3.1. Greenhouse gases and climate change

Main findings

Global and European annual mean air temperatures have increased by 0.3-0.6°C since 1900. 1998 was globally the warmest year on record. There is augmenting evidence that emissions of greenhouse gases (GHGs – mainly carbon dioxide (CO_2)) are causing air temperature increases resulting in climate change. Climate models estimate further increases, above 1990 levels, of about 2°C by the year 2100. It is unlikely that stable, potentially sustainable, atmospheric greenhouse gas concentrations will be realised before 2050. An immediate 50-70% reduction in global CO_2 emissions would be needed to stabilise global CO_2 concentrations at the 1990 level by 2100.

The issue of climate change is being addressed through the United Nations Framework Convention on Climate Change (UNFCCC). The EU's commitments are to stabilise CO_2 emissions by 2000 at 1990 levels and to reduce emissions of the main six greenhouse gases by 8% in 2008-2012 from 1990 levels (Kyoto Protocol).

EU CO_2 emissions decreased by 1% between 1990 and 1996, due to relatively low economic growth, increases in energy efficiency, economic restructuring of the new Länder in Germany and fuel switching from coal to natural gas in the UK. However, CO_2 emissions are projected to increase under the pre-Kyoto baseline scenario by 8% above 1990 levels by 2010 with transport sector emissions increasing by 39% while industrial sector emissions decline by 15%. The shift from solid fuels to gaseous fuels is projected to continue. Total EU GHG emissions are projected to increase 6% above 1990 levels by 2010 – clearly missing the 8% reduction target. Additional policies and measures will therefore be necessary to meet the Kyoto Protocol commitment.

In the Accession Countries CO_2 and GHG emissions are projected to decrease by 8% and 11% respectively between 1990 and 2010. This would imply a 2% increase in GHG emissions for an enlarged EU – still well short of the existing EU's 8% reduction target.

EU action thus far includes target sharing between Member States, an agreement with the car industry to reduce CO_2 emissions from new passenger cars, and energy/CO_2 taxes at national level but not – as yet – EU-wide. Consideration is being given to uses of the so-called 'Kyoto mechanisms' - emission trading, joint implementation, and the 'clean development mechanism', although the total technical reduction potential for measures with costs below 50 euro/tonne CO_2 equivalent is estimated to be more than what is needed to achieve the EU 8% reduction target. Forest carbon sinks in the EU are estimated to be only up to 1% of the 1990 EU CO_2 emissions.

1. An issue under international scrutiny

1.1. From greenhouse gases to climate change

Climate change is widely recognised as a serious potential threat to the world's environment. The problem is being addressed through the United Nations Framework Convention on Climate Change (UNFCCC), most recently at the fourth Conference of the Parties at Buenos Aires in November 1998 (UNFCCC, 1999). It has been identified by the EU as one of the key environmental themes to be tackled under the Fifth Environmental Action Programme (5EAP).

The greenhouse effect of the Earth's atmosphere is a natural phenomenon, without which the Earth's temperature would be much lower, whereby atmospheric concentrations of water vapour and carbon dioxide (CO_2) trap infrared radiation.

Over the past century there have been increases in atmospheric concentrations of anthropogenic greenhouse gases – carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), as well as halogenated compounds such as CFCs, HFCs and PFCs. Over the same period a considerable increase, in historic terms, in global mean temperature has been observed. There is augmenting evidence that emissions of greenhouse gases from human activities are causing an enhanced greenhouse effect in the form of global warming) (IPCC, 1996; IPCC, 1997a and 1997b).

Fossil-fuel combustion resulting in CO_2 emissions is the dominant human activity (driving force) causing the enhanced greenhouse effect. Other activities that contribute to greenhouse gas emissions are agriculture and land-use changes including deforestation, certain industrial processes such as cement production, landfilling of wastes, refrigeration, foam blowing and solvent use.

Climate change resulting from the enhanced greenhouse effect is expected to have widespread consequences, causing:

- sea-level rise and possible flooding of low-lying areas;
- melting of glaciers and sea ice;
- changes in rainfall patterns with implications for floods and droughts;
- changes in the incidence of climatic extremes, especially high-temperature extremes.

These effects of climate change will have impacts on ecosystems, health, key economic sectors such as agriculture, and water resources.

There is now general recognition that policy action is needed to curb greenhouse gas emissions and that it is important to identify the extent to which consequences of climate change can be minimised by adaptation measures. Decreased emissions of greenhouse gases can have other beneficial effects (see also Chapters 3.4 and 3.11), such as:

- reduction in CO_2 emissions from fuel combustion by – for example – fuel switching to natural gas or by increased use of renewables, which also helps to reduce the emissions of other pollutants that cause acidification, troposheric ozone and reduced air quality;
- reduction in methane emissions also helps to reduce the general background levels of tropospheric ozone.

1.2. Current indications and impacts of climate change

Temperature increase

Global mean surface air temperature has increased by about 0.3-0.6°C since the late 19th century (IPCC, 1996). The year 1998 was globally the warmest year on record. In Europe similar increases in temperature have been observed, although the natural variations in regions are larger than those that occur for the global average (Figure 3.1.1).

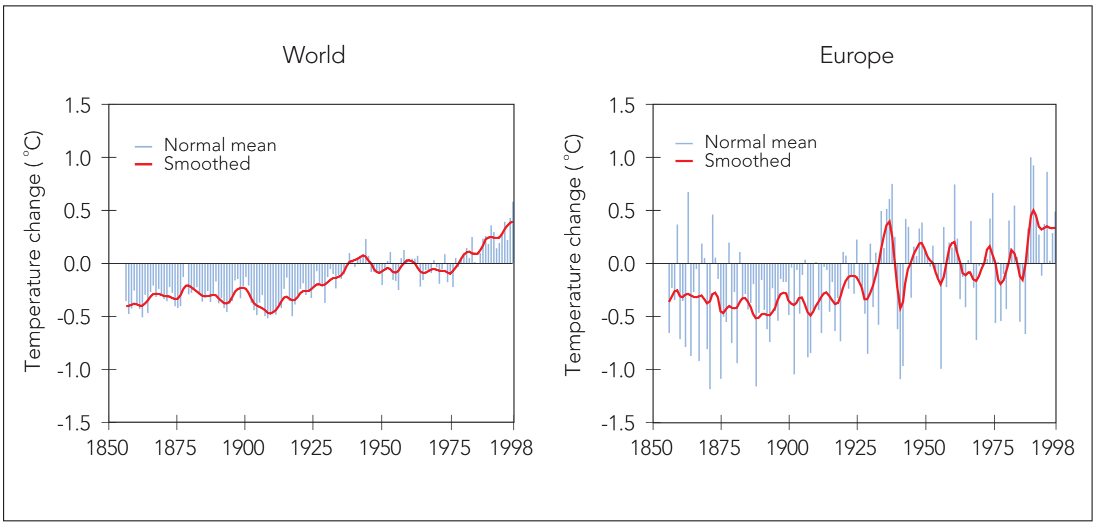
The warming effect is more prominent at higher latitudes in the northern hemisphere (Figure 3.1.2).

An observed sea level rise

Global warming causes oceans to warm and therefore expand, and increases the melting of glaciers and sea ice. Climate change can thus affect sea levels which have increased by

Figure 3.1.1 **Observed global and European annual mean temperature deviations from 1856 to 1998**

Between 1856 and 1998, the yearly deviations from the 1961-1990 global average and European temperature (in addition smoothed to show 10 yearly variations in temperature) show an increase of 0.3° C to 0.6° C. The year 1998 was globally the warmest year on record, and 1997 the warmest before that. This is partly due to the 1997/1998 El Niño/Southern Oscillation (ENSO), which was the largest on record (Hadley Centre/The Met. Office, 1998a). The ENSO phenomenon is a cycle of natural fluctuations of Pacific ocean temperatures resulting in large-scale changes in tropical rainfall and wind patterns.



Source: CRU, 1998; Hadley Centre, 1998a

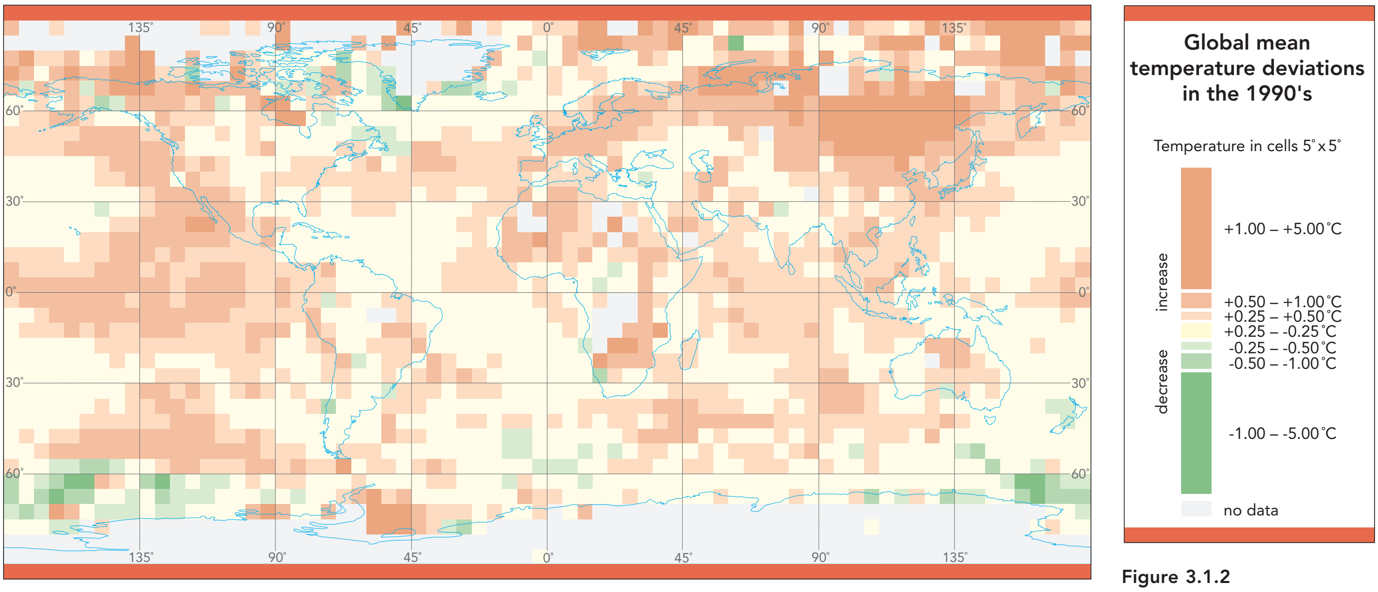


Figure 3.1.2

The mean annual temperatures in the 1990s are well above the mean annual temperatures from 1961 to1990.

Source: CRU, 1998; Hadley Centre, 1998a

10-25 cm in the past 100 years, the range reflecting differences in different parts of the world and uncertainties in the measurements. The rate of increase does not appear to be changing but it is significantly higher than that averaged over the past few thousand years (IPCC, 1996).

Greenhouse gas concentrations and global emissions increase

There has been a marked upward trend in atmospheric concentrations of CO_2, CH_4 and N_2O since pre-industrial times. The so-called 'new greenhouse gases' (the halogenated substances HFC, PFC and SF_6) entered the atmosphere only after mankind started using them in the past few decades. Table 3.1.1 shows the estimated contributions of these gases to global warming.

In addition to these gases, tropospheric ozone (O_3) may also augment global warming, by a further 16% (IPCC, 1996).

Aerosols, consisting of small particles or droplets either emitted directly (primary aerosols) or formed in the atmosphere from sulphur dioxide (SO_2), nitrogen oxides (NO_x) and ammonia (secondary aerosols), can have a cooling effect (see also Chapter 3.4). The IPCC estimates that aerosols have offset about 50% of the total warming to date by the main greenhouse gases (IPCC, 1996). However, unlike the main greenhouse gases, aerosols have a short lifetime in the atmosphere so they cannot become distributed over the whole planet and their effect is regional and short-lived.

The total aggregate emissions in 1990 from industrialised countries reported to the UNFCCC were about 18 Gt (CO_2-equivalent) (UNFCCC, 1998) (Figure 3.1.3), although this is subject to uncertainty and the IMAGE model (see section 1.3) assumes a higher figure (21 Gt). However, between 1990 and 1995 the aggregate emission of all greenhouse gases of industrialised countries, excluding carbon removals/sinks (see Box 3.1.3 in section 5), has decreased slightly (5%), mainly due to decreases from central

Greenhouse gases: concentration changes, contribution to global warming (GW) and main sources — Table 3.1.1.

Gas	Concentration increase (%) since about 1750	Contribution to global warming (%) *	Main anthropogenic sources
CO_2	30%	64%	Fuel combustion, deforestation and land-use change, cement production
CH_4	145%	20%	Energy production and use (including biomass), animals, rice paddies, sewage, organic waste in landfills
N_2O	15%	6%	Use of fertilisers, land clearing, adipic and nitric acid production, biomass burning, combustion of fossil fuels
HFCs	not applicable		Refrigeration, air conditioners, chemical industry
PFCs	not applicable	10%**	Aluminium production
SF_6	not applicable		Electricity distribution

* To compare the impact of different gases, the global warming potential (GWP) relative to CO_2 is often used, with CO_2 having a value of 1. GWP values are strongly dependent on the time horizon considered. Examples of GWP values over a 100-year period are 21 for CH_4, 310 for N_2O and several thousand for a number of halogenated compounds (IPCC,1996). The emissions taking into account GWP values are called 'CO_2 equivalents'.

** all halogenated compounds together , including CFCs and HCFCs

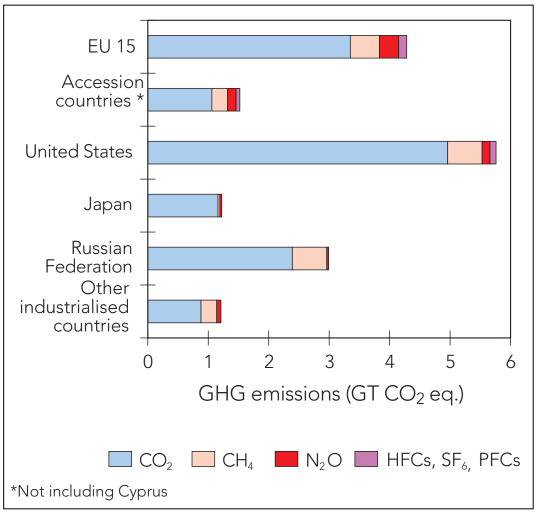
Source: IPCC, 1996

and eastern European countries, in particular from the Russian Federation (with a reduction of 30%).

Greenhouse gas emissions in the EU made up 25% of total emissions in industrialised countries in 1990 (Figure 3.1.3). Carbon dioxide contributes 80-90% of emissions in Western Europe and the US and about 70% in the other countries in the 'industrialised' category (defined by UNFCCC Annex 1). The variations are mainly due to differences in industrialisation and energy intensity and in the importance of carbon dioxide emissions or sinks from land-use change.

Figure 3.1.3 **Greenhouse gas emissions in 1990 by gas in different groups of industrialised (Annex 1) countries (excluding CO_2 sinks)**

Source: EEA, 1998; UNFCCC, 1998



1.3. Future impacts of climate change (until 2100)

Global greenhouse gas emission scenarios
The Intergovernmental Panel on Climate Change (IPCC) has assessed the possible consequences of continuing human enhancement of greenhouse gas emissions and concentrations, using a number of global socio-economic and greenhouse gas emissions scenarios, covering the period up to 2100. These scenarios range from baseline scenarios that assume low growth and a major switch to the use of non-fossil energy sources and large increases in energy efficiency. The scenarios are meant to assess the range of possible impacts on for example temperature and sea-level rise.

Integrated assessment model studies, which simulate the dynamics of the global climate system, have been undertaken for Europe with the global IMAGE model (RIVM, 1998; Alcamo *.et al.*, 1996; European Commission, 1999), using a baseline scenario that is consistent and comparable with the IPCC's mid range ('business as usual') scenario. Estimated 1990 emissions are 21 Gt (CO_2-eq.) for industrialised countries – 55% of the global total – and 16 Gt (CO_2-eq.) for developing countries. World population is projected to be 7 billion by 2010 and 10 billion by 2050. Global average GDP/capita is expected to increases by 40% between 1990 and 2010 and 140% between 1990 and 2050. Global CO_2 emissions are projected to increase from 1990 levels by about a factor of two by 2050 and a factor of three by 2100. Increases of methane and nitrous oxide emissions are less but still substantial by 2100.

Climate change impact indicators by 2050 and 2100
Global average concentrations of the three main greenhouse gases are projected to increase from 1990 to 2050: 45% for CO_2 (from 354 to 512 ppmv), 80% for CH_4 (from 1.60 to 2.84 ppmv), 22% for N_2O (from 310 to 377 ppbv) (IPCC, 1996).

IPCC (1996) findings for global temperature increase by 2100 vary over a wide range with a central estimate of a global mean temperature 2°C higher in 2100 than in 1990 (the uncertainty range is 1-3.5°C), assuming the 'baseline scenario' for global emissions. One of the climate models used in the IPCC (1996) assessment recently presented new results suggesting a global temperature increase of 3°C by 2100 (Hadley Centre, 1998b, 1998c).

According to IPCC (1996) there could be large regional variations. Climate models for Europe indicate that average increases in temperature would be similar to the estimated global increases, with greater warming in northern latitudes than in the south (Figure 3.1.4). The latest results from the Hadley Centre model show that a slowing down of the North Atlantic ocean circulation could occur due to increases of greenhouse gases, but the model still projects an increase of temperature in Europe.

IPCC (1996) and IMAGE estimates indicate that by 2050 sea levels could be almost 20 cm, and by 2100 about 50 cm (range 15-95 cm) above today's levels. There is still considerable uncertainty about these results, particularly regarding the behaviour of polar ice sheets. Sea-level rise is projected to continue after 2100 due to the inertia inherent in atmospheric-oceanic interactions.

Potential impacts from climate change on vegetation patterns and ecosystems are described in Chapters 3.11 and 3.15.

Potentially 'sustainable' targets for climate change impact indicators

The objective of Article 2 of the UNFCCC is to reach atmospheric concentrations that would prevent dangerous anthropogenic interference with the climate system but would allow sustainable economic development (IPCC, 1996).

There is no scientific consensus on sustainable target values for the main climate-change impact indicators, although various proposals have been made. The EU has adopted a provisional 'sustainable' target of a global average temperature increase of 2°C above the pre-industrial level (European Community, 1996a). The increase to 1990 has already been about 0.5°C, leaving a further allowable increase of 1.5°C from 1990 to 2100, or an average increase of 0.14°C per decade. The projected temperature increase of 2°C in 2100 above 1990 is above this provisional 'sustainable' target (IPCC, 1996).

Another provisional 'sustainable' target, consistent with the EU target and with the UNFCCC objective, has also been proposed: a 0.1°C temperature rise per decade (Krause *et al.*, 1989; Leemans, 1998). The projected rate of temperature rise (IPCC, 1996) will be more than double this provisional 'sustainable' target.

A provisional 'sustainable' target for total greenhouse concentrations that is consistent with the 'sustainable' temperature targets is currently considered to be between 450 and 500 ppmv CO_2-equivalent. Under the IPCC (1996) baseline emission scenario, the combined concentration of the three major greenhouse gases is projected to be 700 ppmv in 2050 and to continue to rise thereafter. Stable potentially 'sustainable' atmospheric concentrations of the main greenhouse gases are therefore unlikely to be realised by 2050.

A provisional 'sustainable' target of 2 cm per decade for sea-level rise has been suggested. From IPCC (1996) and the IMAGE analyses, sea-level rise will be approaching this level towards 2050. This potentially 'sustainable' target will most likely be exceeded between 2050 and 2100.

Potentially 'sustainable' greenhouse gas emissions by 2010

The issue of climate change is such that there is a need for setting long-term targets, but also for understanding the short-term implications of such targets. The concept of 'sustainable pathways' can be used to provide information on the level of short-term (2010) greenhouse gas emissions that are compatible with long term sustainable (2050 to 2100) climate goals. The analysis takes into account a range of targets for concentration of greenhouse gases, temperature increase and sea-level rise. The analysis can also show the distribution of emissions between industrialised countries and developing ('non-Annex 1') countries. Within the framework of UNFCCC, developing countries do not yet have to control their emissions (see section 2).

To stabilise the CO_2 concentration below 550 ppmv, twice the pre-industrial level, would mean that future global CO_2 emissions cannot exceed current emissions and would have to be much lower before and beyond 2100 (IPCC, 1996). To stabilise at lower CO_2 concentration levels would of course imply even lower global emissions (IPCC, 1997b). IPCC (1996, 1997b) has presented other emission pathways geared to different options for stabilisation of CO_2 and other greenhouse gas concentrations. For instance, stabilisation of the CO_2 concentration at the 1990 level (of 354 ppmv) by 2100 would involve an immediate reduction of annual CO_2 emissions by 50% to 70% and further thereafter (IPCC, 1996).

The concept of 'sustainable pathways' (IMAGE model) gives results that are consistent with IPCC (1996; 1997b). The results of the analysis are dependent on the choice of 'sustainable' climate protection targets. Here results are shown assuming the EU objective of a maximum global temperature increase of 1.5°C between 1990 and 2100, a maximum global temperature increase of 0.15°C per decade, IPCC (1996) baseline emissions for developing countries and assuming a maximum emission reduction rate for industrialised countries of 2% per year.

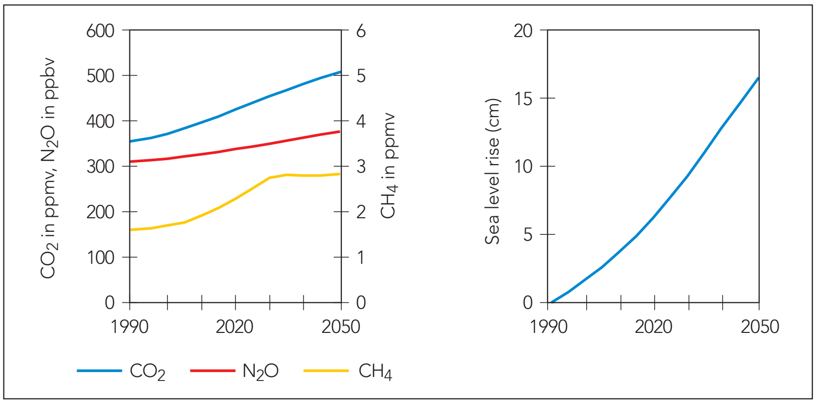
For industrialised countries this 'sustainable pathway' in 2010 implies a reduction of 35% from 1990 levels.

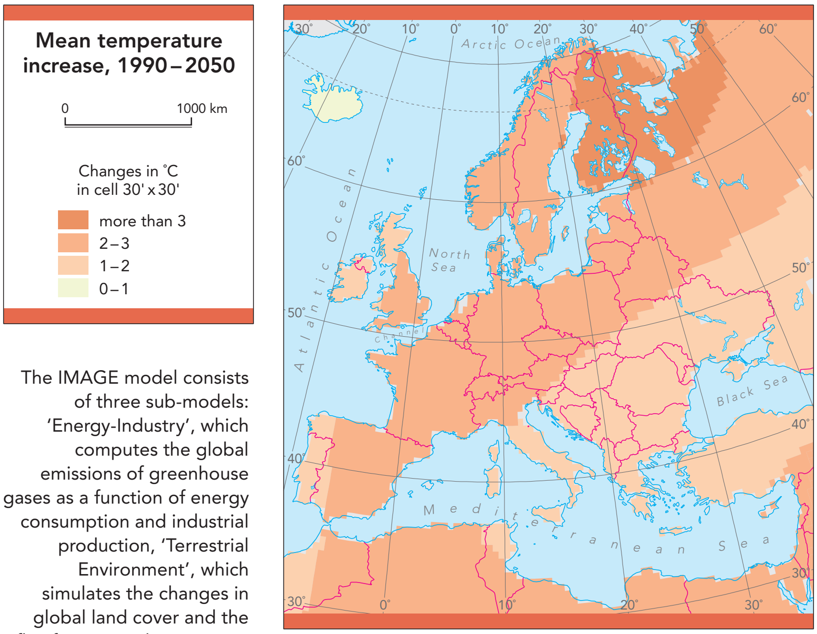
Uncertainties in climate-change scenarios

There are various sources of uncertainty in estimating future climate change by means of scenarios:

- assumptions with respect to socio-economic and sectoral developments and potential emission reductions;

Figure 3.1.4 **Temperature rise, increase of greenhouse gas concentrations and expected sea-level rise in the baseline scenario**





The IMAGE model consists of three sub-models: 'Energy-Industry', which computes the global emissions of greenhouse gases as a function of energy consumption and industrial production, 'Terrestrial Environment', which simulates the changes in global land cover and the flux from greenhouse gases from the biosphere into the atmosphere and 'Atmosphere-Ocean', which computes the average global and regional temperature and precipitation patterns.

Source: European Commission, 1999; Alcamo *et.al.*, 1996

- the process of transformation of greenhouse gas emissions into climate change;
- poorly understood or described processes in the current climate models.

European research is contributing to efforts to reduce these uncertainties, and also to improve understanding of the effects of different sources of uncertainty on the range of outcomes.

Vulnerability to climate change and damage costs
In a recent study (Eyre *et al.*, 1998) an estimate was made of the damage costs of the increasing greenhouse gas concentrations in the atmosphere (Table 3.1.2). The costs are calculated for CO_2, CH_4 and N_2O, using two different economic models and are expressed per tonne CO_2-equivalent emitted resulting in a range of 20 to 80 euros per tonne CO_2-equivalent.

The costs might be inflicted in other parts of the world and countries than where the emissions occur. The two models agree in broad outline: developing countries suffer significantly higher costs than developed regions. For industrialised countries, costs are relatively modest. In both models South and South-East Asia and Africa suffer large costs – the two regions experiencing more than half the total damage costs.

2. Current policy targets and environmental policies

2.1. Policy targets
Governments throughout the world responded to the concerns about climate change at the 1992 UN Conference on Environment and Development by adopting the Framework Convention on Climate Change (UNFCCC). More than 170 countries or groups of countries have now ratified the Convention, including the European Community and all 15 Member States and most other European countries. Developed countries (listed in Annex 1 of the Convention) made a commitment to aim to return their emissions of greenhouse gases, not controlled by the Montreal Protocol, to 1990 levels by 2000.

At the Third Conference of Parties (COP3) of UNFCCC in Kyoto in December 1997 countries listed in Annex B of the Kyoto Protocol (which is similar to the list of Annex I countries) agreed to reduce their emissions of six greenhouse gases by an overall 5% from 1990 levels by 2008-2012 (UNFCCC, 1997b), with emissions expressed in CO_2 equivalents, based on 100 year GWP (Global Warming Potential) values. These gases are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). Each Annex B Party is allowed an assigned amount of greenhouse gas emissions not to be exceeded over the five-year commitment period 2008 – 2012, relative to its carbon dioxide equivalent emissions of all six greenhouse gases in the base year 1990 (or 1995 for HFCs, PFCs and SF_6).

By January 1999, 71 Parties, including the European Community and the US, had signed the Kyoto Protocol, and 2 Parties had ratified it. To become binding international law the Protocol has to be ratified by 55 Parties to UNFCCC and the Annex 1 Parties ratifying have to account for 55% of the 1990

CO_2 emissions (of Annex I Parties). This means that entry into force on the international level could be blocked by Parties accounting for more than 45% of the 1990 CO_2 emissions of Annex I Parties.

Under the UNFCCC the EU and each of its Member States were committed to a reduction of 8% below the 1990 level in the period 2008 to 2012. Central and eastern European countries are committed to reductions of 5-8%. Each Party is required to make demonstrable progress in achieving its commitments by 2005.

According to the Kyoto Protocol, net changes in carbon stocks due to specific types of greenhouse gas sinks, in particular forests, can be used in the national inventories to meet emission reduction commitments. This was controversial since major methodological uncertainties remain in the calculation of carbon removal by sinks (see also Section 5.)

In June 1998 a system of 'burden sharing' (also called 'target sharing') was agreed for the EU Member States (European Community, 1998a) (see Table 3.1.3).

There are three important new 'flexibility mechanisms' introduced in the Kyoto Protocol (the so-called 'Kyoto Mechanisms'):

- emissions trading among industrialised (Annex 1) countries;
- joint implementation among industrialised countries;
- cooperation between industrialised and developing countries in a 'clean development mechanism'.

Emissions trading allows Parties to the Kyoto Protocol that reduce greenhouse gas emissions below their assigned amount to sell part of their emission allowance to other Parties. A Party could also buy additional emission allowance from other Parties for the purpose of meeting its Kyoto commitment. Emissions trading is intended to improve amongst Annex B Parties (industrialised countries) the efficiency of economic resource allocation. However, some countries, for example Russia, could have large quantities of unused assigned amounts of emissions available for trading. This issue is often referred to as trading in 'hot air', since

Box 3.1.1 Vulnerability and adaptation to climate change in Europe:

Even though capabilities for adaptation in managed systems in many places in Europe are relatively well established, significant impacts of climate change still should be anticipated. Coastal systems will be affected through sea-level rise and an increase in storm-surge hazards, with areas most at risk in the EU being the coastlines of the Netherlands and Germany and some Mediterranean deltas. Major effects are likely to be felt through changes in the frequency of extreme events and precipitation, causing more droughts in some areas and more river floods elsewhere. Already occurring water stresses are likely to be enhanced in the Mediterranean region, the Alps and northern Scandinavia. Effects in agriculture could be on growing seasons and productivity as well as increases in some pests and diseases. Boreal forest and permafrost areas are projected to undergo major change. Ecosystems are especially vulnerable due to the projected rate of climate change that would change faster than the ability of plant species to migrate. Human health could be affected through increases in heat-stress mortality, tropical vector-borne diseases, urban air pollution problems, and decreases in cold-related illnesses.

Source: IPCC, 1997a

Damage costs of greenhouse gas emissions — Table 3.1.2.

Impact area	**Damages included in the study**			
Health impacts	expansion of the area amenable to parasitic and vector borne diseases			
Agricultural impacts	changes in area suitable for certain crops and technical changes e.g. irrigation			
Water supply impacts	changes in water resources			
Sea-level rise	losses of land and wetlands; costs of protection; migration effects			
Impacts on ecosystems	valuations based on estimates of species loss			
Hazards of extreme weather events	changes in frequency and severity of cold spells, heat waves, drought, floods, storms and tropical cyclones			
	Marginal Damage from model (euro/tonne CO_2 eq.):			
Model	FUND		Open Framework	
Discount rate	1%	3%	1%	3%
Greenhouse gas				
Carbon dioxide, CO_2	46	19	44	20
Methane, CH_4	25	17	19	18
Nitrous oxide, N_2O	55	21	84	35

Source: Eyre *et al.*, 1998

Box 3.1.2 Article 2 of the UNFCCC:

Objective

The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved 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.

it could imply that no real reduction of emissions would take place. The size of this problem is uncertain, since it depends for example on the economic development of Russia.

Table 3.1.3. **EU 1990 emissions and the Kyoto Protocol targets, including the EU 'burden sharing' agreement (all in CO_2-equivalents)**

Country	Target (%)	Emissions 1990 (Tg CO_2 eq.)	Target 2008 – 2012 (Tg CO_2 eq.)
Austria	-13.0	78	68
Belgium	-7.0	139	129
Denmark	-21.0	72	57
Finland	0	65	65
France	0	546	546
Germany	-21.0	1 208	955
Greece	25.0	99	124
Ireland	13.0	57	64
Italy	-6.5	543	507
Luxembourg	-28.0	14	10
Netherlands	-6.0	217	204
Portugal	27.0	69	87
Spain	15.0	302	348
Sweden	4.0	66	68
United Kingdom	-12.5	790	691
EU Total	-8.0	4 264	3 922
Bulgaria	-8.0	124	114
Czech Republic	-8.0	187	173
Estonia	-8.0	49	45
Hungary	-6.0	80	76
Latvia	-8.0	37	34
Lithuania	-8.0	44	41
Poland	-6.0	591	556
Romania	-8.0	246	226
Slovakia	-8.0	72	67
Slovenia	-8.0	19	17
Croatia	-5.0	7	35
Iceland	10.0	3	3
Liechtenstein	-8.0	0	0
Norway	1.0	55	56
Switzerland	-8.0	54	49

Source: UNFCCC, 1997, 1998; European Commission, 1998f; EEA, 1999a

Joint implementation means that Annex 1 Parties may transfer or acquire from each other emission reduction units on a project basis. Private sector entities can participate in this mechanism under certain conditions.

The Clean Development Mechanism (CDM) creates the possibility that Annex I countries have reductions from projects, undertaken between 2000 and 2008-2012 (the first budget period), in non-Annex I countries credited towards their reduction targets.

At the fourth Conference of Parties (COP4, November 1998) the Buenos Aires Action Plan (UNFCCC, 1999) was adopted, that includes work to be finalised in 2000 on:

- financial mechanisms to assist the developing countries regarding adverse effects of climate change, for example through adaptation measures;
- development and transfer of technology to developing countries;
- work programme on the Kyoto Mechanisms, with a priority on the clean development mechanism;
- work related to compliance and to policies and measures.

The work programme on the Kyoto Mechanisms contains many elements, including guidelines for verification, reporting and accountability for all three mechanisms and the need for clear definitions and organisational and financial mechanisms. It also includes the need to elaborate the quantification of 'supplemental' to domestic action. This was considered a key issue by the EU. In March 1998 the EU Council proposed a quantified limit to be imposed on industrialised countries' use of greenhouse gas emissions trading and the other two Kyoto mechanisms. The proposal aims at ensuring that all Annex B Parties will take domestic measures to limit their emissions. In October 1998 the EU Council concluded that a ceiling on the use of the Kyoto Mechanisms has to be defined in 'quantitative and qualitative terms based on equitable criteria'.

2.2. Current EU policies and measures

Some EU-wide policies and measures, aimed at reducing emissions of greenhouse gases or enhancement of carbon sinks, are in place. Furthermore the Commission has presented various communications and proposals (Table 3.1.4).

The introduction of a mandatory EU-wide energy and CO_2 tax has been proposed by

Main EU actions, policies and measures for reducing greenhouse gas emissions Table 3.1.4.

Type	Policies and measures (and proposals)	Description and objectives
General	Monitoring mechanism for CO_2 and other greenhouse gas emissions (Decision 93/ 389/EEC)	Monitor progress towards the target of stabilisation of Community CO_2 emissions in 2000 on 1990 levels.
	Proposal for amending the Monitoring Mechanism, COM(98) 108	To include other greenhouse gases and report after 2000 and bring in line with Kyoto Protocol.
	Strategy paper for reducing methane emissions, COM(96) 557	Overview of potential measures (methane).
	Climate Change – the EU approach to Kyoto, COM(97) 481	Overview of potential measures, before the UNFCCC Kyoto Protocol agreement.
	Communication on Climate Change – Towards an EU Post-Kyoto Strategy, COM(98) 353	Overview of potential measures, after the UNFCCC Kyoto protocol agreement.
	Council conclusions on targets for Member States on GHG emission reductions CO_2 (June 1998)	New 'burden/target' sharing of Member States in line with the UNFCCC Kyoto Protocol.
Energy efficiency/ energy technologies	New proposal for a EU wide energy products tax COM(97)30	No agreement. Various Member States have implemented an energy/CO_2 tax.
	The energy dimension of climate change, COM(97)196	Overview of implications for the energy sector of reducing GHG emissions.
	Energy efficiency in the European Community – towards a strategy for the rational use of energy, COM(1998) 246	Overview of possible measures/policies to improve energy efficiency.
	JOULE/THERMIE programme 1995/1998 (Decision 94/ 806/EEC)	Promotion of R&D of environmentally friendly and efficient energy technologies and renewable energy.
	ALTENER I programme (1993/1997); proposal for ALTENER II (1998/1999), COM (97) 87	Promotion of renewable energy sources.
	SAVE I (1991/1995) and SAVE II (1996/2000) programmes (Decision 96/737/EC)	Overview of measures to improve energy efficiency.
Industry	Directive 96/61/EC concerning Integrated Pollution Prevention and Control (IPPC)	Requires improvement of energy efficiency in industrial (IPPC) installations.
	Directive on Large Combustion Plants (88/609/EEC) and proposal for revision (1998)	Proposal for revision requires the operator to investigate feasibility of combined heat and power (CHP).
Transport	Communication on implementing the Community strategy to reduce CO_2 emissions from cars: an environmental agreement with the European automobile industry, COM(1998) 495	EU target of reduction of CO_2 emissions from new passenger cars to 120 g/km by 2005 or 2010 at the latest. Industry commitment to reduce to 140 g/km by 2008.
	Trans European Networks (TEN) for transport	Europe wide expansion of transport infrastructure (road, rail, water). Potential modal shift away from road transport.
Waste	Proposal for a Directive on the landfill of waste	Reduction of methane emissions, requirement for operators to install a control system for landfill gas.
Agriculture and forestry	Reform of the Common Agriculture Policy (CAP)	Indirect reduction of methane emissions due to reduction of number of cattle, and of nitrous oxide emissions due to reduced amount of fertilisers.
	Regulation instituting a Community aid scheme for forestry measures in agriculture (Regulation EEC/2080/92)	Afforestation of agricultural land and thereby also enhancement of carbon sinks.
Households	Directives for energy labelling of house-hold refrigerators, freezers, washing machines, dishwashers, lamps.	Labelling of energy consumption for information
	Directives on energy efficiency requirements of hot water boilers, household refrigerators, freezers. Agreements with manufacturers and importers of washing machines, televisions, video.	Minimum standards for energy efficiency.

Sources: European Commission, 1996a, 1996b, 1997a, 1997b, 1997c, 1998a, 1998b, 1998c, 1998d, 1998e, 1998 f; European Community, 1996a, 1998b; EEA , 1999a; UBA, 1998 the European Commission but no agreement has been reached. In 1997, the European Commission presented a proposal for a comprehensive energy products tax, to extend the scope of the existing EU-wide excise system to cover natural gas, coal and electricity as well. Various Member States have already implemented an energy/CO_2 tax: Austria, Denmark, Finland, Sweden and the Netherlands (see Chapter 4.1).

To monitor progress towards the target of stabilisation of EU CO_2 emissions at 1990 levels by the year 2000, the Council adopted in 1993 a monitoring mechanism for CO_2 and other greenhouse gas emissions (European Community, 1993). The European Commission prepared two reports (European Commission, 1996a) and the EEA prepared a draft report with an overview of national programmes to reduce greenhouse gas emissions (EEA, 1999a). In 1998 the Commission presented a proposal for revision of the monitoring mechanism to reflect the agreement reached at Kyoto (European Commission, 1998a).

The Communication 'the EU Approach to Kyoto' (European Commission, 1997b) showed that a 15% reduction in CO_2 emissions would be technically feasible and the costburden would not be insupportable. A more recent Communication (European Commission, 1998f) contains an analysis of the Kyoto Protocol and the implications for the EU and also indicated potential EU policies and measures. Based on the UNFCCC Buenos Aires Action Plan and strategies of the Member States, the Commission will prepare a more complete strategy in 1999.

The European Commission has identified the potential for energy efficiency improvements until 2010 (European Commission, 1998b). For energy in the EU (production and supply), the programmes ALTENER, SAVE and JOULE-THERMIE feature prominently in the policy response to climate change, although their actual impact on GHG emission reductions is quite difficult to assess.

The Integrated Pollution Prevention and Control (IPPC) Directive for industry includes energy efficiency as a criterion for the determination of best available technology (BAT) and could therefore contribute to reduction of CO_2 emissions.

For transport, the European Commission reached an agreement with the car industry in July 1998 to reduce CO_2 emissions from new passenger cars by 25% (to 140 g/km) between 1995 and 2008 (European Commission, 1998d). The Commission's target is to improve fuel efficiency of passenger cars so that emissions are reduced to 120 g/km, and it has proposed a scheme for energy labelling of new passenger cars to help achieving this target.

The revised proposal for a Directive on the landfill of waste aims at reducing landfill methane emissions. Member States would need to fit all new and existing landfills which receive biodegradable waste with a landfill gas control mechanism, where possible using the gas collected for energy production and the directive sets binding targets for the reduction of the amounts of municipal organic waste (see also Chapter 3.7).

In agriculture, the 1992 reforms of the Common Agricultural Policy (see also Chapter 2.1) could indirectly lead to a reduction of methane emissions, caused by reduced numbers of cattle and a reduction of nitrous oxide emissions due to reduced amounts of mineral fertilisers applied. Increased non-food biomass production on set-aside land could help to substitute fossil fuel with biofuel. In the forestry sector, financial support will be provided by the EU for afforestation of agricultural land.

With respect to household consumption, several Directives have been adopted on energy-efficiency requirements for appliances and various agreements with manufacturers and importers on minimum energy standards have been reached.

2.3. Member States' current policies and measures

In addition to initiatives at EU level, the Members States have implemented various national policies and measures (see Table 3.1.5). Although the impact of these measures on the EU total greenhouse emissions is difficult to assess, some estimates are provided in section 4.

3. Sources and trends of greenhouse gas emissions

3.1. Main sources of greenhouse gas emissions in Europe

The energy sector (mainly power and heat generation) is the main contributor to EU CO_2 emissions (32%), followed by transport (24%) and industry (23%) (Figure 3.1.5). In central and eastern Europe transport makes a relatively smaller, and energy supply and

National EU Member States' policies and measures for reducing greenhouse gas emissions — Table 3.1.5.

	Energy general	Power generation	Industry	Transport	Residential	Others
Austria	Energy/CO_2 tax implemented	promotion of combined heat and power (CHP) plants and renewable energy			tightening of energy-relevant regulations for buildings	
Belgium		promotion of CHP and renewable energy		improvement of public transport, promotion of combined rail and road transport	improved energy efficiency	
Denmark	Energy/CO_2 tax implemented for households, similar tax for the industry sector	promotion of CHP and electricity production from biomass; construction of new gas-fired (replacing coal) power plants after 2000. Large scale use of wind energy for electricity		promoting public transport, financial support for purchase of clean vehicles.		
Finland	Energy/CO_2 tax implemented	efficiency improvements, promotion of CHP, electricity production from biomass	promotion of energy saving through voluntary agreements			forestry: measures to enhance carbon sequestration
France		demand-side management		more energy-efficient transport	increasing energy efficiency in buildings	forestry: increasing forest carbon sequestration
Germany		voluntary commitment on improved energy efficiency, legislation on the sale of electricity generated from renewables to the grid	voluntary measures, improving energy efficiency	energy-efficient transportation policy		new Länder: emission reductions by replacement of lignite by other fuels, moderni-sation of industrial installations, improvement of energy efficiency (industry, resi-dential sector)
Greece		introduction of natural gas, development of CHP, large scale exploitation of solar energy	introduction of natural gas	metro in Athens and Thessaloniki	introduction of natural gas	forestry: Control of forest resources, re-afforestation programme.
Ireland		energy efficiency improvements, fuel switching to natural gas, promotion of CHP, increasing the use of renewables	energy efficiency improvements	investment programme for roads and rail networks	energy efficiency improvements	forestry: afforestation programme.
Italy		efficiency improvement, increasing use of renewables	increased use of natural gas	traffic control and rationalisation of urban mobility	increased use of natural gas, increasing energy efficiency in buildings	
Luxem-bourg				promotion of public transport, rail transport and waterways	promotion of CHP	

.../...

	Energy general	Power generation	Industry	Transport	Residential	Others
Nether-lands	Energy/CO_2 tax implemented	increase of CHP, increasing renewable energy and partial fuel switch to wood; providing adequate payments for energy generated from renewable sources	voluntary agreements on energy efficiency	shift to more efficient cars, improvement public transport	energy performance standards, promote energy-efficient products, appliances and heat insulation	waste treatment: 5 million tonnes of waste for energy purposes by 2000
Portugal		introduction of natural gas, increased use of renewables, technological improvements		alternative fuels and infrastructural improvements		
Spain			energy conser-vation, fuel switching, promotion of natural gas and CHP	subsidising public transport, investment in rail infrastructure	energy conservation, fuel switching, promotion of natural gas and CHP	
Sweden	Energy/CO_2 tax implemented	promote renew-able energy (bio-fuels, wind power and solar energy), increase efficiency		tax on petrol		forestry: switch to sustainable practices
United Kingdom		switch from coal to natural gas continu-ing, improvements in the produc-tivity of the nuclear plants, increase CHP, promote renewable sources of energy	voluntary agreements regarding energy savings, promotion of energy efficiency	increase road fuel duties, fuel efficiency improvement of vehicles	stricter regulations for energy efficiency for new buildings	

industry a larger contribution than in the EU. The main sources of CH_4 emissions in EU are agriculture (42%), in particular from ruminants (enteric fermentation and manure management), waste treatment and disposal (36%) and others, mainly coal mining and leakage from natural-gas distribution networks (17%). Estimates for methane are more uncertain than for CO_2 emissions since the major agricultural sources and emissions from waste treatment are less well quantified.

The main sources of N_2O emissions in EU are from fertilised agricultural land (46%), industry (26%), in particular adipic acid and nitric acid manufacture, the transport sector (7%) and the energy sector (7%). Emissions from transport are due to the introduction of three-way catalysts in cars, which reduce emissions of nitrogen oxides, carbon monoxide and hydrocarbons, but as a side-effect increase the emissions of nitrous oxides. As for methane, the data is more uncertain, mainly because the major agricultural sources are less well quantified. In central and eastern Europe the share of agriculture is larger, and that of industry and transport smaller.

3.2. Current trends in EU Member States

Carbon dioxide, methane, nitrous oxide

EU CO_2 emissions decreased by 1% between 1990 and 1996, although the trend varies considerably between Member States (Tables 3.1.6 and 3.1.7). The decrease for the EU as a whole depends strongly on the reductions in Germany and the UK. Germany has the largest national CO_2 emission in the EU, with a contribution of approximately 30% to EU emissions in 1995. Between 1990 and 1996 the largest absolute emission reduction took place in Germany, mainly caused by the economic restructuring of the new Länder. The substantial reduction in emissions in the UK was mainly caused by fuel switching from coal to natural gas.

CO_2 emission trends can be compared with economic development in these years. Between 1960 and 1990, GDP growth for each five-year period varied in EU Member States between 8% and 28%. In the period 1990-1996, GDP growth in the EU was about 9% (almost 6% between 1990 and 1995). With the exception of the second oil crisis in the early 1980s, the five-year average GDP growth in the period 1960 to 1990 was about 16%. This indicates that the reduction of CO_2 emissions between 1990 and 1996 is partly related to the relatively low GDP growth in this period and is partly due to an increase in energy efficiency and the effects of policies and measures to reduce GHG emissions (see Table 3.1.7).

EU nitrous oxide emissions decreased 5% in 1996 from 1990 levels, although this trend varies considerably between the Member States. Although the trend and its causes are more uncertain than for CO_2 the largest reductions appear to be due to falling production levels for adipic and nitric acid in industry and a reduction in the consumption of inorganic nitrogenous fertilisers in agriculture. These reductions were partially offset by an increase in transport emissions as the number of cars with catalytic converters increased (AEA, 1998a).

EU methane emissions fell by 7% between 1990 and 1995, with some variation between Member States. As for nitrous oxides the trend and its causes are more uncertain than for CO_2 emissions. The largest emission reduction appears to be due to the decline of deep mining in the UK (and to some extent in Germany) and the replacement of the old gas distribution pipework. Agricultural emissions also fell, due mainly to a reduction in the number of dairy cows (AEA, 1998b).

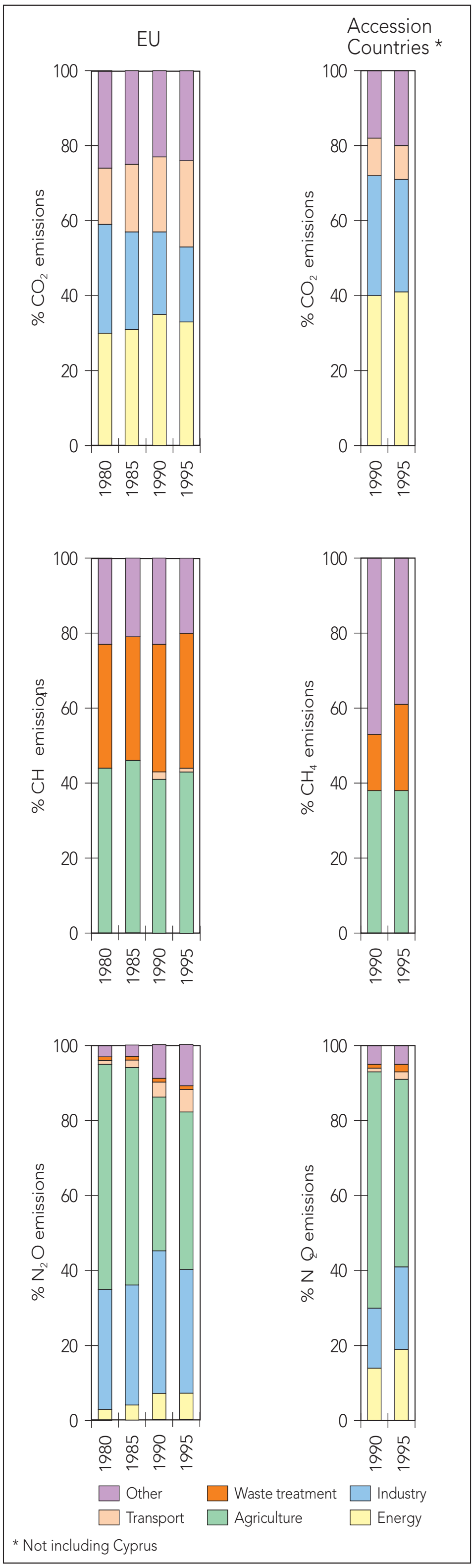
Halogenated gases
Emission estimates of the three groups of halogenated gases HFCs, PFCs and SF_6 have only recently been prepared, but not yet by all Member States. For the EU, 1995 will probably be the base year under the Kyoto Protocol for reduction in emissions of these gases.

Total estimated EU emissions in 1995 of the halogenated gases HFC's, PFC's and SF_6 are about 58 Mt CO_2-equivalents, which is 1-2% of total EU emissions of CO_2, CH_4 and N_2O in 1990 (in CO_2-equivalent). The largest contribution comes from HFCs (64%) followed by SF_6 (25%) (Table 3.1.8).

At present HFCs are mainly emitted as a by-product during the production of HCFC-22. The most important source of SF_6 is electricity distribution (use in switches) and of PFCs industrial production processes in the primary aluminium and the electronics industry.

Greenhouse gas emissions by sector in EU and Accession Countries

Figure 3.1.5



Source: EEA, ETC/AE, 1998

Table 3.1.6.	Greenhouse gas emissions and removals/sinks in 1996 (CO_2, CH_4, N_2O) – EU			
	CO_2 (in million tonnes)		CH_4 (in 1 000 tonnes)	N_2O (in 1 000 tonnes)
MEMBER STATE	Emissions	Removals/Sinks		
Austria	62	14	580	13
Belgium	129	2	591	35
Denmark	60	1	430	33
Finland	66	14	270	18
France	399	60	2844	174
Germany	910	30	4788	210
Greece	92	-	457	29
Ireland	35	6	800	26
Italy	448	36	2516	162
Luxembourg	7	0	24	1
Netherlands	185	2	1179	72
Portugal	51	1	834	14
Spain	248	29	2370	90
Sweden	63	32	297	10
United Kingdom	593	19	3712	189
EU15	3 347	247	21 692	1 076

Estimates for 1996 were not available for Austria, Denmark, France, Italy, Portugal and Spain. For these countries 1994 or 1995 estimates have been used for a preliminary EU15 1996 estimate. The CO_2 estimates are not corrected for temperature or electricity trade. Some Member States use corrected CO_2 estimates to better reflect national circumstances.

Source: EEA, 1999a

Table 3.1.7.	CO_2 emissions and GDP growth in EU: percentage change 1990-1996	
MEMBER STATE	CO_2	GDP
Austria	0.2	11.9
Belgium	10.7	7.8
Denmark	13.9	8.7
Finland	12.0	-3.4
France	1.7	4.8
Germany	-10.3	9.5
Greece	7.8	7.2
Ireland	13.3	35.7
Italy	1.4	6.8
Luxembourg	- 46.6	15.1
Netherlands	14.6	9.5
Portugal	7.9	8.9
Spain	2.2	7.8
Sweden	14.3	4.7
United Kingdom	- 3.5	6.5
EU15	- 0.7	9.0

Source: EEA, 1999a

4. Progress and outlook (2000 and 2010)

4.1 Progress towards EU target of CO_2 stabilisation by 2000

If national projections of CO_2 emissions for 2000 are aggregated for the EU, the result is a 2% reduction compared with the 1990 level (Table 3.1.9), with a decrease in six Member States.

However, these projections are subject to uncertainties related to socio-economic developments and the success of the implementation of policies and measures, and also have methodological differences.

The European Commission has made its own projections, based on a consistent methodology for the EU and derived from the Commission's pre-Kyoto 'baseline' energy scenario (which assumes no additional policy action for CO_2 abatement).

The projections for the year 2000 show EU energy-related CO_2 emissions 2% above 1990 levels; transport is the fastest-growing sector with emissions increasing to 22% above the 1990 level in 2000.

The combination of these two assessments (national estimates and pre-Kyoto EU energy scenario) suggests that EU CO_2 emissions in 2000 could be in the range of 2% above or below 1990 levels.

4.2. Baseline scenario for 2010 (reaching the Kyoto target for EU?)

The EU is also committed (under the Kyoto Protocol) to an 8% reduction by 2008-2012 (from 1990 levels) in emissions of the six main greenhouse gases.

EU total greenhouse gas emissions under the baseline scenario are projected to increase by about 6% in 2010 from 1990 levels (Figure 3.1.6).

Because the Kyoto targets for the EU and other UNFCCC Parties are expressed in CO_2-equivalents, as a sum of all six greenhouse gases, it is essential to combine the information on the emissions in 1990 and 2010 (baseline) for all six gases. Thus it is possible to assess the emission reductions required, on top of the assumptions on policies and measures in the baseline scenario, for achieving the Kyoto target for the EU (Figure 3.1.6).

The Kyoto target of -8% requires a reduction of about 600 Mt CO_2-equivalent from the projected baseline scenario emissions in 2010 (from 4 490 to 3 890 Mt CO_2-equivalent, while the 1990 emissions were 4 227 Mt CO_2-equivalent).

Carbon dioxide

The projected EU CO_2 emissions for 2010 based on the pre-Kyoto baseline scenario are about 8% above the 1990 level (Figure 3.1.7).

This baseline scenario for 2010 is based on the assumption of no additional EU policy action for CO_2 abatement. The pre-Kyoto scenario relates only to fuel-related CO_2 emissions (about 95% of total CO_2 emissions). (For the main assumptions in this scenario, see Chapters 1.1. and 2.2.).

Transport is the fastest-growing sector with emissions projected to increase by 22% (in 2000) and 39% (in 2010) above the 1990 level (Figure 3.1.8). In contrast, industrial CO_2 emissions are projected to decrease by 15% between 1990 and 2010, while CO_2 emissions from the domestic/tertiary sector are projected to remain stable. This is mainly due to expected increased market penetration of electrical and heating equipment – in effect CO_2 emissions are exported to the power generation sector. Nevertheless, CO_2 emissions in the power- and heat-producing sector are projected to remain at the 1990 level until 2010, although some increase can be expected after 2010, due to changes in the power-generation structure (such as retirement of nuclear power plants at the end of their lifetime).

Among the Member States, only Germany is projected to have CO_2 emissions in 2010 below the 1990 level. In both 1995 and 2010, about half of the CO_2 emissions are related to combustion of liquid fuels. An important shift however is occurring away from solid fuels to gaseous fuels. This explains the relatively small increase (+8%) in aggregate CO_2 emissions, compared to the larger increase in total energy consumption between 1995 and 2010 and demonstrates a partial de-coupling between CO_2 emissions and energy consumption.

Methane and nitrous oxide

Various recent studies for the Commission have provided EU baseline scenario emission estimates for methane and nitrous oxides for 2010 (AEA, 1998a, 1998b; Ecofys, 1998a, 1998b; Coherence, 1998). The results are comparable but have some different assumptions on the extent to which measures for

Main emission sources of HFCs, PFCs and SF_6 in EU in 1995 — Table 3.1.8.

Emission estimates (Million tonnes (Mt) CO_2-equivalents)		
HFCs	**PFCs**	**SF_6**
37 Mt	**7 Mt**	**14 Mt**
HFC production/ handling	Primary aluminium production	Electricity distribution
HCFC-22 production	Semiconductor manufacturing	Magnesium production
Refrigeration		Semiconductor manufacturing
Mobile air conditioners		Noise-insulating windows
Foam blowing		Tyres
Solvent use		
Aerosols, Fire extinguishers		

Source: Ecofys, 1998a

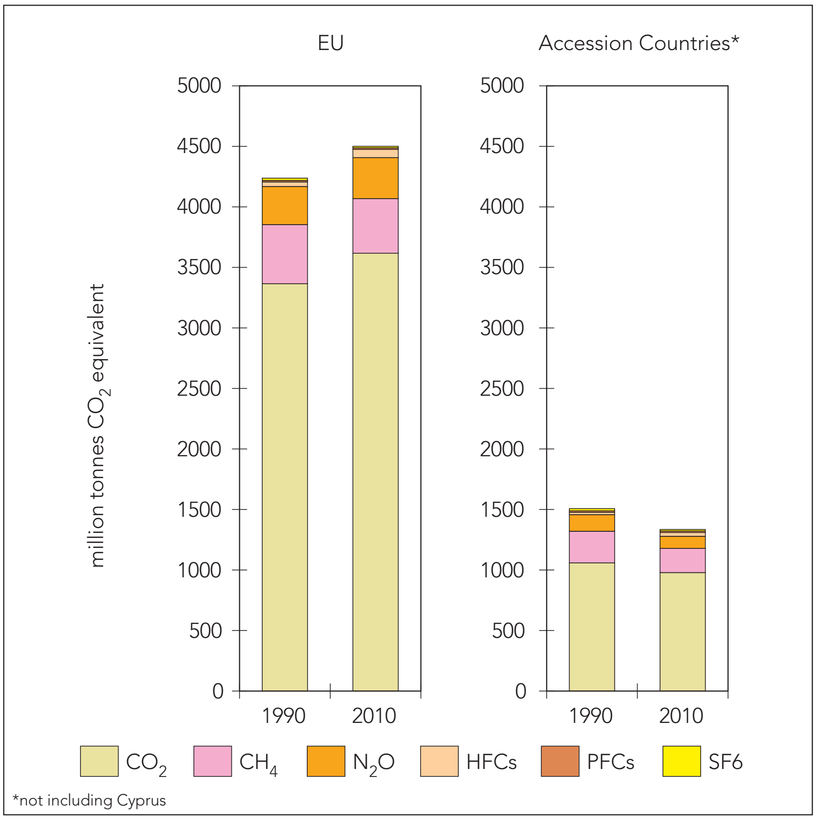
CO_2 emissions in EU Member States, reported (1990) and projected (2000) — Table 3.1.9.

	Inventory 1990	Projections 2000
	(million tonnes CO_2) (Mt)	
MEMBER STATE	**1990 (base year)**	**2000 with measuress**
Austria	62	57
Belgium	116	125
Denmark	52	54
Finland	59	60
France	392	377
Germany	1 014	894
Greece	85	98
Ireland	31	35
Italy	442	446
Luxembourg	13	7
Netherlands	161	189
Portugal	47	50
Spain	226	258
Sweden	55	60
United Kingdom	615	578
EU15	3 372	3 290

The column 'with measures' represents the expected emissions in 2000, taking into account the policies and measures that were already adopted by the Member States and for which an estimation of reduction potential was available from national programmes (1997/1998).

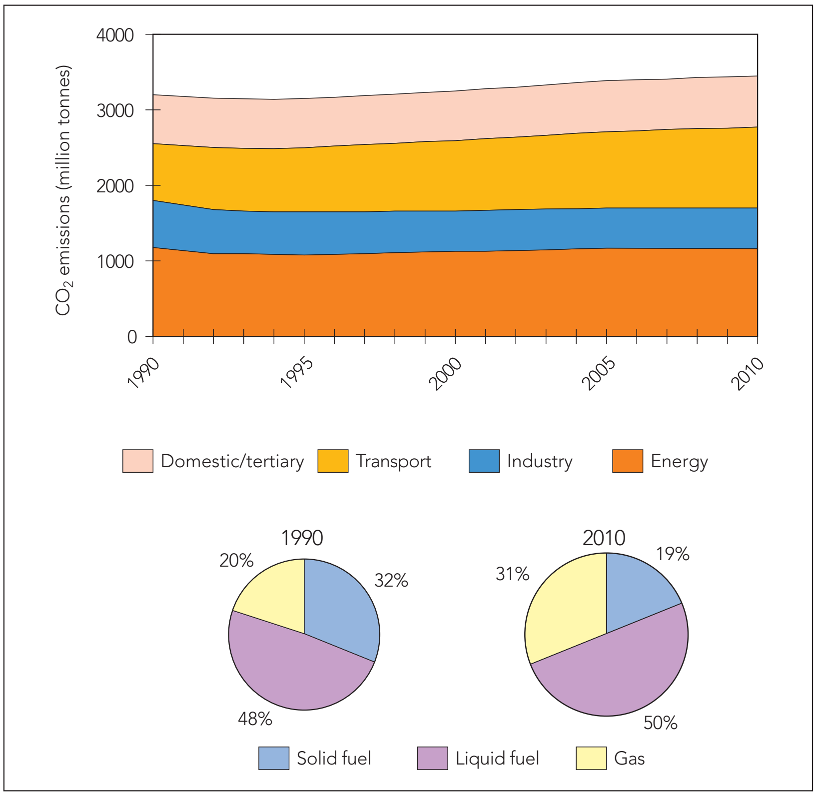
Source: EEA 1999

Figure 3.1.6 **Greenhouse gas emissions in EU and AC10 by 2010 – baseline scenario**



Source: European Commission, 1999; Ecofys, 1998a, 1998b; AEA, 1998a, 1998b, UNFCCC, 1998, EEA, 1999a; EEA, 1999 b.

Figure 3.1.7 **EU15 energy-related baseline CO_2 emission projections by sector and by fuel**



Source: European Commission, 1999; Capros, 1998, European Commission, 1997a

the industry sector (N_2O emissions) and the agricultural sector (CH_4 and N_2O emissions) are included in the scenario.

Methane emissions in the EU are projected to decrease by 8% between 1990 and 2010 (Coherence, 1998) mainly due to large emission decreases from coal mining, as coal production is projected to fall, and from agriculture as cattle numbers are projected to fall. Reductions from the waste sector, for example through measures to collect and remove methane emissions from new landfills, are not included in this baseline scenario (see also section 5).

EU nitrous oxide emissions are projected to increase by 9% between 1990 and 2010 (Ecofys, 1998b), mainly due to increases in emissions from passenger-car catalytic converters. No reductions are assumed from the industrial sector (production of adipic and nitric acid) and only minor reductions from agriculture.

Halogenated gases
For the halogenated gases an indicative baseline scenario emission projection (based on the limited information available) has been prepared for the Commission (Ecofys, 1998a; March Consulting Group, 1998). In 2010, total fluorocarbon emissions are projected to be about 82 Mt CO_2-equivalent, an increase of about 40% compared with 1995 emissions of 58 Mt. The share of HFCs is expected to rise to 79%, while the shares of SF_6 and PFC's would decrease to 15% and 6% respectively by 2010.

Emission reductions by 2010 for an enlarged EU
The analysis given above focuses on the EU. For other countries in Europe much less data is available. This section, however, presents a preliminary analysis of the emissions by 2010 of an enlarged EU, meaning EU15 and the 10 central and eastern European Accession Countries (AC10). These emissions could be compared to the current Kyoto targets for the EU and Accession Countries, although this would only be indicative since agreed targets for a potentially enlarged EU do not exist.

For AC10 information is available from a study performed by IIASA for EEA (EEA, 1999b), using the official energy projections for 2010 provided by these countries.

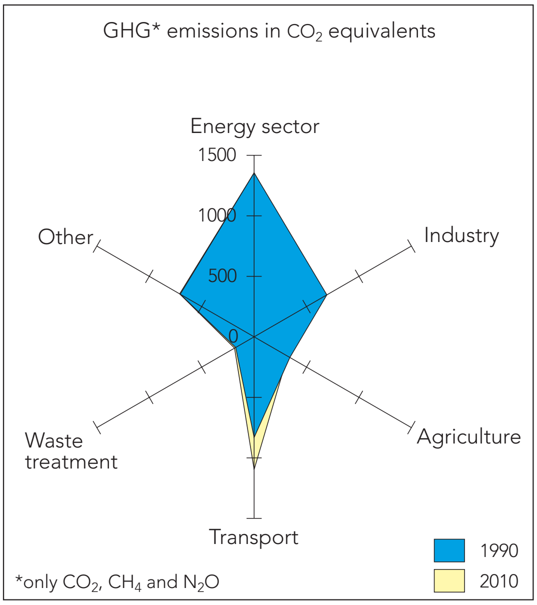
There have been significant falls in greenhouse gas emissions in Eastern Europe since 1990. CO_2 emissions in AC10 fell by 20%

between 1990 and 1995. By 2010, GDP is expected to be 31% higher than in 1990, while energy consumption would rise by only 4% (UNECE, 1996). In addition, there is likely to be a switch to fuels that emit lower amounts of greenhouse gases (EEA, 1999b). The baseline scenario suggests an 8% decrease in CO_2 emissions for the AC10 by 2010.

For AC10 information on baseline emission projections for methane, nitrous oxide and the fluorocarbons is very limited. Nevertheless, some indicative estimates for 2010 for have been prepared by EEA/ETC-AE (see Figure 3.1.6), according to which the total greenhouse gas emissions for the AC10 are projected to decrease by 11% in 2010 from 1990 levels. Combined with the projected 6% increase for EU greenhouse gas emissions, this would probably result in a 2% increase in emissions of a potentially enlarged EU during the same period.

It is clear that under the assumptions of the baseline scenario, an EU25 target for 2012 emissions between 6% and 8% below 1990 levels would not be achievable.

Sectoral contribution to greenhouse gases in the EU (1990-2010) — Figure 3.1.8



Source: EEA

Box 3.1.3 Carbon sinks of forests

According to Article 3.3. of the UNFCCC Kyoto Protocol, Parties can use the net changes in greenhouse gas emissions from sources and removals by sinks to meet their commitments, but only those resulting from direct human-induced land-use change and forestry activities and limited to afforestation, reforestation, and deforestation since 1990. Afforestation and reforestation can increase the stock of carbon and therefore act as a net sink. On the other hand deforestation leads to additional net emissions of CO_2. Further work to clarify the definitions, to remove major uncertainties and to agree methodologies and appropriate modalities will be addressed in future. The IPCC will produce a special report on the issue of carbon sinks in 2000.

Additional land-use and land-use change activities that could be used to contribute to the fulfilment of the Kyoto target may be specified under Article 3.4 of the Kyoto Protocol. UNFCCC negotiations on this issue will start after 2000.

The European Forest Institute prepared for EEA (EFI, 1998) a preliminary analysis of the issue of forest carbon sinks in Europe, related to the Kyoto Protocol. The more comprehensive EUROFLUX project (Martin *et. al.*, 1998) provides similar results, while taking into account all important carbon fluxes. It provides long-term carbon dioxide and water vapor fluxes of European forests. The main conclusions of the EFIstudy are:

- for Europe the land-use change and forestry carbon balance (usually sinks) reported by the countries to UNFCCC using the IPCC Guidelines, is comparable to a uniform estimate from FAO statistics (a carbon sink of 50-70 million tonne (Mt) C per year for EU15);
- there are large differences in the national methods used;
- the forest carbon sink according to the Kyoto Protocol can be estimated in different ways, because the definition of afforestation is not clear. Using FAO definitions the carbon balance for EU15 is estimated to be a sink of 10 Mt C per year, while using the IPCC definitions this is only 1 Mt C per year;
- the forest carbon sinks are relatively small compared with the EU15 CO_2 emissions (of 3 372 Mt or 920 Mt C), depending on the definitions between 0.1% and 1%. This shows that to reach the EU Kyoto commitment for 2008-2012 carbon sequestration can form only a small part of the required policies and measures, although the potential for carbon sequestration can vary considerably between countries.

Furthermore it should be noted that the accounting approach for carbon sinks in the Kyoto Protocol can lead to incentives with negative impacts on biodiversity conservation and soil protection (WBGU, 1998).

Table 3.1.10. **Possible potential for greenhouse emission reduction and costs in the EU**

Sector/measures	Emission reduction (Mt CO_2 eq.)	Average cost (euro/tonne CO_2-equiv.) Low (1)	0-50
CO_2			
Transport, increased passenger-car fuel efficiency	145	X	
Industry (increased energy efficiency)	66		X
Tertiary/domestic (increased	33		X
energy efficiency)			
Power generation			
fossil-fuel switching	86		X
CHP	31		X
renewables (biomass, other)	79		X
EU total CO_2	440	below 50	
CH_4			
Agriculture (improved manure management)	34	X	
	20		X
Waste (landfill gas	23		X
recovery/flaring)	60		X
Energy (reduction	4	X	
gas leakage)	11		X
EU total CH_4	150	below 50	
N_2O			
Agriculture (reduce fertiliser application)	24	X	
Waste	1	X	
Industry (BAT installed in adipic and nitric acid production)	86		X
Energy (combustion)	8	X	
EU total N_2O	120	below 50	
Halogenated gases:			
HFC (HFC manufacturing, reduce leakage or use substitutes)	48		X
PFC	4		X
SF_6	7		X
EU total halogenated gases	60	below 50	
EU total all greenhouse gases	770	below 50	

(1) low means approximately zero costs or cost savings that offset the costs of the measure

Source: Capros, 1998; Coherence, 1998; Ecofys, 1998a, 1998b; AEA, 1998a, 1998b; March Consulting Group, 1998

5. Possible future responses in the European Union

According to the initial analysis, as described above, the effort required to meet the EU reduction objective under the Kyoto Protocol is estimated to be around 600 Mtonnes of CO_2-equivalent.

An important element in an EU climate change policy will be the cost-effectiveness of policies and measures. This means a combination of measures for the six gases that will have the least cost for all sectors together. It should be noted that apart from cost-effectiveness other criteria for selection and implementation of measures are also important, such as political acceptability, fairness (for example between sectors), social barriers and industrial competitiveness.

Use of all abatement measures with a cost below 50 euros/tonne CO_2-equivalent would give a total technical reduction potential of 770 Mt CO_2-equivalent for the six greenhouse gases from (Table 3.1.10), which includes 440Mt from measures targeted at CO_2. This is more than the reduction required for achieving the Kyoto emission reduction target of 600 Mt CO_2-equivalent. It should be noted that there are quite large ranges in cost estimates from the various studies, so the cost estimates should only be regarded as indicative. Some of the measures presented here are already being planned or implemented in various Member States.

The Commission and Member States will undertake further assessments of policies and measures at both EU and national levels in conjunction with the Kyoto Protocol Flexible Mechanisms. The EU Strategy on Climate Change, expected in 1999, will make an important contribution to this process.

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