has been projected, for example, for the Netherlands (MNP, 2006) and the Russian Federation (Golubev and Dronin, 2004; Alcamo *et al.*, 2006, case study on agriculture).

Another issue related to climate variability is the risk of land degradation, desertification and salinisation. Agricultural production in semi-arid areas, such as

Box 3.1 Climate change and its impact on agriculture in Russia *

Russia is the largest country in the world and has many different ecological zones. In many parts of Russia agriculture is problematic because temperatures are too high in the south and too low in the north and because of short growing seasons, limited water availability, poor soils, lack of infrastructure and/or remoteness from agricultural markets. Even when agriculture is possible, only rarely are optimum combinations of temperature and soil moisture available. For centuries agriculture was concentrated near populated areas in European Russia where crop potential was limited by short growing seasons. Although this changed somewhat about 100 years ago, 80 % of current Russian cropland still lies in zones of risky agriculture (Golubev and Dronin, 2004). This is because the areas with better soils and climate often also have high year-to-year climate variability, posing challenges for agriculture. Only 15 out of 89 administrative regions are 'main crop producing regions', that is regions that are responsible for about 50 % of Russian agricultural production and thus provide the rest of Russia with much of its basic food requirements. It should also be stated that recent warming has led to improved agroclimatic conditions in large parts of the main agricultural zone of Russia except the Black Sea area and the southern regions of eastern Siberia (NC4).

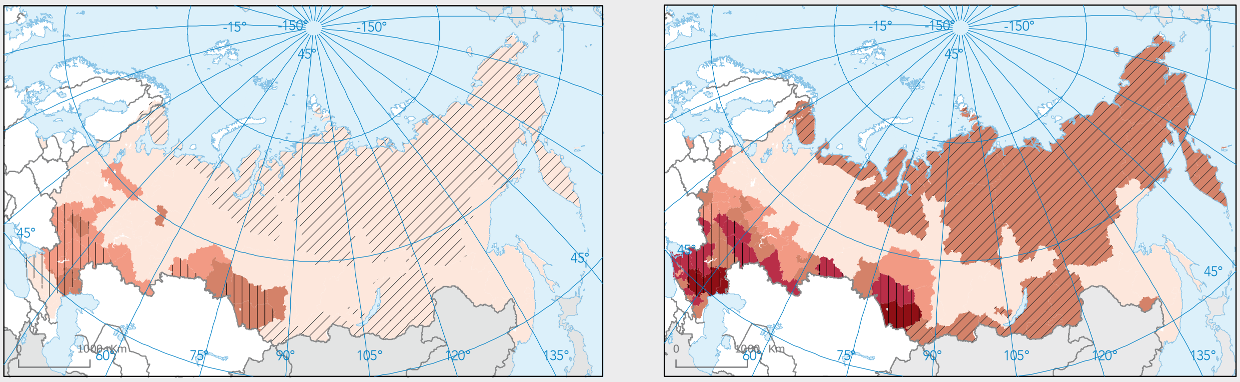
Box 3.1 Climate change and its impact on agriculture in Russia (cont.)

Agriculture in the Russian Federation is also vulnerable to climate variability due to crop selection (wheat — the most important food crop — is very vulnerable to cool weather), and an economically weak agricultural sector with a low adaptive capacity (Golubev and Dronin, 2004). This vulnerability is shown by many catastrophic events over the past 100 years, in which severe droughts frequently reduced crop production in major agricultural areas causing food shortages over the entire country. Over recent decades, the Russian Federation has substantially raised its agricultural productivity through technological improvements, with, for example, the cereal yield now being comparable with that in other countries at the same latitudes including Canada. However, large fluctuations in agriculture yield are observed, due mainly to irregular precipitation patterns, causing droughts in one year, floods in others.

An important question is how Russian agriculture will develop, taking into account projected climate change. Many of the past problems of reduced food production have been caused by periods of droughts. The projected increased temperatures and precipitation in many parts of the Russian Federation, together with increasing CO_2 levels, may lead to an expansion of the potential crop growing area as well as increased yields in many areas that are currently marginal (Alcamo *et al.*, 2003; NC4). This may, however, not always lead to increased food production because of other environmental constraints, for example, nutrient availability and socio-economic barriers including the lack of infrastructure.

Furthermore, there is considerable geographic variation. By 2010–2015 more favourable climatic conditions may result in 10–15 % higher yields in various parts of the country (NC4). Likewise, a 25 % yield increase has been projected for some northern and north-western regions by around 2050, whereas the yield increase in the Ural region might be 15 %. At the same time the agricultural production in 'the current main crop producing regions' is projected to drop by 23–41 % relative to the current average by the 2070s, because these are the regions that will face decreasing precipitation. The net effect of these opposing trends could be a change in the agricultural production of the Russian Federation from – 9 % to + 12 % by the 2020s and – 12 % to – 5 % by 2070, depending on the climate model and the global emission scenario used. Further, taking projected changes in extreme events into consideration, a large part of the Russian Federation may experience more bad harvests. The frequency of these could double by the 2020s and even triple by the 2070s, mainly as a result of more droughts in the 'main crop-growing areas' (Alcamo *et al.*, 2007, Figure CS-1). This may threaten the Russian Federation's food security, unless adaptation measures, including changing crop types; enhancing fertiliser and irrigation use; importing more food; and changing food consumption patterns, are taken.

Map 3.4 Frequency of bad harvest years for the IPCC A2 scenario in combination with the HADCM3 climate model



Years with bad harvests for Russia for 1961–1990 (left) and in 2070 (right)
Based on the IPCC A2 emission scenario and the HadCM3 climate model

Number of years

0 | 1 | 2 | 3–4 | 5–6

Main crop growing area | No substantial crop production | Outside report coverage

Note: * = Based on Alcamo *et al.*, 2003; Golubev and Dronin, 2004; Alcamo *et al.*, 2007; and NC4, 2006.

Source: Alcamo *et al.*, 2007.

Box 3.2 Changes in permafrost

Air temperature, snow cover, and vegetation, all of which are affected by climate change, affect the temperature of the frozen ground and the depth of seasonal thawing. Permafrost temperatures in the northern hemisphere have increased in recent decades, by about 1 °C at depths between 1.6 m to 3.2 m between the 1960s and the 1990s in east Siberia, about 0.3 to 0.7 °C at 10 m in northern west Siberia (Pavlov, 1996), and about 1.2 to 2.8 °C at 6 m between 1973 and 1992 in northern European Russia (Oberman and Mazhitova, 2001).

Over the next 100 years, these changes are projected to continue and their rate to increase, with degradation projected to occur over 10–20 % of the present permafrost area. The southern limit of permafrost is projected to shift northward by several hundred kilometres (ACIA, 2004).

When permafrost thaws, the ground surface subsides (thaw settlement). Typically, this is not uniform but results in a chaotic surface with small hills and wet depressions known as thermokarst terrain. On slopes, the thawing can lead to active layer-detachment slides (Lewkowicz, 1992). Extensive thermokarst development has been discovered, for example in central Yakutia (Gavrilov and Efremov, 2003) where a significant expansion and deepening of thermokarst lakes was also observed (Fedorov and Konstantinov, 2003).

The most sensitive regions of permafrost degradation are coasts with ice-bearing permafrost around the Arctic Ocean. The destabilisation of coastlines is further amplified by decreasing sea ice on the Arctic Ocean. Even the ice-poor permafrost coast along the Russian Arctic coast is retreating by 1.0 m/yr (Rachold *et al.*, 2003). Another point of concern is potential thawing of 'sub-sea permafrost' which depends mainly on sea-water temperature that is projected to increase (Walsh *et al.*, 2005).

Impacts on infrastructure

Already occurring and projected increases in permafrost temperatures are likely to cause severe damage to infrastructure such as roads, buildings and industrial facilities. Failures in transportation and industrial infrastructures are becoming more common as a result of permafrost thawing in northern Russia. Many railway lines have been deformed, buildings, power stations and airport runways in several cities have been severely damaged (ACIA, 2004), and oil and gas pipelines have broken, causing accidents and spills that have contaminated soil over large areas. The concerns of the impacts of thawing permafrost on infrastructures in the Russian Federation were confirmed at the World Climate Change Conference in Moscow 2003 (e.g. Shoigu, 2003).

Photo: © Schirrmeister, AWI, 2006

Based on a moderate global emission scenario running to 2050, risks to several Russian population centres (Yakutsk, Norilsk, Vorkuta), important river terminals (Salekhard, Igarka, Dudinka, Tiksi), industrial facilities (Nadym-Pur-Taz natural gas production complex), and transport infrastructures (Trans-Siberian and Baikal-Amur railway) have been identified in Siberia. The Bilibino nuclear power station and its grid are in an area of high hazard potential in the Russian Far East (ACIA, 2004).

The effects on infrastructure up to 2100 are projected to be more serious and immediate in the discontinuous permafrost zone — large parts of north-western and central Siberia as well as of the Russian Far East than in the continuous zone — areas located mostly more north. Complete thawing is expected to take centuries, and benefits, such as construction on totally thawed ground, would occur only after that time.

Possible adaptation measures include the re-design and re-engineering of infrastructures. This will increase investment costs in the short term, but can avoid the substantial consequences of infrastructure failures experienced in Yakutsk and elsewhere in the Arctic (ACIA, 2004).

Impacts on natural systems

There are important interactions between changes in permafrost and vegetation. For example thawing can lead to severe leaning or total toppling of trees (ACIA, 2004).

The thickening of the active layer — the top layer of permafrost that thaws each year during the summer season and freezes again in winter — and the melting of permafrost may have already contributed, in part, to increased run-off in Arctic rivers (Zhang *et al.*, 2005). Thickening of the active layer results directly in the thawing of decomposed plant materials and other organic matter frozen in the upper permafrost. Thus carbon can be decomposed by

Box 3.2 Changes in permafrost (cont.)

microbial activities, which can release carbon dioxide and methane to the atmosphere (Randerson *et al.*, 1999).

Another important potential source of greenhouse gas emission is the thawing permafrost itself. The vast carbon reservoir contained in permafrost soil in northwest Siberia contains about 500 billion metric tonnes of carbon. If all Siberian permafrost thawed, it could nearly double the 730 billion metric tonnes of carbon now in the atmosphere (Zimov *et al.*, 2006).

Sub-sea permafrost contains or overlies large volumes of methane in the form of gas hydrates at depths of up to several hundred meters. As sub-sea permafrost warms and thaws, destabilisation of the gas hydrates could increase the emission of methane to the atmosphere (Walsh *et al.*, 2005).

Reducing permafrost stability and intensification of coastal erosion due to global warming would increase sediment and carbon input to the Arctic Ocean. This could cause considerable changes in the Arctic coastal currents and circulation.

many parts of several EECCA countries, is highly vulnerable to climate variability as well as change. The possibility of extending irrigation is one of the essential determinants of this risk (IWMI, 2006), because the extension of rain-fed agriculture is often limited.

3.2.8 Nature and biodiversity

Climate change is one of the factors that threaten biodiversity. Its influence has increased over recent decades and it is expected to be the main driver of biodiversity loss in the future (Thomas *et al.*, 2004). The most vulnerable European regions appear to be mountain areas, the Arctic and the Mediterranean (Brooker and Young, 2005; Schröter *et al.*, 2005).

Various impacts of changes in climate on nature have been observed. Growing seasons have extended, leading to dis-synchronisation of food patterns; the composition of ecosystems has changed; and the productivity of many ecosystems has increased, on land as well as in the marine environment.

Even more impacts of future climate change on nature have been projected, but these will not be the same in all regions, for example the growing season is expected to lengthen in many parts of Europe but not in the south (EEA, 2005). Projections show northwards and upwards shifts of many species, affecting current endemic species. For example, 25 % of today's plant species in Romania, Bulgaria, the Iberian peninsula and some other Mediterranean countries may disappear by 2100, and by then more than 35 % of the plant species composition in northern countries may consist of invasive species (Bakkeness *et al.*, 2006).

Another major issue for both plants and animals is the frequency and extent of forest fires and how these will change as a result of climate change. Projections show a considerable increase in the extent and frequency of fires, for example in the Iberian peninsula (IPCC, 2007) and the Russian Federation (Vorobyov, 2004). This may lead to changes in ecosystem composition, favouring fast-growing species.

These issues are further discussed in Chapters 4 and 5.

3.3 Interaction between climate change and ozone-layer depletion

Climate change affects the depletion of the ozone layer and vice versa, both with respect to the emissions of compounds and to the physical and chemical changes in the atmosphere, although the overall effects of this interaction on the recovery of the ozone layer are unclear. So even if climate change and depletion of the ozone layer are two separate issues, it has for this reason been included in this chapter on climate change.

The ozone layer, located in the stratosphere at an altitude between 12 and 50 km, protects life on earth from harmful ultraviolet radiation from the sun. Chlorine and bromine containing compounds have caused a thinning of the ozone layer in the past decades. These compounds are emitted into the atmosphere mainly from human activities, including industry and the use of products in households. The most important ozone-depleting compounds are the so-called chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), halons, carbon tetrachloride, methyl chloroform, methyl bromide and methyl chloride. Their application was, and partly still is, as an agent for refrigeration, air conditioning, foam blowing, aerosol dispersion, fire extinguishing, soil fumigation, and as solvents.

Since about 1980 the ozone layer has become thinner at mid-latitudes, but measurements and model calculations indicate that at the moment the ozone layer is not depleting further: it is near its minimum in northern hemispheric mid latitude (30–60 °N) where it averages about 3 % below pre-1980 values. Furthermore an ozone hole forms over the Antarctic every spring due to emissions of ozone-depleting substances from human activities and very low local temperatures. Depletions of the ozone layer also occur frequently over the Arctic in spring, but to a lesser extent than over the Antarctic and only partly due to ozone depleting substances. Variations in meteorological conditions play a more important role over the Arctic than over the Antarctic.

The thickness of the ozone layer exhibits a natural year-to-year variability. Detection of the start of the recovery is therefore difficult and not expected before the next decade, while a complete recovery of the ozone layer is not expected to occur before the middle of this century. The recovery will lead to a different atmosphere than that before 1980 due to an increase in the concentrations of GHGs; indeed, a super-recovery may occur with a thicker ozone layer than before 1980.

International actions to protect the ozone layer were agreed in the Vienna Convention of 1985 and the Montreal Protocol of 1987, with subsequent amendments and adjustments. This has resulted in a strong reduction in the global production, use and emissions of the major ozone depleting substances. Although the atmospheric concentrations of these substances has also started to decrease, due to their long lifetime they will remain in the atmosphere for decades or centuries to come. However, reductions are not taking place for HCFCs and HFCs which have a smaller effect on the ozone layer and are, in part, used as replacements for CFCs.

Depletion of the ozone layer and climate change are two separate issues, but with interactions:

- many substances that deplete the ozone layer are potent GHGs with warming potentials up to 10 000 times larger than CO_2. They stay in the atmosphere for decades and even centuries due to their long atmospheric lifetimes and will continue to contribute to climate change;
- the temperature in the stratosphere has decreased, in part due to the reduction of stratospheric ozone, but also because of the increases of CO_2. These lower temperatures may cause changes in wind patterns in the stratosphere but also in the troposphere and near the earth's surface. There are indications that the increase in the CO_2 concentration and depletion of the ozone layer can cause stronger westerly winds over Europe with possible effects on temperatures and precipitation;
- the increase in CO_2 concentrations also affect the ozone layer through the decreases in temperatures in the stratosphere. The lower temperatures are likely to increase the thickness of the ozone layer at mid-latitudes, but will probably result in decreases of the thickness of the ozone layer over the polar regions;
- increases in the emissions of other greenhouse gases such as CH_4 and N_2O also affect the chemistry of the ozone layer and may cause decreases and increases in thickness of the ozone layer;
- ozone is a GHG and depletion of stratospheric ozone has caused an indirect cooling effect;
- ozone-depleting substances are replaced in their traditional applications in part by hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs). These substances are GHGs with long atmospheric lifetimes — more than 10 000 years for some PFCs — and they will, therefore, contribute to climate change for many years to come (see also the section above on GHG emissions from industry).

Both the size of the overall effect of GHGs, and their significance for the recovery of the ozone layer, and the chemical and dynamic changes in the stratosphere are unclear and need further research to be resolved.

3.4 Greenhouse gas emissions (6)

3.4.1 Emission trends

Total emissions

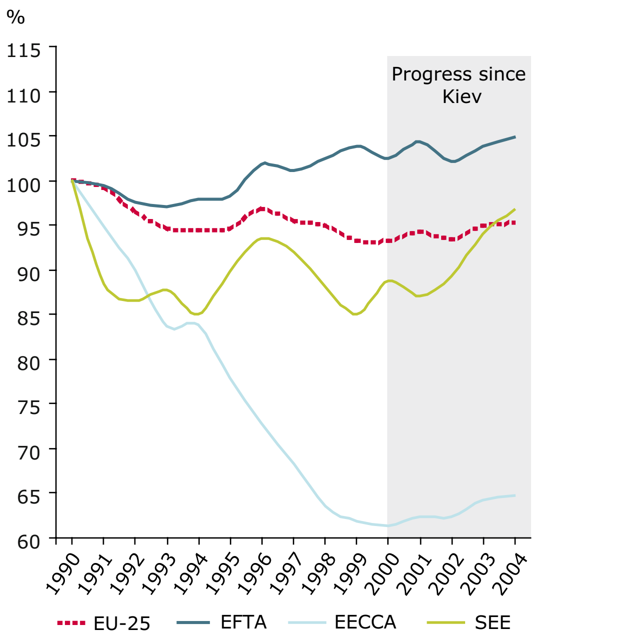
After a decrease during the early 1990s, total emissions of greenhouse gases (GHG) in each European region increased again during the first years of the 21st century (Figure 3.4). In 2004, total emissions from WCE were 5 091 million tonnes CO_2-equivalent (7), excluding land use, land-use change and forestry (LULUCF). This was 23 % of the total (17 981 million tonnes) for all Annex I countries — industrialised countries and countries that are undergoing the process of transition to market economies. Emissions from EECCA were 2 996 million tonnes, of which 2 074 million (69 %) were from the Russian Federation and 413 million (14 %) from Ukraine. Emissions from SEE were 599 million tonnes.

As a comparison the shares of total GHG emissions from industrialised countries, excluding LULUCF, in 2004 were about 40 % for USA, about 8 % for Japan and about 4 % each for Australia and Canada (UNFCCC).

Total emissions in the EU fell by about 5 % between 1990 and 2004. Decreases from the energy, industrial, agriculture and waste sectors were partly offset by increases from transport. The decrease in total EU emissions during the 1990s was due mainly to substantial reductions in the new Member States (EU-10). This, together with reductions during the same period in SEE and EECCA, was due mainly to the introduction of market economies and the consequent restructuring or closure of heavily polluting and energy-intensive industries. The economies in these countries have now recovered and increased emissions have been seen during the past few years. Total emissions in EFTA, except Switzerland, increased during the 1990s as a result of economic growth.

CO_2, the most important GHG, contributes about 80 % of total GHG emissions. Supply and use of energy — including transport — is by far the most important source across Europe, making up 80 % of emissions in EU-25. Transport counts for about 20 % of the emissions. Emissions from transport are more

Figure 3.4 Trends in total greenhouse gas emissions



Note: Total greenhouse gas emissions are based on sectoral reported data by gas, mostly to the UNFCCC. For some countries the reporting of some gases, mainly the fluorinated gases (and if a few number of cases of N_2O), was incomplete. Because of the relatively low weight of the F-gases in total greenhouse gas emissions, the trends presented in the chart above should reflect rather accurately the development of total greenhouse gas emissions in the four regions.
Index 1990 = 100. The volume of emissions in million tonnes of CO_2-equivalents in 1990 was:
EU-25 = 5 231; EECCA = 4 630; SEE = 620; EFTA = 106.

(6) For the presentation in this section the following grouping of countries has been used: EU-25 (EU Member States before 1 January 2007), EFTA, WCE (EU-25 + EFTA), EECCA and SEE. The data presented for those groups of countries is an average and there may be large variations between the individual countries within a group. Furthermore the quality of data used is of varying quality and sometimes data and/or time series are lacking from some of the countries. As far as possible, this is mentioned in footnotes or in the text.

(7) Different greenhouse gases have different climate change effects. To simplify presentations, all gases are expressed as the corresponding effect of CO_2 (CO_2-equivalents).

important in the WCE than in the SEE and EECCA regions (Figure 3.5).

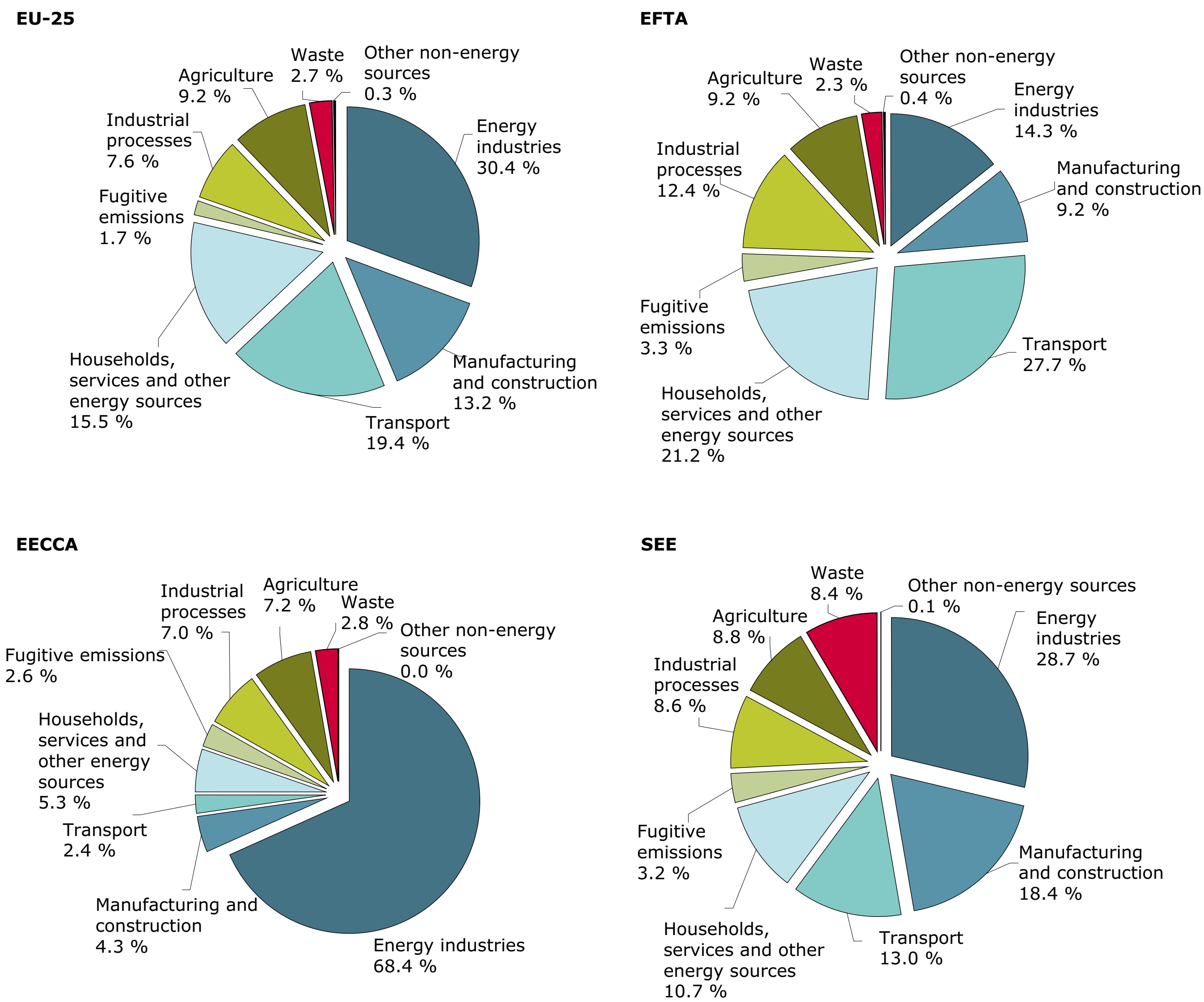
Per-capita emissions

Emissions per capita differ widely between the European countries, even within each region (Figure 3.6), which indicates that the overall economic situation may not be the only determinant. The comparatively high per-capita emissions from the EECCA countries is explained by the dominance of the Russian Federation.

Sectoral emissions

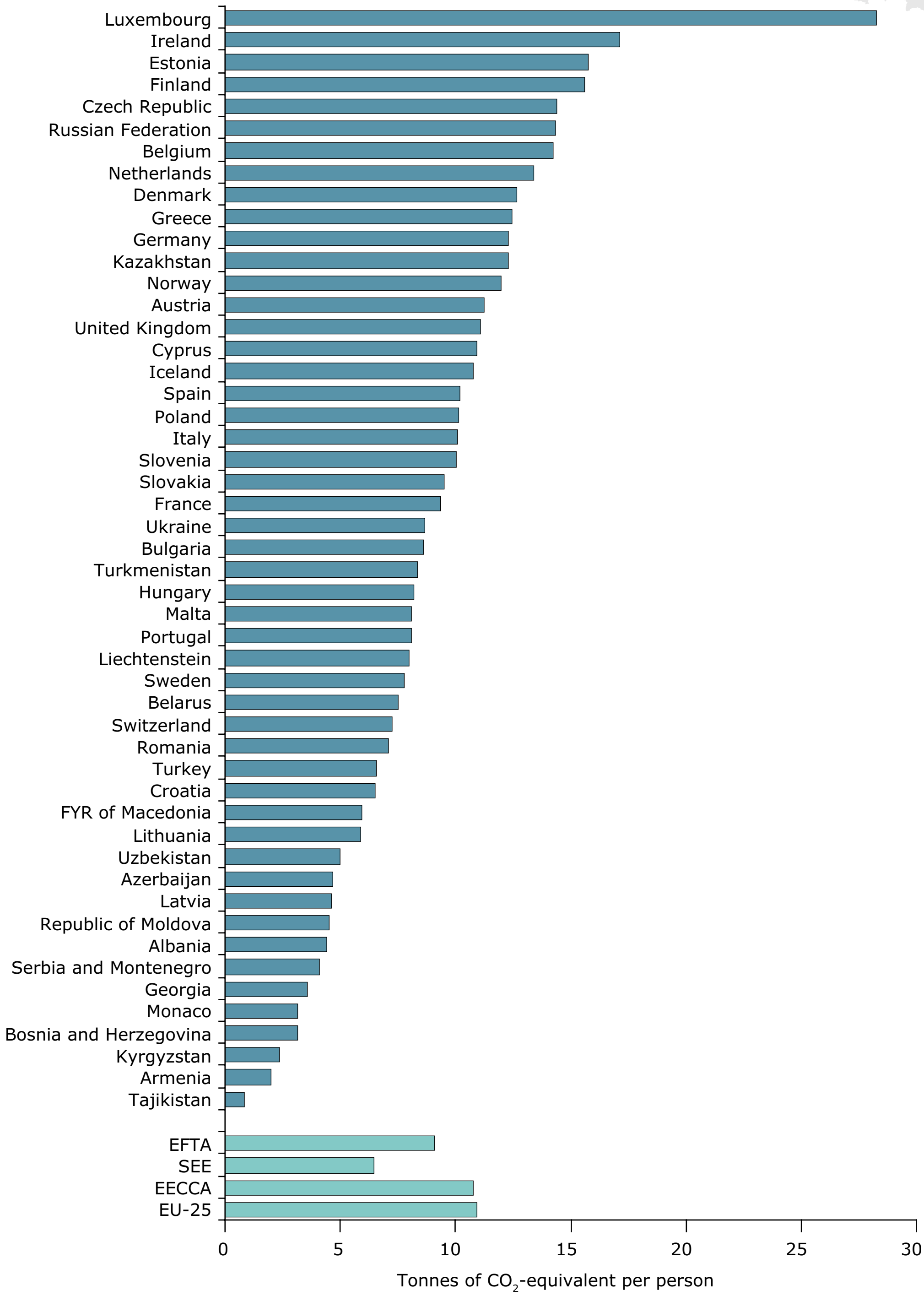
Emissions from energy supply and use, excluding transport, are the dominant source, contributing about 60 % to total GHG emissions in the EU

Figure 3.5 Share of total greenhouse gas emissions by sector in 2004



Note: The sectoral shares have been calculated using available sectoral data at the time of writing this chapter. For the EECCA countries the sectoral shares presented in the chart above fail to capture the current situation. This is mainly due to incomplete sectoral reporting by the Russian Federation. Emissions from transport and fugitive emissions were not reported separately in their NC4, and seemed to have been included under energy industries. The Russian Federation submitted their greenhouse gas national inventory report and CRF tables to the UNFCCC in January 2007. According to the CRF for 2004, fugitive emissions account for about 10 % of total greenhouse gas emissions. Transport was not reported separately. Since the Russian Federation represents more than 2/3 of the total emissions in the EECCA countries, the share of fugitive emissions in EECCA countries would be closer to 9–9.5 %.
The volume of emissions in million tonnes of CO_2-equivalents in 2004 was: EU-25 = 4 980; EECCA = 2 996; SEE = 599; EFTA = 111.

Figure 3.6 Total greenhouse gas emissions per capita in 2004



Note: Total greenhouse gas emissions are based on sectoral reported data by gas, mostly to the UNFCCC. For some countries where UNFCCC data, or official data provided by the country directly to the EEA, was not available, the IEA was the source of CO_2 emissions from the energy sector. For some of these countries (Albania, Armenia, Bosnia and Herzegovina, Serbia and Montenegro) CH_4 and N_2O were estimated using the GAINS model. In some other countries (Georgia, Kyrgyzstan, Republic of Moldova, Tajikistan, Turkmenistan, Uzbekistan) N_2O was not estimated. In the latter three (Tajikistan, Turkmenistan, Uzbekistan) estimates of N_2O and CH_4 were not available. As a result, total greenhouse gas emissions per capita, as presented in the chart above underestimate total greenhouse gases in these countries. The level of the underestimation is directly proportional to the size of the gas/gases not being included. Therefore, the country ranking does not necessarily provide a fair comparison of these countries *vis à vis* the countries where all gases were either officially reported or estimated.

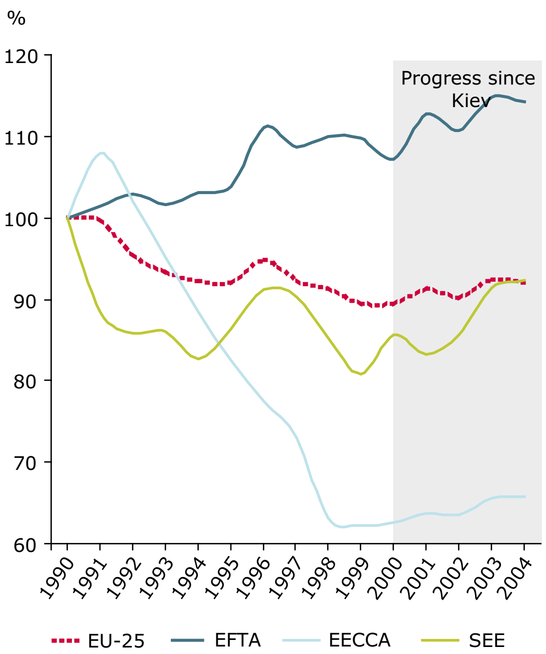
and SEE and about 80 % in EECCA. The share of emissions from the energy sector in EFTA is lower, about 50 %, because of the high share of hydro-power in their energy mixture.

During the 1990s emissions from this sector decreased in all regions except EFTA, with the largest decrease of around 40 % occurring in EECCA. However, in recent years, emissions in all regions have increased.

For further information on the energy sector, see Section 7. 3.

Emissions from transport account for about 20 % of total GHG emissions in WCE (around 27 % in EFTA), 13 % in SEE and 2 % in EECCA ([8]), with the sector showing the strongest increase during the 1990s, other than in EECCA. Emissions are projected to increase in all regions if no further actions are implemented.

Figure 3.7 Trends in energy-related greenhouse gas emissions, excluding transport, 1990–2004



Note: Emissions from transport were not reported separately by the Russian Federation, neither in their NC4, nor in their later 'greenhouse gas inventory' submission to the UNFCCC of January 2007. Transport emissions seem to be included under 'energy industries'. Because of the significant impact (i.e. 2/3 of the total GHG emissions) of the Russian Federation on the overall development for the EECCA countries, the trends shown in the chart above should be treated with some caution.
The volume of emissions in million tonnes of CO_2-equivalents in 1990 was: EU-25 = 3 294; EECCA = 3 650 (including transport from the Russian Federation); SEE = 396; EFTA = 47.

Within the transport sector, road transport is the largest source. International aviation and shipping are not covered by the Kyoto Protocol and are not included in Figure 3.8 left. While emissions from international marine transport were rather constant between 1990 and 2003, emissions from international aviation increased by 50 % (UNFCCC, home page) and are projected to increase dramatically in the coming years (European Commission, 2005a).

For further information on the transport sector, see Section 7. 2.

Emissions from industrial processes, excluding emissions from energy use in industry, contribute about 10 % to total GHG emissions in WCE (7.6 % in the EU and 12.4 % in EFTA), 9 % in SEE and 7 % in EECCA. The main sources are CO_2 from cement and lime production, and iron and steel production; HFCs from consumption of halocarbons, mainly in refrigeration, air conditioning, foam production and as aerosol propellants; and N_2O from the chemical industry, adipic and nitric acid production.

Emissions from industrial processes in the EU have increased in recent years and are projected to increase further (Figure 3.8 right). The main reasons for the growth in 2004, compared with 2003, were increases in cement production in France, Germany and Italy and increases in HFC consumption in refrigeration and air conditioning equipment in Germany and Italy (EEA Report No. 9/2006). Emissions in EECCA and SEE have also grown in recent years and are projected to continue doing so. In Turkey, for example, emissions rose by 69 % between 2000 and 2004 in spite of the introduction of improvements in energy efficiency in the steel and cement industries (Turkey, NC1, 2007).

GHG emissions from agriculture are dominated by nitrous oxide (N_2O) from soils, mainly due to the application of mineral nitrogen fertilisers; and

([8]) This is based on available data but the share for EECCA countries seems to be far too low.

methane (CH_4) from enteric fermentation, mainly from cattle.

In 2004 agriculture contributed about 9 % of total emissions in both WCE and SEE and about 7 % in EECCA.

Emissions from agriculture in EU-25 fell by 13 % between 1990 and 2004 (Figure 3.9 left) and are projected to decrease by a further 18–19 % by 2010. Decreases in fertiliser use and a reduction in the application of manure on land are likely to reduce N_2O emissions, and decreases in the number of cattle and increases in cattle productivity are likely to contribute to a decline in CH_4 emissions.

GHG emissions from waste management are dominated by CH_4 from solid waste disposal in landfills. Smaller sources are wastewater handling (CH_4, N_2O), and waste incineration (mainly CO_2).

In 2004 waste management contributed about 3 % of total emissions in both WCE and EECCA, and about 8 % in SEE.

GHG emissions from waste management in WCE fell markedly the last 10 years (Figure 3.9 right). The reduction is due mainly to legislation aimed at reducing the amount of waste sent to landfill and requiring capture of CH_4, for example for energy use.

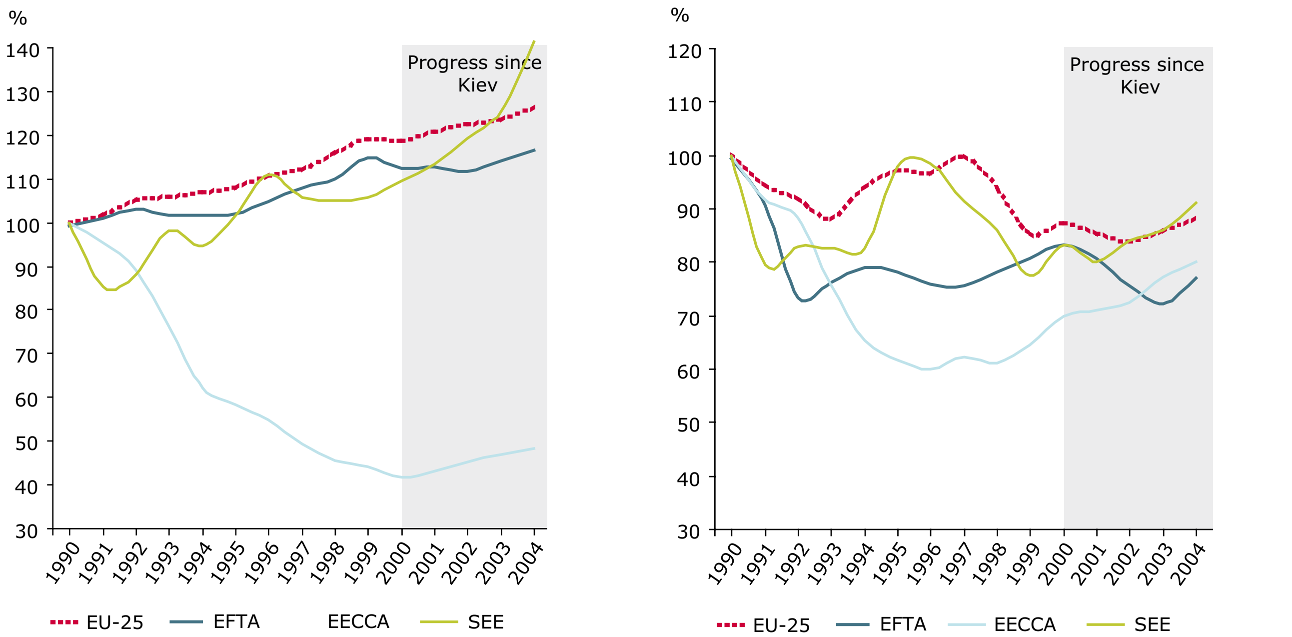
Emissions from waste management in EECCA and SEE increased during the same period but seems to have stabilised in recent years in SEE.

3.4.2 Emission targets and projections

Kyoto Protocol targets

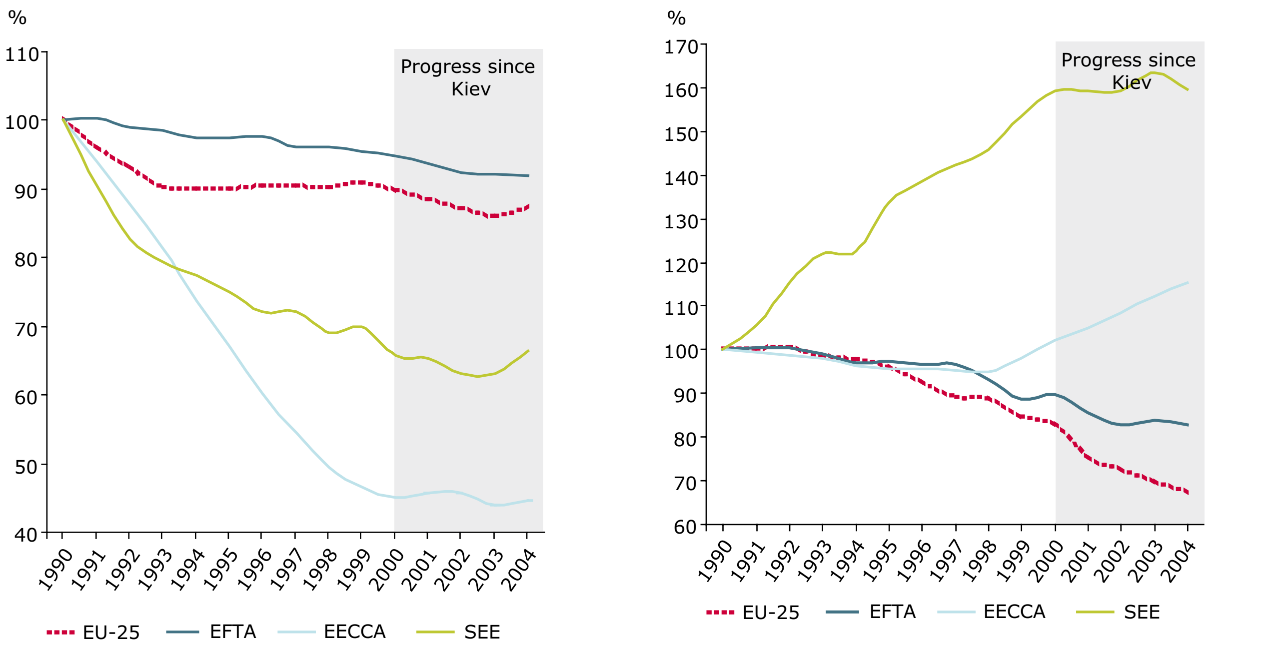
The UN adopted a Convention on Climate Change in 1992. A separate protocol under this convention — the Kyoto Protocol — was adopted in 1997 and entered into force on 16 February 2005. This sets binding targets for industrialised (Annex B) countries to reduce their emissions of GHG by 2008–2012. The EU-15 has a collective reduction target which replaces the individual commitments of these Member States. To meet this joint target,

Figure 3.8 Trends in greenhouse gas emissions from transport (left) and industrial processes (right)



Note: Emissions from transport were not reported separately by the Russian Federation, neither in their NC4, nor in their later 'greenhouse gas inventory' submission to the UNFCCC of January 2007. Transport emissions seem to be included under 'energy industries'. Because of the significant impact (i.e. 2/3 of the total greenhouse gas emissions) of the Russian Federation on the overall development for the EECCA countries, the trends shown in the chart above should be treated with great caution.
Index 1990 = 100. Emissions from transport in million tonnes of CO_2-equivalents in 1990 were: EU-25: 768; EECCA: 137 (excluding the Russian Federation); SEE: 55; EFTA: 27. The chart excludes emissions from international transport (which are not covered by the Kyoto Protocol, but for which data are reported by countries separately as a memo item). Emissions from industrial processes in million tonnes of CO_2-equivalents in 1990 were: EU-25: 431; EECCA: 268; SEE: 56; EFTA: 18.

Figure 3.9 Trends in greenhouse gas emissions from agriculture (left) and waste (right), 1990–2004



Note: Index 1990 = 100. Emissions in million tonnes CO_2-equivalent in 1990 from agriculture were: EU-25: 524; EECCA: 495; SEE: 79; EFTA: 11 and from waste: EU-25: 199; EECCA: 74; SEE: 32; EFTA: 3.

the Member States have agreed to meet individual burden-sharing targets laid down in the Council Decision 2002/358/EC. The targets for the EU-15 and other European Annex B countries are shown in Table 3.3.

By 1 January 2007, 168 countries and one regional economic integration organisation (EU-15) had ratified the Kyoto Protocol (UNFCCC). Among the industrialised countries with high GHG emissions that have chosen not to ratify the protocol are, most strikingly, USA, which produces 40 % of the total emissions from industrialised countries in 2003, and, to a lesser extent, Australia with 4 % of the total emissions in 2004.

The commitments originally included in the protocol, including for USA and Australia, would have reduced total GHG emissions of a basket of six GHGs from industrialised countries to 5.2 % below their levels in the base year — 1990 for most countries ([9]). Since not all developed countries have ratified the protocol, the overall reduction target is lower than foreseen in 1997. Current information on emissions indicates that the reductions projected for the ratifying countries are offset by increased emissions from the industrialised countries that have not ratified the protocol.

Progress towards Kyoto targets

Annex B parties to the Kyoto Protocol recently reported their GHG emission projections in their fourth national communications to UNFCCC. Projections are also available for some non-Annex B countries. In 2004, the aggregate GHG emissions of the EU Member States with a joint commitment (EU-15) were 0.9 % below the base-year level, with an increase of 0.3 % or 11.5 million tonnes CO_2-equivalent between 2003 and 2004. A further reduction of 7.1 % or 303 million tonnes CO_2-equivalent is needed to meet the Kyoto target. This is projected to be met by the implementation of further domestic policies and measures, and the use of the Kyoto mechanisms such as the Clean Development Mechanism (CDM), Joint Implementation (JI) and emissions trading (see

([9]) For the following countries 1990 is not the base year for CO_2: Hungary (average 1985–1987), Poland (1988), Slovenia (1986), Bulgaria (1988) and Romania (1989). Except Finland (1990) and France (1990), countries have selected 1995 as the base year for F-gases.

Table 3.3 Reduction targets (commitments) for industrialised (Annex B) countries in the Kyoto Protocol for 2008–2012

Country	Target (%)
EU-15	– 8
Belarus *	– 8
Bulgaria	– 8
Croatia **	– 5
Czech Republic	– 8
Estonia	– 8
Hungary	– 6
Iceland	+ 10
Latvia	– 8
Liechtenstein	– 8
Lithuania	– 8
Monaco	– 8
Norway	+ 1
Poland	– 6
Romania	– 8
Russian Federation	0
Slovakia	– 8
Slovenia	– 8
Switzerland	– 8
Ukraine	0

* Belarus: Proposed amendment by CMP 2 in Nairobi. Pending ratification by other parties.

** Croatia: Not ratified as of January 2007.

Note: The commitments refer to a base year — normally 1990.

Section 3.4.2). Member States forecast that they will achieve reductions of over 100 Mt CO_2-equivalent per year through the use of the Kyoto mechanisms (EEA, 2006).

The eight new EU Member States that have a Kyoto Protocol target project to meet are, with the exception of Slovenia, doing so, and in some cases even over-achieving their targets by 2010, with existing domestic policies and measures. Slovenia, in order to meet its target, will have to use additional policies and measures and include CO_2 removals from land-use change and forestry.

The EFTA countries Norway and Switzerland project that they will fall short of their Kyoto targets.

The SEE and EECCA countries with Kyoto Protocol targets, Russian Federation, Ukraine, Bulgaria and Romania, all expect to meet them, as does Belarus with the proposed amendment to – 8 %.

Post-Kyoto targets

The Kyoto Protocol is only a first step towards the objective of the UNFCCC, which is to stabilise greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous interference with the climate system within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner (UNFCCC).

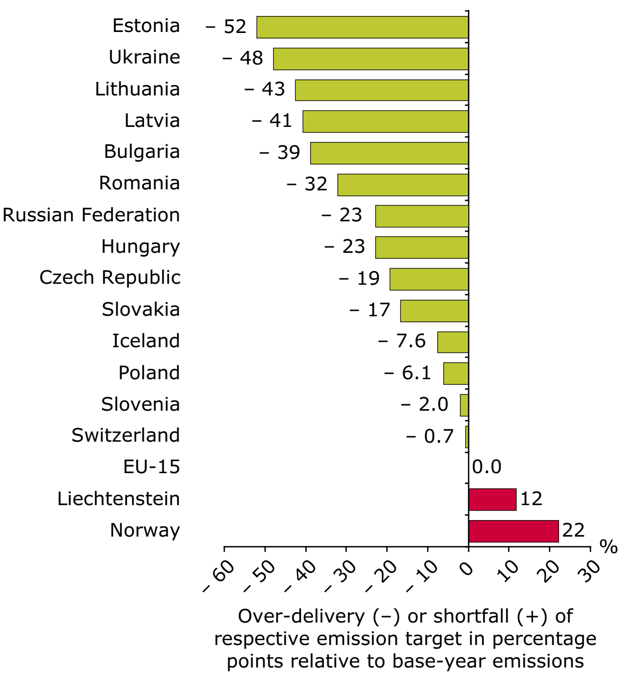
As a long-term target, the EU has proposed limiting global temperature increase to a maximum of 2 °C above pre-industrial levels. To meet this, it has stated a need for a global emission reduction of 15–50 % by 2050 compared to 1990 levels. For developed countries, the EU indicates that this may mean a reduction to 15–30 % by 2020 and 60–80 % by 2050. To achieve that, newly industrialised and/or developing countries, in addition to the current Annex B countries, will have to take actions to reduce their GHG emissions ([10]).

Furthermore, the European Commission has presented a comprehensive package of proposed policies and measures to establish a new energy policy for Europe to combat climate change and boost the EU's energy security and competitiveness. It was presented on 10 January 2007 and contains a series of ambitious targets for greenhouse gas emissions. The Commission was seeking, and essentially achieved, endorsement of the energy and climate change proposals during the Spring European Council on 9 March 2007 and will come forward with legislation in light of the Council conclusions.

At the UNFCCC COP11/MOP1 meeting in Montreal in December 2005 a procedure started to further develop emission reduction approaches with all countries under the Convention, and to establish a second commitment period for all developed countries. This procedure continued at

([10]) Council conclusions 10 March 2006 (7225/06).

Figure 3.10 Relative gaps (over-delivery or shortfall) between projections and targets for 2010



Note: A negative figure means that the Kyoto target is projected to be reached ('over-delivery') by the country. A positive figure means that the Kyoto target is not projected to be reached ('shortfall') by the country. Data based on projections provided by countries before 6 June 2006 (except for Russia and Ukraine). Projections include, where data were available, the projected effects of domestic policies and measures intended but not yet implemented, the use of Kyoto mechanisms and carbon sinks, except for Norway, Liechtenstein, Poland, Iceland and Lithuania. Norway and Liechtenstein project to reach their targets with the use of Kyoto mechanisms.

Sources: EEA report No 9/2006: Greenhouse gas emissions trends and projections in Europe 2006; Ukraine's report on Demonstrable Progress Under the Kyoto Protocol, 2006; Draft of NC4 of the Russian Federation for the Articles 4 and 12 of the UNFCCC and article 7 of the Kyoto Protocol, 2006.

the COP12/MOP2 meeting in Nairobi and further discussions will take place in future COP/MOP meetings.

Longer-term projections, up to 2020, are available for some countries in their national communications. With few exceptions, these projections show increasing emissions after 2010, indicating that mitigation programmes so far might have been focused on the Kyoto targets and that further far-reaching measures will have to be implemented to meet the longer-term targets.

3.5 Mitigation

Domestic programmes with policies and measures to reduce GHG emissions, mainly in order to meet the Kyoto targets, have been implemented in Annex B countries. In addition to domestic measures, the flexible mechanisms under the Kyoto Protocol, including the use of carbon sinks, can be used to meet the targets. In the EU many of the domestic actions that have already been implemented are based on EU coordinated policies and measures.

3.5.1 Domestic policies

Domestic policies and measures intended to reduce national emissions are discussed in this section. Measures to achieve reductions in other countries (Kyoto mechanisms) are discussed in the next section. There may be synergies between actions to mitigate other environmental problems such as air pollution and those to mitigate climate change, but this section focuses on specific GHG emission-reduction measures.

GHG emission-reduction measures need to be implemented in all sectors of the economy. They may be applied to just one sector or more generally to influence a number of sectors. An example of a policy instrument focusing on one sector is direct emissions regulations for certain types of products, such as the commitment made by European, Japanese and Korean car manufacturers for CO_2 emissions from new passenger cars sold in the EU. An example of a more general measure is a CO_2 tax on fossil fuels, which in some EU Member States has been replaced by the EU Emissions Trading Scheme (ETS), which affects a large number of energy and industry installations.

As the energy and the transport sectors are by far the largest contributors to GHG emissions, they require special attention when designing mitigation programmes. These have, to some extent, been successful in the energy sector but less so in the transport sector. Experience with programmes in EECCA and SEE shows that there is a large potential for improvements in energy efficiency (see Section 7.3, Energy).

Examples of policies and measures to reduce emissions of GHGs, including F-gases ([11]), from industrial processes are: abatement measures in adipic and nitric acid production to reduce N_2O emissions; the use of alternatives to HFCs in refrigeration and air conditioning; and modernisation of the steel and cement industry in for example, Turkey and Ukraine. Direct regulations and voluntary agreements are used in many countries as the main policy instruments for achieving emission reductions. For example in June 2006, the EU presented legislation on F-gases and mobile air conditioning (European Parliament and Council, 2006a; 2006b) to further reduce emissions of F-gases.

In the agriculture sector, decreases in fertiliser use and a reduction in the application of manure on land are likely to reduce N_2O emissions, while decreases in the number of cattle, as in the EU, and increases in cattle productivity are likely to contribute to a decline in CH_4 emissions.

The strong decline in livestock numbers and agricultural input use in many EECCA, SEE and EU-10 countries resulting from the political changes since 1990 are the key factors behind falling emissions from the farming sector in these regions.

Technological change, increased economic efficiency, implementation of the EU Nitrates Directive and reforms of the EU agriculture policy have all contributed to the fall in emissions from agriculture in EU.

Increased use of less energy-intensive crops and a decrease in more energy-intensive ones are helping to reduce GHG emissions (e.g. Ukraine).

A substantial reduction in CH_4 emissions from waste management can be achieved by reducing the amount of landfilled waste and requiring the capture of CH_4 emissions from landfills, for example for energy generation. This is an area for quite cost-effective measures.

The Former Yugoslav Republic of Macedonia and Ukraine project a slight decrease in emissions from the waste sector from 2000 to 2010, while all other SEE and EECCA countries are projecting increases — indicating a potential for mitigation measures. In the EU, due to the Landfill Directive, CH_4 emissions fell by around 25 % between 1990 and 2004. Emissions in the EU are projected to decline further by increasing the use of CH_4 for energy generation, and the diversion of biodegradable waste from incineration to composting or anaerobic treatment.

3.5.2 Kyoto mechanisms

The Kyoto Protocol provides for three flexible mechanisms: Joint Implementation (JI), Clean Development Mechanism (CDM) and international emissions trading, which parties, under certain circumstances, may use to supplement domestic measures to meet their commitments. In addition, green investment schemes (GIS) have been promoted, without being specifically mentioned in the protocol. Such schemes involve trading of assigned amount units (AAUs) but also include emission reduction projects and therefore are a net environmental improvement, unlike international emission trading. The EU emissions trading scheme, introduced in 2005 and linked to the Kyoto mechanisms, allows operators within the EU to use credits generated by JI or CDM up to a maximum decided by the individual Member State.

Joint Implementation

Under Article 6 of the Kyoto Protocol, Annex B countries may invest in Joint Implementation (JI) projects which produce emission reduction units (ERUs) by reducing GHG emissions or increasing removals by carbon sinks — land use, land-use change and forestry — in other Annex B countries. Any such projects need the approval of the countries involved and must result in emission reductions that would not otherwise have occurred. The ERUs generated are transferred to the investing country which can use them to fulfil its reduction commitments. Generation of ERUs can only take place during the commitment period (2008–2012).

The JI mechanism gives countries that are having difficulties in meeting their Kyoto targets an

([11]) F-gases are a group of greenhouse gases (fluorinated gases) with a very high climate change potential.

opportunity to invest in projects to reduce GHG emissions in other countries that have a Kyoto target. GHG mitigation costs in these latter countries, for example in the energy demand and supply sector, are expected to be lower than in western Europe. In addition, many of these countries need investment in their energy sector. Thus this is potentially a win-win situation.

In principle, there are two tracks to follow when establishing a JI project. In Track I the host country itself may decide how to monitor, verify and issue ERUs. To be eligible to do this it has to fulfil certain requirements, one of which is having a national system for GHG inventory compilation and reporting. In Track II, the projects are subject to a mandatory international verification procedure established within UNFCCC. A special JI supervisory committee must then verify the ERUs generated.

As of today a number of EU Member States have set up organisational structures and allocated government funding for JI projects, for example Romania and Bulgaria have signed a Memorandum of Understanding with a number of EU Member States (EEA, 2006). EECCA countries, for example Belarus and Ukraine, have reported that they are in the process of setting up JI projects and aiming to be eligible to do so by Track I.

Clean Development Mechanism

Under Article 12 of the Kyoto Protocol, Annex B countries can use the Clean Development Mechanism (CDM) to invest in projects to reduce GHG emissions in developing countries (non-Annex I countries). Depending on the emission reductions achieved, certified emission reduction units (CERs) are issued which Annex B countries can use to meet their commitments. As with JI, CDM projects must result in reductions that would not otherwise have been achieved. They have the additional aim of promoting sustainable development in the host country by offering modern technology.

The costs of CDM projects to reduce emissions are generally expected to be low compared with many domestic policies and measures. Many European countries that are not on track to achieve their Kyoto targets, and also Japan and possibly Canada, will, to some extent, rely on CDM to achieve their targets. Since there is a strong need for investments in non-Annex B countries in SEE and EECCA, in particular in the energy sector, there is a large potential for CDM. During recent years, financial and technical support has been offered to EECCA countries, including through TACIS financing, for capacity building to improve their ability to act as host countries for CDM projects. These projects have resulted in organisational improvements and identification of possible future projects, with, in some cases, memoranda of understanding being signed between EU and EECCA countries. However, by the beginning of 2007, very few projects hosted by EECCA countries had been registered by the CDM Executive Board (see Box 3.3).

Many CDM projects are small-scale, which may be a barrier to the large increase in CDM projects that is needed. Special procedures are continuously being implemented for 'bundling' such small-scale projects to reduce the administrative costs.

International emissions trading

Article 17 of the Kyoto Protocol allows Annex B countries to transfer assigned amount units (AAUs) among each other through emissions trading. Countries that have achieved emission reductions over and above those required by their Kyoto targets may sell their excess AAUs.

The Russian Federation and Ukraine had relatively large emissions in 1990 — the Russian Federation 2 961 million tonnes of CO_2-equivalent (Ref: NC4) and Ukraine 925 million tonnes (Ref: Report on demonstrable progress) — both without LULUCF ([12]). Emissions then fell during the first half of the 1990s due to economic restructuring and a decrease in economic activity. Although these economies have since recovered, Russian and Ukrainian emissions are projected to be substantially below their Kyoto targets (to keep emissions at the 1990 level). Together they will be around 1 100 million tonnes below their Kyoto targets by 2010. The Russian Federation and

([12]) Land use, land-use change and forestry.

Box 3.3 Clean Development Mechanism (CDM) — an opportunity for win-win projects

The use of the Clean Development Mechanism (CDM) was included in the Kyoto Protocol to encourage the industrialised countries to invest in environmentally beneficial technology in developing countries, while at the same time using the resulting GHG emission reductions to help meet their Kyoto targets.

A separate organisation has been set up with an Executive Board and a number of panels dealing with different questions such as monitoring methodologies, accreditation issues and small-scale projects. This organisation and the administrative process is there to ensure that the number of CERs generated by a project is appropriate.

To set up a CDM project the following steps have to be followed:

1. project design;
2. formal approvals by host and investing parties;
3. validation and registration of the project activity;
4. implementation and monitoring;
5. verification and certification;
6. issuance and distribution of CERs.

For small-scale projects certain simplifications have been implemented in the formal process such as a simplified project design document, methodologies for baseline determination, monitoring plans and provisions for environmental impact analyses. The review period for registration is also shorter and the same Designated Operational Entity (DOE) can validate, as well as verify, and certify emissions reductions (UNFCCC). In addition it is possible to bundle small-scale projects into one to further limit the administrative burden.

To avoid creation of other environmental problems the description of the CDM project must include an Environmental Impact Assessment.

CDM projects have been able to generate CERs since January 2000 and these can be banked for use during the first commitment period (2008–2012). The rules governing CDM projects allow only certain types of sink projects — afforestation and reforestation — and may not exceed 1 % annually of a party's base-year emissions. Countries will not be able to use credits generated by nuclear power projects towards meeting their Kyoto targets.

By 1 January 2007, 472 projects were registered by the CDM Executive Board. These were estimated to generate at least 700 million CERs (tonnes of CO_2-equivalents) up to the end of 2012. Major host countries, by number of projects, are India, 29.9 %; Brazil, 18.6 %; and Mexico, 15.3 %. China, with a 43 % share, is by far the largest host country in terms of number of CERs generated.

Taking into account the need and potential for, for example, energy efficiency improvements in EECCA and SEE countries, the use of CDM should be an obvious area for win-win activities in Europe. However, by 1 January 2007 only five CDM projects with EECCA or SEE host countries had been registered.

Table 3.4 CDM projects hosted by EECCA and SEE countries as of 1 January 2007

REF	Host country	Other party	Reductions CO_2-equivalent tonnes/year	Content
Project 0452 11/09/06	Armenia	Denmark	62 832	Methane capture and combustion from poultry manure treatment
Project 0173 29/01/06	Republic of Moldova	Netherlands	11 567	Energy conservation
Project 0159 20/01/06	Republic of Moldova	Netherlands	17 888	Biomass heating
Project 0160 20/01/06	Republic of Moldova	Netherlands	17 888	Biomass heating
Project 0069 28/11/05	Armenia	Japan	135 000	Landfill gas capture

Ukraine, and to a lesser extent some SEE countries, are therefore likely to have a surplus of emission allowances to offer in 2008–2012. In addition, if Kazakhstan ratifies the Kyoto Protocol and if the amendment proposed by the second Meeting of the Parties to the Kyoto Protocol (COP12/MOP2) in Nairobi concerning Belarus comes into force, there will be a further surplus of allowances.

Following negotiation in Marrakech, several countries are allowed to include emissions from forestry management in their base-year emissions, and thus in their emission allowances for 2008–2012. This will increase the number of allowances available for international trading. The Russian Federation, for example, is allowed to account around 120 million tonnes of CO_2 annually during the first commitment period for forest management activities.

Green investment schemes (GIS)

Extensive trading of surplus allowances, as a replacement of domestic actions, would not necessarily decrease GHG emissions during the first commitment period. This is because the country selling the allowances would not need to invest the resources acquired in measures aimed at reducing GHG emissions. Green investment schemes (GIS) have therefore been promoted as an alternative to international Kyoto emissions trading to ensure that actual GHG emission reductions take place. Profits generated from the sale of assigned amount units are invested in programmes that include one or several projects to reduce the GHG emissions. An advantage is that GIS funds, in addition to financing concrete emission-reduction projects, might finance capacity building and the establishment of emissions inventories and reporting systems.

The Russian Federation introduced the concept in the formal UNFCCC negotiations in 2002 and, for example, Romania has made a recent study on the use of GIS (Romania, NC4). Belarus, at the (COP12/MOP2) in Nairobi, stated that, providing the proposed amendment to include Belarus in Annex B of the Kyoto Protocol comes into force, it will invest the income from sales of surpluses of assigned amounts into emission-reduction projects.

3.6 Adaptation to climate change

More pronounced climate change impacts on most sectors of the economy and on natural resources are projected to occur even if emissions of greenhouse gases are reduced drastically. Adaptation strategies are therefore required, in addition to mitigation strategies. Adaptation means policies, practices and projects which can either moderate damage and/or, in some specific cases, exploit opportunities associated with climate change.

Adaptation initiatives

The need for adaptation has been recognised at different levels. At the global level, the 2004 UNFCCC conference agreed to develop a five-year, structured programme of work on the scientific, technical and socio-economic aspects of impacts, vulnerability and adaptation to climate change. Furthermore, UNFCCC and the Kyoto Protocol have initiated several funds specifically to address adaptation in developing countries, which are often the most vulnerable and have the least capacities to adapt.

At the EU level, the need to prepare for and adapt to the consequences of inevitable climate change impacts in many societal sectors has been highlighted, for example in the Environment Council in 2005. Because of the multi-sectoral and international nature of the adaptation issue, the second phase of the European Climate Change Programme (ECCP), launched in October 2005, includes a work programme on climate change impacts and adaptation. The ECCP identified various reasons why adaptation should have a European dimension, although measures will actually be implemented at the regional and local levels. As part of the ECCP, meetings with stakeholders from many sectors and countries were held during the first half of 2006, demonstrating the need to involve a wide range of sectors and organisations in discussions on climate change adaptation. As an outcome of the programme, the European Commission published a green paper in June 2007 (European Commission, 2007) .

At the national level, Member States recognise the need for adaptation strategies, as shown in their national communications to UNFCCC. Some countries, for example Finland have already developed a national adaptation strategy, others are in the process of doing so, for example Denmark, Germany, the Netherlands and the United Kingdom. In many other countries, such as Switzerland, adaptation measures are planned or being implemented in the context of natural hazard prevention, environmental protection and sustainable resource management (EEA, 2005). Furthermore, many EU Member States have initiated research projects/programmes on climate change vulnerability and adaptation. A number of countries, however, have not yet initiated a national adaptation strategy. There are various reasons for this, including relatively more focus on climate change mitigation, uncertainties concerning future climate change impacts, and perceived relatively low vulnerability.

Most SEE and EECCA countries are also quite concerned about the issue, as shown by the adaptation measures proposed in their national communications and the United Nations Convention on Combating Desertification (UNCCD) review report on implementation. Various measures have been proposed, particularly for the agriculture sector because of its importance for the economies of these countries. Many of the measures in this sector are related to reducing the risk of desertification and salinisation. Most of these focus on establishing or improving the efficiency of irrigation systems as a result of the projected decreases in precipitation, for example in Armenia, Romania, the Russian Federation, Tajikistan and Uzbekistan. Other proposed measures deal with changes in crop management, such as alternative crop types, and making use of potential new opportunities. The Russian Federation, for example, explicitly mentioned utilising new areas in central and northern Russia that are likely to become more suitable for crops as a result of climate change in its recent NC4.

Water

Various adaptation measures for the water sector have been proposed, often aimed at addressing water shortage issues (EEA, 2007). Measures proposed in nearly all countries are improved water-use efficiency, a reduction of water losses, and improved water recycling. Less common proposals are changes in lifestyles, for example from Romania, and a redirection of water flows, from Uzbekistan, amongst others. Various countries, including Belarus, Hungary, the Netherlands and Switzerland, have also proposed flood-control measures, often linked to spatial planning. Examples include compartmentalisation of low-lying areas in the Netherlands to limit the area that could become flooded, and the assignment of flood areas in Hungary. Various countries have proposed measures to combat coastal erosion, flooding and inundation of coastal lowlands and saltwater intrusion caused by rising sea levels. Examples include the establishment of good monitoring networks in Turkey, changes in the design of dams, harbours and other structures in Iceland, enhanced coastal protection in Belgium and the Netherlands, and an improvement of coastal environmental conditions.

Biodiversity

Although climate change considerations have not yet been integrated into the EU's Habitats and Birds Directives, the need for adaptation to climate change has been explicitly mentioned in the European Commission's 2006 communication on biodiversity.

Various measures have been proposed and/or planned both at the European and national levels to help nature to adapt to climate change. Examples include:

- Communicating the severity of the climate change issue among biodiversity experts and/or nature conservation organisations;
- reducing non-climate pressures on biodiversity, e.g. from land-use changes;
- improving the quality and extent of current protected areas, such as Natura 2000 areas in the EU;
- connecting protected sites by establishing corridors or additional areas outside protected sites, which could help species to migrate;
- integrating/harmonising biodiversity policy with other policies.

Various SEE and EECCA countries are concerned about the vulnerability of their nature systems to climate change, especially if it results in land degradation or desertification. Proposed adaptation measures include the establishment of a good monitoring network in Albania and Georgia; the inclusion of climate change in nature development plans in Belarus; changes in management in the Russian Federation; and the establishment of new nature areas to act as 'green corridors' in Kyrgyzstan.

Human health

Various countries have also formulated adaptation strategies in the context of human health and climate change. Many strategies include measures such as improved monitoring of vulnerable people in Armenia and France; and of drinking water quality in Albania.

In general, adaptation measures are currently less well-defined and implemented than mitigation measures. Although measures will be implemented at the national and local level, there is a role for the EU and UNECE, for example in facilitating and harmonising the various initiatives that have been proposed. A number of research programmes on adaptation to climate change have recently been started at the European level, which should help to define and implement adaptation measures.