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Tracking progress towards integration

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Summary: Further action needed for achieving environmental integration within the energy sector

Introduction

Energy gives personal comfort and mobility to people, and is essential for the generation of industrial, commercial and societal wealth. On the other hand, energy production and consumption (including heat and electricity production, oil refining and final uses in households, services, industry and transport) place considerable pressures on the environment. These pressures include the emission of greenhouse gases and air pollutants, land use, waste generation and oil spills. They contribute to climate change, damage natural ecosystems and the man-made environment, and cause adverse effects to human health.

Energy supply security, environmental sustainability and competitiveness are central objectives of EU energy policy. These were highlighted in the proposals of the European Council (March 2006) for an Energy Policy for Europe.

Ensuring that all of these objectives are met has become increasingly difficult. Changes in the global geopolitical situation and growing energy demand worldwide have caused substantial rises in oil and gas prices in recent years. This is of particular concern for the EU, which is increasingly dependent on energy imports. At the same time, there is growing awareness of the need for clean energy, particularly due to concerns over climate change. This is underlined by the entry-into-force of the Kyoto Protocol in 2005 and the proposals by the EU Council for further emission reductions for developed countries beyond the Kyoto Protocol period (2008–2012). Further emission reductions are also required with regard to air pollutants, as recognised in the proposed Thematic Strategy on Air Pollution (2005).

In order to face these challenges simultaneously, EU policy aims to integrate environmental concerns within the energy sector by

- reducing the environmental impact of energy production and use;
- promoting energy savings and energy efficiency;
- increasing the use of cleaner energy and its share of total production.

This report is the second EEA report on energy and environment to examine progress in integrating environmental considerations into the EU energy sector. It is based on a set of indicators covering the period 1990 to 2003.

Trends in energy-related environmental pressures

The overall picture shows that environmental pressures from energy production were generally reduced between 1990 and 2003. However, since 1999/2000 this positive trend has slowed and in some cases has even been reversed. More action is thus needed to meet current short- (2010) and long-term policy targets. This applies particularly to the energy-related emissions of greenhouse gases (Key trend 1). Further reductions of air pollutant emissions are also necessary to achieve long-term air quality targets (Key trend 2). Nuclear waste continues to be accumulated and a generally acceptable way to dispose of this waste has yet to be identified and implemented. Oil pollution from offshore installations and coastal refineries has been reduced, but major oil tanker spills continue to occur, albeit less frequently.

Considerable progress has been made in developing both EU-wide and national policies and measures for reducing the environmental impacts of energy

Key trend 1: Energy-related greenhouse gas emissions show recent upward trend after decreases in the 1990s, putting long-term reduction targets at risk

Energy-related greenhouse gas emissions fell by 2.6 % between 1990 and 2003, but have been rising slowly since 1999. A major contributing factor to the recent increase is higher electricity production from coal power plants. In addition, there is a long-term trend of growing transport emissions due to increased transport volumes. This has offset much of the improvements achieved in other sectors. Further substantial decreases of energy-related greenhouse gas emissions are required in order to meet long-term emission reduction targets proposed by the EU.

production and consumption since the 2002 EEA report on energy and environment. However, many of the EU-wide policies have yet to be fully implemented and consequently they have been slow in delivering measurable environmental benefits in the period covered by this report (1990–2003). More positive effects are expected in the coming years after full implementation.

Within the context of rising fossil fuel prices and increasing concerns over energy security, it is important to analyse the interlinkage between the different objectives of the energy policy, and to ensure that environmental sustainability is treated on equal terms with energy security and competitiveness. The key elements of such an integrated strategy are the reduction of energy consumption and the introduction of technologies with low environmental impacts. They can be supported by providing the right price signals to investors and consumers through a stable long-term framework taking into account environmental requirements (and ultimately internalising external costs) and the removal of harmful subsidies. These four interlinked issues are therefore discussed further in the following:

- Exploitation of synergies and minimisation of conflicts between the three goals of energy policy;
- Reduction of energy consumption;
- Development and market introduction of energy technologies with low environmental impacts;
- Internalisation of external costs and removal of harmful subsidies.

Exploitation of synergies and minimisation of conflicts between the three goals of energy policy

The three goals of EU energy policy — security of supply, competitiveness, environmental protection — are highly interrelated. For some issues synergies between them seem apparent, while in others trade-offs appear inevitable. With the changes in the global geopolitical situation and steep increases in oil and gas prices, some relationships have changed.

Liberalisation of the energy market led to significant improvements in electricity generation efficiency and a rapid increase in the use of natural gas during the 1990s (Key trend 3). This was driven by the low capital cost of gas-fired power plants combined with low gas prices, an extended gas infrastructure and environmental legislation. These trends were one of the main reasons for reductions in greenhouse gas emissions of the power sector. After 1999, this synergetic development slowed due to the increase in natural gas prices and heightened concerns over the growing dependence of the EU on oil and gas imports. The result was higher consumption levels of carbon-intensive coal, which led to an increase in emissions.

Market liberalisation and increased competition between utilities together with low global energy prices led to reduced end-use energy prices in the 1990s. This may have acted as a disincentive to energy saving actions, and even encouraged energy consumption. The steep increases in energy prices since 2000 (and in particular after 2004/2005) may in the long run help to constrain energy consumption. This can support environmental protection and reduce the need of energy imports. However, high energy prices may also be detrimental to the competitiveness of energy-intensive industries.

Key trend 2: Energy-related air pollutant emissions declined but air quality continues to have adverse effects on health and ecosystems

Energy-related emissions of acidifying substances, tropospheric ozone precursors and particles decreased by 56 %, 41 % and 47 % between 1990 and 2003, respectively. These reductions were driven by the enhanced use of abatement techniques, energy efficiency improvements and fuel switching from coal to natural gas. Since 2000, the decline in some air pollutant emissions has slowed due to a continuing rise in energy consumption and a renewed increase in the use of coal. Despite reduced emissions of air pollutants, air quality in many cities does not yet meet the limit values set by European legislation. Moreover, human health and ecosystems are still adversely affected. Further emission reductions are needed to achieve long-term air quality targets.

Key trend 3: Fossil fuels continue to dominate energy consumption but abatement measures and fuel switching have reduced environmental pressures

Combustion of fossil fuels is the main cause of carbon dioxide, sulphur dioxide and nitrogen oxide emissions and accounts for almost 80 % of total energy consumption and 55 % of electricity production. Some of these environmental pressures were reduced between 1990 and 2003. One of the main reasons for falling greenhouse emissions was the shift from coal to cleaner natural gas in electricity production, although this fuel switch has slowed since 1999. Oil consumption grew as a result of increased transport volumes and oil continues to be the most important fuel in total energy consumption. The share of nuclear power remained almost constant.

Proposals for a balanced development of the energy sector aiming to simultaneously achieve all three goals of EU energy policy are timely. Such proposals would ensure that the environmental pillar of the EU energy policy continues to be treated as equally important as supply security and competitiveness. One way of reconciling the goals of EU energy policy are integrated strategies to invest in cleaner and more sustainable energy, which can support all three main policy objectives, as stressed by the European Council in December 2005 (European Council, 2005).

There is a need for a regulatory and economic framework that provides accurate long-term price signals (i.e. incorporating environmental and other considerations as far as is possible) to both energy suppliers and end-users, so that they can plan their actions effectively. This is particularly important given the long lead-times for exploiting new energy resources, constructing generation capacity and energy transport infrastructure (e.g. pipelines), and turnover in the building stock, as well as for changing individual behaviour. The imminent need for investment in both European ([1]) and global energy production and transportation infrastructure opens up opportunities for an environmentally-sustainable development of the energy sector. Cumulative investment needs for energy are estimated to be in the range of USD 2 trillion for OECD Europe and USD 16 trillion globally over the period 2001–2030 (IEA, 2003). This underlines the urgent need for the provision of long-term investment security, taking into account environmental considerations.

The EU CO_2 emissions trading scheme has been a notable first step in helping to achieve a reconciliation of competitiveness with economic issues and environmental protection (climate change mitigation). The second phase of the scheme will be an important additional step. Furthermore, long-term targets (beyond 2010) for increasing energy efficiency and the share of renewable energy sources in the EU would provide further clear signals about the direction of energy policy. A move towards a more environmentally sustainable energy policy has been enhanced to some extent by the recently adopted directive on energy services, the green paper on energy efficiency and the discussions on future renewable energy targets for 2015 and 2020 (European Council, 2006; European Parliament, 2005). Policies for renewables and energy efficiency are most effective when addressed simultaneously (EC, 2004a). This underlines the need for an integrated EU energy strategy.

Overall, important steps for environmental integration within the energy sector have been initiated but some still need to be fully implemented. In addition, further strategies, going beyond current policies, will have to be developed to provide a long-term framework for the development of a sustainable energy system. Such a framework may help to deliver the large scale investments in energy production and transportation needed in Europe in an environmentally friendly way.

Reduction of energy consumption

All energy production leads to some kind of environmental pressure, either during exploitation of the primary energy sources or in the subsequent conversion processes. Limiting the growth of and ultimately reducing energy demand is therefore a priority in reducing the environmental pressures.

Nevertheless, energy consumption has increased continuously in the EU since 1990, particularly within the transport sector. Furthermore, the use of electricity grew very rapidly (Key trend 4). This rising consumption offset environmental benefits in electricity production that were achieved due to technological improvements and fuel switching.

Key trend 4: Energy consumption continues to grow, making it more difficult to reduce energy-related environmental pressures

Final energy consumption in the EU-25 increased by 11.6 % between 1990 and 2003. This trend is expected to continue unless additional energy saving measures are implemented. Rising personal incomes and changes in lifestyle with subsequent growing transport volumes led to an increase in energy consumption of households, services and transport. Transport is now the largest consumer of final energy. At the same time energy consumption in industry decreased as a result of energy efficiency improvements and a shift from energy-intensive industries to services. Electricity consumption increased particularly rapidly due to its attractiveness and flexibility in end-use, a growth of the services sector and an increase in the ownership of electrical appliances.

([1]) In 2005, 43 % of the installed fossil fuel power capacity in the EU-25 was older than 25 years; of the installed coal power capacity, 59 % was older than 25 years (Tzimas *et al.*, 2006). Around 60 % of the currently installed capacity will need to be replaced by 2030. In addition, the total installed power generation capacity in the EU is projected to increase to about 70 % above current levels by 2030 in a baseline development (EEA, 2005b).

Despite the increased recognition of the importance of increasing energy efficiency and ultimately reducing the absolute level of consumption, the slowdown in energy growth seen in the early 1990s has not been replicated since. Without additional policies and measures energy demand is likely to continue rising.

There is a need to accelerate progress in energy savings in all sectors. Reducing growth in electricity consumption will be crucial from an environmental viewpoint, especially for consumption from fossil-fuel based electricity. Two to three units of energy input are needed for producing one unit of electricity from fossil fuels with the rest being lost in the process, unless the heat is recovered in a combined heat and power process. This implies that the rise in electricity consumption results in a disproportionate increase in environmental pressures, particularly greenhouse gas emissions. On the other hand, electricity production can also be based on non-emitting energy sources (such as renewables) and use CO_2 capture and storage technologies.

Energy savings in buildings are of high importance as about 40 % of all final energy is used in the household and services sectors. Also the transport sector, which accounts for almost a third of the EU's final energy consumption, offers further opportunities for energy savings (EEA, 2006d).

A number of important EU policies and measures for improvement of energy efficiency already exist and full implementation is important. Some of these aim at significant reductions in the energy intensity of end-use sectors. The main policies include a directive on energy end-use efficiency and energy services (EC, 2006), standards and labels on a number of products as well as a directive on eco-design of energy-using products (EC, 2005h). In the transport sector, a voluntary commitment of European, Japanese and Korean car manufacturers aims to reduce the CO_2 emissions (and increase fuel efficiency) of new passenger cars to 140 g CO_2/km in 2008/2009. Energy efficiency standards for buildings have also been tightened (EC, 2002a). However, the effect of these improved standards will only be seen in the longer term because the rate of turnover in the car fleet and, particularly, the building stock is slow.

Changes in consumer behaviour need to complement technological efficiency improvements, as technological progress is significantly offset by lifestyle changes. These include, for example, trends towards heavier, more powerful cars, more electronic appliances or larger refrigerators. Triggering a change in consumer behaviour may be supported by the provision of information (e.g. labelling of products), awareness-raising campaigns and incentives for environmentally-friendly behaviour. So far, the positive experience gained with improvements in the efficiency of large electrical appliances such as refrigerators and TVs together with the introduction of energy efficiency labels and standards suggest that this may be an effective measure for other consumer products.

Energy savings can be substantial. With full implementation of current legislation and additional dedicated policies and measures, EU energy consumption could be cut by around 20 %, according to the Commission's Green Paper of 2006 on energy efficiency.

Development and market introduction of energy technologies with low environmental impacts

New, cleaner technologies are important for reducing the impact of energy use on the environment. Developments throughout the 1990s demonstrated the positive impact of technological improvements on reducing emissions, particularly in the case of air pollutant emissions from power generation, industrial processes and passenger cars. These reductions were the result of fuel switching and improvements in energy efficiency, and, in particular, the large scale use of abatement technologies such as catalytic converters in passenger cars and flue gas desulphurisation in power plants. Nevertheless, further reductions in emissions through cleaner technologies, particularly of greenhouse gases, will be needed.

There is no single technological answer to substantially reducing greenhouse gas emissions. Various scenarios indicate that a portfolio of a wide range of technological and other measures is needed to significantly further reduce emissions. A combination of substantial energy efficiency improvements in end-use and in production (e.g. through combined heat and power plants), increases in the use of renewable energies and further fuel switching in the power sector is needed. Also, the introduction of CO_2 capture and storage technologies is likely to contribute to further emission reductions in the future. The extended use of nuclear energy to help mitigate greenhouse gas emissions is currently debated. Renewable energy and energy efficiency technologies would in addition reduce the dependence on imports by reducing overall energy demand and making greater use of indigenous resources.

Substantially increased use of renewables and energy efficiency technologies are a key part of a long-term sustainable energy system. This is also highlighted by the European Spring Council in its call for an Energy Policy for Europe (European Council, 2006). However, the shares of renewables in energy and electricity consumption remain limited at the moment (Key trend 5).

Although costs for renewables have often been higher than for fossil fuels, there is great potential for them to become more competitive. Further cost decreases are likely through increased production and economies of scale. Price rises in fossil fuels increase the relative competitiveness of renewables. Furthermore, the wider costs to society from the adverse effects of fossil fuel use on health and ecosystems are not fully accounted for in current prices of energy. If all these factors are taken into account, investment in renewable energy would be more attractive. Nevertheless, exploiting renewable energy sources such as bioenergy requires an integrated strategy in order to prevent other environmental pressures from being created, such as on biodiversity or land and water resources.

Furthermore, the use of CO_2 capture and storage (CCS) technologies may allow a 'smoother' transition away from fossil fuels, while at the same time helping to reduce the environmental pressures (IPCC, 2005). However, while most of the technologies needed for CCS are available, demonstration plants are still needed before CCS can be implemented on a large enough scale. Geological storage of CO_2 (e.g. in depleted oil and gas fields and aquifers) appears to have manageable environmental risks, although further research is needed to clarify this issue. Environmental risks of storage in the ocean could be greater.

Attitudes to nuclear power are mixed. Although nuclear power produces little pollution under normal operations, highly radioactive wastes are accumulating for which no generally acceptable disposal route has yet been established or implemented at large scale. There is still a risk of accidental radioactive releases for existing and even new nuclear power plants. On the other hand, nuclear power does not release greenhouse gas emissions during its operation. Increasing nuclear capacity is being discussed in some Member States in the context of climate change and energy security, while a number of others have made plans for its phase-out and are now starting to implement these plans. There is also a debate on the costs of nuclear energy which depend, i.a. on the extent to which the above factors are taken into account in the methodology of the cost calculations.

Key trend 5: Shares of renewables in total energy and electricity consumption remain at low levels despite large increases of some renewables

The production of energy and electricity from renewable energy sources grew steadily between 1990 and 2003, with particularly large increases in wind and solar electricity. However, the increase in the share of renewables in total energy and electricity consumption was limited due to rising energy and electricity consumption and less hydropower production as a result of low rainfall in 2002 and 2003, offsetting to a large extent the increase in other renewables. In 2003, the share of renewables in total energy consumption and gross electricity consumption was 6 % and 12.8 %, respectively. A significant further expansion will be needed to meet the EU indicative targets of a 12 % share in total energy consumption and 21 % share in gross electricity consumption by 2010.

The need for technological development implies the need for sufficient funding for energy research and development (R&D). This could be enhanced by a better targeted policy framework aimed at supporting new technologies at each stage of development from research and development (R&D) through to market commercialisation and wide-spread deployment. However, from 1990 to 2003, total R&D funding fell significantly in real terms, although the absolute level of funding for renewables was broadly maintained.

Increasing R&D expenditure is necessary. It should address a variety of technologies on the supply and the demand side in order to keep open different options for more environmentally friendly energy systems. Increases are particularly needed for:

- renewable energy;
- end-use energy efficiency;
- efficiency improvements in fossil fuel technologies, and CO_2 capture and storage technologies;
- technologies that better match energy supply and demand such as 'intelligent electricity grids'.

Significant cost reductions are vital to allow the widespread uptake of these technologies, particularly if they are also to be successfully transferred to other regions of the world (e.g. China and India), where demand for energy is rapidly rising. In addition, energy research and development will not only be driven by environmental concerns but also by issues of energy security and price rises for fossil fuels.

Internalisation of external costs and removal of harmful subsidies

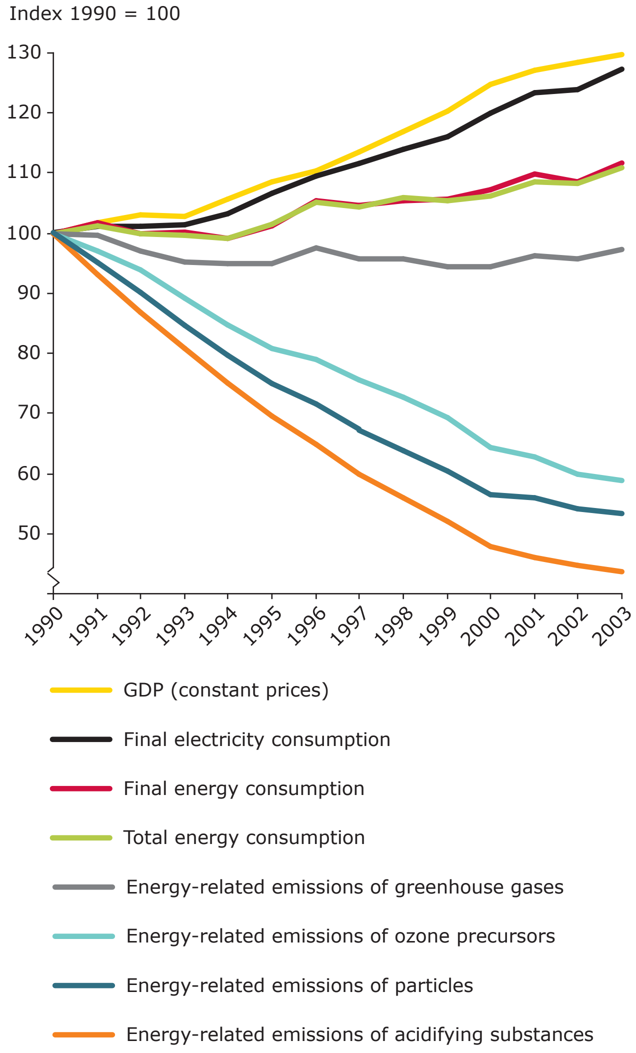
A critical barrier to a more sustainable energy production and consumption system is the fact that external costs are still not fully reflected in energy prices. These environmental externalities arise from the adverse impacts on health and the environment from use and production of energy. Although externalities of electricity generation have approximately halved since 1990 due to emissions reductions and the growth in the use of gas and renewables, they are still significant. Environmental externalities of electricity production are estimated to be in the order of 1–2 % of GDP. Externalities for transport (including environmental costs, but excluding those from accidents) are about roughly 5 % of GDP in the EU-15, Norway and Switzerland.

In addition, end-user energy prices for electricity and natural gas for households were lower in 2003 (in real terms) than they were in 1990 (Key trend 6). This is the case despite price rises since 2000 and substantial tax increases since 1990. Prices still do not reflect the adverse effects on health and the environment of energy use, and thus fail to send the right signals to consumers. Achieving correct price signals is also hampered by a number of subsidies and legislation that favour energy intensive activities. Furthermore, energy subsidies still focus primarily on fossil fuels despite their adverse environmental impacts.

Key trend 6: Most energy prices have been increasing since around 2000 after significant reductions during the 1990s. Tax levels increased since 1990, but external costs have not been fully internalised

With the exception of transport, energy prices for most fuels decreased during the 1990s before starting to increase again around 2000. This increase is mostly due to rising global oil and gas prices. These price rises led to increased calls for enhanced energy saving measures. Throughout the 1990s, price levels were not high enough to offer much incentive for energy savings. Tax levels increased over the entire period, which may indicate that external costs of energy consumption, due to environmental effects, were internalised to a greater extent than in previous years. Nevertheless, tax levels generally remain below the estimated environmental external costs.

Summary of trends in key energy, environment and economic factors from 1990 to 2003, EU-25



Source: EEA, Eurostat.

Introduction

This report analyses trends in the environmental pressures of energy production and consumption, and the underlying societal drivers. It is an update of the European Environment Agency's first indicator-based report on energy and environment in the European Union in 2002 (EEA, 2002), which examined trends in the pre-2004 EU-15 Member States over the period 1990–1999. Since then, important developments both in the global geo-political energy situation as well as in the EU itself have occurred. These developments include the enlargement of the EU to 25 Member States in 2004.

The global geo-political energy situation has seen major upheavals in recent years. After a period of relatively low energy prices during much of the 1990s, both world oil and gas prices have increased substantially. Tensions in the Middle-East, growing energy demand in most regions of the world, particularly in China and India, and an increasing import dependence of the EU have all heightened concerns about the security of the energy supply.

At the same time, the need for clean energy to mitigate climate change has been given greater attention with the entry into force of the Kyoto Protocol in February 2005 and the G8 Gleneagles Plan of Action announced in 2005. There is growing realisation that a great deal more will need to be done to reduce greenhouse gas emissions in the long-term (EC, 2005e). The Council of the EU has called for developed countries to reduce emissions in the order of 15% to 30 % by 2020, and the EU Environment Council and the European Parliament advocate further reductions of 60 % to 80 % by 2050. Several countries, including France, the United Kingdom, Germany and the Netherlands have also set ambitious national long-term greenhouse gas emissions reduction targets. In addition, further emission reductions are required with regard to air pollutants, as called for in the 'Thematic strategy on air pollution' (EC, 2005f).

In the EU, energy now tops the agenda. This has resulted from oil and gas price rises (in particular after 2004/2005), Russian gas supply disruptions in early 2006, discussions on future climate change strategies (initiated at the UNFCCC meeting in Montreal, end of 2005) and increasing investment needs for power generation and energy infrastructure. Europe faces the twin-challenges of climate change and energy supply security with energy import dependency levels likely to rise to about 70 % in 2030, compared to 50 % today.

Energy policy will therefore be at the heart of the European Union's efforts to address the Lisbon agenda, to achieve the Kyoto Protocol target for 2008–2012 and to guarantee energy security for its citizens (EC, 2005a). Energy is one of four 'priority action areas' identified in the Commission's Annual Progress Report on the Lisbon Agenda (EC, 2006a), and a debate on an EU energy policy was initiated in spring 2006. As an input to this debate, the Commission published their Green Paper, 'A European Strategy for sustainable, competitive, and secure energy' (EC, 2006c) in March 2006. The European Spring Council called for an Energy Policy for Europe (European Council, 2006) to support the three objectives of an EU energy policy: security of supply, competitiveness and environmental sustainability (EC, 1998).

Achieving these objectives simultaneously implies that environmental considerations are integrated within energy policy. A process of achieving integration within energy policy was initiated at the Cardiff summit (1998) and has been continued by the EU Sustainable Development Strategies of 2001 and 2005, the sixth Environment Action Programme launched in 2002 and the renewed Lisbon Strategy agreed in 2005. The specific objectives of strengthening environmental integration within EU energy policy are to reduce the environmental impact of the production and use of energy, promote energy savings and energy efficiency, and increase the use of cleaner energy and its share of total production (EC, 1998). The enhanced use of renewable energies and the promotion of energy efficiency are also strongly supported by the European public (Eurobarometer, 2006).

The **energy sector** is defined in this report to include both energy production and final energy consumption in the end-use sectors. Energy production includes public electricity and heat (power) production, oil refining and the production of solid fuels. The end-use sectors are households, industry (including autoproduction) and services (including agriculture and other sectors) and transport.

The last few years have witnessed significant activity centred on bringing forward legislation for improving the environmental performance of the energy sector. This legislation aims to curb energy consumption and promote cleaner forms of energy production. Key developments include: the directive on the energy performance of buildings (EC, 2002a); the directive on energy end-use efficiency and energy services (EC, 2006); the indicative target of 21 % of all electricity consumed to be produced by renewable energy sources in 2010 (EC, 2001a); the target of increasing the share of combined heat and power (EC, 2002d, EC, 2004d) and the launch of the EU CO_2 emissions trading scheme (EC, 2003a) in January 2005.

Despite these measures, energy and electricity consumption have continued to grow whereas the share of renewable energy and combined heat and power has only risen slowly. Rather limited progress has been made in reducing greenhouse gas emissions. Furthermore, the important reductions in emissions of greenhouse gas and air pollutants which took place in some sectors in the 1990s have slowed in recent years.

The objective of this report is to measure progress towards integrating environmental considerations within the energy sector by analysing the above trends in detail. This is achieved by addressing the following policy-relevant questions, which were developed and implemented for the first EEA report on energy and environment (EEA, 2002):

Chapter 1: Is the use of energy having a decreasing impact on the environment?
Chapter 2: Is energy use decreasing?
Chapter 3: How rapidly is energy efficiency increasing?
Chapter 4: Is there a switch to less polluting fuels?
Chapter 5: How rapidly are renewable energy technologies being implemented?
Chapter 6: Are environmental costs better incorporated into the pricing system?

Each of these questions is answered by one or more indicators that measure actual progress made to date. It builds on the EEA's energy and environment indicators (EEA, 2006a; see Annex 2). The indicators are based primarily on emissions data collected from Member States and reported by the European Environment Agency and energy statistics produced by Eurostat for the period 1990–2003 covering the whole EU-25 wherever possible ([2]) (see Annex 3). Time series are sometimes divided into the periods 1990–1999 (covered by the first EEA report on energy and environment) and 1999–2003 to allow for assessments of more recent changes. Some indicators include data from projections to illustrate future possible trends (see box).

This report complements other indicator-based reports produced by the European Environment Agency, most notably: The European Environment: State and Outlook 2005 (EEA, 2005a); an analysis of climate change and a low carbon energy system (EEA, 2005b); trends and projections in greenhouse gas emissions (EEA, 2005c); transport and environment (EEA, 2006d), and the core set of indicators (EEA, 2005d). It also supplements the European Commission's publications on energy, transport and environment indicators (Eurostat, 2005a) and on structural indicators (Eurostat, 2005b) and sustainable development indicators (Eurostat, 2005c) by providing additional analysis of the policy implications of past trends and prospects for the future. Annex 1 presents an overview of key environment-related indicator initiatives in the EU.

Projections are taken from the EEA report on climate change and a low carbon energy system (EEA, 2005b). Potential future developments of the European energy system were modelled with the PRIMES model. The baseline or 'business as usual' scenario is consistent with the latest projections published by the European Commission Directorate General for Transport and Energy (EC, 2004a). The EEA Low Carbon Energy Pathway (LCEP) scenario examines the response of the energy system to a carbon price that will rise to EUR 65 per t CO_2 by 2030. References are also made to the European Commission's 'Scenarios on key drivers' (EC 2004a). These include scenarios examining the impact of energy efficiency policies, and of achieving renewable energy targets. It should be noted that assumed prices for oil and gas in these scenarios are relatively low compared to actual prices in 2006, since the scenarios were developed in 2003/2004. This might imply that (compared to a scenario with higher oil and gas prices) growth in energy consumption is overestimated, and that the scenarios overestimate the use of gas at the expense of coal.

([2]) 2003 was the latest year for which complete datasets were available at the time of writing of the report. Regular updates of data are available at www.eea.europa.eu and www.ec.europa.eu/eurostat.

1 Is the use of energy having a decreasing impact on the environment?

The production and consumption of energy places a broad range of pressures on both the natural and the built-up environment, as well as on public health. Since fossil fuels (e.g. coal, lignite, oil and natural gas) account for the bulk of energy supplies in the European Union (79 % in 2003), this section focuses mainly on environmental pressures arising from their use, namely: greenhouse gas emissions, air pollution by acidifying substances, ozone precursors and particles, and oil discharges.

However, not all pollution from energy-related activities arises from the combustion of fossil fuels. Some combustion-related emissions, such as nitrogen oxides, also arise from energy deriving from biomass, which is a renewable energy source. Moreover, while electricity production from nuclear power produces negligible emissions during normal operation, it accumulates substantial quantities of long-lived and highly radioactive waste, for which no generally acceptable disposal route has yet been developed.

Other environmental pressures from energy production and consumption include: solid waste and water contamination from mining; solid waste from coal combustion; soil damage from spills and leakages of liquid fuels. Impacts on ecosystems come from the construction and operation of large dams, mining operations and land requirements for transmission lines and power plants. Although trends in these areas warrant monitoring, sufficient high quality data are currently often not available for robust indicators to be developed.

1.1 Greenhouse gas emissions

Energy-related greenhouse gas emissions fell by 2.6 % between 1990 and 2003, but have been rising slowly again since 1999. Further substantial decreases of energy-related greenhouse gas emissions are required in order to meet long-term emission reduction targets proposed by the EU.

There is growing evidence that global emissions of greenhouse gases are causing temperatures to increase, resulting in anthropogenic climate change. The European Union is thus committed to helping limit the increase in global temperatures to a

Table 1 Examples of the environmental pressures imposed at different stages of the energy chain

Energy production →				**Energy demand**
Extraction of primary energy sources	**Transportation of primary energy sources**	**Energy conversion**	**Energy transmission and distribution**	**Energy consumption**
Methane emissions from coal mining, natural gas and oil extraction	Methane emissions from pipeline leakage	Greenhouse gas and air pollutant emissions from fuel combustion	Methane emissions from natural gas transmission and distribution	Greenhouse gas and air pollutant emissions from fuel combustion
Solid wastes from mining	Oil spills	Solid waste from coal combustion	Spills and leakages of liquid fuels	Other emissions, such as lead, cadmium and mercury
Ground water contamination from mining	Emissions of greenhouse gases and air pollutants from energy consumption in transportation	Noise and visual intrusion	Emissions of greenhouse gases and air pollutants from energy consumed in transportation	
Radon from uranium extraction		Nuclear waste from power production	Land use for transmission lines	
Oil discharges		Other emissions, such as lead, cadmium and mercury		
Air pollution from flaring		Oil discharges from oil refineries		
Ecosystem degradation (e.g. from surface mining)		Risk of accidental radioactive releases		

maximum of 2 degrees above pre-industrial levels. Under the Kyoto Protocol, the pre-2004 Member States (EU-15) agreed to reduce their combined greenhouse gas emissions to 8 % below the base year level ([3]) over the period 2008–2012. The new Member States (with the exception of Malta and Cyprus) have individual targets under the Kyoto Protocol.

Energy production and consumption (i.e. transport, industry, households and services) are the largest sources of greenhouse gas emissions in the EU-25, accounting for 81.5 % of the total in 2003 (see Figure 1). Energy-related emissions fell by 2.6 % between 1990 and 2003. This decrease occurred largely in the first part of the 1990s, and since 1999 emissions have started rising again (despite a small decrease between 2001 and 2002). Sectors showing the largest decreases in greenhouse gas emissions are industry, services and energy production (see Figure 2). Emissions from transport in the EU-25 increased significantly over the same period as a result of a continuous increase in road transport demand. This has offset much of the decrease in other sectors.

The reductions in energy-related emissions since 1990 were helped by structural changes taking place in the economies of the new EU-10 Member States in the early 1990s. This was combined with large reductions within Germany due to economic restructuring in its new Länder, a decline in the use of coal and lignite and an increase in the use of less carbon intensive natural gas.

The uptake of gas at the expense of coal occurred in many EU-25 Member States as a result of relatively cheap gas prices during the 1990s and an improved infrastructure supported by environmental legislation. It led to a significant reduction of CO_2 emissions per unit of electricity and heat generation from public power production. As a result, the specific greenhouse gas emissions per unit of energy consumption decreased in most Member States between 1990 and 2003 (see Figures 3 and 8). However, a rapidly rising overall demand for electricity meant that total greenhouse gas emissions of this sector decreased only slightly (– 3.6 %). Furthermore, the fuel switch has slowed from around 1999 onwards, with an increase in coal-fired electricity generation as a reaction to rising gas prices.

A range of specific policies and measures have begun to contribute to emission reductions in a number of EU Member States, including the implementation of those set at EU level under the umbrella of the European Climate Change Programme (EC, 2006b). These include, for example, the directive on the promotion of electricity from renewables (EC, 2001a). Of particular significance is the introduction of the EU's CO_2 Emissions Trading Scheme (EC, 2003a), which commenced its first phase at the start of 2005. It should be noted that the majority of these policies will only begin to have a significant impact after the period examined in this report.

Despite these existing policies and measures, current progress indicates that all planned additional policies and measures need to be implemented and the Kyoto flexible mechanisms used in order to meet the EU-15 commitment under the Kyoto Protocol (EEA, 2005c). At the same time, nearly all the new Member States (EU-10) are on track to meet their emission targets.

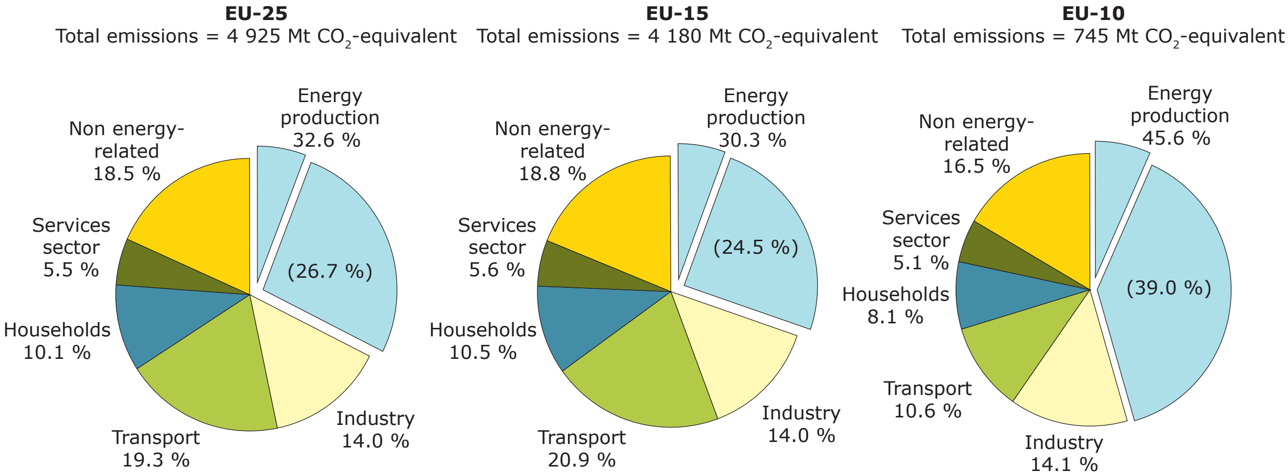
In the long-term, energy- and non-energy-related greenhouse gas emissions ought to be reduced further. The Council of the EU has called for developed countries to reduce emissions by the order of 15% to 30 % by 2020, and the European Parliament advocated further reductions of 60 % to 80 % by 2050. Recent projections (EC, 2004a, EEA, 2005b) indicate that there is significant potential in the long-term to reduce emissions, particularly from the power generation sector, through fuel switching, more use of renewables and potential further nuclear capacity. In addition, emissions from fossil fuels could be reduced through the use of new technologies that capture CO_2 emissions and store them over the long-term (CCS). Nevertheless, reducing overall demand for energy will continue to play a key role.

([3]) The base is 1990 for CO_2, CH_4 and N_2O. For fluorinated gases Member States can choose either 1990 or 1995 as base year; all EU-15 Member States except Finland and France chose 1995. The base year emissions of the EU-15 are the sum of the EU-15 Member States' base year emissions.

The **EU emissions trading scheme**, established by Directive 2003/87/EC, started on 1 January 2005. It currently covers CO_2 emissions from around 11400 installations so far. These installations include: power and heat generators, oil refineries, ferrous metals, cement, lime, glass and ceramic material, and pulp and paper. The emissions trading sector accounts for more than half (52 %) of total CO_2 emissions within the EU. The EU-ETS is a 'cap-and-trade system', with the caps being determined by the allowances specified in National Allocation Plans. For the first trading period (2005–2007), the total number of allowances is as a yearly average 3.5 % above the emissions of the trading sector in 2003 (EEA, 2005c). The outcome of the first verified emission reports for 2005 also indicates that the allocation is higher than actual monitored emissions in 2005 (EC, 2006e). National Allocation Plans for the second trading period (2008–2012) must be submitted to the Commission by 30 June 2006.

Figure 1 Greenhouse gas emissions by sector in 2003, EU-25, EU-15 and EU-10

Total greenhouse gas emissions in the EU-25 amounted to 4925 Mt CO_2-equivalent in 2003 (82.5 % CO_2, 8.2 % CH_4, 7.9 % N_2O and the remaining 1.4 % corresponded to the fluorinated gases). Emissions in the pre-2004 EU-15 Member States accounted for 85 % of total EU-25 emissions. Trends in the EU-15 therefore tend to dominate those of the EU-25 as a whole. In the EU-15, energy production accounts for approximately 33 % of all emissions, of which four-fifths are due to CO_2 emissions from power production. The next largest sets of emissions come from transport and non-energy related emissions followed by industry, households and services. By contrast, in the EU-10 the share of emissions from energy supply is far larger, accounting for around 46 %, while the share of emissions from transport is almost half that in the EU-15. This is largely due to a lower overall efficiency of electricity production in the EU-10 and more use of coal and lignite coupled with lower ownership of private cars.

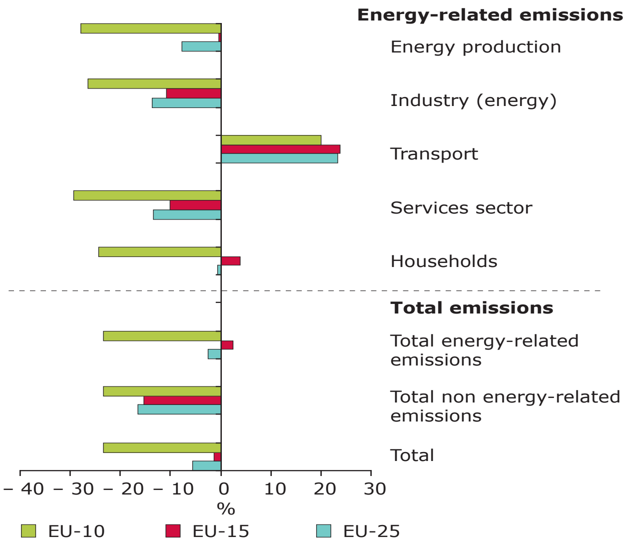


Notes: The numbers in parentheses indicate the share of emissions from public heat and electricity production, which form the major part of emissions from energy production. Annual emissions of CO_2, CH_4, N_2O, HFC, PFC and SF_6 in the UNFCCC reporting format are converted to their global warming potential GWP (100 year time horizon) for addition and comparison with the Kyoto Protocol targets: 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 tonnes CO_2-equivalent.

Source: EEA.

Figure 2 **Overall change in greenhouse gas emissions by sector between 1990 and 2003, EU-25**

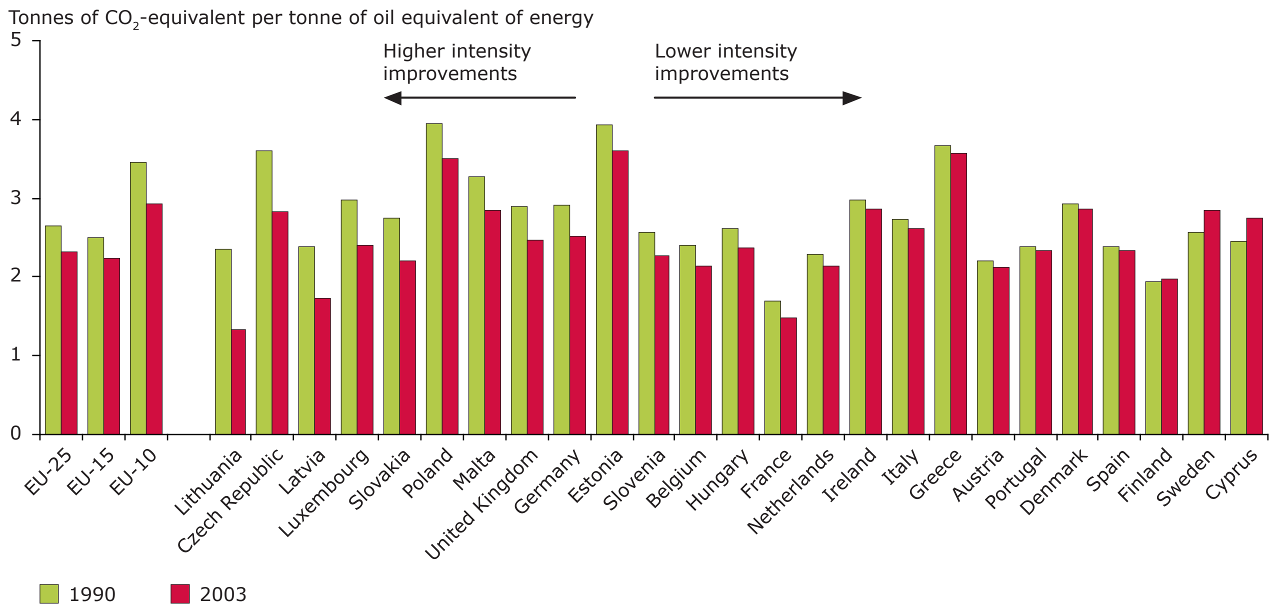
Energy-related greenhouse gas emissions in the EU-25 decreased by 2.6 % between 1990 and 2003. This trend was mainly driven by large decreases in the EU-10 Member States (– 23.5 %), as EU-15 energy-related emissions actually increased (2.5 %) over the period. The reduction in energy-related emissions was much less than that observed for non-energy related emissions in agriculture, waste and other sectors. These fell substantially supported by improved waste management and emission reductions in industrial processes and agriculture. While greenhouse gas emissions from the energy production, services and industry sectors all decreased between 1990 and 2003, emissions from transport in the EU-25 rose significantly over the same period. This factor offset the reductions from other sectors.



Source: EEA.

Figure 3 **Greenhouse-gas emissions intensity of energy consumption by country in 1990 and 2003**

The greenhouse gas emissions intensity of energy consumption in the EU-25 fell by 12.2 % between 1990 and 2003, indicating a move towards a less carbon intensive fuel mix. This decrease in emissions intensity was a major reason for the overall reduction in energy related greenhouse gas emissions in the EU and was caused largely by a decreasing share of coal in total energy consumption (down from 27.7 % to 18.2 %), with an increase in the shares of natural gas (up from 16.7 % to 23.6 %) and to a lesser extent nuclear and renewables. However, there were wide variations between countries, with some of the highest improvements in emissions intensity seen in Lithuania, the Czech Republic and Latvia. This was mainly due to a fall in the share of heavy fuel oil in Lithuania and of coal and lignite in the Czech Republic and Latvia. In contrast, Sweden and Cyprus saw slight increases in their greenhouse emissions intensities. In the case of Sweden, a decline in the share of nuclear power contributed to the increase and in Cyprus a major cause was a rise in the use of oil.



Source: EEA, Eurostat.

1.2 Air pollution

Energy-related emissions of acidifying substances, tropospheric ozone precursors and particles fell significantly between 1990 and 2003. Nevertheless, air quality in many cities does not yet meet the limit values set by European legislation. Moreover, public health and ecosystems are still adversely affected. Further emission reductions are needed to achieve long-term air quality targets.

Air pollutant emissions can cause a variety of impacts on public health and ecosystems. Acidifying substances lead to changes in soil and water quality, and damage to forests, crops and other vegetation as well as damage to buildings and cultural monuments. Emissions of ammonia and nitrogen oxides can cause an excess input of nutrient nitrogen (eutrophication) leading to a loss of biodiversity and nitrogen leaching into water courses. Particle emissions may increase the frequency and severity of a number of respiratory and other health problems. Emissions of ozone precursors contribute to the formation of ground level (i.e. tropospheric) ozone, which is a powerful oxidant and can have a range of adverse impacts on both health and ecosystems.

Ceilings for total (i.e. energy and non-energy related) emissions of sulphur dioxide, nitrogen oxides, ammonia and non-methane volatile organic compounds have been set for 2010 in the national emissions ceilings directive (NECD; EC, 2001b). This was amended by the Treaty concerning the accession of the new Member States to the European Union.

Energy production and consumption contributes around 66 % of EU-25 emissions of acidifying substances, 77 % of emissions of tropospheric ozone precursors and about 81 % of particles emissions (see Figure 4). The energy-related emissions of acidifying substances, tropospheric ozone precursors and particles decreased by 56 %, 41 % and 47 % between 1990 and 2003, respectively (see Figure 5). They fell more than total emissions (see Figure 6).

These emission reductions have primarily been the result of the increased use and effectiveness of abatement technologies and improvements in efficiency. These include, for example, flue gas desulphurisation and the use of low NO_X-burners in power generation (see Figure 8). Their introduction has been 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 technologies, substantial emissions reductions have been made in the power production sector due to a combination of fuel switching from coal and oil to natural gas, the closure of old inefficient coal plants, and the overall improvement in generation technology — particularly via the use of Combined Cycle Gas Turbines (CCGT).

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

In the transport sector, the introduction of catalytic converters mainly contributed to reduced emissions. This was complemented by measures to improve petrol and diesel quality, such as reducing the sulphur content of these fuels. These measures were implemented due to EU emission legislation.

Air pollution issues

		Acidifying substances	Particles*	Ozone precursors	Eutrophying substances	NECD target***
Sulphur dioxide	SO_2	✓	✓			✓
Nitrogen oxides	NO_X	✓	✓	✓	✓	✓
Ammonia	NH_3	✓	✓		✓	✓
Non-methane volatile organic compounds	NMVOCs			✓		✓
Primary PM_{10}	PM_{10}		✓			
Methane**	CH_4			✓		
Carbon monoxide	CO			✓		

* Emissions of primary PM_{10} particles are those emitted directly into the atmosphere and secondary particulate-forming pollutants are the fraction of sulphur dioxide, nitrogen oxides and ammonia which, as a result of photo-chemical reactions in the atmosphere, transform into particles with a diameter of 10 µm or less.

** CH_4 is also a greenhouse gas and is covered under the Kyoto Protocol.

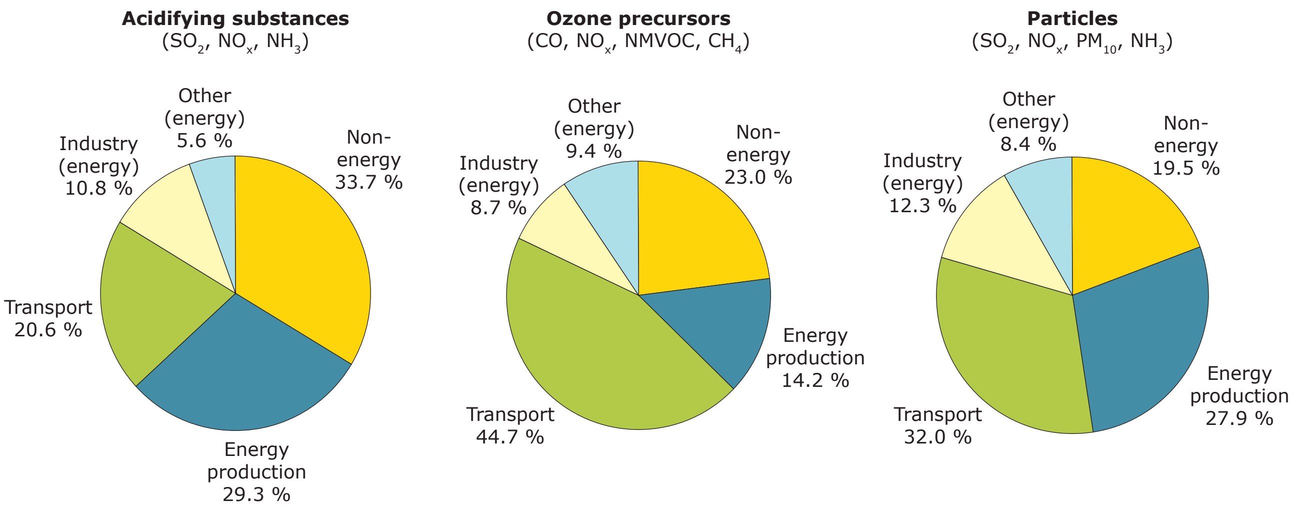
*** NECD targets are those set in the national emissions ceiling directive (EC, 2001b).

Despite reduced emissions of air pollutants, urban air quality still often exceeds the limit values set for protection of the public health, especially in streets and other urban hotspots (EEA, 2006b). 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' thus calls for further reductions in air pollutant emissions by 2020 in order to achieve long-term air quality targets (EC, 2005f).

It is expected that future emissions of most air pollutants are likely to continue to fall in the EU-25 (Amann *et al.*, 2004), especially those from the traditionally dominant source sectors (e.g. road transport and energy production). Thus, in the future, other sectors, for which there is currently less stringent legislation, will cause the majority of emissions. For example, substantial emission increases (particularly of SO_2 and NO_X) are expected from maritime activities that, without further action, will most likely surpass land-based emissions, in absolute terms, in the EU-25 within approximately the next 20 years. Tighter emission standards are thus considered by the Commission to complement those set by the International Maritime Organisation (EC, 2005f).

Figure 4 Emissions of air pollutants by sector in 2003, EU-25

In 2003, energy-related emissions of acidifying substances, ozone precursors and particulate matter accounted for around 66 %, 77 % and 81 % of total emissions in each of these categories, respectively. Energy-related emissions in transport and energy production tend to account for half of all emissions, with the transport sector particularly dominant in relation to ozone precursors due to NO_X emissions. These have decreased steadily since 1990 due to the introduction of catalytic converters.



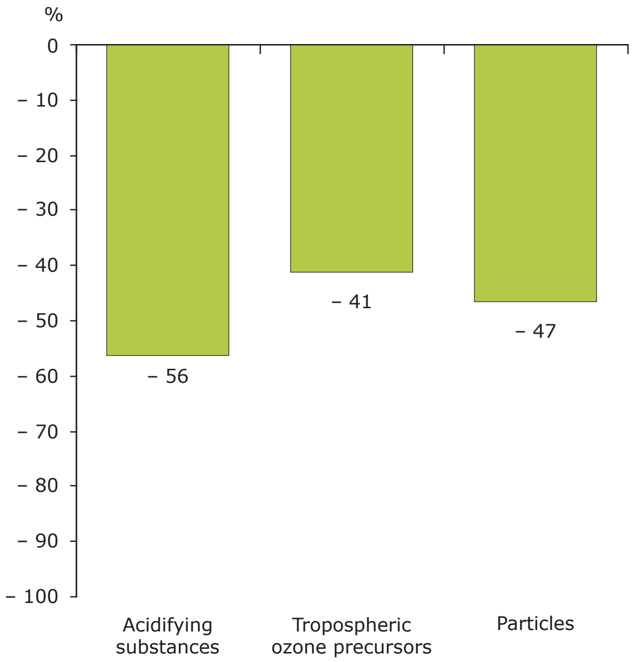
Note: 'Other' includes energy-related emissions from households, services and agriculture.

Source: EEA.

Abatement technologies can be used to reduce or eliminate airborne pollutants such as particles, sulphur oxides, nitrogen oxides, carbon monoxide, 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.

Figure 5 Overall changes in energy-related emissions by main group of air pollutants in the EU-25, 1990–2003

The emissions of most energy-related air pollutants were reduced significantly between 1990 and 2003. Energy-related acidifying emissions decreased by 56 % over the period 1990–2003, while energy-related emissions of particle matter and ozone precursors fell by 47 % and 41 %, respectively. Most of the emissions reductions were achieved in energy production, industry and transport sectors (excluding air and marine transport), and were largely the result of abatement techniques and fuel switching.



Note: The emissions of acidifying pollutants (SO_2, NO_X and NH_3) are each weighted by an acid equivalency factor prior to aggregation to represent their respective acidification potentials. These factors are: 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. For tropospheric ozone formation, the relative impact of the combined contribution of NO_X, NMVOC, CO and CH_4 can be assessed based on their tropospheric ozone forming potentials (TOFP). These are: 1.220, 1.000, 0.110 and 0.014, respectively. For particle formation, emissions are estimated using the following aerosol 'formation factors': primary PM_{10} = 1, NO_X = 0.88, SO_2 = 0.54 and NH_3 = 0.64.

Source: EEA, de Leeuw, 2002.

Figure 6 Overall change in emissions of acidifying substances by country, 1990–2003

The majority of EU-25 Member States have contributed to the reduction in overall emissions of acidifying substances. In particular, many of the EU-10 Member States have already met or exceeded their indicative targets under the national emission ceilings directive (NECD) due to structural changes in their economies, such as the decline in heavy industry and the closure of older inefficient power plants. This has led to a decline of over 50 % in many cases, even though total per capita emissions often still remain high. However, some EU-15 Member States are currently not on track to meet their 2010 emissions targets under the NECD.

Notes: The graph shows the emissions of acidifying pollutants (SO_2, NO_X and NH_3) each weighted by an acid equivalency factor prior to aggregation to represent their respective acidification potentials (see note to Figure 5). The target indicated is the aggregate 2010 national emissions ceiling directive target for the combined acidifying pollutants NO_X, SO_2 and NH_3. They are based on absolute emission levels. Targets for the new Member States are temporary and are without prejudice to the review of the NEC directive. Data for Malta are not available.

Source: EEA.

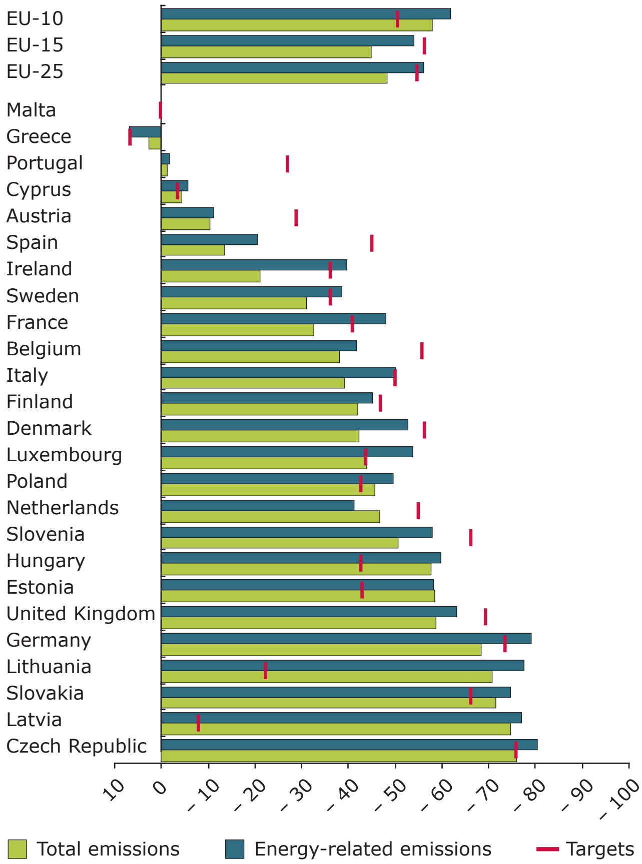


Figure 7 Change in the emissions intensity of energy-related air pollutants in the EU-25, 1990–2003

The intensity (i.e. in kg of emissions per tonne of oil equivalent of energy consumed) of most energy-related air pollutant emissions has declined significantly over the period 1990–2003. In particular, there has been a significant decline in the intensity of CO and SO_2 emissions, which have more than halved. A main factor contributing to the decrease in CO emissions has been the introduction of catalytic converters in cars and the increased penetration of diesel cars into vehicle fleets. SO_2 emissions have been reduced to a large extent in electricity generation due to the introduction of abatement technologies, such as flue gas desulphurisation, and a switching from high sulphur-containing fuels, such as coal and heavy fuel oil, to natural gas coupled with the use of coal with lower sulphur content.

Note: PM_{10} includes only primary particle emissions. The intensity of energy-related NH_3 emissions is not visible in the figure (0.06 kg/toe in 2003) and was thus excluded.

Source: EEA, Eurostat.

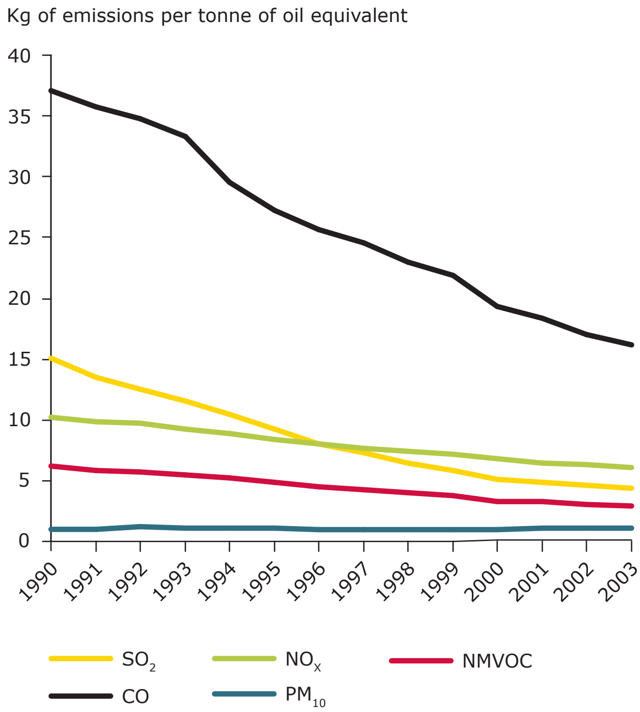
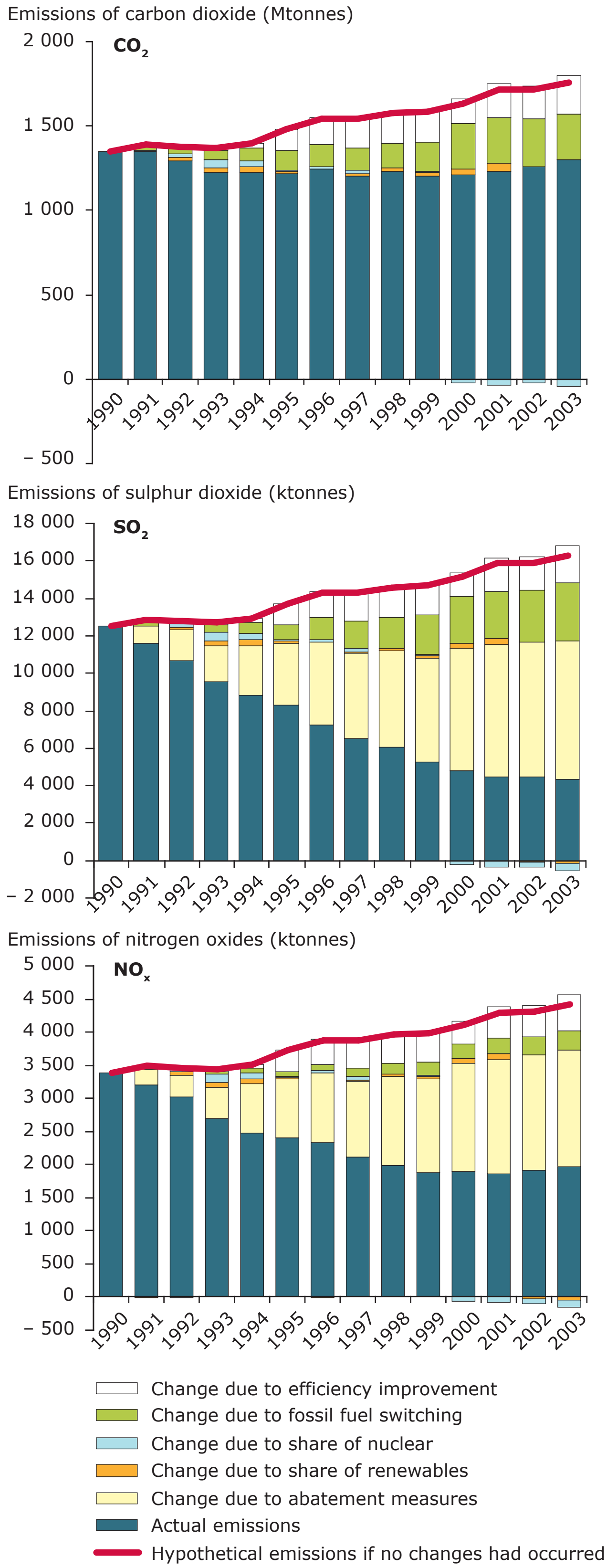


Figure 8 **Estimated impact of different factors on the reduction of CO_2, SO_2 and NO_X emissions from public heat and electricity generation in the EU-25, 1990–2003**



The emissions of CO_2, SO_2 and NO_X from electricity and heat generation depend on both the amount of electricity and heat produced as well as on the emissions per unit produced. The latter is influenced by the share of non-fossil fuels in power generation (i.e nuclear and renewables), the contribution of different fossil fuels (i.e. gas, oil and coal), as well as the overall generation efficiency, and in the case of NO_X and SO_2, the extent to which abatement techniques are applied.

If the structure of electricity and heat production had remained unchanged from 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 share of renewables in certain years. However, in 2002 and 2003 the share of renewables was relatively low due to limited hydropower production as a result of low levels of rainfall. The share of nuclear in electricity production was below its 1990-levels in recent years, which would have led to increased emissions.

For both SO_2 and NO_X emissions reductions the application of abatement technology appears to be the dominant factor. It accounts for the majority of hypothetical SO_2 and NO_X emission reductions (i.e. emissions that would have occurred if these developments had not taken place). Improvements in efficiency also had an important impact on emissions reductions in both cases. The effect of fuel switching is more pronounced in the case of SO_2 emissions as gas has much lower sulphur content than coal. From around 1999 onwards the decrease in SO_2 emissions slowed significantly and NO_X emissions actually increased.

Note: The technique used to derive the above graphs is based on the multiplicative 'IPAT' and 'Kaya' identities, which is a frequently used approach for portraying the primary driving forces of emissions. The components should not be seen as fundamental factors in themselves nor should they be seen as independent from each other.

Source: EEA, Eurostat.

1.3 Other energy-related pressures

Highly radioactive waste from nuclear power production continues to accumulate. A generally acceptable way to dispose of this waste has yet to be identified. Oil pollution from offshore installations and coastal refineries has been reduced, but major oil tanker spills continue to occur.

Nuclear power is responsible for a steady accumulation of radioactive waste that poses a potential threat to the environment. The release of radioactivity into the environment can result in acute or chronic impacts that, in extreme cases, can cause a loss of biota in the short-term and genetic mutation in the long-term. They may also result in unknown effects or fatalities. Increased levels of radioactivity can also be passed up through the food chain and affect human food resources. Spent nuclear fuel is the most highly radioactive waste. It decays rapidly at first, i.e. after 40 years the level of radioactivity has typically dropped to 1/1000th of the initial value. But it takes around 1000 years to drop to the level of the original uranium ore, which was needed to produce that quantity of spent fuel (WNA, 2003).

The annual quantities of spent fuel in the EU in 2003 remained at its 1990-levels (see Figure 9). This amount is governed mainly by the quantity of electricity produced by nuclear power plants as well as efficiency improvements within existing plants (NEA, 2003). But even stable or decreasing annual quantities of waste imply that the accumulated quantity of waste will continue increasing. Work is on-going to try to establish final-disposal methods that alleviate technical and public concerns over the potential threat that this waste poses to the environment. In the meantime, the waste accumulates in stores. The European Commission therefore suggested more support for research and development on nuclear waste management in its proposal for a sustainable development strategy (EC, 2001) and proposed a directive on the management of nuclear waste (EC, 2004c; EC, 2002e).

Oil pollution from coastal refineries, offshore installations and maritime transport put significant pressures on the marine environment. Oil consistency 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 increased oil production and ageing of many major oil fields (see Figure 10). This improvement has mainly been the result of the increased application of cleaning and separation technologies.

Tanker oil spills continue to occur, although both their frequency and the volumes involved seem to have declined over the past decade (see Figure 11). However, this trend is to a large extent 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 ([4]). Nevertheless, it is encouraging that the apparent improvement has come 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, 2005g), and the proposed accelerated introduction of double-hull tankers (EC, 2006d).

Residues from coal combustion indicate the quality of the coal used for power generation and the use of pollution abatement technologies. Their environmental impact can be low if they are utilised in an environmentally safe way, but there is a risk of local water pollution. Residues from the combustion of coal for energy production have increased slowly in the EU-15. They accounted for 3.5 % of total waste generation in 2001; waste mainly consisting of ashes and gypsum from flue gas desulphurisation. The utilisation of coal residues reaches almost 100 % in some European countries, whereas it is still low or non-existent in others, thus exerting pressures on the environment.

Further environmental pressures can also arise from energy-related land use 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) also release small quantities of heavy metals, e.g. mercury, lead and cadmium. These can accumulate in biological organisms over time, and have potentially toxic effects.

([4]) For example, Helcom states that the number of all ship accidents in the Baltic almost doubled between 2003 and 2004, mainly as a result of increased maritime traffic (Helcom, 2006). However, most of the accidents did not cause notable pollution.

Figure 9 Annual quantities of spent nuclear fuel from nuclear power plants in the EU, 1990–2003

Quantities of spent fuel in the EU remained at its 1990-levels in the year 2003. While in most Member States spent fuel production was fairly stable over that period, it fluctuated strongly in the United Kingdom. This was caused partly by variations in electricity production from UK nuclear plants. However, the large peaks shown in the chart are linked to the decommissioning of a number of older nuclear power plants. During normal operations only a fraction of a reactor core is refuelled each year and the spent fuel removed. However, during decommissioning the reactor is completely de-fuelled.

Notes: The vast majority of highly radioactive waste consists of spent fuel and spent fuel reprocessing wastes. No data on quantities of spent fuel from nuclear electricity production are available for Lithuania or Slovenia, and limited time series data are available for the Czech Republic and Hungary prior to 1995 and Slovakia prior to 1999.

Source: OECD, 2004; NEA, 2005.

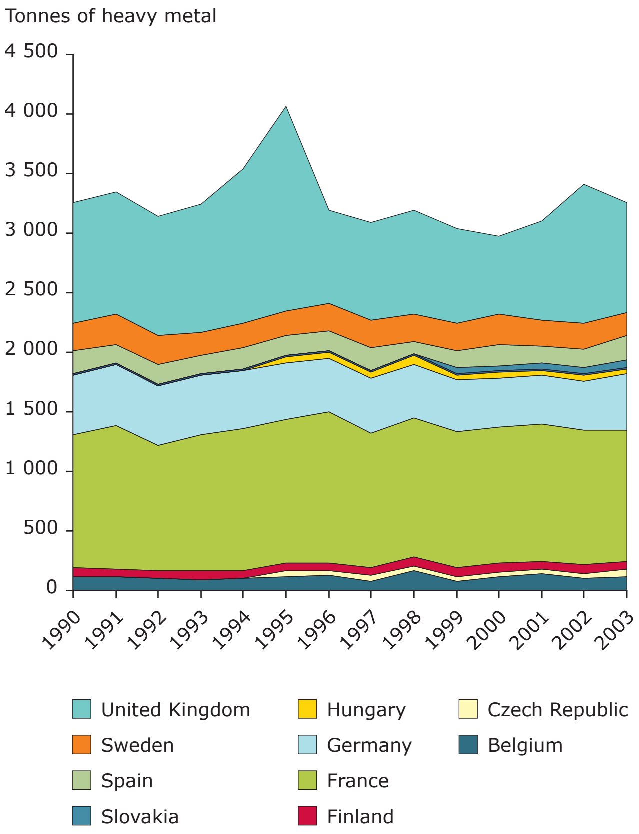


Figure 10 Oil production and discharges from offshore oil installations in the north-east Atlantic

Discharges of oil from offshore installations can occur from 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 likely that further reductions of oil discharges will continue in the future. This will be supported by new regulation on drill cuttings (OSPAR, 2000), which entered into force in 2000.

Notes: Data only available from Denmark, Germany, Ireland, the Netherlands, the United Kingdom and Norway, hence coverage is restricted to north-east Atlantic; Production data for 1990 is not available.

Source: OSPAR Commission, Eurostat.

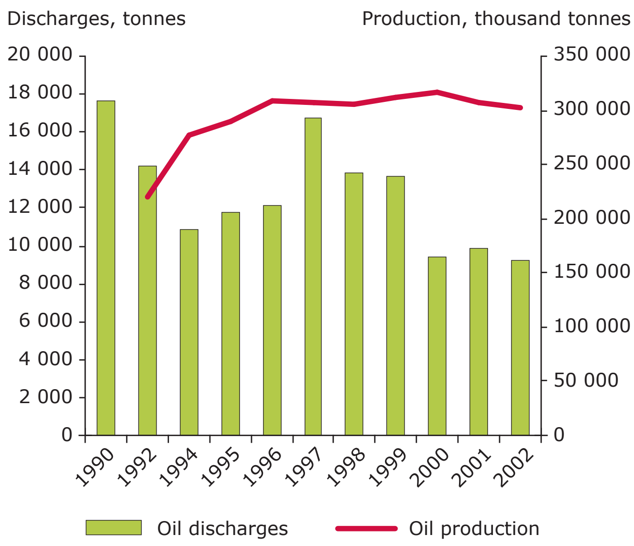
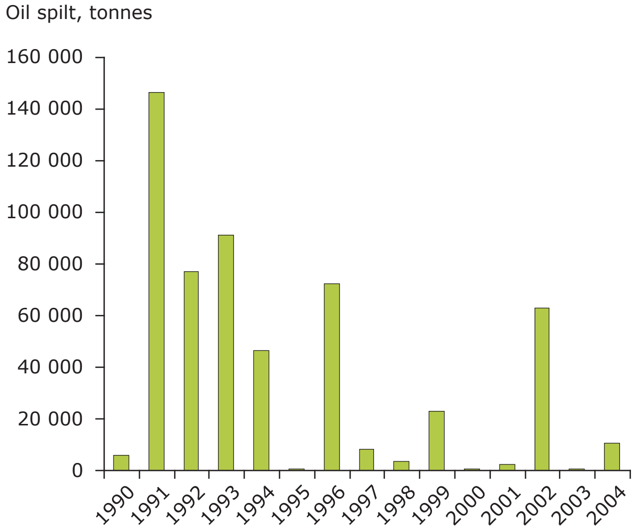


Figure 11 Accidental tanker oil spills (above 7 tonnes per spill), European seas

Accidental tanker oil spills into European seas have decreased significantly over the past 15 years. From the total amount of oil spilt during that period (around 551 000 tonnes), two thirds were spilt over the period 1990–1994. During the five year periods 1995–1999 and 2000–2004, around 19 % and 14 % were spilt, respectively. However, this trend is to a large extent dependent on the occurrence of large tanker accidents.

The data do not include spills and discharges below 7 tonnes. The figures therefore underestimate oil pollution from maritime transport. Nevertheless, small spills are estimated to make only a limited contribution towards total spills.



Notes: European Seas cover the north-east Atlantic, Baltic, Mediterranean and Black Sea. Oil spilt in an incident includes all oil lost to the environment, including that which is burnt or remains in a sunken vessel.

Source: International Tanker Owners Pollution Federation Ltd, ITOPF.

2 Is energy use decreasing?

Energy consumption in the EU-25 continues to grow, making it difficult to reduce energy-related environmental pressures. This growth is driven primarily by the transport sector, which has become the largest consumer of final energy. Electricity consumption has grown over twice as fast as final energy consumption. These trends are expected to continue in the future unless dedicated energy saving policies and measures are implemented.

Every type of energy production or conversion technology leads to some kind of environmental pressure. Ultimately, reducing the overall level of energy consumption is thus the most robust way of reducing energy-related environmental pressures. Promoting energy savings and energy efficiency are central elements of the EU strategy for environmental integration within the energy sector. The European Commission's green paper on energy efficiency stresses the need for capping EU energy demand at present levels and then ultimately reducing it. It states that a reduction of up to 20 % could be achieved with cost-effective measures (EC, 2005b).

Final energy consumption in the EU-25 increased steadily at an annual average rate of approximately 0.8 % during the period 1990 to 2003. A faster increase occurred in the period from 1999 onwards. All end-use sectors experienced a rise in energy consumption (see Figure 12), except for industry (for which energy consumption started to rise again after the mid-1990s).

The trends in final energy consumption were stimulated by the rapid growth of a wide range of service sectors and a shift to less energy-intensive manufacturing industries. Furthermore, structural changes in many countries (including the post re-unification effects in Germany) and the rapid transition of new Member States to market-based economies also led to changes in energy consumption.

Transport showed the fastest growth in energy consumption ([5]) and is now the largest consumer of final energy (see Figure 13). This was supported by the development of the internal market, which resulted in increased freight transport as companies exploited the competitive advantage of different regions. In addition, rising personal incomes have permitted higher standards of living and changed many people's lifestyle. These changes have included a greater demand for travel and private cars. Improvements in the transport infrastructure and spatial developments (e.g. urban sprawl) also influenced transport demand.

Higher comfort levels and larger dwellings, reflected in increased demand for space heating and cooling, and domestic electrical appliances have contributed to higher final energy consumption in the households sector. This demand has fluctuated quite substantially from year to year due to the effect of the outdoor temperature.

There are significant differences between the EU-15 Member States and the new EU-10 Member States (see Figure 14). The EU-10 has seen falling final energy consumption throughout the 1990s mainly as a result of economic restructuring.

Final energy consumption covers all energy supplied to the final consumer's door for all energy uses. It is usually disaggregated in the final end-use sectors industry, transport, households, services and agriculture. **Total energy consumption** (or gross inland energy consumption) represents the quantity of all energy necessary to satisfy inland consumption. The difference between total and final energy consumption is mainly due to losses in the conversion process, such as electricity generation, the consumption of the energy branch, transport and distribution losses and the part allocated to final non-energy consumption (e.g. feedstocks used by the chemical industry).

([5]) Final energy consumption of the service sector without agriculture and other sectors increased even slightly faster than in the transport sector. However, this report aggregates the services and agriculture sectors in order to be consistent with the breakdown in projection data.

However, this has begun to rise again from 2000 onwards in line with the economic recovery in these countries. By contrast the EU-15 experienced steady, continued growth in final energy consumption from 1990 to 2003. As a result, final energy consumption per capita in the EU-15 was around 1.5 times above EU-10 levels (see Figure 15).

Final electricity consumption grew across the EU-25 more than twice as fast as the overall final energy consumption (1.9 % p.a., see Figure 12) due to its attractiveness and flexibility in end-uses. It thus increased its share in final energy consumption to almost 20 % in 2003, up from 17.4 % in 1990 ([6]). Growth in electricity consumption was particularly strong in the service sector, and, to a lesser extent, in the households sector. In both cases, this was linked to an increased use of electrical appliances (e.g. lighting, air conditioning, information technology) and the advent of new electrical appliances. This rise offset the enhanced efficiency of conventional white goods such as refrigerators (ADEME, 2005).

Baseline projections indicate a continuing rise in final energy and electricity consumption until 2030. This could be reduced by assuming a carbon-permit price (EEA, 2005b) or dedicated energy efficiency policies (EC, 2004a). If energy efficiency policies were implemented along the lines of the Action Plan on Energy Efficiency (EC, 2000), the EU-25 primary energy consumption would remain at the same level as that of the year 2000. This contrasts markedly to a projected rise of almost 20 % by 2030 in a baseline case scenario (EC, 2004a). The highest absolute savings compared to the baseline are projected to be improvements in space heating and cooling in both the households and service sector due to a combination of increased insulation and more efficient heating systems. The largest relative savings are for electricity in these sectors, due to the significant potential for efficiency improvements in lighting and appliances.

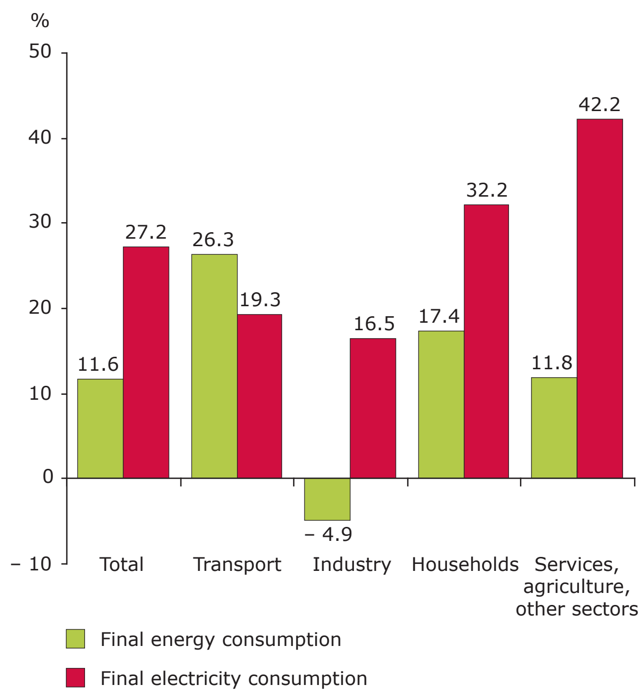
Figure 12 Overall changes in final energy and electricity consumption by sector between 1990–2003, EU-25

Final energy consumption increased by 11.6 % over the period from 1990 to 2003. The largest increase was seen in transport, which was largely driven by rising passenger cars and increasing road freight transport. The decline in heavy industry and a switch to services actually led to a decrease in consumption in the industry sector. However, consumption began to increase again after the mid-1990s.

Stronger electricity growth compared to increases in final energy consumption has led to a rising share of electricity consumption within final energy in industry and services and households. Electricity consumption increased particularly fast in the services sector, followed by households.

Note: The services sector alone (excluding agriculture and other sectors) increased slightly more than the transport sector.

Source: Eurostat.



([6]) The increasing share of electricity in final energy consumption can be of particular concern for the environment when produced from fossil fuels. Electricity production from fossil fuels (particularly coal) is associated with important efficiency losses and relatively high emissions of greenhouse gases if not produced in combined heat and power plants. However, electricity production can also be based on non-emitting sources (such as wind energy) and allows the use of CO_2 capture and storage technologies in future.

Figure 13 Share of final energy and electricity consumption by sector in 2003, EU-25

The share of final energy consumption is largest in the transport sector, followed by industry, households and services. Household and service sector energy consumption is predominantly found in space heating. Here, electricity consumption is dominated by lighting, electrical appliances and a growing level of space cooling. Industry uses a substantial portion of final electricity consumption, an important part of which is due to the need for specific sub-sectors, such as aluminium production. The small amount of electricity used by the transport sector is mainly due to electrified railways, while road transport relies on the use of oil.

Note: Mtoe means million tonnes of oil equivalent; TWh means Terrawatt hours.

Source: Eurostat.

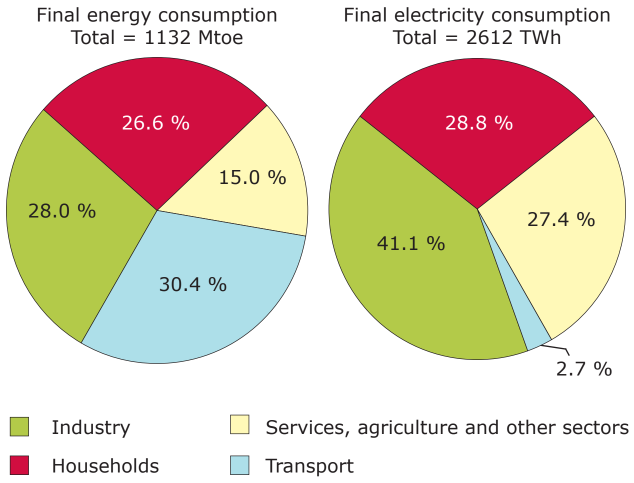


Figure 14 Average annual change in final energy and electricity consumption in EU Member States between 1990–2003

The average level of energy and electricity consumption in the EU-25 grew by an average annual rate of 0.8 % and 1.9 % respectively from 1990 to 2003. This has increased in recent years, with an average annual growth of 1.4 % and 2.4 % respectively from 1999 onwards.

Energy and electricity consumption grew much more rapidly in the EU-15 than in the EU-10, where energy consumption actually declined by 1.5 % on average per annum. However, from 2000 onwards it started to rise again. With the exception of Austria, Denmark, Sweden and Slovenia, final electricity consumption increased faster than final energy consumption, resulting in a greater share of electricity within the final energy fuel mix. In the EU-15, the most rapid expansions in final energy consumption occurred in Ireland, Spain and Portugal due to increased demands associated with rapid economic growth.

Note: The change in Germany refers to 1991–2003.

Source: Eurostat.

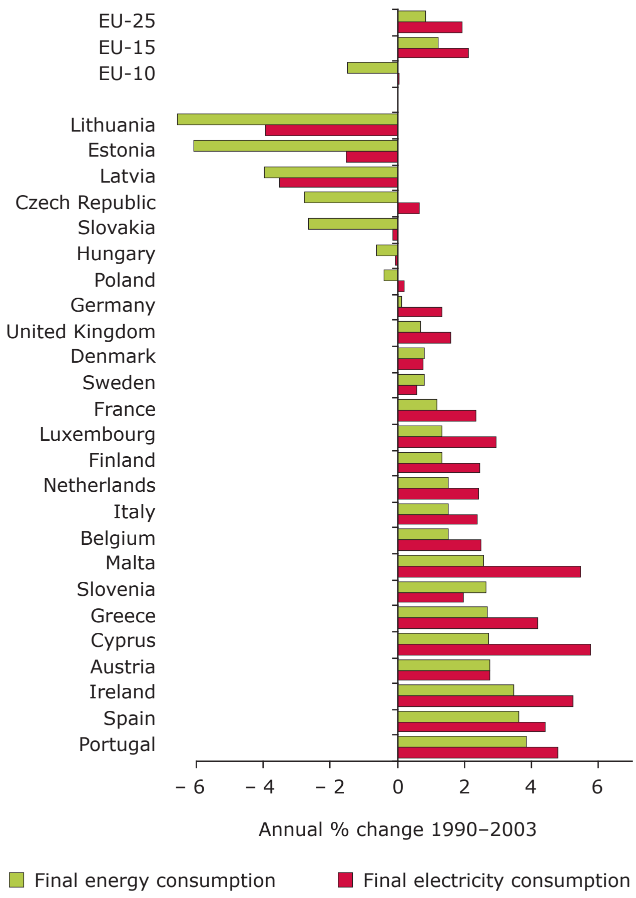
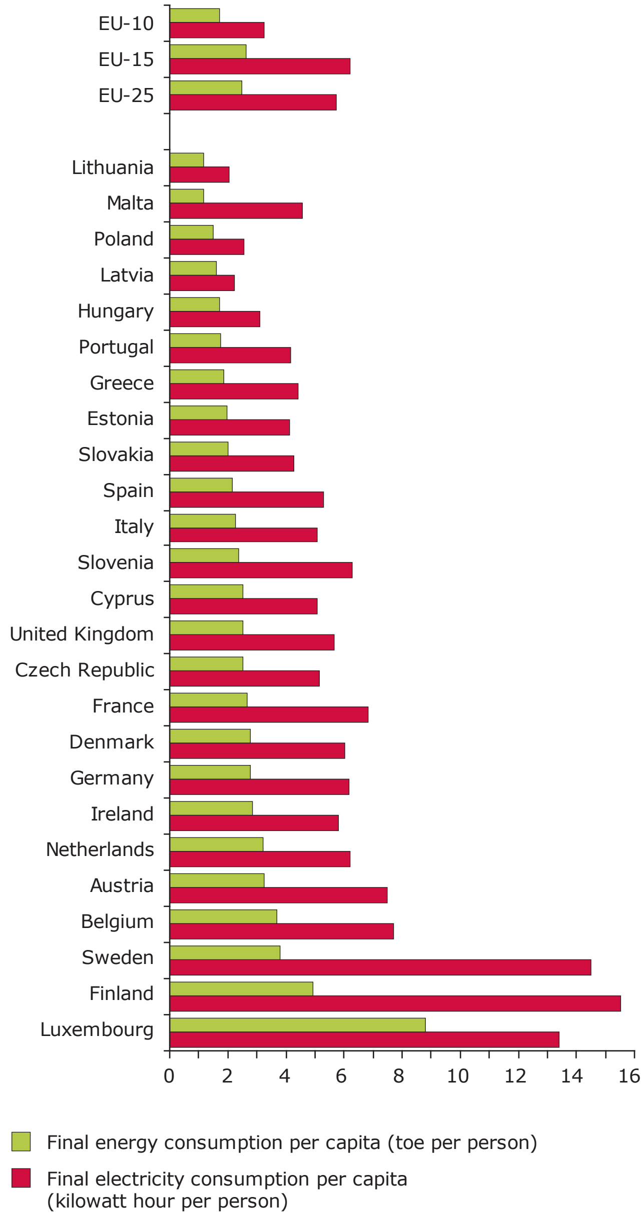


Figure 15 Final energy and electricity consumption per capita in EU Member States, 2003

In 2003, final energy and electricity consumption per capita in the EU-15 was on average around 1.5 times and almost 2 times higher than in the EU-10, respectively. Differences in final energy consumption per capita between Member States can be explained by a variety of factors including climate, income levels and the structure of the economy. The lowest per capita consumption occurs in some EU-10 Member States and southern European countries. Higher levels occur in northern Europe, which tends to be both more affluent and has a colder climate.

Electricity consumption per capita follows a similar pattern. Although the use of air conditioning in southern European countries is responsible for a large increase in electricity consumption during the summer months (see Figure 14), the highest consumption per capita was in the most northerly countries, Sweden and Finland. Here, electricity meets a large part of the overall heating requirements.



Source: Eurostat.

3 How rapidly is energy efficiency increasing?

The energy intensity of the EU's economy decreased by 15 % between 1990 and 2003 due to rising energy efficiency and structural changes taking place within the economy. Nevertheless, total energy consumption is still increasing. The efficiency of electricity production from fossil fuels also improved over the period, but at the same time the share of electricity in final energy consumption grew. This factor offset the reduced pressures on the environment deriving from greater efficiency.

Reducing energy intensity (i.e. energy consumption per unit of gross domestic product) and increasing energy efficiency is a central objective for environmental integration in the energy sector. An action plan on energy efficiency is expected in 2006, following the Green Paper on energy efficiency (EC, 2005c). Increasing energy efficiency was also highlighted by the European Council in its proposal for an Energy Policy for Europe (European Council, 2006).

Total energy intensity in the EU-25 decreased by an estimated 1.2 % per annum between 1990 and 2003 (see Figure 16). Average annual energy intensity in the new EU-10 Member countries decreased significantly faster than in the pre-2004 Member States (i.e. more than 3 times). Despite this converging trend, the total energy intensity in the EU-10 is on average still 1.5 times higher than in the EU-15 (compared at Purchasing Power Standards).

The relative decoupling of energy consumption from economic growth was influenced both by improvements in energy efficiency and structural changes within the economy. The latter included a shift from energy intensive sectors such as heavy industry to the services sector and less energy-intensive industries, and one-off changes in some Member States (e.g. most new Member States, Luxembourg and Germany) ([7]), associated with reductions in the energy intensity of the economy. For example, creating one unit of value added in the manufacturing sector requires almost nine times more energy than in the service sector.

Trends in **final energy intensity** differed substantially between the end-use sectors (see Figure 17). While substantial improvements occurred in industry and services, transport and households showed only limited decoupling of energy consumption from economic growth and population growth, respectively. This was influenced by rising living standards, leading to a larger number of households, lower occupancy levels and an increased use of household appliances. Growing transport levels outweighed the improvements in fuel efficiencies of cars. These improvements were achieved as a result of significant fuel price rises and the car industry's efforts to meet the voluntary commitments of vehicle manufacturing associations to gradually reduce CO_2 emissions of new vehicles (EC, 2005b).

Reductions in the overall energy intensity were also helped by improvements in the **efficiency of electricity generation**. The average level of efficiency of conventional thermal electricity production improved by 3 percentage points to around 38 % over the period 1990–2003 (see

Energy **intensity** is the ratio of energy consumption to another measure, such as GDP or population. It is not strictly a measure of energy efficiency as it can be affected by structural and behavioural changes, such as a shift away from energy-intensive industries, or a change in household heating patterns. Improvements in **energy efficiency** signify the use of less input energy to provide the same level of energy service (e.g. less electricity via the use of a compact fluorescent lightbulb or less primary energy used to produce one unit of electricity). Improvements in energy efficiency can be offset by increased demand. The goal is not just to improve energy efficiency or reduce energy intensity but to achieve **energy savings**, thus reducing energy consumption in absolute terms.

([7]) Decomposition analysis suggests that in the EU-15, structural changes were the most significant factor in the decrease in energy intensity during the first part of the 1990s with energy efficiency becoming responsible for a higher share of intensity improvements afterwards (ADEME, 2005). The stagnating trend in energy intensity since 2000 was primarily due to a slowing in the rate of GDP growth from this point, compared to a continued growth in overall energy consumption.

Figure 19). This increased efficiency was stimulated by improvements in existing technologies and the replacement of inefficient plants. This was often combined with a switch from coal-fired power plants to high-efficiency combined cycle gas-turbines. However, the rapid growth in fossil-fuel based electricity production has outweighed some of the environmental benefits of efficiency improvements ([8]).

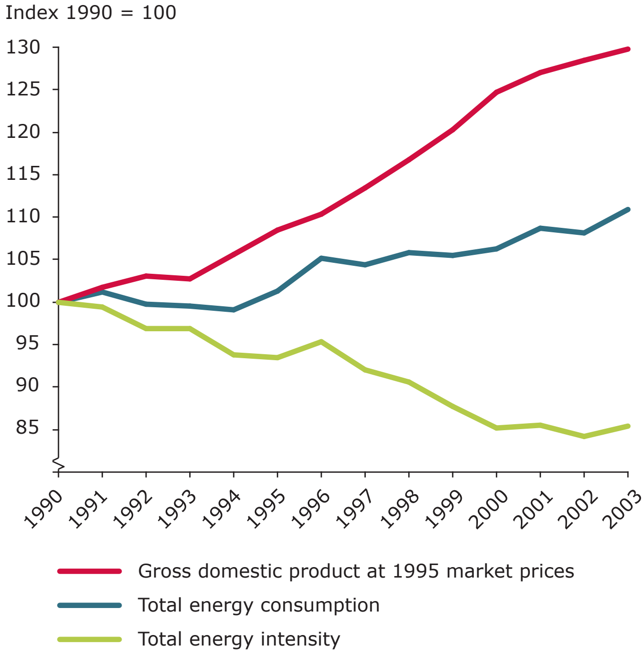
Increasing the share of **combined heat and power** plants is another option for increasing the efficiency of electricity and heat generation as it makes use of the heat that is otherwise lost in conventional thermal power plants. The EU thus aims to promote the share of combined heat and power and ultimately double it to around 18 % in 2010 (in the EU-15: EC, 1997a; EC, 2002d, EC, 2004d, European Council, 2006b). However, the share of electricity produced from combined heat and power remained almost constant at 9.2 % in the EU-15 between 2000 and 2002 (compared to 15.4 % in the EU-10, see Figure 18). Policy support to promote the technology in many Member States was counteracted by the effect of increasing gas prices and relatively low electricity prices. These factors reduced the competitiveness of gas-fired CHP-plants.

Despite the relative decoupling of energy use from economic growth, total energy consumption increased continuously between 1990 and 2003. This trend is expected to continue if no action is taken. However, with implementation of existing and additional policies and measures, substantial further improvements in the efficiency of final energy use and to a lesser extent in power generation can be expected (see Chapter 3; EEA, 2005b; EC, 2004a). The Green Paper on energy efficiency thus launched a debate on how to achieve a reduction of the energy consumption within the EU by 20 % (EC, 2005c).

The **continued potential of energy savings** in all sectors is widely recognised. In the building sector, where about 40 % of all final energy is used today, the directive on energy performance in buildings (EC, 2002a) is expected to help further improve efficiency. The directive on end-use efficiency and energy services (EC, 2006) sets indicative energy

Figure 16 Total energy intensity in the EU-25 between 1990–2003, 1990 = 100

Total energy consumption in the EU-25 grew at an annual rate of 0.8 % over the period from 1990 to 2003, while Gross Domestic Product (GDP) grew at an estimated average annual rate of 2.0 %. As a result, total energy intensity in the EU-25 fell at an average rate of 1.2 % per year. This means that the total energy intensity in 2003 was in real terms almost 15 % less than in 1990, indicating that each unit of growth of GDP now requires around 15 % less energy. Since 2000, the decrease in energy intensity has slowed, and even increased between 2002 and 2003. This was primarily due to a slowing in the rate of GDP growth from this point onwards, but with continued growth in overall energy consumption.



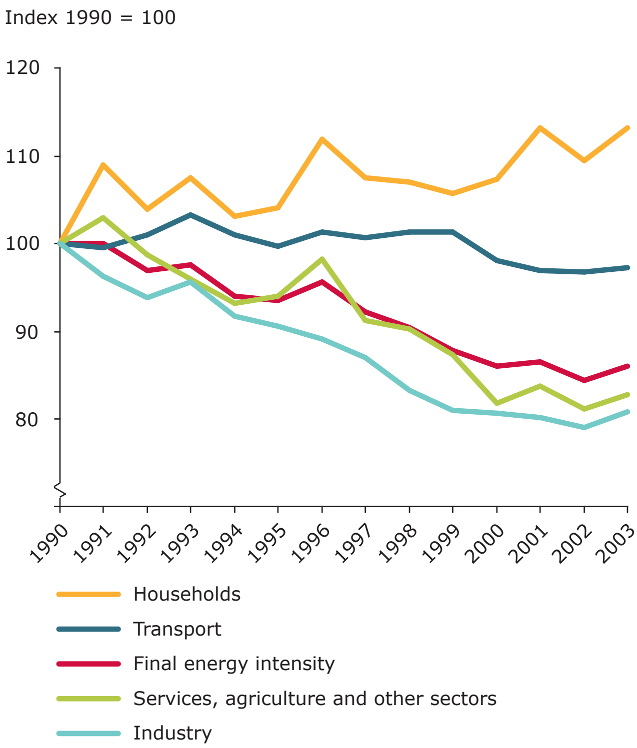
Note: Some estimates have been necessary in order to compute the EU-25 GDP index in 1990. For the Czech Republic (1990–1994), Hungary (1990), Poland (1990–1994), Malta (1991–1998) and for Germany (1990), Eurostat data was not available. GDP for the missing years were then estimated on the basis of annual growth rates (Ameco database), which were applied to the latest available GDP from Eurostat. For Estonia (1990–1992), Malta (1990) and Slovakia (1990–1991) neither data was available, and GDP in missing years was assumed to take the value of the nearest reported year. These assumptions do not distort the trend observed for the EU-25's GDP, since the latter three countries represent about 0.3–0.4 % of the EU-25's GDP.

Source: Eurostat and Ameco database, European Commission.

([8]) The ratio of final to total energy consumption highlights the efficiency with which primary energy is converted into final energy and the level of conversion losses. It remained fairly constant at 65 %. This happened despite an increase in the generation efficiency of electricity production, which is the result of an increasing share of electricity in final energy demand.

Figure 17 Trends in final energy intensity, EU-25

Final energy intensity in 2003 was 14 % less than in 1990. In particular, industry and services required less energy for each additional unit of economic output in 2003 than in 1990. This was due both to efficiency improvements and structural changes of the economy. The energy intensity of the household sector (final energy consumption of the household sector per capita) worsened due to increasing living standards and a greater number and size of dwellings. As a large part of household energy consumption is used for space heating, it fluctuates significantly with outdoor temperatures. Transport energy consumption showed only a very limited decoupling from economic growth as a result of increasing transport volumes. This offset the technical efficiency improvements made. However, it should be noted that final energy intensities between sectors are not directly comparable, because the normalising variables are not the same.

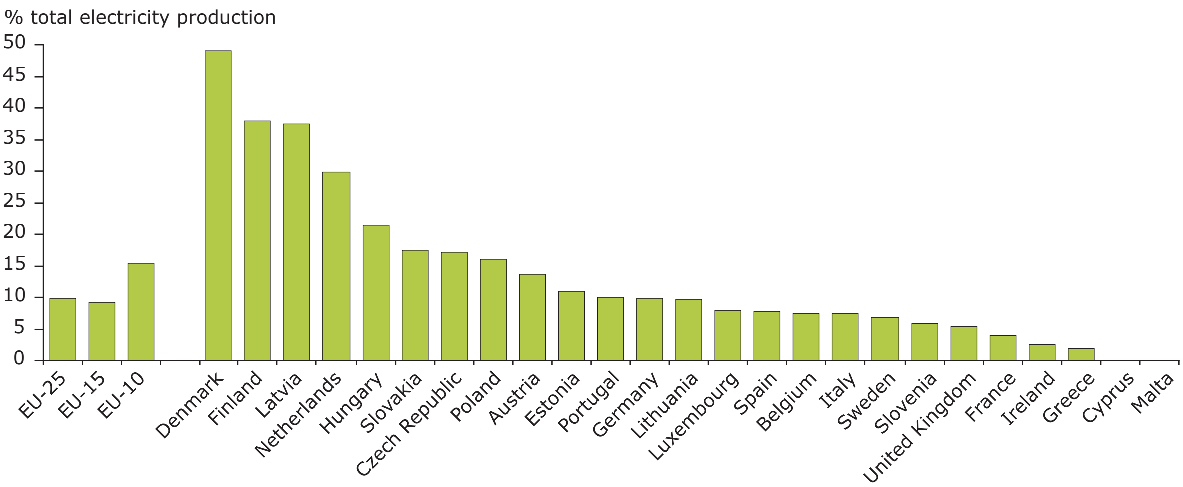


Note: The indicator serves to highlight the evolution in energy intensity within each sector. The denominators for the total, household, transport, industry (excl. construction) and services (incl. agriculture) sector energy intensities are, respectively; GDP, population, GDP, Gross Value added in industry (excl. construction), and Gross Value Added in Services (incl. agriculture).

Source: Eurostat, European Commission's Ameco database and National Technical University of Athens.

Figure 18 Share of combined heat and power in gross electricity production in 2002

The share of combined heat and power generation varies considerably among Member States. In the EU-10 the share of CHP is 1.7 times that of the EU-15, due to a greater prevalence of district heating networks, which utilise the heat generated. Countries with a particularly high market penetration of combined heat and power generation include Denmark, Finland, Latvia and the Netherlands. This reflects a combination of government support (such as tax incentives), the availability of district heating infrastructure and of natural gas, which is the favoured fuel for CHP, and the cold climate, which leads to a significant need for heat as well as electricity.



Note: The method for data collection by Eurostat on CHP was revised in 2000 and 2002 and has tended to decrease the overall share of electricity from CHP. Therefore the current share is not directly comparable to the 18 % target outlined in (EC, 1997a).

Source: Eurostat.

saving targets at 9 % for Member States. This should be achieved after nine years of application of the directive. The efficiency of electric appliances has improved significantly (e.g. a 27 % decline in average consumption of cold appliances in the EU from 1990 to 1999; IEA, 2005), supported by standards and labelling. Moreover, there is considerable scope for further improvements, which could be supported by accelerated market introduction of efficient appliances and the extension of labelling and standards to other appliances.

Figure 19 Efficiency of conventional electricity generation in 1990 and 2003

The efficiency of electricity production from conventional thermal power plants improved steadily between 1990 and 2003 in most Member States. This was due to the closure of old inefficient plants, improvements in existing technologies and the installation of new, more efficient technologies. In the EU-10, the efficiency in electricity generation increased at a higher rate (+ 3.7 %) than in the EU-15 Member States (+ 2.5 % between 1990 and 2003). Despite this converging trend, the electricity conversion efficiency is still 6.9 percentage points lower in the new Member States on average. Significant decreases in the efficiency of electricity production were witnessed in Lithuania and the Czech Republic between 1990 and 2003. Nevertheless, closer examination of the trend shows a sharp fall in efficiencies during the period of economic transition in the early 1990's due to the low utilisation of plants. This was followed by steadily increasing efficiencies in more recent years due to higher load factors on existing plants, refurbishment and new investment.

Note: The efficiency is calculated as total electricity output from conventional thermal power plants divided by total fuel input. In some Member States, the efficiency of combined heat and electricity production increased faster than that of electricity production alone. 1990 electricity data for Germany refers to 1991.

Source: Eurostat.

4 Has there been a switch towards less polluting fuels?

Fossil fuels are the main cause of carbon dioxide, sulphur oxide and nitrogen oxides emissions. They account for almost 80 % of total energy consumption and 55 % of electricity production. However, environmental pressures have been restrained by switching from coal and lignite to relatively clean natural gas. Since 1999 this trend has slowed and a slight increase in the share of coal has occurred.

Increasing the share of cleaner fuels is one of the objectives of the European Commission's strategy of environmental integration within the energy sector (EC, 1998). Other recent documents strengthen the need for cleaner energy technologies as a pre-requisite for sustainable energy production (European Council, 2005).

The main source of energy-related environmental pressures is the release of pollutants from the combustion of fossil fuels. The degree of environmental pressure depends on the relative share of different fossil fuels and the extent to which pollution abatement measures are applied. Natural gas, for instance, has approximately 40 % less carbon content than coal, and 25 % less carbon content than oil. Moreover, it contains only marginal quantities of sulphur.

Renewable energy sources such as biomass, solar, wind energy and hydro-power produce no (or very little) net CO_2 and usually significantly lower levels of other pollutants ([9]). Renewable energy can, however, have impacts on landscapes and ecosystems. Nuclear power also produces little pollution under normal operation. However, there is a risk of accidental radioactive releases and no generally acceptable disposal route has yet been established for radioactive waste.

The share of fossil fuels in total energy consumption declined only slightly between 1990 and 2003, reaching 79 % (see Figure 20). Nevertheless, the environment benefited from a major change in the fossil fuel mix. This was mainly due to fuel switching in power generation with coal losing about one third of its market share and being replaced by relatively cleaner natural gas, which now has a 24 % share. However, from around 1999 onwards the use of coal actually increased due to both a recent rise in the price of gas and increased concerns over the energy import dependency associated with gas (see Figure 22).

The switch towards less polluting fuels mainly occurred in power production (see Figures 21, 23). It has been driven by a combination of liberalisation, an extended gas infrastructure and environmental legislation. Liberalisation tended to favour the use of gas-fuelled technologies due to the lower fuel price in the 1990s and installation costs. Overall, these changes resulted in reduced emissions of greenhouse gases and acidifying substances. However, continuing increases in energy consumption have offset some of these improvements.

Oil accounted for around 37 % of total energy consumption in 2003, and continued to be the major source of fuel in the transport sector. Its increase from 1990 was mainly the result of an increased demand for petrol and diesel within the transport sector, although this was partly offset by its lower level of use within the power generation sector.

Renewable energy has seen rapid growth in absolute terms and was the fastest growing energy source (together with natural gas). However, it started from low levels, and, despite increased support at EU and national level, its contribution to total energy consumption remained low at 6 % in 2003 (see Chapter 5).

The share of nuclear power grew slowly and reached almost 15 % of total energy consumption in 2003. This increase was less rapid than during the 1980s, and was due to fewer new nuclear plants being commissioned. Electricity produced from nuclear fuels continued to grow in absolute terms from the

([9]) The combustion of biomass is related with emissions of air pollutants. The amount of emissions depend on the type of biomass and the conversion technology as well as the use of abatement measures.

1990s through to 2003 in the EU-25. Nevertheless, it grew at a slower rate than total electricity production. This meant that its share of total production fell slightly to 31 % in 2003 (see Figure 21). While some Member States have plans to phase out nuclear power due to concerns about safety and nuclear waste, other Member States are re-considering the nuclear power option in the contexts of climate change, increasing gas prices and energy supply security. There is also a debate on the costs of nuclear power, which is still seen as an expensive option within a liberalised market.

One of the major determinants of further switching, apart from the development of coal and gas prices and energy import dependency (EC, 2002f), will be the need to meet the EU's greenhouse gas reduction targets under the Kyoto Protocol. The fuel mix will increasingly be affected by the impact of the emissions trading scheme (favouring lower carbon fuels) and other policies.

Both baseline and climate change scenario projections (low-carbon energy pathway LCEP) indicate a further increase in the share of natural gas and renewables in total energy consumption and, in particular, electricity production. This would take place primarily at the expense of coal (see Figures 20 and 21). The increase of gas will be more rapid in the latter scenario, which assumes a rising carbon permit price. With recent increases in oil and gas prices and wider concerns about energy security, this fuel switch may become less pronounced than projected. Furthermore, carbon capture and storage, which was not considered in these scenarios, may offer new opportunities for the use of fossil fuels with low emissions of greenhouse gases. Oil consumption is projected to more or less maintain its existing share due to a lack of large-scale alternative sources in the transport sector, despite the fact that biofuels may to a certain degree offer an alternative source.

Carbon dioxide capture and storage (CCS) offers the possibility of continuing to use fossil fuels while significantly reducing the amount of CO_2 that enters the atmosphere from their use. It is best applied to large stationary sources such as power generation or oil refineries, which offer economies of scale in construction and minimise the extent of the supporting transport network, such as a pipeline. CO_2 can be captured at various stages of the combustion process and then be transported to storage sites.

Capture of CO_2 is already a commercial industrial process, but improvements are needed to make the transition to large-scale power plants; reducing costs and associated energy losses. 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 is the option with the largest impact on the overall plant production efficiency. CO_2 capture with oxyfuel 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, the capture of CO_2 requires substantial amounts of energy and leads to efficiency losses in the process of 11 % to 40 % (IPCC, 2005). As a result, some 80–90 % of the CO_2 emissions from a plant without CCS can be net avoided. However, the rise in primary energy requirements implies an increase in the environmental pressures associated with mining etc.

Storage of CO_2 in geological repositories such as depleted oil or gas reservoirs, aquifers and coal beds is generally considered as a storage option with manageable environmental impacts. Nevertheless, leakage rates need to be explored and monitored during and after use. Storage of CO_2 in the deep ocean is also an option with potentially high environmental impacts.

Figure 20 Total energy consumption by fuel, EU-25

In 2003, fossil fuels dominated total energy consumption with a share of 79.3 %. Natural gas consumption increased most rapidly over this period, driven largely by the increase in use in electricity generation. It has become the second most important fuel after oil. Under the baseline scenario, fossil fuels are expected to continue to dominate total energy consumption, with a rising share of natural gas counteracting a decline in the use of coal. Under the low-carbon energy pathway (LCEP), the overall growth in energy consumption is lower due to improved efficiency. The LCEP scenario also assumes a small increase in nuclear production in response to the increasing price of carbon. This factor also favours the use of renewables over other sources and a more rapid decline in coal.

Source: Eurostat and EEA, 2005a.

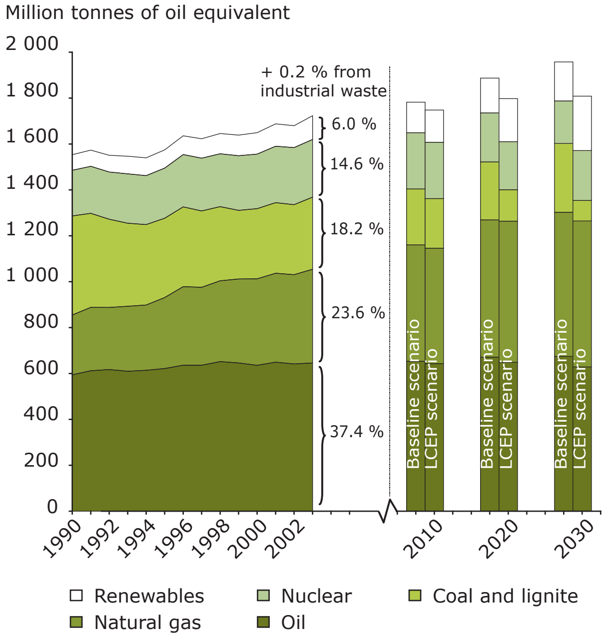


Figure 21 Electricity production by fuel, EU-25

Fossil fuels accounted for 55 % of all fuels for electricity production in 2003 with natural gas becoming the fuel of choice for new fossil-fuelled power plants. Nuclear power continued to grow in absolute terms from the 1990s through to 2003, although its share of total production fell slightly to just under one-third. The other major contributor to electricity production was renewable sources. Future baseline projections show gas and renewables taking an increasing share of electricity production. Nevertheless, assuming higher oil and gas prices might result in a slower fuel switch with coal decreasing less rapidly. Under the LCEP scenario the impact of a carbon permit price leads to a more rapid decrease in coal generation and an increase in natural gas and renewables.

Note: Data for Germany in 1990 include West Germany only. 'Other fuels' include pumping in hydropower stations and fuels not included elsewhere.

Source: Eurostat and EEA, 2005a.

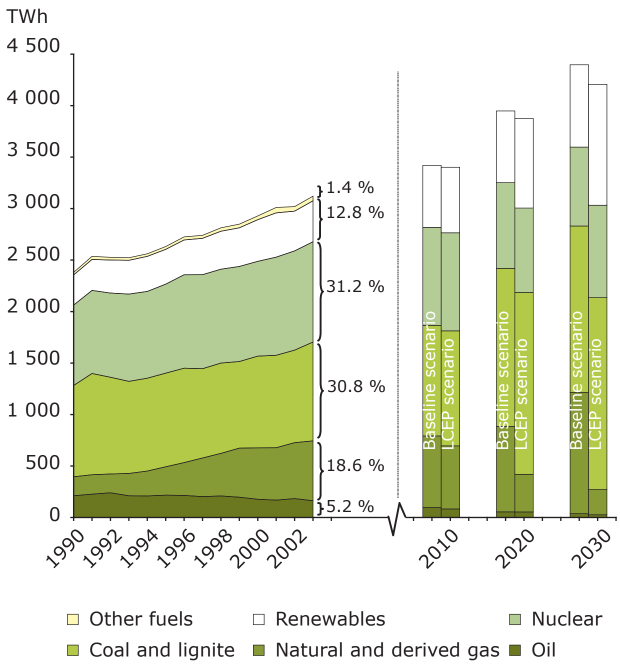


Figure 22 Average annual change in total energy consumption by fuel, EU-25

Over the period 1990–2003 growth in total energy consumption increased by an average of 0.8 % per year. It should be noted that this increase was most marked in the period from 1999 onwards. Steady annual average growth in the overall consumption of renewables, nuclear and natural gas has been seen throughout most of the period 1990–2003. Coal shows an overall decrease, but the more rapid decrease took place before 1999. Consumption increased again from this point onwards. The growth in oil has slowed sharply 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.

Source: Eurostat.

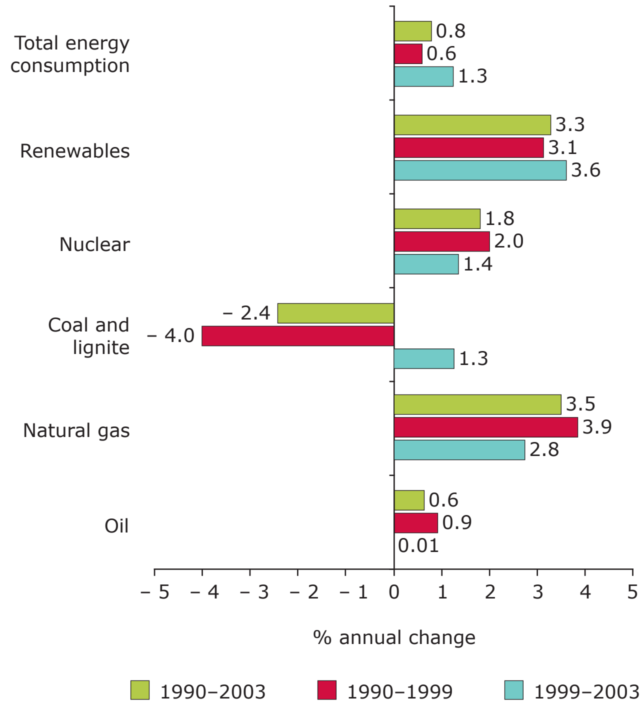
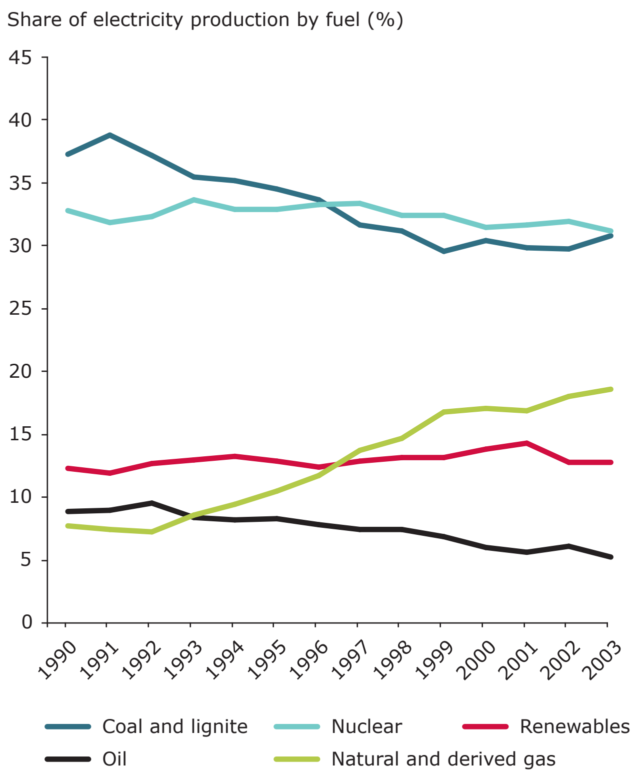


Figure 23 Share of electricity production by fuel, EU-25

Natural gas more than doubled its share in electricity production from 1990 to 2003, primarily at the expense of oil and coal. The share of coal decreased steadily until 1999, when increasing gas prices led to a re-increase in its use. Despite growth in absolute terms renewables and nuclear have more or less maintained their share due to rising overall electricity production. The share of electricity from renewables has only grown slowly due to rapid rising electricity demand. However, the drop in 2002 and 2003 was due to low hydro production, from lower than average levels of rainfall.

Note: Electricity produced from pumping in hydro power plants is not considered a renewable source of energy and it is not shown in the chart.

Source: Eurostat.



5 How rapidly are renewable energy technologies being implemented?

The share of renewable energies in total energy consumption and gross electricity consumption increased to reach 6 % and 12.8 % respectively in 2003. However, these shares still remain low and significant further growth will be needed to meet the EU indicative targets for renewable energies of 12 % and 21 % by 2010, respectively.

Renewable energies are generally more environmentally benign than fossil fuels with regard to levels of greenhouse gas emissions as well as many other air pollutants emitted. They are thus an important option for reducing pressures on the environment from energy use. In addition, they can contribute to energy security by replacing imported fossil fuels. Their significance has been recognised in a number of EU policy documents concerned with accelerating their deployment, notably the renewable energies white paper (EC, 1997b), which sets an indicative target of 12 % of the EU total energy consumption to be derived from renewable sources by 2010 ([10]). Discussion about targets beyond 2010 have commenced, including proposals for a 15 % target in 2015 and a 20 % target in 2020 (European Council, 2006; European Parliament, 2005).

The directive on the promotion of electricity from renewable energy sources (EC, 2001a) sets an indicative target of 22.1 % of EU-15's gross electricity consumption to be derived from renewable sources by 2010. For the EU-25, this target has become 21 %, after taking into account individual targets for the EU-10 Member States (as included in the accession treaties). An indicative target of replacing 5.75 % of petrol and diesel consumption for transport purposes with biofuels by 2010 is set in the directive on the promotion of biofuels (EC, 2003b).

The promotion of renewable energy is also a matter for individual Member States, since resources vary between countries as do the infrastructures and market conditions.

Renewable energy currently accounts for 6.0 % of total energy consumption in the EU-25. This compares to a share of 4.4 % in 1990. Total production has increased by more than 3.3 % on average per year since 1990 (see Figure 24). The main sources of renewables are biomass and waste, hydropower, and to a much lesser extent, geothermal, wind and solar (see Figure 25) ([11]).

Electricity production from renewables has also grown rapidly in absolute terms (2.4 % on average annually). Nevertheless, the rapid growth in electricity consumption over this period has meant that its share in gross electricity consumption has only increased marginally from 12.3 % to 12.8 %. Lower electricity production from hydropower in 2002 and 2003 as a result of little rainfall implied that this share has fallen since 2001. However, production from both wind, and biomass and waste increased by more than 20 % between 2002 and 2003. This factor helped to partly offset the decrease in hydropower.

There are significant differences in the share of renewable electricity between the EU-25 Member States (see Figure 26). For large hydropower, these are determined to a large extent by the geographical situations within each country. For other renewable sources, these variations reflect differences in the policies selected by each country to support the development of renewable energy as well as the availability of natural resources. For example, in Denmark almost all the renewable energy is generated from wind and biomass, supported by a combination of taxes and subsidies that favour renewables over fossil fuels. Germany shows a strong growth in wind energy use, triggered by the guaranteed favourable feed-in price for renewable electricity. Latvia, Finland and Sweden have particularly high shares of biomass

([10]) This target officially applies to pre-2004 Member States only.

([11]) This has been calculated based on Eurostat data. If an alternative approach to calculate the contribution of different energy sources (the 'substitution approach') was used, biomass and wastes would account for 44 % instead of 66 % of all renewable energy in the EU in 2003.

and waste in total energy consumption, about 29 %, 19 % and 17 % 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).

With the exception of large hydropower, there is still substantial potential for further growth in energy produced from renewable sources. However, the growth of biomass use in particular is lagging behind expectations (EC, 2004a). The Biomass Action Plan thus proposes a number of measures to increase the production and use of biomass for energy use to reach some 150 Mtoe in 2010 (EC, 2005d).

Without additional measures, neither the target of a 12 % share in total energy consumption, nor the 21 % target in electricity consumption is likely to be reached by 2010 (EC, 2004a). With existing policies, the share of renewables in total energy and electricity consumption could reach 9 % and 18 % by 2010 (EC, 2004b). However, with stronger policies to promote renewables and an emphasis on energy efficiency, various scenarios indicate that both targets are plausible by 2010 (EEA, 2005b; EC, 2004a). Evaluations from the European Commission thus concluded that European states need to step up efforts to cooperate among themselves, optimise their support schemes, and remove administrative and grid barriers for green electricity in order to meet their targets. Nevertheless, the Commission concluded that at this stage it is not appropriate to present a harmonised European system (EC, 2005g).

The *environmentally-compatible* biomass potential

Increasing the production and use of biomass is required in order to meet ambitious renewables targets. However, an increase in biomass production may counteract other EU policies and objectives, such as halting the loss of biodiversity or waste minimisation. It is thus important to ensure that the designated rise in the production of biomass for generating energy does not create additional environmental pressures on biodiversity and soil and water resources. A recent EEA study calculated such an '*environmentally-compatible* bioenergy potential' for Europe. The study included the use of biomass from agriculture, forestry and waste. It found that the *environmentally-compatible* biomass potential for producing energy could increase from around 190 Mtoe in 2010 to about 300 Mtoe in 2030. The study concluded that environmental guardrails have yet to be developed to ensure that bioenergy production develops in an environmentally-sustainable way (EEA, 2006c).

Figure 24 Annual average growth rates in renewable energy consumption, EU-25

Growth in renewable energy sources averaged 3.3 % per year from 1990 to 2003, and came predominantly from 'new' technologies, in particular wind. The use of solar power also increased rapidly, albeit from low levels. The growth of biomass is lacking behind what would be needed to reach the 2010 target of a 12 % share for renewables. Nevertheless, its average annual growth rate increased over the period 1999–2003 compared to the 1990s. Production of hydropower has actually decreased in recent years due to low levels of rainfall.

Source: Eurostat.

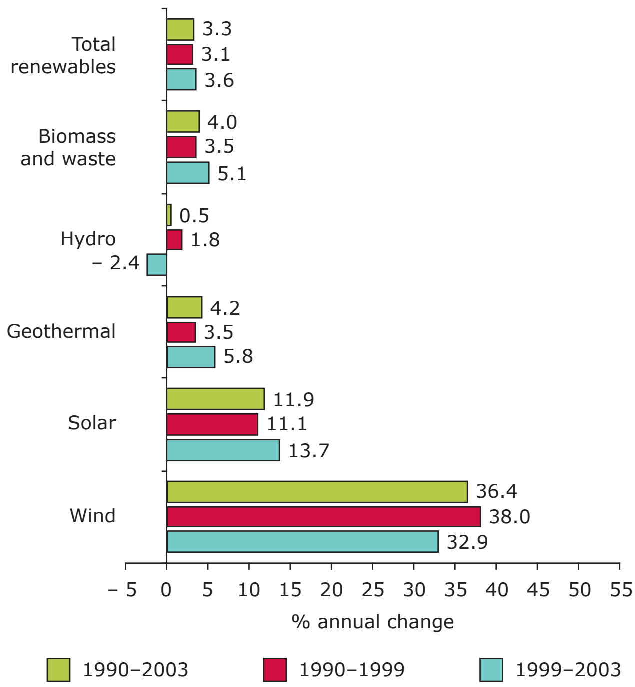
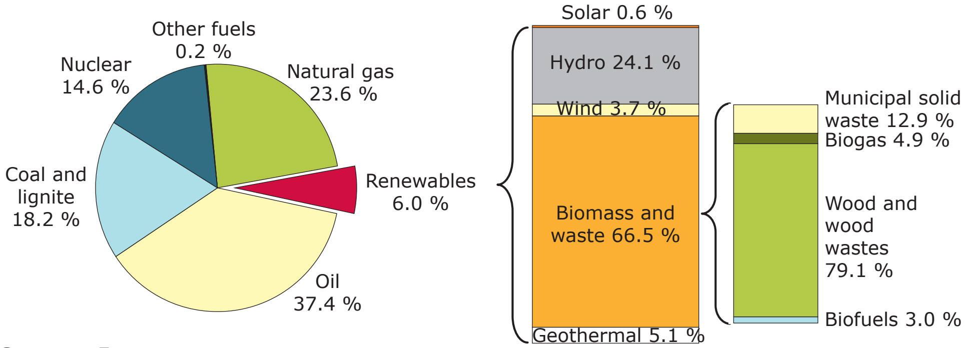


Figure 25 Energy consumption by renewable energy sources in 2003, EU-25

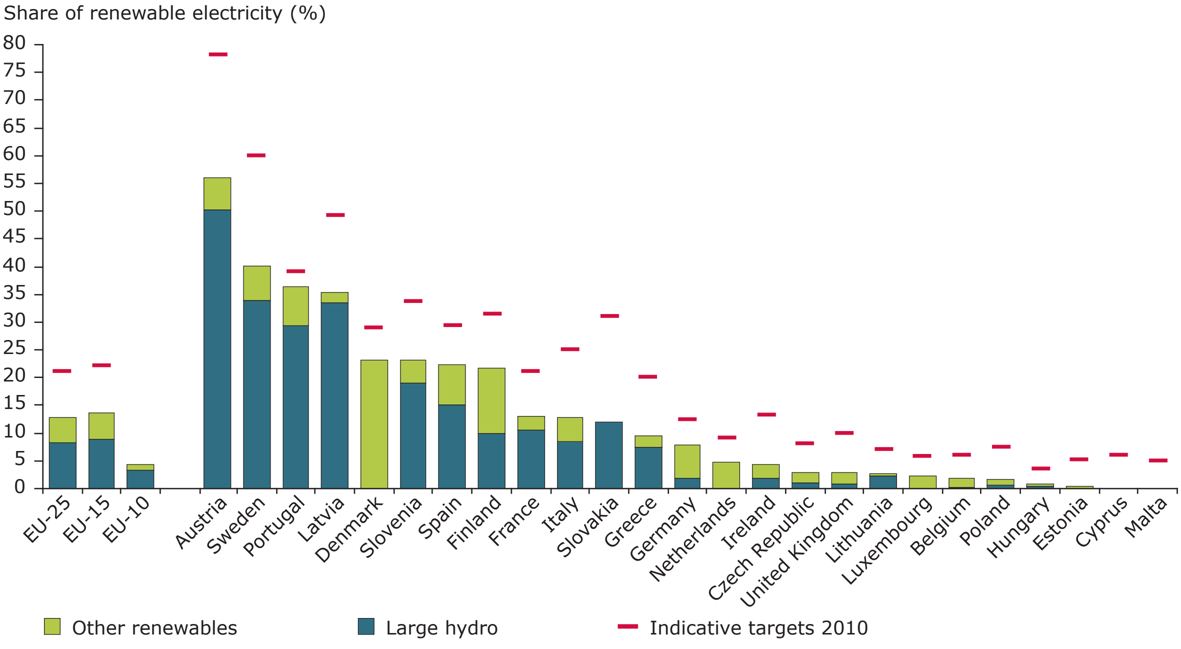
Renewable energies currently account for 6 % of total EU-25 energy consumption, compared to 4.4 % in 1990. Most of the energy produced from renewables in 2003 came from biomass, waste and hydro. The main source of biomass is low cost wood and wood wastes, which are used primarily for heating and in CHP systems. Only a small part of biomass is currently used for biofuels. Hydro and wind are only used for electricity and changes in annual rainfall can significantly impact upon the share of hydropower.



Source: Eurostat.

Figure 26 Renewable electricity as a percentage of gross electricity consumption, 2003

The share of renewable electricity in the EU-25 reached 12.8 % in 2003, dominated by large-scale hydropower (8.3 %), and varied substantially within the EU-25. In 2003, Austria had the largest share of renewable electricity in gross electricity consumption. Denmark and Finland showed the largest shares of renewable electricity in gross electricity consumption when large hydropower was excluded. Finland's high share was mainly due to electricity production from biomass, while Denmark's renewable electricity was produced by wind power and, to a lesser extent, biomass and wastes. In absolute terms, Germany was the largest production of renewable electricity excluding large hydropower. This came mainly from wind and biomass. Within the new Member States, Latvia and Slovenia had the largest share of electricity from renewable energy in 2003, with most of this coming from hydropower.



Note: The renewable electricity directive (EC, 2001a) 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 total electricity consumption but it is not included as a renewable source of energy. Large hydropower plants are those with a capacity of more than 10 MW.

Source: Eurostat, Indicative targets (EC, 2001a), Accession Treaties.

6 Are environmental costs better incorporated into the pricing system?

With the exception of transport, energy prices for most fuels decreased during the 1990s. However, in recent years they have started to increase, mostly as a result of rising global oil and gas prices. Throughout the 1990s price levels were not high enough to offer much incentive for energy savings. Tax levels increased over the entire period. This may indicate that external costs of energy consumption are being internalised to a greater extent than in previous years. Nevertheless, they still remain below externalities. Total Member State expenditure on energy R&D funding has declined significantly.

Current energy prices do not always reflect the full costs of their use, because they do not account fully for the adverse impacts of energy production and consumption on public health and the environment. The sixth environment action programme stresses the need to internalise these external environmental costs. 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, 2002d).

The real end-use price of electricity and natural gas in the pre-2004 EU-15 fell overall between 1991 and 2005, except in the case of natural gas for industry (see Figure 27). Electricity prices saw the largest reductions during the 1990s, due to increased competition within electricity markets. However, prices in general began to rise again from 1999 onwards. Prices in the new EU-10 Member States now better reflect the economic costs of energy production than in the early 1990s, due to the removal of cross subsidies and the introduction of market liberalisation.

During the same period, the absolute level of taxes on final energy products in the EU-15 also increased significantly. Increasing tax rates may indicate that the external costs of energy consumption are being internalised to a greater extent than in previous years ([12]). Despite increases in taxation, tax levels remain below external cost levels. The real price of most fuels fell or only increased by a smaller percentage than the tax increase, leading to a larger proportion of tax within the end-use price. Transport fuel prices increased the most, in relation to tax increases, due largely to increases in the world price for oil. Taxes in the new EU-10 Member States are significantly lower than in the EU-15, broadly increasing for household gas and electricity, but remaining stable for industrial fuels.

External costs that arise from the environmental impact of electricity production are significant in most EU-25 countries, and reflect the dominance of fossil fuels in the generation mix (see Figure 28). In the EU-25, externalities of electricity production were estimated to be roughly in the order of 0.7 % to 2 % of GDP in the year 2003 (depending on the assumptions made for external costs per unit of air pollutant and CO_2 emissions). Compared to 1990, externalities have decreased substantially, mostly due to a significant reduction in air pollutant emissions. In 2003 average external costs of electricity production in the EU-25 were approximately 2–7 eurocents/kWh compared to 6–18 eurocents/kWh in 1990. The externalities of transport were estimated to be even higher at around 5 % of GDP in 2000 for the EU-15, Switzerland and Norway. These transport externalities include air pollution, noise and climate change, but exclude accidents (EEA, 2006d).

Despite considerable progress since 1990, externalities are still not adequately reflected in the overall level of energy prices or the relative prices of different fuels. Consumers, producers and decision makers do not therefore get the accurate price signals that are necessary to reach decisions about how environmentally best to use resources. There is thus limited incentive to improve the management of energy demand, and low price levels during the 1990s may have even encouraged energy consumption. The decrease in the real price of electricity has, in part, contributed to it gaining a higher share in final energy consumption, particularly within industry.

([12]) External costs can also be internalised by other policy instruments such as standards.

Energy subsidies in the EU-15 amounted to an estimated 29 billion euros in 2001 with over 73 % oriented towards the support of fossil fuels (see Figure 29). These also continue to distort price signals to consumers despite the pressures that the fuels put on the environment (EEA, 2004). Support for renewable energy, which is on balance considered environmentally beneficial, has increased steadily, although progress until now suggests that the level of support remains inadequate for reaching the 2010 EU renewable energy targets.

Development of new technologies and deployment of existing low-carbon technologies is one central element for reducing the environmental pressures of energy production. This is particularly true for further reductions in greenhouse gas emissions (EC, 2005e; IEA, 2000a). There is thus a need for a better targeted policy framework to help support new technologies at each stage of development, and to allow greater involvement of the private sector. Governments can ensure that short- as well as long-term goals are followed. This could be achieved by stimulating the right conditions for bringing existing technologies on to the market ('pull') and developing new technologies ('push'). For example, grant support for renewable technologies helps 'push' forward their 'bottom-up' development in the early stages, while mechanisms such as tariffs or quotas help to provide a combined 'top-down' pull towards large-scale deployment. These mechanisms create more stable market conditions for the emerging technology (IEA, 2006). Both elements are required in order to reduce the costs of new technologies (IEA, 2000b).

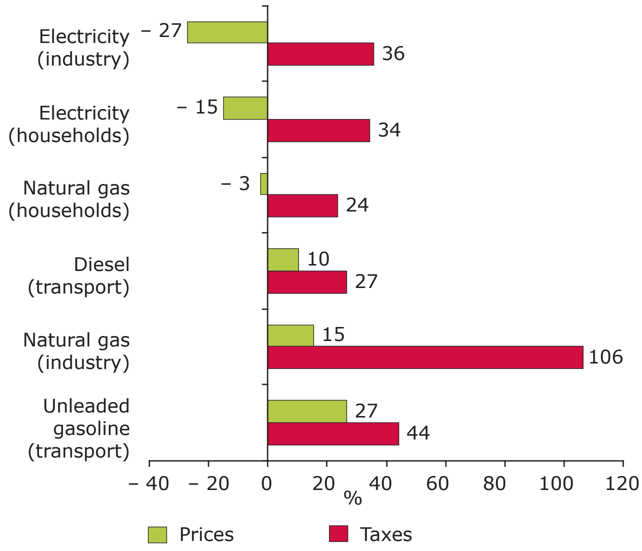
Nevertheless, the energy research and development expenditure of the EU and individual EU-15 Member States has been reduced at a time when innovation is needed to develop less polluting technologies. Total public expenditure on energy R&D declined by 34 % between 1990 and 2003. However, the majority of this decline in funding was in nuclear fission, fusion and fossil fuels, while EU-15 Member States' R&D funding for renewables increased by 10 % over the period and more than doubled for power and storage technologies (see Figure 30).

Externalities (or external costs) of the energy sector are costs that energy producers and consumers impose on others without paying the consequence. Environmental external costs include the impact on air, waste and water pollution and climate change. Social costs are higher than private costs as these external costs are not included in conventional market prices for energy. Conventional market prices contribute to inefficiencies in resource allocation decisions. By including externalities in market prices, such inefficiencies can be corrected. The most extensive study concerning externalities of the energy sector is the ExternE project (ExternE, 2005) and a number of subsequent studies, which provide 'bottom up' analysis of the external costs of the fuels used in the electricity supply sector. The ExternE methodology produces a damage value, expressed per kWh electricity or per tonne of pollutant. It focuses on the cost to public health, crops, materials, forests, ecosystems and climate change. It can include damage at all fuel cycle stages from fuel extraction to generation. Following on from the original ExternE project, the methodology for calculating external costs has been further developed and improved in a number of projects including New-Ext (2004), ExternE-Pol (2005) and the cost-benefit analysis undertaken for the CAFE (2005) Clean Air for Europe programme.

Marginal damage cost factors (cost in EUR per tonne of pollutant) were taken from ExternE-Pol (2005) in the case of CO_2 (low estimate) and from CAFE (Clean Air for Europe programme) in the case of the other air pollutants. The external costs for CO_2 (high estimate) are taken from Watkiss *et al.* (2005). However, it needs to be noted that the costs for CO_2 are highly uncertain and that they are only a sub-total of the full costs. This uncertainty also applies to the external costs of nuclear, which in addition to the above factors includes an estimate of the impact of radioactive emissions (across the nuclear fuel chain) on public health. The nuclear plant itself is estimated to contribute 5 % or less to this. Differences between the low and high estimate in the marginal damage costs of air pollutants are mainly due to different methods of valuating changes in longevity.

Figure 27 Change in selected end user energy prices and taxes between 1991 and 2004 or 2005, EU-15

Over the period 1991–2005 the real price of electricity and gas for household dropped by 14.9 % and 2.6 % respectively. Similarly, the price of electricity for industry also dropped by 27.3 %. In all sectors gas and electricity prices followed a similar pattern: Liberalisation and fuel switching led to decreased in prices throughout the 1990s. This was followed by a price increase from 1999 onwards. In the case of gas for industry this increase has already exceeded the previous price fall. For transport, prices fluctuated during the period 1991–2004, but in general unleaded gasoline rose at a more rapid rate than diesel. By contrast taxes increased for all fuels in all sectors over the period, most notably in natural gas for industry. Whereas many of the tax increases for gas and electricity purchased by industry were seen after 2000, fuel tax levels for road transport rose substantially in the 1990s. Also for households, taxes followed a mostly upward trend over the entire period from 1991–2005.



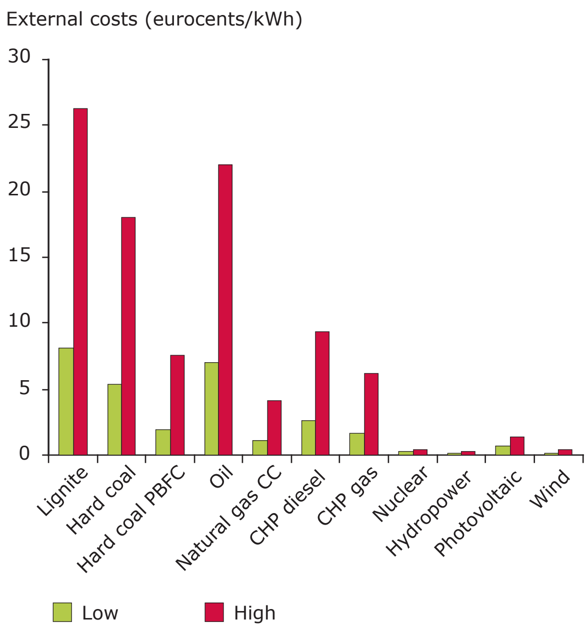
Notes: Price and tax changes are between 1991 and 2004 for gasoline and diesel and between 1991 and 2005 for electricity and gas. Prices for industrial users do not include VAT. Industrial gas users are defined as follows: annual consumption of 41 860 GJ, and load factor of 200 days (1 600 hours). The reference annual consumption of gas for households is 83.70 GJ. Industrial electricity users are defined as follows: annual consumption of 2 000 MWh, maximum demand of 500 kW and annual load of 4 000 hours. The reference annual electricity consumption for households is 3 500 kWh of which 1 300 are at night. DG TREN, European Commission collects the data for transport fuels. All prices and taxes have been deflated to constant prices using the 1995 GDP deflator.

Source: Eurostat, European Commission.

Figure 28 Estimated average EU-25 external costs for electricity generation technologies in 2003

External costs shown here include climate change damage costs associated with emissions of CO_2; damage costs (e.g. impacts on health, crops) associated with other air pollutants and other social costs.

Traditional fossil systems (coal, oil and, to a lesser extent, natural gas) exhibit the highest external costs for electricity generating technologies. The majority of these external costs occur during the production of electricity itself, although there is a small component associated with other parts of the fuel cycle (e.g. due to the mining and transport of the fuel). The introduction of advanced technologies (such as combined heat and power and pressurised fluidised bed combustion) can substantially reduce the external costs of fossil systems. Renewable energy and nuclear power show the lowest damage per unit of electricity, but it should be noted that only parts of the externalities of nuclear are included.



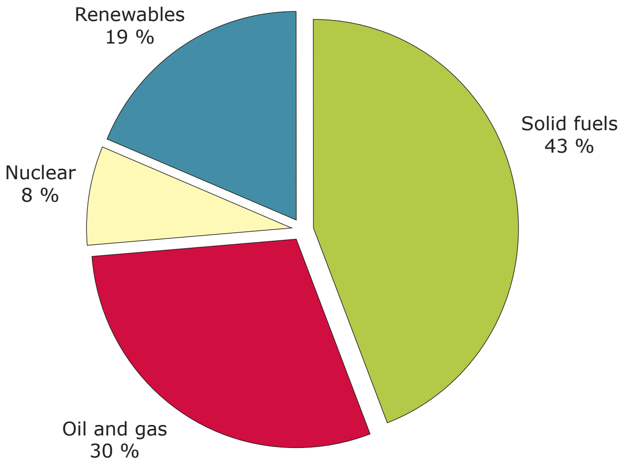
Note: Average emissions per unit of electricity generation are taken from ExternE-Pol (2005) and include emissions from the operation of the power plant and the rest of the energy chain. The components of external costs include the marginal damage cost factors for CO_2 (low estimate) and non-environmental social costs for non-fossil generating technologies (both taken from ExternE-Pol, 2005), and the high/low marginal damage cost factors for SO_2, NO_X, NMVOCs and $PM_{2.5}$ (taken from CAFE). The high estimate for the external costs of CO_2 emissions is taken from Watkiss *et al.* (2005). PBFC means pressurised fluidised bed combustion, CHP means combined heat and power, CC means combined cycle.

Source: ExternE-Pol, 2005; CAFE, 2005; European Environment Agency.

Figure 29 Indicative estimate of the distribution of energy subsidies in the EU-15, 2001

Energy subsidies in the EU-15 amounted to around EUR 29 billion in 2001; most of which is still being directed towards fossil fuels.

This number includes 'on budget' and 'off budget' subsidies. 'On-budget' subsidies are cash transfers paid directly to industrial producers, consumers, universities etc. and appear on national balance sheets as government expenditure. They can also include low interest or reduced-rate loans, administered by government or directly by banks with state interest rate subsidy. 'Off-budget' subsidies are typically transfers to energy producers and consumers that do not appear on national accounts as government expenditure. They may include tax exemptions, rebates and other forms of preferential tax treatment. They may also include market access restrictions, regulatory support mechanisms, such as feed-in tariffs, border measures, external costs, preferential planning consent and access to natural resources etc.



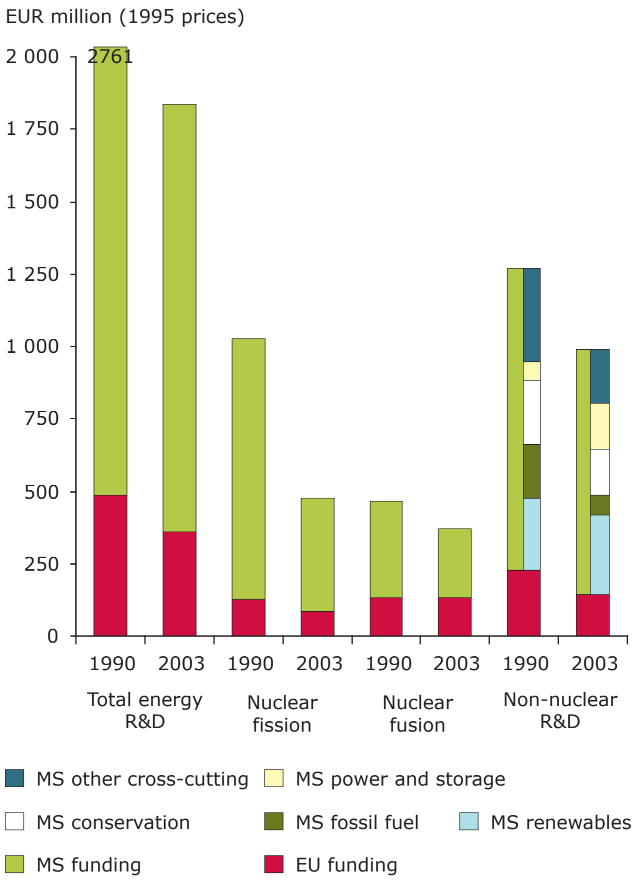
Source: EEA, 2004.

Figure 30 Total energy R&D expenditure, EU-15 Member States and EU level funding

Total R&D funding on energy dropped by 34 % between 1990 and 2003. The majority of this occurred at Member State level. The largest absolute drop occurred in funding for nuclear fission at Member State level. Also EU funding in the area of nuclear fission, mainly focusing on safety and waste issues, fell while EU funding for nuclear fusion remained fairly constant. EU funding for non-nuclear R&D decreased by 37 % over the same period. Member States funding for renewables increased by approximately 10 %.

Note: MS means Member State.

Source: IEA, 2005b for Member States; data for European funding are planned expenditure figures from the 6th Framework Programme (EC, 2002b).



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Annex 1: Key environment-related indicator initiatives in the EU

Sustainable development indicators: The sustainable development indicators (SDI) were introduced to assist the monitoring of progress in achieving the policy targets of the EU Sustainable Development Strategy, which was adopted by the European Council in Gothenburg in 2001. The SDI consist of 155 indicators (34 of which are not feasible yet and 11 are replaced by proxies), divided into 10 themes that reflect the political priorities of the Strategy.

They were adopted in February 2005 and used for the first time in the Commission's first progress report on the implementation of the sustainable development strategy published in December 2005. This report complements the Commission's communication on the review of the sustainable development strategy (EC, 2005a), http://www.ec.europa.eu/eurostat/ Sustainable Development.

Structural indicators: The primary objective of the structural indicators is to measure progress towards achieving the EU's Lisbon Strategy goal — *to become the most competitive and dynamic knowledge-based economy in the world capable of sustainable economic growth with more and better jobs, greater social cohesion and a high level of environmental protection.*

The set of structural indicators thus covers the general economic background, employment, innovation and research, economic reform, social cohesion and environment, and are used in the Commission's annual progress report on the Lisbon objectives (Eurostat, 2005b), http://www.ec.europa.eu/eurostat/ Structural Indicators.

Core set of indicators: The EEA has developed a core set of indicators (CSI). The aim is to:

- provide a manageable and stable basis for indicator reporting by the EEA on the web and in its indicators-based reports;
- prioritise improvements in the quality and geographical coverage of data flows, especially priority data flows of the European environment information and observation network (Eionet);
- streamline EEA/Eionet contributions to other European and global indicator initiatives, e.g. structural indicators and sustainable development indicators.

There are 37 core set indicators agreed by the EEA management board + 2 proposals related to waste. Some of these indicators are also SDI and SI indicators (EEA, 2005d), http://themes.eea.europa.eu/IMS/CSI.

Annex 2: List of EEA energy and environment indicators

The EEA's 24 indicator fact-sheets on energy and environment constitute the basis for this energy and environment report and are listed below. Five of these indicators are EEA core set indicators. A number of them are also related to the EEA's core set indicators on climate change and air pollution. The fact sheets are organised around policy questions and are available from the EEA's website http://www.eea.europa.eu/

Is the use and production of energy having a decreasing impact on the environment?

- EN01 Energy and non-energy related greenhouse gas emissions
- EN02 Energy-related greenhouse gas emissions
- EN05 Energy-related emissions of ozone precursors
- EN06 Energy-related emissions of acidifying substances
- EN07 Energy-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

Is energy use decreasing?

- EN16 Final energy consumption by sector (core set indicator 27)
- EN18 Electricity consumption

How rapidly is energy efficiency increasing?

- EN17 Total energy consumption intensity (core set indicator 28)
- EN21 Final energy consumption intensity
- EN19 Energy efficiency of conventional thermal electricity generation
- EN20 Combined heat and power

Is there a switch to less polluting fuels?

- EN26 Total energy consumption by fuel (core set indicator 29)
- EN27 Electricity production by fuel

How rapidly are renewable energy technologies being implemented?

- EN29 Renewable energy consumption (core set indicator 30)
- EN30 Renewable electricity (core set indicator 31)

Are environmental costs better incorporated into the pricing system?

- EN31 Energy prices
- EN32 Energy taxes
- EN34 Energy subsidies
- EN35 External costs of electricity production

Annex 3: 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 http://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, http://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 X-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_2005_4/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.

The EEA maintains the greenhouse gas inventory database, which includes other EEA countries in addition to the EU-25 Member States. The database is available from the EEA web site as:

1) a detailed greenhouse gases database with all the CRF sectors as reported by countries: It consists of 176 sectors and sub-sectors in the Common Reporting Format (CRF), based on the IPCC classification. The database can be found on the EEA's website http://dataservice.eea.europa.eu/dataservice/ (thematically > climate change > Trends in emissions of greenhouse gases) For more expert use, the underlying statistics and emissions factors are included in the CRF tables as currently reported by countries in separate Excel files annexed to the Inventory Report http://reports.eea.europa.eu/technical_report_2005_4/en/tab_content_RLR;

2) a web application with fewer sectors which are used for EEA reporting. The CRF sectors are aggregated to a manageable yet meaningful number of sectors, which are then used by the EEA in its main publications. The web application also shows the individual gas emissions in CO_2-equivalents, which are weighted by the 100-year global warming potentials (as specified in the Kyoto Protocol). The application is publicly available through the EEA data service http://dataservice.eea.europa.eu/dataservice/ (thematically > climate change > Emissions data for Indicators).

For the purpose of EEA reporting and based on the IPCC classification, sectors have been aggregated using the following definitions:

- The 'energy sector' (CRF 1 'Energy') is responsible for energy-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).

The greenhouse gas data stored in the EEA's inventory database 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.

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/EMEPCORINAIR4/en

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 1990–2003 on behalf of the European Commission http://reports.eea.europa.eu/technical_report_2005_6/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/ceilings.htm. 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.

The EEA maintains the air pollutants inventory database, which includes other EEA countries in addition to the EU-25 Member States. The database is available from the EEA web site as a detailed air pollutants database, officially reported by countries to CLRTAP and as a web application with fewer sectors which are used for EEA reporting http://dataservice.eea.europa.eu/dataservice/ [thematically > 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. Methodological information on the annual Joint Questionnaires and data compilation can be found in http://ec.europa.eu/estatref/info/sdds/en/sirene/energy_base.htm A detailed description of Eurostat's concepts used in the energy database can be found in http://forum.ec.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 is working on 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. The energy data are publicly available from Eurostat's website http://ec.europa.eu/comm/eurostat/.

Eurostat energy data are also the basis for the calculation of the EEA's five core set indicators on energy http://themes.eea.europa.eu/IMS/CSI.

At the end of May 2006 Eurostat published a revised time series for Latvia. There were important corrections for the year 1990 with regard to final energy consumption, total energy consumption, total input to conventional thermal power plants and, to a lesser extent, final electricity consumption. These changes have been taken into account as much as possible in this report when providing data on Latvia. However, the EU-10 and EU-25 aggregates could not be updated. Changes to these aggregates are likely to be limited as in 1990 the total energy consumption in Latvia represented approximately 3 % and 0.5 % of the total energy consumption in the EU-10 and EU-25, respectively.

Annex 4: Data summary

Table A4 Summary of key energy, environment and economic factors from 1990 to 2003, EU-25

	Total energy consumption	Final energy consumption	Total electricity consumption	Final electricity consumption	CO_2 energy intensity (energy-related CO_2 emissions/ total energy consumption)	Efficiency of electricity production from conventional thermal power stations (electricity output/ total input)	Share of CHP electricity in total electricity generation	Share of renewable energy sources in total energy consumption	Share of renewable energy sources in total electricity consumption
	Annual % change 1990–2003	Annual % change 1990–2003	Annual % change 1990–2003	Annual % change 1990–2003	Annual % change 1990–2003	Annual % change 1990–2003	% in 2002	% in 2003	% in 2003
EU-25	0.8	0.8	1.8	1.9	– 0.9	0.7	9.9	6.0	12.8
EU-15	1.0	1.2	2.0	2.1	– 0.8	0.5	9.2	6.1	13.7
EU-10	– 0.8	– 1.5	0.2	0.1	– 1.3	1.0	15.4	5.3	4.3
Belgium	1.3	1.5	2.4	2.5	– 0.9	1.1	7.5	1.9	1.8
Czech Republic	– 0.6	– 2.8	0.6	0.6	– 1.8	– 1.6	17.1	2.8	2.8
Denmark	1.1	0.8	1.1	0.8	– 0.2	0.4	49.1	13.3	23.2
Germany	– 0.3	0.1	0.8	1.3	– 1.0	0.3	9.8	3.4	7.9
Estonia	– 4.5	– 6.1	– 1.6	– 1.5	– 0.7	1.8	11.0	9.5	0.5
Greece	2.4	2.7	4.1	4.2	– 0.2	1.1	1.9	5.1	9.6
Spain	3.2	3.6	4.4	4.4	– 0.1	1.2	7.8	7.0	22.3
France	1.4	1.2	2.2	2.4	– 1.0	– 0.1	4.0	6.4	13.0
Ireland	3.0	3.5	4.7	5.2	– 0.3	0.7	2.5	1.7	4.3
Italy	1.3	1.5	2.5	2.4	– 0.3	0.2	7.4	5.9	12.8
Cyprus	2.6	2.7	5.7	5.8	0.8	2.0	0.0	1.5	0.0
Latvia	– 4.4	– 4.0	– 3.3	– 3.5	– 2.7	0.8	37.5	33.2	35.4
Lithuania	– 4.3	– 6.6	– 2.4	– 3.9	– 4.6	– 2.8	9.7	7.8	2.8
Luxembourg	1.3	1.3	2.5	2.9	– 1.7	5.3	7.9	1.4	2.3
Hungary	– 0.4	– 0.6	0.3	0.0	– 0.8	1.6	21.5	3.4	0.9
Malta	3.2	2.6	5.6	5.5	– 1.1	1.0	0.0	0.0	0.0
Netherlands	1.4	1.5	2.6	2.4	– 0.4	– 0.2	29.9	2.5	4.7
Austria	2.1	2.7	2.5	2.7	– 0.3	0.4	13.6	20.3	55.9
Poland	– 0.5	– 0.4	0.3	0.2	– 0.9	1.9	16.0	5.4	1.6
Portugal	3.2	3.8	4.4	4.8	– 0.2	0.6	10.0	17.0	36.4
Slovenia	1.8	2.7	1.7	2.0	– 0.9	1.4	5.9	10.5	23.1
Slovakia	– 0.8	– 2.6	– 0.1	– 0.2	– 1.8	– 1.6	17.5	3.3	12.0
Finland	2.0	1.3	2.5	2.5	0.1	– 0.4	38.0	21.2	21.8
Sweden	0.6	0.8	0.2	0.6	– 0.7	– 0.8	6.8	26.3	40.0
United Kingdom	0.7	0.7	1.5	1.6	– 1.0	1.1	5.4	1.4	2.8

Note: 1990 electricity data for Germany refers to 1991.
Source: EEA, Eurostat.

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