THE EUROPEAN ENVIRONMENT

STATE AND OUTLOOK 2010

MITIGATING CLIMATE CHANGE

European Environment Agency

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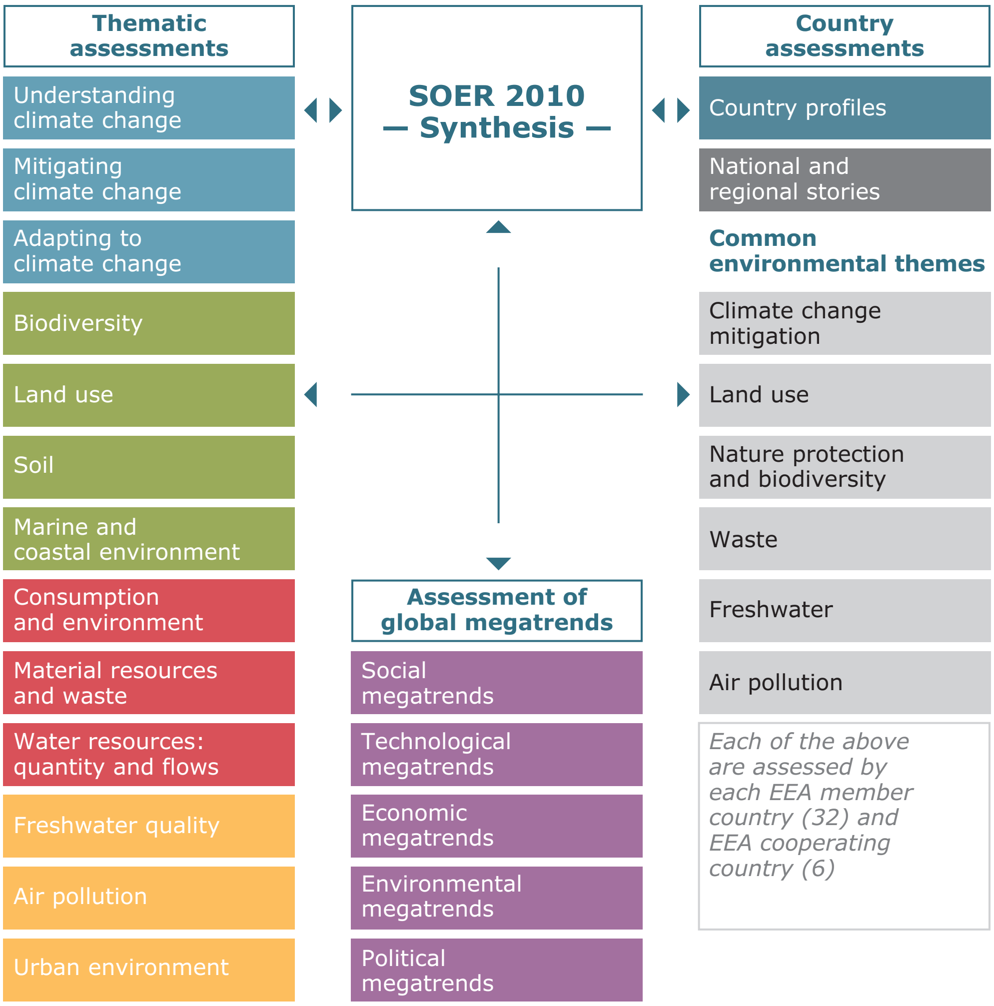
2. an exploratory assessment of **global megatrends** relevant for the European environment;
3. a set of 38 **country assessments** of the environment in individual European countries;
4. a **synthesis** — an integrated assessment based on the above assessments and other EEA activities.

SOER 2010 assessments



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Mitigating climate change

Summary

The EU emitted close to 5 billion tonnes (Gt) of CO_2-equivalent emissions in 2008. It contributes today around 12 % of annual global anthropogenic direct greenhouse gas emissions. The EU is making good progress towards achieving its emission reduction targets. A rapid, sustained and effective transition to a low carbon economy is necessary to mitigate climate change and to meet global greenhouse gas emission targets.

What are global trends in greenhouse gas emissions?

Scientists estimate that, in order to keep the global temperature increase below 2 °C compared to pre-industrial levels, global greenhouse gas (GHG) emissions must peak by 2020 at a level of 44–46 Gt CO_2-equivalent and then be reduced by at least 50 % compared to 1990 levels by 2050. In the past 150 years, there have only been a few periods when CO_2 emissions fell, notably during the global recession in the early 1930s and as a result of the oil shock of the late 1970s and early 1980s. Otherwise, CO_2 emissions have risen relentlessly throughout the period, notably since the 1950s. Despite significant efficiency improvements, fossil fuel combustion continues to increase. Besides emissions from fossil fuel combustion, deforestation and forest degradation have increased over time. According to the UN-REDD Programme, these account for nearly 20 % of global GHG emissions.

GHG emissions are not equally divided across the world. GHG emissions as defined in the Kyoto Protocol ([1]) have fallen in the EU during the past 30–40 years; whereas emissions in Asia have increased more than three-fold since 1970.

Many of the ozone-depleting substances that are addressed in the UNEP Montreal Protocol ([2]) are also potent GHGs, but are not addressed under the Kyoto Protocol. The reduction of GHG emissions due to the Montreal Protocol has been significantly larger than the emission reductions that will take place as a result of the Kyoto Protocol by the end of 2012.

What are European greenhouse gas emission trends?

The 27 Member States of the EU currently contribute around 12 % of annual global anthropogenic direct GHG emissions. In 2007, the EU agreed on an independent binding target to reduce its emissions by at least 20 % by 2020 compared to 1990 levels. This commitment would increase to 30 % if major emitting countries outside Europe made similar challenging commitments under a global climate agreement. The EU is making good progress towards its 2020 target. Emissions of its 27 Member States were 11.3 % below 1990 levels in 2008 and, according to preliminary EEA estimates, 17 % below 1990 levels in 2009. Under the Kyoto Protocol, 15 Member States of the EU ('EU-15') are committed as a group to reduce their GHG emissions by 8 % compared to 1990 levels during the commitment period 2008–2012. The EU-15 is well on track to meeting its target, with emissions in 2008 being 6.9 % lower than the base-year. Preliminary estimates of the EEA indicate that EU-15 emissions were further reduced in 2009 to 13 % below base-year levels. Of the EU-12 Member States, 10 have individual targets and are on track to meet these.

A large proportion of the GHG emission reductions achieved in Europe over the last two decades took place during the 1990s as a result of the economic restructuring that occurred mainly in eastern Europe. Further reductions were achieved as a combined result of policies and measures implemented to reduce GHG emissions, such as the EU Emission Trading Scheme (EU ETS), and more recently from the short-term effects of the global economic crisis.

([1]) The Kyoto Protocol is an international agreement setting binding targets for reducing greenhouse gas emissions in certain countires.
([2]) This international agreement aims at phasing out a number of substances depleting the ozone layer.

CO_2 emissions from the residential and commercial sectors have fallen significantly since 1990. Greenhouse gas emission increases could be observed due to the consumption of halocarbons (HFCs) used in the production of cooling devices such as air conditioning systems and refrigerators. Other key sources at EU level showing GHG emission increases are road transport (freight and passenger cars), international aviation and maritime transport ([3]).

What are the challenges?

Looking at the longer term and assuming current trends and policies are continued, global annual GHG emissions are expected to increase from some 40 Gt to almost 70 Gt CO_2-equivalent per year in 2050. The reduction pledges made by countries under the 2009 Copenhagen Accord fall short of keeping global GHG emissions below the earlier mentioned peak level of 44–46 Gt CO_2-equivalent per year by 2020.

The EU's 20 % reduction target will lead to a lower contribution of the EU to global GHG emissions, going beyond the 8 % reduction foreseen for 15 EU Member States under the current provisions of the Kyoto Protocol. In the short term, and as set out above, the EU-15 is on track to meet its target under the Kyoto Protocol. Assuming the full implementation of recent EU legislation ('climate and energy package'), projections show that the EU will indeed reduce emissions by 20 % in 2020. By then the EU would contribute some 9 % to global GHG emissions.

([3]) The two latter sectors are not covered by the Kyoto Protocol.

1 Introduction

Meeting the global greenhouse gas (GHG) emission targets necessary to mitigate climate change requires a rapid, sustained, and effective transition to lower carbon economies. A range of national initiatives are required across all sectors of the economy in order to reduce GHG emissions — from power and heat generation plants, and from industrial, transport, agricultural, household and waste sectors.

Conversely, actions are also needed at the global level to protect and ensure the ability of ecosystems to absorb GHGs, for example to prevent global deforestation and degradation. Substantial financial support, especially towards developing countries, will be required to mitigate and adapt to the future effects of climate change. Nevertheless, the cost of addressing climate change is according to Stern (2006) estimated to be low compared to the general cost of inaction.

With 8 % of the world's population, Europe presently annually emits around 12 % of the global total direct GHG emissions. Internationally, discussions to agree on future reductions of greenhouse gas emissions are taking place in the context of the United Nations Framework Convention on Climate Change (UNFCCC). However also at the regional, national and local scales, there are many examples of targeted actions and programmes being successfully implemented to help mitigate emissions of GHGs.

Even with new future global commitments such as may occur under the UNFCCC policy framework, climate change will still impact communities and eco-systems. Countries need to start adapting and planning to adapt, and to build resilience into natural and man-made systems. This applies not only to Europe but especially beyond, since the least developed countries are among the most vulnerable but have the least financial and technical capacity to adapt.

This publication presents an assessment of past and future greenhouse gas emission trends in Europe and information concerning the policy frameworks under which actions to reduce emissions have occurred. The assessment does not discuss in detail country trends nor the science underpinning climate change discussions, nor information concerning its potential associated impacts. For information on these issues, reference should be made to the other SOER report sections (see the inside of the front cover).

2 Trends in greenhouse gas emissions

2.1 Global emission trends

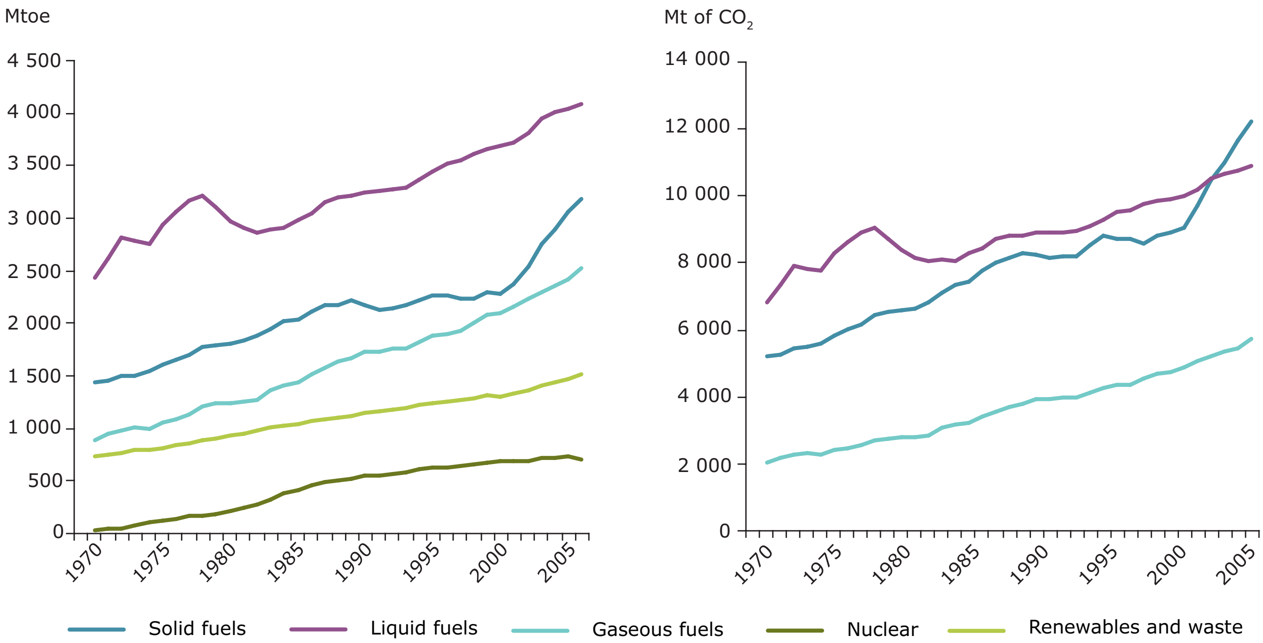
Current and future trends in global greenhouse gas (GHG) emissions will determine whether the world will exceed the target of a maximum 2 °C temperature increase compared to pre-industrial levels. Since 1970, real gross domestic product (GDP) has tripled, population has doubled to nearly 7 billion, primary energy consumption has more than doubled, and GHG emissions, particularly from the combustion of fossil fuels, have also doubled.

The combustion of fossil fuels from human activities is largely responsible for the increase in GHG concentrations in the atmosphere and the resulting increase in global temperature (IPCC, 2007). Carbon dioxide (CO_2) is the most important contributor to total GHGs. The demand for more energy and subsequent increased fossil fuel combustion is causing GHG concentrations to accumulate in the atmosphere. Most countries rely on fossil fuels — oil, gas and coal — to satisfy their energy demand. The increases in CO_2 and other GHG in the atmosphere during the industrial era are mostly caused by human activities.

In the past 40 years, fossil fuel consumption increased almost relentlessly (Figure 2.1). The increase in the use of solid fuels (i.e. hard coal and lignite) has been particularly fast since 2000. After a few years of very strong growth, coal has became the most climate-damaging energy source worldwide, outpacing CO_2 emissions from crude oil and petroleum products. Natural gas consumption increased very rapidly although emissions did not increase as rapidly because its carbon intensity to deliver the same amount of energy is much lower than that of coal and of oil. It is worth noting the strong increase in renewable energy, which in absolute terms was mainly due to biomass burning for heat and electricity and hydro power. Nuclear power generation has also increased significantly since 1970.

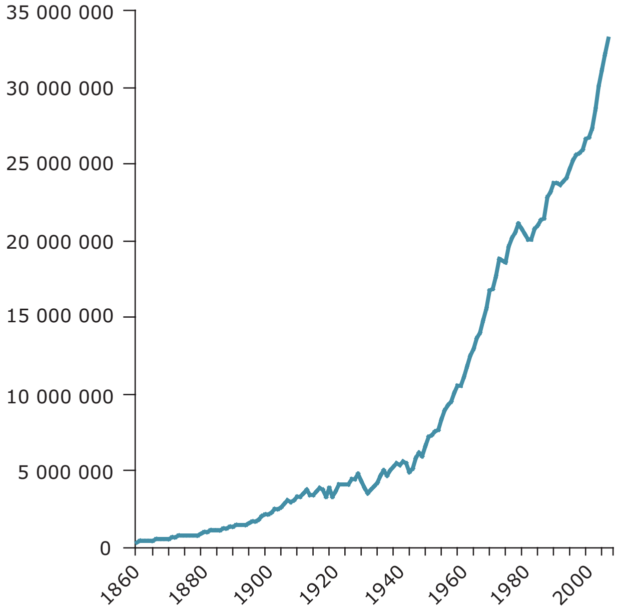
Figure 2.2 shows the increase in world CO_2 emissions since 1860. In the past 150 years, there have only been a few periods in which CO_2 emissions actually fell: notably during the global recession of the early 1930s and as a result of the oil-shock of the late 1970s and early 1980s. Otherwise, CO_2 emissions have risen

Figure 2.1 World primary energy consumption (left) and CO_2 emissions from energy combustion (right), 1970–2007



Source: International Energy Agency, 2009a.

Figure 2.2 Global CO_2 emissions, 1860–2006



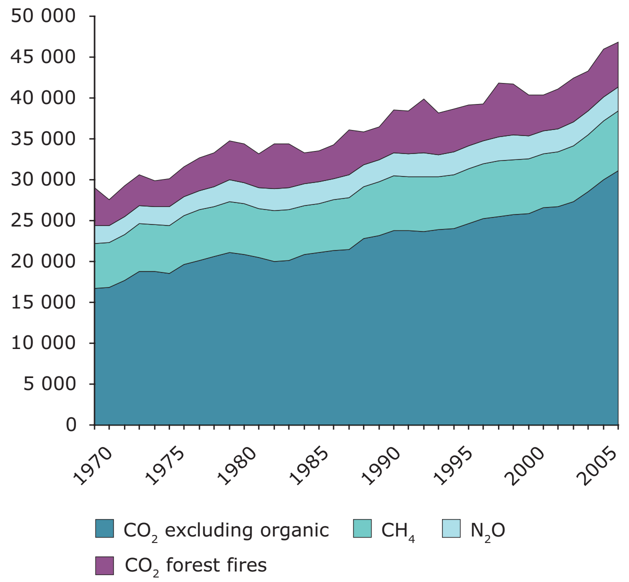
Source: Adapted from Pleijel, H. (ed.), 2009.

Reducing emissions from deforestation and forest degradation (REDD) is at the core of the climate debate in relation to mitigation actions in land use, land use change and forestry (LULUCF). The aim is to create a financial value for the carbon stored in forests and provide incentives for developing countries to reduce their emissions from deforestation as well as to invest in low carbon paths to sustainable development. REDD+ goes further and includes the role of conservation, sustainable management of forests and enhancement of forest carbon stocks. According to the UN-REDD Programme (UN, 2010), deforestation and forest degradation account for nearly 20 % of global greenhouse gas emissions, and mitigation actions in this area are therefore key to help keep temperature increases to below 2 °C compared to pre-industrial levels. Forest fires are one of many drivers of deforestation and its contribution to global greenhouse gas emissions is considerable (Figure 2.3), let alone the impacts deforestation has on ecosystems and biodiversity. Other drivers linked to land use changes such as the expansion of agricultural land, the conversion to pastureland, infrastructure development and destructive logging are more difficult to quantify globally. It is also worth noting that maintaining forest ecosystems can

relentlessly throughout the period, and especially since the 1950s. Fossil fuel combustion continues to increase, despite significant improvements in the efficiency of transformation and the carbon intensity of production.

Most of the global increase in total greenhouse gas emissions can be attributed to the combustion of fossil fuels. Energy-related CO_2 emissions have increased by a factor of 1.9 between 1970 and 2005. Methane (CH_4) and nitrous oxide (N_2O) emissions increased by a factor of 1.3 (Figure 2.3). However, the global warming potential (GWP) of these non-CO_2 gases is much larger than that of CO_2 ([4]). Methane has an average lifetime of 12 years. This would suggest reductions in methane emissions would yield the largest gains in terms of climate change mitigation in the short term. Some of the key sources of methane are fugitive emissions from energy production (e.g. coal mines, natural gas pipelines) emissions from waste (e.g. solid waste disposal on land, wastewater handling) and agriculture (e.g. enteric fermentation and manure management). There has also been a very rapid growth in emissions from fluorinated gases, the most potent greenhouse gases, although their overall contribution to total GHG emissions is still relatively low.

Figure 2.3 Global greenhouse gas emissions by gas type, 1970–2005



Source: EC-JRC/PBL. EDGAR version 4.0, 2009.

([4]) Based on the IPCC 4AR (IPCC, 2007) the 100-year GWP for methane is 25 times stronger than CO_2, and the GWP of nitrous oxide is 298 times stronger. Methane has a 20–year GWP 72 times stronger than CO_2 when considering its shorter average lifetime. Moreover, the GWP of methane relative to CO_2 has been revised upwards in successive assessments of the IPCC (from the FAR and SAR to the TAR and 4AR).

contribute to increased resilience to the impacts from climate change.

Map 2.1 illustrates the global picture of GHG emissions in 2005. The lines over the oceans represent emissions from international maritime transport routes. Regions of higher emissions are notably in western and central Europe, the eastern region of the United States of America, India, China and Japan. GHG emissions of the six Kyoto gases in the EU-27 represent about 12 % of global GHG emissions, excluding net CO_2 removals from land use, land-use change and forestry (LULUCF). Including global emissions from deforestation, the EU's share would be around 11 %. Contrary to the global picture, the EU's LULUCF sector is a net sink (i.e. not a net source of emissions) due to the significant build-up of carbon stocks in European forests since 1990.

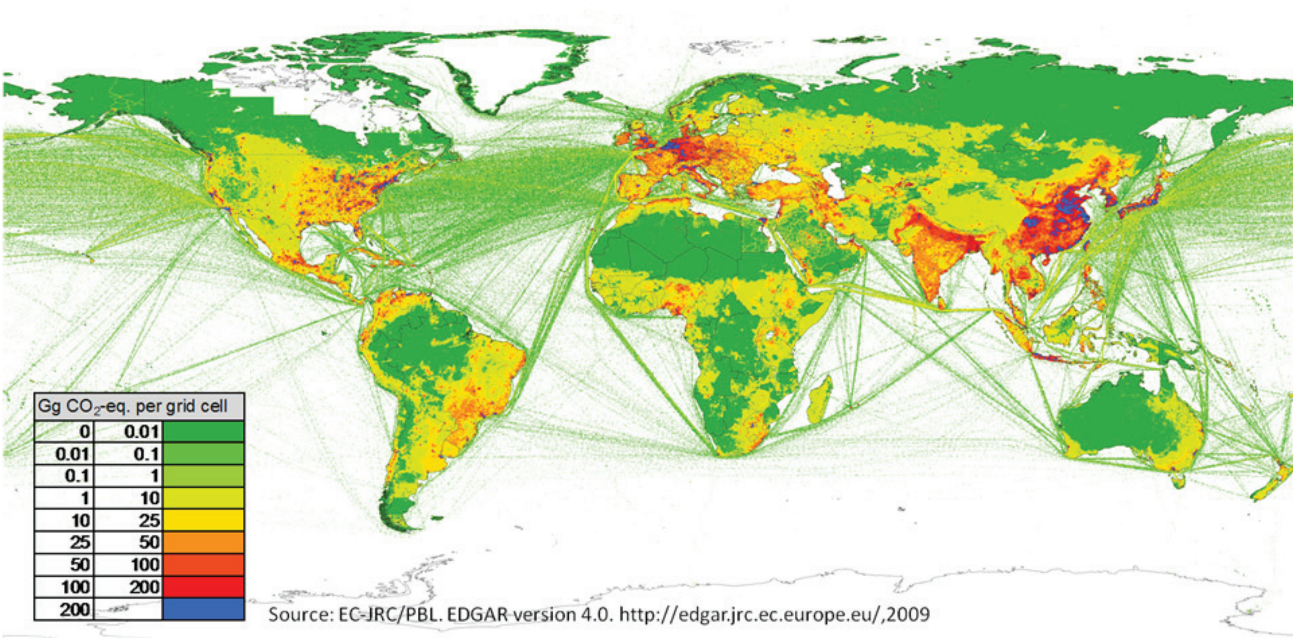
The average EU citizen emits about 9.6 t CO_2-equivalent (excluding LULUCF) every year, which is above the world average of approximately 6.7 t CO_2-equivalent per person, but still well below per capita emissions in the United States, Canada and Australia (Map 2.2). Greenhouse gas emissions per capita also vary widely between European countries, mainly reflecting differences in primary energy consumption.

While global emissions have and continue to increase, this has not been at the same rate in all countries and regions of the world (Figure 2.4, left). During the past 30–40 years GHG emissions, as defined by the Kyoto Protocol, in the EU have fallen whereas emissions in several large Asian countries have increased more than three-fold since 1970. In more recent years GHG emissions from Annex I parties to the UNFCCC — the richest in terms of GDP per capita — have for the first time been exceeded by emissions from the non-Annex I countries — so-called developing countries — for which currently no emission reduction targets have been agreed. In absolute terms, and excluding emissions from LULUCF, China is now the single largest emitter of GHGs, followed by the United States, the EU-27, India and Russia.

It is however important to set this development in a historical perspective. GHG emissions are increasing rapidly, particularly in key developing countries such as China and India. However, per capita emissions in non-Annex I countries are on average significantly lower (Figure 2.4, right) and emissions in industrialised countries are also increasing, notably in the United States. In 2005, average emissions per capita in non-Annex I countries were about 4 t CO_2-equivalent, compared to an average of 15 t CO_2-equivalent per person in industrialised countries.

World trade developments are also important in understanding the rapid increase in GHG emissions, particularly in some developing countries. Based on Eurostat data (2009), the EU was the world's leading trader in 2007 and accounted for 18 % of world trade,

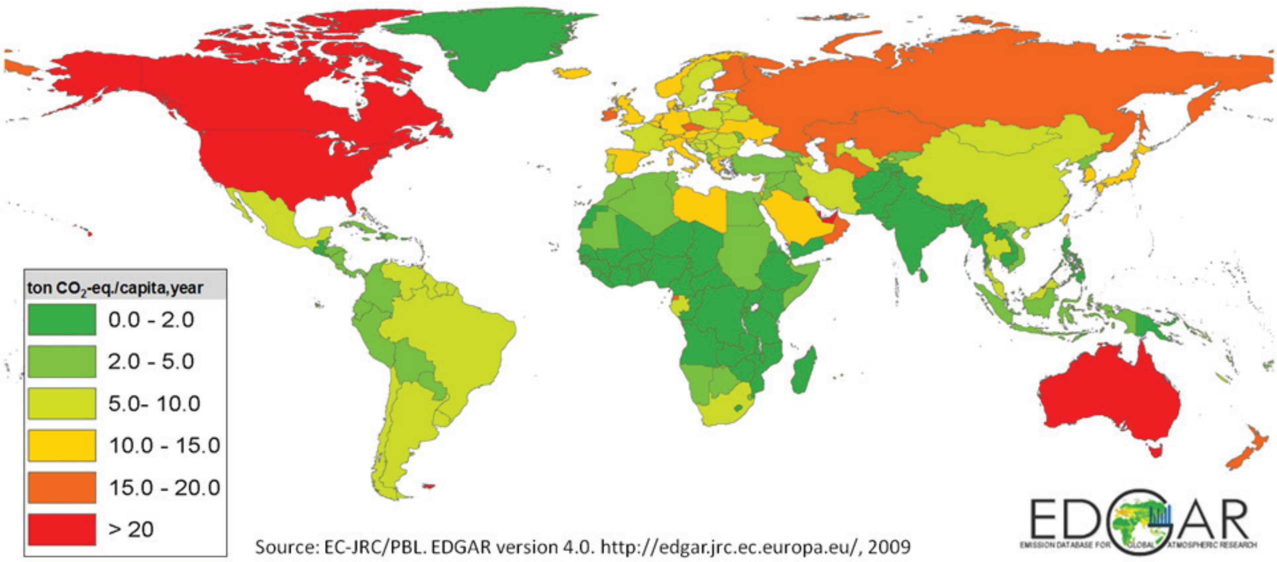
Map 2.1 Global greenhouse gas emissions, 2005



Note: The map does not include aviation emissions.

Source: EC-JRC/PBL. EDGAR version 4.0.

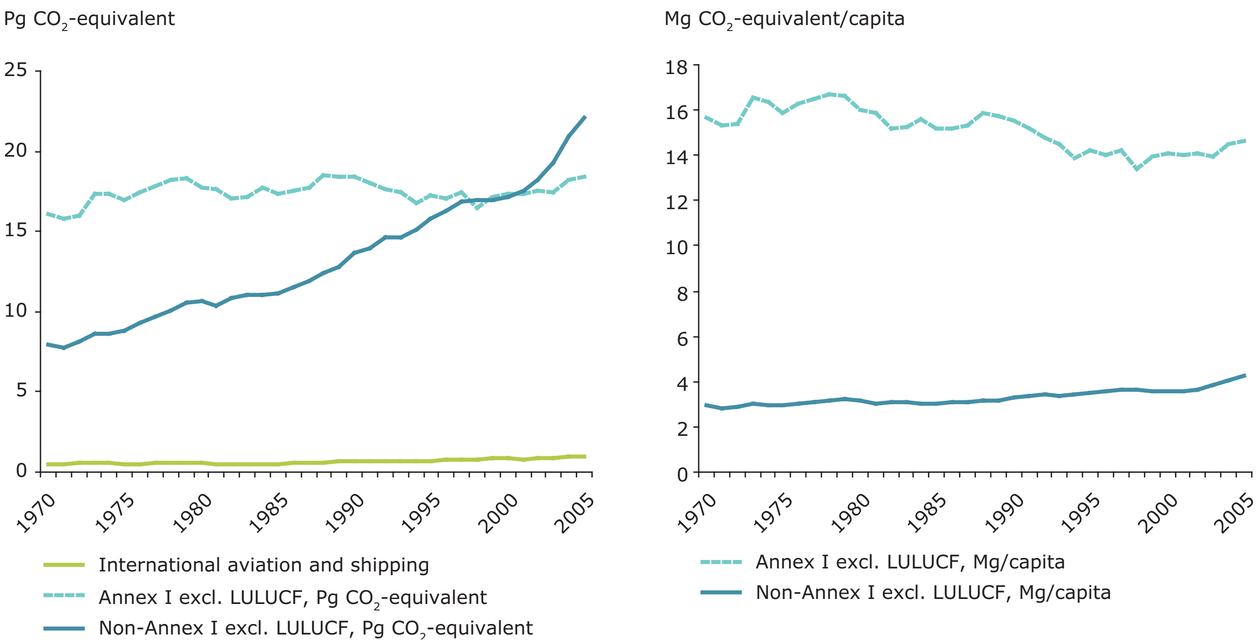
Map 2.2 Global greenhouse gas emissions per capita, 2005



Source: EC-JRC/PBL. EDGAR version 4.0.

valued at EUR 15 trillion. The EU was the biggest exporter and second biggest importer, after the USA, with a considerable trade deficit with Asian countries that had more than doubled between 2002 and 2007. About two thirds of imports are manufactured goods. China has become the EU's first supplier and bilateral trade has more than quadrupled since 1999, with total EU imports from China reaching EUR 233 billion in 2007.

Figure 2.4 Trends in global greenhouse gas emissions (left) and per capita in Annex I and non-Annex I countries (right), 1970–2005



Source: EC-JRC/PBL, EDGAR version 4.0.

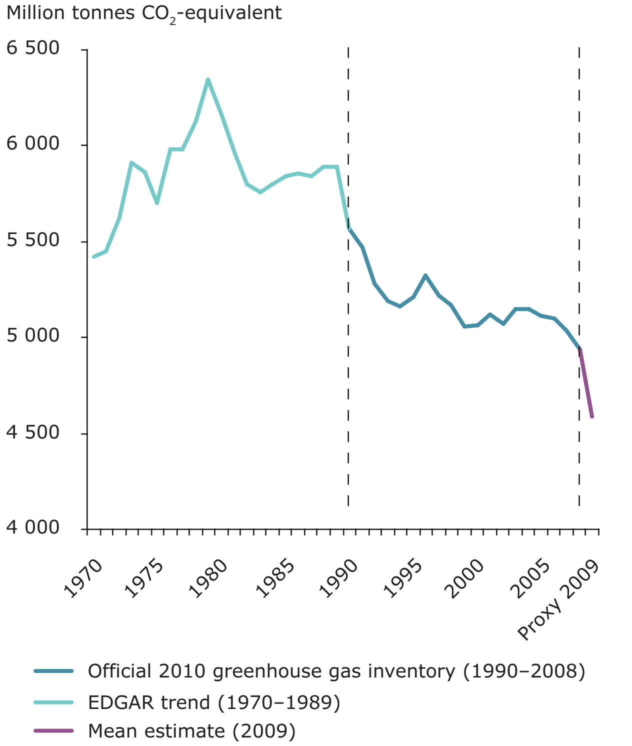
Whereas worldwide imports into the EU reached EUR 1.4 trillion, the value of exports was as high as EUR 1.2 trillion in 2007, according to Eurostat (2009). Indeed, EU trade is characterised by a permanent yet relatively modest trade deficit. So while Europe may be partly responsible for some of the emissions generated elsewhere by EU consumption — exported emissions — a share of Europe's own emissions can be traced to consumption of European goods in some of Europe's main trading partners — imported emissions. The main products exported from the EU are road vehicles and industrial and electrical machinery; while imported goods are dominated by IT and telecommunication products and electrical machinery. The energy and carbon intensity of the production of goods and services in both industrialised and developing countries will by and large determine the real shares of exported and imported emissions. This is a key topic in the current climate debate that requires greater understanding.

2.2 European emission trends

Emissions of the six Kyoto GHGs ([5]) from anthropogenic sources in the EU have fallen each year since 2003 (EEA, 2010a). In the past 18 years, GHG emissions have declined in both the EU-15, as party to the Kyoto Protocol, and in the EU-27. The EU-15 stood 6.9 % below its base-year emissions under the Kyoto Protocol in 2008 ([6]) — a net reduction of 295 million tonnes of CO_2-equivalent. Total emissions in the EU-27 were 11.3 % below 1990 in 2008 ([7]), — equivalent to a net reduction of 627 million tonnes of CO_2-equivalent (see section 3).

On a longer time perspective, EU emissions have been decreasing since the mid to late 1980s and the downward trend is expected to continue at least until 2009 (Figure 2.5). Early 2009 greenhouse gas estimates published by the EEA during 2010 showed EU emissions decreased by 6.9 % in 2009 compared to 2008. Based on these estimates, the EU-27's 2009 emissions stand approximately 17.3 % below the 1990 level. The EU-15 stands 12.9 % below the base-year level, achieving its Kyoto commitment to an 8 % reduction for the first time. The strength of the 2009 recession affected all economic sectors in the EU. Consumption of fossil fuels (coal, oil and natural gas) fell compared to the previous year, mainly for coal. The decreased demand for energy linked to the economic recession was accompanied by

Figure 2.5 Absolute GHG emissions in the EU-27, 1970–2009



Note: The 1970–1990 time series was calculated using the annual change in EDGAR (EC-JRC/PBL, 2009) emissions applied to 1990 UNFCCC (EEA, 2010a) emissions. The 2009 early GHG estimate for the EU-27 (EEA, 2010b) is based on publicly available verified EU ETS emissions for 2009 and published activity data, as of mid-July, at both national and European level disaggregated by major source categories in sectors reported under the UNFCCC and the Kyoto Protocol.

Source: EEA, 2010a, 2010b; EC-JRC/PBL, 2009.

([5]) CO_2, methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons HFCs, perfluorocarbons PFCs and sulphur hexafluoride (SF_6).

([6]) Under the Kyoto Protocol (UNFCCC, 1997), the EC (at the time EU-15) agreed to reduce its GHG emissions by 8 % by 2008–2012 compared to its base year. Following the UNFCCC reviews of Member States' initial reports during 2007 and 2008 and pursuant to Article 3, Paragraphs 7 and 8 of the Kyoto Protocol, the base-year emissions for the EU-15 have been fixed at 4 265.5 million tonnes of CO_2-equivalent. On the basis of the 2010 GHG inventory, the EU-15 would need to reduce GHG emissions by about 341 million tonnes on average between 2008 and 2012 in order to meet its 8 % Kyoto target. This can be achieved through a combination of existing and planned domestic policies and measures, and using carbon sinks and Kyoto mechanisms.

([7]) The Climate Action and Renewable Energy package was adopted by the European Council on 6 April 2009 (EC, 2009). The Package represents the EU's response to limiting the rise in global average temperature to no more than 2 °C above pre-industrial levels. To achieve this Member States agreed to reduce total EU GHG emissions by 20 % compared to 1990 by 2020. Both trading, the EU Emissions Trading Scheme (ETS), and non-trading sectors will contribute to the 20 % objective. Minimising overall reduction costs to reach the 20 % objective implies a 21 % reduction in emissions from EU ETS sectors compared to 2005 by 2020 and a reduction of approximately 10 % compared to 2005 by 2020 for non-EU ETS sectors. The non-trading sectors broadly include direct emissions from households and services, as well as emissions from transport, waste and agriculture. The coverage of the non-trading sectors currently represents about 60 % of total greenhouse gas emissions.

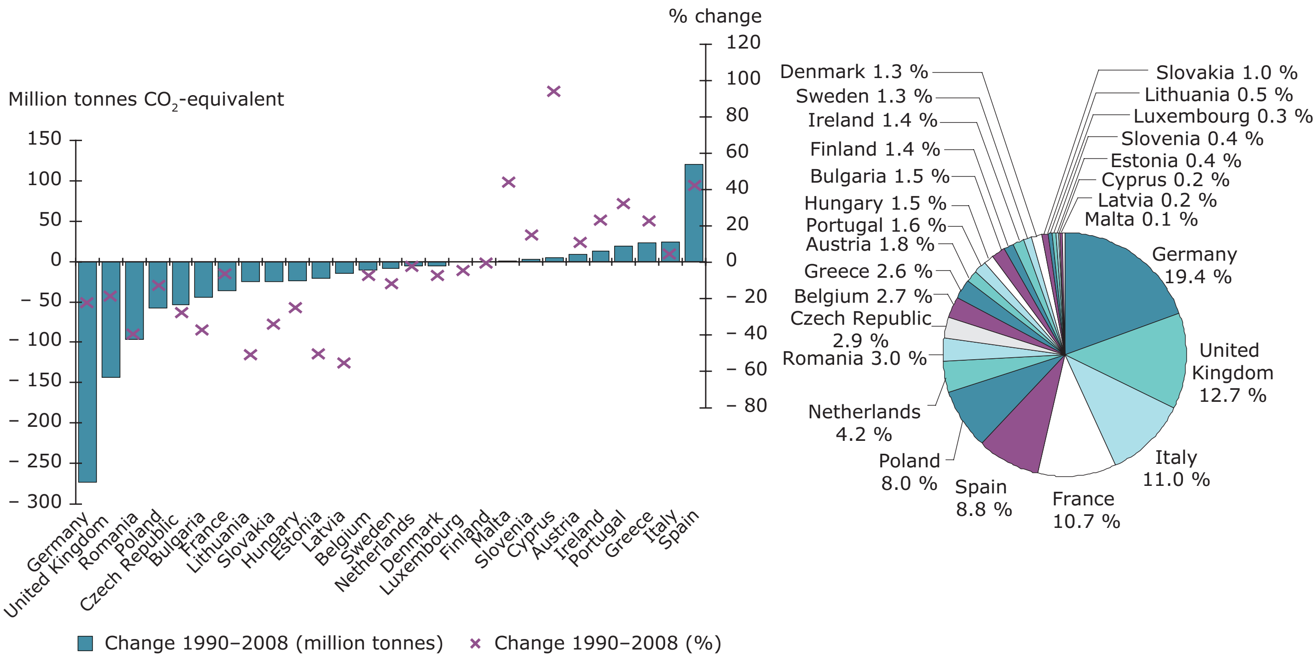
cheaper natural gas and increased renewable energy use, which together contributed to lower emissions (see footnote 10). The relatively colder winter of 2009 increased the residential sector's heating needs, partly offsetting the total reduction in greenhouse gas emissions. In relative terms, the largest emission reductions occurred in industrial processes reflecting lower activity levels in the cement, chemical and iron and steel industries. The 2009 verified emissions from the sectors covered by the EU Emission Trading Scheme (EU-ETS) decreased by 11.6 % compared to 2008 (EEA, 2010b). The recession in 2009 accelerated, temporarily, the downward trend in total greenhouse gas emissions. Of the estimated 1 billion tonnes of CO_2-equivalent reduced between 1990 and 2009, one third would have been accounted for by the 2009 economic recession (EEA, 2010c).

Overview by Member State

At the Member State level, 18 countries recorded a net reduction in GHG emissions between 1990 and 2008 (Figure 2.6). About two thirds of the EU-27 net reduction was accounted for by Germany and the United Kingdom. On the negative side, Spain increased emissions significantly despite its rapid deployment of renewable energy technologies. The main reasons for the favourable trend in Germany were increasing efficiency in power and heating plants and the economic restructuring of the five new Länder after German reunification. Lower GHG emissions in the United Kingdom were primarily the result of liberalising energy markets and the subsequent fuel switch from oil and coal to gas in electricity production, as well as N_2O emission reduction measures in adipic acid production (i.e. used for nylon production). The recession in 2009 accelerated the decline in total greenhouse gas emissions in most Member States, temporarily.

Figure 2.7 shows total greenhouse gas emissions per capita (left chart) and per GDP relative to the EU-27 in purchasing power standards (right chart). Differences among countries can be explained by a number of factors, including the carbon intensity of fossil fuel production (i.e. fossil fuel mix), the penetration of renewables, the existence of nuclear power for electricity generation, the efficiency in the transformation of primary energy into useful energy as well as the penetration of combined heat and power, the actual energy demand of end users, and energy efficiency improvements (and savings) linked to that demand. Other factors arising from specific climatic conditions (i.e. wind, hydro, average temperature) and

Figure 2.6 Change in greenhouse gas emissions by EU Member States, 1990–2008 (left) and share of emissions in 2008 (right)



Note: The red crosses in the chart (ref. right axis) denote the percentage change in greenhouse gas emissions between 1990 and 2008. The blue bars (ref. left axis) show the absolute change in million tonnes of CO_2-equivalent between 1990 and 2008. Total greenhouse gas emissions in EU-27 represented 91.2 % of total greenhouse gas emissions of all EEA member countries in 2008. The change in total greenhouse gas emissions in the remaining EEA countries between 1990 and 2008 was: Iceland (+ 42.9 %), Liechtenstein (+ 14.7 %), Norway (+ 8.0 %), Switzerland (+ 0.5 %) and Turkey (+ 96.0 %). Croatia's total GHG emissions fell by – 0.9 % between 1990 and 2008.

Source: EEA, 2010a, 2010c.

the economy (i.e. fuel and carbon prices and economic growth) may also affect the ranking of countries in specific years, sometimes significantly.

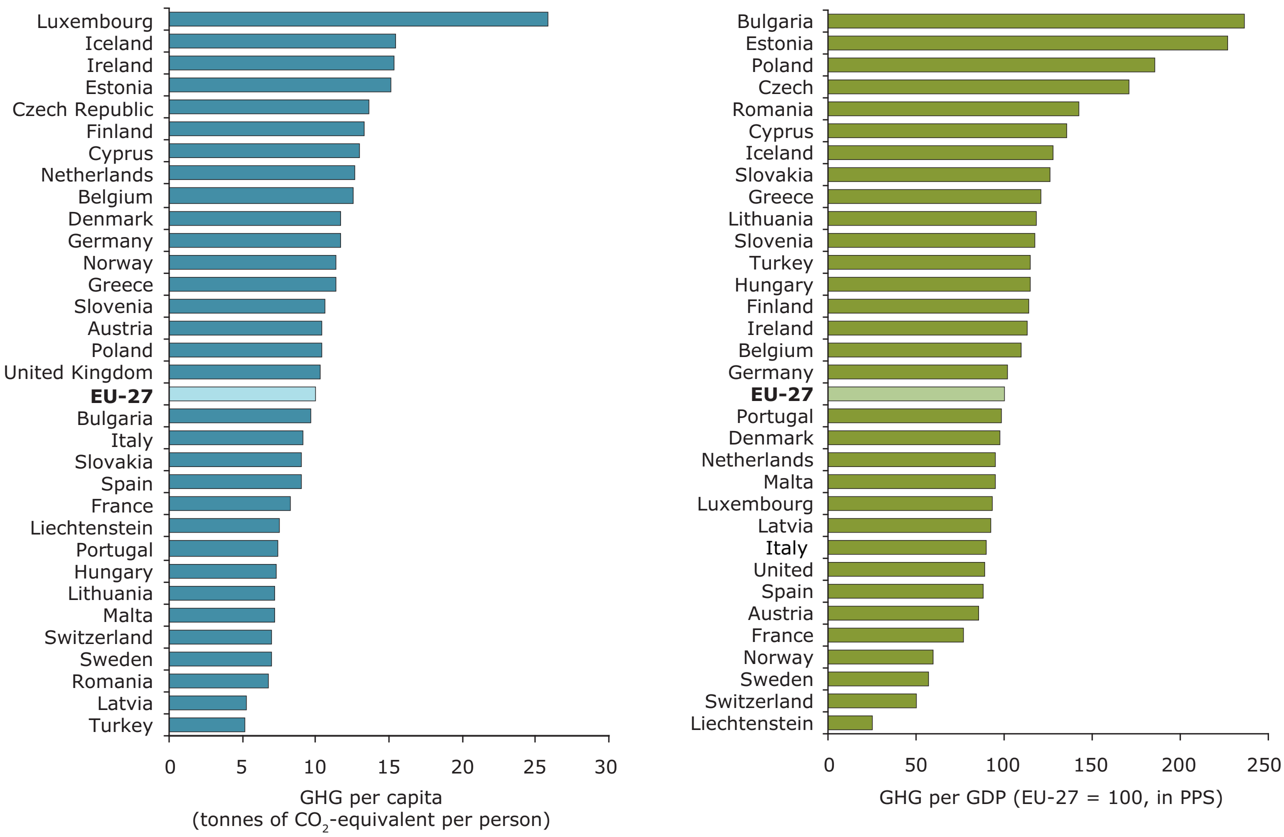
Overview by greenhouse gas type

In terms of the main GHGs, CO_2 was responsible for the largest reduction in emissions since 1990 (Figure 2.8) — currently, 83 % of all EU GHG emissions are CO_2, excluding LULUCF and international transport. About 93 % of the CO_2 released to the atmosphere originated from the combustion of fossil fuels, and the remaining 7 % from industrial processes. Much of the CO_2 emitted in Europe nowadays comes from combustion and industrial installations under the European Trading Scheme (EU ETS). Emissions are expected to decline as a result of improvements in energy efficiency and fuel switch motivated by carbon prices and the restricted supply of emission allowances. The implementation of the EU Climate and Energy Package should also lead to a reduction in emissions from sectors outside the EU ETS, such as transport and buildings (residential and commercial).

Emissions of CH_4 and N_2O also fell between 1990 and 2008 — CH_4 represented 8.3 % of total GHG emissions in 2008 — and N_2O — 7.3 % of the total. The reduction in CH_4 emissions reflects lower levels of coal mining and post-mining activities as well as lower emissions from managed waste disposal on land. There has also been a significant reduction in CH_4 emissions from agricultural livestock, due to a reduction in numbers but also to changes in the agricultural management of organic manures. N_2O emissions fell because of lower emissions from agricultural soils.

Key EU polices such as the Nitrates Directive, the Common Agriculture Policy (CAP) and the Landfill Waste Directive have been successful in reducing greenhouse

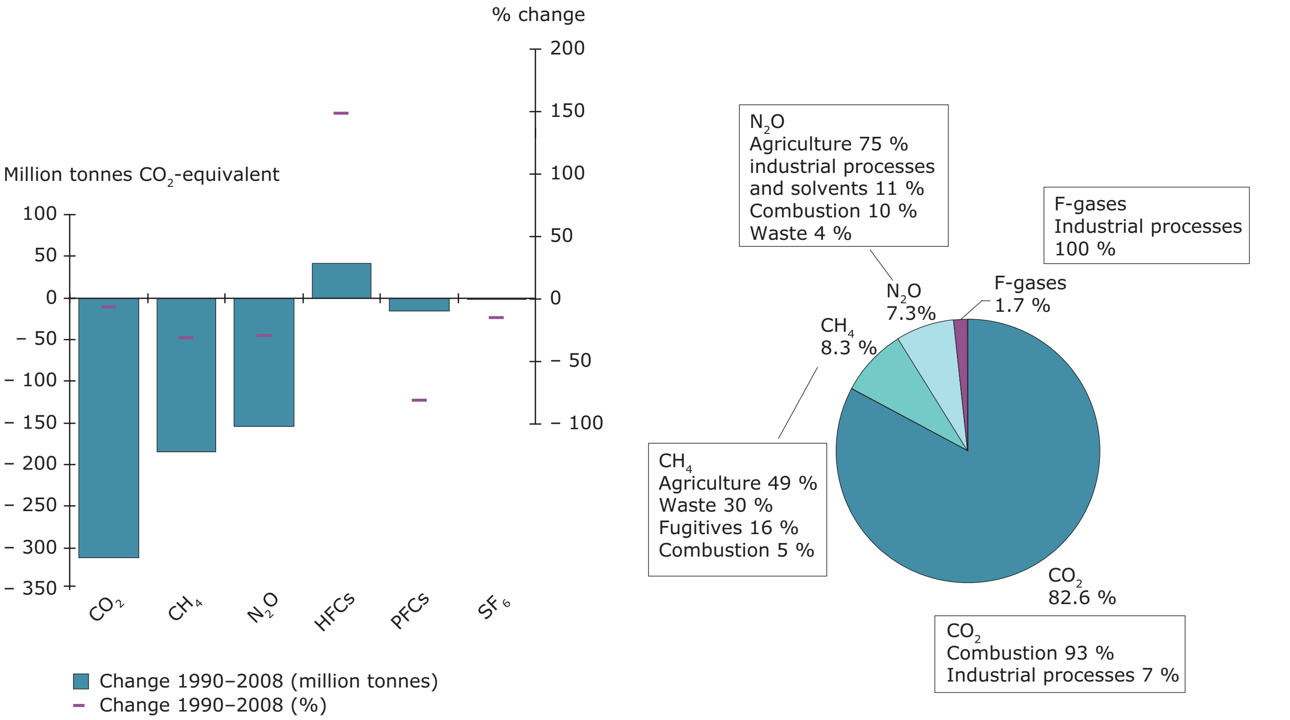
Figure 2.7 Greenhouse gas emissions per capita (left) and per unit of GDP (right) in purchasing power standards in 2008



Note: Total greenhouse gas emissions in EU-27 represented 91.2 % of total greenhouse gas emissions of all EEA member countries in 2008. Total GHG emissions per capita in Croatia stood at 7 tonnes and its GHG economic intensity was 15 % higher than the EU's in 2008.

Source: EEA, 2010a, 2010c; Eurostat, 2010.

Figure 2.8 **Change in GHG emissions by main gas in EU-27, 1990–2008 (left) and breakdown by gas in 2008 (right)**



Source: EEA, 2010a.

gas emissions from methane and nitrous oxides. The Nitrates Directive (EC, 1991) which aims at reducing and preventing water pollution caused by nitrates from agricultural sources has had a significant impact on greenhouse emissions. The so-called first pillar of the CAP (dealing with market support) also had a strong impact through the milk quota system by reducing animal numbers in the dairy sector to compensate for increasing animal productivity. The Landfill Waste Directive (EC, 1999) which requires Member States to reduce the amount of biodegradable waste landfilled has also contributed to an increase in the amounts of waste recycled, composted and an increase in the recovery of landfill gas.

One of the key EU emission sources is the consumption of hydrofluorocarbons (HFCs) used in industrial processes. HFCs were the only group of gases for which emissions increased between 1990 and 2008. HFCs are used in the production of cooling devices such as air conditioning systems and refrigerators and the increase is consistent with both warmer climatic conditions in Europe and higher standards of comfort demanded by citizens. HFC emissions from air-conditioning systems in motor vehicles are of concern because HFC-134a is the largest contributor to total HFCs emissions and has a global warming potential (GWP) about 1 400 times stronger than CO_2. In Europe, however, the use of HFC-134a for mobile air-conditioning in new cars will be phased out between 2011 and 2017 (EC, 2006). From January 2011, EU Member States will no longer grant EC type-approval or national type-approval for a type of vehicle fitted with an air conditioning system designed to contain fluorinated GHGs with a GWP higher than 150, and from January 2017, Member States will have to refuse registration and prohibit the sale of such new vehicles.

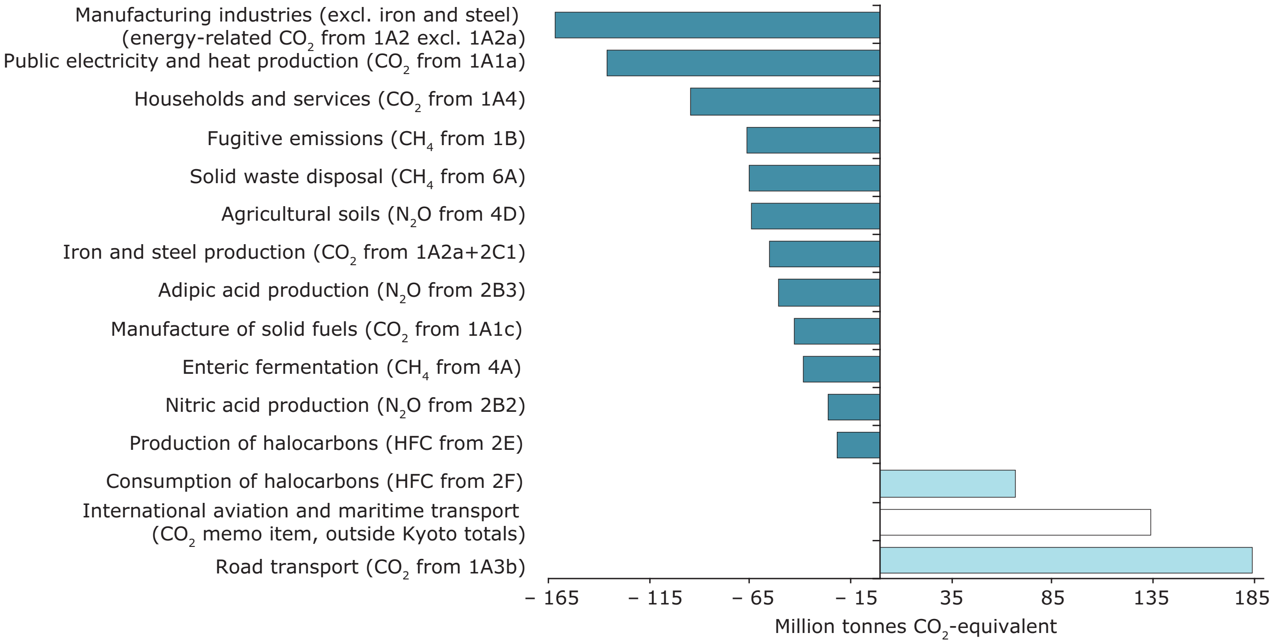
Overview by main sector

Figure 2.9 shows the key emission sources explaining the net change in total greenhouse gas emissions in the EU between 1990 and 2008. The sectors and gases explaining the largest decreases were manufacturing industries and construction (CO_2), public electricity and heat production (CO_2), and households and services (CO_2). The sectors and gases with the largest increases over the period were road transportation (CO_2) and the consumption of HFCs in industrial processes. CO_2 emissions from international aviation and shipping also increased very rapidly during the 18-year period, although they are excluded from the Kyoto targets. A short description of the trends in each of these key sources is presented below.

Sectors achieving the largest emission reductions

On the positive greenhouse gas trends (i.e. lower emissions), manufacturing and construction was the largest source of emission reductions in both absolute and relative

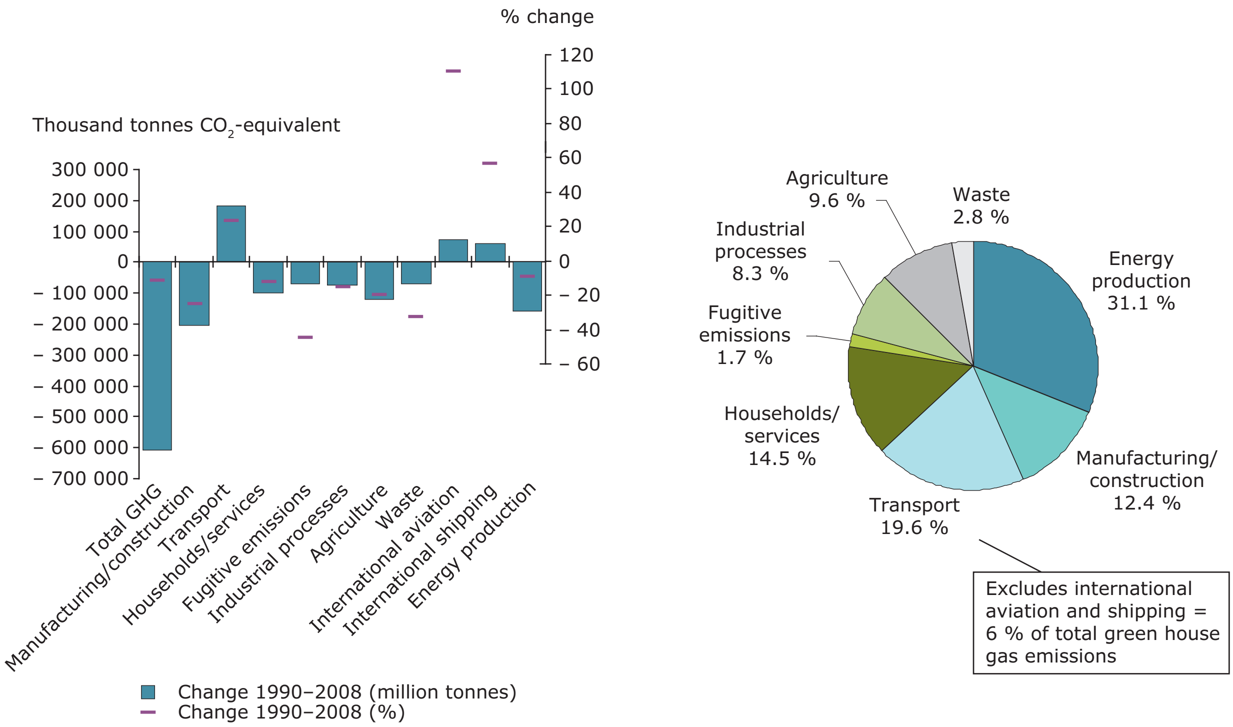
Figure 2.9 Overview of top decreasing/increasing GHG sources in the EU-27, 1990–2008



Note: The ranking is based on the so-called key source category analysis at EU level, 2010 EU GHG inventory to the UNFCCC. The numbers in brackets refers to exact coding used for reporting greenhouse gas emissions sources according to the UNFCCC Reporting Provisions (UNFCCC, 2006)

Source: EEA, 2010a.

Figure 2.10 Change in GHG emissions by main sector in EU-27, 1990–2008 (left) and breakdown by sector, 2008 (right)



Note: International aviation and shipping account for an additional 310 million tonnes of CO_2-equivalent (about 6 % of total EU-27 GHG emissions excluding LULUCF).

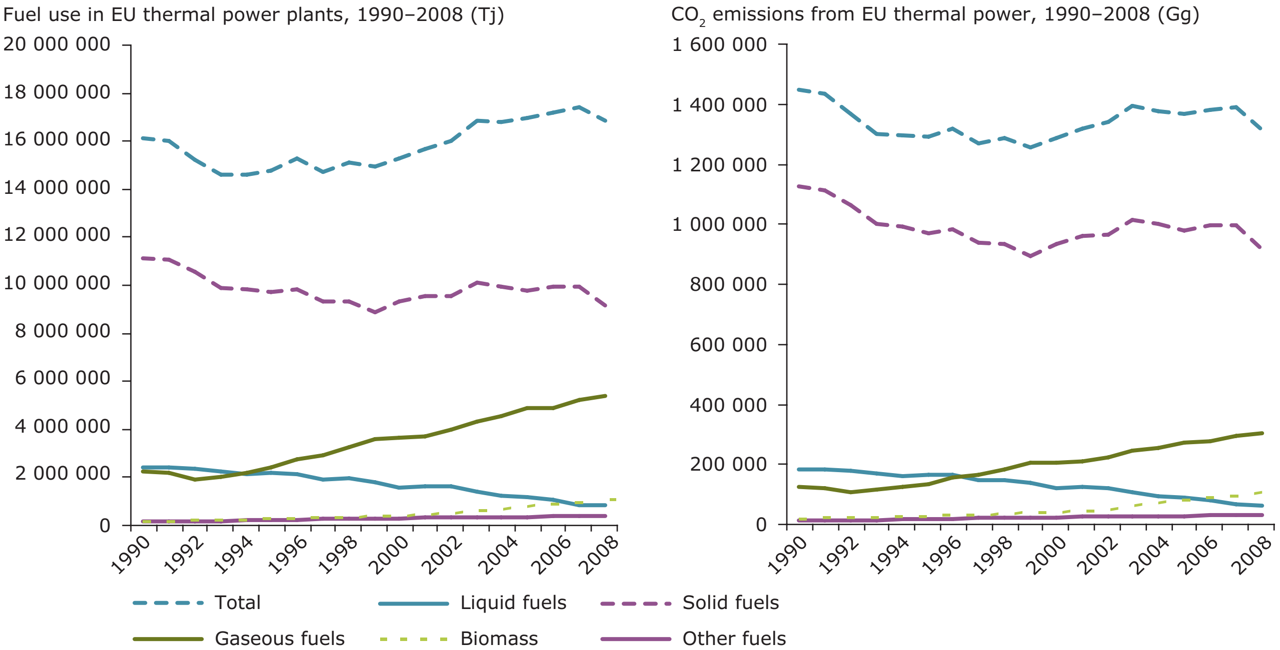
Source: EEA, 2010a.

terms between 1990 and 2008 (Figure 2.10). This resulted partly from improved efficiency in restructured iron and steel plants, partly the increased share of gaseous fuels and biomass (and lower share of liquid and solid fuels), and also by lower emissions from the construction sector. The economic recession that began in the second half of 2008 and continued through to 2009 has had a strong impact on overall emissions, particularly from this sector.

The second largest emission reductions in the EU were achieved in the production of electricity and heat. This sector is currently the most important source of CO_2 emissions — contributing around one-third of the total — the largest source of sulphur dioxide (SO_2) and second largest of nitrogen oxides (NO_X). At the EU level, there has been a downward trend in the production of derived heat (i.e. distributed heat) from district heating plants which was offset by an increase in heat from combined heat and power plants. Overall, total heat output has remained broadly stable, despite some fluctuations in the 18-year period since 1990. Electricity output, however, has increased rapidly. Total fuel input to public electricity and heat production increased between 1990 and 2008 (Figure 2.11). Yet, there has been a net reduction in emissions from EU thermal plants during this period that can be partly explained by some fossil fuel switching and efficiency improvements (including more CHP) in the transformation of energy. For example, average thermal efficiency has improved, with a significant reduction in the fossil-fuel input per unit of output. There has also been a significant reduction in CO_2 emissions per unit of fossil-fuel input, achieved, for example, by switching from coal and oil to natural gas. About three fourths of the 30 % increase in total electricity production in the EU since 1990 is accounted for by natural gas-fired power stations. Renewables have also contributed positively to the reduction in emissions. Nuclear generation of electricity has increased since 1990 although its share in total electricity production has fallen.

Emissions from households, and to a lesser extent from services, have also fallen significantly since 1990, despite the growth in the number of private households — now standing at about 196 million units in the EU-27, according to Eurostat figures (Eurostat, 2010). Households represent one of the largest sources of GHG emissions and are affected by such variables as climatic conditions, fuel prices, the existence of district heating, energy efficiency in buildings and the fuel mix for heat generation ([8]).

Figure 2.11 Fuel use and CO_2 emissions from public electricity and heat production in EU-27



Source: EEA, 2010a.

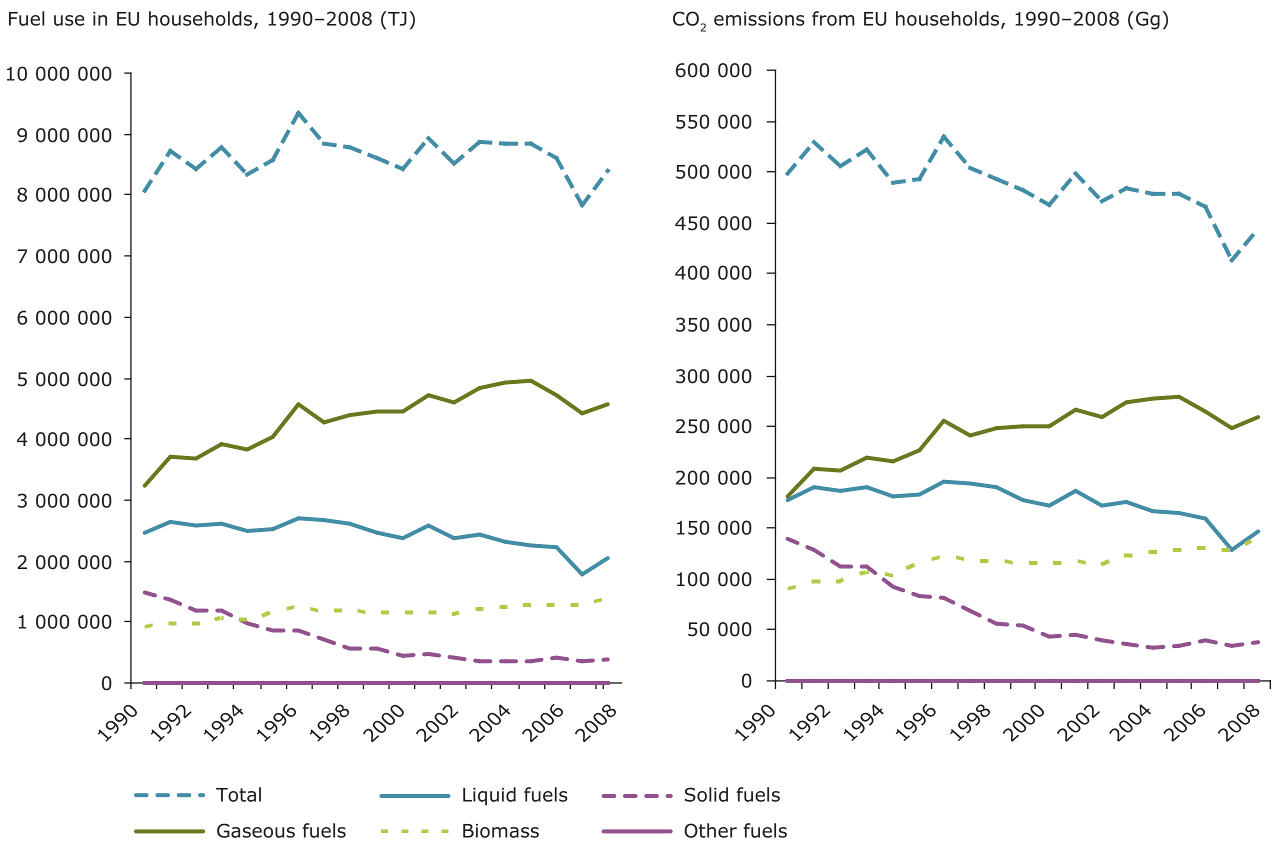
([8]) GHGs stemming from households only include emissions resulting from direct fuel combustion. They do not include indirect emissions, e.g. GHG emissions linked to the production of heat from district heating and combined heat and power (CHP) plants and electricity supplied to households are reported under public electricity and heat production. It is worth noting that direct combustion emissions from households and services are outside the EU ETS.

The most popular fuel in European households is gas, with more than half of all the fuel input in 2008. Oil is the second and biomass the third most widely-used fuel for heating. While there is no clear trend in the overall fuel use in households since 1990, there is a distinctive downward trend in emissions which can be partly explain by fuel switching. Figure 2.12 shows the development of the fuel mix and related CO_2 emissions in EU households between 1990 and 2008. The use of gas has increased significantly since 1990. Despite its popularity gas consumption fell after 2004 and only increased again in 2008, partly reflecting higher heat demand as a consequence of a colder winter. In parallel there has been a steady increase in the use of biomass, which is considered CO_2 neutral according to IPCC/UNFCCC reporting (UNFCCC, 2006). Coal use in households has declined throughout the period and represents less than 5 % of the fuel mix nowadays. As a result, the change in the fuel mix in households has led to important savings in CO_2 emissions because of the better emission intensity per unit of energy of the fuels being replaced.

As mentioned earlier, CO_2 emissions from households have fallen since 2004. This was a direct consequence from the lower use of fossil fuels, particularly oil and gas. It is worth noting household emissions in 2008 increased, and preliminary estimates suggest emissions increased again in 2009, because of the colder winter. One of the factors behind the reduction of oil and gas use in households in the last years appears to be economic. According to Eurostat data (2010), fuel prices have increased very rapidly, particularly since 2004. Large increases in fuel prices were the norm in all Member States. The increase was so rapid that it significantly outpaced the growth in gross disposable household incomes.

The other factor that helps explain the changes in fuel use (and emissions) from the residential sector is climatic (Figure 2.13). Mean land surface temperature is increasing globally, but also in Europe, and has done so particularly in the past 30–40 years. Also, winter temperatures in Europe are increasing more rapidly than summer ones. Thus in the long term, summers are warmer now than

Figure 2.12 Fuel use and CO_2 emissions from heating in European households



Source: EEA, 2010a.

they were in the past but today's winters are even warmer than winters then.

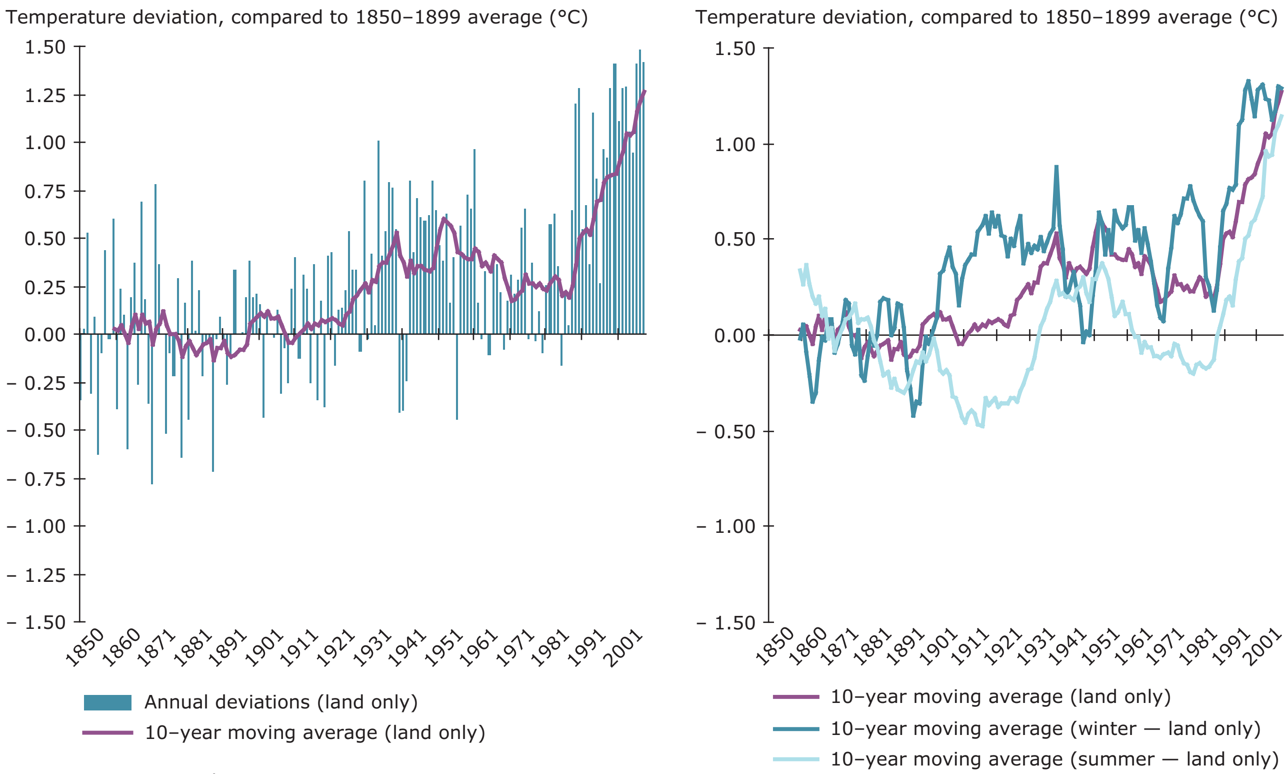
Figure 2.14 shows that current heat demand in Europe is below its long-term average (defined as 1980–2004). Heating degree days, an indication of heat demand based on outdoor temperatures, have gone down since about 2004. There was a short term increase in 2008 and then again in 2009, but heat demand still remained below the 1980–2004 mean. Heating needs, as measured by heating degree days, have indeed declined in almost all European countries since 2004.

Finally, net removals from land use, land use change and forestry (LULUCF) have increased in the EU between 1990 and 2008. Net LULUCF emissions and/or removals are not included in national greenhouse gas totals under the UNFCCC (9). Based on the 2010 EU GHG inventory, net removals increased by almost 20 % in the EU-27 between 1990 and 2008 (29 % including all EEA countries) and the net sink has increased from 6.2 % of total GHG emissions in 1990 to 8.3 % in 2008 (from 6.8 % to 9.5 % in EEA countries). In 2008, net removals from the LULUCF sector in the EU-27 amounted to 410 million tonnes of CO_2-equivalent (517 million tonnes of CO_2-equivalent for EEA member countries). The key driver for the increase in net removals is a significant build-up of carbon stocks in forests as harvesting only represents 60 % of the net annual wood increment. EU environmental policies have also resulted in less intensive agricultural practices and an increase in forest and woodland conservation areas for the purpose of preserving biodiversity and landscapes.

Sectors with the largest emission increases

Turning now to the negative side of trends (i.e. higher emissions), road transport emissions (from both freight and passenger cars) have increased throughout the period since 1990. Between 1990 and 2007 car ownership levels in the EU-27 increased markedly. The number of new passenger cars rose by about 68 million in the past 17 years, and passenger car use (measured in passenger km) increased by 38 %. Road freight volumes (measured in tonne km) increased by 79 % between 1990 and 2007. Overall, and despite improvements in the energy efficiency of new

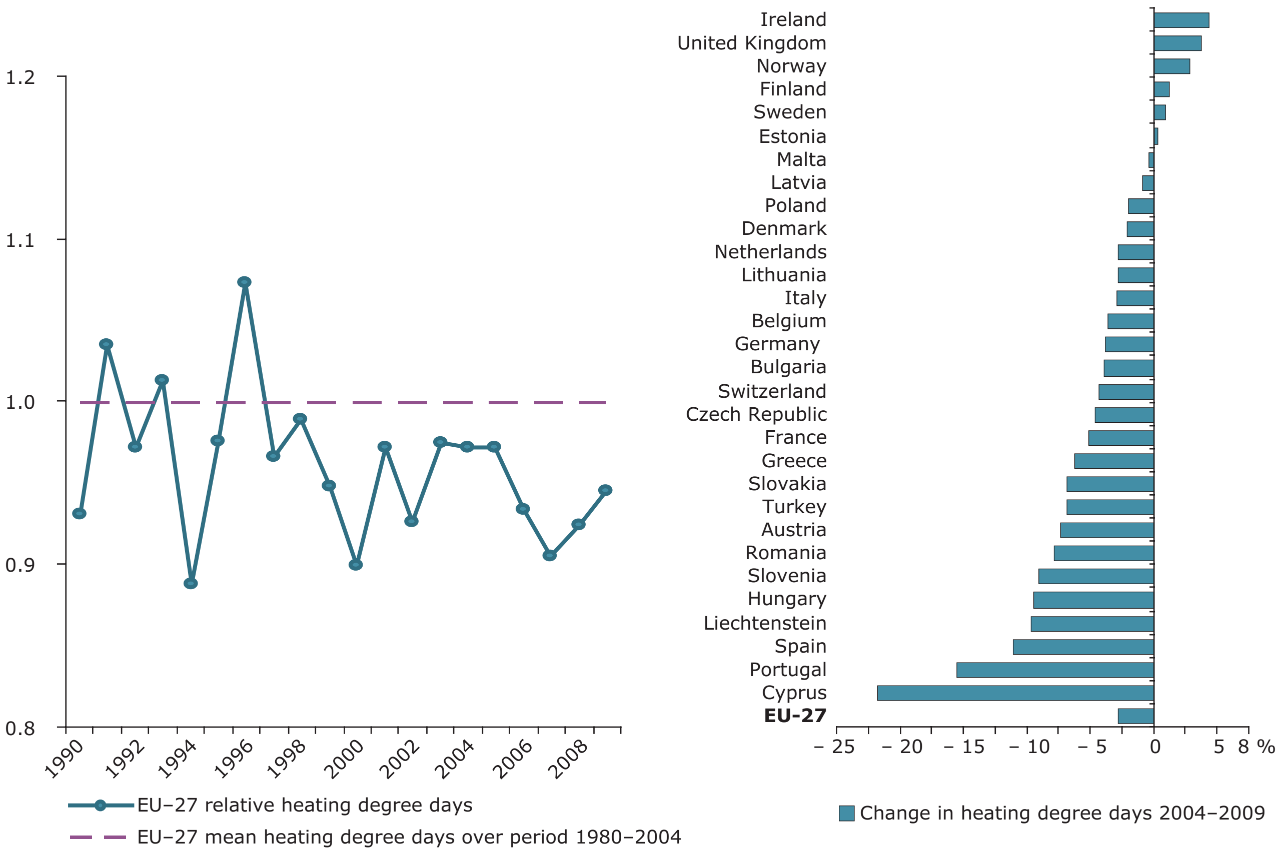
Figure 2.13 Mean surface temperature in Europe 1850–2009, annual and by season



Source: EEA, 2010d.

(9) Under Article 3.3 of the Kyoto Protocol, greenhouse gas removals through afforestation and reforestation since 1990 shall be accounted for when meeting their Kyoto Protocol targets. Emissions from deforestation activities would be subtracted from the amount of emissions that a Party may emit over its commitment period. Under Article 3.4 of the Kyoto Protocol, Parties can also include additional anthropogenic activities related to LULUCF (i.e. forest management, cropland management, grazing land management and re-vegetation).

Figure 2.14 Change in heating degree days as fraction of EU-27 mean heating days (left) and change in heating degree days 2004–2009 (right)

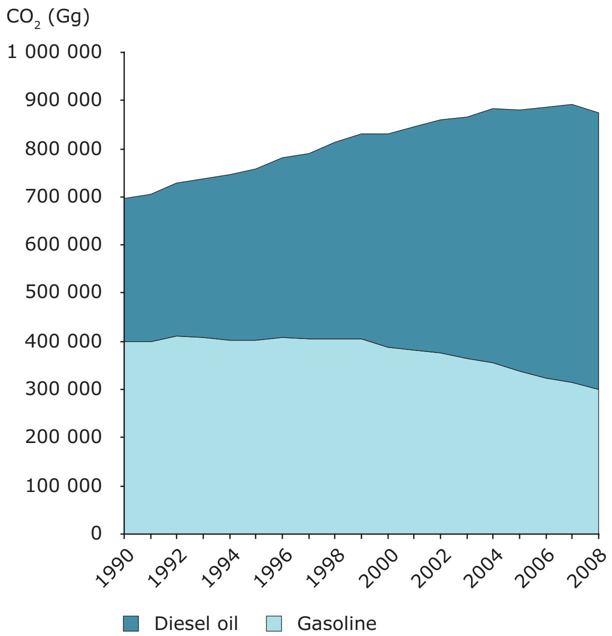


Source: EEA, based on Eurostat's heating degree days (Eurostat, 2010).

vehicles, the net increase in CO_2 emissions from road transport between 1990 and 2008 was 185 million tonnes. This increase was fully accounted for by a strong uptake of diesel and a decline in gasoline use (Figure 2.15). This is despite of diesel engines being more energy efficient than similar performance gasoline engines. Since transport roughly represents about one third of emissions from the sectors not covered by the EU ETS, transport emissions would need to fall significantly if the EU and its Member States are to meet their limitation targets under the Effort Sharing Decision for non-trading sectors by 2020 compared to 2005. In 2009, the EU adopted legislation establishing emission performance requirements for new passenger cars to reduce average emissions to 120 g CO_2/km (130 g through vehicle technology improvements and 10g through more efficiency vehicle features such as tyres and air conditioning systems) by 2015, and further to 95 g CO_2/km by 2020 (EU, 2009).

Emissions from international aviation and maritime transport (1990–2008) continued to rise and grew three times faster than road transport emissions in relative terms. Contributions from international transport, currently not included in the national GHG totals under the UNFCCC and Kyoto Protocol, increased by 134 million

Figure 2.15 CO_2 emissions from diesel and gasoline in the EU-27, 1990–2008



Source: EEA, 2010a.

tonnes between 1990 and 2008. EU GHG emissions from international aviation are lower than for international maritime transport but are growing significantly more rapidly. Together, the two sectors in 2008 accounted for about 6 % of total EU GHG emissions. Emissions from international aviation will be captured in the third phase of the EU ETS starting in 2012. A decision on the inclusion of greenhouse gas emissions from international maritime transport is yet to be taken.

The only other key emission source partly offsetting the decline in total greenhouse gas emissions was the consumption of HFCs linked to refrigeration and air conditioning equipment. HFCs were the only group of greenhouse gases which increased between 1990 and 2008 (see section on the overview by main greenhouse gas).

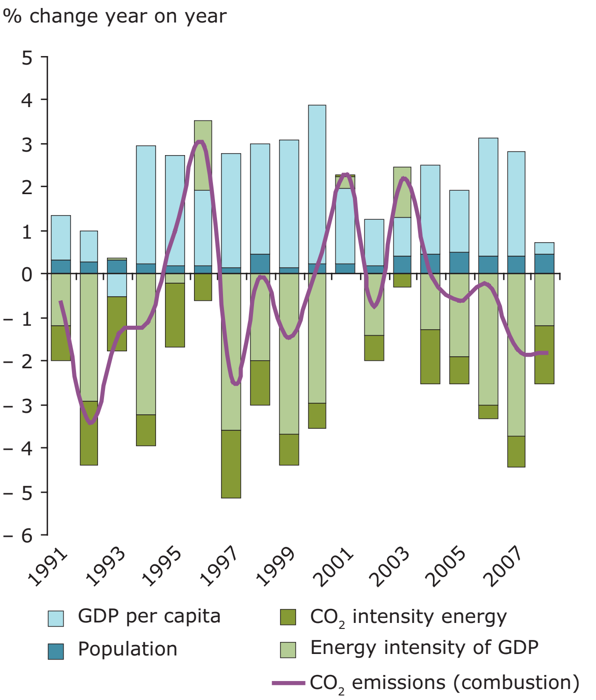
Other factors explaining the trends in greenhouse gas emissions

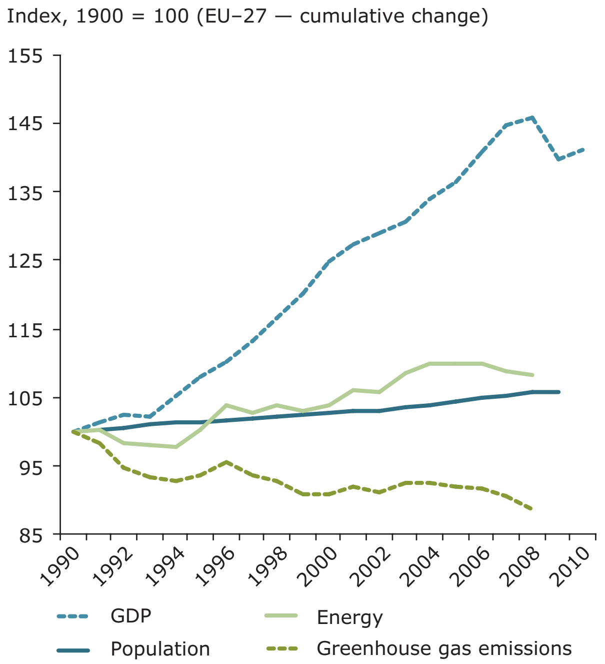
Energy combustion (i.e. the production and consumption of energy by all sectors, including transport) accounts for 92 % of the reduction in EU-27 greenhouse gas emissions between 1990 and 2008. Figure 2.16 shows a breakdown of the factors that help explain or illustrate year-on-year changes in CO_2 emissions from the combustion of fossil fuels.

CO_2 emissions from energy combustion (EEA, 2010a) fell by 7.1 % (288 million tonnes) in the EU-27 between 1990 and 2008, while real GDP increased by 46 % and population grew by almost 6 % (27 million people, Eurostat, 2010) over the 18-year period (EC, 2010a). A growing population and GDP generally contribute to higher CO_2 emissions. A faster growth in GDP relative to population has led to significant increases in GDP per capita, particularly in the mid-to-late 1990s.

The remaining two factors, i.e. the energy intensity and carbon intensity of the economy are key for understanding the evolution of CO_2 emissions from energy-related sources. Energy intensity has fallen almost every year since 1990, partly due to a contraction in primary energy consumption, partly due to a more rapid increase in real GDP. Carbon intensity has also declined and this is mainly due to the switch to less polluting fuels. These two factors are further analysed below.

Figure 2.16 Change in GDP, population, primary energy and emissions, 1990–2010





Note: The chart to the left shows the estimated contributions of the various factors that have affected CO_2 emissions from energy production and consumption in the EU-27. This approach is often used to portray the primary forces driving emissions. The explanatory factors should not be seen as fundamental factors in themselves nor should they be seen as independent of each other. The chart to the right shows the increase in GDP, population, primary energy and total greenhouse gas emissions in the EU-27 compared to 1990.

Source: EEA, 2010a; Eurostat, 2010; European Commission, 2010a.

Carbon intensity can be defined as the amount of CO_2 released to the atmosphere per unit of primary energy consumed (relatively small amounts of methane are also emitted). At EU level, one of the sectors contributing most to the net emission reduction between 1990 and 2008 was the production of heat and electricity. Less coal and oil, more gas and more combustible renewables (i.e. biomass) explain why this sector emitted 136 million tonnes of CO_2 less than in 2007.

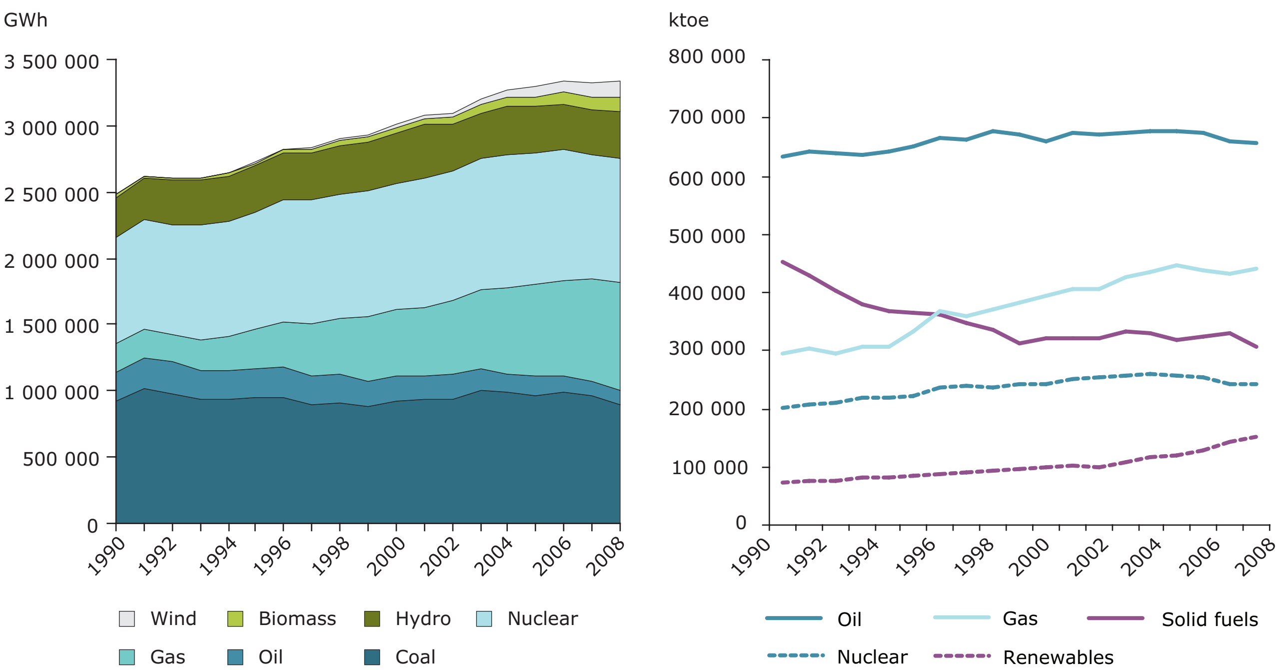
The change in the fuel mix in the production of heat and electricity in thermal stations has led to important savings in CO_2 emissions. The average 2008 implied emission factor (i.e. carbon dioxide emitted per unit energy released) for coal was 100 t CO_2/TJ, compared to 76 t CO_2/TJ for liquid fuels and 57 t CO_2/TJ for gas. Therefore, the reduced contribution of both coal and liquid fuels in the average household fuel mix, together with the increased contribution from gas and biomass, have led to a better CO_2 emission intensity per unit of energy generated (see also earlier discussion on the sectors achieving the largest emission reductions and Figure 2.11). Other factors clearly contributed to the decline in greenhouse gas emissions in the EU-27. Eurostat 2008 energy balances confirm the decline of primary consumption of solid fuels and the increase in natural gas. The energy balances also show a strong increase in the amount of renewable energy, particularly from biomass, wind and hydro for electricity generation.

Nuclear electricity production also increased between 1990 and 2008 (Figure 2.17).

Energy intensity can be defined as the amount of primary energy consumed within a country relative to its gross domestic product. The contribution of energy intensity to lower CO_2 emissions from energy combustion has declined in most years throughout the last 18-year period.

Moreover, the ratio of final energy consumption to primary energy consumption increased somewhat in the EU-27 between 1990 and 2008. This has resulted in lower energy losses per unit of primary energy to meet final energy demand. Two factors can help explain this improvement. First, there was a strong increase in renewables, some of which can produce electricity by means of mechanical energy without any combustion. The avoided transformation losses in thermal power stations partly explain why higher final energy demand was met using less primary energy. Second, the transformation efficiency in conventional thermal power stations in the EU increased by as much as 8 percentage points, to almost 50 % (including district heating plants) in 2008. This implies less input of primary energy per output of useful energy. The increased use of electricity from combined heat and power (i.e. cogeneration) and recovery of excess heat has also contributed to higher energy efficiencies in the EU.

Figure 2.17 Gross electricity and primary energy consumption by main fuel in EU-27, 1990–2008



Source: EEA, 2010a; Eurostat, 2010.

2.3 Ozone-depleting substances as greenhouse gases

The UNFCCC and Kyoto Protocol do not cover all GHGs ([10]). The Montreal Protocol was agreed by countries in 1987 in order to phase out the production of a number of substances that deplete the ozone layer — it has since been widely recognised as one of the most successful multilateral environmental agreements to date. Implementation of the Montreal protocol has led to a very significant decrease in the atmospheric burden of ozone-depleting substances (ODSs) in the lower atmosphere and in the stratosphere. Importantly however, many of the substances addressed in the Montreal protocol such as chlorofluorocarbons (CFCs) are also potent GHGs in their own right but are not addressed under the Kyoto Protocol. Thus the direct effects of the Montreal Protocol in reducing emissions of ODS have also indirectly contributed to a very significant reduction in emissions of some potent greenhouse gases.

Consumption and production of ozone-depleting substances has gone down markedly in EEA member countries, particularly in the first half of the 1990s. Before the Montreal Protocol was signed in 1987, EEA ODS production exceeded half a million ODP (ozone depletion potential) tonnes. ODS production was negative (see note to Figure 2.18) in 2007 and 2008, although it increased again in 2009 to reach 747 ODP tonnes. ODS consumption in EEA member countries fell from about 80 thousand ODP tonnes in 1986 to almost zero in 2009 (see Figure 2.18).

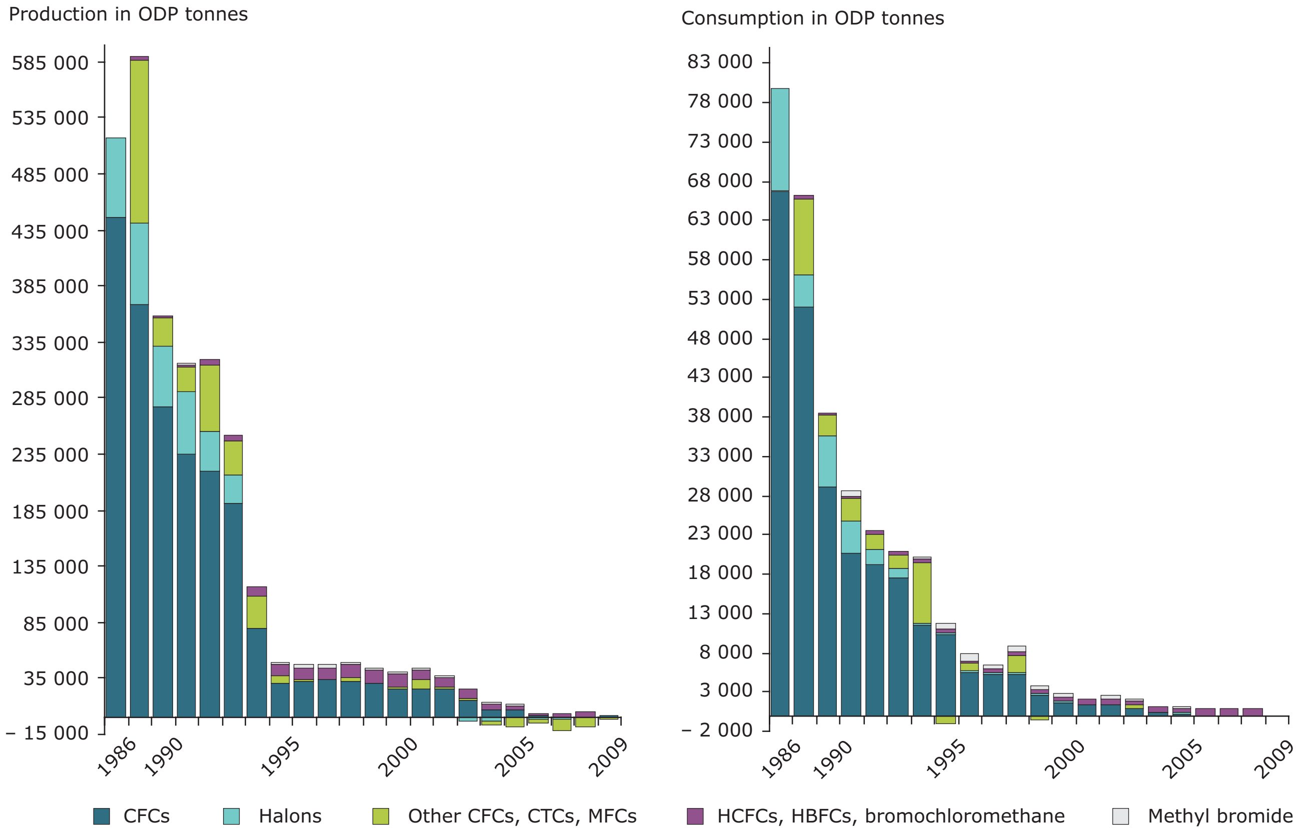
According to the 2006 assessment reports from UNEP's Scientific, Environmental and Technology and Economic Assessment Panels under the Montreal Protocol (UNEP, 2006), ozone depletion also influences climate change since both ozone and the compounds responsible for its depletion are active greenhouse gases. The implementation of the Montreal Protocol has therefore indirectly led to a stark reduction in emissions of these potent greenhouse gases, such as chlorofluorocarbons (CFCs), which are outside the remits of the Kyoto Protocol. The phasing out of climate-changing ODS under the Montreal Protocol has reduced greenhouse gas emissions by an amount significantly larger than the Kyoto Protocol is expected to deliver by the end of 2012. The reduction in GWP-weighted ODS emissions expected as a result of compliance with the Montreal Protocol have been estimated globally at 10–12 Gt CO_2-equivalent per year between in 2010 (Velders et al., 2007). In contrast, the reduction of greenhouse gases under the Kyoto Protocol (assuming full compliance by all developed countries) is about – 5 % on average between 2008 and 2012 compared to base year emissions. This is equivalent to about 1 Gt CO_2-equivalent on average per year during the Kyoto first commitment period (2008–2012). The Kyoto Protocol sets binding targets to reduce greenhouse gas emissions for 37 industrialised countries and the European Union. In contrast, the Montreal Protocol has been ratified by 196 countries. This partly explains the significantly higher success as a global mitigation instrument, while addressing different gases.

UNEP's Assessment concluded there are various options to achieve a global recovery in the ozone layer (i.e. returning to pre-1980 levels). These include addressing the strong growth in the production and consumption of hydrochlorofluorocarbons (HCFCs) in developing countries and the immediate collection and safe disposal of large quantities of ODS contained in old equipment and buildings (the so-called ODS 'banks'), which have a very significant ozone-depleting and global warming potential. At the EU level, the EU regulation on substances that deplete the ozone layer, which in many aspects goes further than the Montreal Protocol, also brings forward the production phase-out of HCFCs from 2025 to 2020.

The projected recovery of the ozone layer is sensitive to future levels of greenhouse gases and the associated changes in climate. On the one hand, climate change will influence the exposure of all living organisms to UV-B radiation via changes in cloudiness, precipitation, and ice cover. On the other hand, HCFCs both damage the ozone layer and contribute to global warming and their concentrations continue to increase in the atmosphere. Given these interlinkages, international efforts to safeguard the earth's climate (e.g. UNFCCC and its Kyoto Protocol) and protect the ozone layer (Montreal Protocol) can be mutually supportive. In 2007, governments from developed and developing countries agreed to freeze production of HCFCs in developing countries by 2013 and bring forward the final phase-out date of these chemicals by ten years in both developed and developing countries (Montreal/Nairobi, 22 September 2007). This

([10]) Apart from the ODS GHG controlled by the Montreal Protocol, there are other variables not captured in the national totals under the UNFCCC and Kyoto reporting; such as international aviation and maritime transport. CO_2 emissions from the combustion of biomass with energy recovery, for example for electricity, heat and transport, are considered neutral for reporting purposes under UNFCCC/Kyoto. The assumption is that harvesting does not outpace annual re-growth, and that unsustainable biomass production would show as a loss of biomass stock in the LULUCF sector. However, part of the biomass combusted in Europe is imported from countries which are not required to report annual GHG inventories to the UNFCCC. Moreover, the latest assessment of the IPCC AR4 (IPCC, 2007) revised the global warming potentials of key GHGs, such as CH_4 — up to 25 times stronger than CO_2 over 100 years — and N_2O 298 times stronger than CO_2. There are also other rapidly growing GHGs such as NF3 which are outside the scope of any binding international agreement at the moment, although their current contribution to total GHG emissions in Europe is small.

Figure 2.18 Production and consumption of ozone depleting substances in EEA member countries, 1986–2009



Note: Production is defined under Article 1(5) of the Montreal Protocol as production minus the amount destroyed minus the amount entirely used as feedstock in the manufacture of other chemicals. Since the figures are for each calendar year, it is quite possible that in some years the destroyed amounts and/or the feedstock figure may exceed the production figure of that year, if they include ODS from a carry-over stock. The calculated production could be negative in such cases. Consumption is defined as production plus imports minus exports of controlled substances under the Montreal Protocol. As with calculated production, the consumption of ODS can be negative, also because exports in any one year can exceed production and imports if they include ODS from carry-over stocks.

Source: EEA, 2010e.

has been referred to as a historic agreement to tackle the challenges of protecting the ozone layer and combating climate change at the same time. However, while HCFCs have largely replaced CFCs in both developed and developing countries, in many HCFC applications there is now a gradual replacement with hydrofluorocarbons (HFCs), which, although not ozone-depleting, are potent greenhouse gases.

The depth and area of the ozone hole over Antarctica remains large although it contracted in 2009 compared to 2008. Between 7 September and 13 October of 2009, the average ozone-hole area reached 21.7 million square kilometres, with a daily maximum of 24.1 million square kilometres — equivalent to about 6 times the territory of the EU (NASA, 2010). According to UNEP's 2006 Assessment, failure to comply with the Montreal Protocol and the continuation of large agreed exemptions could delay or even prevent the recovery of the ozone layer — with additional implications for climate change.

A new 2010 report by the Scientific Assessment Panel of the Montreal Protocol (UNEP, 2010) concludes the Antarctic ozone hole provides the most visible example of how ozone depletion affects surface climate, leading to important changes in surface temperature and wind patterns. Overall, there is stronger evidence of the effect of stratospheric ozone changes on the earth's surface climate, and also of the effects of climate change on stratospheric ozone. Increasing abundances of greenhouse gases such as carbon dioxide and methane are expected to significantly affect future stratospheric ozone through effects on temperature, winds, and chemistry. The report also highlights the substantial co-benefits between the protection of the ozone layer and climate change and presents a number of options for policymakers.

3 Outlooks 2020 and policy responses

3.1 Short-term outlook: progress towards Kyoto Protocol targets

Under the Kyoto Protocol, the EU-15 has taken on a common commitment to reduce emissions between 2008 and 2012 by 8 % on average, compared to base-year emissions. Within this overall target, differentiated emission limitation or reduction targets have been agreed for each of the 15 pre-2004 Member States under an EU accord known as the 'burden-sharing agreement'. The EU-27 does not have a Kyoto target, since the Protocol was ratified before 2004 when 12 countries became EU Member States. However, 10 of these EU-12 Member States have individual targets under the Kyoto Protocol, while Cyprus and Malta do not have targets. Of the other EEA member countries, Iceland, Liechtenstein, Norway and Switzerland also have individual targets under the Kyoto Protocol. Turkey acceded to the Kyoto Protocol in February 2009 but, like Cyprus and Malta, has no quantified emission reduction commitment under the Kyoto Protocol. Figure 3.1 presents the GHG emission targets in Europe under the Kyoto Protocol (2008–2012) relative to base-year emissions.

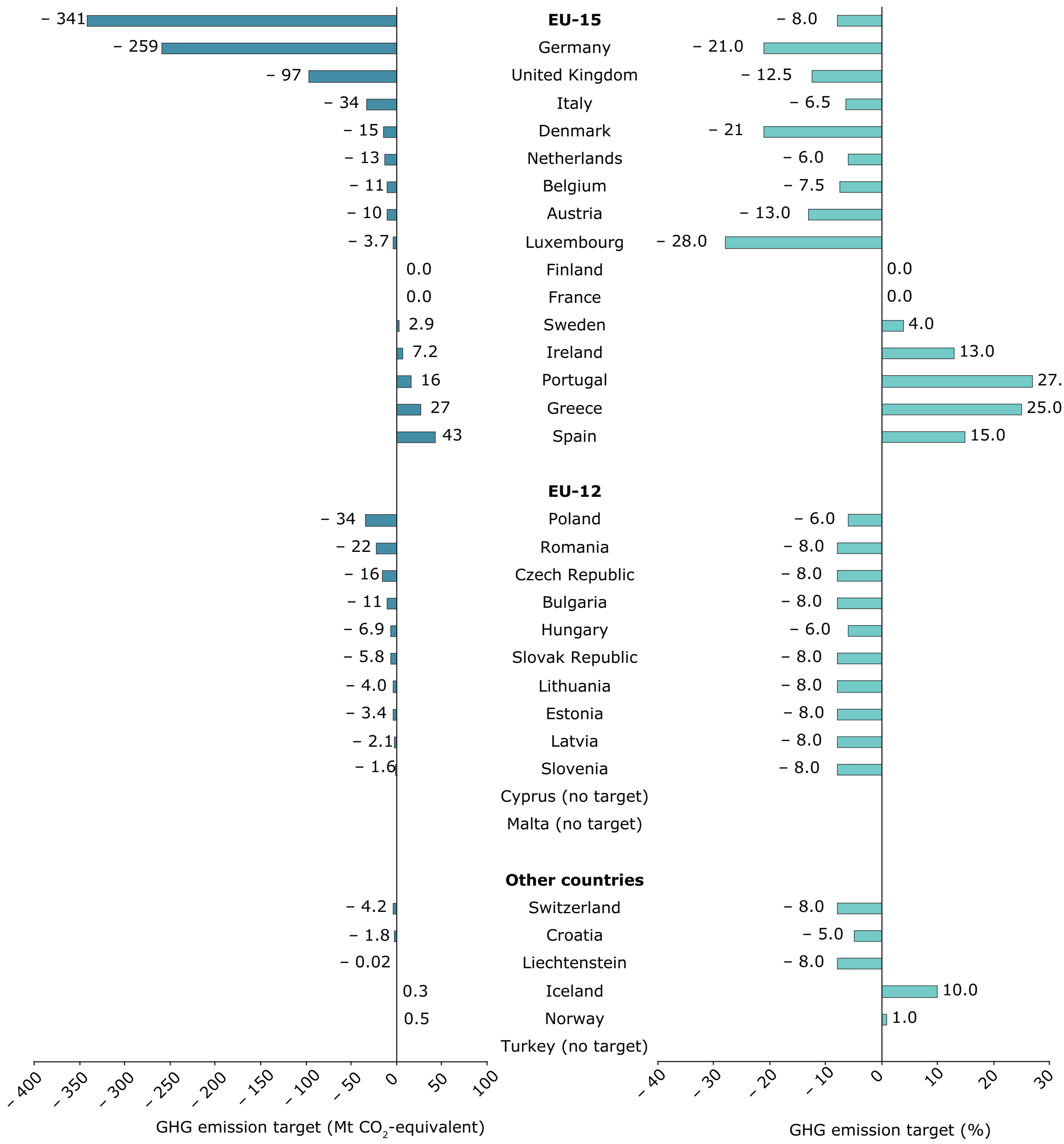
In 2008, the EU-15 achieved a GHG emissions reduction of 6.9 % compared to 1990 levels (EEA, 2010a). In 2010 the European Commission published a GHG emission scenario for the period to 2030, reflecting trends such as the economic crisis and policies implemented in the EU and the Member States as of spring 2009 (PRIMES/GAINS baseline scenario, European Commission, 2010b). These policies include new provisions of the EU ETS for CO_2, strong national renewable support policies, Carbon Capture and Storage (CCS) demonstration plants, EU regulation on CO_2 emissions from cars, energy efficiency directives and the revival of nuclear energy in some countries. The non-CO_2 baseline takes account of additional implemented legislation such as the CAP reform and the Directives on Landfill and Waste. As shown in Figure 3.2, the historic trend, combined with the results of the PRIMES/GAINS baseline scenario, indicates that the EU-15 is on track to meets its Kyoto Protocol target. Progress towards Kyoto Protocol targets by individual countries is described in EEA (2010b). The shown PRIMES/GAINS reference scenario evaluates the effect of the Climate and Energy Package (see Section 3.2).

3.2 Medium-term outlook: the impact of the Climate and Energy package

Looking beyond the first commitment period of the Kyoto Protocol, in March 2007 the European Council committed the EU-27 to reduce its GHG emissions by at least 20 % compared to 1990 levels by 2020 and to increase this to a 30 % reduction if major emitting countries outside of Europe make similarly challenging commitments under a global climate agreement. The PRIMES/GAINS baseline scenario (Figure 3.3, left panel) shows that with existing policy measures EU GHG emissions are projected to be 761 Mt CO_2-equivalent, including international aviation, 14 % lower than 1990 in 2020. This means that in 2020, a 6 % gap will remain to be filled with additional measures or the financing of emission reduction initiatives outside the EU (the green line in Figure 3.3). The emission reduction in the baseline scenario assumes a 6 % reduction in CO_2 emissions in the period 2005–2020, mainly in the ETS sector, and a 13 % reduction of non-CO_2 emissions in the same period, mainly in the non-ETS sector.

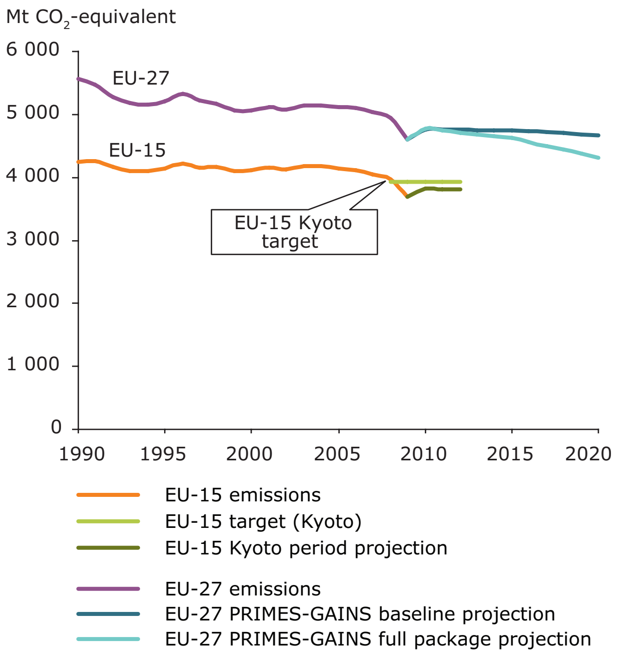
The 20 % target was put into legislation with the Climate and Energy package adopted in April 2009. Under this, the target, which is equivalent to a 14 % reduction in GHG emissions between 2005 and 2020, is split into two sub-targets: a 19 % reduction target compared to 2005 for the emissions covered by the EU ETS — including aviation — and a 10 % reduction target compared to 2005 for the remaining non-ETS sectors. Starting from the baseline scenario, the PRIMES/GAINS model evaluated the impact of the Climate and Energy package through the so-called reference scenario. This assumes full national implementation of the Climate and Energy package, including non-ETS emissions and renewable energy targets. The resulting emission trend projection shows that the EU-27 emissions in 2020 would be 20 % lower than the 1990 values — 14 % lower compared to 2005. As illustrated in Figure 3.3 (right panel), the reference scenario shows a 12.5 % emission reduction between 2005–2020 for CO_2 emissions, an ETS emission reduction of 18 % and non-ETS emission reduction of 6 %. Non-CO_2 emissions are reduced by 21 % in the 2005–2020 period, with 75 % and 17 % reductions in the ETS and non-ETS sectors respectiively. The PRIMES/GAINS result indicate

Figure 3.1 Greenhouse gas emission targets in Europe under the Kyoto Protocol (2008–2012) relative to base-year emissions



Source: EEA, 2010f.

Figure 3.2 Total GHG emissions in EU-15 and EU-27 in Mt CO_2-equivalent



Note: Emissions from international aviation, although included in the 2020 target, are not taken into account in this figure's past trends, projections and targets. The figure includes emissions from domestic maritime transport.

Sources: EEA, 2010c; European Commission, 2010b.

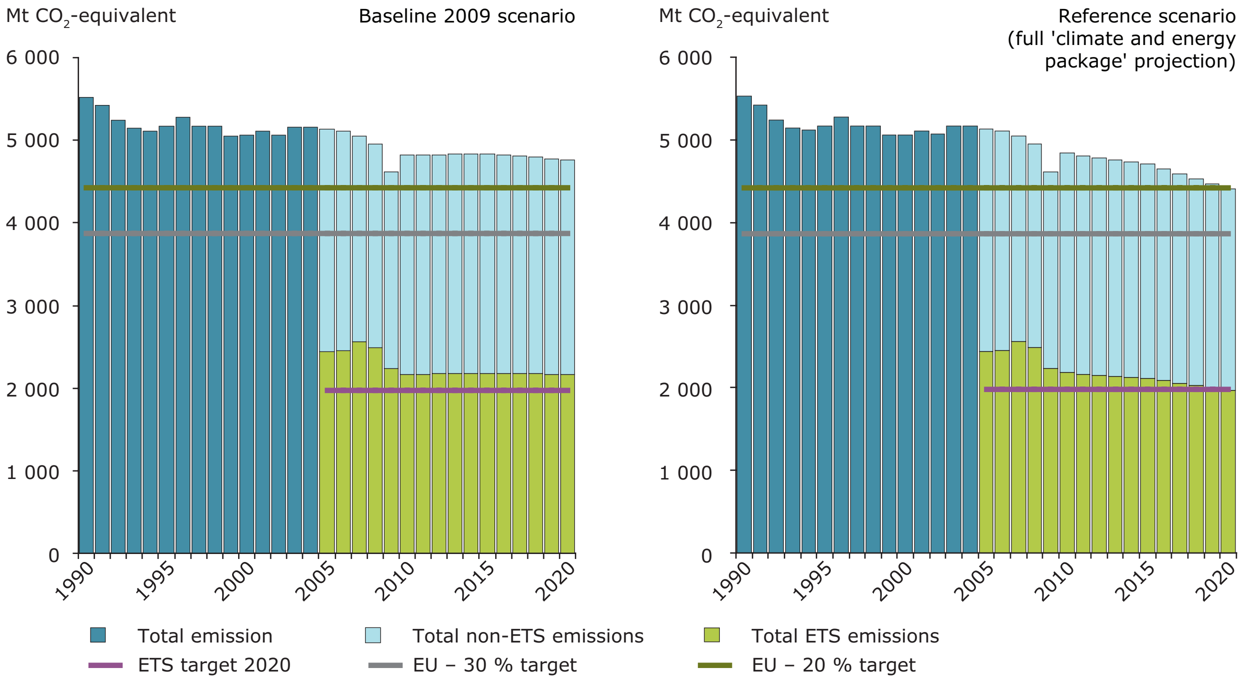
that over the period 2013–2020 the emission reduction can be achieved domestically with no international credits needed.

3.3 Medium-term outlook: the impact of the Copenhagen Accord

The consensus in the EU is that in order to limit serious impacts of climate change, global temperature increase should be kept below 2 °C compared to pre-industrial levels. This requires that global GHG emissions must peak by 2020 at a level of 44–46 Gt CO_2-equivalent and then be reduced by at least 50 % compared to 1990 levels by 2050 (Van Vuuren et al., 2010).

The 15th Conference of the Parties (COP15) of the UNFCCC resulted in the Copenhagen Accord in 2009. Although it does not include legally binding reduction targets, the Accord recognises the need for considerable emission reductions in light of the IPCC assessments. The UNFCCC, has subsequently received submissions of national intentions (pledges) to cut and limit GHG emissions by 2020 from 125 parties, which together account for more than 80 % of global emissions (European Commission, 2010b). In the Copenhagen Accord two types of pledges are recorded. The low pledge is an unconditional pledge by countries to reduce their emissions; the high pledge is a conditional additional

Figure 3.3 Total GHG emissions PRIMES/GAINS baseline in EU-27 in Mt CO_2-equivalent



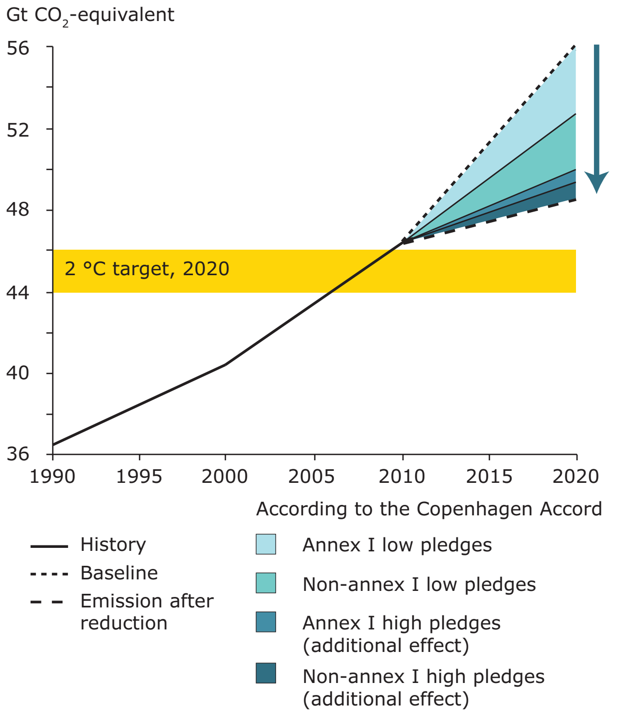
Source: Modified from European Commission, 2010b.

emission reduction. The reduction pledged by Annex I countries for 2020 amounts to 12–28 % compared to 1990 levels. The EU-27 submitted a low pledge of 20 % and a high pledge increasing this commitment to a 30 % reduction if major emitting countries outside Europe make similarly challenging commitments under a global climate agreement. The pledges by non-Annex I countries are more difficult to assess due to their qualitative nature. For example, China will lower its carbon intensity per unit of GDP by 40–45 % in 2020 compared to 1990. The resulting emission reductions are uncertain; PBL (2010) assumes an emission reduction of 6 % while the Prospective Outlook on Long-term Energy Systems (POLES) model analysis (European Commission, 2010b) calculates that, depending on future carbon market developments, China's emission reduction could be between 9 % and 17 %.

PBL (2010) evaluated the emission reduction pledges under the Copenhagen Accord and factors that would influence the effectiveness of climate policy such as new surplus emission allowances and accounting rules for forestry and land-use change. Figure 3.4 illustrates the impact of the low and high pledges on global GHG emissions compared to a baseline scenario. The baseline scenario follows the trends of the International Energy Agency's (IEA) World Energy Outlook 2007 and takes into account the economic crises of 2008/2009. This scenario shows global emissions increasing from around 36 Gt CO_2-equivalent in 1990 to 56 Gt CO_2-equivalent in 2020. This is about 20 Gt above the peak emission level required in 2020 to have a reasonable chance of staying within a 2 °C target. If both Annex I and non-Annex I countries meet their low pledges, emissions in 2020 would be 50 Gt CO_2-equivalent and if all countries meet their additional emission reduction targets — high pledges — a further reduction would lead to the emission of 48.7 Gt CO_2-equivalent in 2020. This means that the pledges under the Copenhagen Accord would be about 2–4 Gt CO_2-equivalent short of keeping emissions below the peak levels identified in the scientific literature. One should however realise that, as mentioned above, the impact of China's and India's pledges are related to the ratio of CO_2 to GDP of which the estimated effect is uncertain. It might well be that the gap of 2–4 Gt CO_2-equivalent will in fact be much smaller or even higher. PBL (2010) identified several options for decreasing this gap including the implementation of national climate plans in China and India, additional reduction of deforestation emissions, and emission targets for international aviation and marine transport.

EU-27 emissions of 5.1 Gt CO_2-eqivalent in 2005 contributed around 11 % of global GHG emissions in 2005. Under the Climate and Energy package EU-27 emissions would be reduced to 4.8 Gt CO_2-eqivalent in 2020, which is foreseen to be 9 % of global emissions in that year. Implementation of additional emission reductions under the high pledge would lead to a further reduction of 0.6 Gt CO_2-eqivalent resulting in Europe contributing around 8 % of global GHG emissions in 2020.

Figure 3.4 **Total GHG emissions Gt CO_2-equivalent**



Note: The figure shows GHG emissions including CO_2 from land use but excluding additional emission allowances after 2012.

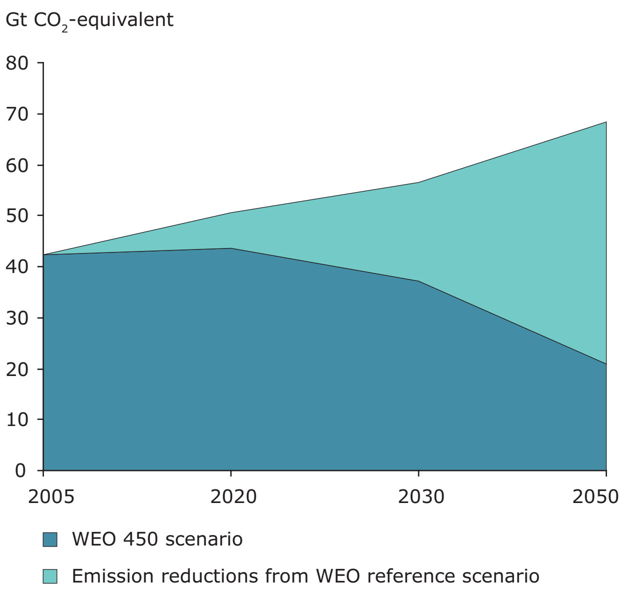
Source: Netherlands Environmental Assessment Agency, 2010.

3.4 Long-term outlook: pathways to low-emission economies

A number of modelling exercises are being carried out at national, European and global levels to project long-term greenhouse gas emissions under various scenarios. Two studies are presented here, the annual World Energy Outlook (WEO) by the IEA and the POLES model study by the European Commission.

In its annual WEO, the IEA (2009b) also presents two emission scenarios for energy-related CO_2 emissions: the Reference Scenario and the 450 Scenario. The baseline scenario assumes no further developments beyond existing policies and measures, but accounts for the impacts of the latest EU directive and the economic crises. As shown in Figure 3.5, if current trends and policies are continued in the period 2005–2050, annual global GHG emissions are expected to increase from about 40 Gt CO_2-equivalent now to almost 70 Gt CO_2-eqivalent in 2050.

Figure 3.5 **World anthropogenic GHG emissions under the WEO baseline scenario**



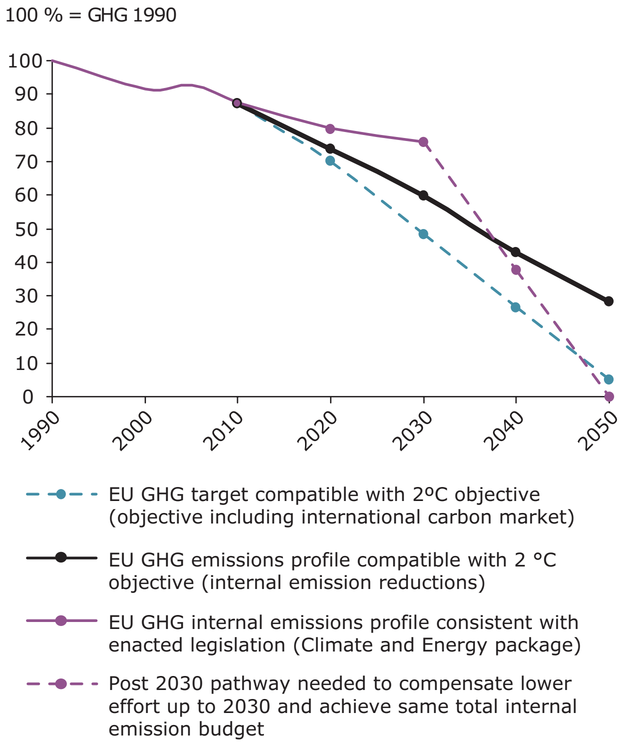
Source: Modified from IEA, 2009b.

The WEO 450 Scenario assumes that governments adopt commitments to limit the long-term concentration of GHGs in the atmosphere to 450 parts per million (ppm) CO_2-equivalent. On a global scale, this means that by 2050 global GHG emissions should be reduced by about 50 Gt CO_2-eqivalent (Figure 3.5). The WEO study identifies that the largest potential for reduction is the energy sector. In the 450 Scenario, the WEO study identifies that global CO_2 emissions will have to be reduced by 14 Gt in 2030 with more than half of this reduction coming from energy efficiency improvements and 20 % from the use of renewable energy. The reduction measures needed in the EU according to WEO show a different sector pattern. To reduce CO_2 emissions in the energy sector from 3.5 Gt — the reference scenario — to about 2.2 Gt by 2050 — 450 Scenario — the measures required include energy efficiency contributing 35 % of the total reductions, renewable energy 20 %, nuclear 20 % and CCS 20 %. The role of biofuels is assumed to be relatively small at around 4 % and other measures account for 1 %. The results of the WEO study do not assume implementation of the Climate and Energy package or the possibility of reducing emissions by 30 % in 2020 under the condition of an ambitious global climate treaty.

The WEO 450 scenario indicates that an additional effort would be needed after 2020 to reduce European GHG emissions. This need has been evaluated by the POLES model of the European Commission. The model results included in European Commission study (2010b) consider global reduction of emissions in the order of 50 % compared to 1990 levels. These reductions are assumed to be achieved through a low carbon economy — more than 50 % less fossil fuels in energy supply — and contributions from CCS technologies. The scenario further assumes the presence of an international carbon market with participation by developing countries. The relation between the mid-term emission trends in Europe (see also Section 3.2) and the longer-term trends compatible with a 2˚C scenario is presented in Figure 3.6.

Figure 3.6 presents, based on POLES model results, the percentage of emission reduction in any given year compared to the year 1990. The blue line shows the reduction needed in line with a 2 °C. In 2020 the required reduction would be 30 % in 2020, which means that according to the POLES model results, the Climate and Energy package (solid purple line) will fall 10 % short of the 2 °C reduction target. In 2030 the required emission reduction would about 50 %, whereas the Climate and Energy package is expected to lead to a 25 % emission reduction compared to the base year. This means that either additional domestic measures are needed in Europe on top of the Climate and Energy package (solid black line) or that a further reduction has to be achieved through the international carbon market (blue line). An alternative would be that the EU does not take additional

Figure 3.6 **EU emission profiles compared to a 2 °C compatible long-term target**



Source: European Commission, 2010b.

measures to the Climate and Energy package but follows a stringent emission reduction policy after 2030 (dashed purple-line).

3.5 The co-benefits of climate policy on air pollutants

As shown in the WEO 2009 (IEA, 2009b) study, half of the global GHG emission reductions are to be achieved through energy efficiency measures. In general terms this means that less traditional fossil fuel combustion will be needed to meet global energy demands. Various scientific studies have identified that an important co-benefit of climate policies that lead to lower fossil fuel combustion is the strong reduction in emissions of air pollutants such as SO_2, NO_x and particulate matter (PM). Further information on the interaction between climate and air pollution policy can be found in the SOER 2010 air pollution assessment (EEA, 2010g).

References

European Commission: Joint Research Centre (JRC)/ Netherlands Environmental Assessment Agency (PBL), 2009. *Emission Database for Global Atmospheric Research (EDGAR), release version 4.0*. http://edgar.jrc.ec.europa.eu.

EC, 1991. Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources. Official Journal L 375 , 31/12/1991.

EC, 1999. Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste. Official Journal L 182, 16/07/1999.

EC, 2006. Directive 2006/40/EC of the European Parliament and of the Council of 17 May 2006 relating to emissions from air-conditioning systems in motor vehicles and amending Council Directive 70/156/EEC. Official Journal L 161/12, 14/06/2006.

EC, 2009. Legal acts on climate and energy as published in Official Journal L 140, Volume 52, 5 June 2009.

European Commission, 2010a. Annual macro-economic database (AMECO). http://ec.europa.eu/economy_finance/db_indicators/ameco/index_en.htm.

European Commission, 2010b. Commission staff working document accompanying the Communication from the Commission to the European Parliament, The Council, The European Economic and Social Committee and The Committee of the Regions. Analysis of options to move beyond 20% greenhouse gas emission reductions and assessing the risks of carbon leakage. Background Information and analysis. Part II. COM(2010) 265 final.

EEA, 2010a. *Annual European Union greenhouse gas inventory 1990–2008 and inventory report 2010*. EEA Technical report No 6/2010. European Environment Agency.

EEA, 2010b. *EU ETS data viewer.* http://dataservice.eea.europa.eu/PivotApp/pivot.aspx?pivotid=473.

EEA, 2010c. *Recession accelerates the decline in EU greenhouse gas emissions*. European Environment Agency, Copenhagen. www.eea.europa.eu/highlights/recession-accelerates-the-decline-in.

EEA, 2010d. Core set indicator Global and European temperature (CSI 012) — Assessment published June 2010. www.eea.europa.eu/data-and-maps/indicators/global-and-european-temperature/global-and-european-temperature-assessment-3.

EEA, 2010e. *Core set indicator, Production and consumption of ozone depleting substances (CSI 006)* — Assessment published January 2009. www.eea.europa.eu/data-and-maps/indicators/production-and-consumption-of-ozone/production-and-consumption-of-ozone-1.

EEA, 2010f. *Tracking progress towards Kyoto and 2020 targets in Europe*. EEA Report No 7/2010. European Environment Agency, Copenhagen. www.eea.europa.eu/publications/progress-towards-kyoto.

EEA, 2010g. *The European environment — state and outlook 2010: air pollution.* European Environment Agency, Copenhagen.

Eurostat, 2009. External and intra-European Union trade 2009 edition Data 2002–07.

Eurostat, 2010. *Online statistical database*. http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/themes.

International Energy Agency (OECD/IEA), 2009a. *CO_2 Emissions from Fuel Combustion, 2009 Edition*. OECD/IEA, Paris.

International Energy Agency (OECD/IEA), 2009b. *World Energy Outlook 2009*. OECD/IEA, Paris.

IPCC/OECD/IEA,1997. *Revised 1996 IPCC Guidelines for National Greenhouse Inventories*, OECD, Paris.

IPCC, 2007. *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)). IPCC, Geneva, Switzerland, 104 pp.

NASA, 2010. Ozone Hole Watch, Goddard Space Flight Center. http://ozonewatch.gsfc.nasa.gov/meteorology/annual_data.html.

Netherlands Environmental Assessment Agency (PBL), 2010. *Evaluation of the Copenhagen Accord: Chances and risks for the 2 °C climate goal*. PBL publication number 500114017. May 2010.

Pleijel, H. (ed), 2009. *Air pollution & climate change. Two sides of the same coin?* Swedish Environmental Protection Agency, Stockholm. 167 pp.

Stern, N.; Peters, S.; Bakhshi, V.; Bowen, A.; Cameron, C.; Catovsky, S.; Crane, D.; Cruickshank, S.; Dietz, S.; Edmonson, N.; Garbett, S.-L.; Hamid, L.; Hoffman, G.; Ingram, D.; Jones, B.; Patmore, N.; Radcliffe, H.; Sathiyarajah, R.; Stock, M.; Taylor, C.; Vernon, T.; Wanjie, H. and Zenghelis, D., 2006. *Stern Review: The Economics of Climate Change*, HM Treasury, London.

UNEP, 2006. *UNEP's Scientific, Environmental and Technology and Economic Assessment Panels under the Montreal Protocol.* http://ozone.unep.org/Assessment_Panels/.

UNEP, 2010 *Executive Summary of the Scientific Assessment of Ozone Depletion: 2010.* http://ozone.unep.org/Assessment_Panels/SAP/ExecutiveSummary_SAP_2010.pdf.

UNFCCC, 2006. *UNFCCC reporting guidelines on annual inventories following incorporation of the provisions of decision 14/CP.11*. UFCCC/SBSTA/2006/9.

UNFCCC, 1997. *Kyoto Protocol.* http://unfccc.int/essential_background/kyoto_protocol/items/1678.php.

United Nations, 2010. *United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries*. www.un-redd.org.

Van Vuuren, D.P.; Stehfest E.; den Elzen. M.G.J.; Van Vliet, J. And Isaac M., 2010. *Exploring IMAGE model scenarios that keep greenhouse gas radiative forcing below 3 W/m2 in 2100*. Energy Economics, doi:10.1016/j.eneco.2010.03.001.

Velders, G.J.M.; Andersen, S.O.; Daniel, J.S.; Fahey, D.W.; McFarland, M., 2007. *The importance of the Montreal Protocol in protecting climate.* Proc. Natl. Acad. Sci. USA. 104, 4 814.

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