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CLIMATE CHANGE IN THE EUROPEAN UNION

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PREFACE

GLOBE EU (Global Legislators Organisation for a Balanced Environment) requested the European Environment Agency to prepare an assessment of the trends, state and outlook of the environmental theme climate change and the main related sectors 'energy' and 'transport' in the European Union (EU) for its conference *Responding to Climate Change* (Linz, Austria, 6 September 1996). This assessment does not include policy options open to European Countries and the European Union to mitigate climate change.

Due to the limited period available the Agency has prepared the requested assessment as an update of the assessment reported by the EEA in the state of the environment report *Environment in the European Union - 1995; Report for the Review of the Fifth Environmental Action Programme*. This update includes:

- recent data on energy consumption and supply;
- recent data on emissions and state of the environment;
- recent information on Community actions, communications and conclusions;
- new scientific insights (such as the 1995 Scientific report of the IPCC).

Data for this paper were provided by the Statistical Office of the European Communities (Eurostat), the Dutch National Institute for Public Health and Environment and the Agency's Topic Centre on Air Emissions. The paper was prepared by André Jol and Keimpe Wieringa. Technical comments were received from the European Commission. I wish to express my appreciation and thanks to these organisations for their co-operation.

The IPCC Second Assessment report showed both the scale of the problem and the urgent effort to be made, in particular by developed countries, including the EU, to achieve a more sustainable situation.

The findings of the present EEA report confirm that the EU is making progress in stabilising emissions of greenhouse gases. There is however considerable uncertainty whether the EU will meet the now considered humble target of stabilisation of CO_2 emissions at 1990 levels by 2000. Current measures are insufficient to prevent a further increase in CO_2 emissions after 2000, when substantial reductions are required.

Setting, agreeing and implementing substantial emission reduction targets, including appropriate action for the year 2010 and beyond appears the key for future climate change policy at EU level. That implies a much larger effort and, in general, accelerated and adequate EU policies in very controversial but relevant areas, such as energy and transport. This is required if the EU is to contribute efficiently to avoiding adverse effects on ecosystems and to assure at least, as the EU has declared, that the global average temperature should not exceed two degrees Celsius above pre-industrial levels.

Adequate burden sharing strategies or approaches will also be required and agreed inside and beyond the EU to assure the achievement of sustainable development.

The Agency is building up a more operational environmental reporting system to support the policy process by providing timely information, as started with the *Environment in the European Union - 1995* report and now reflected by this present report. In this way the Agency is planning to be increasingly able to report clearly on the environmental situation and above all the prospects and the scale of the efforts required.

Domingo Jiménez-Beltrán
Executive Director

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1. EXECUTIVE SUMMARY

1.1 MAIN CONCLUSIONS

The European Union is making progress in stabilising emissions of greenhouse gases. There is however considerable uncertainty whether the EU will meet the target of stabilisation of CO_2 emissions at 1990 levels by 2000. Current measures are insufficient to prevent a further increase in CO_2 emissions after 2000. Actions taken to date will not lead to full integration of environmental considerations into economic sectors or to sustainable development. If the EU wants to achieve its targets of avoiding adverse effects on health and ecosystems, an accelerated policy is needed. Substantial reductions of all green house gases are therefore needed.

These are the main conclusions of an assessment of the trends, state and outlook of the environmental theme climate change and the main related target sectors 'energy' and 'transport' in the European Union (EU) by the European Environment Agency (EEA), as requested by GLOBE EU (Global Legislators Organisation for a Balanced Environment) for its conference *Responding to Climate Change* (Linz, Austria, 6 September 1996). The assessment is an update of the assessment reported by the EEA in *"Environment in the European Union - 1995; Report for the Review of the Fifth Environmental Action Programme (5EAP)"*.

The main conclusions of this present assessment are a confirmation of the conclusions of the report mentioned, which showed the following. Some of the pressures on the environment have decreased in recent years. Regarding climate change there have been reductions in the production and consumption of chlorofluorocarbons (CFCs) and its substitutes and some reduction of carbon dioxide (CO_2) emissions (partly due to short-term effects) although in the same period further economic and industrial growth occurred. However to achieve stabilisation of the concentration of greenhouse gases in the atmosphere a more substantial emission reduction is necessary. The report also concluded that climate change should be one of the key issues on which to focus future policy at the European level. Mitigating climate change will also have significant positive side effects for other environmental issues, such as ozone depletion, acidification, air quality and waste management.

1.2 ENERGY

The key strategy of the European Community's 5EAP is to integrate environmental considerations into other policy areas, focusing on five target sectors, therefore aiming to initiate changes in current trends and practices. For the environmental theme of climate change the two most important target sectors are 'energy' and 'transport'. Despite this strategy, the driving forces behind the pressures on the environment have not changed or lessened. Apart from agriculture, all sectors show upward trends, resulting in more energy use and transport mobility.

Energy consumption continues to increase, because improvements in energy efficiency in industry and the domestic sector are counterbalanced by the increased consumption in the transport sector. The most important other trend, resulting in (relatively) less pressure on the environment is the relative reduction in economic and industrial growth rate (despite the completion of the Internal Market).

Since the early 70s, energy intensity (energy consumption per GDP) has decreased mainly due to energy efficiency improvements and changes in the overall structure of the economy. This implies a weakening of the links between GDP, growth in population and energy consumption. However, total gross energy consumption increased steadi-

ly between 1980 and 1992 by about 1% per year on average and stabilised during the last years. Implementing the current 5EAP measures (at EU and national level) will hardly lead to any change in these figures. In fact the reductions in energy intensity will be lower. Major underlying factors are the remaining low prices of energy (which discourage energy conservation measures) and the increased use of energy in the transport sector (which counterbalances the lower energy use in industry).

During the last decade the structure of energy supply has changed. The share of solid fuels has fallen, whilst the share of natural gas has increased. It is expected that gas supply will further increase in place of solid fuels. The present share of renewable energy accounts for some 5%, which may increase to 7.5% in 2010.

Environmental pressure from the transport sector shows a steady increase. Forecasts suggest a near doubling of freight road transport and about a 50% increase of passenger road transport between 1990 and 2010. To date, the EU has played a key role in establishing environmental requirements for the transport sector (technical and fuel standards, for example the Auto-Oil Programme). Apart from introducing further technology-forcing product requirements, the challenge is to design new transport systems including the re-engineering of infrastructure to satisfy mobility demands in a more sustainable way than road transport. Efforts to encourage a decrease in the overall demand for mobility (facilitated, for example, by the 'information society') will also be necessary.

1.3 CLIMATE CHANGE

THE ISSUE

The continuing and rapid increase in the atmospheric concentration of greenhouse gases can cause climate change. The latest Second Assessment Report of IPCC (1995) concluded inter alia that :

- "the balance of evidence suggests a discernible human influence on global climate";
- "if CO_2 emissions were maintained at near current levels, they would lead to a nearly constant rate of increase in atmospheric concentrations for at least two centuries reaching almost twice the pre-industrial concentration level by the end of the 21st century";
- "for the mid-range IPCC scenarios of future emissions, and assuming the best estimate value of climate sensitivity, models project an increase in global mean temperature, relative to 1990, of about 2° C by the year 2100 (the uncertainty range is 1-3.5° C)".

Timing is a key issue in climate change. There is a considerable time delay between a reduction of the emissions of these gases and stabilisation of atmospheric concentrations. Once climate change has become manifest, it will show an irreversible character or, when actions are undertaken, a long recovery time. Furthermore, there are the societal time-lags inherent in, for example: raising public awareness, development and timing of policy actions, and fully implementing these measures (taking into account the relatively short turnover of capital goods).

Geographical distribution of climate change policies is another key issue. The global average annual per capita emissions of CO_2 due to the combustion of fossil fuels is at present about 4 tonnes, in developed and transitional economy countries about 10 tonnes and in developing countries about 2 tonnes. The European Union is aiming to set emission targets for the year 2005 and 2010. This target setting will require an extensive discussion and agreement on the allocation of these targets, and will be influenced by equity and efficiency issues with respect to the developing countries.

STATE

In the period 1980 to 1990 the total *global* greenhouse gas (GHG) emissions (CO_2-eq.) increased 15 %, mainly due to a growth of the CO_2 emissions in the other, less industrialised, countries. From 1990 global CO_2 emissions did not grow, mainly due to the economic recession/restructuring in the CEE and CIS countries. The emissions of CFC have decreased in this period, resulting in a decrease of global GHG emissions (CO_2-eq) of 5 % from 1990 to 1994. However, GHG emissions (CO_2-eq) in OECD countries have increased, whereas the UNFCCC target is to stabilise the emissions between 1990 and 2000.

After a period of steady increase, total emissions of carbon dioxide in *the European Union* fell

slightly (2 %) between 1990 and 1994, mainly due to short-term factors, such as the temporary decrease of industrial and economic growth rates, the restructuring of industry in Germany, the closing of coal mines in the UK, and the conversion of power plants to natural gas. Although CO_2 emissions from industry and the energy sector have decreased, emissions from the transport sector show an increase.

The emissions of the other greenhouse gases nitrous oxide (N_2O) and methane (CH_4) show some decrease between 1990 and 1994. However it should be noted that the uncertainty of the emission data of these pollutants is much higher than for CO_2.

Chlorofluorocarbons (CFCs) and their substitutes (HCFCs) are other relevant greenhouse gases. These pollutants furthermore cause depletion of the ozone layer. At present, this problem is universally recognised and international negotiations on the tightening of limitations (eg, of CFC production as proposed in the Montreal protocol) have accelerated. In this regard, the European Union is playing a pioneering role. The production and consumption of CFCs show a decreasing trend: an 80% reduction between 1986 and 1994. The 1994 target for halons has been reached. The production of HCFCs (targeted for complete phase out by 2015) has increased during the period 1986-1994 as a result of the substitution for previous uses of CFCs.

The atmospheric concentrations of GHGs, *inter alia* CO_2, CH_4 and N_2O, have grown significantly since pre-industrial times: by about 30 %, 145 % and 15 % respectively. In the same period global mean surface air temperature has increased by between about 0.3 and 0.6 degrees Celcius.

OUTLOOK

Achieving the target of stabilisation of EU CO_2 emissions at 1990 levels *by 2000* seems to be the cornerstone of EU environmental policy. There is, however, great uncertainty about whether the EU will meet this target. There is a range of estimates, depending on the scenarios used. However, most scenario studies indicate an increase of emissions up to 5 % in 2000, compared to 1990. The main causes of uncertainty are: continuous transport growth, continuing low energy prices, the slow improvement of energy efficiency and the fact that many of the measures in National Programmes will not be completed before 2000. The proposal for one of the key measures at the Community level (the energy/carbon tax) has not been adopted, but some Member States (Denmark, Finland, the Netherlands, Austria and Sweden) have already introduced such taxes to date. However, the contribution of these countries to the total EUR 15 emissions of CO_2 is not large.

Current measures are insufficient to prevent a further increase in CO_2 emissions *after 2000* as a result of the expected growth of production, consumption and transport. However, to achieve the stabilisation of the concentration of greenhouse gases at the lowest possible level in the shortest possible time, substantial emission reductions are necessary. The EU has declared that global average temperatures should not exceed 2 degrees Celcius above pre-industrial level. To reduce major risks for ecosystems, food production and sensitive coastal areas, emissions in industrialised countries (including the EU) should be reduced by minimal 30 to 55 % in 2010 compared to 1990, depending on the baseline emissions in the developing countries.

Recognising the need for full integration of environmental considerations into economic sectors the Agency's contribution - from reliable and comparable information on the environment through integrated assessments to regular reporting - is to support this process.

2. Energy

2.1 THE ISSUE

The 5EAP emphasises the importance of long-term energy strategies to ensure that environmental stress from energy supply and consumption is reduced to sustainable levels. Greater efforts are required to achieve this, particularly taking into account the considerable growth forecast in the transport sector.

The response to this within the energy sector is largely influenced by the debate on the role the Community can play in shaping the energy dimension of the future. No specific energy title was included in the Maastricht Treaty. New guidelines have been drawn up and are presented in a Green Paper *For a European Union Energy Policy* (EC, 1994). This paper defines the Community's approach to future policy, stressing that within a deregulated energy market a clear energy policy framework offers better possibilities for the development of integrated resource or least-cost planning. It also includes a section on environmental objectives, which emphasises clean technologies, improving the efficiency of supply and internalising the external costs of energy use.

The White paper (EC, 1995), which followed the Green paper, considers the strategic objectives of overall competitiveness, security of supply and environmental protection as being most relevant to the energy sector. The primary goal for the smooth functioning of the internal energy market will be the liberalisation of the electricity and gas market. The White paper also notes that with respect to sustainable development, the internalisation of external costs other than through taxation needs to be given a higher profile. Renewable energy sources should be promoted and offered an increased share in the EU's energy balance (this will also reduce the external dependency).

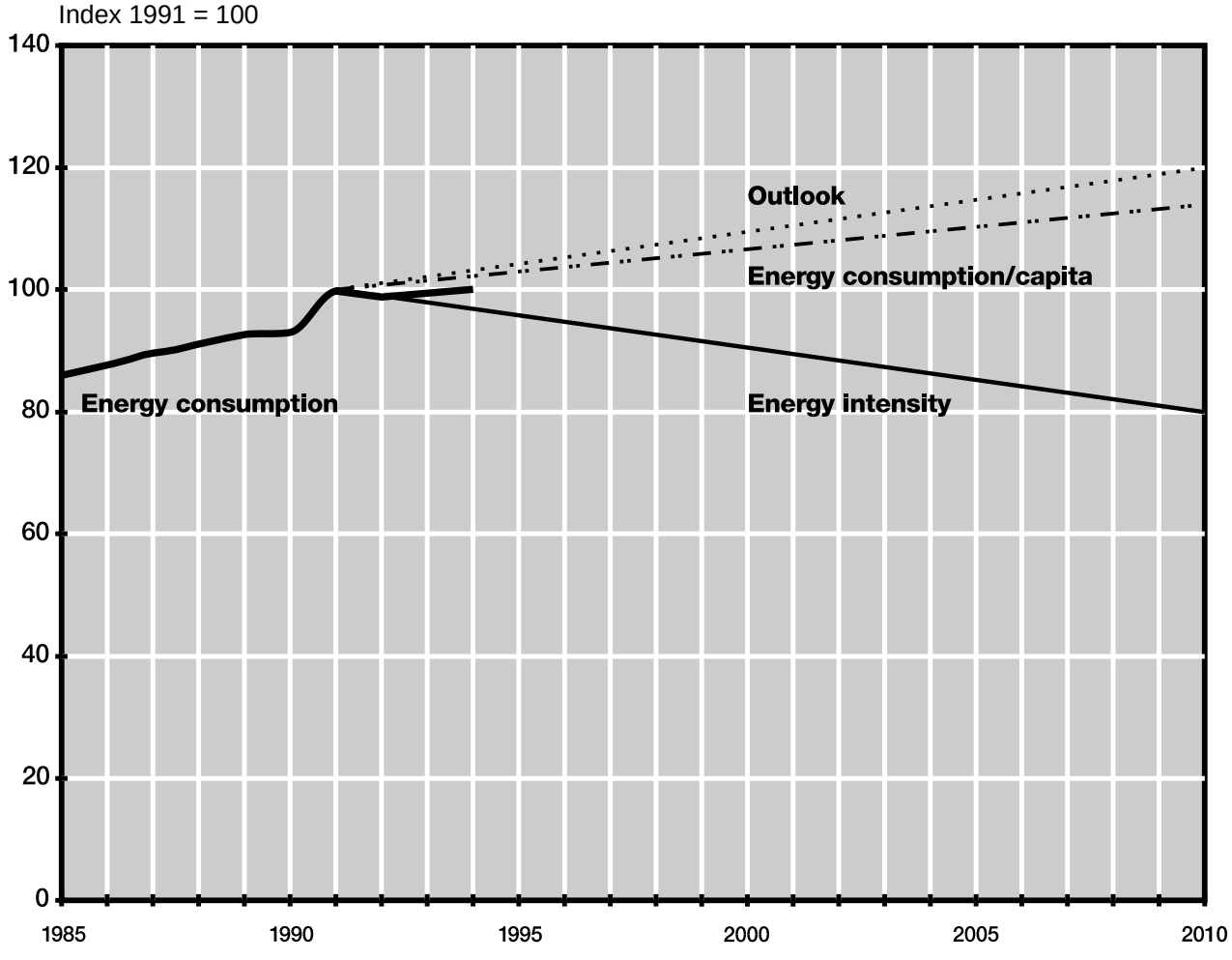
Box 2.1: EU state of action in the transport and energy sector (consumption and supply) since 1992.

5EAP objectives for EU (1992-1995)	Actions achieved
Awareness building	
• Economic and fiscal instruments	• New proposal for Directive on CO_2/energy tax (COM(95)172) - would establish a harmonised framework for Member States wishing to apply a carbon/energy tax *(*Communication on Environmental Levies used in Member States, in preparation) • Amended proposal (COM(94)147) on excise duties applicable to fuels of agricultural origin
Energy Efficiency	
Implementation of PACE, SAVE and national efficiency programmes:	**SAVE** - has supported 25 pilot projects in least cost planning and demand side management
• energy efficiency standards for appliances, products and vehicles	• Three energy efficiency Directives have been adopted: hot water boilers, labelling of household appliances & omnibus Directive 93/76
• efficiency standards for energy technology	• Directive proposed on efficiency of refrigerators and freezers and draft proposal on least-cost planning
	Communication on a Community strategy to reduce CO_2 emissions and improve fuel economy (Council conclusions, June 1996)

Box 2.1 continues next page

Technology Programmes Implementation of THERMIE and JOULE programmes including: • R&D of new energy technologies and promotion and use thereof • R&D on renewables (ie biomass)	• 3rd and 4th Framework Research Programmes
Promotional Programmes • ALTENER: promotion of renewable energy	• Programme adopted by Decision 93/500 - promotion of renewable energy sources (ALTENER). Standards for biodiesel have been formulated and support given to pilot projects. Effects not expected until year 2000.
Nuclear Safety Programmes • Study on safety and waste aspects of nuclear energy	• Ongoing
Transport user behaviour - development of inter-active communication infrastructures • Locking and tracking systems, electronic home, video conferences	• R&D efforts through a range of programmes covering vehicle-based telematics, telecommunication and telecommuting. Some funds from the Drive 2 Programme in particular are being diverted into environmental assessment of advanced telematics.

Figure 2.1: Development of gross energy consumption in EUR15 (the former East Germany is included from 1991 onwards)
Source: Eurostat; EC,1995



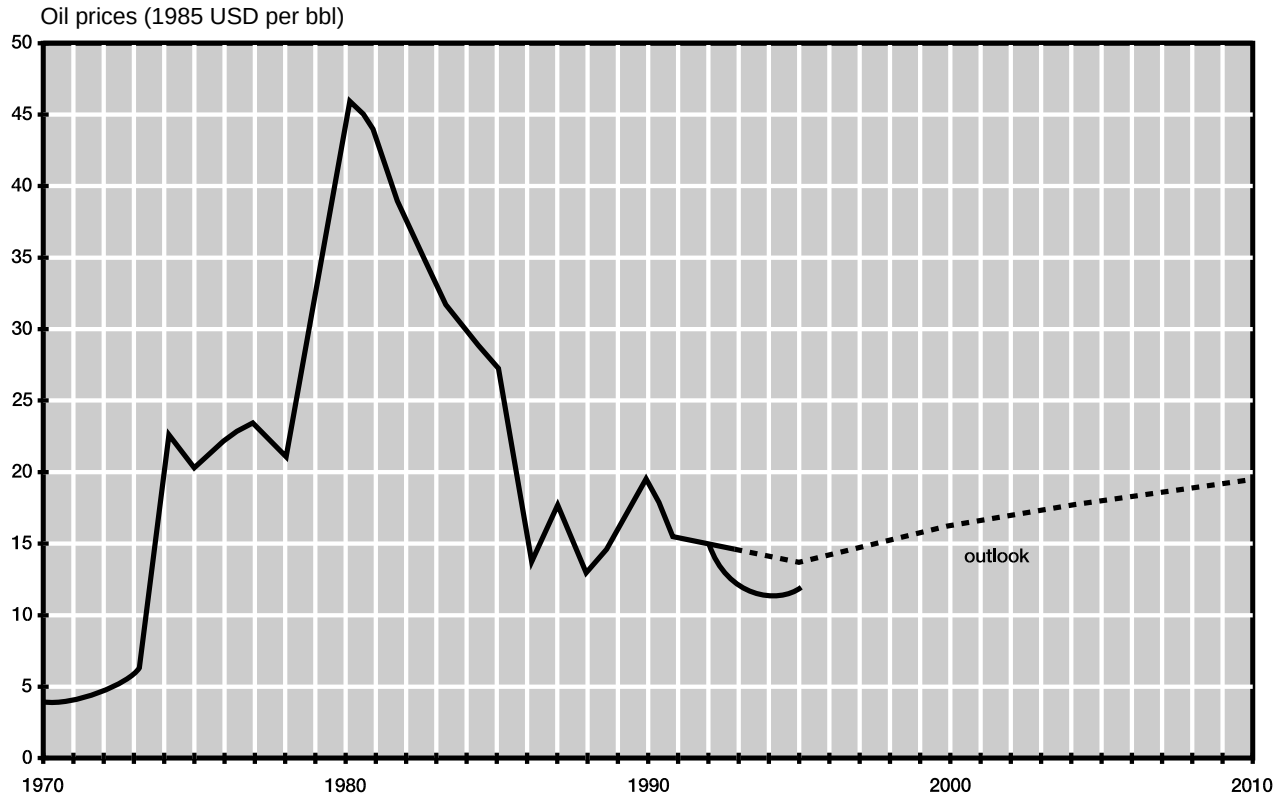


Figure 2.2 World market oil prices. Source: DEA, 1995; EC, 1995

2.2 PAST TRENDS

Energy consumption and prices

Since the early 1970s energy intensity[1] has decreased mainly due to energy efficiency improvements and changes in the economic structure (eg, less heavy industry, less reliance on production of intermediate goods). This implies a weakening of the links between GDP, growth in population, and energy consumption. However, total gross energy consumption in the EU increased steadily between 1980 and 1990 by about 1% per year on average and stabilised between 1991 and 1994 (see *Figure 2.1*). The rate of increase differs across Member States and is considerably higher in the more peripheral economies of the EU such as Finland, Ireland, Italy, Portugal and Spain.

A number of driving forces influence energy consumption including:

- economic growth;
- increased demand for transport services;
- low energy prices; and
- growing concern about the environmental issues.

1 Energy intensity: here, gross inland energy consumption per GDP

Oil prices increased sharply during the 1970s, peaked in the early 1980s and have been falling gradually since 1980 (see *Figure 2.2*). The current real price of energy is now at the same level as the early 1970s. The price has not been significantly influenced by energy-taxes. The consumer price of other energy sources was generally made dependent on the oil price.

Energy consumption within each sector has its own characteristic; the pattern in the households and the industry and transport are described briefly below (see also *Figure 2.3*).

- Energy consumption in **industry** in the EU shows a steadily decreasing trend from 1985 to 1994. This evolution corresponds to significant decrease of the energy intensity of the sector, especially given that overall industrial capacity increased steadily. Energy consumption in energy-intensive branches, such as iron & steel, chemicals, and non-metallic minerals, was also significantly lower in 1994 compared to 1985. Sweden is one of the very few countries where energy consumption by industry increased.

- In the **transport** sector, energy consumption grew steadily from 1985 to 1994. In this sector, energy demand has grown faster than overall economic activity. Therefore, energy intensity in the transport sector increased by 0.7% pa in the period 1980-1990 (EC-DGXVII, 1994). Also, real prices for transport fuel dropped, helping to push up fuel consumption. Significant decrease of the energy intensity of vehicles was counteracted by an increasing number of cars, a higher share of larger, more powerful cars in the transport sector and an increase in kilometres travelled per capita. Over the period 1980-1990 passenger transport (in kilometres) by road increased by almost 40%. These developments are reflected in road transport's share of total energy consumption in the transport sector, which increased from 79% in 1974 to 83% in 1992.

- In the **households** and the **tertiary** sector, energy consumption grew slightly from 1985 to 1994, although consumption in this sector varies with climatic conditions and fluctuations. Other important factors are population size, number of households, private income and evolution of the services sector. It is not possible to give a full split between both subsectors, but indications are that there has been growth in energy demand in commerce (supermarkets, shopping centres, etc) and in households as a consequence of widespread penetration of household appliances. This growth in total demand has largely outweighed technological and other efficiency improvements. In most Member States, there has been a tendency for demand to stabilise or decrease over this period; exceptions to this include former East Germany, Greece and Portugal.

In the **electricity** sector, there has been an almost continuous increase in electricity consumption between 1974 and 1992 by an average of 2.7% pa. In 1992 electricity demand decreased to 1.3% growth as a result of economic slow down. In 1993 there was, for the first time, a drop in consumption by about 1%, reflecting economic recession.

Energy supply

The import dependency for energy supply has remained stabled during the period 1985-1994: about 45% of the total energy supply was imported (mostly oil).

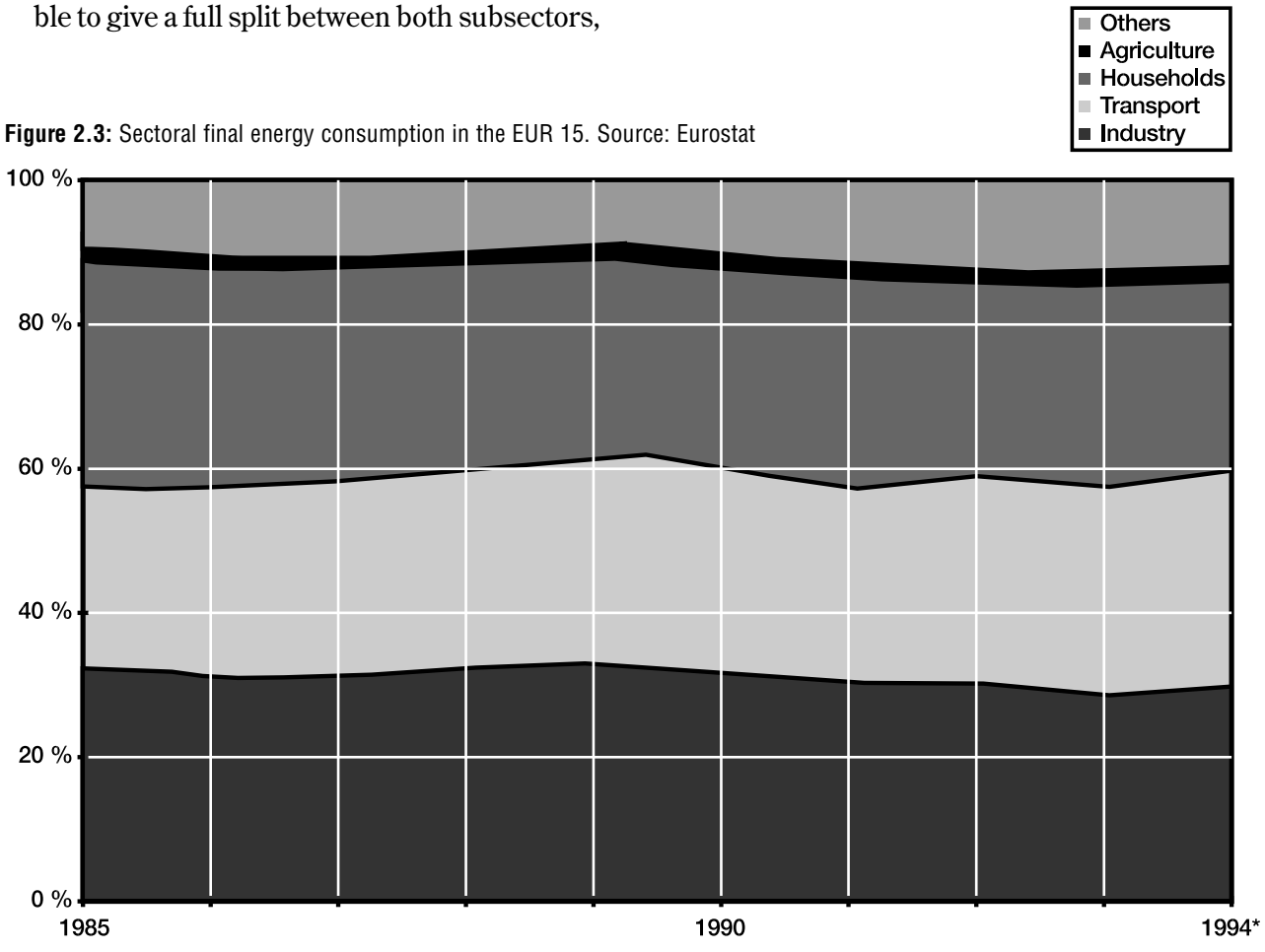


Figure 2.3: Sectoral final energy consumption in the EUR 15. Source: Eurostat

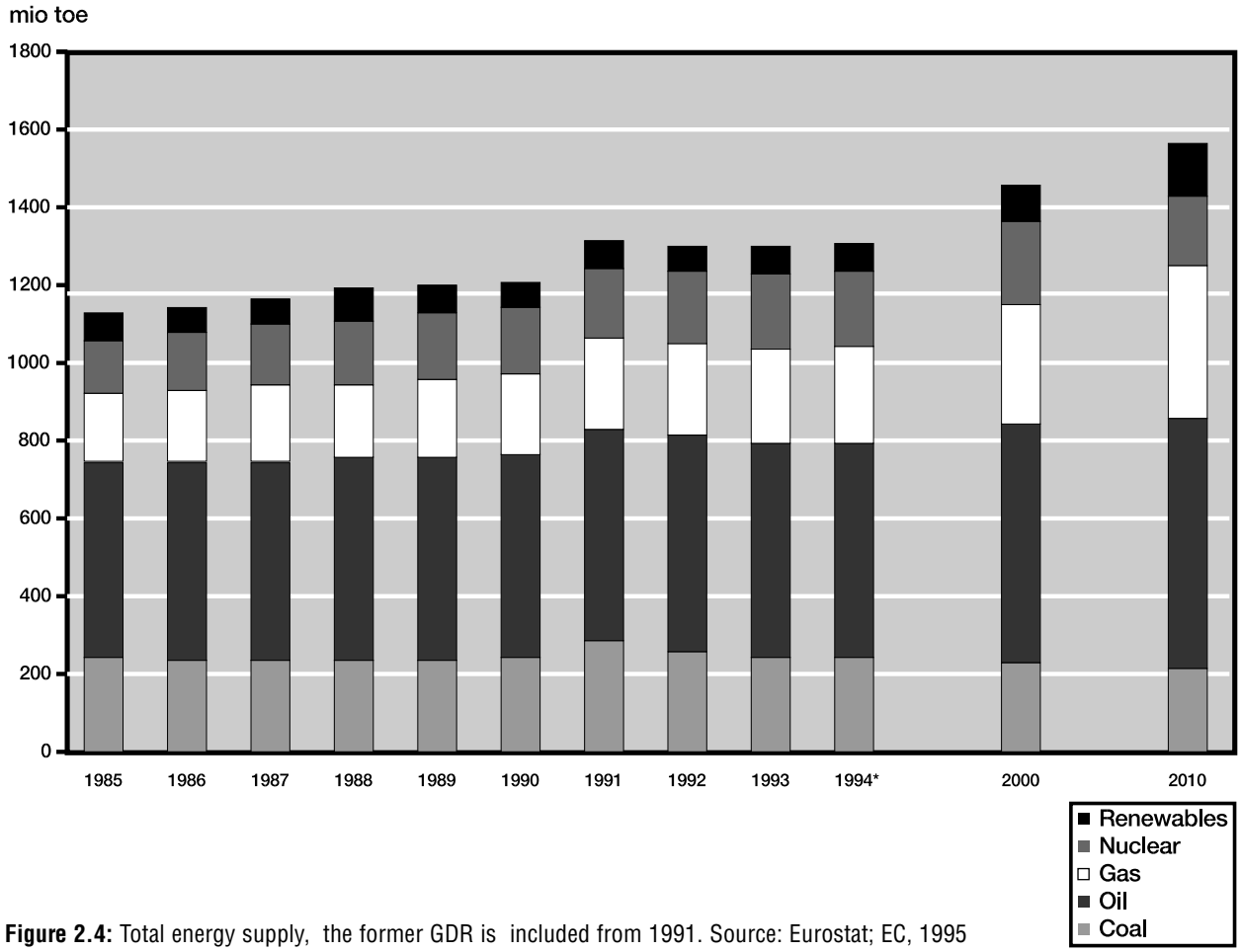


Figure 2.4: Total energy supply, the former GDR is included from 1991. Source: Eurostat; EC, 1995

The mix of fuels in the total energy supply of the EUR 15 during the period 1985 to 1994 is shown in *Figure 2.4.* Oil accounts for the largest share of total supply (42% in 1994); actual supply from this source has remained relatively stable since the 1980s. The trend in the share of energy supply by coal (18% in 1994) has been falling over the period, while the share by natural gas (19% in 1994) is slowly increasing. Nuclear power accounts for about 15% of the total energy supply. The share of renewable energy has remained stable in the period 1985-1994 at about 5%.

National factors (own energy sources, direct access to harbours, climate, economic structure, political preferences, etc) explain the large differences in the type of energy used across the EU. The new Member States very much reflect the varying energy source structure for electricity generation in the EU: Austria has almost equal shares of solids, oil and gas, and a relatively substantial share of hydro; Finland is largely dependent on nuclear (45%) as is Sweden (70%).

2.3 OUTLOOK

In 1990 the EC report *Energy for a New Century: the European Perspective* identified three major themes: the changing geopolitical framework, the internal market and the environment. Subsequent studies in 1992 and 1995 present several scenarios identifying the range of influences at work that could affect the direction of energy demand and supply in the longer term. From the latest Commission study - *European Energy to 2020; A scenario approach* (EC, 1995) - the so-called Conventional Wisdom scenario has been used. This scenario denotes the 'business-as-usual' world, representing a conventional wisdom view of the most likely evolution of events[2].

Energy consumption and prices

In the period 1990-2010 an average growth in primary energy consumption of around 1% pa is expected (see *Figure 2.1*) (EC, 1995). The same figure also shows the development in energy consumption per capita. It can be concluded that the

2 Other scenarios are called Battlefield, Forum and Hyper- market, which describe other futures regarding the energy world

growth in energy consumption will be driven by production and consumption growth per capita. The growth in population will be relatively insignificant.

At the time of the 5EAP, the average growth pa was estimated at slightly less than 1% for the same period. Thus, despite the promotion and co-financing of energy conservation initiatives at the EU and national level, current energy consumption forecasts are virtually unchanged in comparison with the former projections. Lower energy use in industry and stable use in the domestic and commercial sector will be counterbalanced by increased use in the transport sector.

According to the current estimates, real oil prices would increase by about 60% between 1995 and 2010, and will arrive at the same level as it was in 1990 (see *Figure 2.2*). It is expected that coal and gas prices will decline relative to the price of oil.

Unsurprisingly, due to the lack of economic incentives, future reductions in energy intensity are likely to be modest. In industry, energy intensity gains must be considered together with a continuing change in industrial processing structures. Intensities in the domestic sector are also expected to decline. Energy intensity is estimated to decrease by about 1.2% pa to 2010, although the energy intensity has stabilised in the last 10 years.

One of the EU policy initiatives with a potential short term impact on the demand side is the SAVE Programme. This Programme (renewed in 1995) aims to attain a 20% energy efficiency improvement between 1986 and 1995. Estimates indicate that only about 10% of the improvement will be achieved. Recently adopted directives on efficiency for freezers and refrigerators may yield some results in the immediate future. An energy/CO_2 tax has been suggested by the EC as a cost-effective instrument for substantial, short-term, improvements in energy efficiency, taking into account the responsiveness of energy demand to an increase in prices which would follow from the imposition of a tax. While an EU wide tax would be creating 'a level playing field' within the EU, some Member States (Denmark, Finland, Sweden, Austria, The Netherlands) have already introduced an energy/CO_2. Those countries which already have such a tax allow exemptions to industry subject to international competitiveness.

Energy supply

The forecasts in 1995 for EU internal energy production in the period 1990-2010 show a steady decrease and the import dependency is expected to increase (from 45 to 65%) (EC, 1995).

The share of total energy supply accounted for by coal will (further) by around 1% pa due to their environmental drawbacks (SO_2, NO_x, CO_2) and rapid substitution by natural gas in power generation, in spite of their competitive pricing (see *Figure 2.4*). The demand for natural gas is expected to increase rapidly (about 3% pa). The total shares for coal and gas in 2010 will be about 15 and 25% respectively. The efficiency, convenience and cleanliness of natural gas has been widely recognised by residential and commercial consumers. The prevailing trend in the electricity sector is the penetration of natural gas combined cycle plants, also built for co-generation of heat and power (CHP). The industrial market for hard coal and residual oil is also threatened by competition from natural gas. The projected further expansion of distribution, particularly in Denmark, Spain, Portugal, Ireland and Greece, will favour gas penetration in industry. Nevertheless, price relations between gas and its competitors are considered decisive. Oil products remain important for end-use, it is expected that their share in the market will remain stable.

The share of nuclear power will hold virtually constant to 2000 and will show a decrease afterwards (EC, 1995). Although the present share of renewable energy sources accounts for some 5%, this source has the highest future growth rate forecast compared to other energy sources and is expected to account for 7.5% in 2010.

3. Climate change

3.1 THE ISSUE

Climate change, resulting from global warming, is a global environmental issue identified by the EU as one of the key environmental themes to be tackled under the 5EAP. Global warming is expected to take place as a result of increasing amounts of anthropogenic emissions of gases that affect the absorption and emission of radiation in the atmosphere. These gases, in particular carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and chlorofluorocarbons (CFCs) and their substitutes are referred to collectively as greenhouse gases (GHGs). The contribution to the overall global warming effect of these pollutants is shown in *Table 3.1*. Tropospheric ozone (O_3) also contributes to global warming. CFCs and HCFCs (less damaging substitutes for CFCs) furthermore cause depletion of the ozone layer.

The continued emission and accumulation of these gases is expected to result in an enhanced 'greenhouse effect' and an attendant rise in the global mean temperature, which might affect the overall climatic conditions on the planet. This is expected to affect sea level, run-off patterns of watercourses, frequency of droughts and flooding, agriculture, forests, precipitation levels and biodiversity.

The severity of these impacts is extremely uncertain, though in recent years the international scientific community has made considerable progress in understanding the relationships between, for example: GHG emissions, atmospheric concentration, temperature, and economic costs.

The Second Assessment Report of IPCC (1995) concluded *inter alia* that :

- "the balance of evidence suggests a discernible human influence on global climate";
- "changes in greenhouse gases and aerosols, taken together, are projected to change regional and global climate-related parameters such as temperature, precipitation, soil moisture and sea level. Potentially serious changes have been identified, including an increase in some regions in the incidence of high-temperature events, floods and droughts, with resultant consequences for fires, pest outbreaks, and ecosystem composition, structure and functioning, including primary production";
- "if CO_2 emissions were maintained at near current levels, they would lead to a nearly constant rate of increase in atmospheric concentrations

Table 3.1: Greenhouse Gases - Sources and Contribution to Global Impact

Gas	Main Anthropogenic Sources	Contribution (%)
CO_2	Energy use, deforestation and changing land use, cement production	65
CH_4	Energy production and use, enteric fermentation, rice paddies, wastes, landfills, biomass burning, domestic sewage	20
CFCs & HCFCs	Industrial, primarily refrigeration, aerosols, foam blowing, solvents	10
N_2O	Fertilised soils, land clearing, acid production, biomass burning, combustion of fossil fuels	5

Source: IPCC (1994, 1995)
Note: based on 1994 source emission data adjusted using 100 year Global Warming Potentials (RIVM, 1996)

for at least two centuries reaching almost twice the pre-industrial concentration level of 280 ppmv by the end of the 21st century";

- "for the mid-range IPCC scenarios of future emissions, and assuming the best estimate value of climate sensitivity, models project an increase in global mean temperature, relative to 1990, of about 2° C by the year 2100 (the uncertainty range is 1-3.5° C) and an associated increase in sea level of about 50 cm from 1990 to 2100 (the uncertainty range is 15 to 95 cm)";

- "the global average annual per capita emissions of CO_2 due to the combustion of fossil fuels is at present about 4 tonnes, in developed and transitional economy countries about 10 tonnes and in developing countries about 1.8 tonnes".

While the findings vary (a range of 1 - 3.5 degrees Celcius by 2100), the overall conclusions generally support the view that policy action is essential to curb global GHG emissions to control global warming.

Timing is a key issue in climate change. There is a considerable time delay between a reduction of the emissions of these gases and stabilisation of atmospheric concentrations. Once climate change has become manifest, it will show an irreversible character or, when actions are undertaken, a long recovery time. Furthermore, there are the societal time-lags inherent in, for example: raising public awareness, development and timing of policy actions, and fully implementing these measures (taking into account the relatively small annual turnover of capital goods).

Environmental policies and EU targets

In an international context, governments responded to the concerns about climate change at the 1992 UN Conference on Environment and Development (Rio de Janeiro). At the Conference, the Framework Convention on Climate Change (UNFCCC) was opened for signatures and individual countries or groups of countries made commitments to control their emissions of CO_2 and other greenhouse gases. Annex-1 Parties (i.e. industrialised countries) made commitments to aim at returning individually or jointly their emissions of greenhouse gases not controlled by the Montreal Protocol to their 1990 levels and to communicate detailed information on its policies and measures on the mitigation of climate change. The European Community and all Member States have ratified the UNFCCC.

The European Union has set two overall environmental climate change objectives: to not allow the natural absorbing capacity of the Earth to be exceeded, and to follow the activities set out in the Framework Convention on Climate Change. The Fifth Environmental Action Programme (5EAP) *Towards Sustainability* mentions a target for the EU, as a whole, to stabilise CO_2 emissions at the 1990 level by the year 2000. The document also identified the need for a monitoring mechanism, which was established under Council Decision 93/389. In the recently presented Review of the 5EAP, the Commission proposes as one of the key strategies to identify reduction objectives for CO_2 and other greenhouse gases for 2005 and 2010, and to define policies and measures for their achievement (EC, 1996f).

The first Conference of the Parties to the Convention was held in March/April 1995. This Conference agreed "to begin a process to enable it to take appropriate action for the period beyond 2000, including the strengthening of the commitments of Annex-1 Parties, through the adoption of a protocol or another legal instrument" (the so-called Berlin Mandate).

At the Ministerial segment of the second session of the Conference of the Parties to the Convention the 1995 IPCC Second Assessment Report was endorsed (July 1996) "as currently the most comprehensive and authoritative assessment of the science of climate change, its impacts and response options now available". The Ministers further stated that the Report "should provide a scientific basis for urgently strengthening action at the global, regional and national levels, particularly action by Annex-1 Parties to limit and reduce emissions of GHGs". It was agreed to accelerate negotiations on the text of a legally-binding protocol or another legal instrument to be completed in due time for adoption at the third session of the conference (Kyoto, Japan, December 1997).

The EU Member States individually and the Commission on behalf of the European Community have submitted their communications, as required under the UNFCCC. These Communications contain inventories of GHG emissions and removals by sinks and describe programmes, policies and measures which are taken or will be taken to

address climate change. The commitments of the Community are to be reached with complementary Community and National Programmes (EC, 1996b). A monitoring mechanism has been established under which the National Programmes and the details of measures which Member States are putting in place are assessed. Likely emission profiles for each Member State and the Community as a whole up to the year 2000 are described by the Commission (EC, 1996a).

Furthermore the EU has presented a separate communication on a "community strategy on climate change" after the meeting of the Council of Ministers in June 1996 (EC, 1996c), which concludes *inter alia* :

- "a protocol or another legal instrument should be set up in a combined approach, including commitments for Annex-1 Parties regarding policies and measures as well as quantified emission limitation and reduction objectives within specified time-frames";

- "….the Council believes that global average temperatures should not exceed 2 degrees Celcius above pre-industrial level and that therefore concentration levels lower than 550 ppm CO_2 should guide global limitation and reduction efforts. This means that the concentrations of all GHGs should also be stabilised. This is likely to require a reduction of emissions of GHGs other than CO_2, in particular CH_4 and N_2O";

- "…it is essential that each of the Annex-1 Parties - it is being understood that the Community is treated as one Party - agrees to set quantified objectives for significant overall reductions of GHG emissions after the year 2000 below 1990 levels, within specified timeframes, not simply to limit growth of total emissions";

- "…it is feasible for the Community as a whole to reach reduction of CO_2 emissions by the year 2010 compared to 1990 level, through the implementation of policies and measures identified by Member States and the Commission, at national and Community level".

Apart from National Programmes EU has also taken action on a Community level, such as energy efficiency programmes (see *Chapter 2*) and, recently, its strategy to reduce CO_2 emissions from passenger cars (EC, 1996d). The aim of the latter is to achieve a substantial emission reduction for new cars in 2005 (at the latest in 2010). Binding CO_2 emission limit values and fiscal measures are not foreseen at the moment.

The proposal for one of the key measures at the Community level (the energy/carbon tax) has not been adopted, but some Member States (Denmark, Finland, the Netherlands, Austria and Sweden) have already introduced such taxes to date. However the contribution of these countries to the total EUR 15 emissions of CO_2 is not large.

The climate change policy has concentrated on the control of CO_2 and its stabilisation at 1990 levels by the year 2000, since CO_2 is the largest contributor to the problem. No EU policy measures and targets have yet been developed for N_2O and CH_4, although the Commission intends to present a communication on methane during 1996. Some Member States have taken action to reduce these emissions. Actions to achieve these reductions include the introduction of a landfill levy and regulations, agricultural policies to reduce fertiliser use and livestock numbers, as well as measures to reduce leakage from gas pipes.

On CFCs and HCFCs international negotiations to tighten existing limitations (eg, of CFC production as proposed in the Montreal protocol) have accelerated and the European Union is playing a pioneering role in this.

A summary of EU policy measures aimed at achieving the targets set out in the 5EAP is presented in *Box 3.1. (Next page)*

3.2 STATE OF THE ENVIRONMENT

Past trends and current status

Given the difficulties in measuring climate change and its environmental effects, the most common indicators used are the pressure indicators of emissions of the individual gases. An examination of changes in key stress indicators (CO_2, CH_4, N_2O) over the last 30 years shows a steady increase in emissions.

Recent trends in GHG emissions are now monitored more regularly due to the commitments of the EU and individual Member States under the UNFCCC. There are a number of different databases for CO_2 emissions including National Programmes, Corinair, Eurostat and the UNECE

5EAP objectives for EU (1992-1995)	Actions achieved
CO_2 - stabilisation at 1990 levels	See also *Box 2.1* on Energy
• Energy conservation measures, such as: - environmentally benign energy use - behavioural changes - economic and fiscal measures	• Decision 93/389 for a monitoring mechanism of Community CO_2 and other greenhouse gas emission (Commission proposal COM(95)172 concerning a carbon/energy tax) Communication on a Community strategy on climate change - Council conclusions, June 1996
• Improvement of energy efficiency, such as: - R & D - infrastructural changes - change in transport modes - economic and fiscal measures	See also *Box 2.1* on Energy
• Fuel substitution towards less or no CO_2 emitting sources (renewables, natural gas, etc), such as: - R & D - infrastructural changes - economic and fiscal measures	• Communication on a Community strategy to reduce CO_2 emissions and improve fuel economy (Council conclusions, June 1996)
CFCs + carbon tetrachloride + Halons + 1,1,1-trichloroethane - phase out before 1.1.96, except for essential uses • Inventory of data	• Regulation 3093/94 halon production/consumption phased out by 1994, CFCs and carbon tetrachloride by 1995, 1,1,1-trichloroethane by 1996;
HCFCs limitation of use to maximum 5 % of 1990 CFC use level • Inventory of data	• Commission Decision 95/107 allocating production and import quotas for HCFC and methylbromide and setting quotas on use; HCFCs targeted for phase out by 2015
Methane and nitrous oxide - measures to be identified by 1994 and applied • Inventory of data	(Communication on methane emissions in preparation) • Decision 93/389 for a monitoring mechanism of Community CO_2 and other greenhouse gas emission, includes a requirement for Member States to include data on emissions of other (non-CO_2) greenhouse gases.

Box 3.1: - EU state of action in the Climate Change theme since 1992

Convention on Long Range Transboundary Air Pollution (LRTAP), although each is based on national data. There are difficulties in selecting a data set which meets all the criteria of reliability, consistency, completeness and multiple years. Corinair is the emission inventory developed in collaboration with Member States and maintained by the EEA. Provisional results of the 1994 inventory are available. The Corinair emission inventory includes fossil fuel related and other emission sources and is in line with the IPCC Guidelines. However only emission data for 1990 and 1994 are presently available. Therefore for the following trend analysis emission data from Eurostat are also used. Up-to-date data from Eurostat for CO_2 emissions from fossil fuel combustion indicates 3100 million tonnes (Mt) in 1994 for the EUR 15 (2.7 % reduction compared to 1990 level). *Figure 3.1* shows the trend in total CO_2 emissions in EUR 15 from 1980 to 1994 (excludes final non-energy consumption and bunkers). The latest provisional Corinair emission data for EUR 15 (EEA-ETC/AEM, 1996) are in line with these figures (reduction of 3290 Mt in 1990 to 3230 Mt in 1994), showing that fossil fuel related emissions account for 95 % of the total emissions.

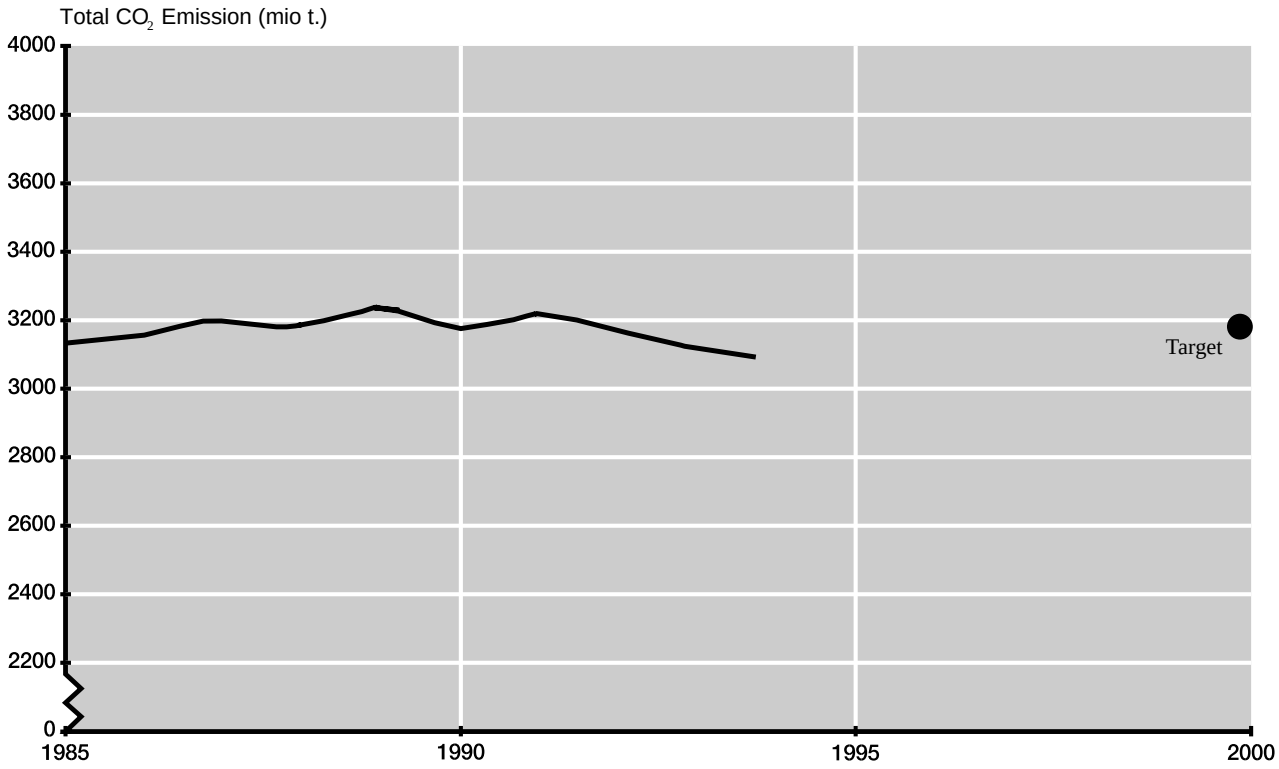


Figure 3.1: Development of CO_2 emissions in EUR 15 from fossil fuel (excludes final non-energy consumption and bunkers) (1985-1994). Source: Eurostat (data includes emissions from former East Germany)

Emissions from fossil fuel combustion in the EUR 15 increased by about 1% overall in the period 1985-90. Emission reductions were achieved by Germany, Denmark and France during 1985-90. From 1990 to 1994 emissions of several countries (Germany, France, United Kingdom) decreased, resulting for the EUR 15 in an emission reduction of approximately 2 %, mainly due to short-term factors like the temporary decrease of industrial and economic growth rates, the restructuring of industry in Germany, the closing of coal mines in the UK and the conversion of power plants to natural gas.

Figure 3.2 shows the sectors responsible for CO_2 emissions from fuel combustion in 1985 and 1994. Although emissions from industry have reduced, emissions from the transport sector show an increase. The average EUR 15 annual per capita CO_2 emissions from fuel combustion only in 1990 is 8.8 tonnes, of which around 2.1 tonnes (24 %) is originating from transport. CO_2 emissions per capita from transport can be further divided in respectively 1.2 tonnes from passenger cars, 600 kg from heavy duty vehicles and buses and 300 kg from other mobile sources (including air transport) (see also *Appendix I*).

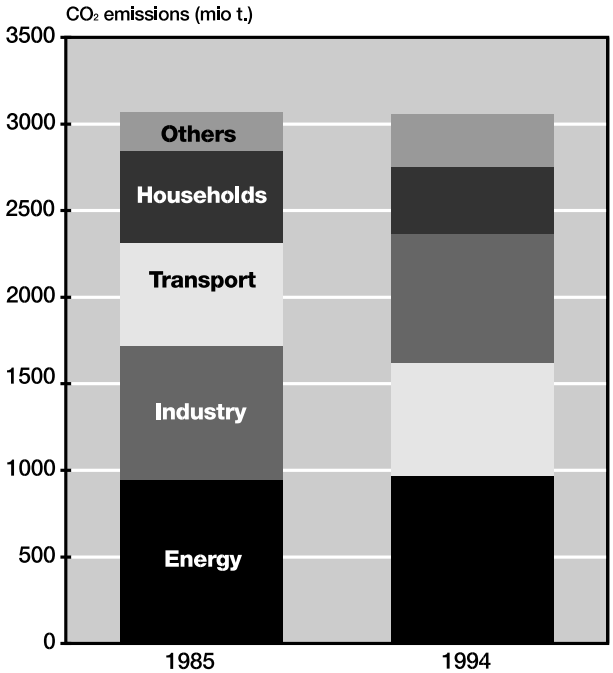


Figure 3.2: Source apportionment of CO_2 emissions from fuel combustion. Source: Eurostat (data includes emissions from the former East Germany)

Figures 3.3 and 3.4 show emissions of N_2O and CH_4 in the EUR 15 in 1994 by source. The main sources of N_2O emissions are agriculture and industry, with a total of 0.9 million tonnes and the

main sources of CH_4 emissions are agriculture and waste treatment, with a total of 22.8 million tonnes in 1994, both excluding natural emissions (provisional results, EEA-ETC/AEM, 1996). Natural sources of both these gases are also significant.

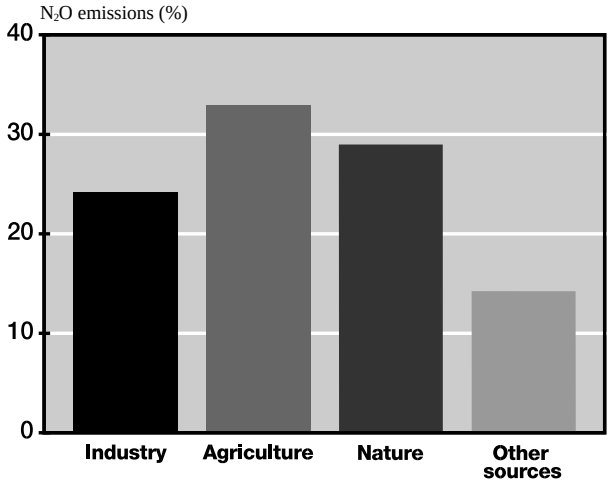


Figure 3.3: Source apportionment of N_2O emissions in 1994
Source: EEA-ETC/AEM, 1996

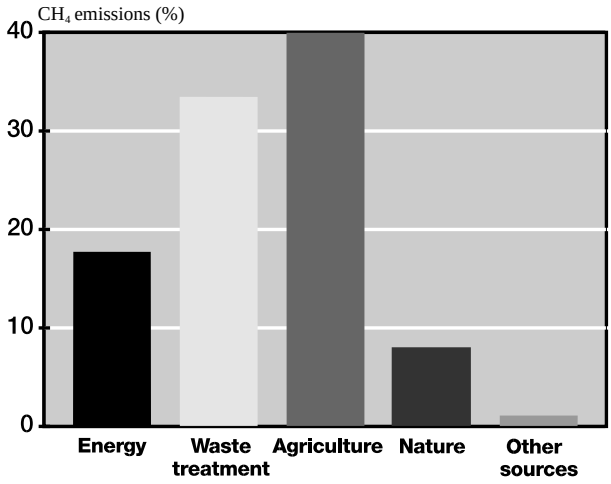


Figure 3.4: Source apportionment of CH_4 emissions in 1994
Source: EEA-ETC/AEM, 1996

The production and consumption of CFCs show a decreasing trend: an 80% reduction between 1986 and 1994 (*Figure 3.5*). The 1994 target for halons (phase out) has been reached. The production of HCFCs (targeted for complete phase out by 2015) has increased during the period 1986-1994 as a result of the substitution for previous uses of CFCs.

To compare the effect of different GHGs the Global Warming Potential is usually expressed in CO_2-equivalents. On a global scale the contribution of CO_2 emissions to the total GHG emissions (CO_2-eq.) is approximately 65 %, of CH_4 20 %, of N_2O 5 % and of CFCs 10 % (see *Table 3.1*). The share of the total GHG emissions (CO_2-eq.) originating from OECD countries is 40 %, from Central and Eastern European countries and the CIS (former Soviet Union) countries 10 % and from other countries 50 %. In the period 1980 to 1990 total global GHG emissions (CO_2-eq.) increased 15 %, mainly due to growth of CO_2 emissions in the less industrialised countries. From 1990 to 1994 global CO_2 emissions did not grow, mainly due to the economic recession/restructuring in the CEE and CIS countries. The emissions of CFC have decreased in this period, resulting in a decrease of global GHG emissions (CO_2-eq) of 5 % from 1990 to 1994 (RIVM, 1996). However, GHG emissions (CO_2-eq) in OECD countries have increased over the period 1990 to 1994, whereas the UNFCCC target is to stabilise the emissions between 1990 and 2000 (WEC, 1996).

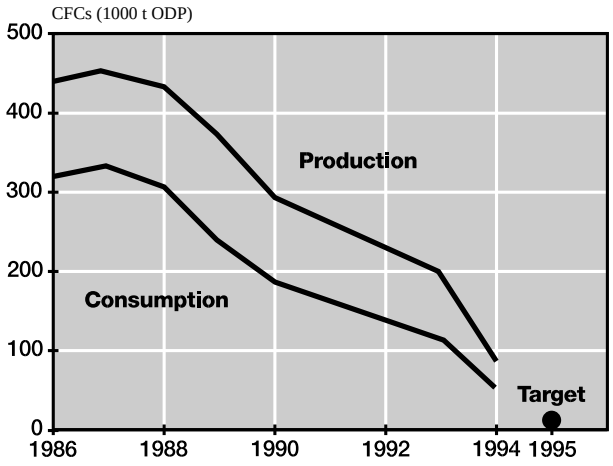


Figure 3.5: Production and consumption of CFCs in the EUR 12. Source : EC-DGXI

Figure 3.6: Development of CO_2 concentration (1950-1994) (at Mauna Loa, Hawaii). Source: CDIAC, 1994

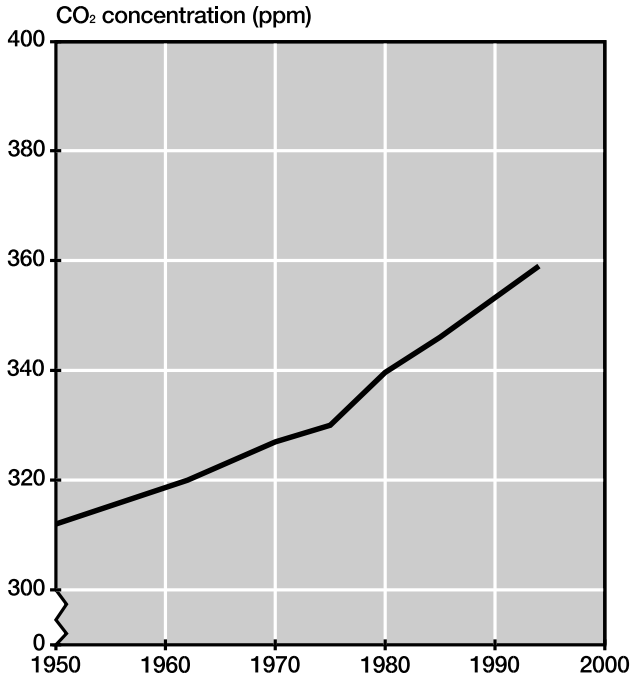
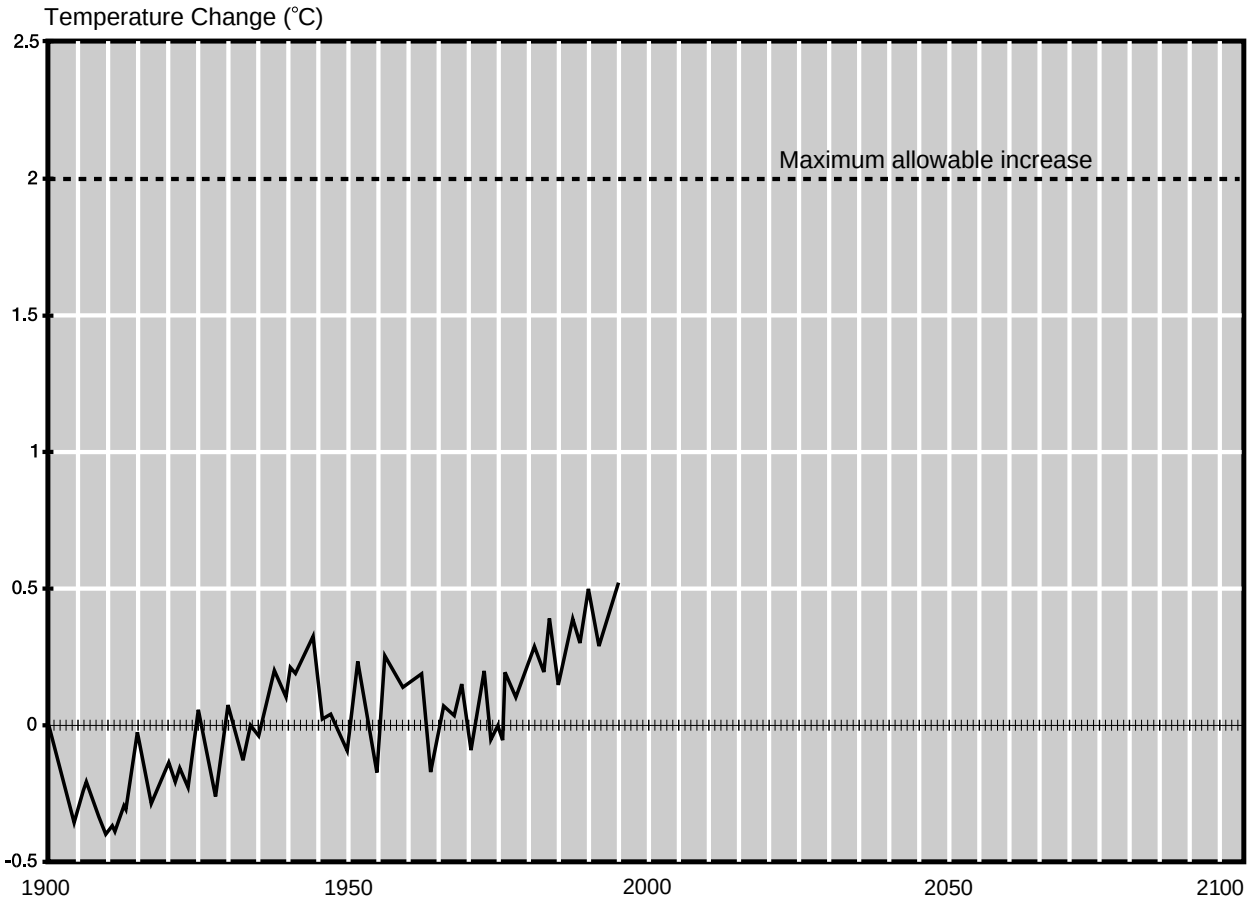


Figure 3.6 illustrates the trend towards increasing concentration of CO_2 in the atmosphere since the 1950s as recorded at one of the monitoring stations existing at that time (located in Hawaii). According to the IPCC the atmospheric concentrations of GHGs, *inter alia* CO_2, CH_4 and N_2O have grown significantly since pre-industrial times: by about 30 %, 145 % and 15 % respectively (values for 1992) (IPCC, 1995). Since 1950 the concentration of CO_2 has increased 16 %.

Figure 3.7 shows the global mean temperature since 1900. Global mean surface air temperature has increased by between about 0.3 and 0.6 °C since the late 19th century (IPCC, 1995). For the year 1995 the global mean surface temperature was 0.40 degrees Celcius above the 1961-1990 average (CRU, 1996). The EU objective of a maximum of 2 degrees Celcius increase above pre-industrial temperature in 2100 is also shown. Taking into account the present increase of approximately 0.5 degrees Celcius this means a maximum additional 1.5 degrees Celcius temperature increase until 2100 relative to 1990.

Figure 3.7: Changes in global mean temperature since 1900. Source : CRU (1996).



Underlying factors and new insights

The main driving force for GHG emissions is fuel combustion, which is driven by activity in the energy, industry and transport sectors (see *Chapter 2*). The principal objective of policy instruments is to decouple the link between energy consumption and GHG emissions from growth in these sectors.

In the current context it is important to consider a number of key issues:

- *Penetration of energy efficient technologies.* The rate of penetration of more efficient technologies depends on economic decisions, which are based on the increased capital cost of the technology and the future benefits in terms of energy cost savings. Incentives (including price incentives via taxes) and information dissemination are required to counteract the expected impact of decreasing energy prices and to encourage the uptake of efficient technologies.

- *Increasing natural gas use could increase CH_4 emissions.* Natural gas is expected to increase its share of primary energy in the EU due to the efficiency of gas technologies and the low

emissions (CO_2, SO_2, NOx and particulates) characteristics of the fuel. It is important to ensure that this increase in use is not accompanied by an increase in emissions of CH_4 resulting from leakage in the distribution system.

- *Member States' economic structure.* The ability of a Member State to stabilise CO_2 emissions depends on its economic and energy structure in the base year (1990) as the scope for improving energy efficiency and reducing emissions is greater in the energy intensive sectors (metals, building materials, paper, etc) than the knowledge intensive sectors (eg, electronics, services).

- *The transport sector is critical.* The transport sector (road and air) is currently the fastest growing sector in the majority of EU economies and therefore the fastest growing contributor to GHG emissions.

- *CO_2 emissions will remain the largest contributor.* CO_2 contributes around 65% to total GHG emissions, mainly from the use of fossil fuels, which is most easily monitored. It is, therefore, the gas for which the policy initiatives are best developed. However, there are also opportunities to reduce emissions of other GHGs such as methane from agriculture and waste; measures to phase out CFCs are in place. HCFCs, which have greater global warming potentials than CFCs, are targeted for complete phase out by 2015.

In order to fully integrate environmental objectives (such as eliminating climate change) into economic and sectoral policies in an efficient way, it is essential that the external costs of activities (such as those concerning the combustion of fossil fuels) be incorporated into the prices that consumers pay for their energy.

Effect of removal by sinks

The enhancement of removal of CO_2 by sinks, generally through the encouragement of forestry, is currently not counted as part of achieving the EU target, which is presently based only on emissions, since the UNFCCC target only relates to emissions. Afforestation can remove CO_2 from the atmosphere. However it does not halt the gross growth in emissions or affect the main cause of rising CO_2 emissions, namely the combustion of fossil fuels.

3.3 PROGRESS AND OUTLOOK

The target of stabilisation of EU CO_2 emissions at 1990 levels by 2000 is being monitored by the European Commission. All Member States have submitted Annual Inventories for at least 1990 and National Programmes in which they make projections for the future and describe the measures that are proposed to bring about reductions. However transport and mobility patterns have not been addressed in most National Programmes.

Although Member States intend to stabilise emissions overall, targets for every Member State have not been established. It is recognised that the overall stabilisation will be achieved through burden sharing of emissions and that some Member States (e.g Spain, Portugal, Ireland), will increase, while others intend to make reductions (e.g. Germany, Netherlands, Denmark). Approaches to limiting emissions and measures implemented by Member States are discussed in *Chapter 2: Energy*.

Progress towards target

There have been several studies that have attempted to estimate whether the EU will comply with the CO_2 stabilisation target. Studies include DRI (1994), DG XVII, DGXI. The EU has evaluated the National Programmes (EC, 1996a). The report concluded that there is still considerable uncertainty regarding the expected emission level in 2000. A compilation of an EU trajectory for 2000, by adding up the individual Member States trajectories could only give indicative results, due to difference in methodology and assumptions used by the Member States.[1] Therefore separately for the EU, projections of emissions in 2000, 2010 and 2020 have been calculated using different scenarios, based on the Member States trajectories but using common assumptions (EC, 1996b). The Conventional Wisdom scenario, which denotes the "business as usual" world representing a conventional wisdom view of the most likely evaluation of events (see also *Chapter 2*), resulted in an expected increase (compared to 1990 levels) of 5 % in 2000, 13 % in 2010 and 16 % in 2020. Stabilisation would only be within reach if the maximum potential of the estimated effects of measures, reported by the Member States in their National Programmes, is actually realised [2]. If energy prices remain low and GDP growth is faster than expected the increase could be 5 % or even higher.

1 The Agency is now developing a projection methodology consistent with Corinair emission estimates to provide comparable and reliable time series of emissions.

2 For example, evaluation studies in the Netherlands suggest an overshoot of the Dutch emission in 2000 of 3-6 % (compared to 1990), although the National Programme, which is reported to the EU, presents a reduction of 3 % in 2000 compared to 1990 (RIVM et al., 1995).

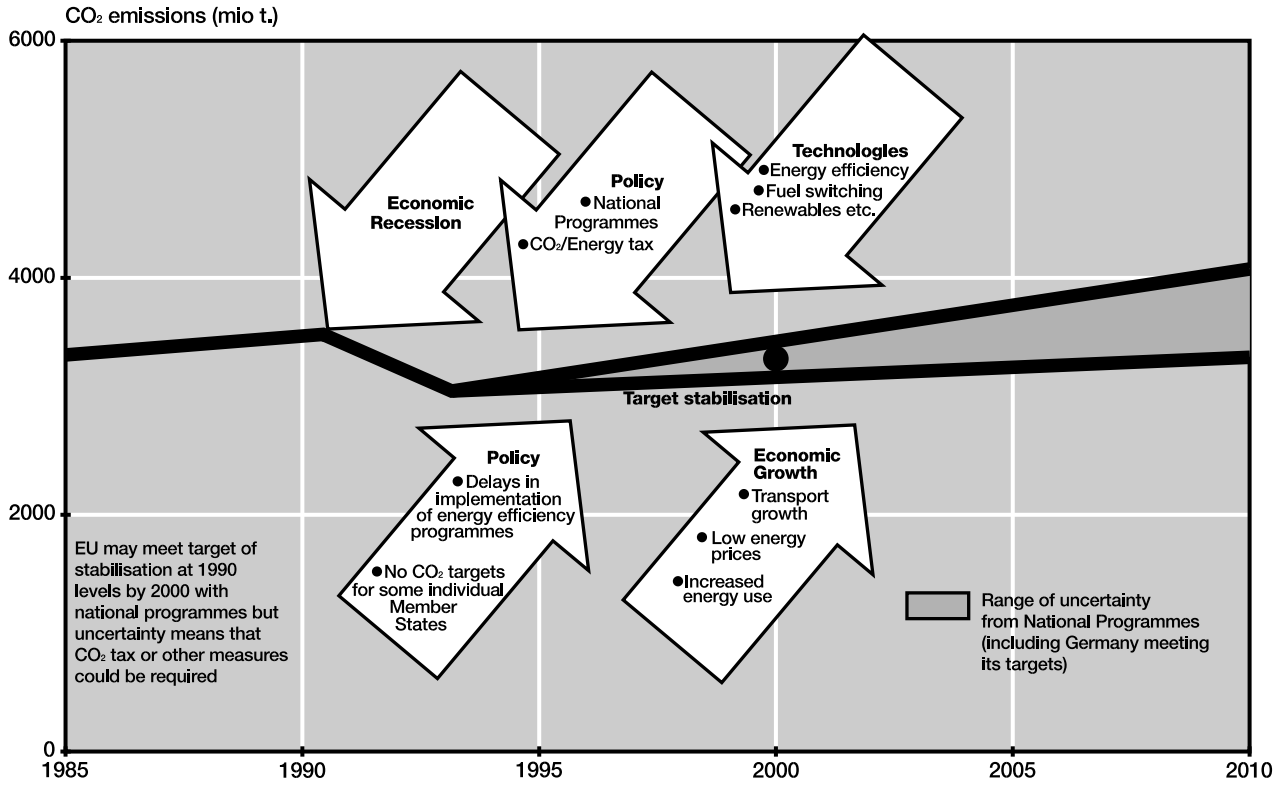
In summary, there is great uncertainty about whether the EU will meet the target for 2000 and there is a wide range of estimates from an increase of 10% above the stabilisation level (DG XVII) to a 5% reduction by 2000 (DRI et al., 1994), which assumes the introduction of a carbon/energy tax. The outcome is highly dependent on the reduction achieved by Germany, which contributed about 30% of EUR15 emissions in 1990 and has not yet set a target for 2000, although a target for 2005 is set . A preliminary forecast based on the German National Programme predicts that the interpolated target for 2000 will be overshot by 1%. These ranges and the key driving factors are illustrated in *Figure 3.8.*

In consideration of the specific measures which have contributed to the reduction of emissions to date and which will affect the likelihood of meeting the targets, a number of key issues are worth highlighting:

- Short-term factors have been a major cause of the reduction of emissions between 1990 and 1994.
- The EC programmes, SAVE, THERMIE, ALTENER and JOULE have had some impact, but full evaluations of these programmes have not yet been carried out. However, only half of the target of 20% improvement in energy efficiency is expected to be achieved under the SAVE programme.
- Only 3 of the 12 intended Directives on household appliance efficiency have been adopted, although there has been a switch in domestic fuel consumption from coal to an increased use of gas.
- In the transport sector there has been limited progress in fuel substitution towards less CO_2 emitting sources, such as non-fossil fuels (bioethanol, electricity from renewables or gas).
- A number of Member States have introduced policies which are likely to have a positive impact; these are mainly fiscal measures (see *Chapter* 2).

After 2000, CO_2 emissions in the EU are likely to rise further by about 1% per year as a result of the continuing growth of production, assuming that no additional policy measures are taken to tackle emissions (DRI et al.,1994; RIVM, 1992; EC, 1996b).

Figure 3.8: Progress towards CO_2 stabilisation in the EUR15



Methane emissions are also expected to increase from the 1990 level. The emission reduction in agriculture (due to the decrease in livestock population as a result of the CAP reform) might be offset by the increased use of natural gas as a primary energy source. It is uncertain how N_2O emissions will develop: reductions of emissions from agriculture, by limiting the use of artificial fertilisers, might be counterbalanced by industry and transport. Community policy for both gases is (still) absent, although some individual Member States are developing programmes.

SUSTAINABLE PATHWAYS TOWARDS 2010

Setting of EU emission reduction targets for 2010 appears the key for future climate change policy. Although the Berlin Mandate also mentions 2005 and 2020 as target years, the EU Council of Ministers and the Review of the 5EAP explicitly refer to 2010 (EC, 1996c; EC, 1996f). As stated above the EU has declared, based on present knowledge, that global average temperatures should not exceed 2 degrees Celcius above pre-industrial level in 2100 (which in practice means a maximum 1.5 degrees temperature increase from 1990) by 2100. Reaching this objective is dependant on the following key issues.

Distribution of emissions

Climate change is a global issue. Discussions on strategies to reduce the risks of an enhanced greenhouse effect involve agreement on the distribution of the 'environmental space' among countries, especially between industrialised (the so-called Annex-1 Parties of the UNFCCC) and the non-Annex-1 countries. Current (1990) anthropogenic CO_2 , CH_4 and N_2O emissions for these two groups are 5.8 and 4.4 Gt C (CO_2 equivalent) respectively, or 55 and 45% of total global emissions.

IPCC has developed a range of scenarios, without specific mitigation policies, but including assumptions concerning population growth, land-use, technological changes, energy availability and fuel mix. These IPCC scenarios, which are described here as "baseline emission scenarios" give for the year 2010 for non-Annex-1 countries results within the range of 5.3-7.0 Gt C (as there are no commitments for these countries to limit their emissions). The upper value represents (a relatively) high economic growth and growth of emissions in non-industrialised countries. The lower value marks low population growth, favourable economic development and halting deforestation. However, the 'achievability' of the lower value can be supported by industrialised countries through "Activities implemented jointly" and technology transfer to developing countries.

Timing of actions

Another debate is on the question when actions aimed at mitigating climate change effects should be started in Annex-1 countries. This is motivated by the argument that waiting for actions gives more time in order to attain firmer scientific ground. Another argument is that costs of measures might be reduced by developing improved (cheaper) technology. However, due to the long atmospheric lifetime of greenhouse gases, delays in introducing reduction policies will certainly lead to the requirement for substantial additional actions at a later stage. According to the IPCC, global emissions of greenhouse gases should be reduced immediately by 50 to 70 % and further thereafter to achieve stabilisation of the concentration of CO_2 at the present level by 2100 (IPCC, 1995).

What are the possible scenarios for the EU after 2000 or, in other words, how can long term objectives be translated in short term targets? Assuming that the EU maximum temperature objective refers to the year 2100, allowable emissions can be computed for the year 2010 (see *Table 3.2*). The results are depending on the allowable temperature increase per decade. Scientists have proposed to use a provisional limit for sustainability of 0.1°C temperature rise per decade (Krause et al., 1990) and a provisional limit of a 2 cm rise in sea level per decade to prevent damage to coastal zones, wetlands and coral reefs caused by too rapid climatological changes (AGGG, 1990). Increases above this limit will cause major risks for ecosystems, food production and sensitive coastal areas.

Table 3.2 shows that if the sustainable limit of 0.1 °C temperature increase per decade up to 2100 is added as a climate target, emissions in industrialised countries (Annex-1 countries, including EU) should be reduced by *at least* 30-55 % in 2010 compared to 1990 levels, depending on the baseline emissions in the non-industrialised countries.

This would for example mean for CO_2 emissions from fossil fuel a reduction of the annual average

Required rate of temperature increase 1990-2100[a])	Global emission corridor in 2010	Max. allowable emissions Annex-1 Parties [b]) in 2010	Min. emission reductions Annex-1 Parties[b]) in 2010
(°C/decade)	(Gt C CO_2 equiv.)	(index 1990=100)	(index 1990=100)
0.1	7.6 - 9.5	45 - 70	30 - 55
0.15	7.6 - 12.3	90 - 120	[c]) - 10

Table 3.2: Maximum allowable CO_2 equivalent emissions scenarios and associated minimum emission reductions for Annex-1 Parties in 2010 (based on EU objective of 1.5 degrees Celcius temperature increase between 1990 and 2100).

a) Including (unavoidable) violations of the temperature increase concerned in two decades. A temperature increase of 0.1 degrees Celcius per decade could be regarded as a limit for sustainability. An increase of 0.15 degrees Celcius per decade is substantially above this level
b) Range presents non-Annex-1 Parties baseline emissions of 5.3 - 7 Gt C equivalent CO_2 in 2010 and only includes the upper limit of the emission corridor
c) The lowest baseline emission value for non-Annex-1 Parties means that in this case (upper limit of emission corridor) that no emission reduction by Annex-1 Parties is required

Source: IMAGE computations by RIVM using the so-called safe landing method (Alcamo and Kreileman, 1996)

per capita emission (EUR15) of 8.8 tonnes in 1990 to 5.8 and 3.7 tonnes respectively in 2010 (accounting for some increase in population). The present global average per capita CO_2 emission from fossil fuel is 4 tonnes and in developing countries 1.8 tonnes.

The ranges of allowable global emissions in 2010 (the so-called emission corridors) include the minimum and maximum reductions according to the timing of policy measures. Following the upper limit of the emission corridor maximum actions are required after 2010 (i.e. *global* reductions of emissions of 2% per year). Only the maximal allowable emissions in 2010, according to the upper limit of the corridor, are presented in *Table 3.2.* If the lower limit of the corridor is followed, alternative strategies (including lower emission reductions) are still open after 2010. *Table* 3.2 also shows the emissions corridors for a considerably higher rate of temperature increase per decade.

Apart from the above-mentioned issues and trade-offs which have to be dealt with, strategies have to be developed regarding the reduction schemes for the separate greenhouse gases CO_2, CH_4 and N_2O. CFCs should already be phased out by 2010, but its substitutes will require further attention. Although CO_2 is the most important greenhouse gas, scientists argue that high priority should also be given to methane. Based on 100 year Global Warming Potentials reduction of methane emissions would be 25 times more effective in reducing the enhanced greenhouse effect than CO_2 (IPPC, 1995). It will provide additional benefits of reducing the potential for increasing tropospheric ozone (summer smog). Furthermore, reduction measures for CH_4 might be more feasible (technical and economic) than CO_2 reductions.

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APPENDIX 1
SOME ENVIRONMENTAL DATA BY COUNTRY

CLIMATE CHANGE

Table 1: CO_2 emissions by country (excluding bunker and final non-energy-consumption, including emissions from the former East Germany). Source: Eurostat, 1996

COUNTRY		(Mio t CO_2)		
		1985	1990	1994
EU15		3150	3190	3103
Austria		54	58	57
Belgium		105	111	117
Denmark		61	53	63
Finland		48	53	61
France		378	368	349
Germany		1088	992	897
Greece		58	73	78
Ireland		26	31	32
Italy		350	402	393
Luxembourg		12	12	12
Netherlands		145	157	164
Portugal		26	40	45
Spain		183	209	229
Sweden		60	52	56
United Kingdom		556	579	550

Table 2: Annual per capita CO_2 emissions by country (excluding bunker and final non-energy-consumption, including emissions from the former East Germany). Source: Eurostat, 1995,1996; EEA-ETC/AEM, 1996

COUNTRY	Tonnes CO_2 per capita		
	1985	1990	1994
EUR 15	8.7	8.8	8.4
Austria	7.0	7.4	7.2
Belgium	10.6	11.1	11.6
Denmark	12.0	10.2	11.9
Finland	9.8	10.6	12.0
France	6.7	6.5	6.1
Germany	13.8	12.4	11.1
Greece	5.7	7.2	7.6
Ireland	7.6	8.9	8.9
Italy	6.1	7.0	6.7
Luxembourg	32.4	31.6	30.8
Netherlands	9.8	10.5	10.8
Portugal	2.7	4.1	4.5
Spain	4.8	5.4	5.8
Sweden	7.1	6.0	6.4
United Kingdom	9.8	10.0	9.5