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Executive summary

This report assesses the key drivers, environmental pressures and some impacts from the production and consumption of energy, taking into account the main objectives of the European policy on energy and environment including: security of supply, competitiveness, increased energy efficiency and renewable energy, and environmental sustainability. The report addresses six main policy questions and presents trends existing within the EU compared to other countries.

1 What is the impact of energy production and use on the environment?

The production and consumption of energy places a wide range of pressures on the environment and on public health, some of which have been decreasing. Following are the key trends observed in Europe.

1. Energy-related greenhouse gas (GHG) emissions remain dominant, accounting for 80 % of the total emissions, with the largest emitting sector being electricity and heat production, followed by transport.
2. Between 1990 and 2005, energy-related GHG emissions in the EU-27 fell by 4.4 % but a significant part of this occurred in the beginning of the 1990s due to structural changes taking place in the economies of the EU-12 Member States (1). The intensity of CO_2 emissions from public conventional thermal power plants in the EU-27 decreased by 27 % due to efficiency improvements and the replacement of coal with gas in the power sector.
3. Between 1990 and 2005, energy-related emissions of acidifying substances, tropospheric ozone precursors and particles in the EU-27 decreased by 59 %, 45 % and 53 %, respectively, mainly due to the introduction of abatement technologies in power plants and the use of catalytic converters in road transport. Improvements in reducing air pollution (e.g. SO_2 and NO_X) recently showed a tendency to slow down due to the increased use of coal in power and heat generation.
4. The annual quantity of spent fuel from nuclear power generation declined by 5 % over the period of 1990–2006 despite a 20 % increase in electricity production. However, the high-level waste continues to accumulate, exceeding a total of 30 000 tonnes of heavy metal in 2006. Currently, there are no commercially available facilities for permanent storage of this waste.
5. Since the 1990s, oil discharges from installations and accidental spills from tankers have diminished due to a decrease in large tanker accidents. Improved safety measures, such as double-hulled tankers, also contributed to this trend.

Baseline (reference) scenarios taken from POLES, WEM and PRIMES models indicate that by 2030 primary energy consumption is likely to increase by 10–26 % compared to 2005, with fossil fuels maintaining a high share in all cases. Under these assumptions, environmental pressures from energy production and consumption are also likely to increase in the future. It is only under scenarios involving more stringent policies for energy and climate change (2) that the absolute increase in primary energy consumption slows down and, actually starts to decline between 2020 and 2030, primarily due to greater improvements in energy efficiency. Under these scenarios, the positive trend of declining environmental pressures associated with the consumption and production of energy continues, due to significant reductions in primary energy demand and higher penetration rates for renewable energy. For instance, it is possible to achieve, by 2030, reductions in CO_2 emissions of about 20 to 30 % compared to 2005.

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(1) Member States that joined the EU from 2004 onwards: Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia and Slovenia.

(2) For example, the POLES GHG reduction scenario is based on a possible emissions trajectory to 2050, which can lead to the EU's objective of limiting global temperature rise to 2 °C. More details of the scenarios are given in Annex I to this report.

Taking a long-term perspective, it is also important to consider the potential impact of climate change on energy production and consumption.

1. Climate change will alter energy demand patterns. Electricity consumption in southern Europe and the Mediterranean region will increase due to projected temperature increases and the associated increasing demand for space cooling. Energy demand for space heating in northern Europe will decrease, but the net effect across Europe is difficult to predict.
2. Climate change will affect power production. Due to projected changes in river runoff, hydropower production will increase in northern Europe and decrease in the south. Furthermore, across Europe, summer droughts are projected to be more severe, limiting the availability of cooling water and thus reducing the efficiency of thermal power plants.
3. Both types of impacts may lead to changes in emissions of air pollutants and greenhouse gases from energy, which are, however, difficult to estimate at present.

2 What are the trends concerning the energy mix in Europe and what are its related environmental consequences?

The concept of energy security in Europe encompasses a wide range of issues including energy efficiency, diversification of energy supply, increased transparency of energy demand and supply offers, solidarity among the EU Member States, infrastructure and external relations. Together with the energy efficiency, the energy import dependency aspect of security of supply has direct environmental consequences. Some of the links between the environment and the energy import dependency are determined by the fuel mix used to deliver energy services, the level of demand for those services and the speed with which these services have to be delivered. Reducing energy import dependency can have positive or negative effects on the environment, both within the EU and outside its borders, depending on the energy sources imported and the ones being replaced. In Europe, a higher penetration of renewable energy sources in the energy mix, coupled with a switch from coal to gas, resulted in reduced energy-related GHG emissions and air pollution but also in increased dependency on gas imports. However, these environmental benefits were partially offset by increasing energy consumption and, more recently, by the tendency to increase the use of coal in electricity generation due to concerns about security of supply as well as concerns over high and volatile prices for imported fossil fuels.

1. The current energy system within the EU is heavily dependent on fossil fuels. The share of fossil fuels in total energy consumption declined only slightly between 1990 and 2005: from around 83 % to 79 %.
2. Over 54 % of primary energy consumption in 2005 was imported, and this dependence on imported fossil fuel has been rising steadily (from 51 % in 2000).
3. Dependence is increasing rapidly for natural gas and coal. Natural gas imports accounted for some 59 % of the total gas-based primary energy consumption in 2005, while for hard-coal-based primary energy, imports accounted for 42 %. Oil imports accounted for as much as 87 % in 2005 — up from 84 % in 2000 — driven by substantial increases in demand from the transport sector, reflecting a lack of real alternatives in this sector and low EU oil reserves.
4. The largest single energy exporter to the EU is Russia, having supplied 18.1 % of the EU-27 total primary energy consumption in 2005 (up from 13.3 % in 2000). Russia supplies 24 % of gas-based primary energy consumption, 28 % oil-based of the primary energy consumption and is the second largest supplier of coal after South Africa, with 10 % of coal-based primary energy consumption in 2005
5. Between 1990 and 2005, the final electricity consumption increased on average, by 1.7 % a year, whereas final energy consumption increased only by 0.6 % a year.
6. A change in the energy mix is taking place in Europe. Renewable energy has the highest annual growth rate in total primary energy consumption, with an average of 3.4 % between 1990 and 2005. Second comes natural gas, with an annual average growth rate of 2.8 % over the same period. The annual growth rate of oil consumption slowed down, particularly in recent years due to its partial replacement in power generation by gas and coal.
7. The switch to gas due to environmental constraints (including concerns over climate change) and a rapid increase in electricity demand brought about some environmental benefits (reduction of CO_2 emissions) but increased dependency on gas imports. Natural gas consumption increased, between 1990 and 2005, by over 30 %.

Baseline (reference) scenarios from POLES, WEM and PRIMES models show a rising dependence on imports of fossil fuels. This is particularly true for gas, with imports (as a percentage of gas-based primary energy consumption) rising from around 59 % in 2005 to up to 84 % by 2030. Even in scenarios built on the assumption of a more stringent policy for energy and climate the import share of all fossil fuels still rises. In these scenarios, improvements in energy efficiency and the penetration of renewables occur more rapidly but the positive effect is more than offset by the decline in the EU's indigenous fossil production (and consequently, increased imports of fossil fuels required to meet the growing energy demand).

3 How rapidly are renewable technologies being implemented?

Renewable energy technologies usually have less environmental impacts than fossil fuel, although some concerns exist with respect to the environmental sustainability of particular types of biofuels. In recent years, they have accomplished high rates of growth but further action is necessary to achieve the proposed 2020 goals.

1. In 2005, renewable energy accounted, for 6.7 % of total primary energy consumption in the EU-27 — compared to a share of 4.4 % in 1990. Over the period, the share of renewable energy in final consumption has also increased from 6.3 % in 1991 to 8.6 % in 2005.
2. Wind power remains dominant, representing 75 % of the total installed renewable capacity in 2006 (excluding electricity from large hydropower plants and from biomass). The strongest growth took place in Germany, Spain and Denmark — which accounted for 74 % of all installed wind capacity in the EU-27 in that year. In the same year, Germany alone accounted for 89 % and 42 % of the installed solar photovoltaics and the solar thermal systems, respectively.
3. The share of renewables in the final energy consumption varies significantly across countries: from over 25 % in Sweden, Latvia and Finland to less than 2 % in the United Kingdom, Luxembourg and Malta. Newer Member States showed the most rapid growth in shares, with increases of over 10 percentage points in Estonia, Romania, Lithuania and Latvia.
4. From 1990 to 2005, electricity production from renewables increased in absolute terms (an average of 2.7 % annually), but a significant growth in electricity consumption partially offset the positive achievement limiting the RES share in gross electricity consumption to only 14.0 % in 2005.

Baseline (reference) scenarios from POLES, WEM and PRIMES models show that the share of renewables in primary energy consumption is expected to increase, to a value between 10 % in 2020 and 18 % in 2030. In scenarios where more stringent policies to reduce GHG emissions, and promotion of RES and energy efficiency are assumed, higher shares of renewables in primary energy consumption are envisaged ranging from 13 % in 2020 to over 24 % in 2030. The rising share is also supported by more rapid improvements in energy efficiency, which reduces the absolute level of energy consumption. The estimations vary significantly depending on the model used and the specific scenario chosen, since various scenarios make different assumptions about costs for the various technologies, the carbon prices and the speed of improvements in energy efficiency.

Achieving the proposed new target for renewable energy will require a substantial effort, to fill the gap between the current levels (8.5 % in the final energy consumption in 2005) and the objective of 20 % of renewable energy in the final energy consumption in 2020. To meet the proposed targets, 15 Member States will have to increase their national share of renewables in the final energy consumption by more than 10 percentage points compared to 2005 levels. Substantially reducing final demand for energy will help Europe achieve the target for renewables.

4 Is the European energy production system becoming more efficient?

Increasing the European energy system's efficiency can reduce environmental effects and dependence on fossil fuels and can contribute to limit the increase in energy costs. Whilst in recent years, the efficiency of energy production has increased, the potential for further improvement is still significant, for example, through a greater use of combined heat and power and other energy-related efficient technologies that are already available or close to commercialisation.

1. Between 1990 and 2005, the total energy intensity (total energy divided by GDP) in the EU-27 decreased by an estimated 1.3 % per annum. The energy intensity decreased three times faster in the new Member States.
2. Over the period of 1990–2005, the average level of efficiency in the production of electricity and heat by conventional public thermal plants improved by around 4.2 percentage points, reaching 46.9 % (48.5 %, if district heating is also included) in 2005.

3. Some 25 % of the primary energy is lost in generation, transport and distribution of energy. The largest share in the energy losses occurs in generation (around 3/4 of total losses), hence, the urgent need to deploy available state-of-the-art technologies.
4. In 2005, the share of electricity generated from combined heat and power (CHP) plants, in total gross electricity production in the EU-27, was 11.1 %. CHP can be a cost-effective option to improve energy efficiency and reduce CO_2 emissions. It could be further enhanced in the EU.

5 Are environmental costs reflected adequately in the energy price?

Current energy prices vary significantly among the EU Member States due to differences in tax levels and structures, subsidies for different forms of energy generation and different market structures. Including all relevant externalities to establish the true costs of energy use will help provide the correct price signals for future investment decisions in energy supply and demand. It is difficult to identify within current energy price structures the share attributed to the adverse external impacts of energy production and consumption on public health and the environment.

1. In 2007, the nominal end-user electricity price for households increased, on average, by 17 % compared to 1995 levels. This was due to a combination of factors including a certain level of internalisation of environmental externalities (via increased taxation and effects of other environmental policies, such as the EU Emissions Trading Scheme), increased energy commodity prices (particularly coal and gas), and other market factors stemming from the liberalisation process. Significant increases (around 50 %, compared to 1995 levels) occurred in Romania, the United Kingdom, Poland and Ireland.
2. In 2007, nominal end-user gas prices for households increased, on average, by 75 % compared to 1995 levels, mainly because of increasing world commodity prices. Increases above the average level occurred in Romania, the United Kingdom, Latvia and Poland.
3. Overall, in 2005, the external costs of electricity production in the EU-27 were estimated to be about 0.6 to 2 % of the GDP. The external costs decreased, between 1990 and 2005, by 4.9 to 14.5 eurocents/kWh and reached an average value of 1.8 to 5.9 eurocents/kWh (depending on whether high or low estimates for external costs are used) in 2005. Among factors that contributed to this downward trend are the replacement of coal and oil with natural gas, the increased efficiency of transformation and the introduction of air pollution abatement technologies. Further efforts are needed to develop methodologies to better quantify these externalities.

6 What is the role of the household sector in addressing the need to reduce the final energy consumption and what are the observed trends?

End-use energy efficiency measures should be implemented in the residential sector to ensure that energy services (i.e. heating, cooling, and lighting) remain affordable. At the same time, improved energy efficiency will also deliver environmental and social benefits. Despite the significant potential for cost effective savings, energy consumption in the household sector continues to rise.

1. In 2005, the residential sector in Europe accounted for 26.6 % of the final energy consumption. It is one of the sectors with the highest potential for energy efficiency. Measures to reduce the heating/cooling demand in buildings represent a significant part of this potential. In Ireland and Latvia, measures in the residential sector account for over 77 % of the overall national target under the Energy Services Directive, while in the United Kingdom, the proportion is just over 50 %. Cyprus estimates that the residential sector can deliver savings of more than 240 ktoe, 1.3 times the national target set for 2016 (185 ktoe, representing 10 % of the final inland consumption — calculated in accordance with the requirements of the directive).
2. Between 1990 and 2005, the absolute level of final household energy consumption in the EU-27 rose by an average of 1.0 % a year.
3. Final household electricity consumption increased at a faster rate attaining an annual average of 2.1 %.
4. Final energy consumption of households per m^2 decreased annually by about 0.4 %.
5. Two key factors influence the overall household energy consumption: fewer people living in larger homes and the increasing number of electrical appliances. Together, they contribute to a rise in the household consumption of 0.4 % a year.

7 EU trends compared to other countries

During the 13th Conference of Parties to the UN Climate Convention, parties agreed that there exists a need for a shared view on how to deal with climate change in the long-term perspective. Alongside a shared view, there should also be a shared responsibility for action — given both historic and current trends in generating global GHG (particularly CO_2) emissions. These trends vary from country to country. In the EU and in countries such as China and USA, there is a growing recognition that it is crucial to improve the energy efficiency and expand renewable energy — not only because of the current global context of rising energy demand and energy prices, but also because these are important measures to reduce CO_2 emissions. Experience accumulated in the EU-27 shows that the consistent implementation over time of environmental and energy policies can be effective but much more has to be accomplished in the near future to ensure the substantial reductions in the level of CO_2 emissions that are necessary to avoid irreversible effects of climate change.

1. Between 1990 and 2005, the EU-27 experienced an average GDP growth rate of 2.1 %, while reducing its energy-related CO_2 emissions by a total of about 3 %. During the same period, CO_2 emissions increased by 20 % in USA and doubled in China. Energy-related CO_2 emissions in Russia decreased by 30 % due to economic restructuring.
2. From 1990 to 2005, the EU's per capita CO_2 emissions decreased by 6.7 %, having become less than half of those in USA and about 25 % lower than per capita emissions in Russia. Per capita emissions in China are now 52 % below the EU level but they are growing fast due to the pace of economic development and the increase in the use of coal for power production.
3. Between 1990 and 2005, the CO_2 emissions intensity of the public electricity and heat production in the EU-27 decreased by 18.2 % while in many other parts of the world, including Russia, the opposite is true. A slight decrease occurred in China and USA (0.8 % and 2.5 %, respectively), partly because of changes in the renewable production (less hydroelectricity due to less rainfall) which offset improvements resulting from the implementation, in recent years and particularly after 2004, of energy efficiency policies.
4. Policies for energy efficiency and renewable energy are being implemented in the EU-27, USA and China, but the overall objectives of these policies may differ. For instance, in the EU-27 and USA, environmental protection is one of the key stated policy objectives, while China needs to find a balance between the enormous increase in its energy demand and the subsequent environmental consequences (e.g. increased air pollution). Enhancing security of energy supply is a driver everywhere.

In all countries, efforts are being made (and are expected to continue) to boost the renewable energy. Under the WEM (IEA) baseline scenario, by 2030, electricity produced in the EU-27 Member States from renewable energy could account for as much as 18 % of the global total, followed by China with 17 %, and the United States of America with a share of 12 %. Under the WEM alternative scenario, electricity generated by China from renewables, could represent as much as 20 % of the global total, followed by the EU-27 with 16 %, and the United States of America with 11 %. The shares of the EU-27 and USA in the global total appear to decrease, because in this scenario all countries are expected to step up their efforts to increase the share of renewables in their energy mix.

Looking at the WEM baseline and alternative scenarios (concerning the possible evolution of the global total of CO_2 emissions), it is clear that in the EU-27, as well as in other countries — such as China and USA, it is still imperative to take measures to decrease the energy intensity of the economy and to deploy renewable energy faster. According to the WEM baseline scenario, by 2030, China's share of the total CO_2 emissions in the global total could be as high as 27 %, surpassing USA and the EU-27 with a share of 16 % and 10 %, respectively. Even considering a more stringent energy and climate policies, China's share in the global total CO_2 emissions remains significant (26 %), and so does that of USA (18 %), followed by the EU-27 (with 10 %). Under the alternative scenario, all countries are expected to reduce their total CO_2 emissions, which explains why the share of USA appears to be higher and the EU-27 appears to remain at a constant level.

Introduction

The issues

The challenge for the 21st century is how to develop sustainably and maintain the quality of life for a growing population with higher expectations for well-being. Underlying this challenge is the need for sufficient and sustainable supplies of energy to provide the economic activity underpinning these expectations.

According to the recent World Energy Outlook (IEA, 2007a), if governments around the world continue with current policies, the world's energy needs would be 55 % higher in 2030 than in 2005, with China and India accounting for much of this rising demand. Some 84 % of the increase in primary energy demand will have to come from fossil fuels. Energy production and use, particularly of fossil fuels, have a number of **environmental impacts** including air pollution, greenhouse gas emissions and adverse impacts on ecosystems.

In the same IEA reference scenario, if no further action is taken to reduce the energy demand, energy-related CO_2 emissions will increase by 49 % by 2030 compared to 2005 levels and all regions will face **higher energy prices** in the medium- to long-term. In addition, **energy security** risk will be greater due to the increased EU dependence on fossil fuel imports from a small group of countries with high (existing) oil and gas reserves, notably Middle Eastern members of OPEC and the Russian Federation.

By contrast, according to the latest report from the International Panel for Climate Change (IPCC, 2007), to avoid significant impacts of climate change, the maximum global average temperature rise must not exceed about 2 °C (the EU target). To make this possible, global CO_2 emissions should peak before the year 2015 and then decrease by 50 to 85 % by 2050 (compared to the year 2000).

Emissions will have to be reduced across all economic sectors. The need to reduce CO_2 emissions emerged concurrently with the forecasts for a rise in energy demand and prices and increased energy security risks. All of this stimulated action in Europe. The EU took a number of initiatives to urgently address its energy demands and aims to lead the global transition to a low-carbon economy.

Building on the EU's three principal goals for energy policy (*security of supply, competitiveness* and *environmental sustainability*) on 10 January 2007 the Commission proposed an integrated climate change and energy package (EC, 2007a). On 9 March 2007, the Council endorsed the package and agreed on a target to reduce greenhouse gas emissions (GHG) by 20 % by 2020 (or 30 %, if other developed countries join a global post-2012 climate change agreement). The package also includes mandatory targets to increase the EU contribution from renewable energy to 20 % of the total final energy consumption with a 10 % binding target for renewable energy in transport (provided this target is achieved sustainably). It also introduces a target to increase energy efficiency by 20 % against a baseline/reference scenario with existing policies and measures with 2005 as a base year. On 23 January 2008, the Commission proposed a series of legislative measures to implement the package (EC, 2008a).

Increased **energy efficiency** is key for achieving simultaneously environmental and energy security as well as competitiveness objectives. . In the climate change and energy package, the Commission published a first assessment of the National Energy Efficiency Action Plans (NEEAPs) (EC, 2008b) where some positive trends were revealed. A number of Member States have higher targets than those required under the Energy Service Directive (EC, 2006f), whilst others introduced ambitious targets for reducing CO_2 emissions in the public sector. However, while significant energy savings are expected to come from existing measures, much less emphasis is put on innovative solutions. Many countries face significant challenges in addressing transport and spatial planning adequately. Overall, there seems to be a considerable gap between the level of ambition and the actual commitments as reflected in current measures and resources allocated. One of the key areas with the highest economic potential for reductions is the **consumption of energy** in buildings — as highlighted by the IPCC in its 2007 assessment (IPCC, 2007).

Enhancing **renewable energy** is another key factor for reaching the dual goals of security of supply and reduction in GHG and air pollution emissions. In addition, a more mature market for renewable energy technologies is expected to bring about a number of social and economic benefits, including regional and local development opportunities, export opportunities, social cohesion and employment. The global market for eco-industries (including renewable technologies) is worth about EUR 600 billion a year, and the EU currently holds about one third of the world market (European Commission, 2007). This market is likely to grow substantially in the future.

Implemented separately, the three main targets (GHG emissions reduction, renewable energy and energy efficiency) will not be sufficient for ushering in necessary changes and shifting the European energy system towards using cleaner and more sustainable energy technologies, whilst ensuring that the energy supply is competitive and secure. However, if addressed simultaneously, Renewable Energy Systems (RES) and GHG emissions reduction measures are likely to bring about significant technological changes. Energy efficiency is, potentially, the most significant option to reduce Europe's dependency on energy imports. It will also play a key role in helping the Member States to meet their RES and GHG emissions targets and to maintain energy services (i.e. heating, cooling and lighting) at affordable levels.

Enhancing energy efficiency is often a very cost-effective policy, too. As a result of the triple challenge we are facing today (*climate change, energy security and rising energy prices)*, it is crucial to run a **systematic assessment of the true cost of energy supply,** complete with external costs including damage to the environment and human health. On the energy supply side, investment decisions must be based upon the true cost of each energy option. On the demand side, energy policies should trigger a change in the consumers' behaviour in order to minimise the costs imposed on the society as a whole. However, internalising environmental externalities — for instance, via carbon taxes or the introduction of a CO_2 price through the EU Emissions Trading Scheme (EU ETS) — in the cost of energy generation tends to increase prices for the end-consumer. To ensure that **energy services remain affordable,** while at the same time delivering environmental (e.g. reductions in CO_2 emissions) and social benefits (higher quality of life), it is **necessary to implement end-use energy efficiency measures,** to minimise the overall demand for energy.

The scope and the objectives of the EER

This report assesses key drivers, environmental pressures and some impacts from the production and consumption of energy, taking into account the main objectives of European policy on energy and environment: security of supply, competitiveness and environmental sustainability.

The energy and climate (CARE) package proposed by the European Commission on energy and climate change represents a milestone in the process of integrating energy and environmental policy in Europe. Given the challenges ahead, it is important, for the purpose of the report, to show future scenarios for energy production and consumption as different energy pathways may have different environmental consequences. For this purpose, scenarios considered were those described in POLES, WEM and PRIMES models. The structure of the EER follows the Drivers Pressures State Impact Responses (DPSIR) conceptual framework used to report on environmental issues, with each of the building blocks identified in Figure 0.1.

The report addresses six main questions.

Chapter 1: What is the impact of energy production and use on the environment?

Chapter 2: What are the trends concerning the energy mix in Europe and what are its related environmental consequences?

Chapter 3: How rapidly are renewable technologies being implemented?

Chapter 4: Is the European energy production system becoming more efficient?

Chapter 5: Are environmental costs reflected adequately in the energy price?

Chapter 6: What are the energy consumption trends in households, and what policies exist to improve energy efficiency?

Chapter 7: EU trends compared to other regions.

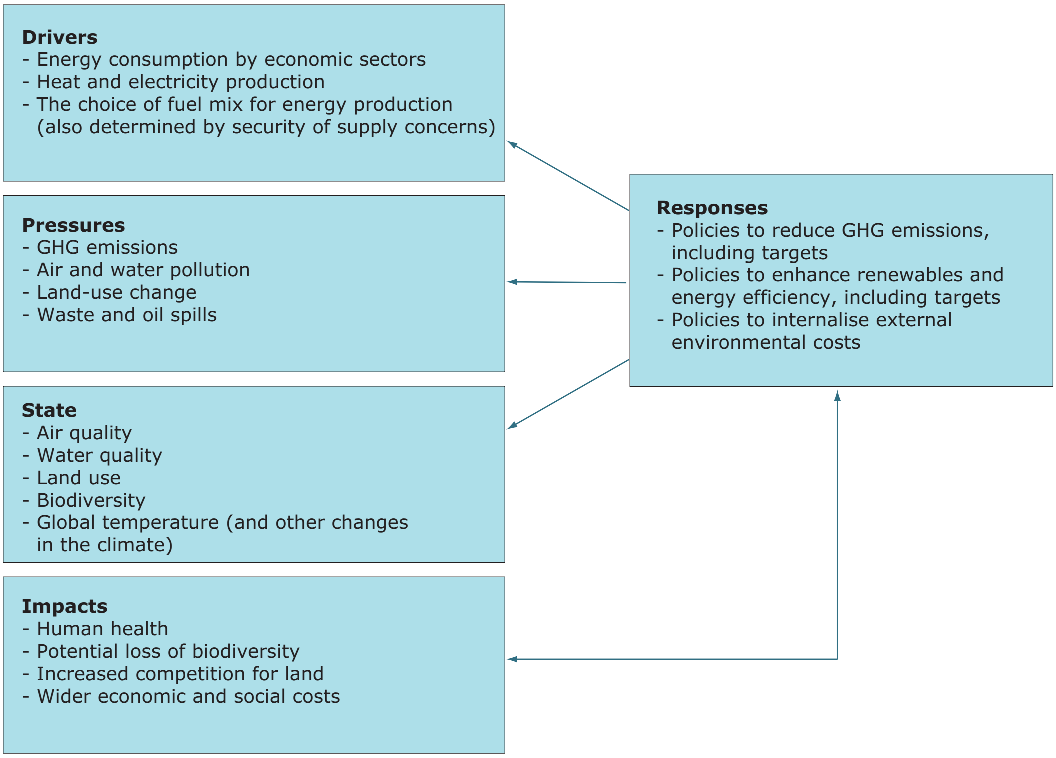
The EEA has a set of energy and environment indicators and Core Set of Indicators (CSI indicators) which are used in this report to underpin the analysis. However, to strengthen the analysis, in particular with respect to renewable energy, energy efficiency, security of supply, and energy affordability, some new indicators have been developed and some old ones were improved. For example, there are new indicators to monitor the share of renewable energy in final energy consumption, energy import dependency, energy efficiency in transformation and energy efficiency developments in the households sector.

A concluding chapter is included to describe trends in the EU as compared to other countries.

However, a number of topics are not covered in this report, since they are much more extensively discussed and presented in several other EEA reports (3). These are as follows:

- *Transport and environment ('TERM');*
- *Greenhouse gas emission trends and projections (analysis of progress towards the Kyoto targets);*
- *Biodiversity and water indicator-based assessment report.*

Figure 0.1 The DPSIR conceptual framework applied to energy and environment issues



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(3) See http://reports.eea.europa.eu/index_table?sort=Thematically for further information.

1 What is the impact of energy production and use on the environment?

Main messages

The production and consumption of energy places a broad range of pressures on the environment and on public health, some of which have been decreasing. Key trends observed in Europe include:

1. Energy-related greenhouse gas (GHG) emissions remain dominant, accounting for 80 % of the total emissions, with the largest emitting sector being electricity and heat production, followed by transport.
2. Between 1990 and 2005, energy-related GHG emissions in the EU-27 fell by 4.4 % but a significant part of this occurred in the beginning of the 1990s due to structural changes taking place in the economies of the EU-12 Member States (4). The intensity of CO_2 emissions from public conventional thermal power plants in the EU-27 decreased by 27 % due to efficiency improvements and the replacement of coal with gas in the power sector.
3. Between 1990 and 2005, energy-related emissions of acidifying substances, tropospheric ozone precursors and particles in the EU-27 decreased by 59 %, 45 % and 53 %, respectively, mainly due to the introduction of abatement technologies in power plants and the use of catalytic converters in road transport. Improvements in reducing air pollution (e.g. SO_2 and NO_X) recently showed a tendency to slow down due to the increased use of coal in power and heat generation.
4. The annual quantity of spent fuel from nuclear power generation declined by 5 % over the period of 1990–2006 despite a 20 % increase in electricity production. However, the high-level waste continues to accumulate, exceeding a total of 30 000 tonnes of heavy metal in 2006. Currently, there are no commercially available facilities for permanent storage of this waste.

Other energy-related pressures include:

(a) Life-cycle GHG emissions from electricity production vary considerably between different energy sources. The electricity production from coal and gas generates the highest level of emissions estimated (in 2000) to be approximately 1 000 CO_2-eq./kWhel for coal and 500 CO_2-eq./kWhel for gas, with far lower emissions for renewable sources — such as solar PV, wind and small hydro (ranging from 38 CO_2-eq./kWhel for solar thermal to 166 CO_2-eq./kWhel for wind). Estimated GHG emissions for electricity production from woody biomass can vary from – 1 600 CO_2-eq./kWh to + 200 CO_2-eq./kWh, depending on the type of feedstock, the combustion technology used and whether or not it is being used in combined heat and power CHP production mode.
(b) Since the 1990s, despite increased production, oil discharges from installations have diminished.
(c) Since 1990, accidental spills from oil tankers have also decreased significantly.

Baseline (reference) scenarios shown in POLES, WEM and PRIMES models indicate that, compared to 2005, primary energy consumption is likely to increase by 10–26 %, by 2030, with fossil fuels maintaining a high share in all cases. If this proves to be the case, future environmental pressures from energy production and consumption are likely to increase. Only scenarios involving more stringent policies for energy and climate change show the possibility that the absolute increase in primary energy consumption will slow down and actually start to decline between 2020 and 2030, primarily due to greater improvements in energy efficiency. In these scenarios, the positive trend of declining environmental pressures associated with the consumption and the production of energy would continue — due to significant reductions in primary energy demand as well as higher penetration rates for renewable energy. For instance, by 2030,

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(4) Member States that joined the EU from 2004 onwards: Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia and Slovenia.

CO_2 emissions can be reduced by about 20 % to 30 % (compared to 2005).

In the long-term, it is also important to consider the potential impact of climate change on energy production and consumption:

- Climate change will alter energy demand patterns. Electricity consumption will increase in Southern Europe and the Mediterranean region due to projected temperature increases and the associated increases in the demand for space cooling. Energy demand for space heating will decrease in northern Europe, but the net effect across Europe is difficult to predict.
- Climate change will affect power production. Due to projected changes in river runoff, hydropower production will increase in northern Europe and decrease in the south. Furthermore, across Europe summer droughts are projected to be more severe, limiting the availability of cooling water and thus reducing the efficiency of thermal power plants.
- Both types of impacts may lead to changes in emissions of air pollutants and greenhouse gases from energy which are, however, currently difficult to estimate.

Box 1.1 Abatement technologies

Air pollution

Abatement technologies can be used to reduce or eliminate airborne pollutants, such as particles, sulphur oxides, nitrogen oxides, carbon monoxide, carbon dioxide, hydrocarbons, odours, and other pollutants from flue or exhaust gases. SO_2 emissions can be reduced through flue gas desulphurisation systems. 'Wet scrubbers' are the most widespread method and can be up to 99 % effective. Electrostatic precipitators can remove more than 99 % of particulates from the flue gas. Emissions of NO_x can be either abated or controlled by primary measures or flue gas treatment technologies. The former include burner optimisation; air staging; flue gas recirculation; and low NO_x burners. Primary measures for NO_x control are now considered integral parts of a newly built power plant, and existing units retrofit them whenever they are required to reduce their NO_x emissions. Other examples of NO_x abatement include catalytic converters for use in vehicles. These technologies will be particularly important for Large Combustion Plants (> 50 MW) given the formal implementation of the Large Combustion Plant Directive (LCPD) (EC, 2001c).

Improvements in road transport abatement will continue to be driven by the Euro standards (see EEA, 2008a for further information on transport and environment trends). For Light Duty Vehicles, new Euro 5/6 standards have already been agreed by the Council and the Parliament (EC, 2007b). The implementing legislation is currently under preparation and Euro 5 will enter into force in September 2009. The main effect is to reduce the emissions of PM from diesel cars from 25 mg/km to 5 mg/km. Euro 6 is scheduled to enter into force in January 2014 and will reduce mainly the emissions of NO_x from diesel cars even further: from 180 mg/km to 80 mg/km. Similar proposals and legislation are being developed for the next stage of standards for heavy-duty vehicles: Euro 5 (due to enter into force in October 2008) and new Euro 6 proposals (EC, 2007c).

Carbon capture and storage

Among other options for reducing significantly CO_2 emissions, in the power sector and energy-intensive industries, carbon dioxide capture and storage (CCS) can be a promising solution. This technology is best applied to large stationary sources such as power generation or oil refineries, which have large, concentrated streams of CO_2 emissions. CO_2 can be captured at various stages of the combustion process and then be transported to storage sites.

For a limited number of applications capture of CO_2 is a commercially run industrial process, but to transfer it to large-scale power plants and to reduce costs and associated energy losses, improvements have to be made. In a pre-combustion capture process, CO_2 is removed prior to combustion, leaving a hydrogen-rich fuel stream. Post-combustion can be applied to existing power plants, but it is the option with the largestimpact on the overall plant production efficiency. Capture of CO_2 with oxy-fuel combustion is based on the use of oxygen instead of air in combustion, thus producing a more pure CO_2 stream for easier storage. Depending on the power plant type and the capture process, it is possible to avoid some 80 % of the CO_2 emissions compared to a plant without CCS. The negative factor is that large scale CCS technologies require substantial amounts of energy and lead to efficiency losses in the process, ranging from 10 to 40 % (IPCC, 2005), thus leading to potential increases in upstream environmental pressures.

Box 1.1 Abatement technologies (cont.)

Storage of CO_2 in geological repositories, such as depleted oil or gas reservoirs, aquifers and coal beds, is generally considered a safe option with manageable environmental impacts. Nevertheless, it is imperative to introduce and maintain rigorous conditions on the selection, operation and closure of the geological storage site and clear provisions on monitoring for and reporting of leakage.

Further developments in CCS are being pushed by both industry and policy initiatives. The EU Strategic Energy Technology Plan (SET-Plan) (EC, 2006b) recognised the need to have CCS demonstration projects in order to accelerate the learning curve about the real potential of these technologies. In January 2008, the EC adopted a proposal for a Directive on the geological storage of carbon dioxide. This has been done to enable environmentally safe CCS development by providing a legal framework to manage environmental and human health risks, remove barriers in the existing environmental legislation and introduce provisions for ensuring environmental integrity throughout the life-cycle of the plant (site selection up to post closure) (EC, 2008e). The CO_2 captured and stored will be recognised as not emitted under the EU ETS, creating de facto an incentive for operators to store their CO_2 emissions instead of venting them to the atmosphere. For this purpose, CCS installations can be opted into Phase II (2008–2012) of the EU ETS, and will be explicitly included in Phase III (2013–2020) of the scheme. In addition, a Communication on promotion of demonstration plants was issued. By the end of 2008, the Commission is expected to publish its recommendations on financing CCS as part of a wider communication on financing its proposed Strategic Energy Technology Plan (EC, 2007d).

There is, currently, a number of CCS projects operational worldwide. The longest running project is Sleipner in Norway. It is part of an offshore platform in the middle of the North Sea. Since 1996 it has been sequestering, 1 Mt/year (Statoil, 2007). The Weyburn project in southeastern Saskatchewan, Canada, is currently the world's largest carbon capture and storage project — sequestering approximately 2 million tonnes a year (EnCana, 2008). The total global storage capacity for the main geological storage reservoirs was estimated by the IEA Greenhouse Gas R&D Programme (2008) and is summarized in the table below (based on injection costs of up to USD 20 per tonne of CO_2 stored). The Commission's CCS Impact Assessment (EC, 2008i) provides storage estimates per Member State. The calculations were conducted using data from Gestco, Castor and Geocapacity projects and power generation capacity from the Primes model. The injection capacity was estimated at 0.5 Gt of CO_2 up to 2030 (in the most favourable scenario for CCS uptake (5)). Annual energy-related CO_2 emissions in Europe in 2005 were approximately 4 Gt of CO_2. Figures estimated in the CCS impact assessment are not directly comparable with global capacity estimated by the IEA in the table below.

Storage option	Total global capacity Gt CO_2
Depleted oil and gas fields	920
Deep saline aquifers	400–10 000
Non-minable coal seams	> 15
World energy-related CO_2 emissions in 2005 = 27 Gt CO_2	

Source: IEA GHGR&D, 2008; IEA.

A number of new pilot plants are being currently developed around the world. In April 2008, the TNO-CATO post-combustion pilot plant at the E.ON coal-fired power plant was officially opened on the Maasvlakte (TNO-CATO, 2008). This multi-purpose test facility utilises the post-combustion capture. The pilot plant diverts flue gases from the power plant,after which a special amino solvent scrubs 90 % of the CO_2 from the flue gases. It is then regenerated again by heating and extracting the pure CO_2. This is the most advanced capture technology today. It has the advantage of being easily adaptable to the large existing base of power stations. In order to reduce the CO_2 emissions from existing power plants, post-combustion capture is the only viable multi-applicable solution. Other methods, such as pre-combustion capture, are only applicable for new power plants and will, therefore, be only a part of the total solution. However, looking ahead, it is not yet clear, which option(s) will prove to be more viable in the longer term. For example, Vattenfall are focusing significant efforts on Oxyfuel technology (with a new 30 MW demonstration plant which opened in September of 2008), whilst continuing to undertake work on large-scale post-combustion demonstration projects (Vattenfall, 2008).

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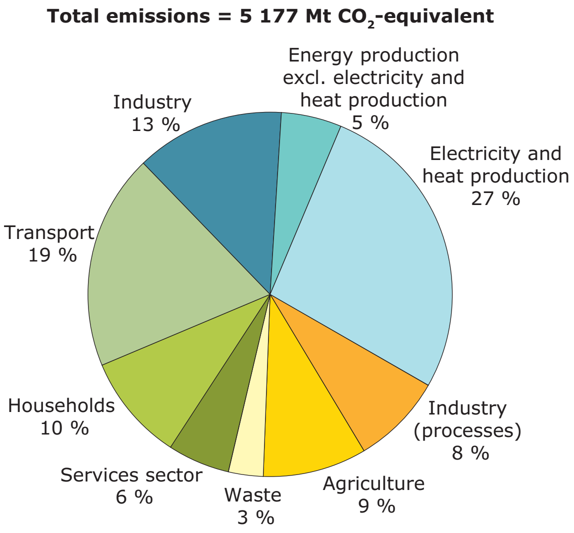
(5) The scenario referred to is Option 2, variant 2d, which assumes that from 2020 onwards, apart from enabling CCS under EU ETS, a mandatory requirement to apply CCS is placed on new coal and gas-fired power plants and that existing plants are being retrofitted between 2015 and 2020. At the moment, the climate change and energy package does not foresee that such a mandatory requirement be introduced.

1.1 Greenhouse gas emissions

In 2005, the total greenhouse gas emissions in the EU-27 was 5 177 Mt CO_2-equivalent comprising 82.5 % CO_2; 8.1 % CH_4; 8.0 % N_2O, while the remaining 1.4 % corresponded to the fluorinated gases. Energy-related emissions continue to be the dominant representing approximately 80 % of the total emissions (see Figure 1.1), with the largest emitting sector being the production of electricity and heat, followed by transport (see also EEA, 2007a for more detailed information on EU-27 GHG emissions).

Figure 1.1 Structure of total greenhouse gas emissions by sector, EU-27, 2005



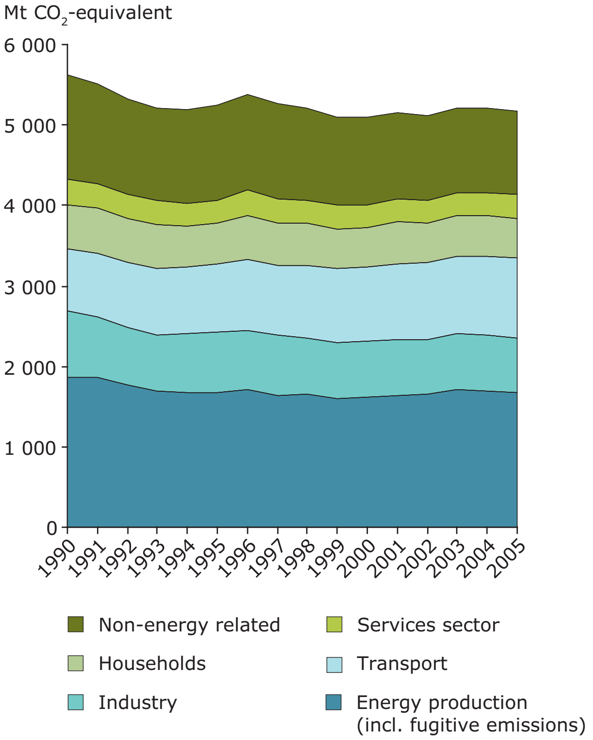
Note: (i) Greenhouse gas emissions are those covered by the Kyoto Protocol and include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and three fluorinated gases, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6).
(ii) Greenhouse gas emissions have been calculated in t CO_2-equivalent using the following global warming potentials (GWP) as specified in the Kyoto Protocol: 1 t CH_4 = 21 t CO_2-equivalent; 1 t N_2O = 310 t CO_2-equivalent; 1 t SF_6 = 23 900 t CO_2-equivalent. HFCs and PFCs have a wide range of GWPs depending on the gas, and emissions are already reported in t CO_2-equivalent.
(iii) Emissions from international marine and aviation bunkers are not included in national total emissions but are reported separately to the UNFCCC. They are, therefore, not included in the graph.
(iv) The energy production sector includes public electricity and heat production, refineries and the manufacture of solid fuels. Energy-related fugitive emissions include releases of gases from exploration, production, processing, transmission, storage and use of fuels. The vast majority of energy-related fugitive emissions are connected with activities of the energy production sector. Only a very small percentage of fugitive emissions are connected with activities of the transport sector. All energy-related fugitive emissions have, therefore, been attributed to the energy production sector.
(v) 'Services sector' also includes military and energy-related emissions from agriculture.

Source: EEA, 2007a, as reported by countries to UNFCCC and under the EU GHG Monitoring Mechanism Decision.

Sectors showing the largest decreases in greenhouse gas emissions are industry and non-energy related (e.g. industrial processes) (see Figure 1.2). However, over the same period emissions from transport in the EU-27 increased significantly due to a continuous increase in road transport demand, thus offsetting much of the decrease in other sectors (see EEA, 2008a for further information on transport and the environment in the EU).

Between 1990 and 2005, energy-related emissions fell by 4.4 %. A decline in the use of coal and lignite and an increase in the use of the less carbon-intensive natural gas also led to a significant reduction of CO_2 emissions per unit of electricity and heat generation in the public power production (see Figure 1.4). As a result, during the period between 1990 and 2005, the specific greenhouse gas emissions per unit of energy consumption decreased in most Member

Figure 1.2 Trends in greenhouse gas emissions by sector between 1990–2005, EU-27



Note: See Figure 1.1.

Source: EEA, 2007a, as reported by countries to UNFCCC and under the EU GHG Monitoring Mechanism Decision.

States. However, rapidly rising overall demand for electricity offset some of these improvements. Since 1999, GHG emissions started to rise again, with some fluctuation over the period of 2004–2005.

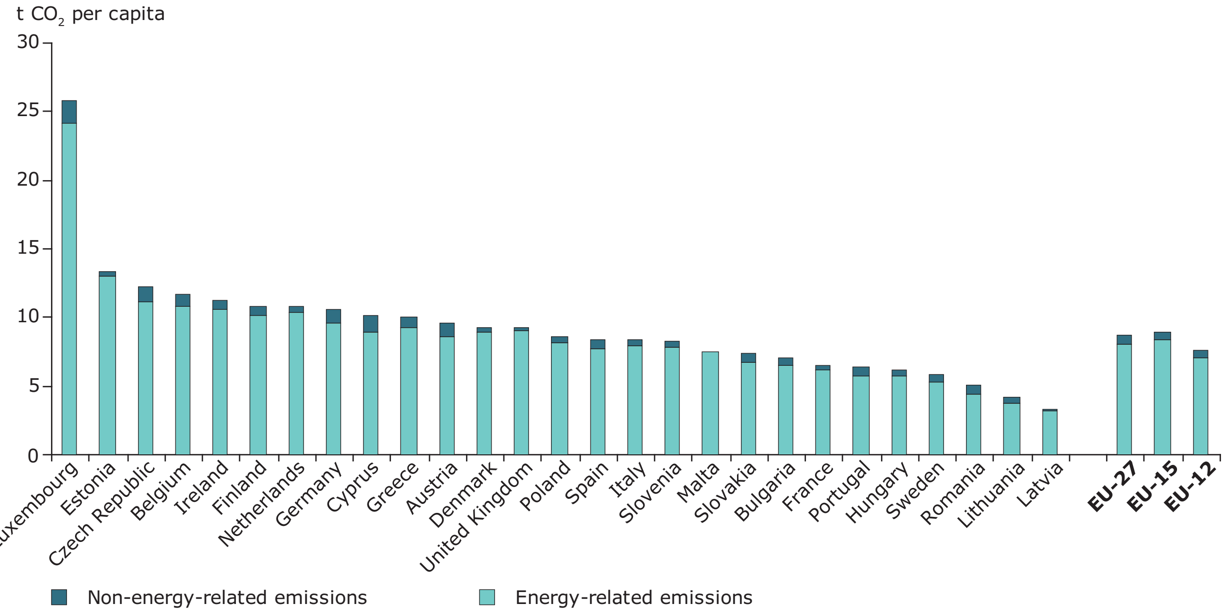
The reduction in energy-related emissions was much smaller than that observed for non-energy-related emissions in agriculture, waste and other sectors. These sectors reduced their emissions substantially — by 19.6 % across the EU-27 — due to improved waste management, emission reductions in industrial processes (as well as general restructuring leading away from heavy industry, particularly in the EU-12) and agriculture. While greenhouse gas emissions from the energy production, services and industry sectors all decreased between the years 1990 and 2005, emissions from transport in the EU-27 rose by 26.0 % over the same period, offsetting some of the reductions from other sectors.

Energy-related emissions continue to dominate emissions per capita across all Member States (see Figure 1.3). Total emissions per capita in Luxembourg are almost double of what they are in Estonia and higher by a factor of six than in Latvia at the other end of the spectrum. The high level of emissions per capita in Luxembourg is linked to a high level of GDP in a country with the small population. However, it is caused, primarily, by the high cross-border sales of transport fuels (due to the tax differential with neighbouring countries), with emissions allocated to the point of sale (IEA, 2000).

Average emissions in the EU-15 are around 17.5 % higher than in the EU-12. A number of opposing trends drive the evolution of per capita emissions: higher levels of wealth (which tend to increase the overall levels of energy demand), higher levels of energy efficiency, climatic differences and differences in the structure of the energy supply system.

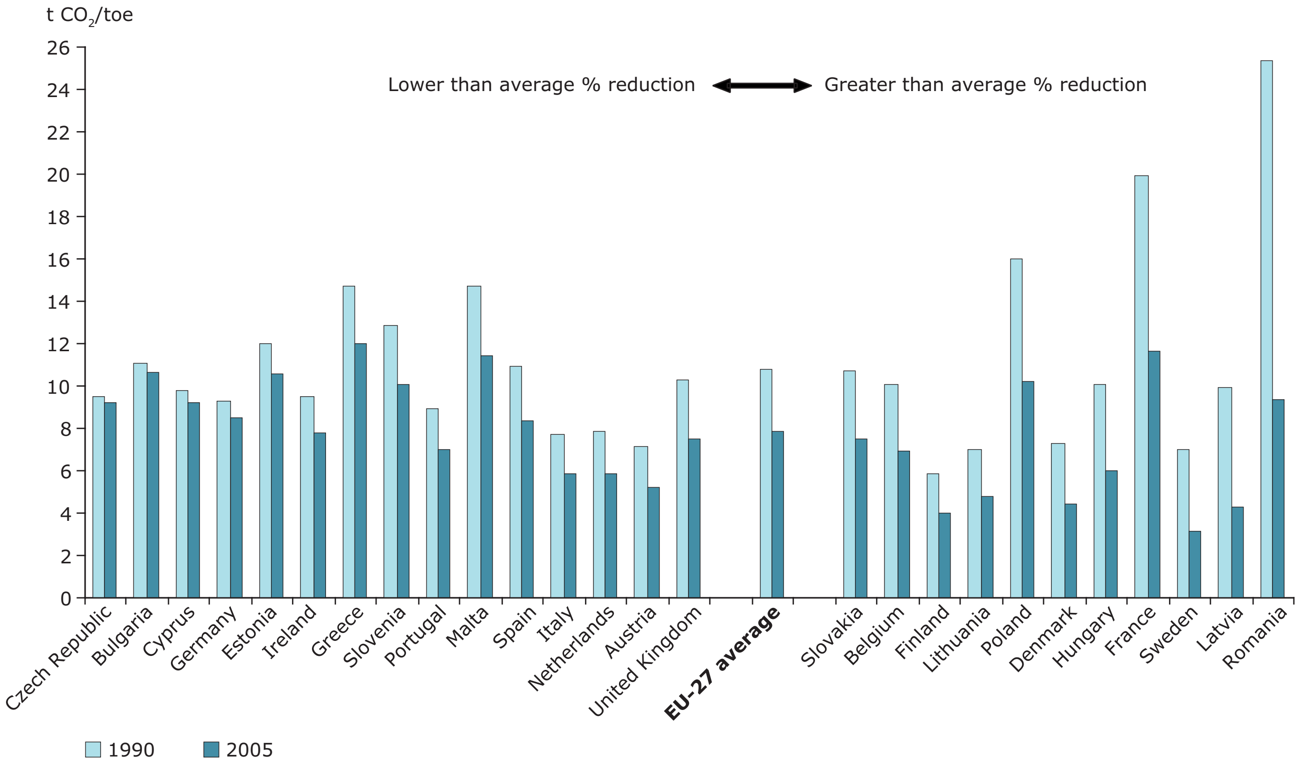
The intensity of carbon dioxide emissions from public conventional thermal power plants in the EU-27 decreased by about 27 % during the period from 1990 to 2005, due to improvements introduced in all Member States. However, increased gas prices towards the end of the period led to a higher utilisation of existing coal plants in some EU Member States and, as a result, the CO_2 emissions intensity has changed relatively little since 2001. Romania, Latvia and Sweden achieved the largest reduction in the intensity of carbon dioxide emissions in the percentage terms in the EU-27, with an average annual decrease of 6.4 %, 5.5 % and 5.2 %, respectively. These reductions were largely due to a significant reduction in the use of heavy oil in Romania (which was partially replaced by gas and partially by coal), while in Latvia, a high level of CO_2 emissions reductions were achieved due to

Figure 1.3 CO_2 emissions per capita by country (split by energy and non-energy related emissions), 2005



Source: EEA; Eurostat.

Figure 1.4 Emission intensity of carbon dioxide from public conventional thermal power production



Note: Emissions intensity is calculated as the amount of pollutant produced (in tonnes) from the public electricity and heat production divided by the output of electricity and heat (in toe) from these plants.

Source: EEA; Eurostat.

the increased use of gas for electricity production at the expense of coal, lignite and oil. Sweden had the lowest CO_2 emissions intensity in 2005, mainly because of a negligible share of coal and lignite in public conventional thermal power production.

1.2 Air pollution

Energy production and consumption (⁶) contributes to approximately 55 % of the EU-27 emissions of acidifying substances, 76 % of emissions of tropospheric ozone precursors and about 67 % of (primary) particles emissions (see Figure 1.5). Energy-related emissions in transport and energy production account for half of all emissions, with the transport sector particularly dominant in relation to ozone precursors (due to NO_X emissions). These have been decreasing steadily since 1990, due to the introduction of catalytic converters. Agriculture also contributed with around 25 % of emissions from acidifying substances due, in part, to the emissions of ammonia.

Between 1990 and 2005, the energy-related emissions of acidifying substances, tropospheric ozone precursors and particles decreased by 59 %, 45 % and 53 %, respectively (see Figure 1.6).

These emission reductions have been the result of the increased application and effectiveness of abatement technologies, improvements in efficiency and fuel switching. For example, the introduction of flue gas desulphurisation technologies and the use of low NO_X-burners in power generation was encouraged by the Large Combustion Plant Directive (EC, 2001c) and the use of best available technologies required by the Integrated Pollution Prevention and Control Directive (EC, 1996). In addition to the use of abatement

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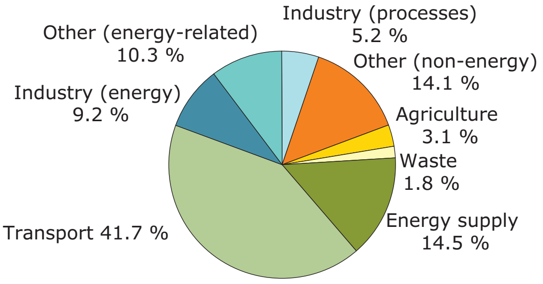
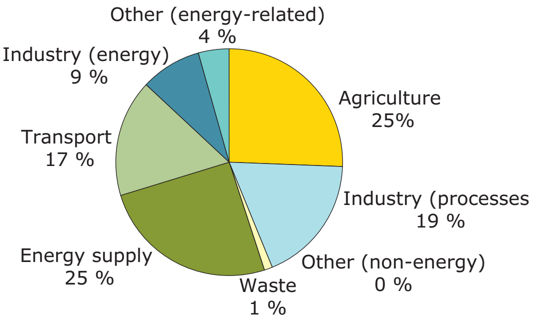
(⁶) The contribution of energy production and consumption includes the following sectors: transport, energy supply, industry (energy) and other (energy-related).

Figure 1.5 Emissions of air pollutants by sector in 2005, EU-27

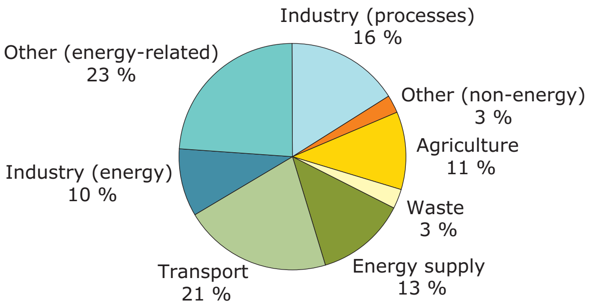
Ozone precursors (2005 total = 27 463 kt)



Acidifying substances (2005 total = 893 kt)



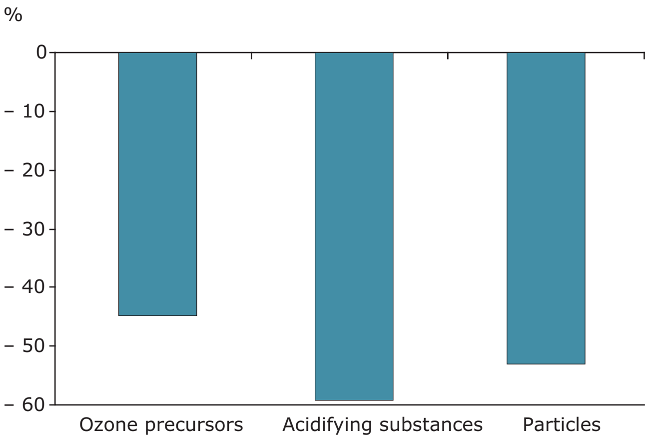
Primary particulate matter (PM_{10}) (2005 total = 2 491 kt)



Note: The graph above shows the emissions of ozone precursors (methane CH_4; carbon monoxide CO; non-methane volatile organic compounds NMVOCs; and nitrogen oxides NO_X) each weighted by a factor prior to aggregation to represent their respective tropospheric ozone formation potential (TOFP). The TOFP factors are as follows: NO_X 1.22, NMVOC 1, CO 0.11 and CH_4 0.014 (de Leeuw, 2002). Results are expressed in NMVOC equivalents (kilotonnes — kt). Data not available: for Iceland (emissions of CO, NMVOC, NO_X were not reported) and Malta (CO). The figure also shows the emissions of acidifying pollutants (sulphur dioxide SO_2, nitrogen oxides NO_X and ammonia NH_3), each weighted by an acid equivalency factor prior to aggregation to represent their respective acidification potentials. The acid equivalency factors are given by: w (SO_2) = 2/64 acid eq/g = 31.25 acid eq/kg, w (NO_X) = 1/46 acid eq/g = 21.74 acid eq/kg and w (NH_3) = 1/17 acid eq/g = 58.82 acid eq/kg. The graph shows the emissions of primary PM_{10} particles (particulate matter with a diameter of 10 µm or less, emitted directly into the atmosphere).

Source: EEA.

Figure 1.6 Overall changes in energy-related emissions by main group of air pollutants in the EU-27, 1990–2005



Note: As per Figure 1.5. However, the change in particulate matter includes emissions of both primary and secondary particulate-forming pollutants (the fraction of sulphur dioxide SO_2, nitrogen oxides NO_X and ammonia NH_3 which, as a result of photo-chemical reactions in the atmosphere, transform into particulate matter with a diameter of 10 µm or less). Emissions of the secondary particulate precursor species are weighted by a particle formation factor prior to aggregation: primary PM_{10} = 1, SO_2 = 0.54, NO_X = 0.88, and (NH_3) = 0.64 (de Leeuw, 2002).

Source: EEA.

technologies,substantial emissions reductions have been made in the power production sector due to a combination of factors. These are: fuel switching (from coal and oil to natural gas) closure of old inefficient coal plants and the overall improvement in generation technology, particularly via the use of combined cycle gas turbines (CCGT) (see EEA, 2008b for further information).

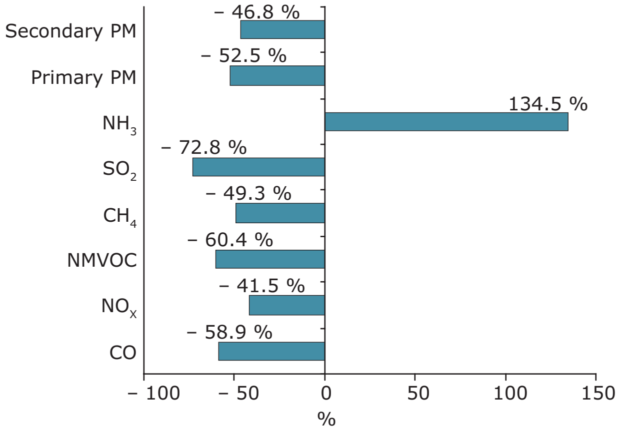
However, rapid reductions in the emissions intensity from power generation seen in the 1990s slowed in recent years for some air pollutants (such as SO_2 and NO_X emissions), due to the continuing rise in the overall electricity consumption and a rise in the use of coal for electricity generation from 1999 onwards.

In the transport sector, the introduction of catalytic converters contributed significantly to reduce emissions. This was complemented by the EU legislative measures aimed at improving petrol and diesel quality, such as reducing the sulphur content of these fuels.

Despite reduced emissions of air pollutants, urban air quality still often exceeds the limit values set for protection of public health, especially in the streets and other urban hotspots (EEA, 2006). Even though the situation has improved, acidification, eutrophication and high ozone levels continue to have adverse effects on many ecosystems. The 'Thematic Strategy on Air Pollution' calls for further reductions in air pollutant emissions by 2020 to achieve long-term air quality targets (EC, 2005a).

It is expected that future emissions of most air pollutants in the EU-27 are likely to continue to fall (IIASA, 2007a), especially those from the traditionally dominant source sectors (e.g. road transport and energy production). Thus, other sectors for which there is currently a less stringent legislation are likely to become a significant source of emissions in the future (e.g. emissions of SO_2 and NO_X from maritime activities). Tighter emission standards and policy measures are being considered by the Commission to complement those set by the International Maritime Organisation (IIASA, 2007b). Ceilings for total (i.e. energy- and non-energy related) emissions of sulphur dioxide, nitrogen oxides, ammonia and non-methane volatile organic compounds were set for 2010 in the National Emissions Ceilings Directive (NECD; EC, 2001a). In addition, in April of 2008, another directive was adopted on ambient air quality and cleaner air for Europe. This new document merges four other directives and one Council decision into a single directive, which introduces standards for air quality in the European Union in terms of fine particle $PM_{2.5}$ pollution.

Figure 1.7 Change in the emissions intensity (per toe) of energy-related air pollutants in the EU-27, 1990–2005



Source: EEA; Eurostat.

The intensity of most energy-related air pollutant emissions (i.e. in kg of emissions per tonne of oil-equivalent of energy consumed) declined significantly over the period of 1990–2005. In particular, there was a significant drop in the intensity of carbon monoxide (CO), non-methane volatile organic compounds (NMVOCs) and SO_2 emissions. A key factor contributing to the decrease in CO and NMVOC intensity was the introduction of catalytic converters in cars and the increased penetration of diesel cars into vehicle fleets. The decline in SO_2 intensity occurred primarily in the sphere of electricity generation due to the introduction of abatement technologies and a switch from high sulphur-containing fuels (such as coal and heavy fuel oil) to natural gas, coupled with the use of coal with a lower sulphur content. The increase in intensity of NH_3 emissions is due, partly, to the increasing use of SCR (selective catalytic reduction) in power generation used to reduce NO_X emissions. SCR can utilise various forms of ammonia as a reducing agent, but if the catalyst temperatures are not in the optimal range for the reaction, or if too much ammonia is injected into the process, unreacted NH_3 can be released (known as ammonia slip).

The direct emissions (7) of CO_2, SO_2 and NO_X from electricity and heat generation depend on both the amount of electricity and heat generated and the emissions per unit produced. The fuel mix in power generation influences the latter, as well as the overall generation efficiency, and, in the case of NO_X and SO_2, the extent to which abatement techniques need to be applied.

If the structure of electricity and heat production had remained unchanged since 1990, i.e. if the shares of input fuels and efficiency had remained constant, emissions would have increased in line with the increase in electricity and heat production. This hypothetical development is indicated in the top line of the charts.

The estimated effects of the various factors on emission reductions are shown in each of the bars.

The main factors in reducing CO_2 emissions from electricity and heat generation are the improvement in efficiency and fuel switching (from coal to gas), and to a much lesser extent — the change in the contribution of renewables in certain years. However, in 2002 and 2003, the share of renewables

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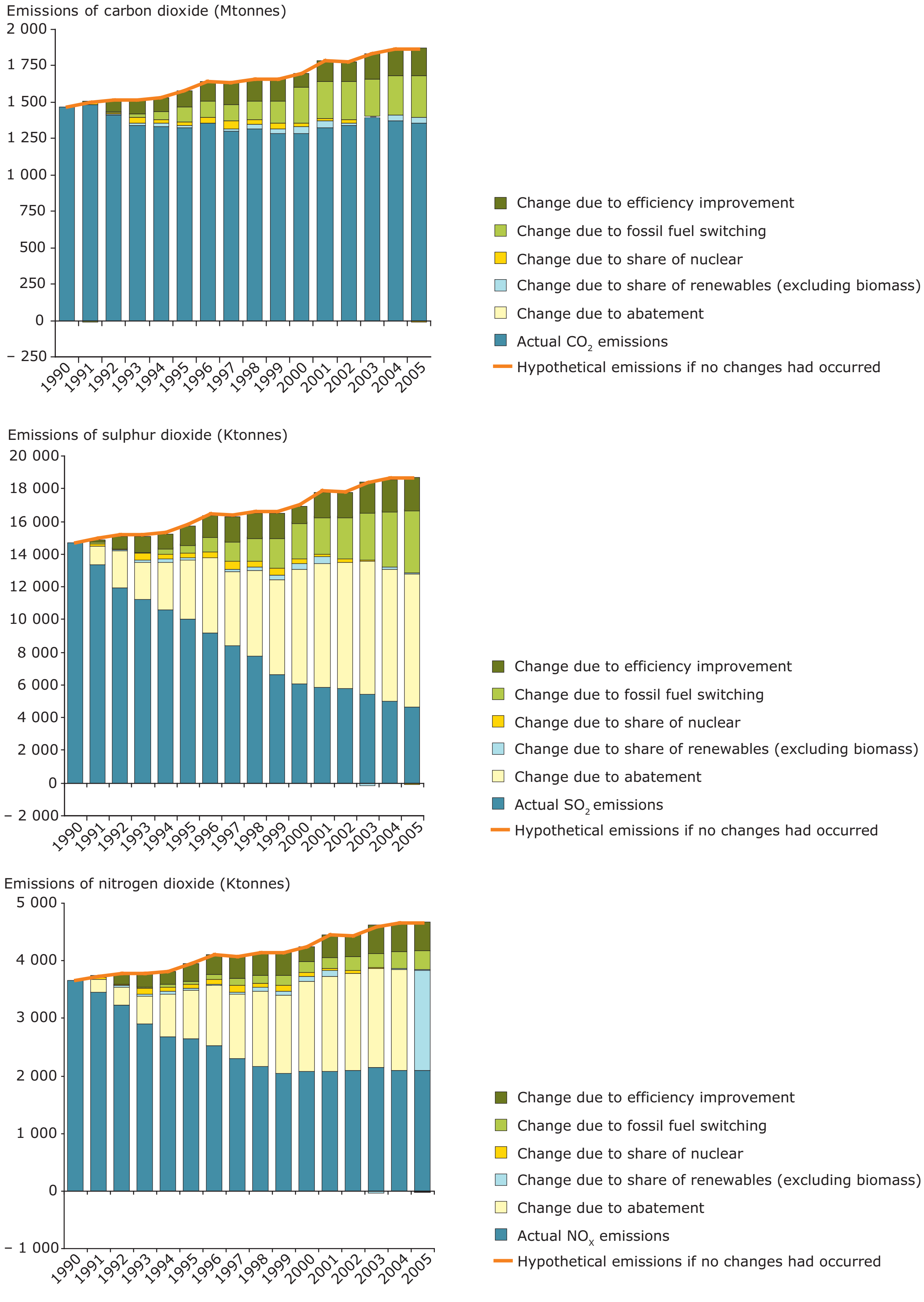
(7) Figure 1.8. does not consider life-cycle emissions.

Figure 1.8 **Estimated impact of different factors on the reduction of CO_2, SO_2 and NO_X emissions from public heat and electricity generation in the EU-27, 1990–2005**



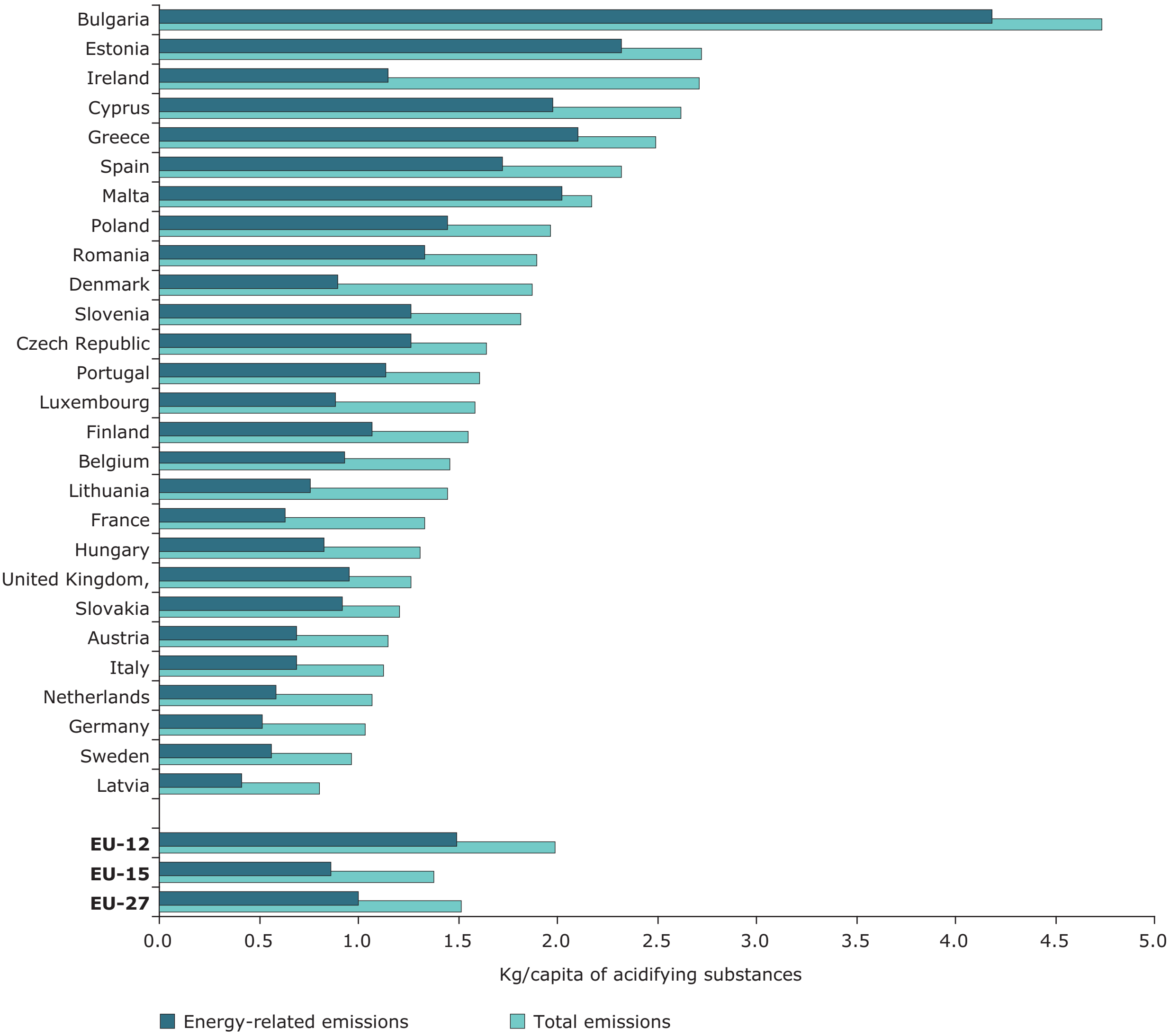
Source: EEA; Eurostat.

was relatively low, due to limited hydroelectricity production as a result of low levels of rainfall. The share of nuclear in electricity production in 2005 was also below its 1990-levels, which led to increased emissions (as indicated via the very small negative portion of the bar for this year).

For SO_2 and NO_X emission reductions, the dominant factor appears to be the use of abatement technology, as it accounts for the most significant difference between the hypothetical line and the actual level of emissions. Efficiency improvements and fuel switching also played an important role in emissions reductions of these pollutants, although the latter was more significant in the case of SO_2 — due to an additional switch towards low-sulphur coal. From around 1999 onwards, the decrease in SO_2 emissions slowed significantly, whilst NO_X emissions have broadly, stabilised.

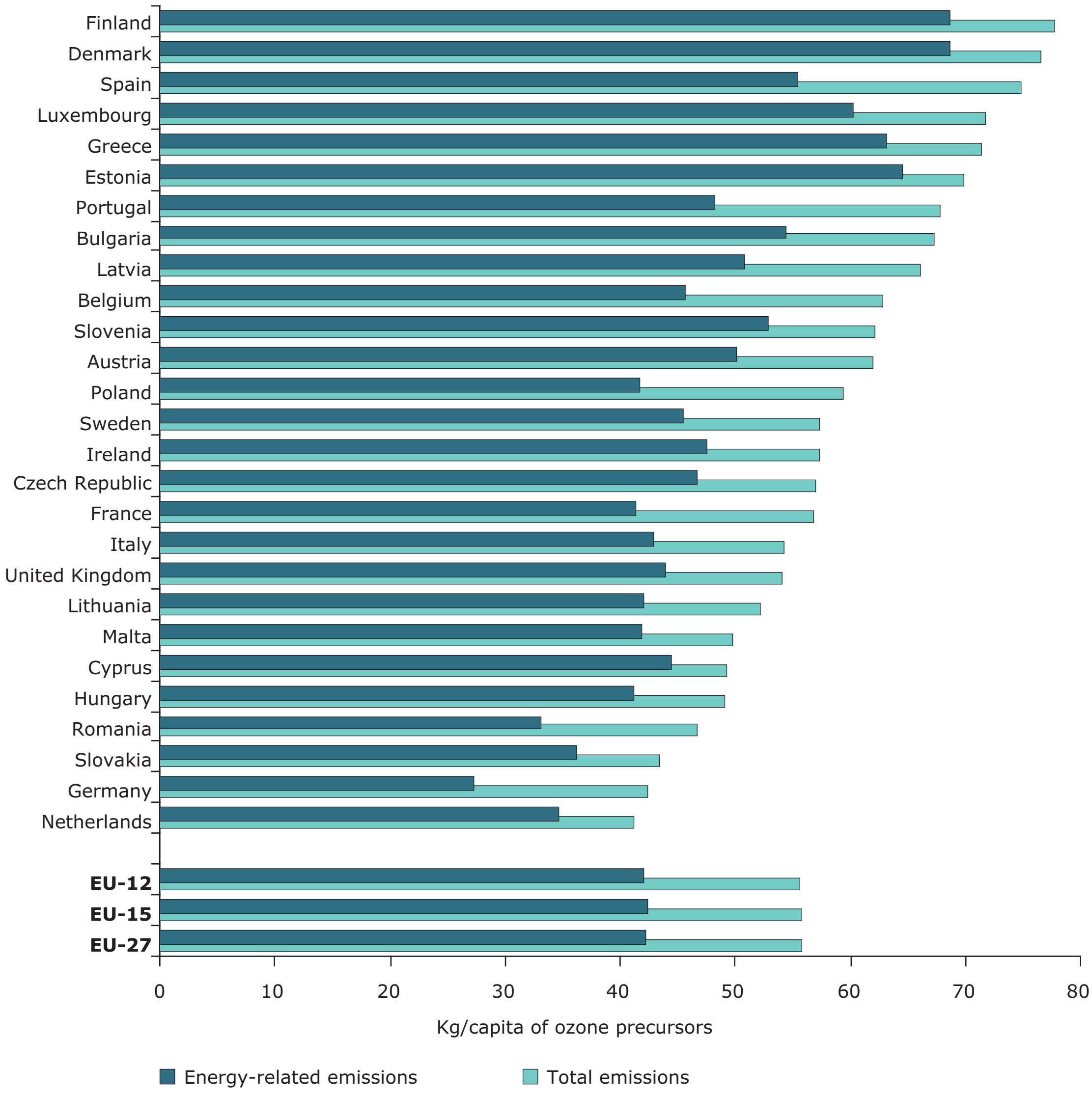
Due to a range of factors, per capita emissions of air pollutants vary significantly across the Member States. These include: the level of demand for energy, the energy supply mix, level of efficiency and abatement technologies employed, as well as the mix of economic sectors. For example, the greater prevalence of agriculture in some Member States leads to higher non-energy related emissions.

Figure 1.9 **Emissions of acidifying substances, ozone precursors and particulate matter (primary and secondary) per capita, 2005**



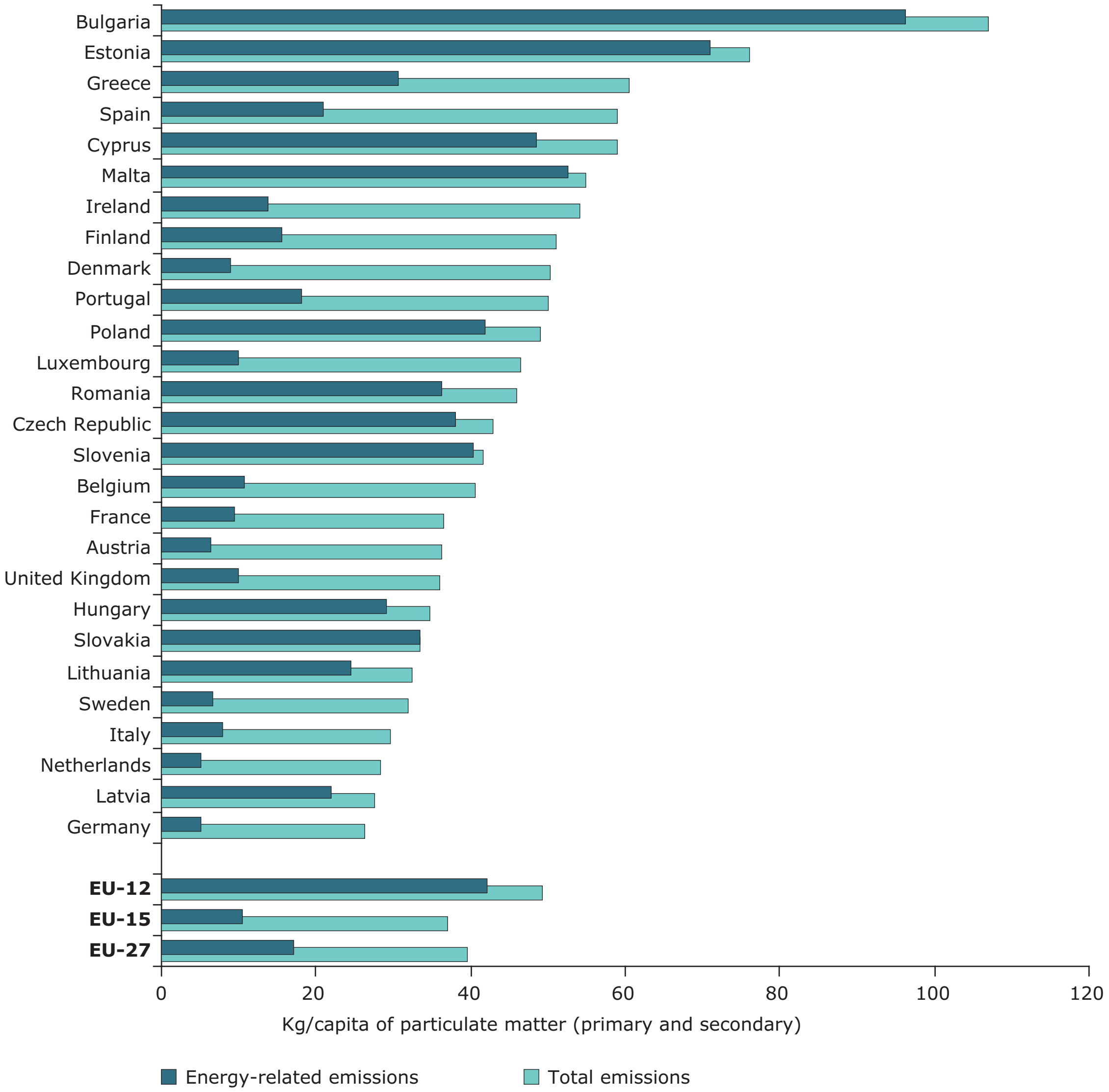
Source: EEA; Eurostat.

Figure 1.9 Emissions of acidifying substances, ozone precursors and particulate matter (primary and secondary) per capita, 2005 (cont.)



Source: EEA; Eurostat.

Figure 1.9 Emissions of acidifying substances, ozone precursors and particulate matter (primary and secondary) per capita, 2005 (cont.)



Source: EEA; Eurostat.

1.3 Other energy-related environmental pressures

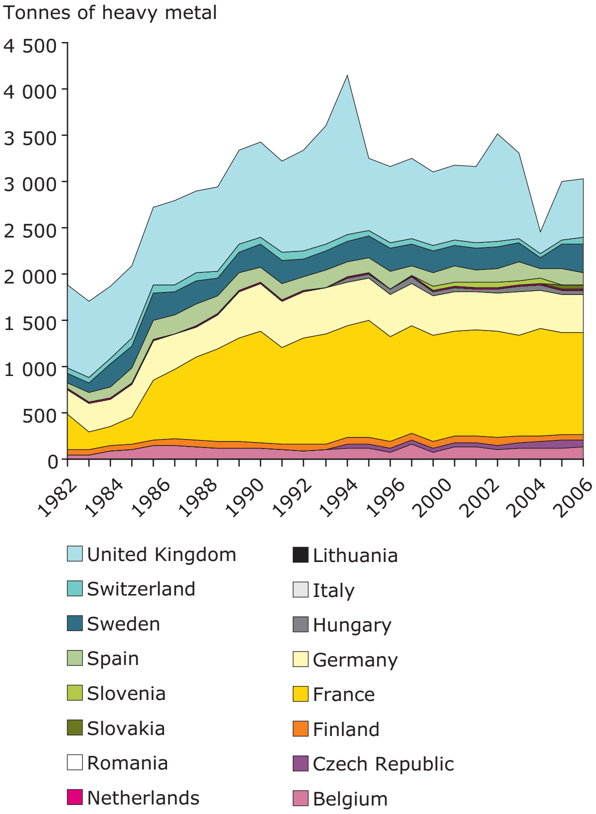
Whilst the primary focus of this report relates to the use and supply of energy as well as emissions of air pollutants and greenhouse gas, a range of other energy-related environmental pressures may also occur.

Nuclear waste

The European Commission and the European Council, in its conclusions of 8/9 March 2007 (EC, 2007e), noted that nuclear energy could also make a contribution towards addressing growing concerns about the security of energy supply and reduction of CO_2 emissions. Following the Council's decision, the European Forum for Nuclear Energy (8) was established to provide a platform for a broad discussion among all stakeholders on the opportunities and risks of nuclear energy. Nuclear power has also been included in the European Strategic Energy Plan (EC, 2006b) as one of the key low-carbon technologies. However, the use of nuclear energy also generates nuclear waste, which must be carefully stored and disposed of. While final disposal methods exist for low- and medium-nuclear waste, solutions for a permanent disposal of high-level nuclear waste are yet to be found. To date, Finland remains the only European country with a clear strategy and a time frame for implementing measures for permanent disposal of high-level nuclear waste.

The annual quantity of spent fuel is determined by the quantity of electricity produced by nuclear power plants but also by other factors, such as the plant type and efficiency. However, even with stable or decreasing annual quantities of spent fuel, the highly radioactive nuclear waste continues to accumulate. Work is underway to establish final disposal methods that can alleviate technical and public concerns over the potential threat that this waste poses to the environment and human health. In the meantime, the waste accumulates in dry and wet storage facilities.

Figure 1.10 Annual quantities of spent nuclear fuel arising from nuclear power plants in the EU (tonnes of heavy metal)



Note: No information has been included for Bulgaria due to a lack of data.

Source: OECD, 2007; IAEA, 2003b; NEA, 2007.

A limited decline in the annual quantity of spent fuel (approximately 5 %) was registered over the period from 1990 to 2006, while the electricity produced by nuclear installations, over the same period, increased by approximately 20 %. Very few new nuclear power plants have come online since 1990, while several plants in the United Kingdom, Lithuania, Germany, Sweden and Bulgaria have been shut down. The reduction in spent fuel arising per unit of power is driven by a combination of different factors, including an increase in plant availability in the past decades (reduced the number of start-ups), an improvement in net plant electric efficiency and improvements in fuel enrichment and burnup (WNA, 2003). The large variations in the United Kingdom are primarily linked to the decommissioning of a number of older nuclear power plants. During a normal operation, only a fraction of the reactor core is refuelled each year and the corresponding spent fuel removed — hence the limited correlation between the amount of spent fuel sent to storage and the electric output of the plant. However, during decommissioning the reactor is completely de-fuelled.

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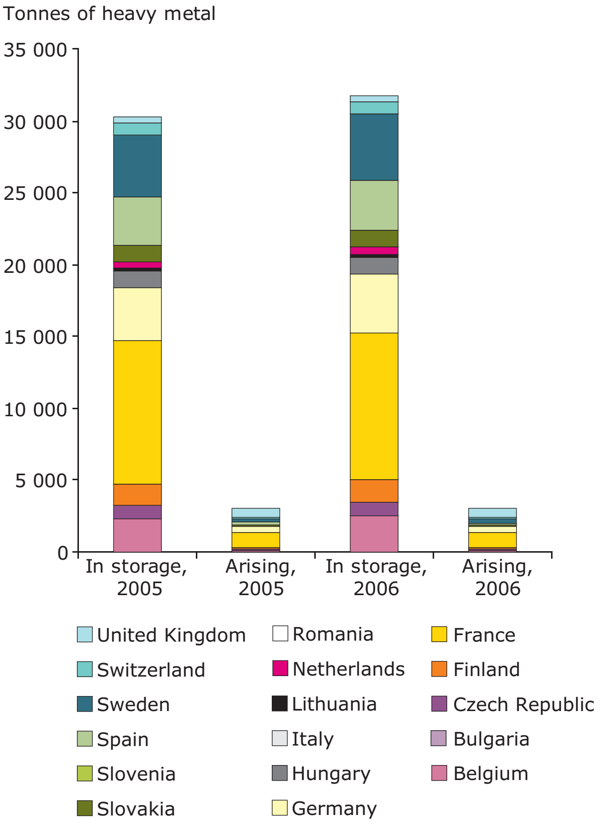
(8) Further information on the Forum's activities is available at http://ec.europa.eu/energy/nuclear/forum/index_en.htm.

Figure 1.11 Total stored amount of high level waste



Note: No information has been included for Bulgaria due to a lack of data.

Source: OECD, 2007; IAEA, 2003b; NEA, 2007.

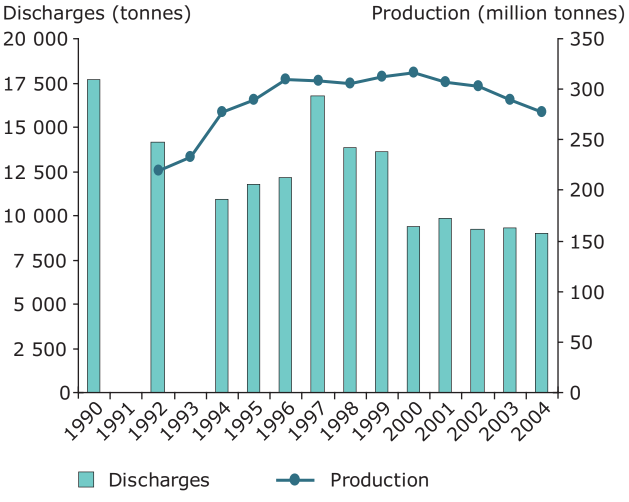
Spent fuel is first stored for several years (usually < 10, but sometimes > 20) in spent fuel ponds 'at reactor' until the heat generation and radiation of the spent fuel is sufficiently low to allow for handling. After this period, fuel is either reprocessed or temporarily stored. Temporary storage, for a period of 50–100 years is required, to decrease further radioactivity and the heat generation of the spent fuel before final storage. Spent fuel in the EU is temporarily stored in both wet and dry storage systems. Facilities are designed to limit radiation to surroundings and to remove the heat from the spent fuel. Storage capacity in western and eastern Europe 'away from reactor' is approximately 66 ktonnes of heavy metals, of which approximately 53 ktonnes is wet storage (IAEA, 2003b). Interim storage facilities range from bunkers, able to withstand airplane crashes (such as Habog in the Netherlands), to open air storage in canisters. There is, at present, no commercial storage facility for permanent storage of HLW (HLW = high-level waste). Facilities are being designed and planned to become operational in 2020–2025 in Belgium, Czech Republic, Finland, the Netherlands, Spain, Sweden and France.

Pollution from oil spills

Oil pollution from coastal refineries, offshore installations and maritime transport put significant pressures on the marine environment. The consistency of spilled oil can cause surface contamination and smother marine biota. In addition, its chemical components can cause acute toxic effects and long-term impacts. Since 1990, oil discharges from offshore installations and coastal refineries have diminished, despite increases in oil production and the ageing of many major oil fields (see Figure 1.12). This improvement is mainly the result of the increased application of cleaning and separation technologies.

Discharges of oil from offshore installations can occur from the production water, drill cuttings, spills and flaring operations. Despite the one-off increase of oil discharges from offshore installations in 1997, which was mainly due to an exceptional accidental spillage, it is expected that further reductions of oil discharges will continue in the future, partly as a result of the new regulation on drill cuttings (OSPAR, 2000), which entered into force in 2000.

Figure 1.12 Oil production and discharges from offshore installations in the north-east Atlantic



Note: Data available only from Denmark, Germany, Ireland, the Netherlands, United Kingdom and Norway; hence, coverage is restricted to the north-east Atlantic; no data for 1991 and 1993.

Source: OSPAR, 2006; Eurostat.

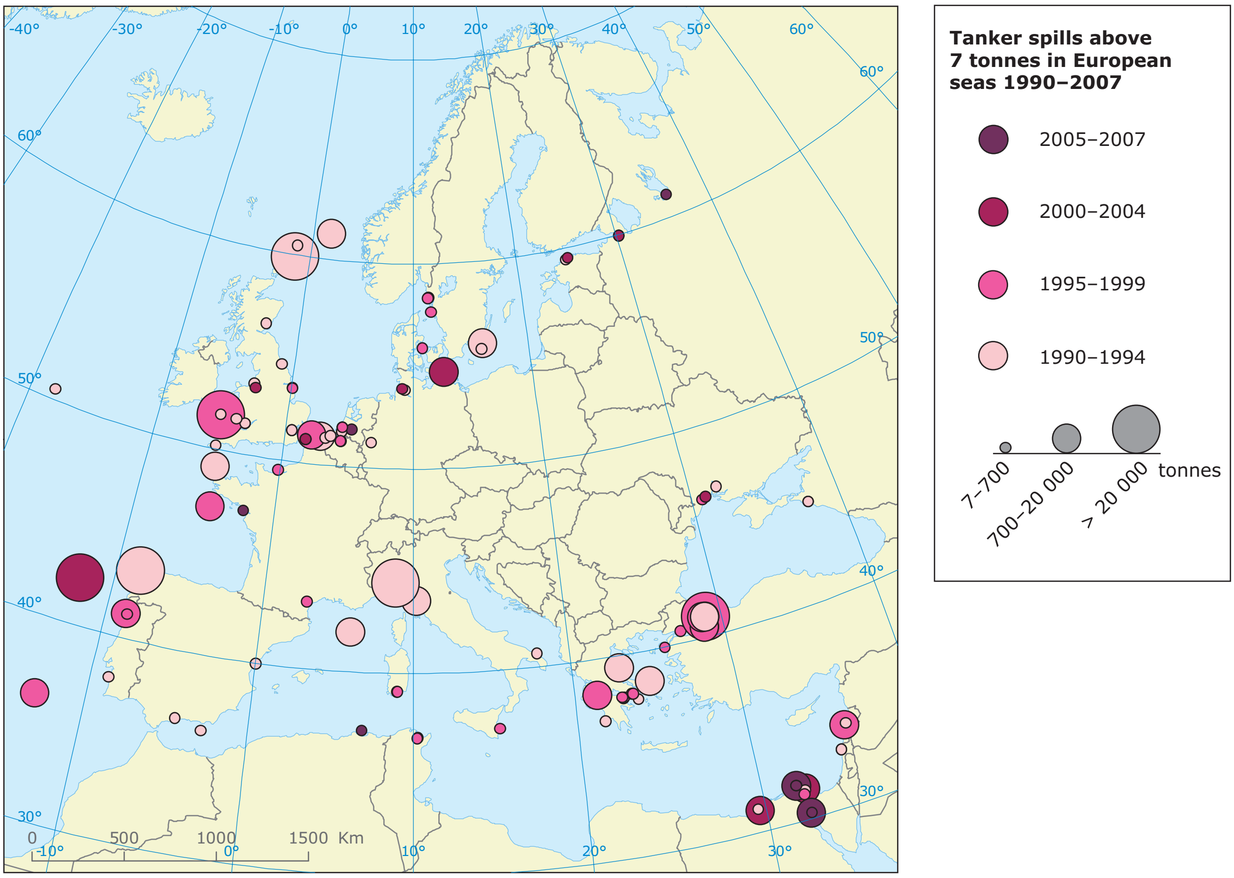
On the other hand, tanker oil spills continue to occur, although both their frequency and the volumes involved seem to have declined over the past decade (see Figure 1.13). However, this trend is largely dependent on the occurrence of large tanker accidents, as a few very large accidents are responsible for a high percentage of the oil spilt from maritime transport. Such major accidents still occur at irregular intervals. Nevertheless, it is encouraging that the improvement took place despite a continued rise in the maritime transport of oil. Increased safety measures, such as the introduction of double-hulled tankers (as mandated by the IMO), have contributed to this positive trend. Further increases in maritime safety are also supported by the EU in the proposed third maritime safety package (EC, 2005c) and the proposed accelerated introduction of double-hull tankers (EC, 2006c).

Accidental oil tanker spills into the European seas decreased significantly over the past 17 years. From the total amount of oil spilt in large accidents (i.e. more than 7 tonnes) during the 1990–2005 period (553 000 tonnes), two thirds were spilt over the period of 1990–1994. During the two five-year periods (1995–1999 and 2000–2004), around 19 % and 14 % were spilt, respectively. In 2005, 2 100 tonnes were released into the environment. However, this trend is largely dependent on the occurrence of large accidents, as a few very large accidents are responsible for a high percentage of the oil spilt from maritime transport. For example, during the period 1990–2005, of 106 accidental spills over 7 tonnes, just 7 accidents (causing spills of around 20 000 tonnes or more) account for 89 % of the spilt oil volume (causing spills of around 20 000 tonnes or more). The map does not include spills and discharges below 7 tonnes.

Other environmental pressures.

Further environmental pressures also arise from the energy-related use of land for power plants, refineries, transmission lines, mining operations, etc. This can lead to degradation and fragmentation of ecosystems. In addition, combustion plants (particularly coal and lignite) release small

Figure 1.13 Large (> 7 tonnes) tanker spills in European waters 1990–2007



Source: ITOPF, 2008.

quantities of heavy metals, e.g. mercury, lead and cadmium. Over time, these can accumulate in biological organisms, and have potentially toxic effects. Furthermore, many types of energy sources, including renewables, may affect biodiversity in the local environment (for example, via the creation of a dam for a hydropower facility). These environmental pressures and other related issues are explored in greater detail in other European Environment Agency reports, for example, see EEA, 2007b.

1.4 Climate change impacts on energy production and consumption

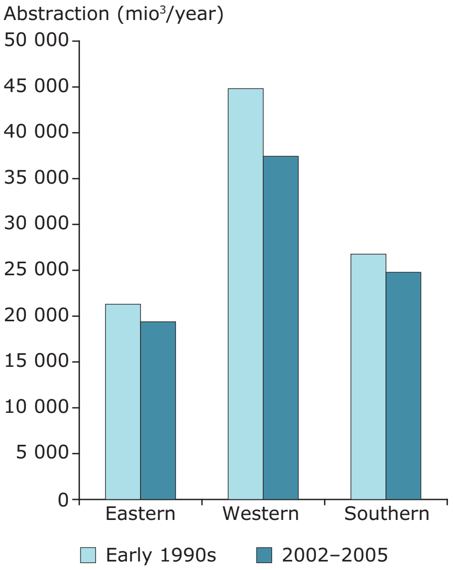
As shown in Section 1.1 above, energy production and consumption constitute the most important source of greenhouse gas emissions in Europe and, hence, an important driver for climate change. However, in their turn energy production and consumption will also be affected by climate change. Two particular aspects related to climate change impacts and adaptation are discussed below. They are also closely linked with topics addressed later in this report, namely, Europe's dependence on imported fossil fuels and household energy consumption.

Energy and water

Numerous studies have demonstrated that energy demand is linked to climatic conditions (e.g. outside temperature), particularly in the household sector, but also in the service and industry sectors (Eurostat, 2007). For example, from 1990 to 2005 in all EU-27 Member States, electricity consumption per person in the households sector increased on average by 31.1 %, while in Turkey it increased by more than 150 % (see Figure 6.1). This was partially due to the increasing demand for cooling in southern Europe. However, the production of electricity strongly depends on the availability of water, both for cooling thermal power plants as well as for hydropower. Due to climate change, water availability may increase in some regions (particularly in Northern Europe) — due to increased river runoff — while other regions will be facing higher risks of water scarcity (for instance in the Mediterranean region) (EEA, 2008c). During heat waves and drought periods, if limit values for water temperature are exceeded, the use of cooling water may be restricted. This may force thermal power plants to operate at a reduced capacity and in a suboptimal efficiency regime (e.g. because of an increased demand for energy needed for pumps to maintain the desired condensing temperature, changes from wet to dry cooling towers, etc.) (9). In addition, future projections of the rising sea level and associated impacts of this development on the coastal systems show potentially large increases in the risk of coastal flooding (EEA, 2008c). Consequently, new thermal power plants may need to be built inland, where they will compete with other public uses for fresh water supplies (e.g. agriculture) and be subject to stricter environmental regulations.

In Europe, water abstracted for cooling in energy production accounts for about 44 % of the total use of water. The western European countries and the central and northern countries of eastern Europe are the largest users of water for cooling; for example, more than half of water abstracted in Belgium, Germany and Estonia is used for this purpose (see Figure 1.14).

Figure 1.14 **Water abstraction for energy cooling (million m^3/year) in early 1990s and 2002–2005**



Note: Eastern (central and northern): Bulgaria (1990; 2005), Czech Republic (1990; 2002), Estonia (1990; 2002), Hungary (1992; 2002), Poland (1990; 2005) and Romania (1991; 2005).
Western (central and northern): Austria (1990; 2002), Belgium (1994; 2003), England and Wales (1990; 2004), Finland (1990; 2005), Germany (1991; 2004), Netherlands (1990; 2005), Sweden (1990; 2004) and Switzerland (1990; 2005).
Southern: France (1990; 2002), Spain (1991; 2004).

Source: EEA.

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(9) More detailed information is available from the ADAM project at http://www.adamproject.eu/.

Changing rainfall patterns (and hence the water quantity available) and water temperature, due to climate change, are likely to put a strain on energy companies in the near future, placing further constraints on some countries (particularly in southern Europe) to address security of energy supply concerns.

For cooling energy plants, the critical limit for the intake of cooling water is 23 °C. However, in recent years the number of days when the temperature exceeded this threshold has grown (the case of the River Rhine is shown in Figure 1.15). For example, during the particularly hot summer of 2003, the high water temperatures and low river level threatened the cooling capacity of several power stations in the Netherlands and France. The requirement is that cooling water may only be discharged at a temperature no warmer than 30 °C. In practice, it meant that several companies could only satisfy this criterion by reducing their production capacity. The three hydroelectric power stations — on the Meuse, Nederijn and Vecht — also had to run on a very limited capacity for several weeks (10–25 % of their normal capacity). The combined result was a significantly increased risk of electricity shortages (due to a lower peak capacity margin) in the Netherlands.

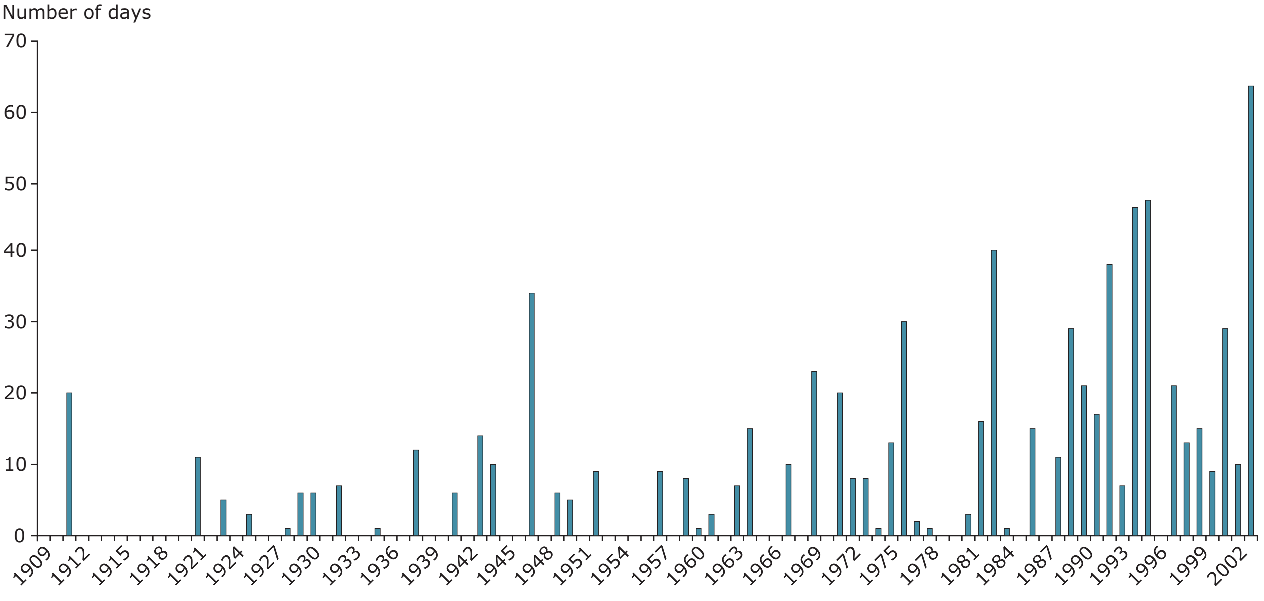
Changing energy demand patterns

Climate change is likely to have yet another significant impact on energy production and consumption: it is going to affect the patterns of energy demand. The changing climate in Europe is likely to cause a decrease in the demand for winter heating (particularly in Northern Europe) and an increase in summer cooling (in the Mediterranean region). This can be described as either an impact or an adaptation measure that in some cases can offset mitigation efforts (see Figure 1.16). This shift in energy demand will also trigger changes in the energy mix and the types of energy plants needed, as energy services — such as heating and cooling — are usually supplied from different energy sources. This development will have an impact on future GHG emissions in Europe but could also influence the evolution of imports for fossil fuels as, for example, gas-fired power plants are currently preferred not only for their environmental benefits but also for their versatility (in terms of meeting the peak demand). Other climatic factors that affect energy demand include wind chill, illumination and cloud cover, and precipitation.

1.5 Life cycle analysis (LCA) of energy systems

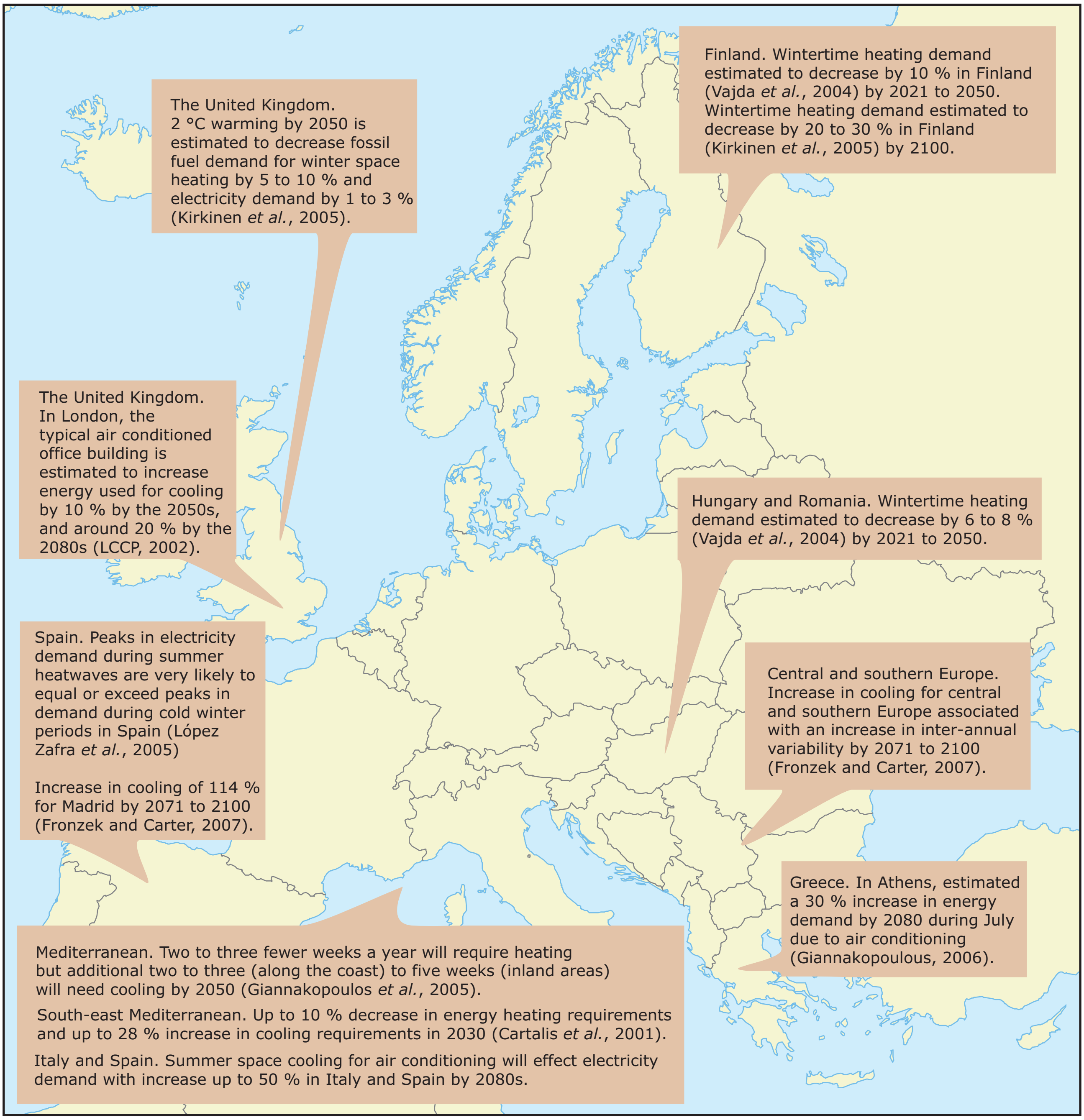
A life cycle analysis (LCA) of various energy sources identifies the environmental impacts of various activities along the supply chain: from resource extraction to end-use and includes the manufacturing stage for all processes involved (Oeko, 2006). This methodology quantifies the environmental impacts (i.e. on air quality — air emissions, water and soil)

Figure 1.15 Number of days with water temperature in the River Rhine > 23 °C



Source: Bresser *et al.*, 2006.

Figure 1.16 Projections of energy demand for several time horizons in Europe



The United Kingdom.
2 °C warming by 2050 is estimated to decrease fossil fuel demand for winter space heating by 5 to 10 % and electricity demand by 1 to 3 % (Kirkinen *et al.*, 2005).

Finland. Wintertime heating demand estimated to decrease by 10 % in Finland (Vajda *et al.*, 2004) by 2021 to 2050. Wintertime heating demand estimated to decrease by 20 to 30 % in Finland (Kirkinen *et al.*, 2005) by 2100.

The United Kingdom.
In London, the typical air conditioned office building is estimated to increase energy used for cooling by 10 % by the 2050s, and around 20 % by the 2080s (LCCP, 2002).

Hungary and Romania. Wintertime heating demand estimated to decrease by 6 to 8 % (Vajda *et al.*, 2004) by 2021 to 2050.

Spain. Peaks in electricity demand during summer heatwaves are very likely to equal or exceed peaks in demand during cold winter periods in Spain (López Zafra *et al.*, 2005)

Increase in cooling of 114 % for Madrid by 2071 to 2100 (Fronzek and Carter, 2007).

Central and southern Europe. Increase in cooling for central and southern Europe associated with an increase in inter-annual variability by 2071 to 2100 (Fronzek and Carter, 2007).

Greece. In Athens, estimated a 30 % increase in energy demand by 2080 during July due to air conditioning (Giannakopoulous, 2006).

Mediterranean. Two to three fewer weeks a year will require heating but additional two to three (along the coast) to five weeks (inland areas) will need cooling by 2050 (Giannakopoulos *et al.*, 2005).

South-east Mediterranean. Up to 10 % decrease in energy heating requirements and up to 28 % increase in cooling requirements in 2030 (Cartalis *et al.*, 2001).

Italy and Spain. Summer space cooling for air conditioning will effect electricity demand with increase up to 50 % in Italy and Spain by 2080s.

Source: EEA, 2008c.

of all resources, raw materials and energy carriers involved throughout the life cycle of a certain product or process. Furthermore, this methodology aggregates these environmental impacts over time and space to determine the environmental pressures at a global scale, such as global warming, ozone layer depletion, eutrophication, eco-toxicological and human-toxicological pollutants, desertification, land use as well as depletion of minerals and fossil fuels (10). Most of the studies applying life cycle approaches limit their focus to energy and greenhouse gas emissions only.

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(10) For further details see http://lca.jrc.ec.europa.eu/lcainfohub/lcagoalPage.vm.

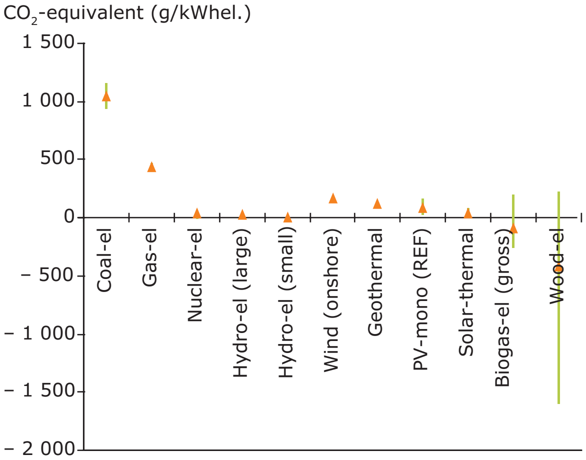
The LCA approach applied to energy sources is data-intensive. It includes both direct emissions (from conversion processes) and indirect emissions stemming from activities such as mining, processing, transport, and production/extraction of the raw materials needed for manufacturing processes. For the nuclear industry, it also includes enrichment and fuel-rod production ([11]).

For each of the sources, the level of emissions can vary, depending on the fuel quality — for coal and natural gas, differences exist between imported fossil fuel ([12]) from non-EU Member States and domestic fossil fuel, between plant efficiency, between different technologies. For instance, for PV (photovoltaics), the LCA emissions vary depending on the type of the cell (i.e. monocrystalline, multicrystalline and amorphous modules). For solar thermal technologies, from an LCA perspective, it matters whether it is a parabolic trough, a solar tower plant with concentrating mirror fields, or a parabolic solar dish mirror. For biomass, the level of emissions is determined, among others factors, by the type of feedstock applied and the different conversion technologies used.

In Figure 1.16, the LCA GHG emissions associated with various energy sources are shown. The figure is derived from the LCA analysis carried out by the Oeko Institute for the European Environment Agency. It uses the GEMIS database developed in 1987–1989 as a tool for the comparative assessment of environmental effects of energy ([13]).

The LCA results presented here ([14]) for renewable energies include the material acquisition and manufacturing of the primary conversion systems (e.g. wind turbines, photovoltaic modules, solar-thermal collectors). For dedicated bioenergy crops, processes like planting, harvesting, transport and inputs needed (e.g. fertiliser, pesticides, transport fuels) as well as final conversion are also included ([15]). For residues and wastes, on the other hand, no upstream activities, other than transport, are to be considered, as they are by-products of agriculture or forest operations, or other activities (e.g. food and wood industry, household).

Figure 1.17 LCA GHG emissions of various energy systems (2000)



Note: For solar electricity, a concentrating solar-thermal power generation system with parabolic trough, a solar tower plant with a concentrating mirror field and a parabolic solar 'dish' mirror with a Stirling engine. For PV, three types of cells were considered: monocrystalline, multicrystalline, and amorphous — placed on a reference site with 1 000h/a of sunlight. For wind power, an on-shore wind park with 1.5 MW-size turbines is considered (10 turbines, wind speed of 9m/s). For geothermal, a large geothermal steam turbine plant in Italy (1 MWel) and a small scale 'binary' ORC (Organic Rankine Cycle) system in Germany that uses a closed loop are considered in the life cycle assessment.

Source: GEMIS database, Oeko Institute.

The LCA emissions of GHGs from electricity generation are highest for coal and gas, which is due, primarily, to emissions released during combustion, with smaller quantities associated with upstream activities such as mining. Emissions from other technologies are far smaller, with generally negligible emissions from generation (e.g. for renewables such as wind and hydro) but, rather associated with their production/construction.

Emissions ([16]) from biomass electricity constitute a somewhat separate case, with significant ranges and, in some cases, sizeable negative emissions. As

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([11]) The life cycle emissions for nuclear exclude the 'back end' of the nuclear fuel cycle — as no valid data are available on the conditions of future final repositories for spent nuclear fuel. Also, the 'recycling' of PU-239 from spent fuel through reprocessing and MOX fuel fabrication is not included, as no adequate data is available.

([12]) The data shown for coal include both lignite and hard coal that are domestically produced and imported (from Russia, the United States of America and South Africa). The import life cycle includes transport ships to move the coal to Europe. The natural gas data include Russia and Norway.

([13]) http://www.oeko.de/service/gemis/en/index.htm

([14]) From GEMIS, other analysis may include different/additional elements in the life cycle.

([15]) Bioenergy life cycle analysis does not include direct and indirect land use change in these figures.

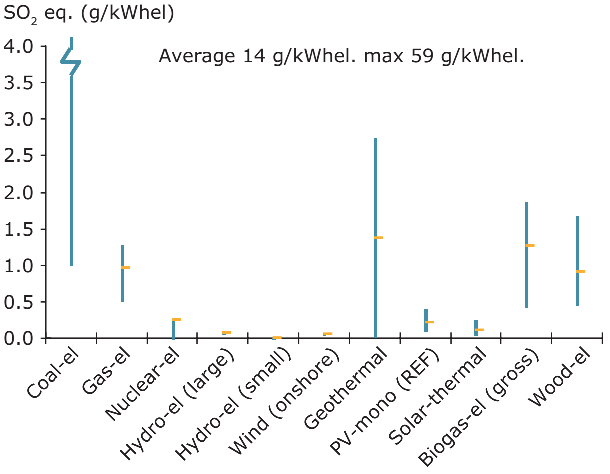
([16]) The emissions presented are net emissions (assuming gas-heating systems to be substituted). Thus, the results are based on the substitution method, whereas current accounting rules, for instance for biofuels in the RED, is based on allocation of the by-products.

shown above, the net biogas electricity emissions are smaller than zero, i.e. the credit for cogenerated heat is larger than the total emissions for both electricity and heat. Furthermore, the larger biogas plants, and the larger ICE cogenerators, have lower emissions than small fermenters with smaller ICE systems. In addition to various biogenic waste streams, woody residues from forestry and straw (as an agricultural residue) can be used to generate electricity. The easiest option is co-firing in electricity-only (steam turbine) plants and cogeneration backpressure power plants. Figure 1.17 also includes smaller-scale cogeneration technologies, like steam engines, organic rankine cycles (ORC) and stirling motors, as 'new' technologies. Furthermore, solid biomass can be gasified in fixed-bed (FB) and circulating fluidised-bed (CFB), or pressurised fluidised-bed (pFB), gasifiers, and then used in internal combustion engines (ICE), gas turbines (GT) for cogenerating electricity (and heat), or for electricity alone in combined-cycle (CC) plants. Data given in this figure for these new technologies are for year 2010.

Electricity from woody biomass in particular shows a very large range in estimated life cycle GHG emissions, from approximately – 1600 to + 200 g CO_2eq./kWhel. Electricity from woodchips in an ORC cogeneration system produces highly negative net GHG emissions over the life cycle, whilst fluidised bed gasification (FBG) and pressurised FBG (pFBG) technologies (without cogeneration) result in GHG emissions at the other end of the scale. FBG and pFBG are rather intense in emitting N_2O; therefore, their direct emissions in CO_2-eq. are rather high. This is not the case for the 'direct-fired' steam engines and the ORC cycles. Even though the electric efficiency of the combined cycle (CC) schemes is quite high, there is no 'credit' for avoided emissions from heating systems. The small-scale ORC (and steam engine) cogeneration systems, on the other hand, have a rather low electric efficiency, but receive a substantial credit due to the high amount of 'waste heat' assumed to be used for heating (the heat amount is a direct function of the low electric efficiency) ([17]).

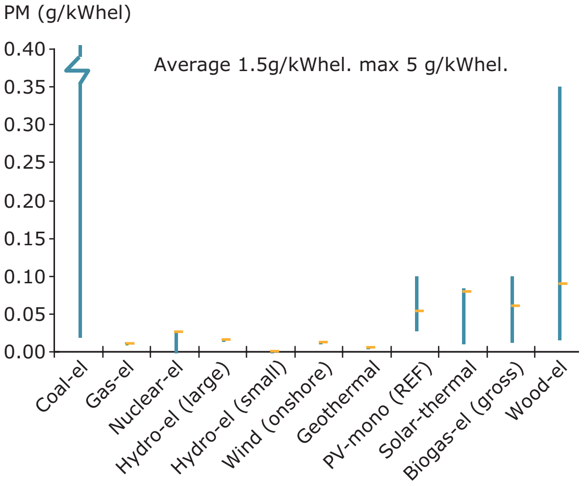
In Figures 1.18 and 1.19, similar estimates are given of the life cycle emissions of air pollutants with acidifying potential (e.g. SO_2, NO_X and NH_3) and PM (particulate matter), respectively. Emissions of acidifying substances are higher for coal-fired power plants (even considering plants that are 'state of the art'), because of high SO_2 emissions that occur during the coal mining, particularly in the case of lignite (surface) mining. For biogas used for electricity production, NO_X emissions are relatively high when maize is used as feedstock, followed by

Figure 1.18 LCA emissions of acidifying substances for various energy systems (2000)



Source: GEMIS database; Oeko Institute.

Figure 1.19 LCA PM emissions for various energy systems (2000)



Source: GEMIS database; Oeko Institute.

([17]) When the 'new allocation' approach is applied, the results would change, favouring the high-efficient electric systems more. Still, with high amounts of cogenerated heat, the 'remaining' share of GHG emissions for electricity from ORC/SE cogeneration plants would be low.

manure. Note that the same technology (internal combustion engine-cogeneration) has been applied for all biomass sources, but the feedstock is different.

Figure 1.19 emphasises the large range of PM emissions calculated for both fossil fuel and renewables for electricity production. Electricity produced from coal has the highest emissions, followed by electricity produced from woodchips.

In general, LCA results aggregate the emissions specific to the material or energy used in each step of the life cycle. However, these results do not, normally, account for numerous other environmental pressures associated with each stage of the energy supply chain.

For example, exploration and extraction of oil and natural gas, mining for coal and uranium, harvesting crops, using river basins for hydropower (especially if it is a large hydro) and drilling at a geothermal site — all these activities can have severe impacts on their environment. Those impacts can be in terms of water (both surface and ground) and soil contamination, as well as disruption to the ecosystem caused by removing the land from its normal use.

In the case of underground coal mining, waste materials are piled at the surface, creating runoff that both pollutes and alters the flow of local streams. Not only do the underground mines produce an impact on the groundwater hydrology, but they also create the risk of subsidence (CATF, 2001). Land oil extraction can destabilize the terrain and disrupt underground aquifers by removing large volumes of oil and methane from the ground. Oil drilling near the ocean can draw seawater into fresh water aquifers. Oil fields leak waterborne ions and chemicals into the surrounding ecosystems (sodium, chloride, boron, benzene and arsenic from offshore drilling — all of these can create threats to sensitive marine ecosystems, e.g. coral reefs). In addition, both gas and oil transports carry a high risk of accidents, and such an accident can cause severe environmental damage.

Another important factor relates to land-use requirements in terms of the final site of the plant (both its size and location) and the adverse impacts produced earlier on in the life cycle, for example in relation to mining of primary fuels such as coal or uranium (as mentioned above). Other examples include geothermal exploration, which can create land disturbance, fluid (water, gases) discharge, water withdrawal, noise, the loss of vegetation and the risk of erosion. Dams and powerhouse turbines for hydropower can have significant impacts on river conditions as well as on the land and vegetation bordering the water bodies. This may significantly affect the fish populations and other wildlife — depending on the location of the dam.

Bioenergy production, because it interacts strongly with its environment, can create a loss of biodiversity, interfere with both water quality and quantity, and it can even cause high GHG emissions — for example, when the bioenergy feedstock is cultivated on high carbon stock lands, and due to indirect changes in the land use. Natural forests and grasslands contain significant amounts of carbon in vegetation, hence, when virgin land or forest is converted to agricultural land for biomass production, the carbon in the soil and in the original plant will be released. Peat soils, for example, store significant amounts of carbon, and drainage of this soil for crop cultivation will cause oxidation of these stocks.

Whilst a small number of studies (e.g. in relation to water use for biofuels, see Renew, 2008) have tried to quantify at least some of these additional elements within LCA, they are generally more problematic to include — due to a lack of available, consistent data. More information on LCA emissions from bio energy is also available in the EEA report on bioenergy use and associated environmental issues (EEA, 2008d).

It should be noted that some countries, such as Switzerland, are looking to introduce formal legislative requirements for the producers and importers of biofuels to undertake LCA. This aims to cover the entire production cycle: from planting of raw materials — right up to the end consumer at the pump. They will be also required to prove that biodiversity, forest or ecosystems have not been endangered (FOEN, 2008).

1.6 Scenarios

Existing scenarios described in Table 1.1 (taken from the POLES, WEM and PRIMES models) show that under baseline/reference scenarios, incorporating existing policies and measures, many of these pressures are likely to increase in future (See Annex 1 for further details of the various models and scenarios). All baseline (or reference) scenarios show increasing absolute levels of primary energy consumption: by 10–26 % by 2030 (compared to 2005), with fossil fuels maintaining a high share in all cases.

In case of a more stringent energy and climate change policy, the absolute increase in primary energy consumption is much lower and, actually, starts to decline between 2020 and 2030 — primarily due to greater improvements in energy efficiency. In these circumstances, pressures on the environment from energy sector are likely to decrease, due to significant reductions in primary energy demand as well as higher penetration rates for renewable energy. It is, therefore, possible, by 2030, to achieve reductions in CO_2 emissions ranging from around 20 % to 30 % compared to 2005.

Table 1.1 Scenarios of primary energy consumption, imports-exports of electricity (Mtoe) and energy-related related CO_2 emissions (Mt CO_2), EU-27

Type (Mtoe)	Actual	(IPTS) POLES 2006				(IEA) WEO 2007				(EC) PRIMES 2008	
		Baseline		GHG reduction		Reference		Alternative policy		Baseline	
	2005	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030
Coal and lignite	320	354	367	212	168	299	275	195	142	342	336
Oil	666	647	657	576	524	677	670	635	595	702	708
Gas	445	552	516	508	428	547	610	509	529	505	516
Nuclear	257	262	336	293	320	194	159	266	230	221	206
Renewables + industrial waste	121	332	415	351	461	227	291	259	348	197	237
Imports-exports of electricity	2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1	1
Total energy consumption	1 810	2 147	2 291	1 941	1 901	1 944	2 006	1 863	1 844	1 968	2 005
Total energy-related CO_2 emissions (Mt CO_2)	3 982	4 359	4 341	3 463	2 757	4 133	4 176	3 508	3 244	4 253	4 264

Source: EEA; Eurostat; IPTS, 2006; IEA, 2007a; EC, 2008f.

2 What are the trends concerning the energy mix in Europe and what are its related environmental consequences?

Main messages

The concept of energy security in Europe encompasses a wide range of issues including energy efficiency, diversification of energy supply, increased transparency of energy demand and supply offers, solidarity among the EU Member States, infrastructure and external relations. Together with the energy efficiency, the energy import dependency aspect of security of supply has direct environmental consequences. Some of the links between the environment and the energy import dependency are determined by the fuel mix used to deliver energy services, the level of demand for those services and the speed with which these services have to be delivered. Reducing energy import dependency can have positive or negative effects on the environment, both within the EU and outside its borders, depending on the energy sources imported and the ones being replaced. In Europe, a higher penetration of renewable energy sources in the energy mix, coupled with a switch from coal to gas, resulted in reduced energy-related GHG emissions and air pollution but also in increased dependency on gas imports. However, these environmental benefits were partially offset by increasing energy consumption and, more recently, by the tendency to increase the use of coal in electricity generation due to concerns about security of supply as well as concerns over high and volatile prices for imported fossil fuels.

1. The current energy system within the EU is heavily dependent on fossil fuels. The share of fossil fuels in total energy consumption declined only slightly between 1990 and 2005: from around 83 % to 79 %.
2. Over 54 % of primary energy consumption in 2005 was imported, and this dependence on imported fossil fuel has been rising steadily (from 51 % in 2000).
3. Dependence is increasing rapidly for natural gas and coal. Natural gas imports accounted for some 59 % of the total gas-based primary energy consumption in 2005, while for hard-coal-based primary energy, imports accounted for 42 %. Oil imports accounted for as much as 87 % in 2005 up from 84 % in 2000 — driven by substantial increases in demand from the transport sector, reflecting a lack of real alternatives in this sector and low EU oil reserves.
4. The largest single energy exporter to the EU is Russia, having supplied 18.1 % of the EU-27 total primary energy consumption in 2005 (up from 13.3 % in 2000). Russia supplies 24 % of gas-based primary energy consumption, 28 % oil-based of the primary energy consumption and is the second largest supplier of coal after South Africa, with 10 % of coal-based primary energy consumption in 2005
5. Between 1990 and 2005, the final electricity consumption increased on average, by 1.7 % a year, whereas final energy consumption increased only by 0.6 % a year.
6. A change in the energy mix is taking place in Europe. Renewable energy has the highest annual growth rate in total primary energy consumption, with an average of 3.4 % between 1990 and 2005. Second comes natural gas, with an annual average growth rate of 2.8 % over the same period. The annual growth rate of oil consumption slowed down, particularly in recent years due to its partial replacement in power generation by gas and coal.
7. The switch to gas due to environmental constraints (including concerns over climate change) and a rapid increase in electricity demand brought about some environmental benefits (reduction of CO_2 emissions) but increased dependency on gas imports. Natural gas consumption increased, between 1990 and 2005, by over 30 %.

Baseline (reference) scenarios from POLES, WEM and PRIMES models show a rising dependence on imports of fossil fuels. This is particularly true for gas, with imports (as a percentage of gas-based primary energy consumption) rising from around 59 % in 2005 to up to 84 % by 2030. Even in scenarios built on the assumption of a more stringent policy for energy and climate the import share of all fossil fuels still rises. In these scenarios, improvements in energy efficiency and the penetration of renewables occur more rapidly but the positive effect is more than offset by the decline in the EU's indigenous fossil production (and consequently, increased imports of fossil fuels required to meet the growing energy demand).

2.1 Energy security

On 13 November 2008, the European Commission put forward, in the context of the second strategic energy review, a five-point EU Energy Security and Solidarity Action Plan to address the growing concerns over security of energy supply. Apart from energy efficiency — which is at the forefront of this initiative — measures include promoting infrastructure needs and diversification of energy supply, a greater focus on energy in the EU's international relations, improve oil and gas stocks and crisis response mechanisms, and making better use of the EU's indigenous energy resources.

In this chapter, energy security is discussed mainly from the perspective of diversification of energy sources, as different strategies for energy supply will have different environmental consequences. Chapters 4 and 6 provide additional insights on the role of energy efficiency.

Nowadays, there exists a big discrepancy in the global energy market in terms of natural resource availability, particularly when it comes to fossil fuels. Taking into account the forecasted increase in energy dependency (mainly fossil fuels), securing key energy supplies and supply lines is critical for the European Union as a whole, particularly in times of tight energy markets, increasing global energy demand and complex geopolitical circumstances. In order to mitigate the various risks associated with imports of fossil fuels while, at the same time, delivering environmental and social benefits, efforts must continue to reduce the demand for energy services and to increase reliance on natural resources that are more widely available — such as renewable energy (see also discussions in Chapters 3, 4, 6 and 7).

Europe's renewed focus on energy security was triggered both by internal and external factors. Internally, rising energy prices, declining European energy production and a fragmented internal energy market triggered concerns over Europe's ability to secure future energy supplies. Externally, the strain on global demand exerted by newly industrialised economies such as China and India, persistent instability in energy producing regions, the threat of terrorist strikes against energy infrastructure, and, at times, strained relationships with the Russian Federation — all pointed to the necessity to manage energy security risks and to act accordingly.

It is also imperative to view impacts on energy security in the light of changing energy prices (which constitute a primary driver in shifting the fossil fuel mix) and the developments in infrastructure. It applies, in particular, to liquefied natural gas, for it can provide a greater flexibility in the origin of imports, but is also needed in terms of strengthening links in intra-European energy infrastructure. For example Switzerland aims to become an electricity hub of Europe (18). There are, however, concerns that many decisions, e.g. concerning long-term oil or gas purchases (to compensate for rising spot prices) or (low) levels of infrastructure funding, are made solely at a national level, leading to difficulties in ensuring a coordinated EU approach to energy policy with respect to multiple, potentially conflicting, objectives (energy security, environmental and competitiveness) (CRS, 2008).

The mix of primary energy consumption (by fuel type) varies considerably between countries. It is strongly linked, via the reliance on imports, to the notion of energy security (see Figure 2.1). At one extreme, Malta and Cyprus meet virtually all of their needs for primary energy supply through importing oil, whilst at the other end of the scale — Sweden meets only 35 % of its primary energy demand from fossil fuels, most of which is imported. This is in contrast to the EU-27 as whole, where 79 % of the primary energy consumption comes from gas, oil and coal in proportion of 24.6 %, 36.7 % and 17.7 % respectively.

The EU's dependence on imports of fossil fuel from non-EU countries rose over the period from 2000 to 2005 (see Figure 2.2). The total volume of imports of natural gas, coal and crude oil, as a share of total primary energy consumption, rose from 50.8 % in 2000 to 54.2 % in 2005. Natural gas and coal saw the largest increase over the same period — around a 7 % increase in imports compared to total primary consumption of each fuel type. The diversity of countries from which the EU imports is lowest for natural gas, followed by crude oil and then coal. The largest single exporter to the EU is Russia, supplying 18.1 % of the EU's primary energy in 2005 (up from 13.3 % in 2000). It is the largest single exporter of gas and crude oil and second largest (after South Africa) for coal. Norway is the second largest exporter for

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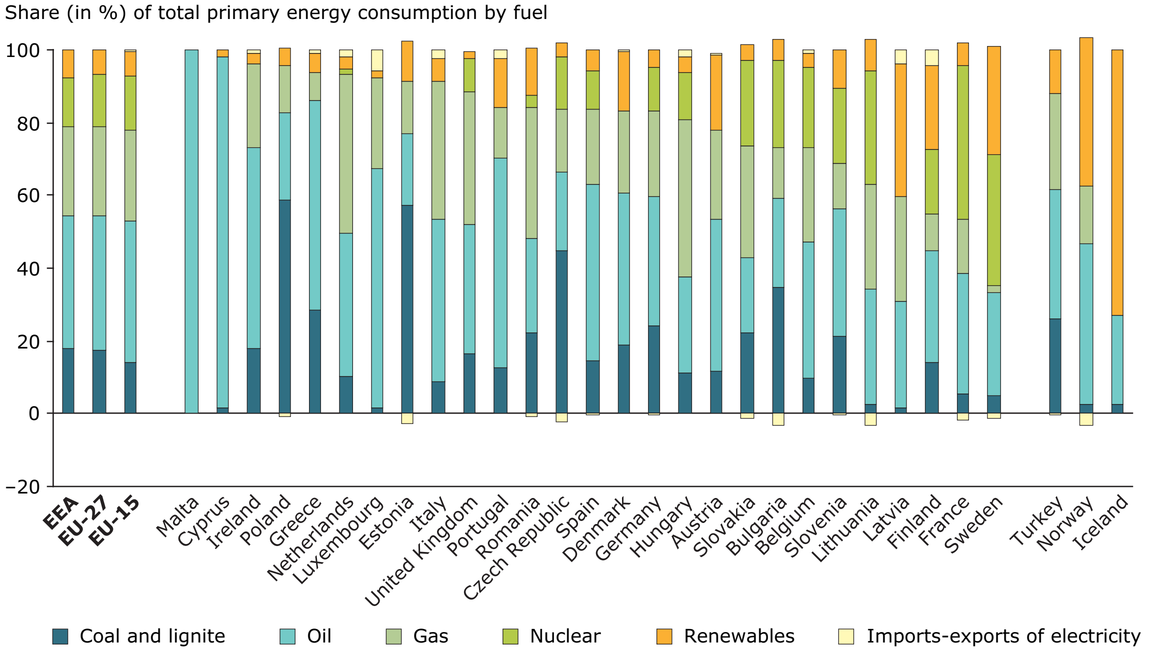
(18) See, for instance, bilateral files: Switzerland-EU, available at www.europa.admin.ch/.

Figure 2.1 Share of total primary energy consumption by fuel, by country in 2005



Note: Negative shares of electricity indicate exports and the reverse is true for imports.

Source: Eurostat; IEA.

oil and gas, accounting for 9 % of the EU's primary energy consumption.

Not surprisingly, the level of CO_2 emissions associated with imported fuels was high in 2005, with some 40 % of the total being associated with coal imports, approximately 60 % — with natural gas imports, and over 90 % — with oil imports (see Figure 2.3).

The availability of uranium reserves is also an important consideration — given current debates in Europe. Currently, uranium production meets about 60 % of the world reactor requirements, with the remaining gap being met by stockpiles of natural uranium, stockpiles of enriched uranium, reprocessed uranium from spent fuel and re-enrichment of depleted uranium tails. Most secondary resources are now in decline, and the gap will increasingly need to be met by new uranium production. Uranium availability varies quite widely at the global level. For example, Australia and Canada together account for some 45 % of the total uranium production, while the other half is split between Kazakhstan, North America, Russia, Niger and Ukraine which accounted for 15 %, 14 %, 10 %, 5 % and 4 %, respectively, in the share of 2006 reserves (19) (OECD/IAEA, 2008).

The level of imports is determined by several factors, including the evolution of final energy demand (see also discussion in Chapter 6) as well as the efficiency of the energy system (see also discussion in Chapter 4).

The absolute level of final energy consumption in Europe was increasing, over the period from 1990 to 2005, at an average annual growth rate of 0.6 %, but accelerated especially from 1999 onwards. The final consumption of electricity rose even faster — at an annual growth rate of 1.7 % over the same period, and accelerated from 1999 onwards. One reason for high electricity consumption is that the electricity is a versatile commodity and can be used for a wide variety of energy services. Final electricity consumption in households and services is driven, to a large extent, by greater ownership of electrical appliances and IT equipment, and in industry, by the declining cost of electricity relative to other fuels (although this trend has started to reverse in more recent years). For trends in final energy and electricity consumption, see Figures 2.4, 2.5 and 2.6 (for a more

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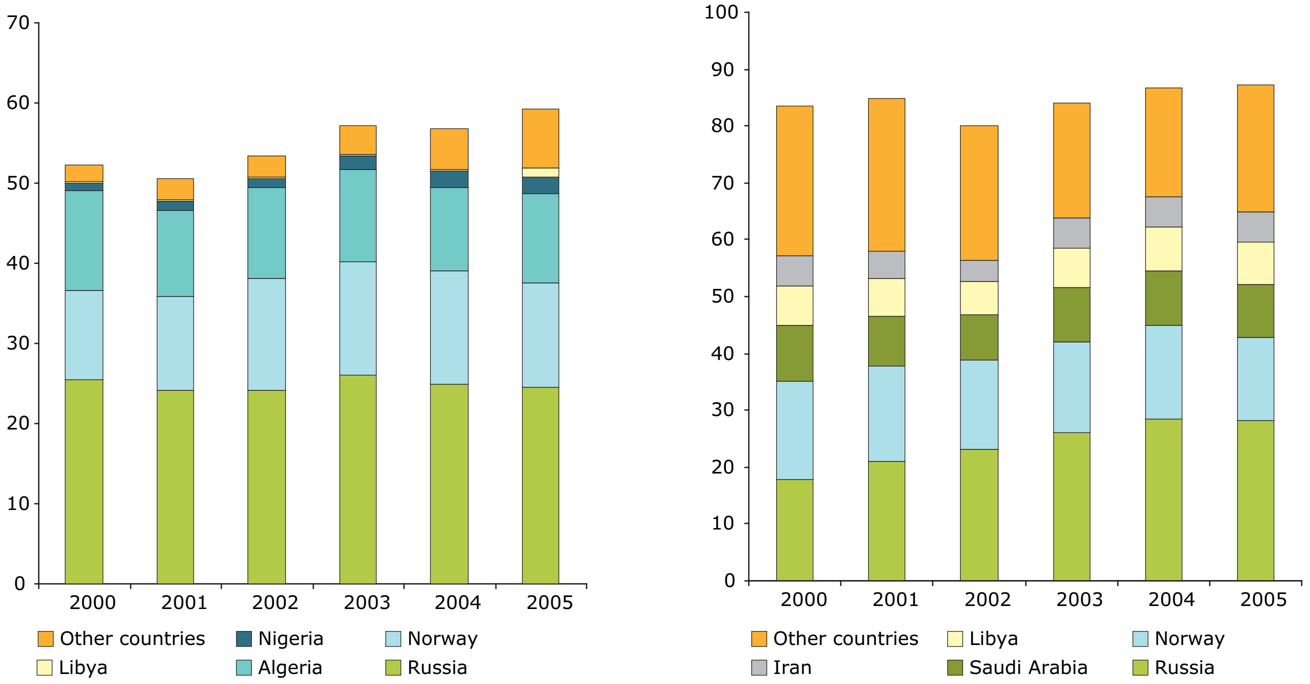
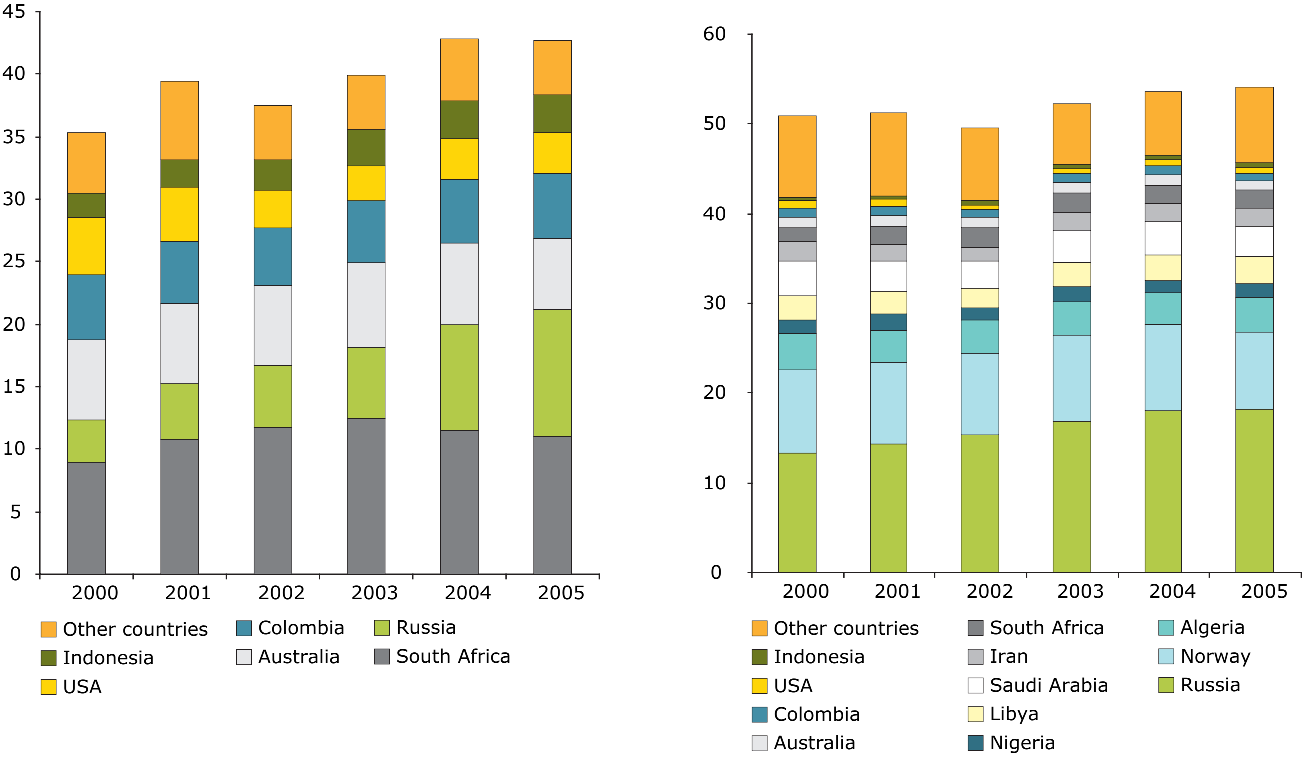
(19) Conventional uranium resources that can be mined for less than USD 130/kg. In 2006, these reserves were estimated to be about 5.5 million tonnes.

Figure 2.2 EU-27 imports of natural gas, crude oil, hard coal and the sum of these, by country of origin, as a % of primary energy consumption



Natural gas imports as a % of GIEC of gas

Crude oil imports as a % of GIEC of oil



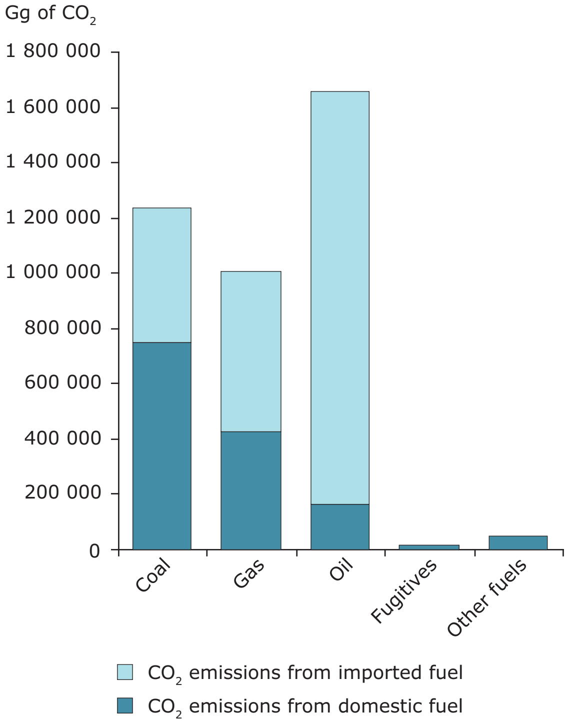
Hard coal imports as a % of GIEC of solid fuels

Natural gas, crude oil and hard coal imports as a % of total

Note: GIEC = gross inland energy consumption (or primary energy consumption).

Source: Eurostat.

Figure 2.3 **CO_2 emissions in EU-27 by fuel and by origin of the fuel (domestic vs. imported), 2005**



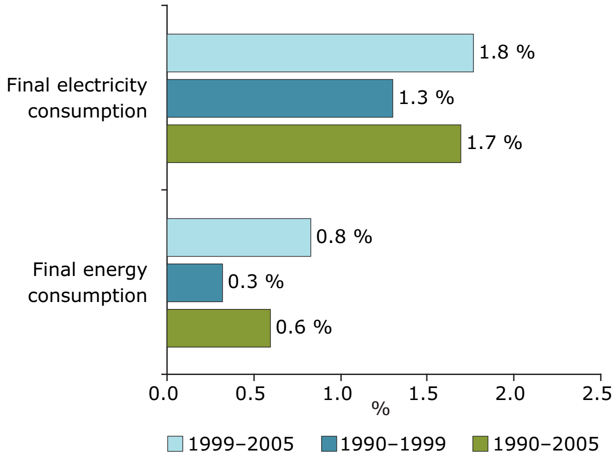
Note: The chart takes into account that different fuels have different implied emission factors. All fugitive emissions are domestic; other fuels exclude CO_2 from burning biomass in power plants.

Source: EEA.

detailed discussion of the final energy consumption trends in households, see also Chapter 6).

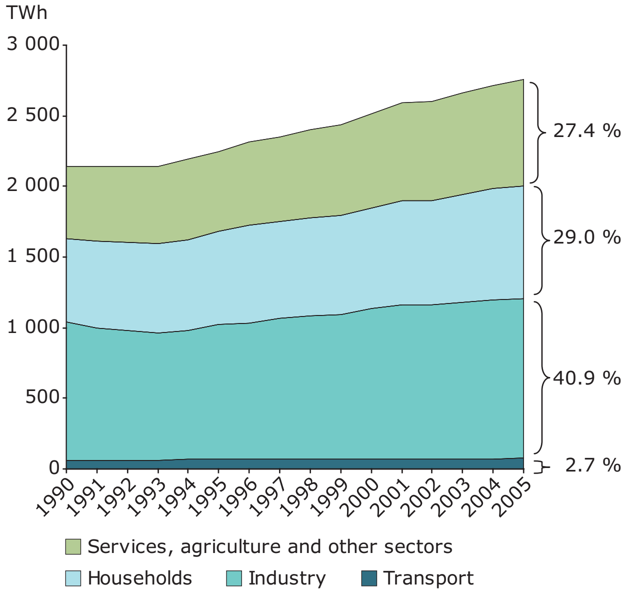
During the period from 2004 to 2005, final energy consumption in the EU-27 fell by 0.3 %, but in general, between 1990 and 2005, it increased by 9.3 %. This increase offsets, to some extent, reductions in the environmental impact of energy production (in terms of reductions in GHG emissions), reductions that were achieved because of fuel mix changes and technological improvements. Over the period, the fastest-growing sector was transport (followed by households and services), rising, on average, by 1.7 % per year. It is now the largest consumer of final energy. This trend is pushed forward by the increased ownership of cars in addition to higher volumes of freight transport and the demand for aviation. Between 1990 and 2005, final energy consumption in industry fell on average by 12.5 %, but most of this reduction occurred during the economic recession of the early 1990s.

Figure 2.4 **Average annual change in final energy and electricity consumption in EU-27, 2005**



Source: Eurostat.

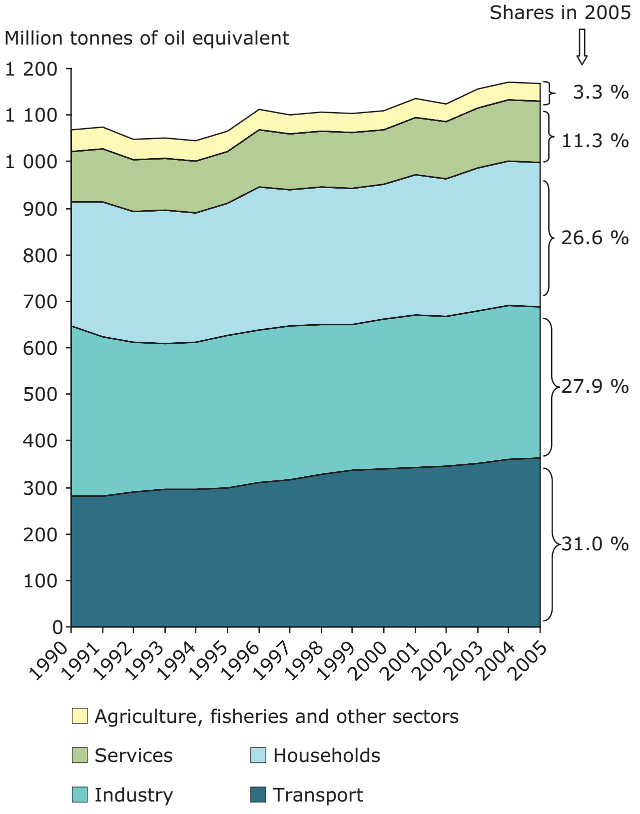
Figure 2.5 **Final electricity consumption by sector, EU-27**



Source: Eurostat.

Per capita consumption of electricity varies greatly from country to country, with the lowest per capita consumption occurring in some new Member States as well as southern European countries (Romania, Lithuania, Latvia, Poland, Hungary and Portugal). Although the use of air conditioning in southern European countries contributes to a large increase in electricity consumption during the summer months, the highest consumption per capita was registered in the most northerly countries with

Figure 2.6 **Final energy consumption by sector, EU-27**



Source: Eurostat.

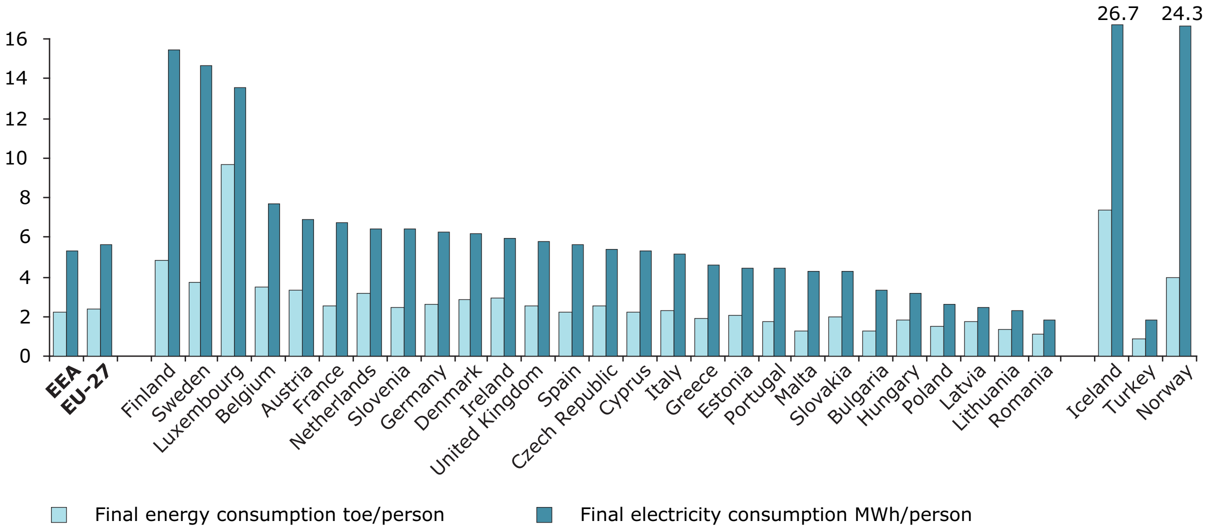
the coldest climate (Norway, Iceland, Sweden and Finland). In these countries, a large part of the overall heating requirements is met by electrical heating in combination with other, mostly renewable, energy sources for heat production. The average electricity use per capita in the EU-27 is almost 2.5 times the global average.

2.2 Has there been a switch in the energy fuel mix?

Over the period of 1990–2005, total primary energy consumption was increasing by an average of 0.6 % per year, but accelerated from 1999 onwards (see Figure 2.8). Throughout the period, renewables, nuclear and natural gas experienced a steady average annual growth within overall consumption. The share of coal in the total primary energy consumption decreased over that period, but in recent years the trend has been reversed. The increase in the share of oil in the total primary energy consumption slowed down in recent years — due to a decrease in its use in electricity generation and, possibly, the early impacts of the voluntary agreement of vehicle manufacturing associations on CO_2 reductions.

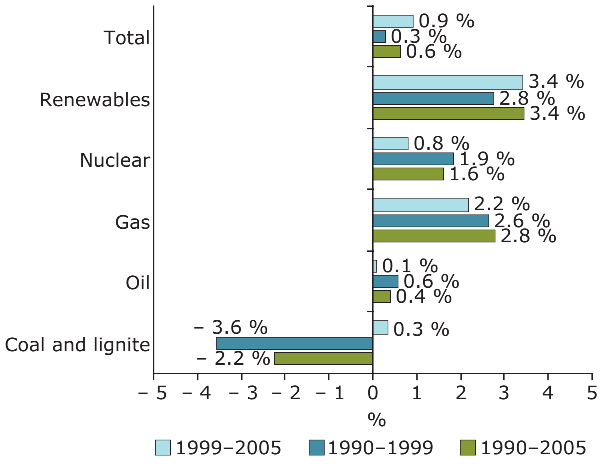
Between 1990 and 2005, the share of fossil fuels in total energy consumption declined only slightly: from around 83 % to 79 % (see Figure 2.9). Nevertheless, the environment benefited from a major change in the fuel mix. This was due, mainly, to fuel switching in power generation — with coal losing about one third of its market share, being replaced by relatively cleaner natural gas, which now has a 24 % share in total primary energy consumption. However, from 1999 onwards, the use of coal picked up again

Figure 2.7 **Final energy and electricity consumption per capita, 2005**



Source: EEA; Eurostat; IEA.

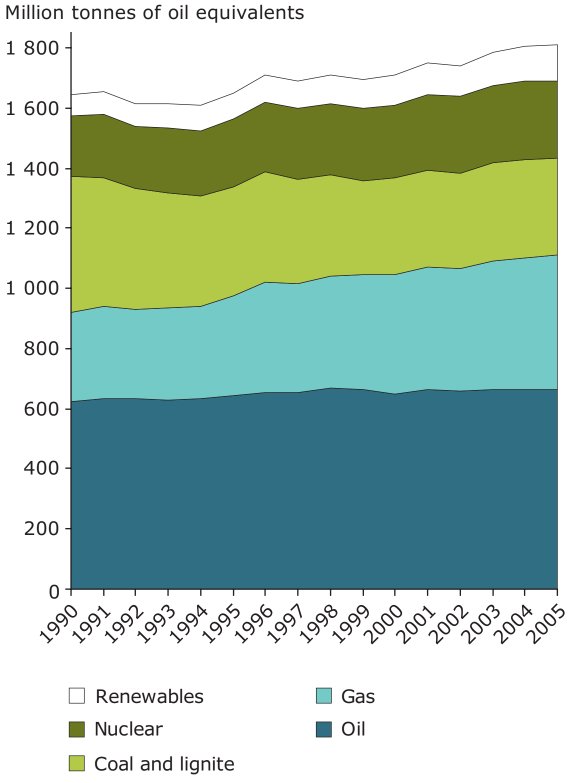
Figure 2.8 Average annual change in total primary energy consumption by fuel, EU-27



Source: Eurostat.

— due to a recent rise in gas prices and increased concerns over security of supply.

Figure 2.9 Total primary energy consumption by fuel, EU-27

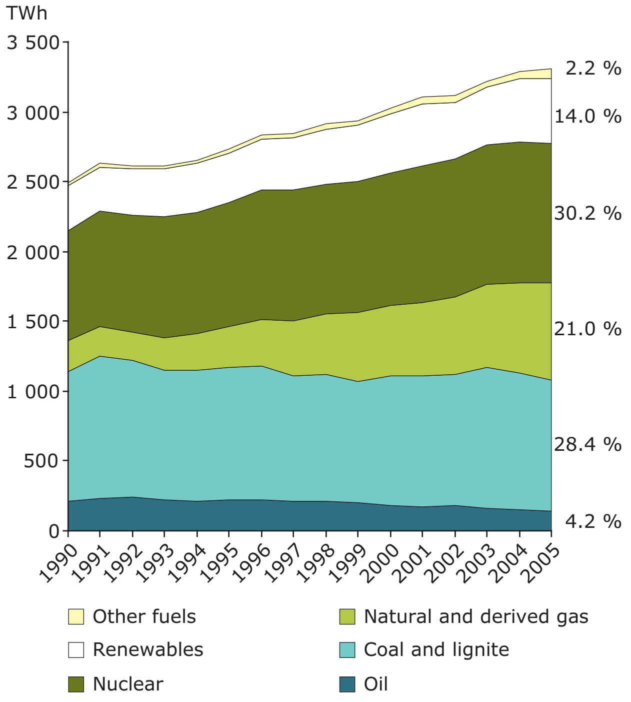


Source: Eurostat.

In 2005, oil accounted for around 37 % of total energy consumption and continued to be the major source of fuel in the transport sector. Its increased use, starting from 1990, was mainly a result of the increased demand for petrol and diesel within the transport sector, although this was partly offset by a lower level of its use within the power generation sector.

Renewable energy started from low levels and, despite increased support at both the EU and national level, its contribution to total energy consumption remains low — 6.7 % of the primary energy consumption in 2005.

Figure 2.10 Electricity production by fuel, EU-27



Note: Data shown are for gross electricity production and include electricity production from the both public plants and auto-producers. Renewables include electricity produced from hydro (excluding pumping), biomass, municipal waste, geothermal, wind and solar PVs. The share of renewables presented in the chart is that for production and, hence, does not correspond to the share for consumption, as required by Directive 2001/77/EC. The difference between both shares is accounted for by the net balance between imports and exports of electricity. The EU-27 value for 1990 includes (former) West Germany, only and since 1991 does it refer to Germany. More than half of the increase in electricity generation in the EU-27 in 1991 was accounted for by Germany alone, compared to just 10 % over the period of 1991–2005. 'Other fuels' include electricity produced from power plants not accounted for elsewhere, such as those fuelled by certain types of industrial waste. It also includes the electricity generated from hydropower plants.

Source: Eurostat.

The share of nuclear power is growing slowly, amounting to around 14.2 % of total primary energy consumption in 2005. This increase was less rapid than during the 1980s, as fewer new nuclear plants were commissioned, while older plants were decommissioned.

The switch towards less polluting fuels occurred mainly in power production (see Figure 2.10). It was driven by a combination of factors including market liberalisation, an extended gas infrastructure and environmental legislation. Due to competitive pressures introduced in the market by the liberalisation process, gas-fuelled technologies were preferred in the 1990s — because of lower fuel price, flexibility and lower investment costs. Overall, these changes resulted in reduced emissions of greenhouse gases and acidifying substances (as highlighted in Sections 1.1 and 1.2). However, continuing increases in energy consumption have offset some of these improvements.

Within the EU-27, electricity produced from nuclear fuels from the 1990s through to 2005, in absolute terms, continued to grow. Nevertheless, it grew at a slower rate than the total electricity production. This meant that its share of total production fell slightly — to 30.2 % in 2005. More recently, environmental concerns as well as concerns over security of supply and high prices for energy led to a new debate in Europe over the prospects of nuclear power.

Another important contributor to the electricity production came from renewable sources, whose share grew, over the period, to reach 14 % in 2005. The drop in 2002 and 2003 was due primarily to low hydroelectricity production from lower than average levels of rainfall. Coal and gas maintain a high share in electricity production — about 50 %, with natural gas increasing at a fast pace.

2.3 Scenarios

Baseline (reference) scenarios show a rising dependence on imports for most fossil fuels, although this is particularly relevant for gas, with imports (as a percentage of primary energy consumption) rising from around 59 % in 2005 to up to 84 % by 2030.

Even under more stringent energy and climate policy scenarios — reflected here in the GHG reduction scenario from POLES, or alternative policy scenario from WEM — the percentage of gas imports (the picture for oil is similar) still rises within the total primary energy consumption. Improvements in the energy efficiency and the penetration of renewables occur more rapidly in these latter scenarios — but the positive effect is more than offset by the decline in the EU's indigenous fossil production (meaning that the higher demand for energy will be met through imports of fossil fuels). Under these latter scenarios, the share of coal imports starts to decline as its share in the electricity generation reduces gradually, given tighter emissions reduction targets and higher carbon prices.

Table 2.1 Net EU-27 imports as a percentage of primary energy consumption (excluding nuclear)

Type	Actual	(IPTS) POLES 2006				(IEA) WEO 2007				(EC) PRIMES 2008	
		Baseline (%)		GHG reduction (%)		Reference		Alternative policy		Baseline (%)	
	2005	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030
Coal and lignite	0.0 %	44	47	40	41	n/a	n/a	n/a	n/a	58.5	62.5
Oil	0.0 %	87	92	86	93	n/a	n/a	n/a	n/a	101	103
Gas	0.0 %	74	79	73	76	n/a	n/a	n/a	n/a	77	84
Imports-exports of electricity (% of final consumption)	0.9 %	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.3	0.3
Total primary energy consumption	0.0 %	52.5	51.7	49.0	46.3	n/a	n/a	n/a	n/a	66.0	68.4

Note: Net imports from PRIMES model are calculated here as a percentage of primary energy consumption. Bunkers are not included.

Source: IPTS, 2006; IEA, 2007a; EC, 2008f.

3 How rapidly are renewable technologies being implemented?

Main messages

Renewable energy technologies usually have less environmental impacts than fossil fuel, although some concerns exist with respect to the environmental sustainability of particular types of biofuels. In recent years, they have accomplished high rates of growth but further action is necessary to achieve the proposed 2020 goals.

1. In 2005, renewable energy accounted, for 6.7 % of total primary energy consumption in the EU-27 — compared to a share of 4.4 % in 1990. Over the period, the share of renewable energy in final consumption has also increased from 6.3 % in 1991 to 8.6 % in 2005.
2. Wind power remains dominant, representing 75 % of the total installed renewable capacity in 2006 (excluding electricity from large hydropower plants and from biomass). The strongest growth took place in Germany, Spain and Denmark — which accounted for 74 % of all installed wind capacity in the EU-27 in that year. In the same year, Germany alone accounted for 89 % and 42 % of the installed solar photovoltaics and the solar thermal systems, respectively.
3. The share of renewables in the final energy consumption varies significantly across countries: from over 25 % in Sweden, Latvia and Finland to less than 2% in the United Kingdom, Luxembourg and Malta. Newer Member States showed the most rapid growth in shares, with increases of over 10 percentage points in Estonia, Romania, Lithuania and Latvia.
4. From 1990 to 2005, electricity production from renewables increased in absolute terms (an average of 2.7 % annually), but a significant growth in electricity consumption partially offset the positive achievement limiting the RES share in gross electricity consumption to only 14.0 % in 2005.

Baseline (reference) scenarios from POLES, WEM and PRIMES models show that the share of renewables in primary energy consumption is expected to increase, to a value between 10 % in 2020 and 18 % in 2030. In scenarios where more stringent policies to reduce GHG emissions, and promotion of RES and energy efficiency are assumed, higher shares of renewables in primary energy consumption are envisaged ranging from 13 % in 2020 to over 24 % in 2030. The rising share is also supported by more rapid improvements in energy efficiency, which reduces the absolute level of energy consumption. The estimations vary significantly depending on the model used and the specific scenario chosen, since various scenarios make different assumptions about costs for the various technologies, the carbon prices and the speed of improvements in energy efficiency.

Achieving the proposed new target for renewable energy will require a substantial effort, to fill the gap between the current levels (8.5 % in the final energy consumption in 2005) and the objective of 20 % of renewable energy in the final energy consumption in 2020. To meet the proposed targets, 15 Member States will have to increase their national share of renewables in the final energy consumption by more than 10 percentage points compared to 2005 levels. Substantially reducing final demand for energy will help Europe achieve the target for renewables.

3.1 Renewable energy deployment

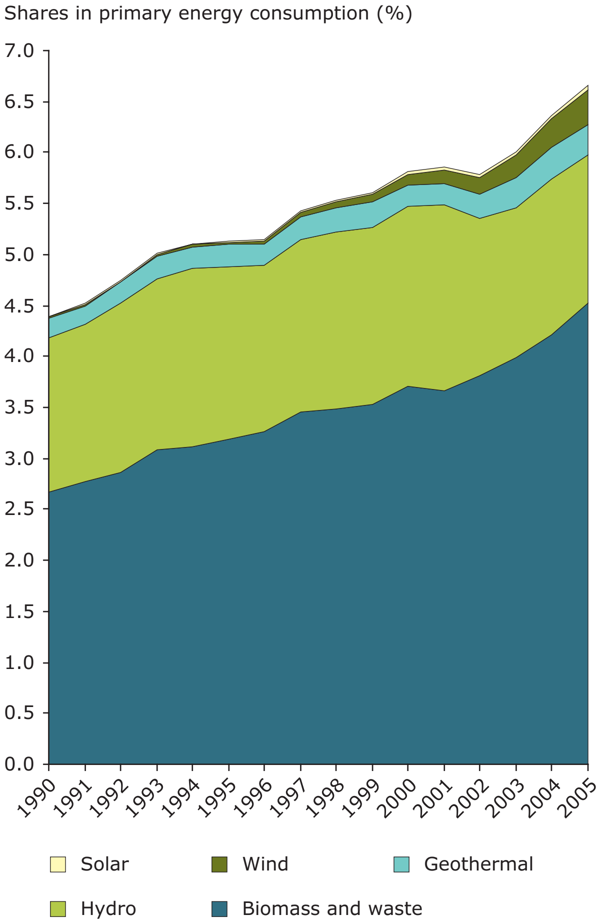
A number of directives on renewable energy are already in place, including the Directive on the promotion of electricity from renewable energy sources (EC, 2001b) and the Directive on the promotion of biofuels (EC, 2003b). In addition, new policies are likely to emerge at national level after the adoption of the climate change and energy package proposed by the Commission in January 2008, which includes an overall 20 % target for renewables in the final energy consumption. It has been recognised that achievements in deploying renewable energy technologies depend largely on the natural endowments and the specific socio-economic circumstances of each Member State. The new proposed EU policy on the promotion of renewable energy, therefore, leaves it to up to the

Member States to decide how to split their national target between the heat and the electricity sector.

The share of renewable energy sources in primary energy consumption in the EU-27 increased slowly — from 4.4 % in 1990 to 6.7 % in 2005. This development led to a reduction in CO_2 emissions (see Figure 1.8 in Chapter 1). However, rising overall energy consumption in absolute terms has counteracted some of the environmental benefits from the increased use of renewables. The strongest increase came from wind and solar energy. In absolute terms, about 80 % of the increase came from biomass. Despite good progress, significant growth will be needed to meet, by 2010, the indicative target for the EU of a 12 % share of renewables (of primary energy consumption).

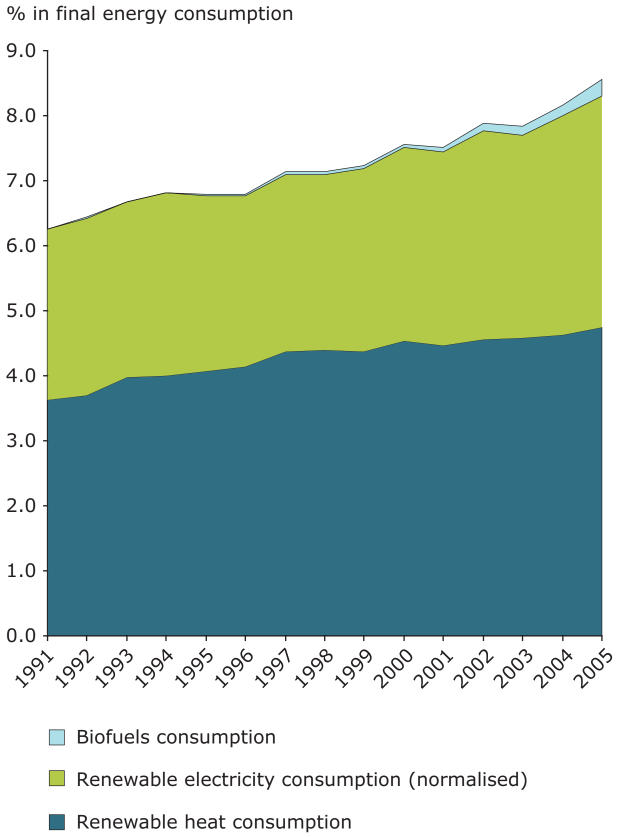
Having in place a sound policy framework, with clear timetables and goals, is also helpful in providing the investor community with the right signal. For example, in Denmark almost all the renewable energy is generated from wind and biomass. This development was supported by a combination of taxes and subsidies that favoured renewables over fossil fuels. Today, renewables make up for 16 % of primary energy consumption in Denmark. Germany's strong growth in wind energy was largely due to a favourable feed-in tariff. Latvia, Finland and Sweden have particularly high contributions from biomass and waste, with a total share of renewables in primary energy consumption of 36 %, 23 % and 30 % respectively. In Latvia, this is due to the large availability of low-cost wood and wood-wastes for heating (EREC, 2004). In Sweden, specific policy support such as taxation to favour non-fossil fuels was introduced in the early 1990s, along with grant support for biomass-fuelled CHP and district heating plants (Johansson, 2001). These

Figure 3.1 **Contribution of renewable energy sources to primary energy consumption in the EU-27**



Source: Eurostat.

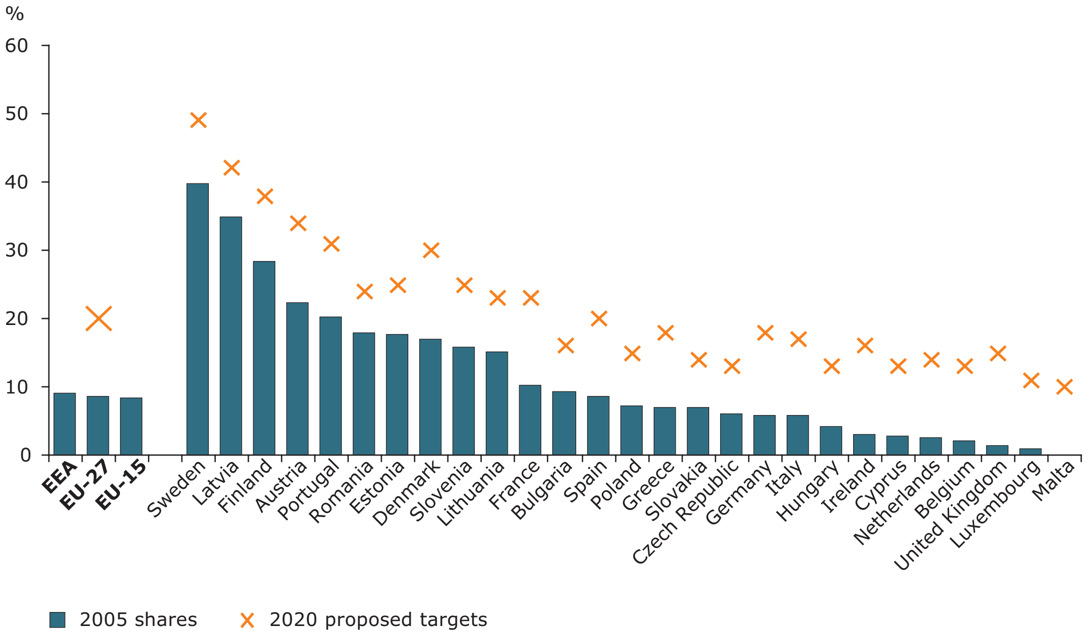
Figure 3.2 **Contribution of renewable energy sources to final energy consumption in the EU-27**



Note: Hydropower was calculated according to the new methodology proposed in the CARE package (15-year average). It is important to note that the final methodology may be subject to further changes.

Source: Eurostat.

Figure 3.3 Renewables as a % of final energy consumption by Member State (2005 data)



Note: The targets proposed in EC (2008) are provisional and may be subject to change.

Source: Eurostat.

support measures stimulated strong growth in the installed capacity, with Germany and Spain leading the way in the new wind capacity, and Germany and Sweden — with the largest installed capacities of solar thermal and heat pump technology, respectively (see Figure 3.6).

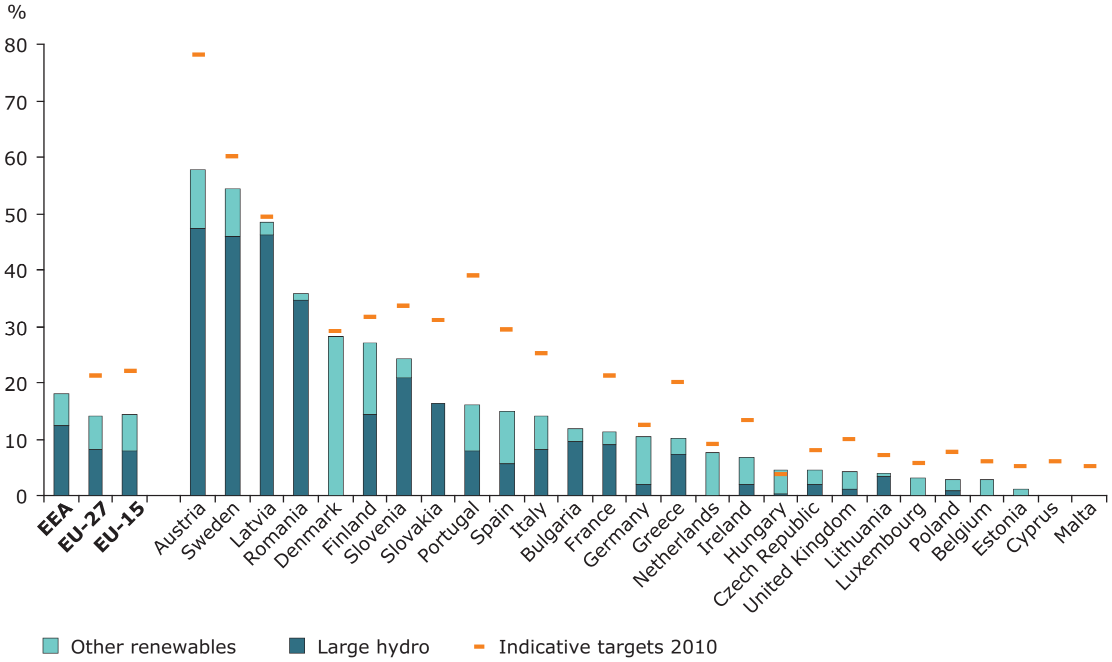
The share of renewable energy sources in final energy consumption has been increasing steadily since 1990 and reached 8.6 % in 2005. Developments concerning renewable heat were driven largely by the increased use of biomass in CHP and, to a lesser extent, solar thermal and heat pump technology. The share of biofuels in road transport fuels only started to rise significantly from 2000 onwards, in response to new EU targets (EC, 2003b).

The percentage of renewables in the final energy consumption varied between countries: from almost 40 % in the case of Sweden — to almost zero at the bottom end of the scale. However, this overview masks the notable progress made across the Member States from 1991 onwards. For instance, over this period, Latvia, Lithuania, Romania and Estonia — all of them increased their absolute share by over 10 %. Ten Member States doubled their share in the final energy consumption, with Bulgaria, Czech Republic, Slovakia, Cyprus and Lithuania increasing their share by over a factor of four, albeit starting from a relatively low base. However, from 1991 to 2005, the shares in a small number of Member States actually declined — due, primarily, to a combination of the rapidly rising final energy consumption and fluctuations in the production of hydropower due to lower rainfall.

Large hydropower (> 10 MW) continues to dominate renewable electricity production in most Member States, accounting, in 2005, for approximately two thirds across the EU-27. This compares to 17 % from biomass and waste, 15 % from wind and the rest from geothermal (1.2 %), and solar (0.3 %). There are significant differences in the share of renewables between the EU-27 Member States. Amongst the EU-27 in 2005, Austria, Sweden and Latvia had the greatest shares of renewable electricity in their gross electricity consumption, including large hydropower. Denmark shows the largest share of renewable electricity when large hydropower is excluded.

Growth in most forms of renewable energy accelerated especially after the year 2000. Growth in solar PV was driven largely by developments in Germany, and for geothermal by the developments in Sweden and Germany (due to large installations of heat pumps). Growth in wind slowed after 2000, as the emphasis began to shift from onshore

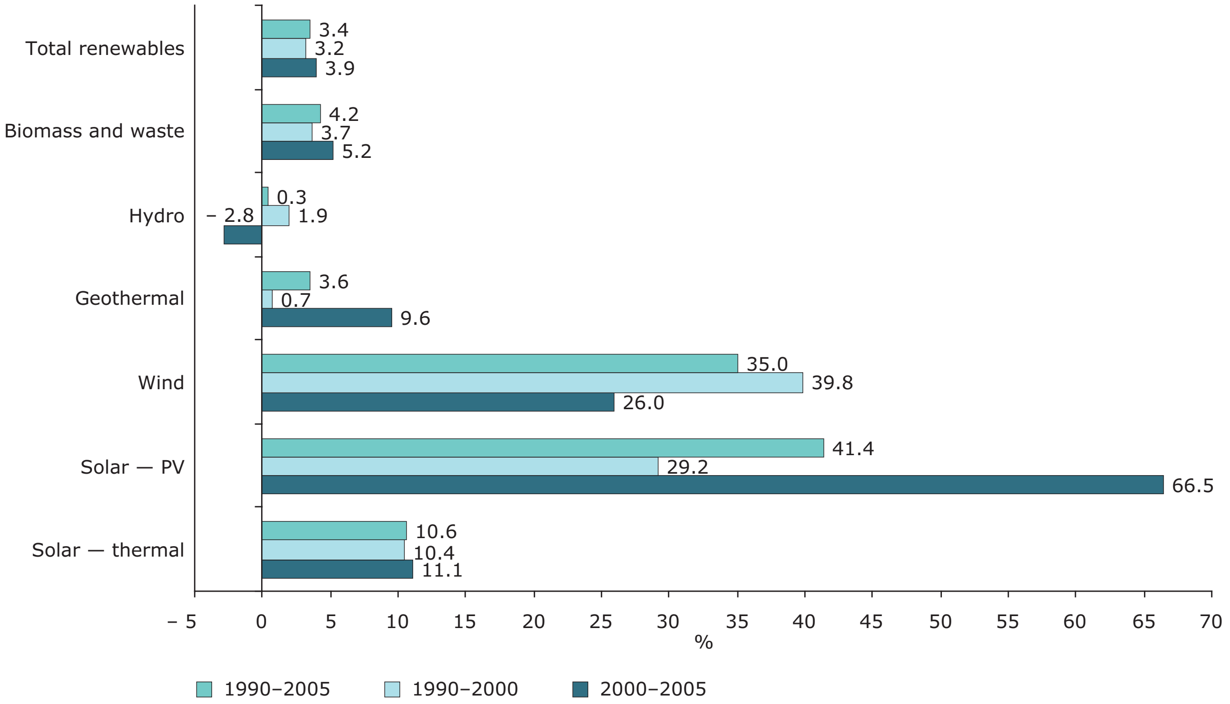
Figure 3.4 Renewable electricity as % of gross electricity consumption (2005 data) EU-27



Note: The Renewable Electricity Directive (2001/77/EC) defines renewable electricity as the share of electricity produced from renewable energy sources in total electricity consumption. The latter includes imports and exports of electricity. The electricity generated from pumping in hydropower plants is included in the total electricity consumption but is not included as a renewable source of energy.

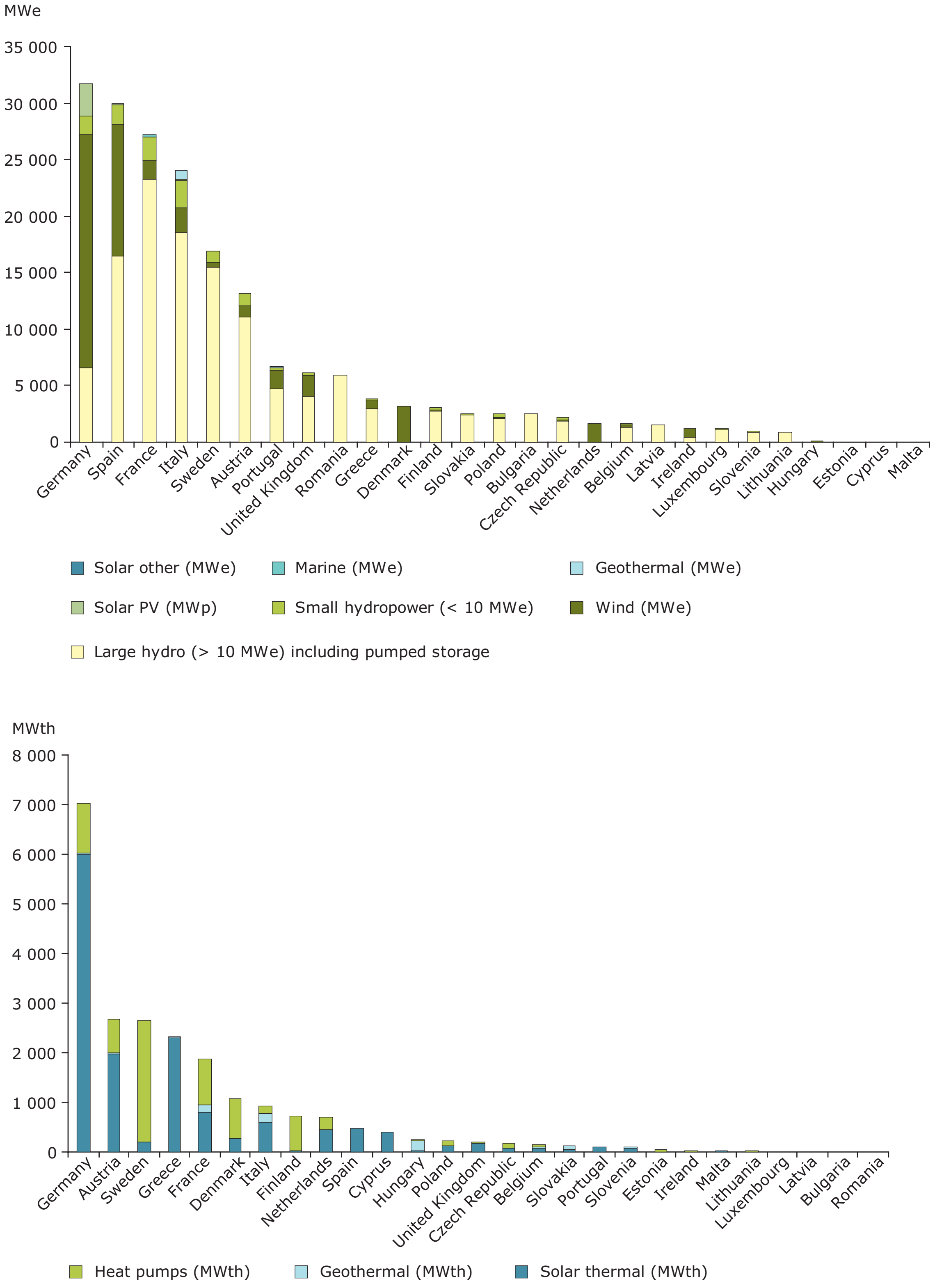
Source: Eurostat.

Figure 3.5 Annual average growth rates in primary renewable energy consumption, EU-27



Source: Eurostat.

Figure 3.6 Total installed electrical and thermal capacity for RES sources, 2006



Note: Data for large hydro is for 2005.

Source: Eurostat; EurObserver'ER (2008).

development (where the most favourable sites have already been explored in countries that are driving the European trend, such as Germany and Denmark) to more expensive and complex offshore wind projects. Hydro consumption declined in recent years — due to climate change (lower than average rainfall), rather than changes in installed capacity.

The total installed wind power capacity in the EU-27 in 2006 was about 48 000 MW. Germany has the largest total installed capacity, although the annual growth rate of new installed capacity has declined in recent years. Spain has the second largest installed wind capacity, but plans to change the legislative framework, since increasing electricity prices (lower support and a cap on the price of electricity coming from wind) might lead to lower increases in future installed wind power capacity. While Germany, Spain and Denmark remain the frontrunners — with installed capacities of 20 622 MWe, 11 615 MWe and 3 135 MWe respectively, they are no longer the only countries installing large wind power capacities. Other countries, such as France, the United Kingdom, Ireland, Netherlands and Portugal, are catching up.

The market for solar PV remains heterogeneous and strongly dependent on developments in Germany. Germany remains also a world leader in manufacturing solar cells — far ahead of Japan and USA. The German success is largely due to a stable and favourable policy framework. Spain has good natural circumstances for solar PV and good market conditions for solar development. Its feed-in-tariff is flexible, calculation being based on the average electricity price. For installations smaller than 100 kW, the support would be 5.75 times the average electricity price on the market, and for installations above 100 kW, the support will amount to three times the average electricity price.

As for small hydro, its development in 2006 was limited by a number of regulatory and environmental constraints, driven by the Water Framework Directive. In Germany, for instance, as of 31 December 2007, the feed-in-tariff for small hydro installations with a capacity of less than 500 kW, shall only apply to installations on flowing water that can demonstrate they have achieved a satisfactory ecological state of the water body in question (20).

Marine energy is slowly gaining in importance in Europe and elsewhere. Today, 90 % of the world's tidal power is produced in France, at the Rance Tidal Power Plant (240 MW) commissioned in 1966. Portugal and the United Kingdom have some projects planned. In 2005, there was created the Ocean Energy Association. Its objective is to support the development of the ocean energy technology and market and to act as a central point for its members for information on technological experiences and EU financial resources (21). Recently, the European Marine Energy Centre (EMEC) decided to use modelling technologies to study water levels, currents and waves at its test sites in the Orkney Islands located north-west of Scotland, United Kingdom. The task is to work out a sufficient resolution for the complex tidal channels and local topographic features (22).

In 2006 — compared to 2005, geothermal electricity increased by 10 MW, reaching the volume of about 855 MW. Italy remains the largest producer — with a total installed capacity of about 810 MW. Portugal and France have a significantly lower capacity for installed geothermal electricity but more geothermal heat. Some 16 European countries have either some geothermal electricity or heat capacity installed. The total installed capacity of geothermal heat was 2 236.3 MWth — up 5.2 % in 2006 compared to 2005.

In recent years, solar thermal also picked up, with Germany continuing to have the largest market (with more than 1.5 million m^2 installed in 2006). This development was taking place even at a time when subsidies for solar heating more than halved (from EUR 104/m^2 before 21 March 2006 — to EUR 40/m^2 at the beginning of January 2007). Despite this subsidy reduction, for a number of reasons the market continued to grow. Those reasons include difficulties in securing gas supplies from Russia, concerns over increasing energy prices and increased awareness of climate change (23). Although far behind Germany, France also experiences strong growth in solar thermal. With some 300 000 m^2 in 2006, the French solar thermal market increased by some 83.1 % compared to 2005.

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(20) EurObserv'ER, 2007.

(21) For information see http://www.spok.dk/seminar/eu-oea_0702_neet_1a.pdf.

(22) http://social.tidaltoday.com/content/emec-opts-mike-modelling-technology; article published on 16 July 2008.

(23) See Supra Note 20.

3.2 Scenarios

The share of renewables in the primary energy consumption is expected to increase under all baseline (reference) scenarios and much more rapidly under the scenarios envisaging GHG reduction or an alternative policy. In the scenarios that assume adoption of more stringent policies to reduce GHG emissions and promotion of RES and energy efficiency, the rising share of renewables is also supported by more rapid improvements in energy efficiency because it reduces the absolute level of energy consumption. However, the scenarios from the models considered here vary quite widely. The variations are in terms of levels of the RES penetration in the primary energy consumption, which, even under the baseline (reference) scenarios, is ranging from just under 7 % in 2005 to around 10–15.5 % by 2020. These variations are caused by different assumptions about costs for the various technologies, the carbon prices and the speed of improvements in energy efficiency. The share of renewables in the gross electricity generation is expected to grow, too — primarily through deployment of new wind, solar and biomass capacity.

Table 3.1 Scenarios of share of renewables, EU-27

Type	Actual	(IPTS) POLES 2006				(IEA) WEO 2007				(EC) PRIMES 2008	
		Baseline (%)		GHG reduction (%)		Reference (%)		Alternative policy (%)		Baseline (%)	
	2005	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030
Share in primary energy consumption — of which	6.7	15.5	18.1	18.1	24.3	12.5	15.3	13.3	17.4	10.0	11.8
Hydro	1.5	n/a	n/a	n/a	n/a	2.0	1.9	1.9	1.9	n/a	n/a
Biomass and waste	4.5	n/a	n/a	n/a	n/a	8.1	9.6	8.6	10.6	n/a	n/a
Other renewables	0.7	n/a	n/a	n/a	n/a	2.5	3.8	2.9	4.8	n/a	n/a
Share in gross electricity generation *	14.0	18.8	21.7	23.1	31.1	25.0	29.1	30.1	38.4	20.2	22.8
Hydro	9.3	9.1	8.1	10.4	10.3	10.4	9.8	11.7	11.9	8.2	8.0
Wind	2.1	n/a	n/a	n/a	n/a	9.1	12.5	11.6	16.9	6.6	7.8
Biomass and waste	2.4	n/a	n/a	n/a	n/a	4.4	4.9	5.7	6.6	4.8	6.4
Geothermal heat	0.2	n/a	n/a	n/a	n/a	0.2	0.3	0.3	0.5	0.2	0.2
Solar, tidal wave etc.	0.0	n/a	n/a	n/a	n/a	0.7	1.5	0.9	2.5	0.3	0.5
Share in final energy consumption	8.6	n/a	n/a	n/a	n/a	6.6	8.1	8.1	11.2	12.7	14.7
Share in biofuels	1.1	n/a	n/a	n/a	n/a	1.4	2.1	1.9	2.9	7.4	9.5

Note: * Net electricity generation for (IPTS) POLES (2006) scenarios.

Source: EEA; Eurostat; IPTS, 2006; IEA, 2007a; EC, 2008f.

4 Is the European energy production system becoming more efficient?

Main messages

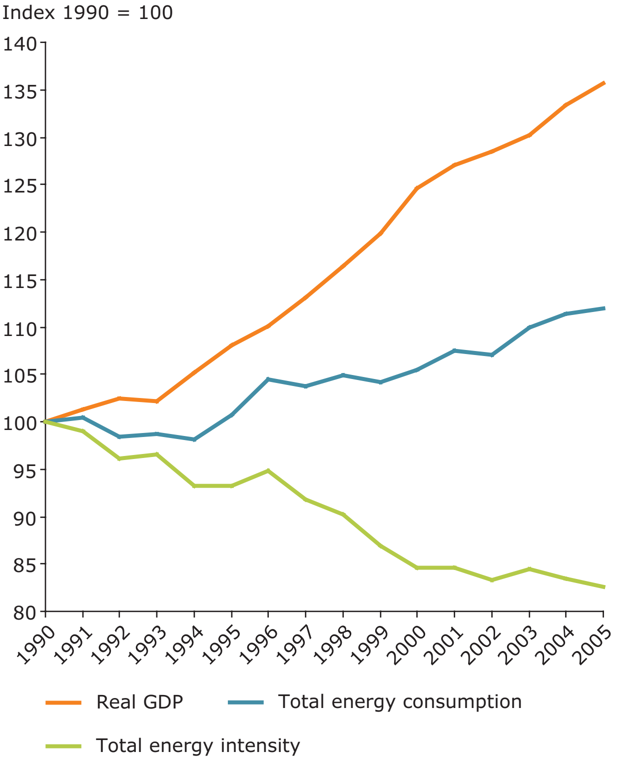
Increasing the European energy system's efficiency can reduce environmental effects and dependence on fossil fuels and can contribute to limit the increase in energy costs. Whilst in recent years, the efficiency of energy production has increased, the potential for further improvement is still significant, for example, through a greater use of combined heat and power and other energy-efficient technologies that are already available or close to commercialisation.

1. Between 1990 and 2005, the total energy intensity (total energy divided by GDP) in the EU-27 decreased by an estimated 1.3 % per annum. The energy intensity decreased three times faster in the new Member States.
2. Over the period of 1990–2005, the average level of efficiency in the production of electricity and heat by conventional public thermal plants improved by around 4.2 percentage points, reaching 46.9 % (48.5 %, if district heating is also included) in 2005.
3. Some 25 % of the primary energy is lost in generation, transport and distribution of energy. The largest share in the energy losses occurs in generation (around 3/4 of total losses), hence, the urgent need to deploy available state-of-the-art technologies.
4. In 2005, the share of electricity generated from combined heat and power (CHP) plants, in total gross electricity production in the EU-27, was 11.1 %. CHP can be a cost-effective option to improve energy efficiency and reduce CO_2 emissions. It could be further enhanced in the EU.

4.1 Efficiency of energy production

From 1990 to 2005, the total primary energy consumption in the EU-27 was growing at an annual rate of 0.8 %, while Gross Domestic Product (GDP) was increasing at an estimated average annual rate of 2.1 %. As a result, the total energy intensity in the EU-27 was falling at an average rate of 1.3 %

Figure 4.1 Trends in total energy intensity, gross domestic product and total energy consumption, EU-27



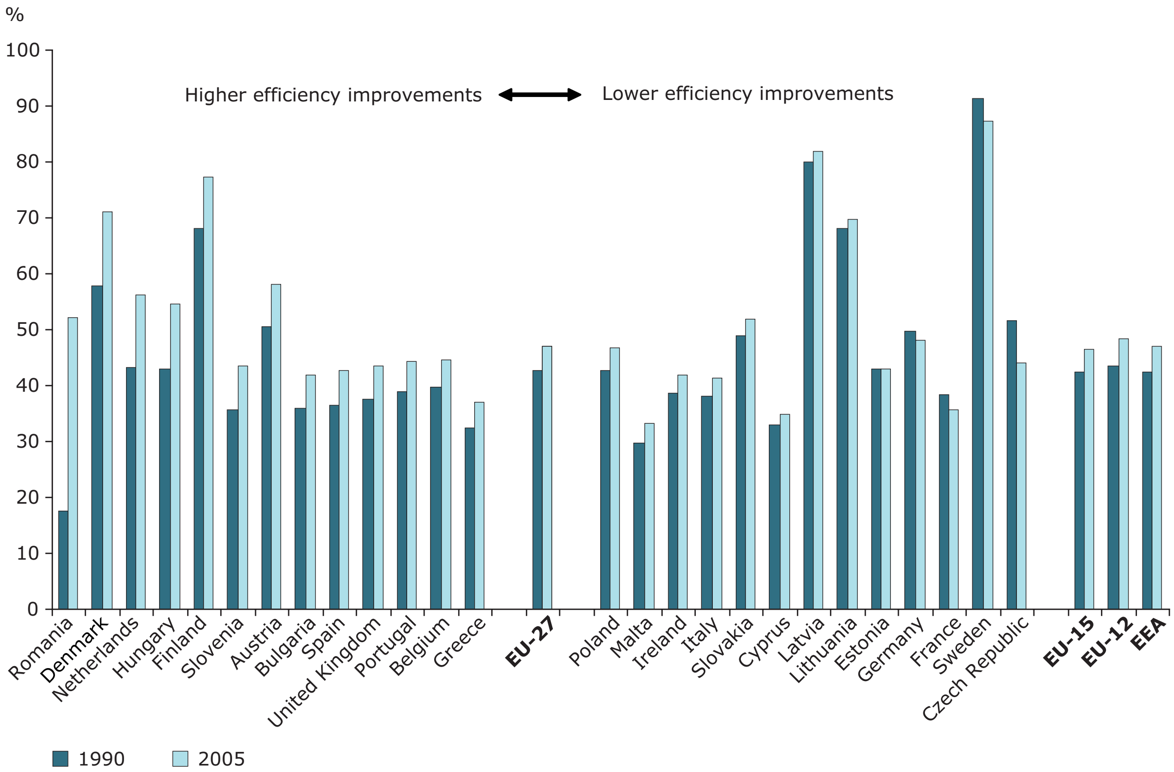
Note: To compute the EU-27 GDP index in 1990, it was necessary to make some assumptions. No Eurostat data were available for the new Member States: Czech Republic (1990–1994), Bulgaria (1990), Romania (1990–1998), Cyprus (1990–1994), Hungary (1990), Poland (1990–1994), Malta (1991–1998) and Germany (1990). To fill in the gaps, use was made of the European Commission's annual macroeconomic database (AMECO) as an additional data source, although this could not be done in all cases. To estimate the EU-27 aggregate, the following assumptions were made: GDP in Germany in 1990 has been estimated by applying the 1990–1991 growth rate in West Germany to the 1991 GDP in Germany. The Commission's forecasts for the autumn of 2004 were used for the GDP in 1990 in Hungary. For Estonia, the GDP in 1990–1992 is assumed as a constant value (in real terms), the value taken was that observed in 1993. For Slovakia, the GDP in 1990–1991 is assumed to have the value of 1992. For Malta and Bulgaria, the GDP in 1990 is assumed to be equal to the GDP in 1991. These assumptions do not distort the trend observed for the GDP of the EU-27 as a whole, since the latter four countries represent about 0.7 of the total GDP of the EU-27.

Source: Eurostat and Ameco database, European Commission.

per year. In Europe, in 2005, each unit of economic output required about 17 % less energy than used to be the case in 1990. Thus, there has been a relative decoupling between economic growth and energy consumption. Since energy is generated from different fuels, the impacts on the environment produced by changes in energy intensity have to be viewed in a wider context, taking into account the fuel mix used in each country. An average EU citizen uses 3.7 tonnes of oil equivalent per year, although this varies widely from country to country.

The efficiency of production of both electricity and heat from conventional public thermal power plants was improving, between 1990 and 2005, at a steady rate. This was due to the closure of old inefficient plants, improvements in existing technologies and the installation of new, more efficient technologies, often combined with a switch from coal power plants to more efficient combined-cycle gas turbines. Overall, the average efficiency tends to be higher in the EU-12 and Scandinavia compared to the EU-15 (48.3 % versus 46.5 %). This is due to a greater use of waste-heat output in industry. Over the same period, a number of countries — such as the Czech Republic and Germany — have shown a slight decrease in efficiency. Closer examination of the trend reveals a sharp fall in efficiency during the period of economic transition in the early 1990s, such as reunification of Germany, where there was a lower utilisation of plants, particularly for electricity production (24). However, in these countries, as well as Sweden and France, the drop over the whole period is primarily due to the lower

Figure 4.2 Efficiency (electricity and heat) production from public conventional thermal plants, 1990 and 2005



Note: Efficiency is defined as output divided by total fuel input to public conventional thermal plants. Here, output consists of both gross electricity generation and any heat sold to third parties (combined heat and power plants) by conventional thermal public utility power stations (excluding district heating). Due to inconsistencies in the Eurostat data set regarding public production in Luxembourg (input data are registered, output data are zero in 1990) and Norway (efficiencies > 100 %), these data are excluded from the figure.

Source: Eurostat.

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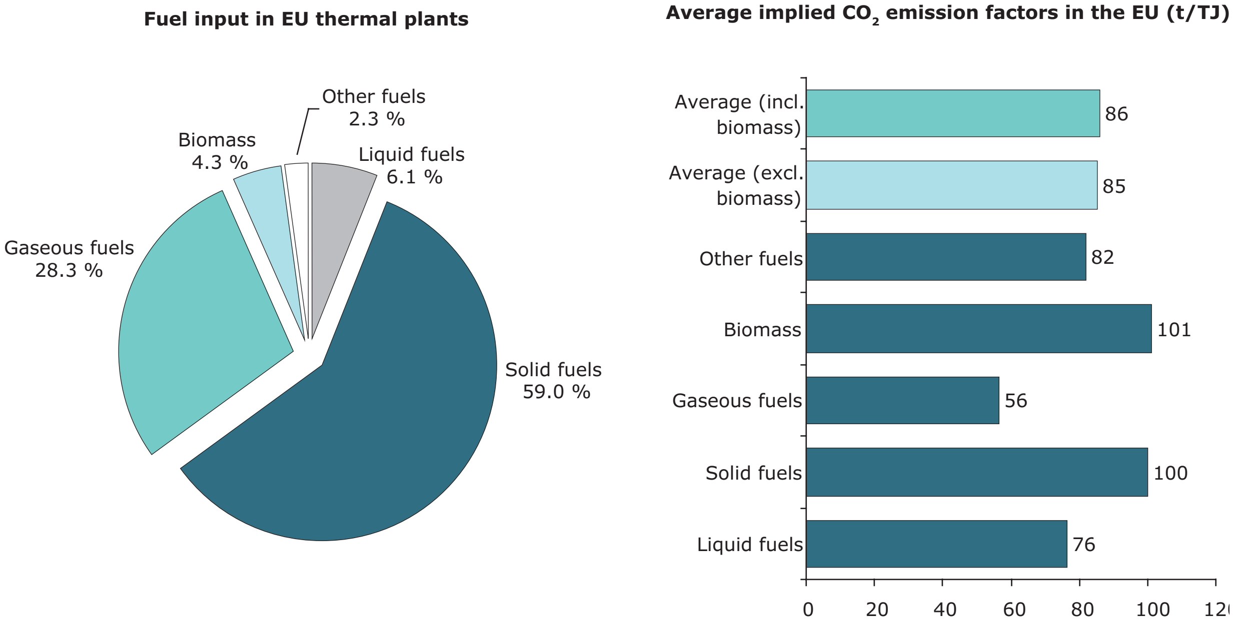
(24) The reunification of Germany had some positive effects on the overall efficiency in the system — due to replacements of the old coal-fired power plants in Eastern Germany. For a more detailed discussion on the situation in the electricity sector, please see also http://www.umweltdaten.de/publikationen/fpdf-l/3195.pdf.

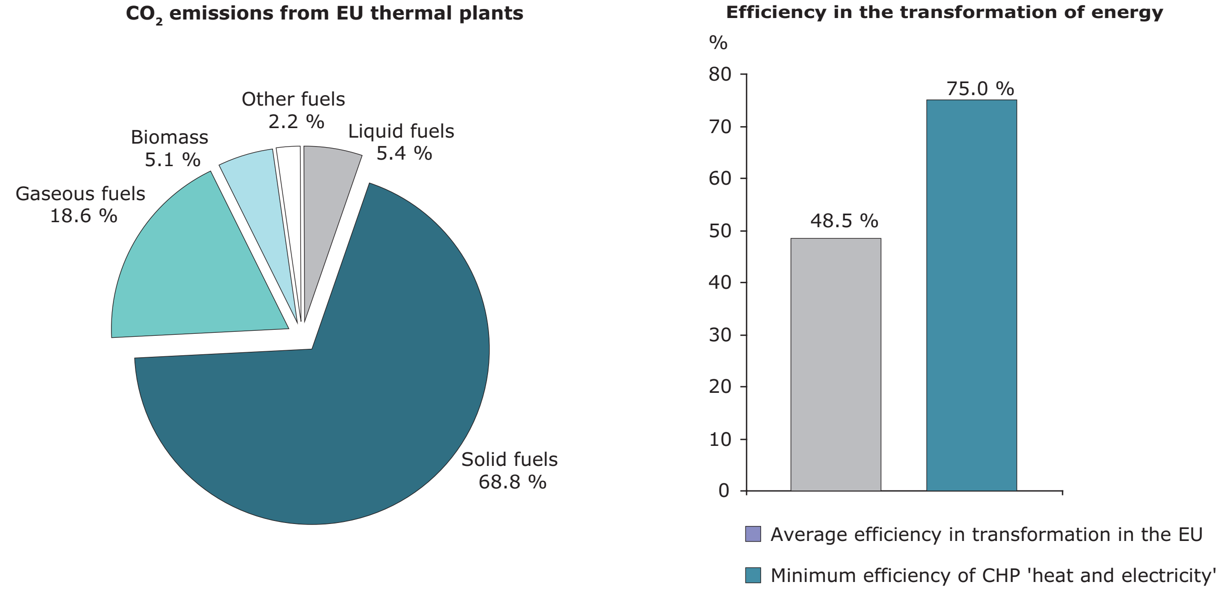
utilisation of 'waste' heat. The trend of improving the overall efficiency is expected to continue in the future, although the rapid growth in fossil fuel-based electricity and heat production present a risk of having an impact on the overall efficiency of the system. They may outweigh some of the environmental benefits resulting from the observed efficiency improvements (see also Figure 1.8. in Chapter 1.).

Figure 4.3 highlights the link between the use of fuel and CO_2 emissions from conventional thermal power plants (electricity-only plants, heat-only plants and combined heat and power plants) in the EU-27. Moving clockwise from top-left through to bottom-left, it illustrates the breakdown of fuel inputs by fuel type across the EU-27 (where the situation is dominated primarily by coal) and the implied average emissions factor for each fuel type based on the plant efficiency (the current average is 48.5 % if district heating is included). From this, it is possible to calculate the proportion of CO_2 emissions caused by each fuel type. For example, gaseous fuels (primarily natural gas) represent a smaller share of

Figure 4.3 Structure of CO_2 emissions from thermal power plants in EU-27


Fuel input in EU thermal plants

Average implied CO_2 emission factors in the EU (t/TJ)


CO_2 emissions from EU thermal plants

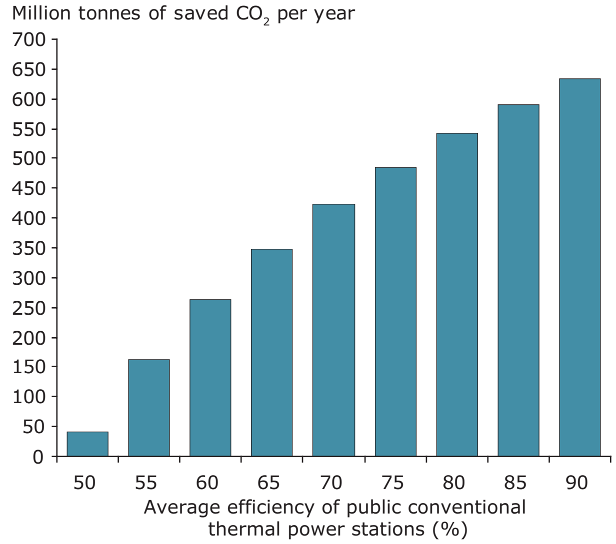
Efficiency in the transformation of energy

Source: EEA; Eurostat.

fuel inputs — relative to their presence in the output emissions: due both to a lower carbon content of the fuel as well as a higher level of efficiency in the power plants which utilise them (Ecofys, 2007a).

Figure 4.4 CO_2 emission savings per year for EU-27 at different transformation efficiencies

Current EU average efficiency of all conventional thermal power stations = 48.5 % (includes electricity-only plants, heat-only plants and combined heat and power plants)

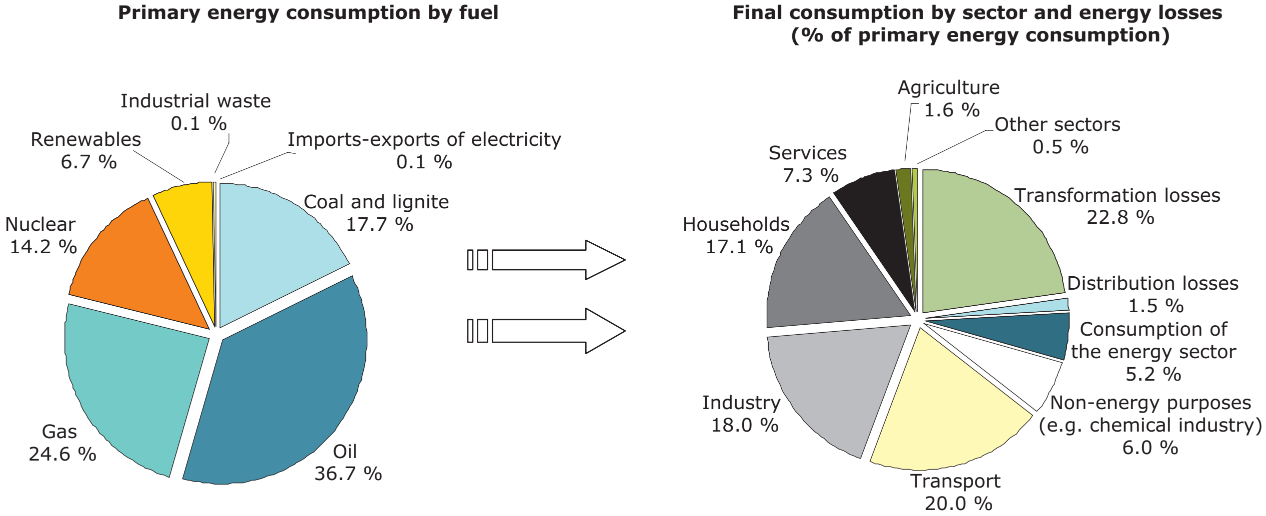


Source: EEA; Eurostat.

Given the current average efficiency and the fuel mix in 2005 shown in Figure 4.3, if conventional thermal power plants in the EU-27 were to improve their efficiency further, it could be possible to achieve significant CO_2 savings (by comparison, the Kyoto commitment for the EU-15 is about 340 Mt of CO_2). The efficiency of new installations can be improved to reach 45 to 60 %, depending on the fuel used (Werring, 2008). For example, state-of-the-art MACC (more advanced combined cycle) gas turbines can achieve the efficiency of electricity generation of 60 % (Ecofys, 2007a). Furthermore, combined heat and power (CHP) plants, which utilise a greater portion of 'waste' heat (e.g. lower grade heat directly for space heating), can reach an even higher level of overall efficiency.

Not all primary energy is available to be utilised as final, useful energy for the end-consumer — due to various losses that occur within the energy system. Key amongst these are transformation losses, which depend on the efficiency with which primary energy is converted to electricity and heat (e.g. in conventional power stations). In 2005, transformation losses represented on average 22.8 % of the EU-27 primary energy consumption. However, these losses also depends on the fuel mix, the level of electricity imports (e.g. in Luxembourg) and the extent to which the nuclear energy is used (25). Other losses (1.5 % of primary energy) occur in distribution. Some energy is also

Figure 4.5 Structure of the efficiency of transformation and distribution of energy: from primary energy consumption to final energy consumption, EU-27, 2005


Primary energy consumption by fuel

Final consumption by sector and energy losses (% of primary energy consumption)

Source: EEA; Eurostat.

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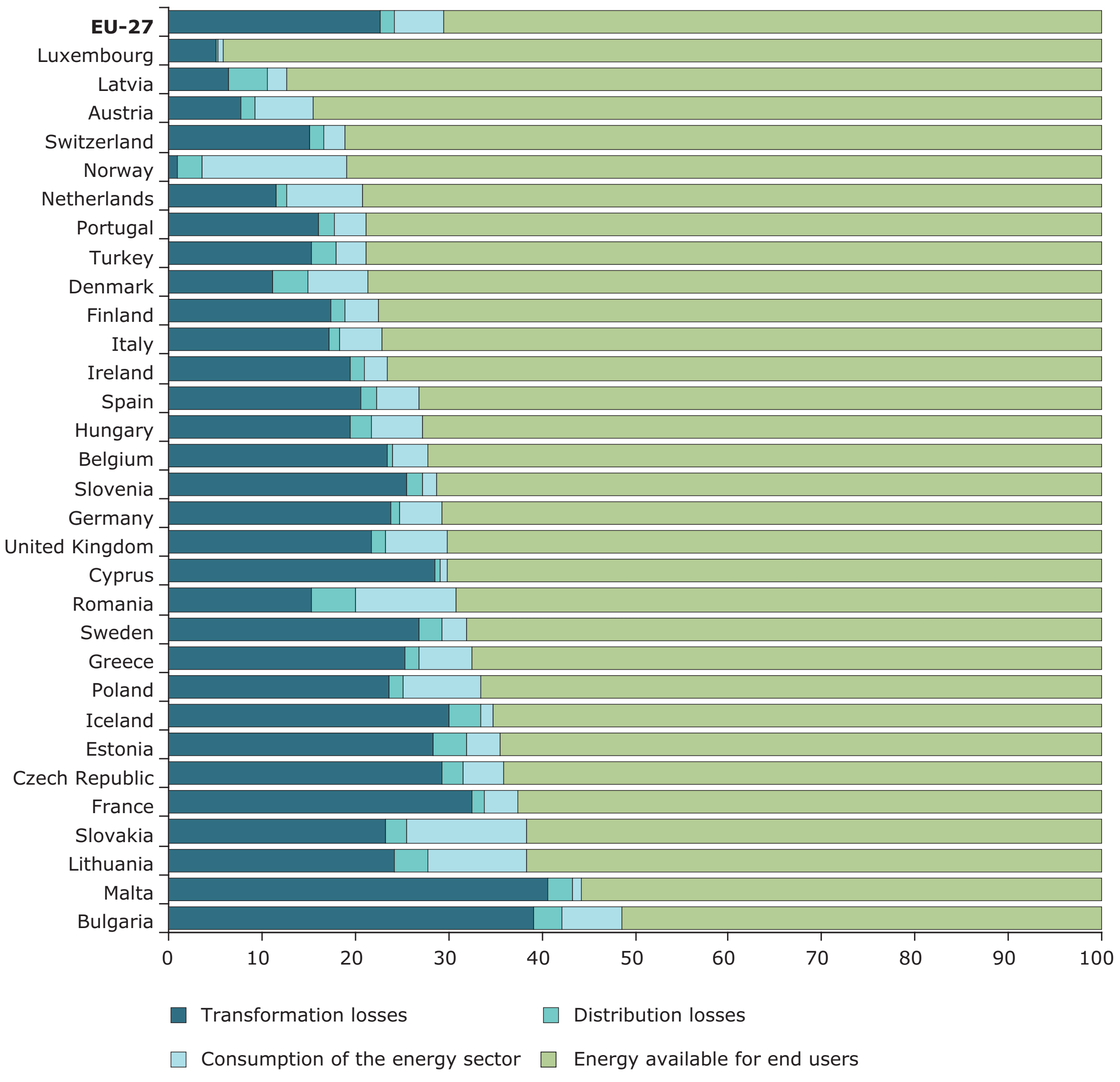
(25) The ratio of 'primary nuclear energy to electricity generated' is fixed within Eurostat energy statistics.

self-consumed by the power generation sector (5.2 %). Around 6 % of the primary energy products are used directly as feedstocks (primarily in the chemicals sector), rather than for energy purposes.

The level of losses in transformation varies considerably across the Member States (see Figure 4.6). At the low end is Luxembourg, where the system is very efficient and the final energy available to the end users is 94 % of the primary energy input. At the high end is Bulgaria, where only 52 % of the primary energy input reached the end consumer in 2005. The EU-27 average is 70.5 %.

Between 2000 and 2005, the proportion of electricity produced from combined heat and power (CHP) in the EU-27 slightly increased — to 11.1 %. In the past, CHP suffered from adverse market conditions in many Member States. Higher penetration rates for CHP have to reflect a balance between higher upfront investment costs and increased gas purchases (gas being predominant fuel for CHP, see Figure 4.8) and the costs of producing electricity and heat in another way. In the past, the low cost of fossil fuels and electricity (due to liberalisation) constituted a significant economic barrier to CHP development. In recent years however, higher

Figure 4.6 Energy used and energy lost in 2005 (% of primary energy consumption)



Note: Elements of the graph are taken directly from these specified categories in the Eurostat Data Explorer (for further information, see Annex 4: Description of main data sources), with the exception of losses in transformation, which is based on the categories: 'Transformation input' minus 'Transformation output'. The resulting energy quantities are then divided by the total primary energy consumption.

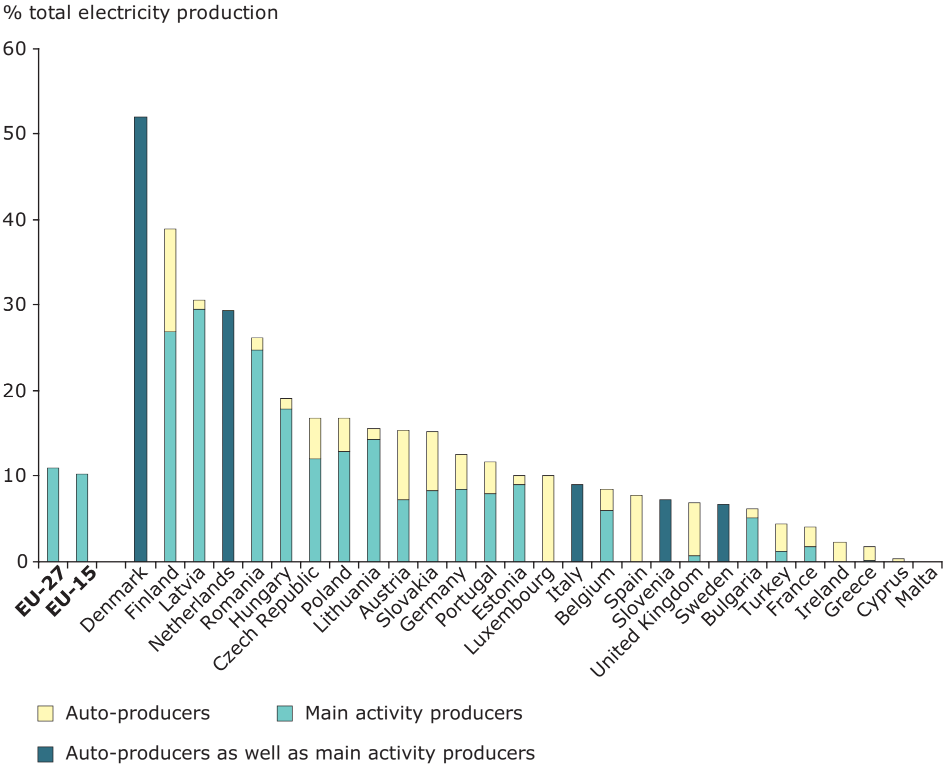
Source: EEA; Eurostat.

energy prices created better market conditions for further CHP development. Other barriers include lack of access to national electricity grids to sell surplus electricity, and, in some cases, lack of a suitable and stable heat demand.

Given the fact that CHP penetration depends on the energy market structure, it is not surprising that substantial differences exist across the EU with respect to CHP development. Countries with a high market penetration of CHP electricity include Denmark, Finland, Latvia and the Netherlands. In Denmark, CHP received strong government support since 1980s (in other words, before the liberalisation process started). The support is provided through tax incentives and subsidies, and growth has been mainly in the public sphere of distributed generation. Until 2005, the distributed generation CHP plants received a fixed feed-in tariff with three time-dependent steps. This created problems with excess production in some hours. From January 2005, the tariff structure changed to a price premium, i.e. the support follows the supply through the spot market prices, which creates incentives for adjusting the supply when there is excess production or excess demand (Ropenus and Skytte, 2005).

Government support was also an important factor in the Netherlands, where it was combined with a widespread availability of natural gas, the favoured fuel for CHP. The high level of CHP production in Finland and Latvia reflects the nature of their cold climate, which causes a significant need for heat as well as electricity. This strong demand for both outputs in combination with a well-developed district-heating network helped stimulate investment in CHP in these countries. The share of CHP electricity remains low in Greece, and to a lesser extent — Ireland and Portugal, due to poor

Figure 4.7 Share of combined heat and power in the gross electricity production in 2005

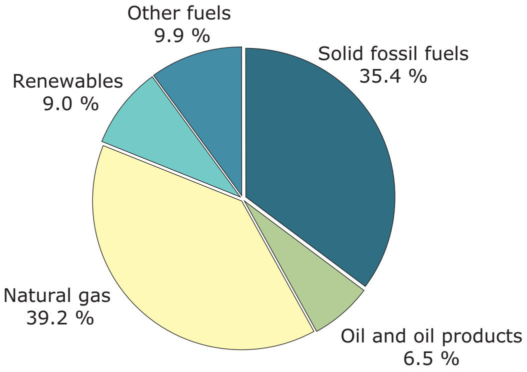


Note: The share is defined as the proportion of CHP electricity production (from both auto-producers and public utilities) in the total electricity production. However, it should be noted that not all electricity production from a CHP 'plant' may be considered as CHP production, as the plant may consist of different types of units (such as heat-only, or flexible units where the 'power-to-heat' ratio may be adjusted). To account for this, in 2000, the method for data collection by Eurostat on CHP was revised (as it had previously tended to overestimate the share of electricity generation from CHP). Therefore, the current share is not directly comparable to the 18 % target outlined in 1997 by the European Commission (COM(97)514 final). The division between auto-producers and main activity producers is unknown for Denmark, Netherlands, Italy, Slovenia and Sweden.

Source: Eurostat.

infrastructure for natural gas and a lower demand for heat. Combined heat/cooling-power conversion may help with overcoming the problem of surplus heat production — in summertime and in warmer countries such as Greece and Portugal.

Figure 4.8 Fuel input to CHP plants in the EU-27 in 2005



Source: Eurostat.

CHP allows a more efficient generation of heat and power than each of these elements does separately, but the use of renewable energies (biomass) as a fuel provides an opportunity to improve its environmental performance further. It accelerates progress towards achieving targets for renewable electricity and heat production. However, in 2005, renewables in the EU-27 provided only 9 % of the fuel input in CHP plants. The share of input fuels varies significantly between the EU-12 and EU-15, with natural gas accounting for more than half of the fuel input in the EU-15, but for only 12 % in the EU-12. Conversely, solid fossil fuels such as coal and lignite provided 74 % of the fuel input in the EU-12, but only 17 % in the EU-15.

5 Are environmental costs reflected adequately in the energy price?

Main messages

Current energy prices vary significantly among the EU Member States due to differences in tax levels and structures, subsidies for different forms of energy generation and different market structures. Including all relevant externalities to establish the true costs of energy use will help provide the correct price signals for future investment decisions in energy supply and demand. It is difficult to identify within current energy price structures the share attributed to the adverse external impacts of energy production and consumption on public health and the environment.

1. In 2007, the nominal end-user electricity price for households increased, on average, by 17 % compared to 1995 levels. This was due to a combination of factors including a certain level of internalisation of environmental externalities (via increased taxation and effects of other environmental policies, such as the EU Emissions Trading Scheme), increased energy commodity prices (particularly coal and gas), and other market factors stemming from the liberalisation process. Significant increases (around 50 %, compared to 1995 levels) occurred in Romania, the United Kingdom, Poland and Ireland.
2. In 2007, nominal end-user gas prices for households increased, on average, by 75 % compared to 1995 levels, mainly because of increasing world commodity prices. Increases above the average level occurred in Romania, the United Kingdom, Latvia and Poland.
3. Overall, in 2005, the external costs of electricity production in the EU-27 were estimated to be about 0.6 to 2 % of the GDP. The external costs decreased, between 1990 and 2005, by 4.9 to 14.5 eurocents/kWh and reached an average value of 1.8 to 5.9 eurocents/kWh (depending on whether high or low estimates for external costs are used) in 2005. Among factors that contributed to this downward trend are the replacement of coal and oil with natural gas, the increased efficiency of transformation and the introduction of air pollution abatement technologies. Further efforts are needed to develop methodologies to better quantify these externalities.

5.1 Estimating external costs of energy production

In view of climate change, concerns over energy security and rises in energy prices, it is crucial to provide a systematic analysis of the true cost of energy — a reflection, which would include all relevant externalities as well as private costs. This is needed in order to give correct price signals for much-needed investment in the infrastructure for energy supply as well as demand side management measures.

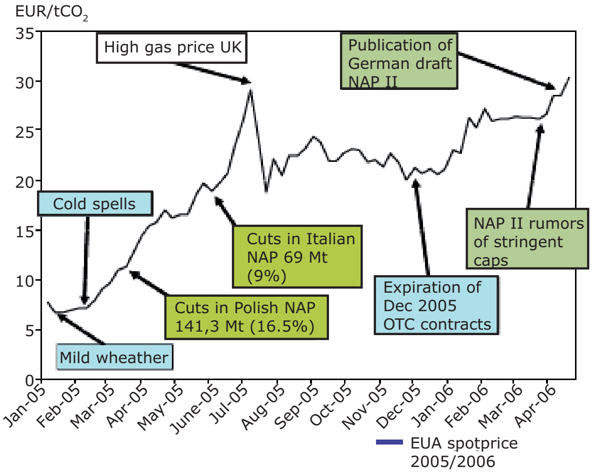
The Sixth Environment Action Programme stressed the need to internalise external environmental costs adequately. It suggests a blend of instruments that include fiscal measures, such as environment-related taxes and incentives, and a phase out of subsidies that counter the efficient and sustainable use of energy (EC, 2002b). The more recent Commission Green Paper on the use of market-based instruments for environment and related policy purposes (EC, 2007f) reinforced this view. However, estimating externalities (environmental, human health, ecosystems, etc) is not a clear-cut issue. Main methodological difficulties include knowledge with some level of precision of the damage of a particular economic activity to the state of the environment, and the value of such damages, which do not occur via the market. There are two ways to internalise external effects through environmental taxation. Ideally, the tax level should be set at the level of the marginal damage costs. Since such costs are difficult to establish, more commonly the level of taxation is set to attain certain environmental objectives and policy targets through induced changes of producer and consumer behaviour. Both approaches run the risk of being economically sub-optimal, when the tax level is set too high or too low. A zero tax would however mean that external costs are not accounted for at all. Of course, external effects are also internalised through other policy measure, but according to economic theory, sometimes in a less efficient way.

A variety of different components in carbon pricing emerged in recent years. They include attempts to calculate the social cost of carbon (26), marginal abatement cost (27), carbon taxes and other market-based instruments such as the EU Emission Trading Scheme (EU ETS). Estimations of the social costs of carbon are used in particular to assess the implications of lack of proper action to mitigate climate change in the longer term (as for example in the Stern-review). Market-based instruments, including carbon taxes and emissions trading systems, support policy action to mitigate greenhouse gas emissions in the shorter term. Marginal abatement costs give an indication of how the policy target groups will react and thereby help policy makers to design these instruments. Carbon taxes increase the price of fossil fuels inducing users to consider at the margin of their operations whether it would be cheaper to pay the higher fuel price than to reduce the use of fuel. Emissions trading systems set an upper limit for the number of emission allowances and thus create a price for emissions, which will again force emitters to consider at the margin whether they better buy extra allowances or reduce their emissions.

Ideally, the carbon tax rate should be set at the level of the social cost of carbon, and systems for trading carbon allowances should be designed in such a way that emerging prices reflect social carbon cost. In practice, social costs of carbon are only know with some certainty in a wide range of values, marginal abatement cost are difficult to valuate, and tax and emissions trading systems are partial and bear the marks of a political compromise.

Under the EU ETS, one of the main differences between various ways to calculate external costs and the market price of CO_2 is the fact that the latter is the actual cost paid by producers and consumers because of the implementation of the scheme (first phase 2005–2007; second phase 2008–2012). Under the EU ETS, the balance between supply of and demand for emission allowances is determined by a combination of different factors. These factors include market expectations concerning the emissions allowances gap, short-term CO_2 abatement costs in industry and power- generation companies, the size of the Clean Development Mechanism (CDM) and Joint Implementation (JI) markets, energy market developments as well as changes in climate (see Figure 5.1). The price of coal, gas and power in Europe, particularly the German base load electricity contract, remains one of the main drivers in the ETS market. In the second trading period, however, due to the availability of historic data and experience gained in the first phase, it is quite likely that the shortage of allowances in the market will be already factored in by the market participants in their trading strategies. Thus, other factors, apart from the expected allowance gap, are likely to play a bigger role in determining the volatility of the carbon price.

Figure 5.1 Forces at work that determined the carbon price under EU ETS, first phase



Source: ECON.

5.2 The EU ETS

The first phase of the EU ETS (2005–2007) was a learning process for Europe. It brought about important institutional developments such as a sound monitoring mechanism and a robust electronic trading system (the CITL). It also created a real market (volumes and price) for carbon trading (see Figure 5.2).

Towards the end of the first trading period, when data concerning the real emissions in 2006 and 2007

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(26) The social cost of carbon is the cost to society and the environment to emit an extra tonne of carbon. For instance in the Stern review, the social cost of carbon, assuming that the world is on track to meet a 550 ppm CO_2-equivalent stabilsation level, was estimated to be some 26.5 USD/t CO_2-equivalent. Other projects as well attempted to put a price on the social cost of carbon such as ExternE-Pol (2005), CAFE, RECaBS (2007).

(27) This is the cost of reducing emissions by an additional tonne through measures in various sectors.

was available, it became evident that the ambition level set nationally during the first phase was too low for achieving carbon prices sufficiently high to trigger much needed changes in the energy market. This explains why the carbon prices collapsed to almost zero in 2007. In the second phase, however, due to sustained pressure from the European Commission, the emissions ceiling for the ETS sectors was tighter, hence, the price remained above EUR 20/t CO_2 (see Figure 5.2).

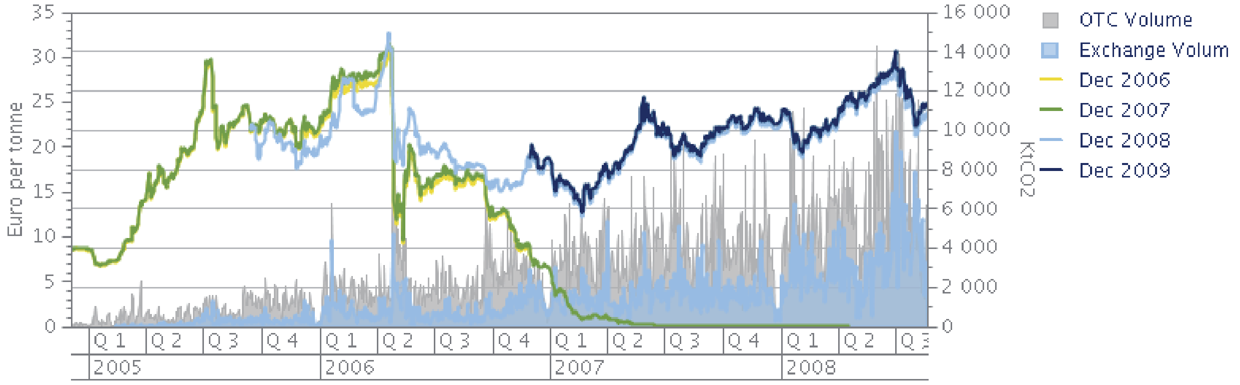
While under EU ETS, the impact of energy commodities prices on the carbon market is relatively easy to detect, it is not a trivial matter to establish quantitatively the impact of the EU ETS on the end-use energy price at present and in the near future (2008–2012). Today, the energy price in Europe is the result of a combination of different factors. These are: rising costs for fossil fuels driven by significant increases in energy demand in Europe (for Europe, see also discussion in Chapter 2) and elsewhere (particularly China and India); the market structure; different levels of taxes and subsidies as well as specific climate and energy policies. The impact produced by the EU ETS after 2012 will depend, largely, on the future (after 2012) design of the scheme (28) as well as on the intensity of efforts to step up the energy efficiency at the point of the end-consumer (see discussion in Chapter 6) along with other factors.

Experiences so far (the first phase of ETS and limited experiences during the second phase) show that end-use energy prices could increase. For instance, in Germany more than 20 coal-fired power plants are now either being built or are at a planning phase, most of them in the coal-rich part of North-Rhine Westphalia. This development triggered some activity in the carbon markets — with the German power contract in 2009 jumping to a high EUR 79.10/MWh. It is 4.25 % higher than previous close (29). This comes at a time when coal prices are also on the rise. In Germany, in the first phase of the EU ETS, a significant part of the carbon price may have trickled down to the end-consumers. Eventually, the significantly high level of energy prices in this market triggered in 2007 an inquiry from the European Commission.

5.3 Estimated external costs

In most EU-27 Member States, external costs that arise from the impact of electricity production on the environment are significant. They reflect the dominance of fossil fuels in the generation mix. In the EU-27, externalities of electricity production in 2005 were estimated to be in the order of 0.6 % to 2 % of the GDP. These estimates depend on the assumptions made for external costs per unit of emissions of air pollutants and CO_2. For CO_2

Figure 5.2 Developments of carbon price and volumes under EU ETS (2005–2008)



Source: Point Carbon.

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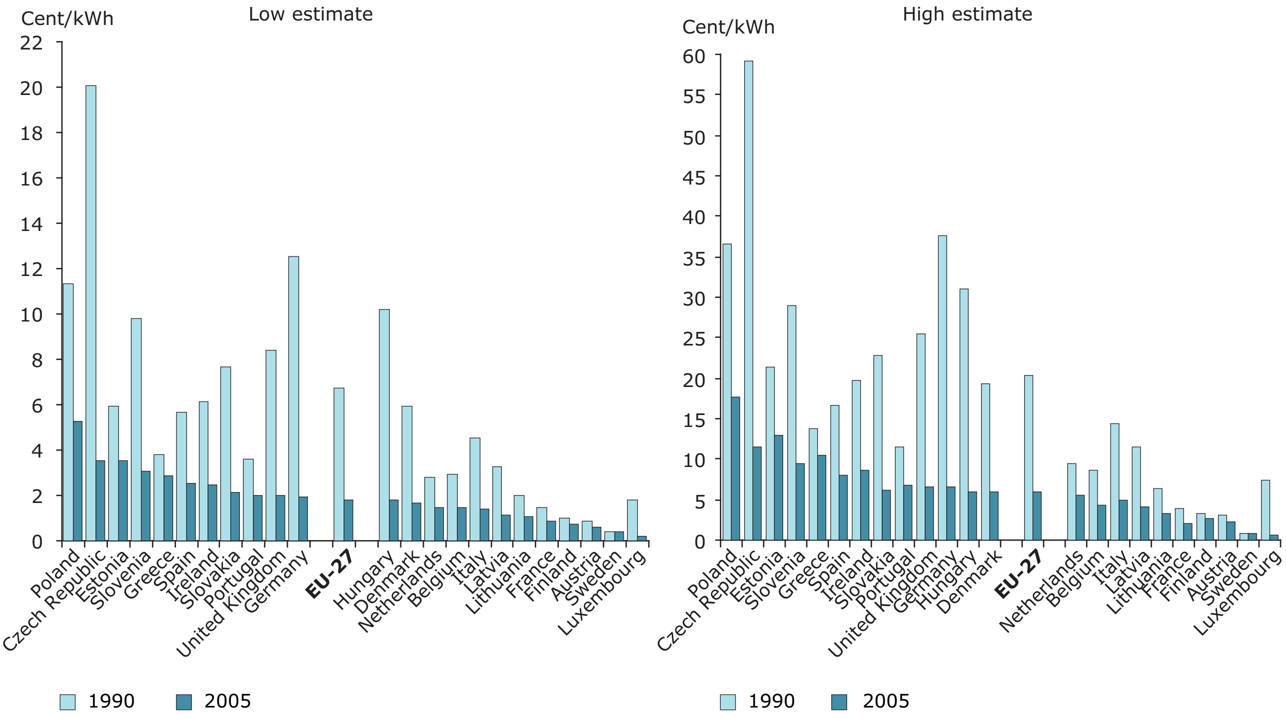
(28) Recent studies for instance show that basing the allocation method on performance benchmarking for the electricity companies will reduce the impact on electricity prices of the scheme compared to the case if the allocation is based on full auctioning or grandfathering. See for instance ECOFYS, 'The IFIEC method for the allocation of CO_2 allowances in the EU Emissions Trading Scheme- a review applied to the electricity sector', March 2008.

(29) 'Point Carbon', Carbon Market Daily, Vol. 4, Issue No 143, 24 July 2008.

Figure 5.3 External costs of electricity production, 1990 and 2005 — low and high estimates



Note: Data for Malta, Cyprus, Bulgaria and Romania is not available. The external costs in the above two figures are based on the sum of three components associated with the production of electricity: costs of damage caused by climate change damage associated with emissions of CO_2; damage costs (such as impacts on health, crops etc) associated with other air pollutants (NO_x, SO_2, NMVOCs, PM_{10} and NH_3), and other non-environmental social costs for non-fossil electricity-generating technologies. The external costs from the nuclear industry have to be treated with caution, as only some externalities are included. The costs reflect, to a large extent, the small amount of emissions of CO_2 and air pollutants, and the low risk of accidents. There is a clear need for new estimates of the damage cost factors for nuclear energy associated with future ExternE projects.

Source: ExternE-Pol, 2005; CAFE, EEA, Eurostat, RECaBS, 2007.

emissions, the shadow price (30) was determined on the basis of the ExternE methodology and considered to be EUR 19/t CO_2 (for the low estimates) and EUR 80/t CO_2 (for high estimates) (Watkiss *et al.*, 2005) (31).

In 2005, the average external costs of electricity production across the EU Member States ranged from 0.2 to 17.8 Eurocent/kWh, with an EU average of approximately 1.8–5.9 Eurocent/kWh.

Overall, over the period of 1990–2005, there was a significant drop in the external costs per unit of electricity generation from an EU average of approximately 6.7–20.4 Eurocent/kWh at the start of the period. Improvements in generating efficiency, a shift from coal and oil to natural gas and the implementation of technologies to abate air pollution — all these factors have contributed to this.

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(30) The shadow price of carbon is similar to the social cost of carbon where it reflects the cost of climate change to society, but differs as to include specific political and technological conditions, e.g. in the EU (see http://www.defra.gov.uk/environment/climatechange/research/carboncost/pdf/background.pdf).

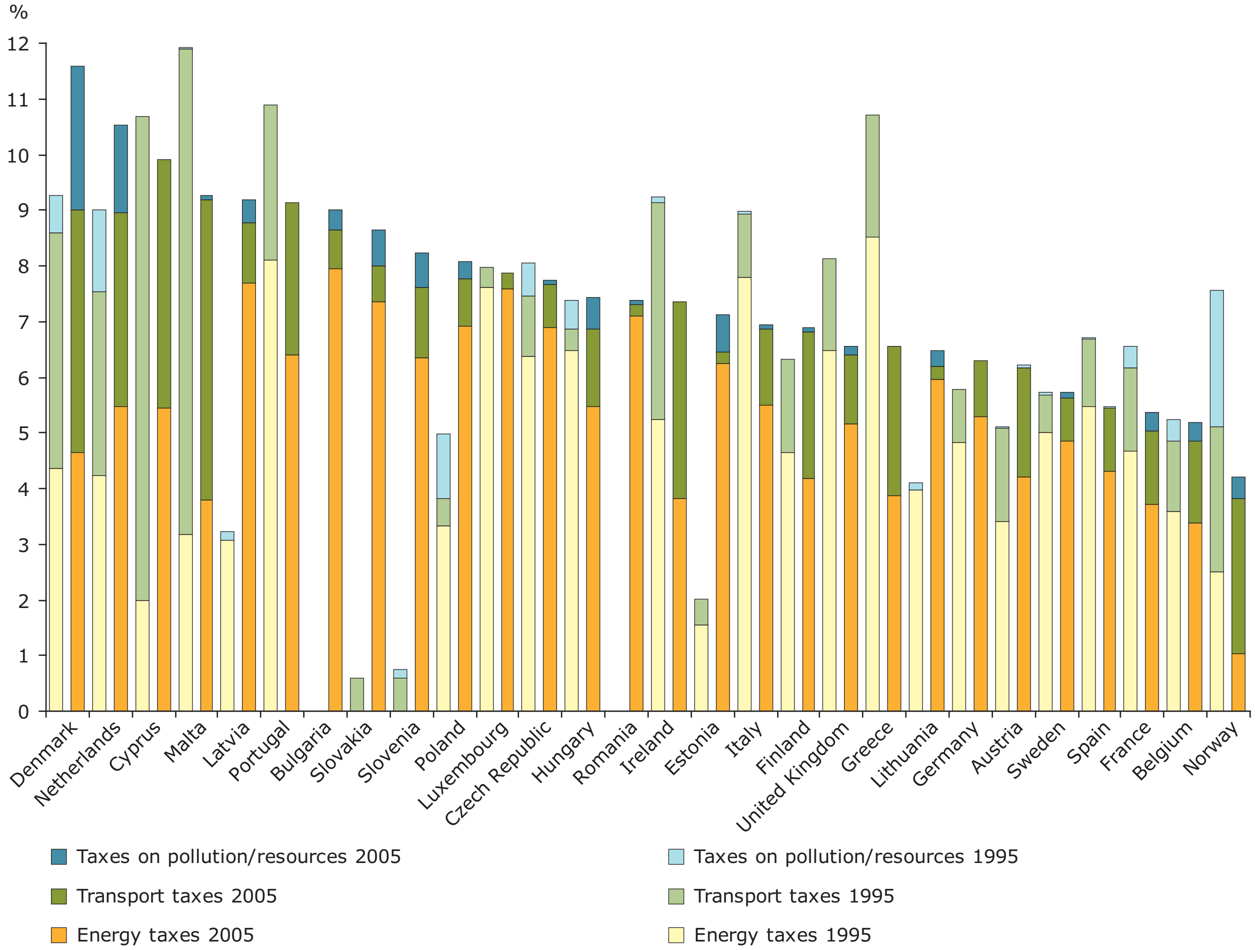
(31) To estimate the shadow price for carbon, the methodology takes into account two different approaches: one based on preferences revealed through policy targets and another — based on the public opinion revealed in a referendum on energy matters in Switzerland. Switzerland was chosen because its decision-making process is slightly different from the rest of Europe, with a significant part of important policy decisions being taken via referendums, including, sometimes, the level of proposed taxes. Hence, the public opinion expressed in the referendum on energy matters could be considered as a good proxy for the societal willingness to pay. In this context, the effects of the EU ETS were implicitly considered but not taken as the only basis for estimating the shadow price for carbon. This was because, at the time, only a limited data was available and it was not clear whether this market would evolve into a real market (thus offering a better estimation for the shadow price). A comparison between the shadow price for carbon developed to calculate externalities of electricity production and the real prices observed under the EU ETS (see discussion in Section 5.2.) is outside the scope of this report. However, it should be noted that the latter remain well within the range considered in the ExternE methodology.

5.4 Environmental taxes

The share of 'environmental' taxes in 2005 varied significantly across the EU Member States: from around 11.6 % of the total tax revenue and social contribution in Denmark to 5.2 % in Belgium. Over the period from 1995 to 2005, the change in the percentage of taxation varied considerably too: with six Member States increasing their share by more than 25 % and more than nine Member States reducing their share by over 10 %. The share of taxes applied directly to pollution/resources is much smaller, with the exception of Denmark and the Netherlands, where in 2005 it accounted for about 2.6 % and 1.6 % of the total revenue, respectively.

It is difficult, however, to draw conclusions about the 'environmental friendliness' of the tax system in each country without examining the specifics of that system (32). In principle, a low share of the total revenue may indicate little use of environmental taxes, or, conversely, it may indicate successful use, whereby the consumers' behaviour has been influenced by the tax and shifted away from the polluting goods, thus eroding the tax base. Almost all of these taxes are not directly related to the internalisation of external costs and are implemented primarily to fulfil a range of policy objectives, in particular general revenue raising (OECD, 2001).

Figure 5.4 Share of environmental taxes in the total tax revenue in 1995 and 2005



Note: The data for 2004 are only available for Portugal and Malta. The data for 1995 are not available for Bulgaria and Romania.

Source: EEA/OECD; Eurostat.

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(32) For further details see the European Commission's Database for TAXES in Europe: http://ec.europa.eu/taxation_customs/taxation/gen_info/info_docs/tax_inventory/index_en.htm.

From 1995 to 2005, a number of countries (such as Slovakia, Estonia, Latvia, Poland and Lithuania) have seen increases of over 50 % in the share of 'environmental' taxes in their total tax revenue, though from a low level. This has been driven largely by an increase in energy taxes (via a combination of the tax base being broadened, raising existing and introducing new taxes). Whilst growth in taxes on pollution/resources has been more rapid in a number of cases, this has been from a very low base. A notable exception is Denmark, where the share of pollution/resource taxes in the total revenue increased from 0.7 % in 1995 to 2.6 % in 2005 (accounting for most of their increase in 'environmental' taxes over this period) from the introduction of excise duty on a number of polluting substances (such as nitrogen or certain pesticides). However, in the case of Denmark, the high level of taxation may not necessarily mean that it is the optimal level. In Denmark there are, for instance, two different types of taxes: one on electricity consumption (EUR 7.4 c/kWh) paid by the consumers and one for district heating (EUR 6.8 c/GJ) paid by the producers that was originally introduced by the Danish government to support gas projects. The high level of taxation was found in recent studies (Deketelaere, 2007) to be disproportionately high by comparison to the external effects of the energy sector but also could have had undesired distributional effects. Furthermore, neither the electricity taxation nor the CO_2 tax distinguish between fuels and sources.

5.5 End-use energy prices

Household electricity prices for the EU-15 dropped slightly during the period from around 1995 through to 1999 but they started to rise again afterwards. The rise has been particularly steep since 2004, and now prices are almost 17 % above the 1995 levels. Gas prices have been displaying a steep upward trend since 1995 but further accelerated from 2004 onwards. In 2007, gas prices were almost 75 % above their 1995 levels. Price rises have been driven, largely, by rising world energy prices, particularly for oil to which the price of gas is often indexed.

By comparison, the gross disposable income the EU-15 households was growing steadily over the period, roughly keeping pace with gas price rises and staying well ahead of changes in electricity, but in recent years this does not appear to be the case anymore. Should households have maintained the 1995 levels of energy consumption, they would have had more disposable income due to the difference between the pace of income growth and the pace of energy price rises. However, given the rise in the household energy consumption and the rapid energy price increases we saw in recent years, that in the near future the energy bill is likely to be a bigger proportion of the household income. In addition, the average figures for the EU mask fluctuations in energy prices that occur across the Member States. Gas and electricity prices and disposable incomes have also followed a similar pattern in industry, although the rise in gas prices in the last few years has been even more rapid.

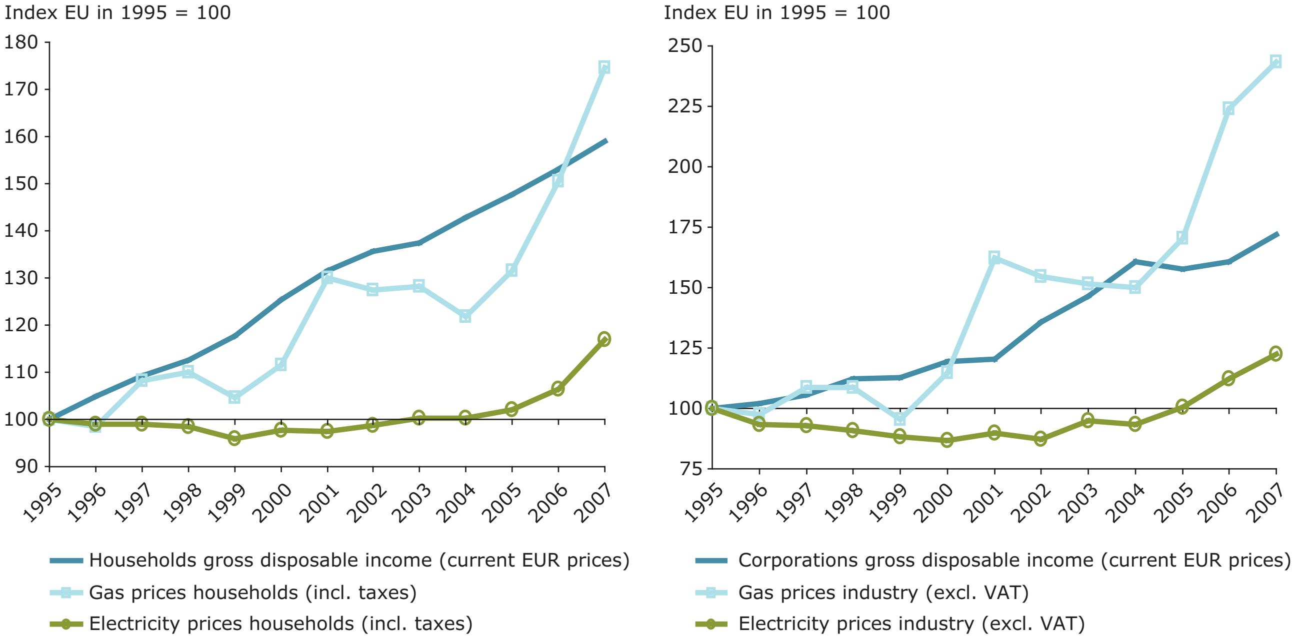
The pattern of price changes for households, excluding taxes, is similar to that of the industry (industry already excludes VAT), hence, the price increases are driven by other factors (than taxes) such as rapid increase in the price of input fuels and the passing of some environmental costs to consumers (e.g. via the EU Emissions Trading Scheme). The price increases, over the period, for diesel and gasoline were driven, primarily, by rising of the world oil prices, and those have both risen by over 50 % from 1990 to 2006.

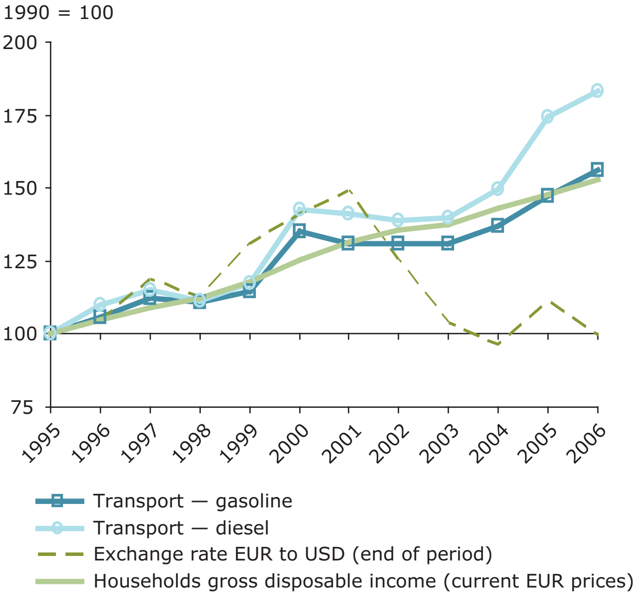
The share of taxes in the household electricity prices in 2007 varied across the Member States from a high of 55 % in Denmark to 5 % in the case of Malta. The average for the EU-15 is 24 %. Similarly, this share in the gas prices ranges from 56 % (in Denmark) to 5 % (in the United Kingdom), with the EU-15 average being 22 %. The wider differences in taxation in this sector tend to reflect different priorities, High taxes in Denmark are part of a deliberate policy to encourage energy efficiency (following from the earlier oil crises in 1973 and 1979). By contrast, the rate of VAT in the United Kingdom is set at a much lower level as the emphasis is, primarily, on affordable supplies of energy for all consumers, particularly those with lower incomes.

Electricity and gas prices vary quite substantially across the EU Member States — even when compared through purchasing power standards (i.e. comparing the cost of a similar 'basket' of goods and services purchased using local currency) as opposed to foreign exchange rates. In the case of electricity, this varies by a factor of three, and a factor of two — in the case of gas. The variation reflects differences in taxation rates, fuel input prices, efficiency of generation, the supply structure and any market distortions resulting from differences in the speed of liberalisation of the energy market (such as subsidies).

Across the EU Member States, the rapid price rises during the period from 2005 to 2007 have been most significant in the case of natural gas, with an average increase of over 30 % (for the EU-15). In particular,

Figure 5.5 Trends in nominal end-user energy prices and disposable income, EU-15





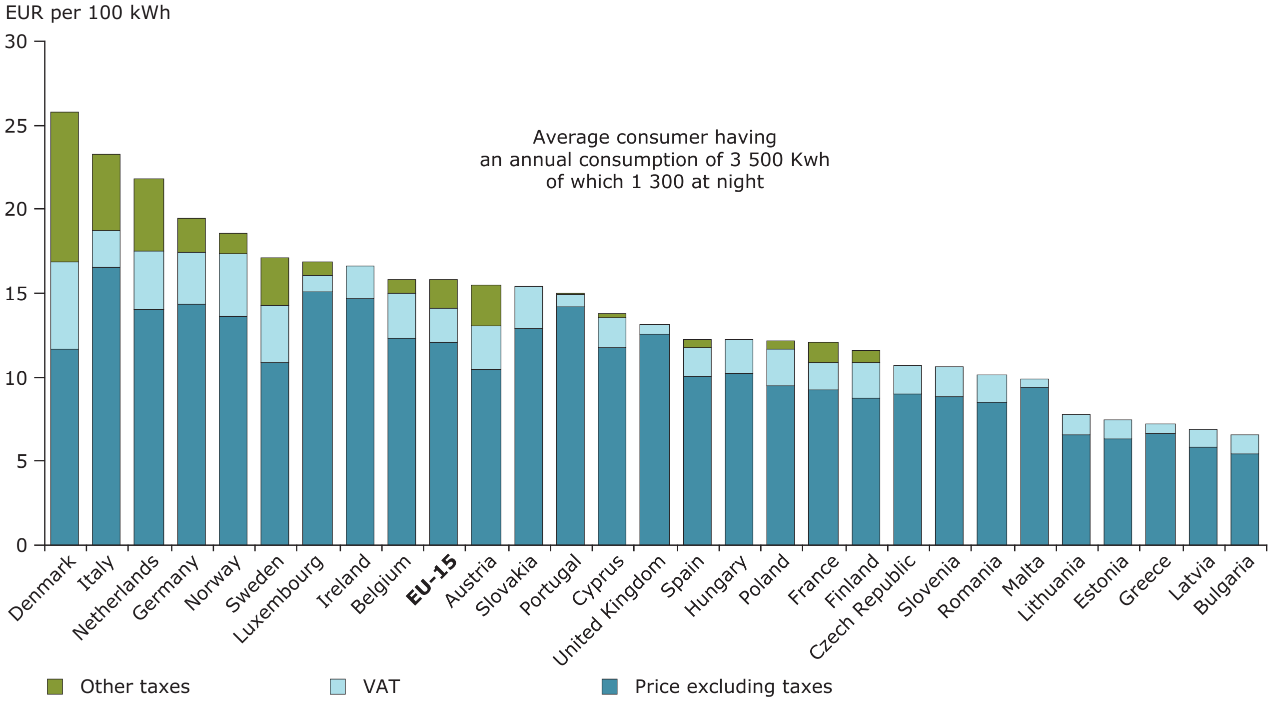
Note: Data are not available for Luxembourg or Ireland.

Source: EEA; Eurostat.

countries such as Romania, Ireland, Latvia and the United Kingdom have seen rises of over 50 %. Electricity prices also rose rapidly in countries such as the United Kingdom, Sweden, Czech Republic and Romania, but not to the same extent as gas, as input fuels for electricity production can be diversified, to a certain extent, as input prices rise.

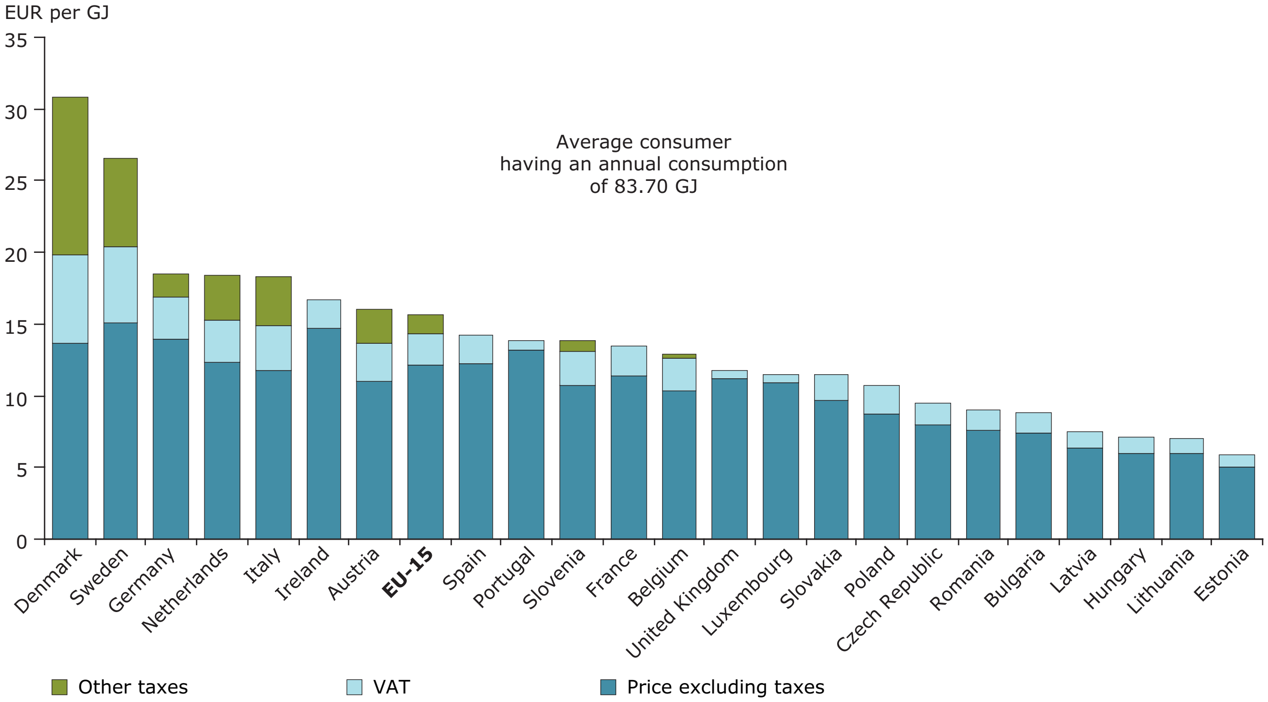
Latvia experiences the lowest electricity prices in Europe due to its generation mix (about 68 % of gross electricity generation in 2005 was from hydroplants), the configuration of the power system and the geopolitical location (bilateral agreements with Russia). A planned integration with other low price areas in Europe (Scandinavia and Poland) could facilitate introduction of lower prices in the future and significantly enhance competition among generators. Energy prices in Romania reflect a complex set of market circumstances, most notably the need for new investments in new generation facilities, market reform and increasing prices for imported gas from Russia.

Figure 5.6 Share of taxes in the electricity prices paid by households in 2007



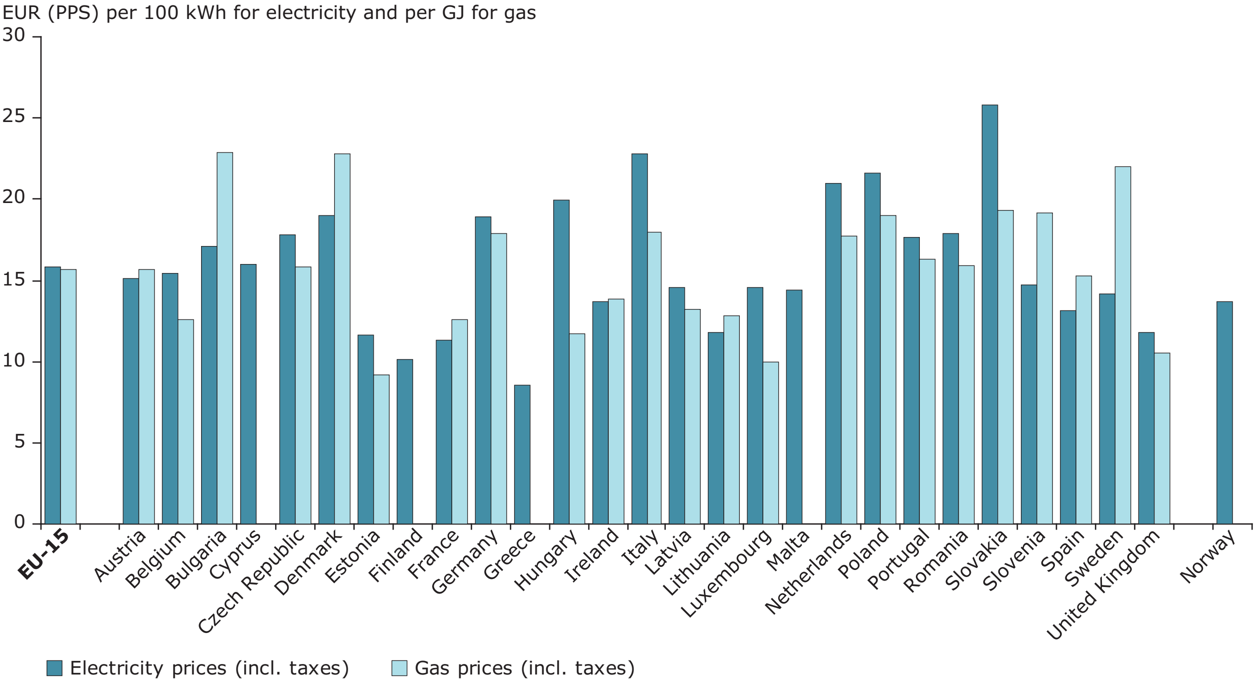
Source: Eurostat.

Figure 5.7 Share of taxes in the gas prices paid by households in 2007



Source: Eurostat.

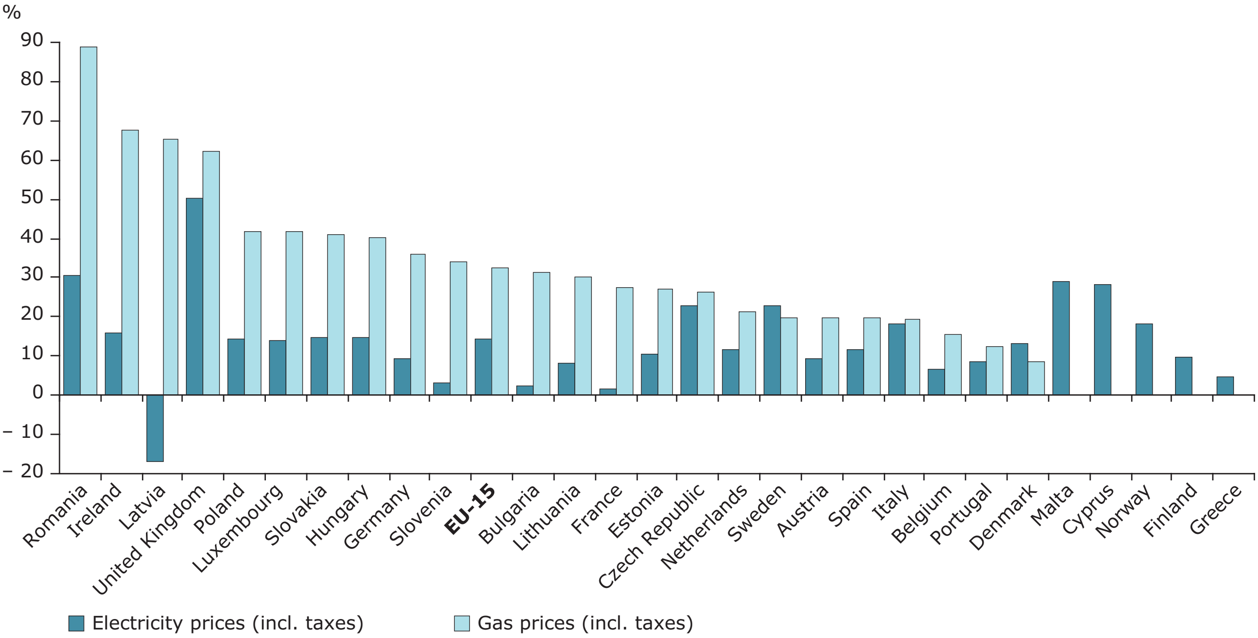
Figure 5.8 Household electricity and gas prices in2007 — adjusted to purchasing power



Note: PPS = Purchasing Power Standards. Electricity prices (PPS) are those paid by an average consumer with an annual consumption of 3 500 kWh, of which 1 300 are consumed at night. Gas prices (PPS) are those for an average consumer with an annual consumption of 83.70 GJ. Data on gas prices are not available for Malta, Cyprus, Norway, Finland and Greece (hence, the last two are not included in the EU-15 figure).

Source: Eurostat.

Figure 5.9 Changes in household electricity and gas prices, 2005–2007



Note: Electricity prices are those paid by an average consumer with an annual consumption of 3 500 kWh, of which 1 300 are consumed at night. Gas prices are those for an average consumer with an annual consumption of 83.70 GJ. Data on gas prices are not available for Malta, Cyprus, Norway, Finland and Greece (hence, the last two are not included in the EU-15 figure).

Source: Eurostat.

6 What are the energy consumption trends in households, and what policies exist to improve energy efficiency?

Main messages

End-use energy efficiency measures should be implemented in the residential sector to ensure that energy services (i.e. heating, cooling, and lighting) remain affordable. At the same time, improved energy efficiency will also deliver environmental and social benefits. Despite the significant potential for cost effective savings, energy consumption in the household sector continues to rise.

1. In 2005, the residential sector in Europe accounted for 26.6 % of the final energy consumption. It is one of the sectors with the highest potential for energy efficiency. Measures to reduce the heating/cooling demand in buildings represent a significant part of this potential. In Ireland and Latvia, measures in the residential sector account for over 77 % of the overall national target under the Energy Services Directive, while in the United Kingdom, the proportion is just over 50 %. Cyprus estimates that the residential sector can deliver savings of more than 240 ktoe, 1.3 times the national target set for 2016 (185 ktoe, representing 10 % of the final inland consumption — calculated in accordance with the requirements of the directive).
2. Between 1990 and 2005, the absolute level of final household energy consumption in the EU-27 rose by an average of 1.0 % a year.
3. Final household electricity consumption increased at a faster rate attaining an annual average of 2.1 %.
4. Final energy consumption of households per m^2 decreased annually by about 0.4 %.
5. Two key factors influence the overall household energy consumption: fewer people living in larger homes and the increasing number of electrical appliances. Together, they contribute to a rise in the household consumption of 0.4 % a year.

6.1 Introduction

This chapter explores trends in the final energy consumption by households, focusing on heating and cooling demands, and associated CO_2 emissions. It also discusses current policy initiatives and good practice in designing and monitoring energy efficiency in the household sector, based largely on the results of a recent expert meeting on energy efficiency (33).

Over the last few years, most EU Member States have also seen significant rises in household gas and electricity prices, 33 % and 14 % respectively, from 2005 to 2007 (see Figure 5.9). This was driven, to a large extent, by rising world prices for oil and gas, but also by more recent attempts to incorporate external environmental costs in the energy price (e.g. the effect of EU ETS on electricity prices). Average gross household incomes were rising too — in line with changes in gas prices, but in recent years, energy prices appear to have risen at a more rapid pace. In addition, the general trend masks significant differences in the levels of income and expenditure on energy across different households.

Concerns are rising about the affordability of energy supplies and the proportion of household expenditure that needs to go to maintaining adequate levels of comfort — as highlighted by the Commission's recent communication on rising energy prices (EC, 2008g). This is particularly relevant for heating (which is currently the largest component of household energy use — around 67 % on average in the EU-15) which is linked with adverse health impacts on vulnerable occupants (e.g. increased winter mortality rates for elderly people).

The generic term for this issue is 'fuel poverty'. It is caused by the interaction of a number of factors, but three specifically stand out: the energy efficiency

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(33) Held at the EEA on 27–28 March 2008.

status of the property, the cost of energy and the household income.

In the United Kingdom, for example (see Box 6.1), a household is said to be in a state of fuel poverty if it needs to spend more than 10 % of its income on fuel to maintain a satisfactory heating regime (usually 21 °C for the main living area, and 18 °C for other occupied rooms) (BERR, 2007).

A key element in reducing fuel poverty is to improve the level of household energy efficiency, particularly with respect to minimising heating demand. This will help to reduce the energy required to maintain comfort levels and, hence, expenditure. This is particularly important in the face of rising prices. It should be noted, however, that those in a situation of fuel poverty tend to be on low incomes, so efficiency measures would need the government support (for example see Box 6.1).

Apart from the United Kingdom, other Member States seem to be having — in place or in the pipeline — measures specifically targeting the low-income

Box 6.1 Monitoring of fuel poverty in the United Kingdom

The United Kingdom is one of the first countries to recognise formally the issue of fuel poverty and put specific measures in place to tackle it. These include spending around GBP 20 billion (EUR 26 billion) on benefits and programmes since 2000, via the:

(1) Energy Efficiency Commitment (EEC) — an obligation of energy suppliers to install 'efficiency measures households', a certain percentage of activity must be targeted at the 'priority' group of more vulnerable households;
(2) UK Fuel Poverty schemes which provide direct grants for efficiency measures in fuel-poor households;
(3) Winter Fuel Payments for vulnerable groups on low incomes;
(4) Decent Homes programme to improve the quality (including energy efficiency) of social housing by local authorities.

The United Kingdom has a target of eliminating fuel poverty in vulnerable households by 2010, and all households — by 2016. Monitoring the number of fuel-poor households is a complex task, due to a range of interacting drivers and the fact that it is not physically possible to survey all households continually. In addition, drivers such as rising energy prices mean that households may enter/re-enter the definition of fuel poverty over time. As such, the headline indicator (on the total number of households in fuel poverty) is built upon a range of sub-indicators, which are themselves based on a wide range of surveys with data extrapolated up to the UK level (BERR, 2007). These include (but are not limited to):

Type	Indicator(s)
Headline	Total number of households in fuel poverty
Income	% of children, working-age adults and pensioners living in households with low incomes Winter fuel payments and cold weather payments
Fuel prices	Expenditure on fuel of households with the lowest 30 % of incomes Fuel prices Others (e.g. customers switching suppliers, disconnections due to fuel debt, customers on prepayment meters)
Housing	Energy efficiency (based on a standardised rating approach) of the housing stock Occupancy levels Excess winter deaths Expenditure on homes helped through UK Fuel Poverty schemes, EEC, and local authority action

households (34). For instance, in France, financial incentives are available for landlords wishing to undertake energy efficiency measures and split the benefits with their tenants. In addition, subsidies for low-cost housing are available to low-income families. In Ireland, there is a Warmer Homes Schemes, under which public funding is available for energy efficiency measures in low-income households. So far, some 3 000 homes have benefited from the programme. Given the success of the programme, an extension is now being considered. In the Netherlands, the TELI subsidy scheme is used to support energy-saving measures in low-income households, such as technological improvements, advice and information on energy saving measures. In the Netherlands, low-income households are defined as households with a yearly income less than EUR 14 000. In this situation, when it comes to energy efficiency, these households appear to face two major barriers: lack of financial resources to undertake small investments and lack of access to relevant information. In addition to these specific measures, low-income households are likely to benefit from other, more generic, type of measures such as sustainable housing design, smart metering and incentives to improve the heating systems or support for a more efficient lighting that are currently in place or planned in most Member States.

6.2 Energy efficiency policy for household heating and cooling

The importance of energy use in buildings, particularly for heating and cooling in the residential sctor, has been widely recognised and policies have been introduced to improve energy efficiency. These policies have a number of environmental and social benefits including reduced CO_2 emissions and air pollution, limiting household expenditure on energy and increased levels of comfort.

Three key policy initiatives are likely to help realise the energy efficiency objectives for heating and cooling residential buildings in EU Member States: the Energy Efficiency Action Plan — EEAP (EC, 2006e), the Energy Performance of Buildings Directive (EPBD) (EC, 2002c) and the Energy End-Use Efficiency and Energy Services Directive (ESD) (EC, 2006f) (35). The EU policy on sustainable production and consumption is also relevant. The main building blocks of EU policy in this area include: the Integrated Product Policy (IPP); the Thematic Strategy on the Sustainable Use of Natural Resources;the Thematic Strategy on Waste Prevention and Recycling; the Eco-Management and Audit Scheme (EMAS), the Ecolabelling Scheme, the Environmental Technologies Action Plan (ETAP); Green Public Procurement (GPP); the Eco-design of Energy Using Products Directive (EuP) and the European Compliance Assistance Programme — Environment & SMEs.

The 'Action Plan on Sustainable consumption and production and sustainable industrial policy' adopted in July 2008 (EC, 2008h) includes a number of product-related policies, which aim to enhance the energy efficiency of household appliances and buildings. In particular, it includes a proposal to extend the scope of the Ecodesign Directive (EC, 2005d) to include, not only energy-using products, but other environmentally significant products that have an impact on energy consumption, such as windows and insulation elements. It also includes a proposal to extend the scope of the Energy Labelling Directive in line with the conclusions of the Ecodesign Directive.

In addition, the presidency conclusions of the Energy Council held on 10 October 2008 (36) highlighted the crucial role of energy efficiency measures in addressing concerns about the security of supply, by reducing the need for imported fossil fuels, and in combating climate change. They also proposed to gradually ban the sale of inefficient light bulbs starting in 2010, provided that alternative solutions are available in time. In addition, the Commission was called upon to deliver a proposal to revise the Energy Performance in Buildings Directive and to report on the use of CHP to evaluate the impact on the efficiency of the energy generation in November 2008. The Commission, in collaboration with the European Investment Bank, was also invited to identify, adequate financial

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(34) This information was extracted from the National Energy Efficiency Action Plans submitted by the Member States in July 2007, as required by the ESD Directive The plans can be found at http://ec.europa.eu/energy/demand/legislation/end_use_en.htm. See further discussion on the plans in the following paragraphs of this chapter.

(35) Details of the energy efficiency measures implemented in EU Member States and third countries are available in the MURE database (http://www.isis-it.com/mure/), IEA energy efficiency database (http://www.iea.org/Textbase/effi/index.asp), the ODYSSEE project (http://www.odyssee-indicators.org/).

(36) European Council, Document 13649, Bruxelles, 9–10 October 2008 and Draft report on energy security prepared by the French Presidency, Document 13827/1/08, Bruxelles, 8 October 2008.

mechanisms for improving energy efficiency that target municipalities and small and medium size enterprises.

The objective of the Energy Efficiency Action Plan is to reduce primary energy consumption by 20 % by 2020 starting from 2005 as the base year, as compared to the business as usual (baseline/reference) scenario. The plan assumes a potential for savings in the household sector of up to 25 %. A range of policies and measures are envisaged including: financing energy efficiency; economic incentives and energy pricing; changing energy behaviour; and participation in international partnerships (37).The objectives of the EPBD (38) are to improve the energy performance of buildings through cost effective measures and to streamline building standards to converge with those that can deliver ambitious energy savings. The main objective of the ESD is to achieve a reduction of 9 % in final energy consumption over a 9-year period (2008–2016). The target is indicative in nature but will be carefully monitored and reported. In 2007 Member States submitted Action Plans describing the measures they have taken to achieve the target. All measures have to be verifiable and measurable or capable of being estimated. Such measures should not be considered in isolation. For instance, some calculations (ECN, 2006) show that measures considered under the ESD could contribute by as much as one third to reaching the 20 % target planned under the Energy Efficiency Action Plan. The difference between the two policies is explained by the fact that they have a different basis — final energy consumption against primary energy consumption. Furthermore, not all sectors are covered by the ESD (as opposed to EEAP) and the period covered by the ESD is shorter than the EEAP.

A closer look at the measures listed in the National Energy Efficiency Action Plans (39) that were submitted by the Member States to comply with requirements under the ESD, underline the important role of the residential sector when it comes to final energy consumption. It also shows the potential for significant energy and CO_2 savings in this sector. Given the overall context of the report, the remaining part of this chapter will focus on the residential sector.

As can be seen from Table 6.1, the share of the residential sector in Final Inland Energy Consumption — FIEC (40) is over 25 % in most countries (with the exception of Cyprus). In some cases (Hungary, Poland, Romania, the United Kingdom), the share of the residential sector in FIEC exceeds 35 %.The expectation that the residential sector can deliver a significant part of the national targets set under the ESD are equally high. For instance, in Ireland and Latvia, measures in the residential sector account for over 77 % of the overall national target, while in the United Kingdom the share is little above 50 %. Cyprus on the other hand estimates that much more can be achieved in the residential sector, thus exceeding the national target set for 2016. The residential sector is likely to have less impact on the national target in countries like Bulgaria, Malta and Slovakia. Some countries, such as Germany, Sweden and the United Kingdom expect a significant part of their 2016 target to be achieved before 2010, while other countries, such as Hungary, Latvia, Lithuania and Slovenia expect that the plan will deliver mostly after 2010.

All Member States appear to have implemented, currently undertake or plan to put in place measures to improve the energy performance of the building envelope and heating systems, and to increase the share of renewables in the residential sector. These measures contribute to a significant part of the national plan in all Member States, showing the significance of heating and cooling costs in the overall energy bill of households, and the high potential to reduce the energy consumption of buildings. All EEA member countries included measures aimed at changing customer behaviour, such as improving the transparency of the energy bill, smart metering and targeted information

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(37) Such as the EC-US-Japan led International Partnership on Energy Efficiency coordinated via the IEA/OECD.

(38) For instance, there are plans are to recast the Energy Performance of Buildings Directive during 2008. The main areas to be considered in the amended Directive include: the expansion of its scope to buildings with a floor area smaller than the 1 000 m^2 threshold (as such buildings cover over 70 % of the EU building stock, expanding the scope of the directive would affect the major part of the EU's buildings stock), expand the role of the public sector to demonstrate leadership by example on energy-efficient buildings, reinforce the role of the energy performance certificates required by the directive, and measures for Member States to facilitate financing of investments leading to energy performance improvements in the buildings sector. For more detailed discussion see: EPBD buildings platform Newsletter no. 018, December 2007.

(39) All action plans are available at: http://ec.europa.eu/energy/demand/legislation/end_use_en.htm.

(40) Calculated as required by the ESD therefore excluding entities subject to EU ETS.

campaigns. Measures such as energy labelling for domestic appliances and support for efficient light bulbs are also aimed at reducing electricity consumption. Some countries have included innovative measures in their NEEAPs. For instance, pilot projects on energy saving measures are being developed together with building owners and district heating companies in the Netherlands. In 2007, the Dutch government identified 40 districts to be upgraded and national and local governments will cooperate with local residents to upgrade their neighbourhoods. The districts involved in the project also have a significant number of low-income households. Local authorities and housing corporations will contribute financially to implement energy efficiency measures in these districts.

What is less clear from these first national plans is how these measures will actually be enforced and monitored. Very few countries included detailed information on how they plan to monitor policy effectiveness. For instance in the Czech Republic monitoring of fuel consumption will be based mainly on energy statistics and household surveys. In Denmark, a review of measures will be undertaken during 2008 and a standard format for public tendering procedures will be adopted to ensure easy implementation of the policy and to promote green procurement. In the Netherlands, the Kompas company is a dedicated entity that works with stakeholders to develop strategies for energy efficiency and CO_2 savings and monitors progress annually via user panels.

Finally, while the measures listed under the NEEAP will have an impact on the commitment of many countries to GHG emissions reductions, very few Member States have included such quantification at this stage. For example, in Germany, some the measures adopted by residential households are expected to deliver reductions in emissions of almost four Mt CO_2, representing over 70 % of the country's residential target under the national climate change program.

This brief and partial overview of the NEEAPs reveals that a big effort is needed if the household sector is to address the energy related question of costs, security of supply and sustainability. In addition, households can make a significant contribution to the mitigation of climate change. Consequently, urgent action is needed at regional/local level, as well as at the level of the individual European citizen, to complement national and European initiatives to implement energy efficiency measures.

Outside of the EU, a number of significant policy initiatives and programmes to address energy efficiency have recently been put in place at the federal level in USA. The building technologies programme (with funding of circa USD 124 million) supports a number of areas including R&D of energy-efficient building technologies and practices; collaboration with state and local regulatory groups and others to improve building codes; and promotion of market transformation by educating homeowners, builders, and developers. The program has specific targets. For new buildings: a 70 % reduction in energy use and a 30 % increase in on-site power generation, enabling design and construction of zero energy homes by 2020. For existing buildings: a 30 % reduction by 2020.

Another relevant policy instrument is the Energy Independence and Security Act (EISA), which was signed into law on 19 December 2007. The main focus of the law is on reducing greenhouse gas emissions, and consists mainly of provisions designed to increase energy efficiency and the availability of renewable energy. Details of EISA's implementation will be included in the federal agency rules, which have yet to be written (for more details on recent energy efficiency policies in USA and China; see also Chapter 7).

6.3 Household energy consumption and emissions

Household energy consumption is affected by a range of factors such as climatic conditions, energy efficiency and changing patterns in demand (arising, for example from growing wealth and ownership of energy consuming products or changing energy prices). To monitor the effect of energy efficiency policies properly, the impacts of improvements in efficiency should be separated-out from all other factors as far as is possible (monitoring and data issues are further discussed in Annex 2).

From 1990–2005 per capita household energy consumption increased in the majority of Member States and by 11.6 % for the EU-27 (Figure 6.1). Only five Member States decreased their per capita energy consumption. For some countries, the decreasing trend in energy consumption is the result of measures to improve building standards but for others it is more likely to be a result of changes in the economy and in the use of district heating. The rise in electricity consumption has been even greater, at 31.1 % for the EU-27, with all Member States showing a rise in consumption except for Bulgaria (due to a slight decline in per capita

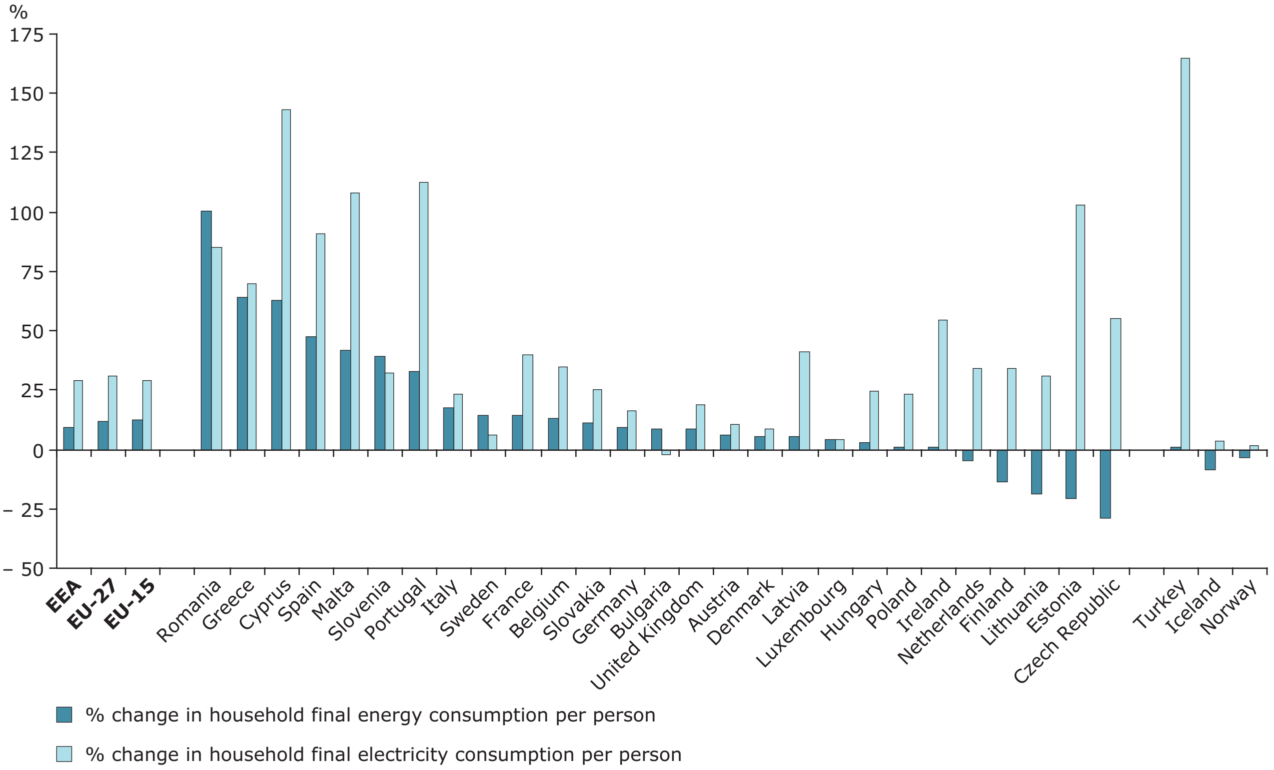
Table 6.1 Overview of targets and estimated savings from the residential sector under ESD Directive

Country	FIEC	Unit	2010 target (ou)	2010 target (% FIEC)	2016 Ntarget (ou)	2016 Ntarget (% FIEC)	Res. (ou)	Res. (% FIEC)	Sav.res (ou)	Sav.res. (% nt)	CO_2 res. (Mt CO_2)
Austria	893 406	TJ	17 868	2	80 407	9	273 933	30.7	n.a.	n.a	n.a
Bulgaria	6 968	ktoe	209	3	627	9	2 160.6	31	52.8	8.4	n.a
Cyprus	1 842.73	ktoe	60	3	185	10	242.4	13.2	264	142.7	n.a
Czech Republic	220 462	GWh	4 126	2	19 842	9		0	6 048	30.5	
Finland	197 700	GWh	5 900	3	17 800	9	56 820	28.7	5 110	28.7	n.a
France	133.3	Mtoe	5	4	12	9		0	n.a.	n.a.	
Germany	9 261	PJ	659	7	1 080	12		0		0	3.86 (partial)
Hungary	177 276	GWh	1 773	1	15 955	9	75 725	42.7	3 550	22.3	
Ireland	145 741	GWh	6 500	4	13 117	9		0	10 315	78.6	
Italy	1 316 261	GWh	35 658	3	126 327	10	333 315.8	25.3		0	
Latvia	38 701	GWh	67	0.17	3 483	9		42.8	2 701	77.5	
Lithuania	3 607.5	ktoe	54	1.5	400	11				0	
Luxembourg	1 7576	GWh	527	3	1 825	10			898	49.2	
Malta	4 195	GWh	126	3	378	9			58	15.3	
Netherlands	568 777	GWh	11 376	2	51 190	9	156 000	27.4	23 576	46.1	
Poland	593 908	GWh	11 878	2	53 452	9	211 561	35.6		0	
Romania	20 840	ktoe	940	4.51	2 800	13	7 665	36.8	n.a	n.a.	
Slovakia	413 500	TJ	12 405	3	37 215	9		0	5 210	14	
Slovenia	47 349	GWh	1 184	2.5	4 261	9	139 72	29.5	1 165	27.3	0.331
Sweden	359 000	GWh	23 300	6.49	32 300	9		0		0	
United Kingdom	151 7000	GWh	136 500	9	272 700	18	556 800	36.7	142 100	52.1	9.3

Notes: FIEC= final inland consumption within the scope of the ESD directive (consumption of entities under EU ETS excluded); 2010 target (ou) = intermediate target as required by ESD directive in original unit; 2010 target (% FIEC) = intermediate target as % of FIEC; 2016 Ntarget (ou) = national target for year 2016 (in this table adopted targets were considered; in some countries the national target is higher than min. 9 %); 2016 Ntarget (% FIEC)= national target as % of FIEC; Res.(ou) = final energy consumption in residential sector (original unit); Res.(% FIEC) = share of residential final consumption in FIEC; Sav.res. (ou) = estimated savings expected from residential sector over the period 2008–2016; Sav.res (% nt) = estimated savings expected from residential sector over the period 2008–2016 as % of the overall national target for 2016; CO_2 res. (Mt CO_2) = estimated CO_2 emissions reductions from residential sector over the period 2008–2016. Where countries provided calculations of the national target and FIEC using coefficients for electricity consumption other than 2.5, as recommended in the Directive (in addition to calculations using the 2.5 coefficient), the values considered in Table 6.1 correspond to FIEC and national targets calculated using the coefficient 2.5 (e.g. Germany). When countries provided a minimum and a maximum for energy savings, the minimum value was considered (e.g. Hungary, Malta, the Netherlands). This provides a rather conservative view of what can be expected to be delivered by the NEEAP in the residential sector but, given the lack of detailed information in many cases on how these policies are going to be monitored and enforced, seems a reasonable approach. Because the focus of this discussion is on the year 2016 and the general contribution expected from the residential sector under the ESD, no distinction was made between the possible contributions of measures under early actions, current and planned policies, although in some cases early actions seem to play a significant part of the overall plan (e.g. Sweden). In some cases, it was not possible to evaluate the estimated energy and CO_2 savings from the residential sector, not because the information was not provided but because the residential sector was treated together with other sectors (e.g. services).

Source: NEEAPs, 2008; EEA calculations.

Figure 6.1 % change households final energy consumption per person, 1990–2005



Note: Population as estimated on 1 January each year.

Source: Eurostat.

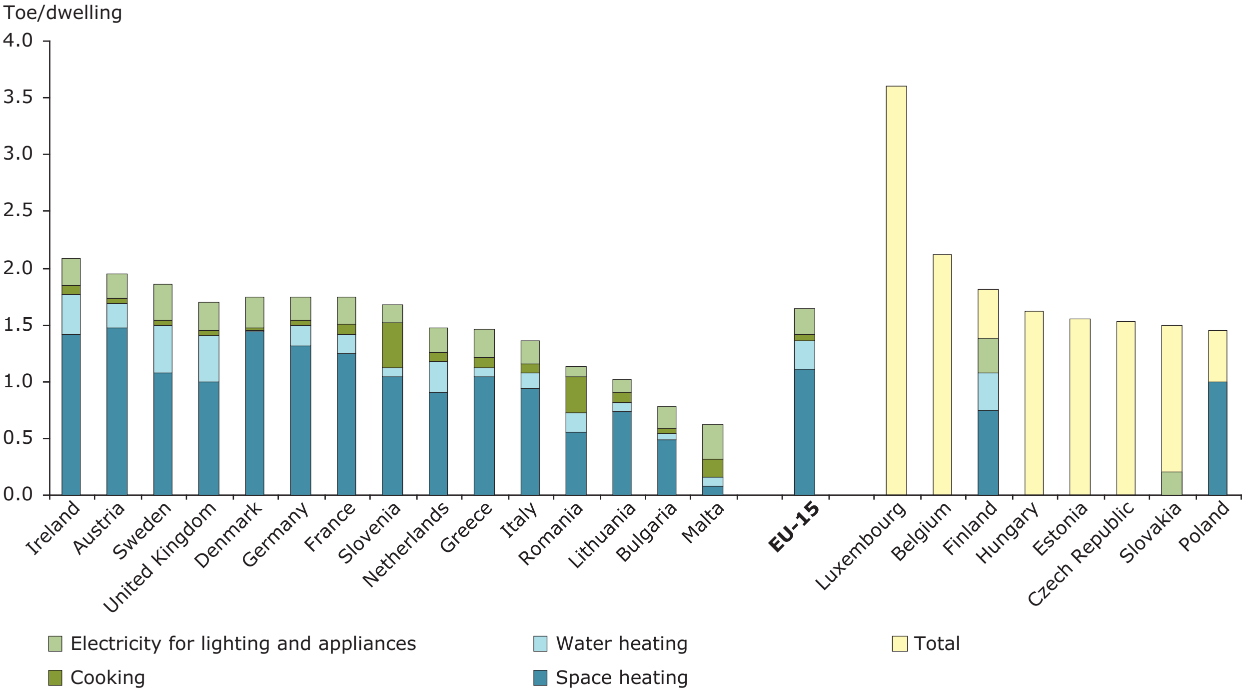
electricity consumption for appliances and lighting, which accounts for 2/3 of all household electricity consumption). Consumption in Cyprus, Malta, Portugal and Estonia has risen by more than 100 %.

Space heating is the largest component of energy use in virtually all Member States, accounting for 67 % at the level of the EU-15, followed by water heating and appliances/lighting (Figure 6.2). These figures are based on estimates (e.g. from surveys) or modelling as it is not possible to measure this directly. It is difficult, for example, to distinguish between households where a central boiler provides both space and water heating or the dwelling uses electricity for heating. The proportion used for space heating depends on factors such as the level of thermal efficiency of the building, the degree of use of on-site renewables and climatic conditions.

Energy efficiency indices can be defined as a ratio between the actual energy consumption of the sector in year t and the sum of the implied energy consumption from each underlying sub-sector/end-use in year t (based on the unit consumption of the sub-sector in a reference year — in this case 1990). Hence, a value of 88 in 2005 for EU-27 households indicates a 12 % improvement in energy efficiency relative to the base year. The sectoral indices shown in Figure 6.3 are composed of a number of weighted unit consumption indicators, to provide a better indication of energy efficiency improvements than simple intensity variations. For households, the evaluation is carried out at the level of three end uses (heating, water heating and cooking) and five large appliances (refrigerators, freezers, washing machines, dishwashers and TVs). For each end use, the following indicators are used to measure efficiency progress: heating — unit consumption per m^2 at normal climate (toe/m^2); water heating — unit consumption per dwelling with water heating; and cooking — unit consumption per dwelling.

Energy efficiency in the EU-15 increased steadily to the mid 1990s but the rate of improvement has since slowed. A more detailed analysis, reported by Odyssee, shows that the heating component follows the same behaviour as a result of the more wide-spread penetration of higher efficiency condensing boilers and the implementation of

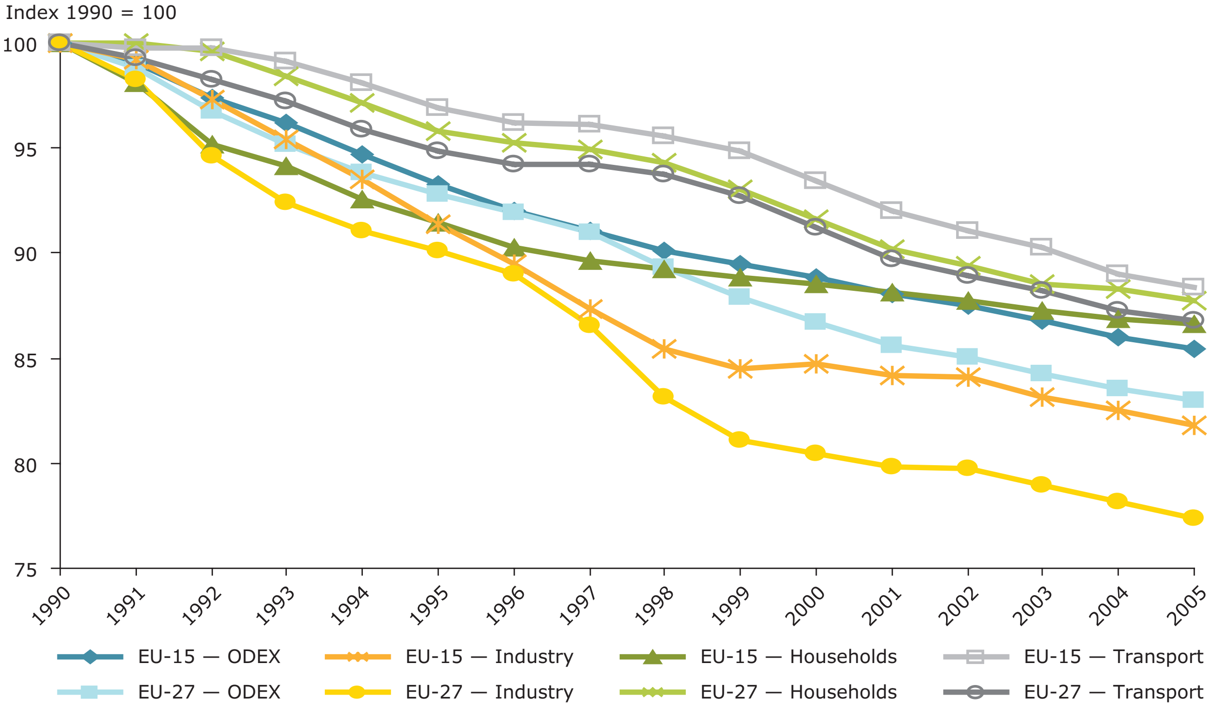
Figure 6.2 Energy consumption by end use per dwelling, 2005



Note: A full breakdown of energy consumption by end-use is not available for the countries listed to the right of the EU-15 graph and hence only the total and available end-uses are shown.

Source: Odyssee.

Figure 6.3 Odyssee ODEX — energy efficiency index



Note: ODEX is the aggregate energy efficiency index of the other three sectors.

Source: Odyssee.

cheaper and easier options (such as loft insulation) in existing houses.

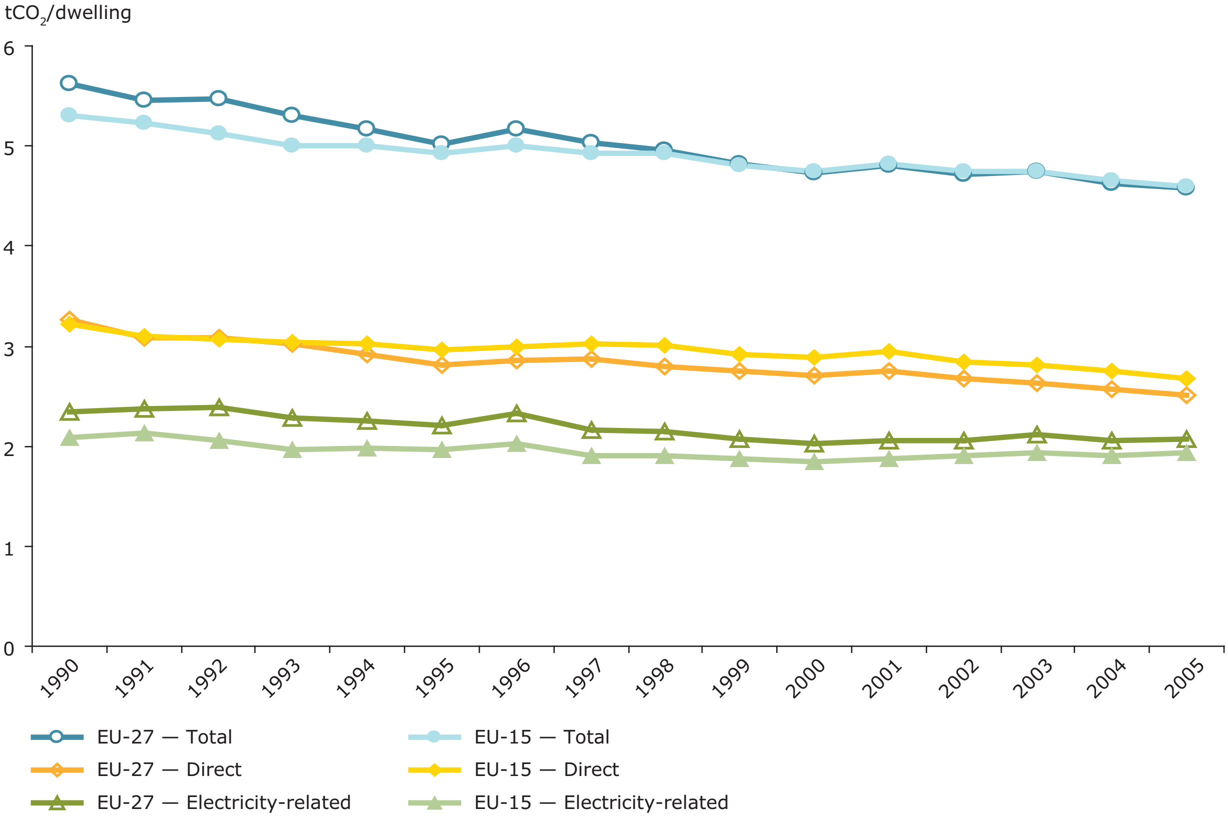
The CO_2 emissions per dwelling from the direct use of fuels in households slowly decreased in both the EU-15 and EU-27 over the period to 2005 (by 17 % and 23 % respectively) (Figure 6.4). This is due largely to improvements in the thermal efficiency of buildings, as well as to the increased efficiency of energy supply systems (primarily boilers) in households. Electricity related emissions also decreased slightly despite a rise in the electricity consumption of households by almost 19 % per dwelling in the EU-27, due, in part, to a more widespread ownership of appliances. The decrease in CO_2 emissions resulted from improvements in the carbon intensity of electricity generation (see Figure 1.4), although the decrease in overall emissions has been lessened by the increase in the number of dwellings in Europe.

This chapter discusses the energy and emissions from the end use in households, including electricity and direct fuel use. Reporting under the UNFCCC and Kyoto Protocol assigns emissions from electricity to the power sector and household emissions refer only to direct fuel use such as gas for heating.

Energy consumption for space heating per m^2 (to account for variations in dwelling size) decreased by around 12 % in the EU-15 and in virtually all Member States from 1990 to 2005, with the exception of Greece and Italy. In many countries, the level of comfort, represented by the temperature and period of heating, has increased over time, which has further tended to increase consumption. In Figure 6.5 the consumption, scaled to the EU average climate, provides a broad illustration of differences in heating efficiency between Member States. Those below the EU-15 average are broadly more efficient; however, the graph does not capture the impact of variables such as comfort or occupancy levels, which may differ substantially between countries.

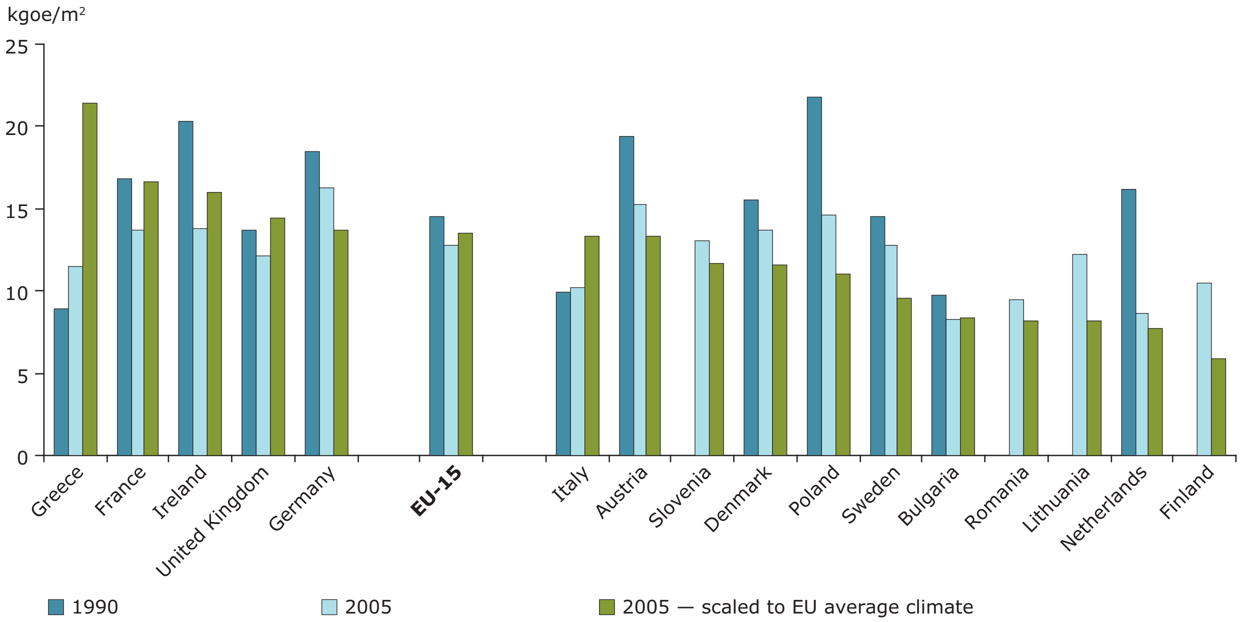
The solid bars in Figure 6.6 represent emissions from the direct use of fuels for space heating in households. Differences in CO_2 emissions for space heating per m^2 between countries broadly reflect the

Figure 6.4 Household CO_2 emissions per dwelling, climate corrected



Source: Odyssee.

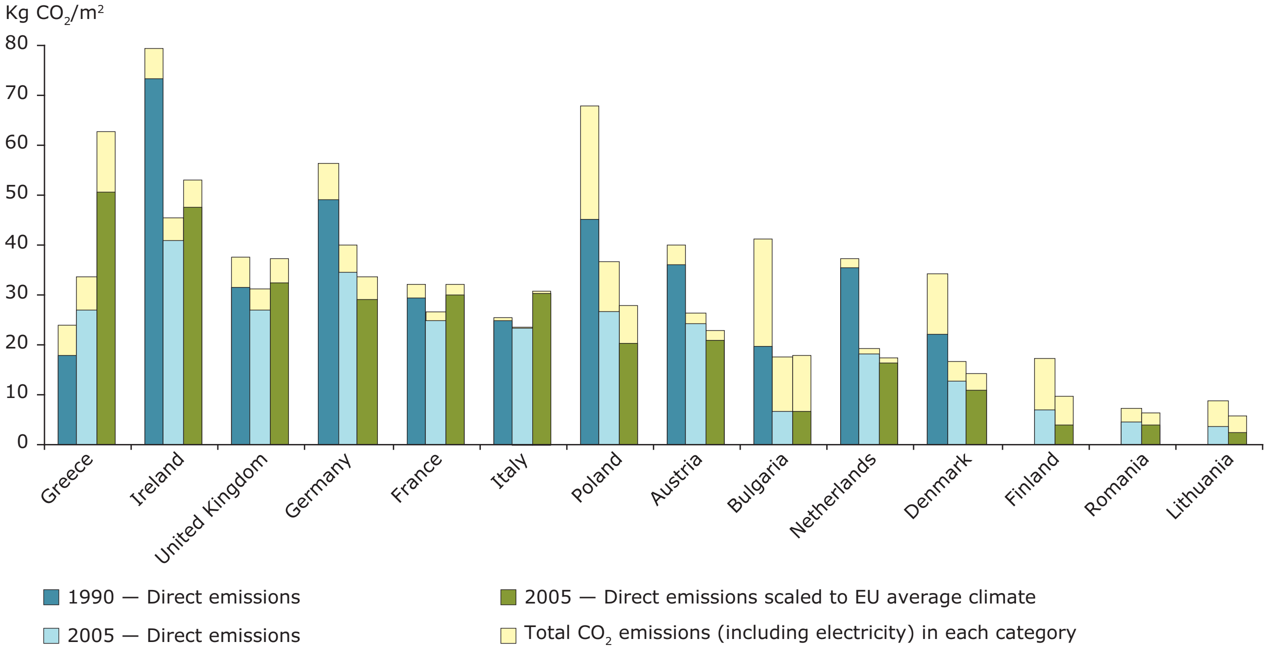
Figure 6.5 Household energy consumption, space heating per m², climate corrected



Note: 1990 and 2005 data are climate corrected against each country's long-term average climate, whereas the last series is climate corrected and scaled against the EU long-term average climate to account for temperature differences between countries.

Source: Odyssee.

Figure 6.6 CO_2 emissions, space heating per m², climate corrected



Note: 1990 and 2005 data is climate corrected against each country's long-term average climate, whereas the last series is climate corrected and scaled against the EU long-term average climate to account for temperature differences between countries.

Source: Odyssee.

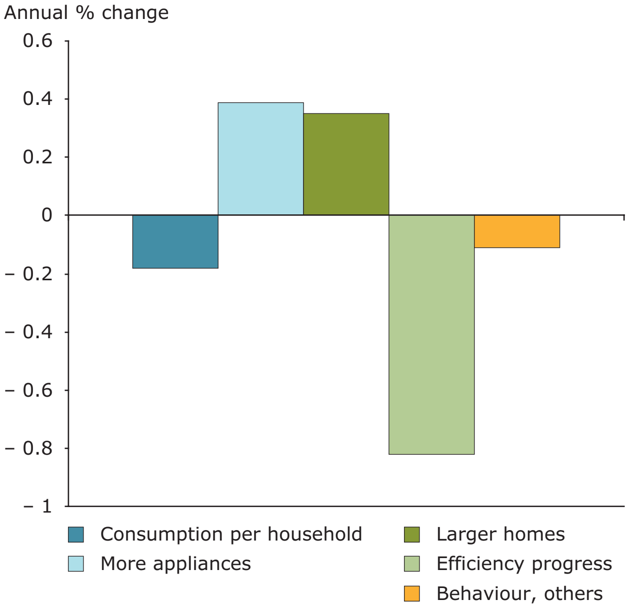
level of energy consumption per m^2 in Figure 6.5, with only a small contribution from fuel mix. Differences in the carbon intensity of the electricity system used for space heating and the use of CHP, lead to lower emissions in countries such as Finland, Romania and Lithuania. In 2005, these countries had emissions (scaled to the average EU climate) that were more than five times lower than countries such as Greece.

In 2004, the average energy consumption per dwelling in the EU-15 was only 3 % below the 1990 level, whereas the energy efficiency index was 12 % below (see Figure 6.3). This means that lifestyle changes have offset almost all the energy efficiency improvements achieved. Three main influences were quantified to measure the impact of these factors on the average annual consumption per household:

- the increase in the average size of dwellings;
- the spread of electrical appliances and central heating, i.e. the influence of increased appliance ownership;
- behaviour related to changes in comfort levels (e.g. hot water, heating temperature and period of use).

Figure 6.7 shows the effect of these factors on household consumption. Larger homes and an increasing number of appliances each contributed to raising the consumption per household by about 0.4 %/year. These two factors partly offset the progress made in energy efficiency (– 0.8 % per year) and behaviour (nearly – 0.2 % per year) resulting in the net decrease in consumption (dark blue bar) of only 0.2 % per year.

Figure 6.7 Drivers of the change in average annual energy consumption per household in the EU-15 from 1990 to 2004



Source: Odyssee.

6.4 Good practice in policy design and evaluation

Defining good practice in the design and monitoring of energy efficiency policies is difficult for the household sector because the success of such measures can depend on local conditions and the availability of sufficient data. There have been a number of different projects aimed at defining good practice. In Europe, these include AID-EE ([41]), BEHAVE ([42]) and MURE ([43]).

The EEA expert meeting outlined a number of general principles that can serve as a foundation for designing and implementing good energy efficiency policies in households. These include:

- Targeting of existing, cost-effective efficiency options. These should generally be undertaken before moving onto more innovative approaches, unless the new approaches are shown to have higher impact. Innovation is also vital for expanding the potential for energy efficiency improvements in the future.
- Policies and measures should aim to tackle the problem at its root. There is a need to accelerate market penetration for clean and efficient technologies, to accelerate the phasing-out of the old equipment and to prevent inefficient equipment from entering the market or inefficient buildings being constructed. For example, any barriers to slow uptake such as lack of finance for investment need to be addressed directly by the policy.
- Policies should provide a long-term perspective to create a stable environment for investments

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([41]) http://www.aid-ee.org/.
([42]) http://www.energy-behave.net/.
([43]) http://www.mure2.com/.

but also need to be sensitive to changing market, economic and social circumstances.
- Policies and measures should consider consumer psychology, for example aversion to taxes or the rationale controlling purchasing habits.
- An integrated approach should be adopted for the design of policies and measures to consider the impact on other policy objectives ([44]).
- The risks and benefits of the policies/measures subsequently being captured by strong interest groups should be carefully considered from the beginning. For instance, it may prove to be an advantage to work with architects and the real estate industry to influence consumer preferences towards better buildings.
- Policies should aim to minimise administrative costs and burdens wherever possible, for example by simplifying their implementation.
- The relationship between the business cycle and the policy cycle should be respected as this may affect the level of investment required to implement efficiency measures (standards are independent from the business cycle while financial incentives are not).
- Differences among Member States should be recognised where relevant (e.g. training needs, building stock, etc.).

A number of possible criteria for good practice in defining energy efficiency policies and measures were identified for the household sector, taking into consideration environmental impacts, energy dependency and impact on energy affordability. It is important to note that such criteria may not apply to every type of measure and may depend on national circumstances. In general, the measure or policy should:

- have had a credible *ex-ante* assessment of its potential impact on markets for clean technologies, and should aim to have sufficiently high impact on energy efficiency;
- have a good ratio between maximum benefits ([45]) (net of possible rebound effects) relative to its implementation and monitoring costs;
- include provisions to enable its effective evaluation , not only at the end of the lifetime of the policy/programme but also at intermediate points during its life;
- aim to involve a large stakeholder base and attract long-term investments;
- stimulate private sector involvement;
- include both an information component that includes the estimated environmental benefits and an assessment of the adequate training needed for its implementation;
- have an impact which is measurable and well anchored in a broader economic and social context;
- have clear goals and targets that address a specific market barrier or driver;
- be replicable in other EU Member States;
- include an overall environmental impact assessment when appropriate, for example, when exchanging oil/gas fuelled boilers for biomass fuelled boilers.

Policies should be designed to stimulate the most cost effective savings, giving a high impact at a reasonable cost. As cost effective savings are being implemented, other measures will also need to be taken in parallel, such as increasing the share of renewables in buildings, to support other policy objectives and the new renewables targets, and to stimulate innovation to lower the cost of such measures in the future.

The literature provides many examples of policies in the household sector that include elements of good practice. European examples of these are defined as having high impact ([46]) in the MURE database. Some of these include:

- The Thermal Modernization Fund in Poland, whereby investors receive a premium of 25 % of any loan used to implement eligible projects. To be eligible, projects should fulfil minimum energy savings and meet certain financial criteria. An energy audit is required to validate the technical and economic evaluation. , The effect of this policy was low up to June 2002, after which date it was amended to decrease the credit interest rates and its positive effect increased significantly. This demonstrates responsiveness to concerns about the policy effectiveness.

([44]) For example, biomass boilers can lead to environmental benefits, if the biomass supply is sustainable, and increase fuel security. However, they are generally less efficient and will increase primary energy consumption.

([45]) The benefits evaluated, participants felt, should not be limited to monetary benefits but should include others such as environment, energy security

([46]) High impact in MURE relates to the scale of carbon savings and not to the cost effectiveness.

- The More with Less action plan in the Netherlands is a comprehensive collection of measures to achieve considerable energy savings in the built environment. It addresses a number of barriers by raising awareness, and providing advice, implementation and 'after sales' service. The *ex-ante* evaluation estimates a saving of 50 PJ of primary energy.
- The Energy Efficiency Commitment (47) in the United Kingdom is one of the largest and most ambitious programmes aimed at tackling efficiency in existing households in the EU. It puts an obligation on large energy suppliers to install energy efficiency measures into households. Suppliers must achieve an energy saving target that is based on individual scores for the installation of a wide-range of efficiency measures into different types of households. Suppliers have flexibility about which measures to install and the approach encourages suppliers to find the most cost-effective way to achieve the target. Suppliers also try to interact with other UK Government policies, such as social housing, to deliver economies of scale. They must also target a percentage of their activity at more vulnerable households (48), thereby forming a link with other policy objectives on fuel poverty and energy affordability. The scheme's various phases (it will run from 2002 to 2020) are subject to a range of *ex-ante* and *ex-post* evaluations and the subsequent phases will be adapted to improve the functioning of the scheme. For example, trying to promote more innovative measures, such as micro-generation, in later phases, may exhaust the potential for improvement by existing measures.

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(47) http://www.defra.gov.uk/environment/climatechange/uk/household/supplier/eec.htm.

(48) 40 % of the carbon savings target required under the current phase of the scheme (running from 2008 to 2011 and now known as the Carbon Emissions Reduction Target) must be achieved from this 'priority group'.

7 EU trends compared to other countries

Main messages

During the 13th Conference of Parties to the UN Climate Convention, parties agreed that there exists a need for a shared view on how to deal with climate change in the long-term perspective. Alongside a shared view, there should also be a shared responsibility for action — given both historic and current trends in generating global GHG (particularly CO_2) emissions. These trends vary from country to country. In the EU and in countries such as China and USA, there is a growing recognition that it is crucial to improve the energy efficiency and expand renewable energy — not only because of the current global context of rising energy demand and energy prices, but also because these are important measures to reduce CO_2 emissions. Experience accumulated in the EU-27 shows that the consistent implementation over time of environmental and energy policies can be effective but much more has to be accomplished in the near future to ensure the substantial reductions in the level of CO_2 emissions that are necessary to avoid irreversible effects of climate change.

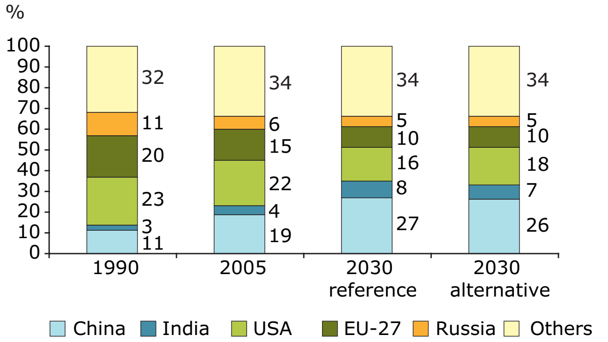
1. Between 1990 and 2005, the EU-27 experienced an average GDP growth rate of 2.1 %, while reducing its energy-related CO_2 emissions by a total of about 3 %. During the same period, CO_2 emissions increased by 20 % in USA and doubled in China. Energy-related CO_2 emissions in Russia decreased by 30 % due to economic restructuring.
2. From 1990 to 2005, the EU's per capita CO_2 emissions decreased by 6.7 %, having become less than half of those in USA and about 25 % lower than per capita emissions in Russia. Per capita emissions in China are now 52 % below the EU level but they are growing fast due to the pace of economic development and the increase in the use of coal for power production.
3. Between 1990 and 2005, the CO_2 emissions intensity of the public electricity and heat production in the EU-27 decreased by 18.2 % while in many other parts of the world, including Russia, the opposite is true. A slight decrease occurred in China and USA (0.8 % and 2.5 %, respectively), partly because of changes in the renewable production (less hydroelectricity due to less rainfall) which offset improvements resulting from the implementation, in recent years and particularly after 2004, of energy efficiency policies.
4. Policies for energy efficiency and renewable energy are being implemented in the EU-27, USA and China, but the overall objectives of these policies may differ. For instance, in the EU-27 and USA, environmental protection is one of the key stated policy objectives, while China needs to find a balance between the enormous increase in its energy demand and the subsequent environmental consequences (e.g. increased air pollution). Enhancing security of energy supply is a driver everywhere.

In all countries, efforts are being made (and are expected to continue) to boost the renewable energy. Under the WEM (IEA) baseline scenario, by 2030, electricity produced in the EU-27 Member States from renewable energy could account for as much as 18 % of the global total, followed by China with 17 %, and USA with a share of 12 %. Under the WEM alternative scenario, electricity generated by China from renewables, could represent as much as 20 % of the global total, followed by the EU-27 with 16 %, and USA with 11 %. The shares of the EU-27 and USA in the global total appear to decrease, because in this scenario all countries are expected to step up their efforts to increase the share of renewables in their energy mix.

Looking at the WEM baseline and alternative scenarios (concerning the possible evolution of the global total of CO_2 emissions), it is clear that in the EU-27, as well as in other countries — such as China and USA, it is still imperative to take measures to decrease the energy intensity of the economy and to deploy renewable energy faster. According to the WEM baseline scenario, by 2030, China's share of the total CO_2 emissions in the global total could be as high as 27 %, surpassing USA and the EU-27 — with a share of 16 % and 10 %, respectively. Even considering a more stringent energy and climate policies, China's share in the global total CO_2

emissions remains significant (26 %), and so does that of USA (18 %), followed by the EU-27 (with 10 %). Under the alternative scenario, all countries are expected to reduce their total CO_2 emissions, which explains why the share of USA appears to be higher and the EU-27 appears to remain at a constant level.

Figure 7.1 Shares of total CO_2 emissions (percentage of global total)



Note: Total CO_2 emissions include emissions from power generation, other energy sector and total final consumption. CO_2 emissions from aviation, industrial waste and non-renewable municipal waste are excluded. Data for 2030 reference refers to the IEA reference scenario while 2030 alternative refers to the IEA alternative scenario (see Annex 1 for details)

Source: IEA, 2007a; EEA.

7.1 The context

Since early 1990s, the EU has made continuous efforts to reduce its CO_2 emissions by changing the fuel energy mix, improving transformation efficiency (see Figure 1.8) and reducing the energy demand of the end-consumer (see Figures 6.3, 6.4 and 6.7). As discussed in previous chapters, much remains to be done, despite these early efforts having led to a reduction in total CO_2 emissions in the EU-27. A sustained global effort is required to tackle global climate change effectively. While the EU-27 Member States remain an important contributor to global CO_2 emissions, USA, China and other countries, including India and the Russian Federation, are the key to achieving the emissions reductions needed to avoid the irreversible global consequences of climate change. In 2005, USA, China and the Russian Federation had a share of total CO_2 emissions in global total of 22 %, 19 % and 6 % respectively. In addition, the projected evolution of CO_2 emissions over the next couple of decades show the increasing impact of China, which is expected to account for over 25 % of global total CO_2 emissions by 2030 even under more sustainable scenarios (see Figure 7.1), overtaking by far both the EU-27 Member States and USA.

During the 2007 UN Climate Change Conference in Bali, the international community began to focus on a shared vision to deal with the challenge of climate change in the aftermath of 2012 and agreed a road map to conduct the negotiation process. The process is envisaged to be completed by the end of 2009 at the 15th Conference of Parties to be held in Copenhagen. The negotiations are likely to focus on four main themes, with mitigation, emissions reduction, and adaptation to the effects of climate change likely to be at the heart of any eventual agreement. In addition, because of their historic responsibilities developed countries accepted the outcomes of the 4th IPCC Assessment report and are contemplating a reduction in their GHG emissions of between 25 and 40 % by 2020 relative to 1990 level. Developing countries are also expected to pursue more carbon-friendly development strategies but will not have quantitative obligations, except for some rapidly developing economies which might also have targets. Developing countries, in particular the least developed countries, will receive special financing from industrialized states to help them adapt to changes in global climate. Finally, technology transfer to help such nations cut their GHG emissions will be supported. Furthermore, at the G8 summit held in Japan in July 2008, the heads of state of the richest industrialized countries plus Russia shared the goal of at least a 50 % reduction in GHG emissions by 2050 relative to the 1990 level and agreed to implement mid-term quantitative national targets. While it is too early in the process to foresee the shape of a possible post 2012 global climate agreement, some G8 countries appear to favour a design based on sectoral approaches. Such an approach might help bringing more countries on board for a global effort through sector-specific objectives and might represent a first step towards establishing national objectives by starting from a bottom-up, sectoral level.

In terms of overall GHG emissions, there are significant differences between countries, with different sectors having different contributions to the total GHG emissions balance. In China in the year 2000 for instance, 31 % of total GHG emissions came from electricity and heat production, 18 % from manufacturing and construction and 21.5 % agriculture. The whole energy sector accounted for 68.3 % of total GHG emissions. In Brazil, 61 % of total GHG emissions came from deforestation (land-use change and forestry) and 20 % agriculture. The whole energy sector accounted for only 14.4 %.

In India, 34.9 % of total GHG emissions came from agriculture, 30.5 % from electricity and heat production, and 12.6 % from manufacturing. The energy sector accounted for 58.3 % of total GHG emissions. In the EU-25, USA and the Russian Federation, most of the GHG emissions came from the energy sector with respective shares of 78.3 %, 91.1 % and 81.54 % (49).

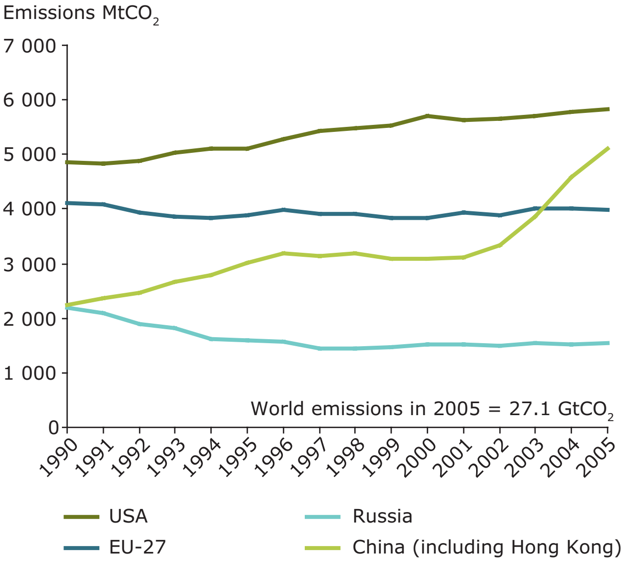
Section 7.2 presents a brief analysis of the EU-27 achievements in CO_2 emissions reductions compared to other countries in the world, taking into account the overall framework of the report. Countries were selected based on their current and expected contribution to global GHG emissions and considering the relatively limited scope of the present report. While relevant for the climate debate, the issues and indicators developed in this report are insufficiently clear (due to lack of data) and relevant to adequately address the comparative contribution to global climate change of countries like Brazil or India. For example, Brazil has a much larger share of emissions from deforestation than most other countries. For this reason, these countries were excluded from the analysis presented in this chapter.

7.2 Trends

The EU-27 absolute level of energy-related CO_2 emissions declined slightly between 1990 and 2005. By contrast, emissions in USA rose by almost 20 % over the same period and those in China have more than doubled (Figure 7.2). This development was driven by rapid industrialisation in China and the corresponding increase in demand for energy. In particular, there has been a rapid increase in electricity consumption supplied primarily by new coal-fired power plants. Emissions in Russia declined by almost 35 % in the first half of the 1990s following substantial economic restructuring, however, they have since risen slowly following renewed economic growth.

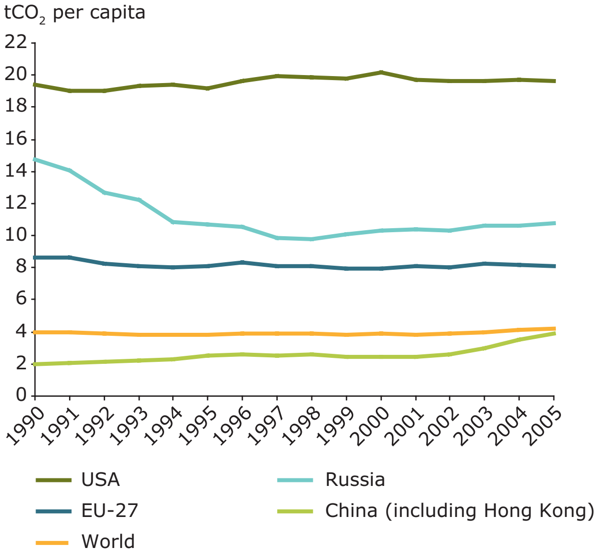
Relative changes in CO_2 emissions are constrained by relative changes in the carbon content of the energy, the energy content of GDP, the evolution of GDP per capita and demographic changes. In the very long-term, per-capita convergence is likely to be part of a more equitable allocation of responsibility among countries concerning their expected CO_2 emission reductions. Until then, there is a need for a transition period during which developed countries continue to reduce their emissions and

Figure 7.2 Total energy-related CO_2 emissions in the EU, USA, Russia and China



Source: EEA; IEA; Eurostat.

Figure 7.3 Energy-related CO_2 emissions per capita in the EU, USA, Russia, China and the World



Source: EEA; IEA; Eurostat.

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(49) Data for Russia are from 2005.

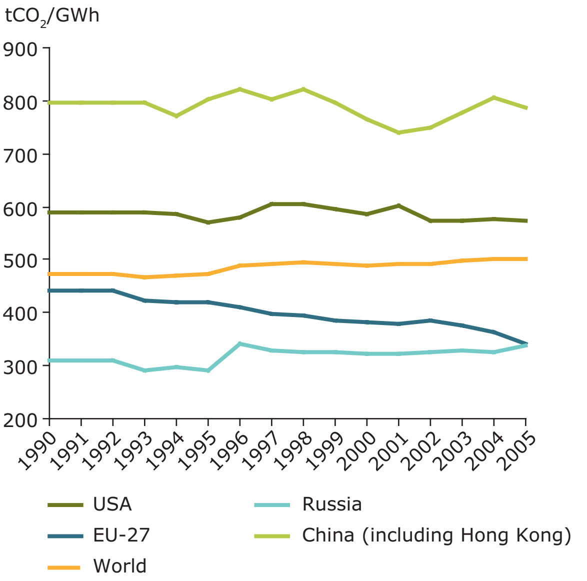
convergence, because current levels of per capita CO_2 emissions (see Figure 7.3) result from a wide-ranging set of country-specific circumstances. During this period, other factors, such as economic conditions, technological potential and relative costs of abatement are relevant for future mid-term target setting assessments.

In the EU, per capita CO_2 emissions decreased by 6.7 % over the period from 1990 to 2005. Most of the reduction took place at the beginning of the 1990s and emissions have since stabilised at around eight t CO_2. Per capita emissions in the EU-27 are less than half of those in USA and around 25 % lower than in Russia. The higher level of per capita emissions in USA and Russia are driven by lower levels of efficiency, particularly within the transport sector in USA, as well as more carbon intensive heat and power production systems (see Figure 7.4). Per capita emissions from China are still around half those of the EU but have increased rapidly in the last few years, driven by a rising demand for energy.

At the global level, the intensity of carbon dioxide emissions from electricity and heat production increased from 1990 to 2005 due to an expansion of coal fired power generation, primarily in developing countries. The emissions intensity of energy production decreased slightly in recent years in China (including Hong Kong) and USA but increased in Russia. However, the share of renewables in electricity production drove the fluctuations seen in China and USA, in particular hydro plants. By comparison, the EU's emission intensity decreased steadily over the period driven by a combination of switching away from coal and oil towards natural gas, an increased share of renewables and improvements in generation efficiency.

Efforts to boost renewable energy are being made in all countries, and are expected to continue (see Figure 7.5). As discussed in previous chapters, renewable energy in Europe could simultaneously help achieve multiple goals including, realizing environmental benefits (including local pollution), improving security of supply and contributing to sustainable development. The IEA alternative scenario assumes that the share of renewables in total primary energy consumption will increase worldwide. The increase in total generation by 2030 is predicted to be greater than the increase in the EU-27, Russia and USA so their share of renewable electricity decreases. At national level, the positive trend to increase the share of RES is expected to continue in all countries discussed. However, China's contribution could become significant in the next couple of decades due to the vast RES potential in this country.

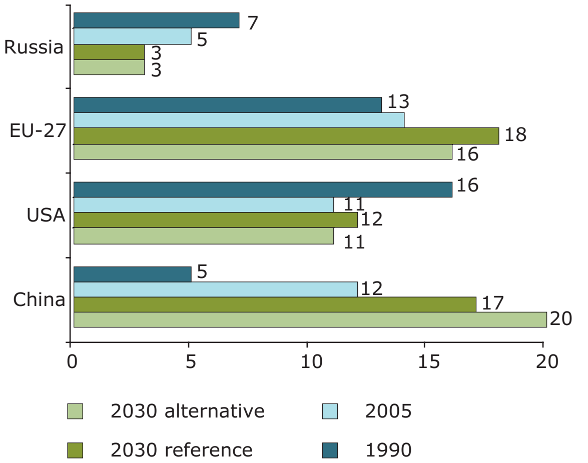
Figure 7.4 CO_2 emissions intensity of electricity and heat output



Notes: The emissions intensity is the level of CO_2, emissions per GWh of electricity and heat produced.

Source: EEA; IEA.

Figure 7.5 Renewable electricity generation in selected countries and regions (percentage of global total renewable electricity generation)



Note: The renewables considered include hydro (small and large), biomass and waste, wind, geothermal, solar, tide and wave.

Source: IEA, 2007a.

7.3 Energy efficiency and renewable energy policies in USA and China

China and USA are the two key countries in the climate debate due to their current large share in global total CO_2 emissions (Figure 7.1). Furthermore, their impact on global emissions is likely to remain significant for decades to come. While improving energy efficiency and increasing the share of renewable energy should remain high on the political agenda in these countries, it is important to recognise the progress these countries have made in recent years.

China reported significant progress in promoting energy efficiency and renewable energy but experiences tremendous challenges in meeting the energy demand of a huge population with increasing purchasing power, in times of impressive economic growth. In 1978, the total installed capacity in China was merely around 57 GW. In 2004, the installed electricity capacity increased more than seven fold. In 2002, some 12 regions in China experienced systematic power shortages and the number doubled a year later, reflecting the fact that power generation in China can hardly keep-up with the pace of economic development. Of its 1.3 bn people, 750 m live in rural areas and some 24 m experience poverty. At the same time, in its first National Climate Change Programme published in June 2007, China recognised that climate change would have significant impacts on its natural ecosystems and socio-economic system in the future. According to the programme, 1 in 5 people in China will be affected by the impacts of global climate change. To address these issues, the Chinese government started to implement a series of measures to improve energy efficiency and promote renewable energy. These measures include a new law to promote renewable energy introduced in 2006 (15 % RES by 2020), measures to increase the efficiency of new power plants (larger, more efficient units, state-of-the-art technologies), increase efficiency in existing plants, plans for the early shut down of inefficient coal power plants (units less than 50–100 MW). According to the Chinese authorities, some 800 mtce (tonnes of coal equivalent) of energy were saved between 1991 and 2005 through energy conservation methods and some 2.94 bnt CO_2 have been avoided. China has a target to reduce the energy intensity of its GDP by 20 % by 2010 and 10 % of its GHG emissions by the same year. China started to launch behaviour change campaigns for households, such as an ambitious energy conservation campaign that has the objective of limiting indoor temperatures to optimal levels (18 °C in winter and 26 °C in summer).

USA was self-sufficient in energy until the late 1950s when energy consumption began to outpace domestic production. In 2006, net imported energy accounted for 30 % of all energy consumed. By 2006, the energy consumed per capita in USA was 55 % higher than 1949 levels but the energy intensity of its GDP decreased by more than 50 % over the same period (50). USA started to implement ambitious programmes at federal level to address the issue of energy dependency by reducing its energy consumption and boosting renewable energy. Some of these policies have already been described in Chapter 6. In addition to these policies, a number of product related energy standards have been or are about to be introduced, including incandescent reflector lamps (2008), small commercial air conditioners (2008), external power supplies (2008), metal halide lamp fixtures (2009), walk-in coolers and walk-in freezers (2009), and single-package vertical air conditioners and heat pumps (2010). Furthermore, a revision of the energy standards for a number of household appliances is planned to take place between now and 2012. Finally, the Executive Order 13423 — Strengthening Federal Environmental, Energy, and Transportation Management — issued in January 2007 includes a couple of relevant measures to be implemented by governmental agencies such as a target to reduce energy consumption by 3 % a year or 30 % by end of 2015 (baseline: 2003), to promote new renewable energy (RE), and a target to reduce water consumption by 2 % annually or 16 % by end of 2015 (baseline: 2007).

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(50) A. Hoffman, presentation delivered during the energy efficiency meeting held at the EEA on 27–28 March 2008.

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Annex 1 Background to scenarios

This section provides a brief overview of the models and scenarios used within this report. These are generally very detailed with a large number of underlying assumptions. For brevity it is not possible to reproduce these here, however, key references for this information are provided below.

PRIMES 2007 baseline scenario

The PRIMES model simulates the European energy system and markets on a country-by-country basis and provides detailed results about energy balances, CO_2 emissions, investment, energy technology penetration, prices and costs at 5-year intervals over a time period from 2000 to 2030.

The current version of the model PRIMES include extensive representation of power generation technologies and incorporates detailed information about future power plants enabled with carbon capture and geological sequestration. The model establishes a complete linkage between supply and demand for energy with endogenous price formation within the EU. This allows CO_2 and renewable policies to be assessed ensuring consistency of technology deployment within market equilibrium in the energy system taking into account feed-back impacts of energy prices on energy demand.

The PRIMES 2007 energy baseline, developed with Member States, reflects current trends and policies and their impact on the energy system. For further information on the model and underlying scenario assumptions see:

- *European Energy and Transport — Trends to 2030 — update 2007*, report produced for the European Commission DG TREN; http://ec.europa.eu/dgs/energy_transport/figures/trends_2030_update_2007/index_en.htm.

The PRIMES model was also used for part of the analytical work underpinning the new EU energy package — for further information see:

- Impact Assessment (and Annex) Document accompanying the Package of Implementation measures for the EU's objectives on climate change and renewable energy for 2020, SEC(2008) 85/3; http://ec.europa.eu/energy/climate_actions/doc/2008_res_ia_en.pdf; http://ec.europa.eu/environment/climat/pdf/climate_package_ia_annex.pdf.

POLES 2006 baseline and GHG reduction scenarios

The POLES (Prospective Outlook for the Long term Energy System) model is a global sectoral simulation model for the development of energy scenarios until 2050. The dynamics of the model are based on a recursive (year by year) simulation process of energy demand and supply with lagged adjustments to prices and a feedback loop through international energy prices.

The model is developed within the framework of a hierarchical structure of interconnected modules at the international, regional and national level. It contains technologically-detailed modules for energy-related intensive sectors including power generation, production of iron and steel, aluminium and cement, as well as modal transportation sectors. In each sector, energy consumption is calculated for both substitutable fuels and for electricity. Each demand equation contains an income or activity variable elasticity, a price elasticity, captures technological trends and, when appropriate saturation effects.

All energy prices are determined endogenously in POLES. Oil prices in the long term depend primarily on the relative scarcity of oil reserves (i.e. the reserve-to-production ratio). In the short run, the oil price is mainly influenced by spare production capacities of large oil producing countries.

The baseline scenario represents a development of the energy system assuming existing policies and measures, whilst the GHG reduction scenario looks at a possible global emissions trajectory until 2050, which can lead to the EU's objective of limiting any global temperature rise to 2 °C.

For further information on the POLES model and underlying scenario assumptions see:

- Global Climate Policy Scenarios for 2030 and beyond — Analysis of Greenhouse Gas Emission Reduction Pathway Scenarios with the POLES and GEM-E3 models, 2006, Report produced by the JRC (Joint Research Centre), European Commission; http://www.jrc.es/publications/pub.cfm?id=1510.

The model work contributed to both the Commission's new climate package (see links above) as well as the earlier:

- Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions, Limiting Global Climate Change to 2 degrees Celsius, The way ahead for 2020 and beyond, SEC(2007) 8; http://ec.europa.eu/environment/climat/pdf/ia_sec_8.pdf.

IEA WEO 2007 Reference and Alternative Policy Scenarios

The IEA's World Energy Model (WEM) is a large-scale mathematical construct designed to replicate how energy markets function. It is the principal tool used to generate detailed sector-by-sector and region-by-region scenarios for both the reference and alternative policy scenarios. The model is made up of five main modules: final energy demand; power generation; refinery and other transformation; fossil-fuel supply and CO_2 emissions.

The reference scenario takes account of those government policies and measures that were enacted or adopted by mid-2006, though many of them have not yet been fully implement. Possible, potential or even likely future policy actions are not considered.

The alternative policy scenario analyses how the global energy market could evolve if countries were to adopt all of the policies they are currently considering related to energy security and energy-related CO_2 emissions. The aim is to understand how far those policies could take us in dealing with challenges and at what cost. These policies include efforts to improve efficiency in energy production and use, increased reliance on non-fossil fuels and sustain the domestic supply of oil and gas within net energy-related importing countries. They yield substantial savings in energy consumption and imports compared with the reference scenario. They enhance energy security and help mitigate damaging environmental effects with the benefits achieved at lower total investment cost than in the reference scenario.

For further information on the WEM model and underlying scenario assumptions see:

- World Energy Outlook 2007, International Energy Agency; http://www.worldenergyoutlook.org/2007.asp.

Annex 2 Data issues on household energy use

Monitoring energy efficiency

There are two broad approaches to the evaluation of savings from energy efficiency improvements:

- A **top-down** calculation method uses the national or larger-scale aggregated sectoral levels of energy savings as the starting point.
- A **bottom-up** calculation method means that energy savings obtained through the implementation of a specific energy efficiency improvement measure are calculated and added to energy savings results from other specific energy efficiency improvement measures.

Within these two approaches are a number of specific techniques used to evaluate energy savings. In general, to understand more accurately the real performance of individual policies detailed bottom-up evaluation approaches are required. By contrast, top-down approaches tend to look at the effect of groups of policies (on a particular sector or group of end-users) and would ideally be used to cross-check the consistency of overall savings.

As part of the ESD, the European Commission is to prepare a series of harmonised indicators and calculation methodologies that Member States must gradually incorporate into their reporting to assess energy savings from their policies. A consortium of 21 organisations under the EMEEES project (51) is undertaking this work for the Commission. Harmonised bottom-up and top-down methodologies are due to be proposed in Spring 2008 with pilot case-studies being undertaken until early 2009. These methodologies will include ones for household energy use, particularly heating and cooling and building fabric improvements.

A key component of the top-down approach under the ESD will be the use of the energy efficiency indicators in policy analysis and cross-country comparisons, developed under the Odyssee project (52). This is a project between ADEME (French Environment and Energy Managment Agency) and the IEE (Intelligent Energy Europe) programme of the European Commission/ DGTREN, supported by national representatives in each of the EU-27 Member States plus Norway and Croatia. It has been running since 1993 and is currently the most comprehensive, harmonised EU-wide approach to the assessment of efficiency improvements. The project relies on a comprehensive database that contains detailed information (energy consumption, activity data, etc.) and is updated twice a year by the various national representatives.

In USA, evaluation is mainly undertaken on a top down basis with the models being informed by bottom-up surveys to understand patterns of consumption within buildings. Three different scenarios are being developed: a business as usual scenario (BAU) or baseline/reference with existing policies and measures, a carbon constrained scenario and a scenario where higher fuel prices are being considered (53). The benefits are assessed based on the assumption that the objectives of the program will be met (100 % probability of success). The data for monitoring energy efficiency in residential buildings is mainly supplied by the **Residential Energy Consumption Survey (RECS)**. The RECS is conducted every 3 years by the Energy Information Administration (EIA). It is a national sample survey of more than 5 000 residential housing units and their energy suppliers. Indicators for residential include demand indicators (number of households, number of household members, number of buildings, floor area) and energy intensity indicators (million Btu per building, per household, per square foot and per capita) (54).

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(51) Evaluation and Monitoring for the (EU Directive on) Energy end-use Efficiency and Energy Services (project), http://www.evaluate-energy-related savings.eu/emeees/en/home/index.php.
(52) http://www.odyssee-indicators.org.
(53) Although there is discussion surrounding what level constitutes 'high' fuel prices in the light of recent price rises.
(54) For details see http://www.eia.doe.gov/emeu/efficiency/ee_ch3.htm#Energy%20Consumption%20in%20the%20Residential%20 Sector.

At the international level, the IEA is developing in-depth indicators to provide data and analysis on energy use and efficiency developments as part of their response to the G8 Gleneagles Summit. Their publication 'Energy Use in the New Millennium: Trends in IEA Countries' (IEA, 2007b) is a major output from this work (the European data is derived from the Odyssee project).

Data for top-down evaluation

Energy intensities are the ratio between energy consumption and an indicator of activity generally measured in monetary units (55) (Gross Domestic Product, value added, etc.). Such ratios are favoured by economists to assess 'energy efficiency' improvements at the level of the whole economy or at the sector level, by illustrating the reduction in energy used to generate one unit of activity (e.g. economic output). However, strictly speaking, these indicators do not show improvements in energy efficiency directly as structural changes in the economy can also lead to lower intensities.

Energy efficiency indicators are used to remove the presence of these structural or other external factors, e.g. by assessing the rate of energy consumption under a constant (hypothetical) structure over time. This is particularly important when trying to compare the actual level of energy efficiency between countries. A number of studies exist that use indicators to study energy efficiency in the household sector, for example the work done by JRC on electricity use in households (56).

In Odyssee, various indicators, referred to as 'unit consumption' indicators, are calculated to depict the changes in energy efficiency by sector at a detailed level. They are expressed in different units, depending on the sub-sector or end use, so as to provide the best proxy of energy efficiency, taking into account the data available. In the household sector the indicators are expressed in:

- toe (tonnes of oil equivalent) per dwelling or per m^2 for heating;
- toe per dwelling or per capita for water heating;
- kWh per dwelling or per appliance for electrical appliances.

Unit consumption indicators are useful to provide a detailed diagnosis by sub-sector or end use and to evaluate the impact of individual policy measures on energy efficiency improvement. However, there is a demand, especially at the policy level, to provide an overall perspective of energy efficiency trends. Under the Odyssee project an aggregate energy efficiency index (ODEX) for final energy consumers has been created, which is based on a combination of the more detailed sub-sector indicators. The detailed sub-sector indicators are first combined to produce sectoral (households, transport, etc.) efficiency indices and these are then combined to produce the overall ODEX. This provides a more realistic proxy for energy efficiency at the aggregate level. The ODEX is calculated as a weighted average of the unit consumption index of each sub-sector or end use, with a weight based on the relative consumption of each sub-sector in the base year.

Data for bottom-up evaluation

The appropriate data to provide bottom-up evaluation depends on the design of a policy and, in best practice, is part of that policy design process. It can include consumption on the level of the household, surveys, number of particular measures implemented or grant spend. For the latter two, an *ex-ante* estimate of the relationship between a measure or grant can be derived, but *ex-post* monitoring is required to test that relationship. Consumption data is a useful indication of whether there is a change in the trend when a policy is implemented but other factors such as changes in comfort levels or activity in a household can also affect consumption.

If the data needed for evaluation is identified at the design stage of the policy, then it is easier to facilitate collection of the data both *ex-post* and *ex-ante*. Bottom-up evaluation of policy is more resource intensive than top-down evaluation but can provide more specific information on why a policy succeeds or fails and is valuable for policy development.

A more detailed discussion of the energy balance of a house and an example of a data issue is presented below.

Energy balance of a house

Figure A.1 illustrates the components that make up an energy balance for a house and are considered in policies such as the EPBD.

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(55) With the exception of the energy intensity for households in EEA factsheet EN21, where the activity unit is population (as opposed to a monetary measure such as household expenditure).

(56) http://sunbird.jrc.it/energyefficiency/.

To calculate the energy balance of a house according to EPBD the following steps should be taken:

1) energy is used to fulfil requirements for heating, lighting, cooling, cooking, etc.;
2) some of these end users are fulfilled by 'natural' energy gains (passive solar, ventilation, daylight) and internal gains (cooking, electric appliances, etc.);
3) the building's net energy use is then determined by the difference between 1 and 2 and the characteristics of the building itself;
4) 'conventional' energy is delivered to the building by a number of energy carriers including direct use of fuels and electricity;
5) in some cases, renewable sources associated with the building itself may be used to provide energy for use in the building or for export;
6) as per 5);
7) primary energy use or CO_2 associated with the building;
8) primary energy or CO_2 emissions associated with on-site generation that is used on-site and is additional to 7;
9) primary energy or CO_2 emissions associated with the exported energy which is subtracted from 7.

Example of data issue: degree days

A key issue for monitoring energy efficiency in households is accounting for climatic variations within and between different countries, as these directly affect the amount of energy consumed.

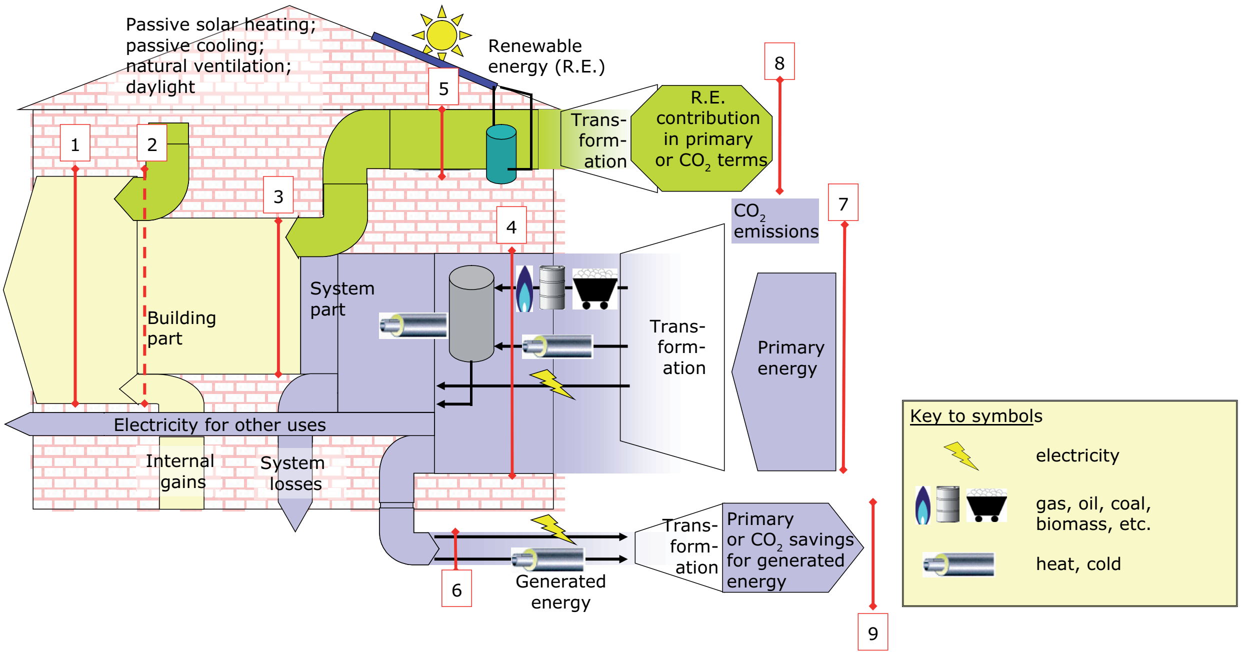
Heating degree days (HDD) express the severity of the cold in a specific time period taking into consideration outdoor temperature and room temperature. An increase in energy consumption of around 7 % is needed to increase indoor temperature by 1 °C. Similarly, hot days, which may require the use of energy for cooling, are measured in cooling degree-days.

To calculate HDD weather data is obtained and HDD are calculated using a methodology applied by EUROSTAT, which forms a common and comparable basis. An example map for HDD in 2005/2006 is presented below.

HDD can then be used in two ways to adjust the level of energy consumption for space heating:

- HDD in a given year in a specific location can be contrasted against a long-run average to account for variations in temperature between years.

Figure A.1 Energy balance in a house



Source: Bertoldi *et al.*, 2006.

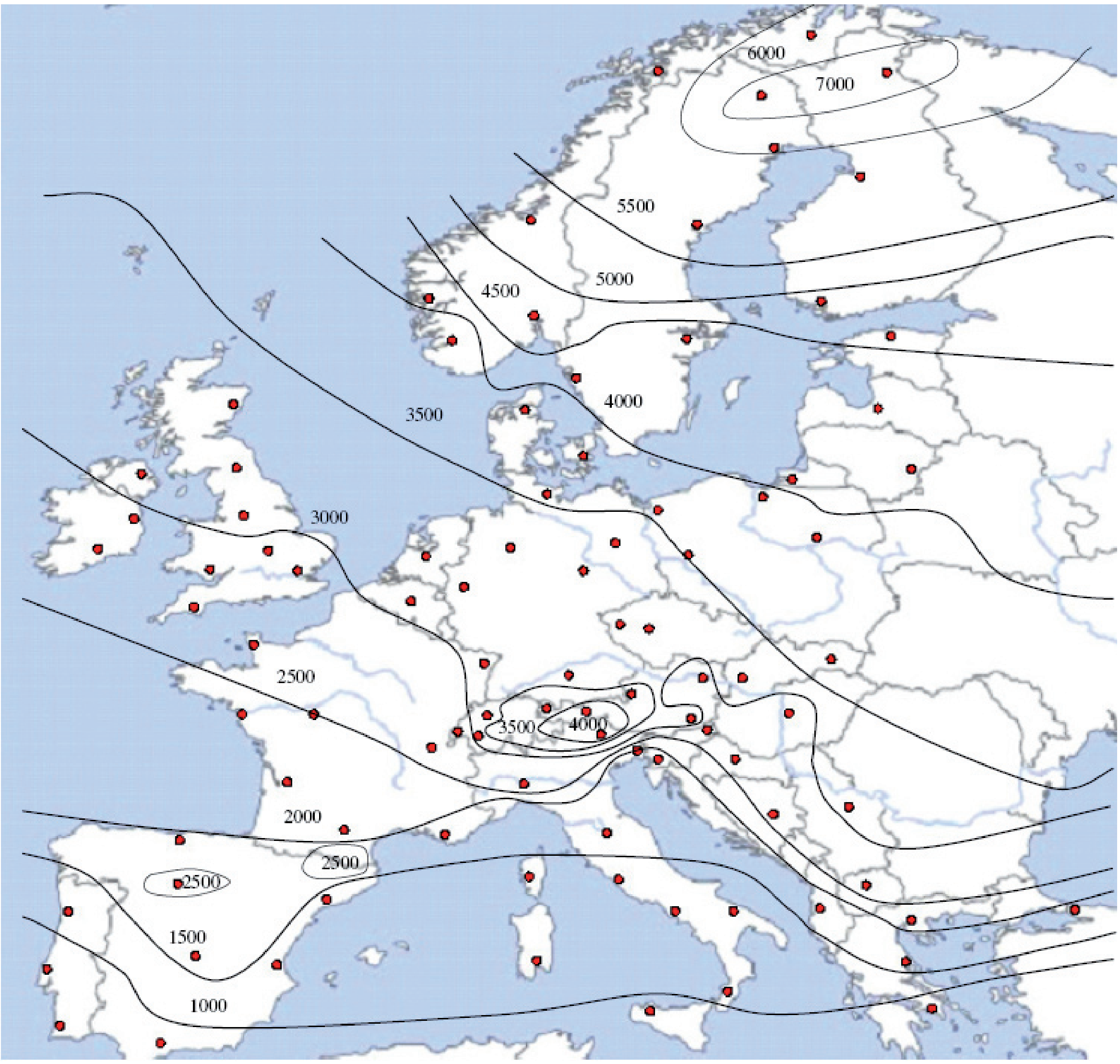
HDD = (18 °C — Tm) if Tm is lower than or equal to 15 °C (heating threshold)

HDD = 0 if Tm is greater than 15 °C

where Tm is the mean ((Tmin + Tmax)/2) outdoor temperature over a period of 1 day.

Calculations are executed on a daily basis, added up to a calendar month — and subsequently to a year.

Figure A.2 Example of heating degree days across Europe



Source: Ecofys, 2006.

- They can be used to scale energy consumption across different countries onto a comparable basis (e.g. a European average climate as shown in Figures 6.5 and 6.6) to account for variations in temperature by location (e.g. Nordic versus Mediterranean countries).

Annex 3 List of EEA energy and environment indicators

The EEA's indicator fact-sheets on energy and environment are published annually and underpin the Energy and Environment report:

EN01	Energy-related energy related greenhouse gas emissions
EN05	Energy-related related emissions of ozone precursors
EN06	Energy-related related emissions of acidifying substances
EN07	Energy-related related particle emissions
EN08	Emissions intensity of public conventional thermal power production
EN09	Emissions from public electricity and heat production — explanatory indicators
EN13	Nuclear waste production
EN14	Accidental oil tanker spills
EN15	Discharge of oil from refineries and offshore installations
EN16	Final energy consumption by sector
EN17	Total energy intensity
EN18	Electricity consumption
EN19	Energy efficiency of conventional thermal electricity generation
EN20	Combined heat and power
EN21	Final energy consumption intensity
EN26	Total energy consumption by fuel
EN27	Electricity production by fuel
EN29	Renewable primary energy consumption
EN30	Renewable electricity
EN31	Energy prices
EN32	Energy taxes
EN34	Energy subsidies
EN35	External costs of electricity production

Indicator fact sheets under development:

ENXX	Renewable final energy consumption
ENXX	Energy efficiency and CO_2 savings
ENXX	Security of energy supply and the environment

For more information about the energy and environment indicators see http://www.eea.europa.eu/themes/energy/indicators.

Annex 4 Description of main data sources

The most prominent sources used in this report relate to greenhouse gas data, air pollutants and energy balances. In addition to these, other sources have been used and quoted in the relevant sections of the report.

Greenhouse gas emission data

The legal basis for the EU greenhouse gas inventories are:

a) Council Decision 280/2004/EC concerning a mechanism for monitoring Community greenhouse gas emissions and for implementing the Kyoto Protocol.
b) Commission Decision 2005/166/EC laying down the rules for implementing Decision 280/2004/EC. http://ec.europa.eu/environment/index_en.htm.

The main objectives of the Community Inventory System are to ensure a) accuracy, b) comparability, c) consistency, d) completeness, e) transparency and f) timeliness of inventories of Member States in accordance with UNFCCC Guidelines for annual greenhouse gas inventories www.unfccc.org and with the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories and Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories www.ipcc.ch/.

The overall responsibility for the EC Inventory lies with DG Environment, European Commission. The EEA assists the European Commission through the work of the European Topic Centre on Air and Climate Change (ETC/ACC), Eurostat (Reference approach for CO_2 emissions from fuel combustion) and the Joint Research Centre (land-use, land-use change and forestry, agriculture).

Member States shall report their anthropogenic greenhouse gas emissions for the year t-2 to the Commission each year by 15 January. This should be in line with the reporting requirements under the UNFCCC. After initial checks Member States send updates and review the EC inventory report by 15 March. The final EC GHG inventory and inventory report are prepared by the EEA's ETC/ACC for submission by the European Commission to the UNFCCC Secretariat by 15 April http://reports.eea.europa.eu/technical_report_2008_6/en The EC Inventory becomes final in June, when potential re-submissions of data by Member States due to the reviewing process under the UNFCCC (15 April–31 May) are over.

For quick access to the latest officially reported greenhouse gas data for Europe, the EEA developed the '**greenhouse gas data viewer**'. Data is available by sector, gas, country and year and can be viewed and downloaded from http://dataservice.eea.europa.eu/PivotApp/pivot.aspx?pivotid=455 The greenhouse gas data collected by the EEA forms the basis for the calculation of the EEA's core set indicator on GHG emissions and removals and for the European Commission's structural indicator on GHG emissions, as well as for various sustainable development indicators.

For the purpose of indicator reporting and based on the IPCC classification, the EEA aggregates sectors using the following definitions:

- The 'energy sector' (CRF 1 'Energy') is responsible for energy-related related emissions, such as those arising from 'fuel combustion activities' (CRF 1A) and 'fugitive emissions from fuels' (CRF 1B).
- Fuel combustion activities include: 'Energy industries' (CRF 1A1), 'manufacturing industries and construction' (CRF 1A2), 'transport' (CRF 1A3), 'other sectors' (CRF 1A4) and other stationary or mobile emissions from fuel combustion (CRF 1A5 'other'). Fugitive emissions from fuels include 'solid fuels' (CRF 1B1) and 'oil and natural gas' (CRF 1B2).
- 'Energy production' includes 'energy industries (CRF 1A1)' (i.e. public electricity and heat production, petroleum refining and the manufacture of solid fuels) and 'fugitive emissions' (CRF 1B) (i.e. emissions from production, processing, transmission, storage

and use of fuels, in particular coal mining and gas production).
- 'Transport' (CRF 1A3) includes road transportation, national civil aviation, railways and navigation, and other forms of non-road transportation (in accordance with UNFCCC and UNECE guidelines, emissions from international aviation and navigation are not included).
- 'Industry' (CRF 1A2) includes fossil fuel combustion (for heat and electricity) in manufacturing industries and construction (such as iron and steel, non-ferrous metals).
- 'Households' (CRF 1A4b) includes fossil fuel combustion in households.
- 'Services sector' (CRF 1A4a + 1A4c + 1A5) includes fossil fuel combustion (for heat and electricity) from small commercial businesses, public institutions, agricultural businesses and military.
- Non-energy related emissions include 'industry' (CRF 2) (i.e. processes in manufacturing industries and construction without fossil fuel combustion including production and consumption of fluorinated gases), 'agriculture' (CRF 4) (i.e. domestic livestock keeping, in particular manure management and enteric fermentation and emissions from soils) 'waste' (CRF 6) (i.e. waste management facilities, in particular landfill sites and incineration plants) and 'other non-energy' (CRF 3 + 7) (i.e. solvent and other product use).

For more information, see www.eea.europa.eu/themes/climate and www.eea.europa.eu/themes/energy.

Air pollutant emission data

The 1979 United Nations Economic Commission for Europe Convention on Long-range Transboundary Air Pollution (UNECE CLRTAP) remains the legal reporting obligation for the Member States and for the European Community. EU Member States are requested to post a copy of their official submission of air emission data to the LRTAP Convention in the central data repository of the European Environment Agency by 15 February of each year. The methods used by the Member States in the compilation of their inventories are based on the joint EMEP/CORINAIR Emission Inventory guidebook:
http://reports.eea.europa.eu/EMEPCORINAIR5/en/page002.html.

The European Community reports to the UNECE Environment and Human Settlements Division emissions-data on SO_X (as SO_2), NO_X (as NO_2), NH_3, NMVOCs, CO, heavy metals (HMs), persistent organic pollutants (POPs) and particulate matter (PM). The European Environment Agency prepared the annual European Community CLRTAP emission inventory 1990–2006 on behalf of the European Commission: http://reports.eea.europa.eu/technical_report_2008_7/en.

In addition, the EU Directive 2001/81/EC on national emission ceilings for certain atmospheric pollutants sets upper limits for each Member State for total emissions by 2010 of the four pollutants responsible for acidification, eutrophication and ground-level ozone pollution (SO_2, NO_X, VOCs and ammonia): http://ec.europa.eu/environment/air/legis.htm#ceilings. Based on the provisions of the directive, Member States are obliged to report their national emission inventories and projections for 2010 each year to the European Commission and the European Environment Agency.

For quick access to the latest officially reported air-pollutant emissions data for Europe, see the relevant 'data viewers, on acidifying substances, ozone precursors, particles, LRTAP Convention and NEC Directive. Data can be viewed and downloaded from http://dataservice.eea.europa.eu/PivotApp/. For more information about Air pollution see http://www.eea.europa.eu/themes/air.

Energy data

Energy data have been traditionally compiled by Eurostat through the five annual Joint Questionnaires, shared by Eurostat and the International Energy Agency, following a well established and harmonised methodology. The energy data are publicly available from Eurostat's website http://ec.europa.eu/comm/eurostat/ Methodological information on the annual Joint Questionnaires and data compilation can be found in http://epp.eurostat.ec.europa.eu/cache/ITY_SDDS/EN/nrg_quant_sm1.htm A detailed description of Eurostat's concepts used in the energy database can be found in http://circa.europa.eu/irc/dsis/coded/info/data/coded/en/Theme9.htm

At the time of writing this report, data collection for energy statistics is based on a gentlemen's agreement with minor exceptions. The European Commission has adopted a Regulation, to be co-decided by the European Council and the European Parliament, with the objective of establishing a common framework for the production, transmission, evaluation and dissemination of comparable energy quantity statistics in the EU. With few amendments to the Commission's proposal, the legal act was adopted in first reading under the co-decision procedure by the Council and the Parliament. The Regulation shall enter into force 20 days after its publication in the Official Journal of the European Union, expected sometime before end 2008.

To highlight that according to the new energy statistics regulation 'Every reasonable effort shall be undertaken to ensure coherence between energy data declared in accordance with Annexe B and data declared in accordance with Commission Decision 2005/166/EC of 10 February 2005 laying down the rules for implementing Decision No 280/2004/EC of the European Parliament and of the Council concerning a mechanism for monitoring Community greenhouse gas emissions and for implementing the Kyoto Protocol'.

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