Environmental issue report | No 31

Energy and environment in the European Union

European Environment Agency

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Foreword

Sustainable development is about improving the quality of life while reducing the use of natural resources and pressures on the environment. Our quality of life is greatly enhanced by energy and the services it provides. The main question is how to make use of available energy resources sustainably without precluding the needs of future generations.

Sustainable development and integrating environmental considerations into Community policies are EU goals (Articles 2 and 6 of the EU Treaty). The process of achieving these goals was initiated in 1998 at the Cardiff Summit, where the Energy and several other Councils were asked to establish environmental integration and sustainable development strategies, identify indicators and monitor progress.

A main tool for ensuring the proper development and implementation of environmental integration and sustainable energy policy is the regular assessment of progress. This should cover not only the current situation, which may not change much from year to year — for example whether environmental pressures and impacts have been reduced or increased and whether there has been progress towards agreed quantitative or qualitative targets — but also trends and prospects, and most importantly the conditions for change that are needed to progress towards a more sustainable energy policy and more environmentally-friendly energy use. Such an assessment should help to identify the measures required to achieve these goals.

Assessing progress is the purpose of this report. It is part of the European Environment Agency's general mandate to carry out integrated assessments of the state of the environment and the pressures placed on it, and to provide information of direct use for shaping and implementing environmental and sustainable-development policies.

The assessment work undertaken by the Agency is complementary to work undertaken in this area by other Community organisations. The independence of the Agency guarantees a balanced assessment and its work underpins the good-governance principles of openness, participation, effectiveness, coherence and, particularly, accountability.

We see it as entirely natural to extend the regular reporting we have already established on transport and environment under the transport and environment reporting mechanism (TERM) to energy and, over time, to other sectors. This was requested in 1998 by a joint Environment-Transport Council and is undertaken in full cooperation with the Commission services. The Agency is currently working on its third TERM report and has also started work on preparing a similar report on agriculture and environment — in cooperation with and financially supported by the Commission.

The aim of this introduction is to really make the case for the Agency's role and contribution in producing this report on energy and environment in the European Union as the need for it is not yet clearly recognised amongst all partners. It is my personal conviction that this report will prove its added-value for the governance of energy policy.

The report follows the TERM model. It has been designed to provide policy makers with the information they need to assess how effectively environmental policies and concerns are being integrated with energy policies. This is achieved with the help of selected indicators measuring the extent of progress.

So what does the report show?

In most of the areas of environmental integration covered, there have been some successes but overall progress has been insufficient.

Curiously enough, we see that energy and environmental goals are often complementary. Security of supply is a main goal of energy policy, and its significance has been highlighted again recently by fluctuations in crude-oil prices as a result of restrictive output policies by oil producers and fears over the vulnerability of nuclear power stations. Increased use of renewable energies and improved energy efficiency benefit security of supply while reducing the pressure on the environment.

Similarly, stricter environmental controls on energy production and consumption reduce environmental pressures and externalities, thus providing for fairer competition and more sustainable competitiveness, another main energy policy goal. Energy market liberalisation benefits competitiveness through reduced costs. However, unless appropriate policy measures, such as fiscal measures, are taken to internalise external costs and improve energy demand management, these lower costs may bring price reductions that are likely to act as a disincentive to energy saving and even encourage greater energy consumption. Such developments run counter to the environmental and security-of-supply goals of energy policy.

This report shows clearly that 'where there is a will, there is a way'. Many countries have shown the way forward by improving the energy efficiency of their economies. However, others have become more inefficient and consequently have a worse environmental record; in particular, their lack of progress towards meeting their greenhouse gas emission targets under the Kyoto Protocol is a source of great concern. This strengthens the case for improved energy demand management, and for fiscal measures to improve it.

Another finding is that good progress has been achieved where effective and efficient policies have been implemented. This is particularly the case with emissions of air pollution from industry, energy production and even from households and transport. However, progress in these last two sectors has been partly offset by increases in the number of households and cars.

The report also points to some key 'vital signs,' such as strong growth in renewables, particularly wind and solar energy. These could show even higher growth if they were provided with more favourable market conditions, such as the internalisation of environmental costs, and not neutralised by unsustainable growth in overall energy demand.

I hope that both the highlighted successes and failures provide a useful input to move the integration and sustainability processes forward at the EU level, thus making the case for Community policies, for example in the area of taxation, to steer the liberalisation of energy markets towards sustainability. I also hope that the information on successes and failures will be useful not only to EU countries but also to all EEA member countries and that it will serve as an initial input for country benchmarking.

This report is intended to be part of the accountability mechanism of EU energy policy but should also be accountable in its own terms. It should be relevant to policy-making and the public participation process, and it should serve information needs. The Agency is keen on feedback so that we can move from providing BAI, or 'best available information', to BNI, or 'best needed information' or 'badly needed information'. I invite readers (including critics!) to comment on this first report on energy and environment so that we can improve future editions.

Lastly, I would like to thank all those who have already contributed input to this report through the review process, and Eurostat for providing most of the data used.

Domingo Jiménez-Beltrán
Executive Director

Summary

Introduction

This is the first indicator-based report produced by the European Environment Agency on energy and the environment. It covers the European Union (EU), and is designed to provide policy-makers with the information necessary for assessing how effectively environmental policies and concerns are being integrated with energy policies, in line with the environmental integration process initiated by the European Council's Cardiff Summit in 1998. The report aims to support the EU sixth environmental action programme and in this way to provide input, from an environmental perspective, to sustainable development in the EU.

Energy is central to social and economic well-being. It provides personal comfort and mobility, and is essential to most industrial and commercial wealth generation. However, energy production and consumption place considerable pressures on the environment, including contributing to climate change, damaging natural ecosystems, tarnishing the built environment and causing adverse effects to human health.

EU energy policy reflects these wide-ranging issues and has three main goals:

- security of supply
- competitiveness
- environmental protection.

While these areas may be considered separately, they are strongly interrelated. For example, improvements in energy efficiency both benefit security of supply by reducing the amount of energy consumed and reduce emissions of greenhouse gases and pollutants by reducing the consumption of fossil fuels. On the other hand, energy market liberalisation and more price competition benefit competitiveness through reduced costs, but unless external costs are fully internalised and energy demand management improves, the reduction of costs may bring price reductions that are likely to act as a disincentive to energy saving and even encourage energy consumption.

In line with the energy policy goals, the specific environmental objectives of EU energy policy on environmental integration (as detailed in the European Commission communication on environmental integration within Community energy policy, 1998) are to:

- reduce the environmental impact of energy production and use
- promote energy saving and energy efficiency
- increase the share of production and use of cleaner energy.

This report provides an assessment, based on indicators, of progress by the energy sector towards environmental integration. These examine performance in the EU as a whole, as well as in individual Member States, and are supported, where possible, by an analysis of progress towards quantitative targets. Factors that have affected change are examined and quantitative analysis is provided where feasible. The indicators examine trends over the period 1990–99 and compare these with baseline projections to 2010, which originate from European Commission studies and assume both a continuation of policies adopted by 1998, and that the EU voluntary agreement with the car industry on reducing carbon dioxide emissions from new passenger cars will be honoured.

In line with the sectoral reporting strategy adopted by the Agency, the report addresses six policy questions to provide a systematic evaluation of all aspects of the environmental integration of the energy sector.

1. Is the use of energy having less impact on the environment?
2. Are we using less energy?
3. How rapidly is energy efficiency being increased?
4. Are we switching to less-polluting fuels?
5. How rapidly are renewable energy technologies being implemented?
6. Are we moving towards a pricing system that better incorporates environmental costs?

Overall, while there have been some successes, there has been insufficient progress in most of the areas of environmental integration covered by this report. In relation to the above six questions, the following conclusions can be drawn:

1. (a) Emissions of greenhouse gases in the EU fell between 1990 and 2000, but without additional measures are unlikely to fall further to 2010 and beyond because of increased energy-related emissions. Ongoing successful initiatives in some Member States appear to point the way forward.
   (b) Measures taken to reduce atmospheric pollution from energy use are proving successful, with a number of Member States on track to meet the reduction targets set for 2010.
   (c) Oil pollution from coastal refineries, offshore installations and maritime transport has been reduced, but still places significant pressures on the marine environment.

2. Energy consumption is increasing, mainly because of growth in transport but also in the household and services sectors. However, the rate of increase is expected to slow by 2010 as fuel efficiency improvements in transport are realised.

3. Improvements in energy efficiency have been slow, but improvements in some Member States are showing the potential benefits of good practices and strategies.

4. The EU is switching from coal to the relatively cleaner natural gas, but after 2010 no further switching is expected. Furthermore, some nuclear installations will retire and, if these are replaced by fossil fuel plants, increases in carbon dioxide emissions are likely. This underlines the need to further strengthen support for renewable energy sources.

5. Renewable energy targets are unlikely to be met under current trends, but experience in some Member States suggests that growth could be accelerated by appropriate support measures.

6. Despite increases in energy taxation, most energy prices in the EU have fallen, as a result mainly of falling international fossil fuel prices but also of the liberalisation of energy markets. In the absence of appropriate policies to internalise the external costs of energy and improve energy demand management, reduced prices are likely to act as a disincentive to energy saving and may encourage energy consumption.

The following sections provide an assessment of each of the key energy and environment policy questions.

1. Is the use of energy having less impact on the environment?

1.a. Greenhouse gas emissions

Greenhouse gas emissions in the EU related to the use of energy fell proportionately less than total greenhouse gas emissions between 1990 and 2000, increasing their share of the total to 82 %. The reduction in energy-related emissions can be partly attributed to one-off reductions in Germany and the UK. Nevertheless, the EU achieved its commitment to stabilise carbon dioxide emissions in 2000 at 1990 levels.

However, it will be difficult for the EU to meet its Kyoto Protocol target of reducing total greenhouse gas emissions by 8 % from 1990 levels by 2010. Without additional measures, total emissions in 2010 are likely to be about the same as in 1990, with a further fall in non-energy related emissions being offset by a rise in energy-related emissions, driven mainly by the transport sector.

Assuming that the Kyoto Protocol target will be met using only domestic measures, the majority of Member States have not made sufficient progress to ensure meeting their targets under the EU burden-sharing agreement. Distance-to-targets analysis performed on the basis of 1999 data shows that Finland, France, Germany, Luxembourg, Sweden and the UK reduced total emissions at least enough to be on track to achieve their 2010 targets. However, in all Member States, with the exception of Sweden, energy-related emissions between 1990 and 1999 either fell less than or increased more than total emissions.

Beyond 2010 energy consumption levels are expected to continue to increase, at least to 2020. Meeting the European Commission's proposed EU total emission reduction target of 1 % per year from 1990 levels up to 2020 would require long-term changes in energy production and consumption patterns (power plants, buildings, transport, etc.). These patterns will be determined by decisions taken imminently, so reducing future energy-related emissions requires policy action now.

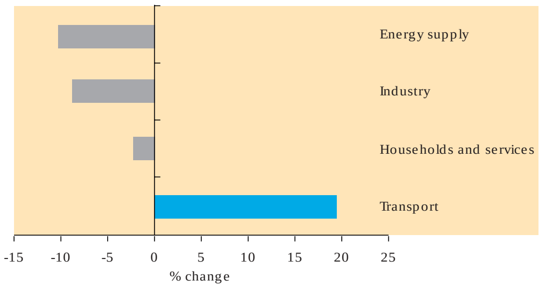
A number of initiatives to pave the way for long-term greenhouse gas emission reductions from energy use are ongoing in Member States. For example, seven Member States have already introduced carbon taxes.

Total EU greenhouse gas emissions fell between 1990 and 2000, but energy-related emissions, by far the largest component, fell considerably less, making significant reductions in total emissions in coming decades unlikely.

Most Member States have failed to reduce greenhouse gas emissions in line with their share of the EU commitment under the Kyoto Protocol.

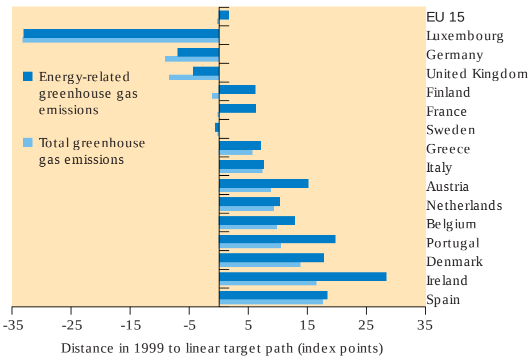
The reduction in energy-related greenhouse gas emissions over the last decade was achieved through considerable reductions by the manufacturing and energy supply sectors, mostly offset by growth in transport.

Change in energy-related greenhouse gas emissions by economic sector, 1990–99



Source: EEA.

Performance in reducing total and energy-related greenhouse gas emissions to meet Kyoto Protocol targets, 1999



Note: The diagram indicates whether a Member State was on track in 1999 to meet its shared Kyoto Protocol target. A negative value suggests an over-achievement and a positive value an under-achievement against the linear target path from 1990 to 2010. For the purpose of this analysis it is arbitrarily assumed that energy-related emissions will be reduced proportionately with total emissions.
Source: EEA.

1.b. Air pollution

Energy use is a major source of atmospheric pollutants. It contributes just over 90 % of EU sulphur dioxide emissions, almost all emissions of nitrogen oxides, about half the non-methane volatile organic compound emissions and around 85 % of particulates.

Measures taken to reduce atmospheric pollution from the use of energy have been successful. These include the introduction of catalytic converters, the use of pollution abatement technologies encouraged by the large combustion plant directive and the use of best avaiable techniques required by the integrated pollution prevention and control directive. Fuel switching from coal and oil to natural gas has also made an important contribution to the reduction of atmospheric pollution.

In the electricity sector, more than half of the reductions in emissions of sulphur dioxide and nitrogen oxides resulted from the introduction of emission-specific abatement meaures, about a quarter from changes in the fossil fuel mix, and the rest from improved efficiency of fossil-fuelled electricity production and increased shares of nuclear and renewables.

Target reductions for total (energy and non-energy related) emissions of sulphur dioxide, nitrogen oxides and non-methane volatile organic compounds for 2010, relative to 1990, have been set in the national emissions ceilings directive. Overall, the EU is on course to meet these targets and is also making good progress in reducing particulate emissions. The energy-related emissions of all these pollutants have been reduced more quickly than total emissions.

Most Member States have contributed to all these reductions but Greece, Ireland, Portugal and Spain need to take further action to ensure that they meet their targets.

☺ Energy-related sulphur dioxide emissions fell considerably between 1990 and 1999. This is the main reason that the EU and most Member States are expected to achieve their 2010 targets for reducing total sulphur dioxide emissions, as set in the national emission ceilings directive.

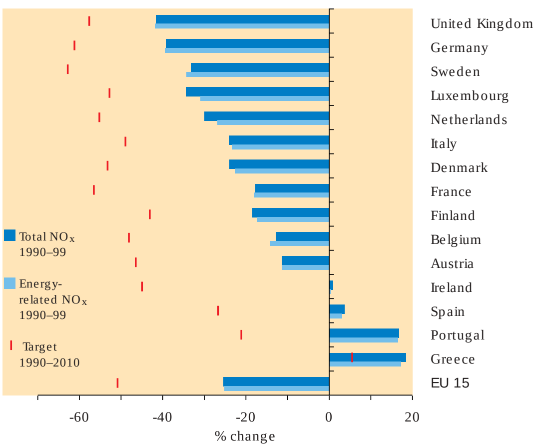
☺ Energy-related emissions of nitrogen oxides also fell, placing the EU and some Member States on track to achieve their 2010 reduction targets for total nitrogen oxide emissions, as set in the same directive.

☺ The reduction in energy-related emissions of non-methane volatile organic compounds (NMVOCs) has greatly helped to put the EU and some Member States on course to achieve their 2010 targets for reducing total NMVOC emissions, as set in the national emission ceilings directive.

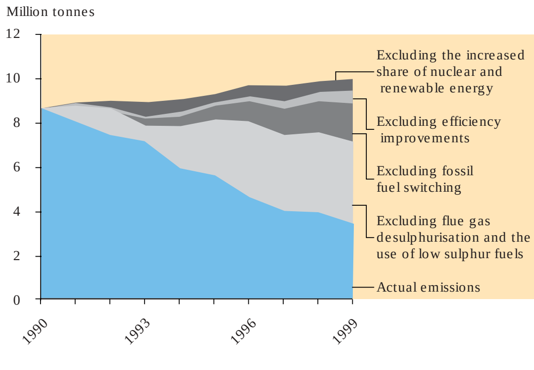
☺ Energy-related emissions of particulates fell by 37 % between 1990 and 1999, mainly as a result of reductions from power plant and road transport.

Note: Target values are for total emissions.
Source: EEA.

Change in total and energy-related emissions of nitrogen oxides, 1990–99



Explanations for the reduction of emissions of sulphur dioxide in the electricity sector, 1990–99



Source: EEA.

1.c. Other energy-related pressures

Other environmental pressures from energy production and consumption include wastes from mines and nuclear plant, water contamination from mining, oil spills and discharges to marine waters, soil damage from spills and leakages of liquid fuels, and impacts on ecosystems from the construction and operation of large dams.

This report provides information on spills and discharges of oil to the marine environment, and nuclear waste. Trends in these areas warrant monitoring, and data, though not comprehensive, are of sufficient quality to indicate pressures from marine oil pollution and radioactive waste production.

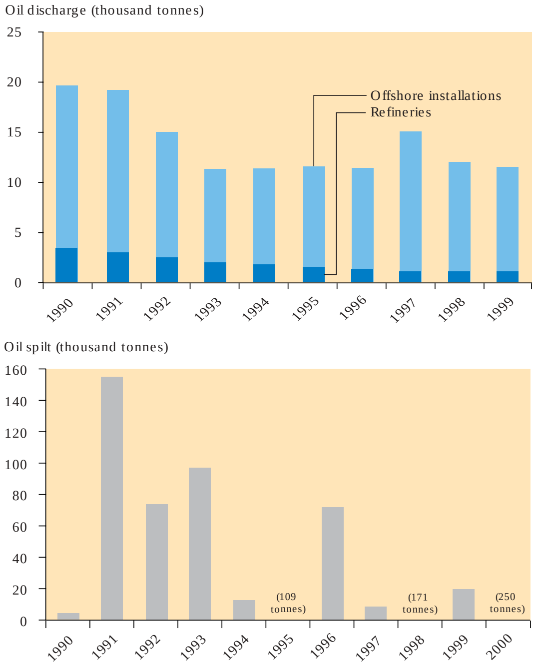
Tanker oil spills continue to occur, although both their frequency and the volumes involved have declined over the past decade. This may reflect the irregular occurrence of such accidents, but it is encouraging that the apparent improvement has come despite the increasing maritime transport of oil. Strengthened safety measures, such as the introduction of double-hulled tankers, have contributed to this. Additionally, oil discharges from offshore installations and coastal refineries have diminished, despite increased oil production, as a result of the increased application of cleaning and separation technologies.

Spent nuclear fuel is the most highly radioactive waste, in many cases taking up to several hundred thousand years to decay. As the amount produced is determined mainly by the quantity of electricity generated from nuclear plants, the annual quantities of spent fuel are likely to decrease as nuclear power production starts to decline. Work is ongoing 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 wastes accumulate in stores. The European Commission has proposed more support for research and development on nuclear waste management in its sustainable development strategy.

Oil pollution from offshore installations and coastal refineries has been reduced, but major oil tanker spills continue to occur.

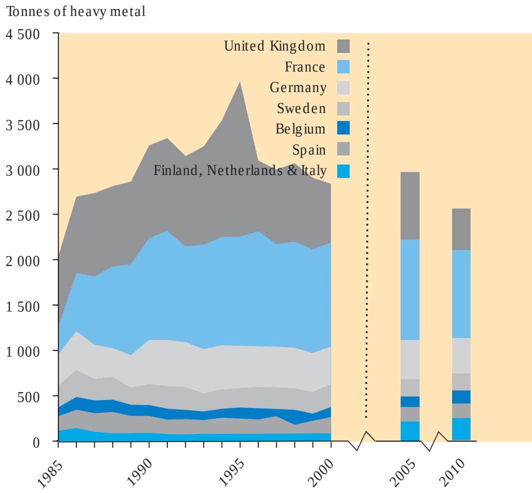
Highly radioactive waste from nuclear power production continues to accumulate. A generally acceptable disposal route is yet to be identified.

Marine environment oil pollution from refineries and offshore installations, and from accidental oil tanker spills (above 7 tonnes per spill)



Sources: Eurostat, OSPAR, CONCAWE, DHI, ITOPF.

Annual quantities of spent nuclear fuel from nuclear power plant



Notes: The vast majority of highly radioactive waste consists of spent fuel and spent fuel reprocessing wastes. 2000 figures for Spain, Sweden and the UK are based on provisional data. Projected data is taken from national projections with the exception of Sweden for 2010, which is a projection from the OECD. Austria, Denmark, Greece, Ireland, Luxembourg and Portugal do not have nuclear power plants. Italy phased out commercial nuclear power in 1987. The projected increase attributed to Finland, Italy and the Netherlands is due to a projected increase from Finland only.
Source: OECD.

2. Are we using less energy?

One of the aims of the EU strategy for integrating environmental considerations into energy policy is to increase energy saving. Cost-effective energy saving has many benefits: it decreases pressure on the environment, improves competitiveness and allows countries to be less dependent on energy imports.

Energy consumption by final energy users increased between 1990 and 1999 in all but one sector, with the fastest growth coming from transport. Manufacturing industry's small decline in energy consumption reflects some improvements in energy efficiency but mainly reveals the effect of structural changes, including a shift towards low energy-intensive industries, relocation of energy-intensive industries away from EU countries, and the post-unification restructuring of German industry.

Baseline projections to 2010 indicate continued growth in energy consumption, but at a lower rate than between 1990 and 1999, mainly because of a slower rate of increase in energy consumption by the transport sector. This is due to expected improvements in road vehicle fuel efficiency as a result of the voluntary agreement between the car industry and the EU, rather than a slowdown in road transport growth.

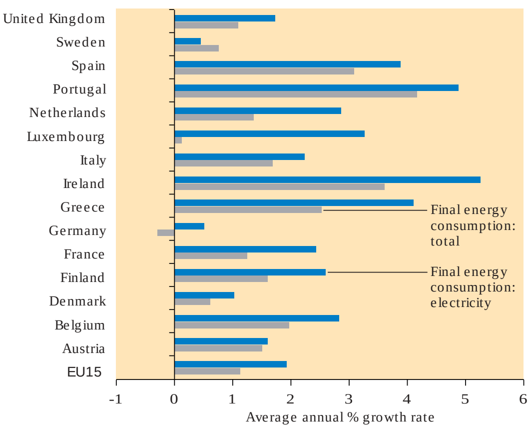
Electricity continues to take an increasing share of final energy consumption in all EU countries, both as a result of more electrical appliances in the services and household sectors, and a greater use of electrically based production processes in industry. Electricity is produced from other fuels and the consumption of each unit of electrical energy requires the consumption of two to three units of another energy source. Growth in electricity consumption will therefore result in a disproportionately greater increase in environmental pressures, especially in carbon dioxide emissions, unless it comes from high-efficiency, low-emission technologies that reduce sufficiently the environmental consequences of electricity production.

The use of electrical energy for heating is a particularly inefficient use of the original energy resource. In Denmark, the Electricity Saving Fund, financed by a levy on domestic electricity consumption, enables the government to grant subsidies for the conversion of electrically heated dwellings to district heating or natural gas. Also, natural gas companies encourage customers to choose gas rather than electricity for cooking, with each new installation being supported by a government subsidy.

☹ Energy consumption in the EU continued to grow between 1990 and 1999; this trend is expected to continue.

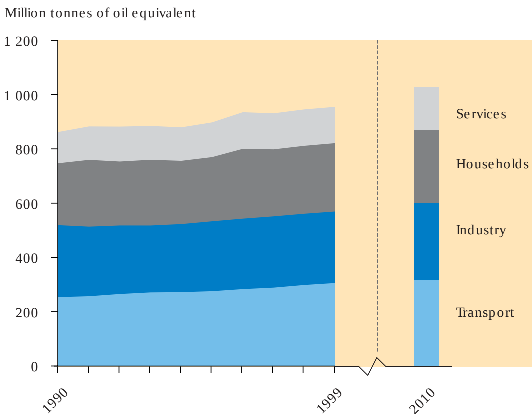
☹ Electricity consumption in the EU grew faster than final energy consumption between 1990 and 1999; this trend is expected to continue.

Final energy consumption and electricity consumption growth, 1990–99



Source: Eurostat.

Final energy consumption



Source: Eurostat.

3. How rapidly is energy efficiency being increased?

The EU as a whole has an indicative target to decrease the energy intensity of final consumption (energy consumption per unit of gross domestic product) by an average of 1 % per year, between 1998 and 2010, above 'that which would have otherwise been attained'. The energy intensity of the EU economy decreased by 0.9 % per year during 1990–99, with little apparent influence from policies on energy efficiency and energy saving. The slow pace with which energy intensity decreased is due to a combination of a generally low priority for such policies, abundant energy supplies and low fossil fuel prices. Only the substantial reduction in Germany, helped by energy efficiency improvements, prevented an increase in overall energy intensity. There were impressive reductions in Luxembourg due to one-off changes (the closure of a steel plant) and in Ireland due to high growth in low energy-intensive industries and the services sector. The implementation of energy efficiency policies in Denmark and the Netherlands played an important role in the reductions in these countries.

The overall efficiency of conversion of primary to usable energy did not improve between 1990 and 1999 because efficiency gains in conversion processes were offset by a larger share of converted fuels (e.g. electricity, petroleum products) in final energy consumption, a trend that is expected to continue.

Combined heat and power (CHP) avoids much of the waste-heat loss associated with electricity production as it produces both heat and electricity as useful outputs. The EU has an indicative target to derive 18 % of all electricity production from CHP by 2010. This target may not be reached because CHP investment across the EU, and in particular in Germany, the Netherlands and the UK, has been hindered by increasing natural gas prices (the preferred fuel for new CHP), falling electricity prices and uncertainty over the evolution of electricity markets as liberalisation is extended. The German CHP law, passed in early 2002, provides an example of how to alleviate this situation through a number of support mechanisms, including agreed electricity purchase prices for existing CHP installations and for new, small-scale units.

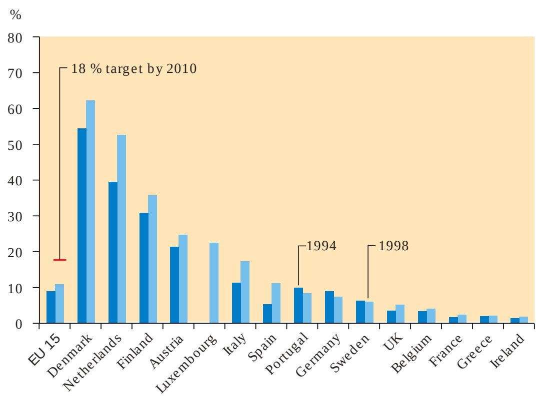
☹ Economic growth is requiring less additional energy consumption, but energy consumption is still increasing.

☹ With the exception of industry, no EU economic sector has decoupled economic/ social development from energy consumption sufficiently to stop growth of its energy consumption.

😐 The efficiency of electricity production from fossil fuels improved between 1990 and 1999, but electricity consumption from fossil fuels grew more rapidly, outweighing the benefits to the environment from these improvements.

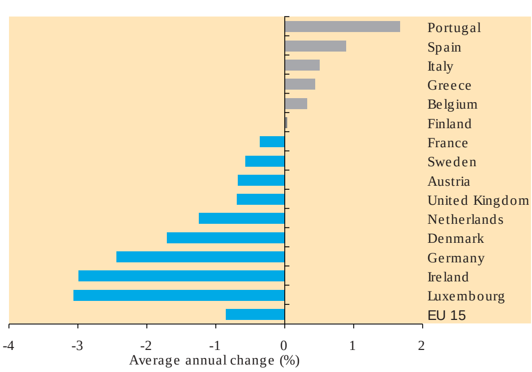
☹ The share of electricity from combined heat and power (CHP) increased across the EU between 1994 and 1998, but faster growth is needed to meet the EU target.

Share of gross electricity production from combined heat and power plant, 1994 and 1998



Source: Eurostat.

Annual change in final energy intensity, 1990–99



Source: Eurostat.

4. Are we switching to less-polluting fuels?

The European Commission strategy to strengthen environmental integration within energy policy stresses the need to increase the share of cleaner energy production and use. This is reflected in the sixth environmental action programme which, as part of the climate change priority actions, encourages the use of renewable and low-carbon fossil fuels for power generation.

The share of fossil fuels in total energy consumption declined only slightly between 1990 and 1999. However the environment benefited from a major change in the fossil fuel mix, with coal and lignite losing about one third of their market share and being replaced by relatively cleaner natural gas, resulting in reduced emissions of greenhouse gases and acidifying substances. This was due mainly to fuel switching in power generation, encouraged by the high efficiency and low capital cost of combined-cycle gas plants, the liberalisation of electricity markets, low gas prices in the early 1990s and the implementation of the EU large combustion plant directive. Oil retained its share of the energy market, reflecting its continued dominance in the ever-growing road and air transport sectors.

Baseline projections suggest only limited changes in the energy mix of total energy consumption by 2010, highlighting the need to strengthen support for renewable energy (see next section). The projections also indicate that fossil fuels will take a larger share of increasing electricity production while the switch to gas-fired electricity production is expected to continue.

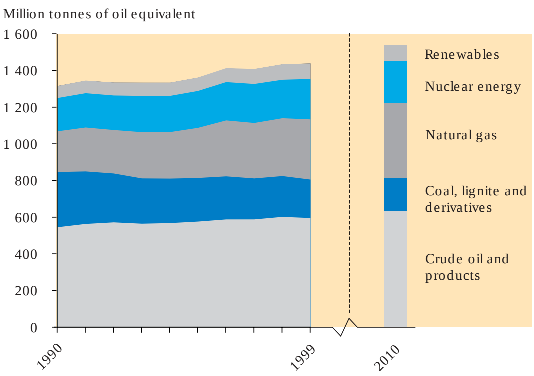
The switch from coal to natural gas is not expected to continue beyond 2010. Increased electricity production from fossil fuels, slow growth of electricity production from renewable sources and the decrease in nuclear-powered electricity production as nuclear plants start to be decommissioned, are then likely to lead to increased carbon dioxide emissions.

😐 Fossil fuels continue to dominate energy use, but environmental pressures have been limited by switching from coal and lignite to relatively cleaner natural gas.

😐 Fossil fuels and nuclear power continue to dominate electricity production, but the environment has benefited from the switch from coal and lignite to natural gas.

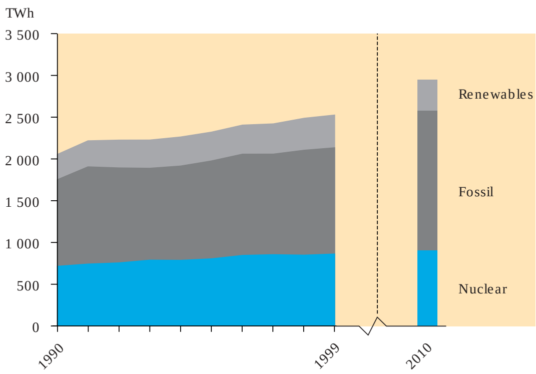
🙂 Carbon dioxide emissions from electricity production fell by 8 % between 1990 and 1999 despite a 16 % increase in the amount of electricity produced.

Total energy consumption by source



Note: Fuels other than those listed in the legend have been included in the diagram but their share is too small to be visible.
Source: Eurostat, NTUA.

Electricity production by source



Source: Eurostat, NTUA.

5. How rapidly are renewable energy technologies being implemented?

Meeting the renewable energy targets will be challenging. Taking account of the projected increase in energy consumption, the growth rate of renewable energy (both electricity and heat) will have to more than double compared with that between 1990 and 1999 if the EU's indicative target of a 12 % share of renewable energy sources in total energy consumption by 2010 is to be met. Similarly the growth rate in electricity from renewable energy sources will have to increase roughly twofold to meet the EU indicative target of 22.1 % of gross electricity consumption from renewable energy sources by 2010.

Financial, fiscal and administrative barriers, the low economic competitiveness of some renewables and the lack of information and confidence amongst investors all hinder the development of renewable energies.

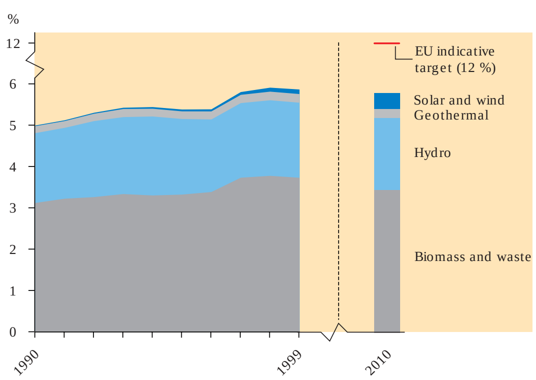
There are, however, encouraging signs that growth in renewable energy can be considerably accelerated with the right mix of support measures. For example the rapid expansion of EU wind and solar electricity was driven by Denmark (wind only), Germany and Spain and resulted from support measures such as 'feed in' arrangements that guaranteed a fixed favourable price. Similarly, Austria, Germany and Greece contributed 80 % of new solar thermal installations in the EU between 1990 and 1999. Solar thermal developments in Austria and Germany benefited from proactive government policy coupled with subsidy schemes and communication strategies, while in Greece the developments were helped by government subsidies.

Renewable energy contributes very little to the growing consumption of the transport sector. The draft EU directive on the promotion of the use of biofuels for transport would require almost 6 % of gasoline and diesel sold for transport purposes to come from biofuels by 2010. However, the production of these fuels is energy intensive and may compete with other energy crops for growing land. There is also some concern over the level of nitrogen oxides emissions and particulates from biofuels.

☹ The share of total energy consumption met by renewable energy grew only slightly between 1990 and 1999. Projections of future energy demand imply that the growth rate of energy from renewable sources needs to more than double to attain the EU indicative target of 12 % by 2010.

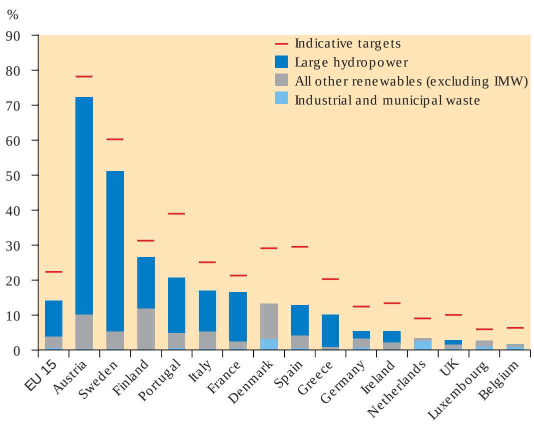
☹ The share of renewable energy in EU electricity consumption grew slightly between 1990 and 1999. Projections of future electricity demand imply that the rate of growth of electricity from renewable sources needs to double to attain the EU indicative target of 22.1 % by 2010.

Share of total energy consumption provided by renewable energy sources



Note: Biomass/wastes include wood, wood wastes, other biodegradable solid wastes, industrial and municipal waste (of which only part is biodegradable), biofuels and biogas.
Source: Eurostat, NTUA.

Share of electricity consumption met by renewable energy sources, 1999



Notes: Industrial and municipal waste (IMW) includes electricity from both biodegradable and non-biodegradable energy sources, as there are no separate data available for the biodegradable part. The EU 22.1 % target for the contribution of electricity from renewable sources to gross electricity consumption by 2010 only classifies biodegradable waste as renewable. The share of renewable electricity in gross electricity consumption is therefore overestimated by an amount equivalent to the electricity produced from non-biodegradable IMW. National targets shown here are reference values that Member States agreed to take into account when setting their targets by October 2002, according to the renewable electricity EU directive.
Source: Eurostat.

6. Are we moving towards a pricing system that better incorporates environmental costs?

Energy prices currently do not always reflect the full costs to society, because prices often do not totally take account of the impacts of energy production and consumption on human health and the environment. Estimates of these external costs for electricity, for example, are about 1–2 % of EU gross domestic product and reflect the dominance of environmentally-polluting fossil fuels in its production.

The sixth environmental action programme stresses the need to internalise these external environmental costs. It suggests a blend of instruments that include the promotion of fiscal measures, such as environment-related taxes and incentives, and the undertaking of a review of subsidies that counter the efficient and sustainable use of energy, with a view to gradually phasing them out.

Energy subsidies between 1990 and 1995 remained focused on the support of fossil fuels and nuclear power, despite the environmental impacts and risks associated with these fuels. Energy research and development expenditure by Member State governments fell between 1990 and 1998 but still concentrated on nuclear power. The share of the research and development budget devoted to renewable energy sources and energy conservation increased, but diminished in absolute terms. More recent data are needed to see whether these energy subsidy patterns have continued.

With the exceptions of diesel and unleaded gasoline for transport, energy prices fell between 1985 and 2001. This reflected trends in international fossil fuel prices and the move towards liberalised gas and electricity markets which stimulated greater price competition. The reductions occurred despite increases in energy taxation — other than that for industrial electricity where the energy tax fell.

In the absence of an appropriate policy framework that aims at the full internalisation of external costs to the environment, and at improved management of energy demand, the reduction of energy prices is likely to act as a disincentive to energy-saving investments and may encourage energy consumption.

☹ Energy prices generally fell between 1985 and 2001, offering little incentive for energy saving.

☹ Despite increases in taxation from 1985 to 2001, energy prices for most fuels dropped and the overall demand for energy increased.

☹ With fossil fuels supplying more than half the EU's electricity, price levels would need to be increased to include the estimated external costs of electricity production.

☹ Subsidies continue to distort the energy market in favour of fossil fuels despite the pressures these fuels place on the environment.

☹ EU energy research and development expenditure has been reduced at a time when innovation is needed to develop less-polluting technologies.

Introduction

This is the European Environment Agency's first indicator-based report on energy and the environment.

Energy is central to social and economic wellbeing. It provides comfort and warmth in our homes, mobility for work and recreation, and services that are essential to most industrial and commercial wealth generation. Energy supply itself is a major source of wealth and employment in the EU. But all phases of the energy production and consumption chain place pressures on the environment (Figure 1). Many of these are leading to exceedances of tolerable levels of some pollutants and contributing to climate change and lasting damage to natural ecosystems, the built environment, agriculture and human health.

The report covers the European Union (EU) and is designed to provide policy-makers with the information needed for assessing how effectively environmental policies and concerns are being integrated with energy policies, in line with the environmental integration process initiated by the European Council Cardiff Summit[1] in 1998. It aims to support the EU sixth environmental action programme (European Commission, 2001a) and provide input, from an environmental perspective, to EU sustainable development (European Council, 2001).

The three main goals of EU energy policy (Council of the European Union, 1995) — security of supply, competitiveness and environmental protection — are strongly interrelated. For example, improvements in energy efficiency should benefit security of supply, by reducing the amount of energy consumed, and abate emissions of greenhouse gases and other pollutants, by reducing the consumption of fossil fuels. Market liberalisation and more price competition will benefit competitiveness through reduced prices, but may act as a disincentive to energy saving and encourage consumption unless external costs are fully internalised and energy demand is better managed.

In line with the three main energy policy goals, the specific environmental objectives of EU energy policy in the area of environmental integration (European Commission, 1998a) are to:

- Reduce the environmental impact of the production and use of energy
- Promote energy saving and energy efficiency
- Increase the use of cleaner energy and its share of total production.

A key challenge for economic, energy and environmental policy is to develop instruments and measures to encourage further economic development, while reducing and ultimately breaking the linkage between the use of energy (both production and consumption) and environmental pressures.

The link between environmental pressures and the drivers for energy demand can be represented by the following relationship (see Box 1 for a detailed explanation).

$$\boxed{\text{PRESSURE}} = \boxed{\text{DRIVER}} \times \boxed{\frac{\text{ENERGY}}{\text{DRIVER}}} \times \boxed{\frac{\text{PRESSURE}}{\text{ENERGY}}}$$

For a systematic evaluation of all aspects of the environmental integration of the energy sector, the report addresses six policy questions drawing on this relationship. It provides its assessment with the help of indicators (Table 1) that are based on the system established by the EEA for reporting on environmental issues: the DPSIR assessment framework (Box 2).

The report builds on statistics contained in the Eurostat publication *Integration — indicators for energy. Data 1985–98* (Eurostat, 2001) and on projections used in the report 'Economic evaluation of sectoral emission reduction objectives for climate change',

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1 The Cardiff Summit invited all relevant formations of the Council to establish their own strategies for giving effect to environmental integration and sustainable development within their respective policy areas. The Summit requested that the relevant formations of the Council should identify indicators and monitor progress, taking account of the Commission's suggested guidelines, and invited the Transport, Energy and Agriculture Councils to start this process (European Council, 1998).

- Is the use of energy having less impact on the environment, i.e. is the pressure being reduced? (Section 1)
- Are we using less energy, i.e. are the driver and energy intensity (energy/driver) being reduced? (Section 2)
- How rapidly is energy efficiency being increased, i.e. is the energy intensity being reduced? (Section 3)
- Are we switching to less-polluting fuels, i.e. is the pressure intensity (pressure/energy) being reduced? (Section 4)
- How rapidly are renewable energy technologies being implemented, i.e. to what extent are we taking up these options for reducing the pressure intensity? (Section 5)
- Are we moving towards a pricing system that better incorporates environmental costs, i.e. are economic decisions taking account of the pressures that energy-related activities place on the environment? (Section 6)

produced by Ecofys, AEAT and NTUA on behalf of the European Commission's Environment Directorate General (Ecofys, 2001)[2]. Information is also drawn from working documents, in the form of detailed indicator fact sheets, prepared by the EEA and its European topic centres and reviewed by the European Environment Information Observation Network (EIONET), and a number of EEA reports on greenhouse gas emissions (EEA 2001a and 2002a), atmospheric pollutants (EEA, 2002b), and transport and environment (EEA, 2001b).

Special attention has been paid to public electricity production, because of its growing share of energy use, and because it is a key option for introducing less-polluting energy sources. The transport sector, which also has a growing share of energy use, is dealt with in detail in the European Environment Agency's report *TERM 2001 — Indicators tracking transport and environment integration in the European Union* (EEA, 2001b). It will also be the theme of the upcoming EEA TERM 2002 report on transport and environment indicators in accession countries.

[2] New updated baseline projections will be released by the European Commission in the second half of 2002.

Figure 1 Examples of the environmental pressures imposed at different stages of the energy supply and demand chain

Energy supply				Energy demand
Extraction of primary energy sources	Transportation of primary energy sources	Energy conversion	Energy transmission and distribution	Energy consumption
• Methane from coal mining, natural gas and oil extraction • Solid wastes from mining • Groundwater contamination from mining • Radon from uranium extraction • Oil discharges • Air pollution from flaring	• Methane from pipeline leakage • Oil spills • Emissions of greenhouse gases and air pollutants from energy consumption in transportation	• Greenhouse gas and air pollutant emissions, and oil discharges from oil refineries • Solid and nuclear waste from power production • Noise and visual intrusion from renewable energy plant	• Methane emissions from natural gas transmission and distribution • Spills and leakage of liquid fuels • Emissions of greenhouse gases and air pollutants from energy consumed in transportation	• Greenhouse gas and air pollutant emissions from fuel combustion

Box 1 Relationship between environmental pressures and the drivers for energy demand

$$\mathit{PRESSURE} = \mathit{DRIVER} \times \frac{\mathit{ENERGY}}{\mathit{DRIVER}} \times \frac{\mathit{PRESSURE}}{\mathit{ENERGY}}$$

The pressure placed on the environment by any activity using energy will depend on:

- driver - the volume of activity that generates demand for an energy-related service (e.g. gross domestic product, industrial value added, demand for road freight delivery or passenger transportation)
- energy intensity - the amount of energy required per unit of driver
- pressure intensity - the pressure on the environment (emissions, discharges, wastes) per unit of energy use.

This points to a set of options for reducing the environmental pressures associated with the use of energy (energy production and consumption):

- Reduce the driver by adopting alternative social or economic practices (e.g. a modal switch from private to public transport).
- Reduce the linkage between the driver and the use of energy (i.e. the energy intensity) through more efficient energy use and the use of less energy-intensive processes.
- Reduce the environmental pressure generated by the use of energy (i.e. the pressure intensity), for example by:

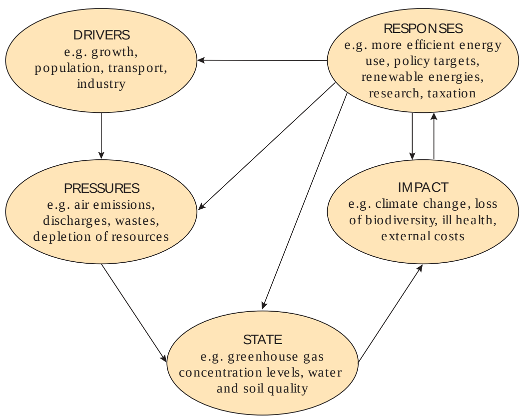
  – less dependence on the more polluting fuels through the development of alternative energy sources;

  – deployment of advanced conversion and end-use technologies that are less polluting.

Box 2 The DPSIR assessment framework

As shown in the figure, the DPSIR (Driving forces, Pressures, State, Impact, Responses) assessment framework recognises the connections between the causes of environmental problems, their impacts and society's responses to them.

- Drivers are the causes underlying the problem.
- Pressures are the pollutant releases into the environment.
- State is the condition of the environment.
- Impact is the effects of environmental degradation.
- Responses are the measures taken to reduce the drivers and pressures on the environment or to mitigate their Impact and effect on the state of the environment.



The report provides an indicator-based assessment based on the DPSIR framework. It assesses the factors affecting energy use (driving forces), the emissions and waste resulting from energy production and consumption (pressures), impacts on the environment and human health (impacts) and the contribution of policy measures designed to mitigate environmental impacts (responses).

Table 1 Indicators of environmental integration of the energy sector

Policy questions		Indicators	Position in DPSIR	Page
Is the use of energy having less impact on the environment?	Greenhouse gas emissions	Energy and non-energy related greenhouse gas emissions	P	24
		Change in energy and non-energy related greenhouse gas emissions (by Member State)	P	26
		Energy-related greenhouse gas emissions by economic sector	P	27
	Air pollution	Energy and non-energy related emissions of sulphur dioxide (by Member State)	P	28
		Energy and non-energy related emissions of nitrogen oxides (by Member State)	P	30
		Energy and non-energy related emissions of non-methane volatile organic compounds (by Member State)	P	31
		Energy-related emissions of particulate matter	P	33
	Other energy-related pressures	Oil discharged to the marine environment from coastal refineries, offshore installations and oil tankers	P	34
		Spent nuclear fuel (by Member State)	P/S	35
Are we using less energy?		Final energy consumption by economic sector	D	37
		Growth in final energy consumption and electricity consumption	D	38
How rapidly is energy efficiency being increased?	Efficiency of energy supply	Ratio of final energy consumption to total energy consumption	R	40
		Efficiency of electricity supplied by fossil fuels	R	42
		Electricity from combined heat and power	R	43
	Efficiency of energy consumption	Energy intensity (by Member State)	R/D	44
		Energy intensity by economic sector	R/D	45
Are we switching to less-polluting fuels?		Total energy consumption by source	D/R	48
		Electricity production by source	D/R	49
How rapidly are renewable energy technologies being implemented?		Total energy consumption from renewable sources	R	52
		Consumption of electricity from renewable sources	R	53
Are we moving towards a pricing system that better incorporates environmental costs?		Final energy prices	D/R	55
		Energy taxes	R	56
		External costs of electricity production	I	58
		Energy subsidies	D/R	59
		Energy-related research and development expenditure	R	60

D = Driver, P = Pressure, S = State, I = Impact, R = Response

1. Is the use of energy having less impact on the environment?

Emissions of greenhouse gases in the EU fell between 1990 and 2000, but without additional measures are unlikely to fall further to 2010 and beyond because of increased energy-related emissions. Ongoing successful initiatives in some Member States appear to point the way forward.

Measures taken to reduce atmospheric pollution from energy use sector are proving successful, with a number of Member States on track to meet the reduction targets set for 2010.

Oil pollution from coastal refineries, offshore installations and maritime transport has been reduced, but still places significant pressures on the marine environment.

The production and consumption of energy places a broad range of pressures on both the natural and the built environment, as well as on human health. Because fossil fuels (i.e. coal, lignite, oil and natural gas) account for the bulk of energy supplies in the European Union (EU) (80 % in 1999) most attention in this section focuses on the environmental pressures arising from their use, namely: greenhouse gas emissions, air pollution from acidifying substances, ozone precursors and particulate matter, and oil discharges.

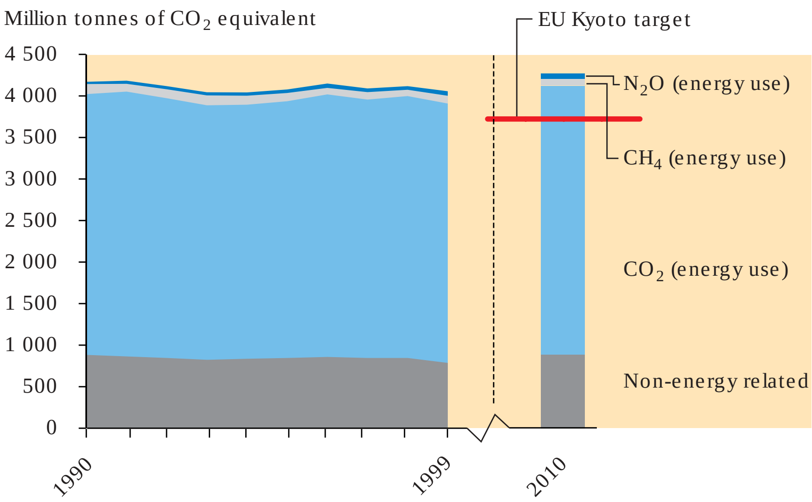
Options for reducing these pressures can be broadly classified into improved management and maintenance, end-of-pipe clean-up, the use of new, less-polluting technologies and switching to cleaner fuels, and, indirectly, more efficient energy use and the use of less energy-intensive processes.

Some pollutants can be responsible for more than one effect. For example methane is both a greenhouse gas and an ozone precursor, and sulphur dioxide contributes both to air pollution (directly and also indirectly by forming fine particulates) and to acidification. The reduction of one pollutant may therefore yield benefits in relation to more than one impact. Policies and measures to reduce greenhouse gas emissions (e.g. switching from coal to natural gas) also often lead to a reduction of emissions of air pollutants. In contrast, however, in some exceptional cases actions to reduce one pollutant may cause an increase in another. For example the use of three-way catalysts has reduced emissions of carbon monoxide, nitrogen oxides (NO_X) and non-methane volatile organic compounds from petrol cars, but with an increase in nitrous oxide emissions. The development of an air pollution strategy has addressed this inter-linkage between pollutants by shifting to a multi-pollutant, multi-effect approach.

Not all pollution from energy-related activities arises from the combustion of fossil fuels. Some combustion-related emissions, such as nitrogen oxides, arise from the use of biomass and waste as fuels. Also, while nuclear power generation produces negligible emissions during normal operation, it is accumulating substantial quantities of long-lived and highly radioactive waste for which no generally acceptable disposal route has yet been developed.

Total EU greenhouse gas emissions fell between 1990 and 2000, but energy-related emissions, by far the largest component, fell considerably less, making significant reductions in total emissions in coming decades unlikely.

Figure 2 Greenhouse gas emissions



Notes: The Kyoto target is for total emissions of carbon dioxide, methane, nitrous oxides and fluorinated gases.The baseline projections for 2010 are taken from the report Economic evaluation of sectoral emission reduction objectives for climate change produced by Ecofys — Energy and Environment, AEA Technology and NTUA on behalf of the European Commission's Directorate General Environment (Ecofys, 2001). See Annex 1 for an outline of the scenario assumptions underlying these projections. Greenhouse gas emissions for 1990 to 1999 are taken from the EEA *European Community and Member States greenhouse gas emission trends 1990–1999* (EEA, 2001a) and the underlying EU greenhouse gas inventory maintained by EEA, assisted by the European Topic Centre on Air and Climate Change (ETC-ACC).

Source: EEA, Ecofys.

1.1.Greenhouse gas emissions

Concern over greenhouse gas (GHG) emissions and climate change is set to remain a priority in EU policy. The EU is committed to taking a lead in reducing global emissions, and the first step is to meet its target, set under the Kyoto Protocol, for an 8 % reduction in total emissions by 2008–12 compared with the 1990 level. Although challenging, this should be regarded as only a first step, since it is estimated that global emissions will need to be reduced by about 70 % in the long term if the atmospheric GHG concentration is to be stabilised at an acceptable level (IPCC, 2001). The European Commission has acknowledged this by proposing an EU target to reduce atmospheric emissions by an average of 1 % per year up to 2020, with a global target of 20–40 % reduction by 2020, both from 1990 levels (European Commission, 2001a and 2001b).

Total EU GHG emissions (i.e. carbon dioxide, methane, nitrous oxide and fluorinated gases) fell by 3.9 % between 1990 and 1999 (EEA, 2001a). According to data just released for 2000 (EEA, 2002a) the EU achieved its original commitment to stabilise carbon dioxide (CO_2) emissions in 2000 at 1990 levels. These early successes might suggest that the EU is on track to achieve its Kyoto Protocol target and to achieve more ambitious emission reductions in the longer term.

This is far from being the case[3], for three reasons.

Firstly, the reduction in emissions came mainly from a non-energy related reduction of 13.9 %. Energy-related emissions fell by only 1.9 %. Since non-energy sources accounted for only 18 % of emissions (in 1999) a bigger contribution to reductions will have to come from energy production and consumption if future abatement targets are to be met. The new 2000 data show that we are moving in the opposite direction. Total emissions increased by 0.3 % from 1999 to 2000 as a result of increased energy-related emissions (EEA, 2002a).

Secondly, about half the stabilisation of CO_2 emissions at 1990 levels by 2000 resulted from one-off reductions in Germany and the UK (Fraunhofer, 2001). From 1999 to 2000, carbon dioxide emissions stopped falling in Germany and increased by 1.2 % in the UK (EEA, 2002a).

Thirdly, baseline projections (see Annex 1), made for the European Commission (Ecofys, 2001), suggest that total EU GHG emissions in 2010 will be about the same as in 1990. Underlying this trend is an increase in energy-related emissions, partially offset by a further reduction in non-energy emissions.

The fact that energy-related GHG emissions are proving particularly difficult to reduce suggests little progress with the fundamental restructuring of energy production and consumption that is vital if more ambitious long-term reduction targets are to be attained. The nature of most energy production and consumption patterns for the next 30 to 50 years (power plants, buildings, transport modes, etc.) will be determined by imminent decisions; reducing energy-related emissions in the long run therefore requires policy action now.

[3] This statement is based on the assumption, for the purpose of this report, that the EU will meet its Kyoto Protocol target by using only domestic policies and measures (including emissions trading within the EU). At the seventh Conference of the Parties to the UN Framework Convention on Climate Change (Marrakesh, November 2001) the Parties agreed to the rules for the use of both the flexible mechanisms (joint implementation, clean development mechanism, international emissions trading) and the sinks for meeting the Kyoto targets (see Box 3) (UN 2001a, UN 2001b). After ratification (expected in 2002), the European Community and the EU Member States could therefore also use these options to meet their targets, although it is not yet known to what extent this will take place.

In addition to domestic action by industrialised countries, the Kyoto Protocol provides three ways in which action taken abroad can help countries to meet their own targets for reductions in emissions of greenhouse gases. The three 'Kyoto mechanisms' comprise two project-based mechanisms (joint implementation and the clean development mechanism) and international emissions trading.

Joint implementation

Joint implementation (JI) is provided for under Article 6 of the Kyoto Protocol. It enables industrialised countries to work together to meet their emission targets. A country with an emissions reduction target can meet part of that target through a project aimed at reducing emissions in any sector of another industrialised country's economy. Any such projects need to have the approval of the countries involved and must result in emission reductions that would not have occurred in the absence of the JI project. The use of carbon sinks (e.g. forestry projects) is also permitted under joint implementation.

Clean development mechanism

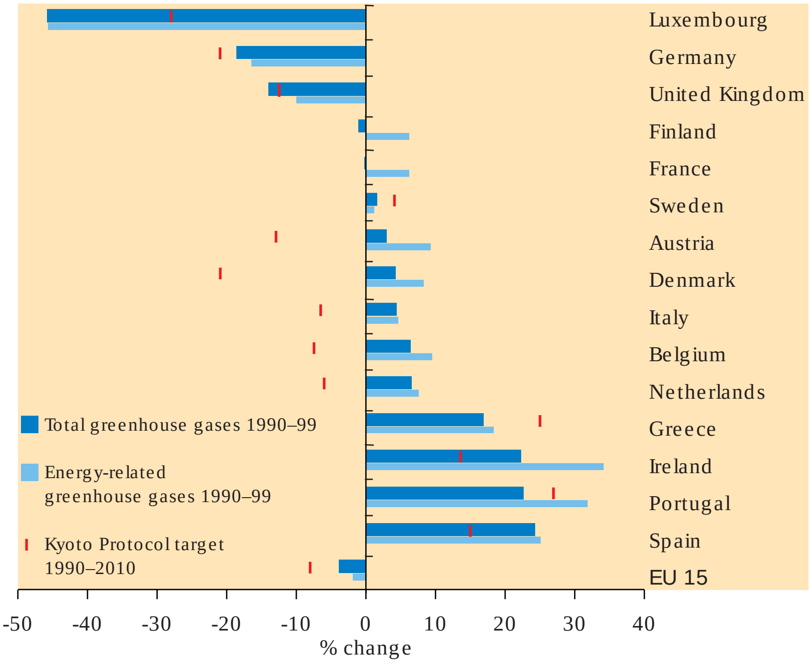
Article 12 of the Kyoto Protocol sets out a clean development mechanism (CDM). This is similar to JI, but project activities must be hosted by a developing country. As with JI, CDM projects must result in reductions that are additional to those that would have been achieved in the absence of the project. They also have the additional aim of promoting sustainable development in the host developing country. The CDM is supervised by an executive board, which approves projects. CDM projects have been able to generate credits since January 2000 and these can be banked for use during the first commitment period (2008–12). The rules governing CDM projects allow only certain types of sinks projects (afforestation and reforestation) and countries will not be able to use credits generated by nuclear power projects towards meeting their Kyoto targets. To encourage small-scale projects, special fast-track procedures are being developed.

Emissions trading

Article 17 of the Kyoto Protocol allows countries that have achieved emissions reductions over and above those required by their Kyoto targets to sell the excess to countries finding it more difficult or expensive to meet their commitments. In this way, it seeks to lower the costs of compliance for all concerned.

Most Member States have failed to reduce greenhouse gas emissions in line with their share of the EU commitment under the Kyoto Protocol.

Figure 3 — Change in total and energy-related greenhouse gas emissions



Notes: Target values are for total emissions. The targets for France and Finland are zero (i.e. no change on 1990). For Denmark, estimates that reflect adjustments for electricity trading (import and export) in 1990 give a reduction in total greenhouse gas emissions of 4.6 % between 1990 and 1999 compared with the increase of 4 % shown in Figure 3. This methodology is used by Denmark to monitor progress towards its national target under the EU burden-sharing agreement.
Source: EEA.

The EU Kyoto Protocol target has been shared amongst Member States in a way that allows for their different economic development patterns.

Finland, France, Germany, Luxembourg, Sweden and the UK limited their total GHG emissions between 1990 and 1999 by at least enough to be in line with their targets for 2008–12 under the EU burden-sharing agreement[4]. The notable improvement in Luxembourg is due to the closure of a primary steel plant (i.e. steel-making from iron ore) with partial transfer of production to electric steel-making using steel scrap. Germany has also made substantial reductions against a challenging target and, because it is the largest emitter, this, together with the UK reduction, has been responsible for the overall reduction achieved by the EU. However, as shown in the indicator that follows, some of the factors driving these changes for Germany and the UK were one-off.

A number of Member States are finding it increasingly difficult to control their GHG emissions. Some, notably the Netherlands, are beginning to pursue joint implementation and clean development mechanism projects under the Kyoto Protocol flexible mechanisms (see Box 3) to supplement domestic (including EU) abatement measures. It is not yet known to what extent Member States will use the flexible mechanisms. The analysis in this report therefore assumes that only domestic policies and measures will be used to meet the Kyoto targets.

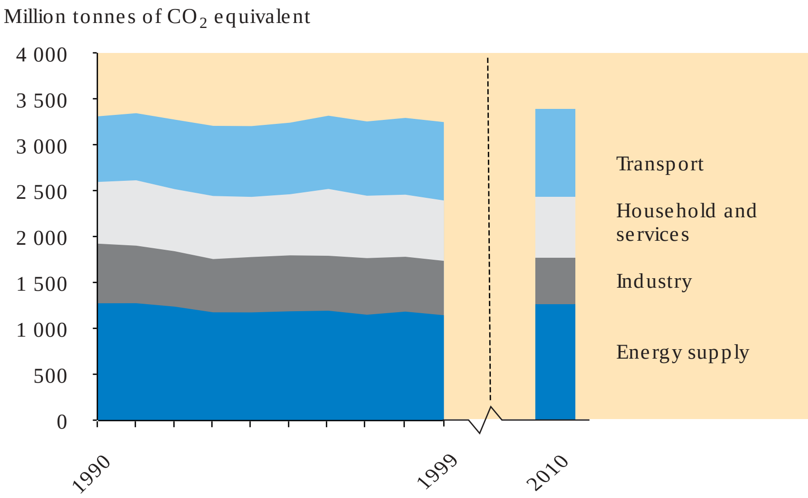
For all Member States, with the exception of Sweden, the performance is worse for energy-related than for total emissions. The large proportion of total emissions that are energy-related (79 % in 1990, rising to 82 % in 1999) means that further progress towards the Kyoto burden-sharing targets, and even more for later and bigger reduction targets, will require additional cuts in emissions from energy production and consumption.

A number of initiatives in Member States and the EU are paving the way for long-term reductions of emission from energy use. For example seven Member States have already introduced a CO_2 tax and the UK launched the first national emissions trading scheme in early 2002. At the EU level, the European Commission proposed a directive on an internal EU-wide trading scheme to start in 2005 which would have the dual benefit of limiting the cost of meeting emission reduction targets while giving the EU an early experience in emissions trading before a global trading scheme possibly gets off the ground in 2008, as part of the Kyoto flexible mechanisms (European Commission, 2001j). Following sections provide further examples of successful Member State and EU initiatives.

4 This conclusion is based on a 'distance-to-target' assessment which measured how far emissions in 1999 were from a linear emission reduction target path from 1990 to 2010, and assessed whether a Member State was on track to meet its target. For a graphical illustration of the results of this 'distance-to-target' analysis see related graph in the Summary.

The reduction in energy-related greenhouse gas emissions over the last decade was achieved through considerable reductions by the manufacturing and energy supply sectors, mostly offset by growth in transport.

Energy-related greenhouse gas emissions | Figure 4



Source: EEA, Ecofys.

Transport[5] is the main area for growth in energy-related GHG emissions, having increased by 19.5 % across the EU between 1990 and 1999, reflecting the growing demand for personal and freight transport. Road transport dominates the sector, accounting for 84 % of emissions in 1998. The bulk of transport emissions is of carbon dioxide (97 %), but transport is also a growing source of nitrous oxide (up from 1.7 % to 2.9 % of transport emissions between 1990 and 1999). This gas is produced in the vehicle exhaust catalysts used to reduce nitrogen oxides and carbon monoxide emissions from passenger cars, but the effect should be reduced as new catalysts that emit fewer nitrous oxides (while giving a greater reduction in emissions of nitrogen oxides) become available.

GHG emissions from industry[6] fell by 8.8 % between 1990 and 1999. The main contributor was Germany as a result of closures of old plant fuelled with coal and lignite, and structural changes towards less energy-intensive manufactured products, particularly in the New *Länder*, combined with investment in energy efficiency measures. Without Germany, EU manufacturing industry emissions would have been on a rising trajectory by 1999.

Between 1990 and 1999, GHG emissions from the energy supply sector[7] fell by 9 % despite an increase in energy demand of 23 %. The main contribution to this was an 8 % cut in CO_2 emissions from electricity production. This is linked to switching from coal and lignite to natural gas, increased efficiency in fossil-fuelled power plant and an expansion of electricity production from nuclear and renewable sources. Much of the reduction was achieved in Germany, mainly from the closure of low-efficiency lignite power plant, in particular in the New *Länder*, and energy efficiency improvements, and in the UK mainly from fuel switching from coal to natural gas.

Looking ahead, baseline projections (Ecofys, 2001) expect total energy-related GHG emissions to grow between 2000 and 2010. This is driven mainly by continued growth of emissions from transport, although this should be less than that experienced between 1990 and 1999 because of the voluntary agreement between the EU and car manufacturers to reduce average carbon dioxide emissions from the new passenger car fleet by an average of 25 % by 2008 (the ACEA Agreement). The growth in emissions from transport is partially offset by a continued fall from industry, driven by further structural change and increased investment in energy efficiency. Emissions from the energy supply sector are expected to stay about level between 2000 and 2010 as the demand for energy continues to grow, but is offset by efficiency improvements and further switching to less carbon-intensive fuels, particularly natural gas.

Looking beyond 2010, there is an added potential for growth in energy-related emissions with the rundown of nuclear power production should this be replaced by fossil-fuelled power stations.

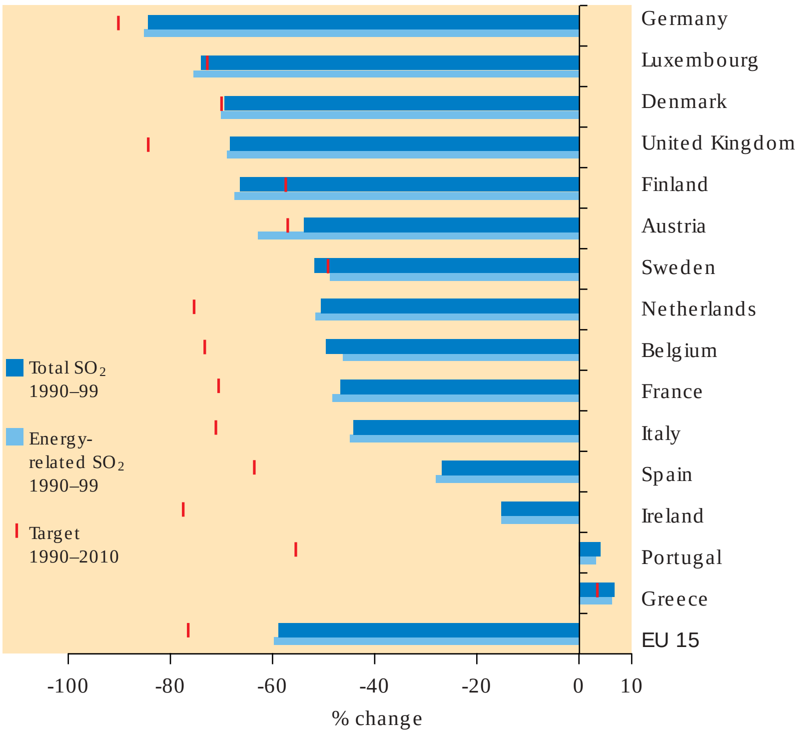
5 Transport emissions exclude emissions from international transport in accordance with reporting requirements of the EU greenhouse gas monitoring mechanism (and also the United Nations Framework Convention on Climate Change (UNFCCC)).

6 Industry emissions are those from all manufacturing industries, including construction. Industry emissions also include emissions from electricity and heat production by the industry.

7 Energy supply sector emissions include those from coal mining, oil and gas exploration and extraction, public electricity and heat production, oil refining and other industries engaged in converting primary energy into energy products. It also includes fugitive emissions from the exploration, production, storage and transport of fuels.

Energy-related sulphur dioxide emissions fell considerably between 1990 and 1999; this is the main reason that the EU and most Member States are expected to achieve their 2010 targets for reducing total sulphur dioxide emissions, as set in the national emission ceilings directive.

Figure 5 Change in total and energy-related sulphur dioxide emissions



Note: Target values are for total emissions.
Source: EEA.

1.2. Air pollution

Sulphur dioxide (SO_2) is produced by the oxidation of sulphur present mainly in coal, lignite and oil fuels. Together with nitrogen oxides it is the main energy-related cause of acid deposition[8] resulting in damage to soil and water quality, crops and other vegetation and terrestrial and aquatic ecosystems. Acid deposition also damages buildings, and is linked to adverse health effects, both directly and through particulate formation. SO_2 itself also causes direct adverse effects on human health.

Action to reduce SO_2 emissions have been taken at the EU level through measures that include targets for reducing total SO_2 emissions for the EU and each Member State set in the national emission ceilings directive (NECD) (European Parliament and Council, 2001c)[9].

Energy production and consumption accounted for over 90 % of emissions in 1999 (see Table 2), with 51 % of this coming from power production. Total emissions have been reduced by 59 % between 1990 and 1999, putting the EU on track to achieve the 77 % reduction by 2010 (relative to 1990) set in the NECD.

With regard to total emissions, most Member States are on track to achieve their NECD targets. Exceptions are Greece, Ireland, Portugal and Spain[10]. The same is true for energy-related emissions, although Spain's rate of improvement was marginally better for these.

All energy activities have contributed to the reduction. Energy supply cut emissions by 59 % between 1990 and 1999, encouraged by the requirements of the directive on large combustion plant (European Parliament and Council, 2001a), but this remains the main source, accounting for 61 % of the total. More than half of the decrease can be attributed to the introduction of flue gas desulphurisation (FGD) and the use of low-sulphur coal and oil. The remainder is due mainly to changes in electricity production including fuel switching (mainly from coal and lignite to natural gas) and improved efficiency, with a small element due to growth in production from nuclear and renewable sources (see Box 4).

The fall in energy-related emissions from households and services (72 % in total) was due mainly to fuel switching to gas. Industry reduced energy-related emissions by 59 % by greater use of gas in place of coal, lignite and oil for space and process heating, fitting flue gas desulphurisation and as a result of structural change. The fall in transport (43 %) was achieved mainly through the reduced sulphur content of diesel fuel in response to the 1993 directive on the sulphur content of liquid transport fuels (European Parliament and Council, 1993a).

8 Ammonia emissions are also an important source of acid deposition but energy-related activities only accounted for 2.4 % of total EU ammonia emissions in 1999.
9 NECD targets were set in absolute terms, but for comparative purposes they are presented here as percentages. Consequently, should the 1990 emissions inventories be revised, this would result in a change in the percentage targets used here.
10 This conclusion is based on a 'distance-to-target' assessment which measured how far emissions in 1999 were from a linear emission reduction target path from 1990 to 2010, and assessed whether a Member State was on track to meet its target.

Table 2

SO_2 emissions by source (ktonnes)

	1990	1999
Energy supply	10 104	4 132
Transport	828	469
Industrial energy use	3 023	1 221
Other energy use	1 596	445
Non-energy sources	811	463
Total	16 362	6 730

Note: 'Other energy use' includes households and services.
Source: EEA.

Box 4

How have reductions in nitrogen oxides and sulphur dioxide been achieved in the electricity sector?

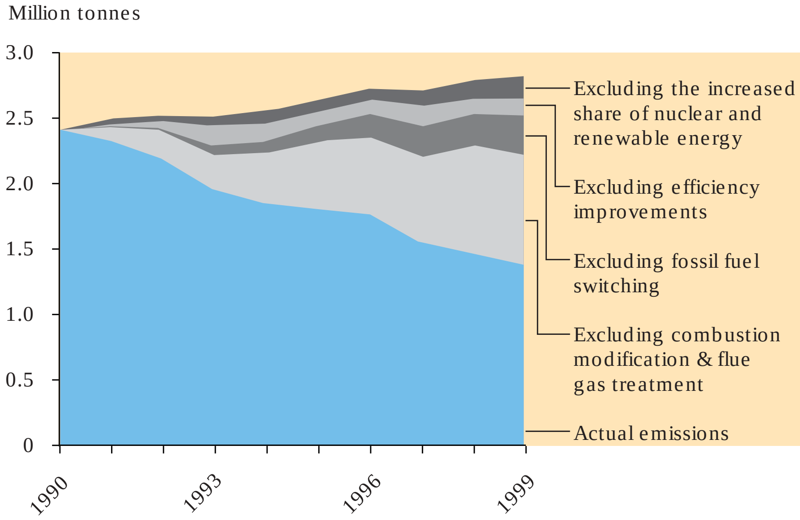
NO_x and SO_2 emissions from electricity production have fallen by 44 % and 60 % respectively over the period 1990 to 1999, despite a 16 % increase in the amount of electricity produced.

If the electricity production industry had remained unchanged (in terms of the type of power plant used and the fuel mix) from 1990, emissions of NO_X and SO_2 would each have increased by 16 % by 1999, in line with the increase in electricity output. In fact, annual emissions of NO_X fell by 44 %, and SO_2 by 60 %, as a result of a number of changes during the period.

For both NO_X and SO_2, around 60 % of the decrease was due to the introduction of emission-specific abatement measures. For NO_X the most important were the introduction of flue gas treatment and the use of low NO_X burners. For SO_2 emissions they were the introduction of flue gas desulphurisation (FGD) and the use of lower-sulphur coal and fuel oil.

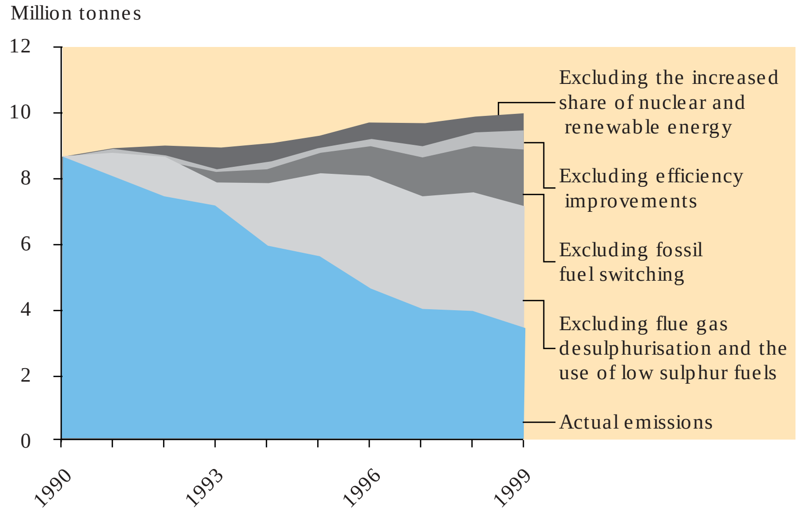
Most of the remaining decrease, for both NO_X and SO_2, was due to changes in the fossil fuel mix (20–25 %), improved efficiency of fossil-fuelled electricity production (about 10 %) and an increased share of nuclear and renewables (about 10 %).

Explanations for the reduction of emissions of nitrogen oxides in the electricity sector



Note: Data and analysis presented here are preliminary results of ongoing work to refine and improve associated statistics and methodology.
Source: EEA.

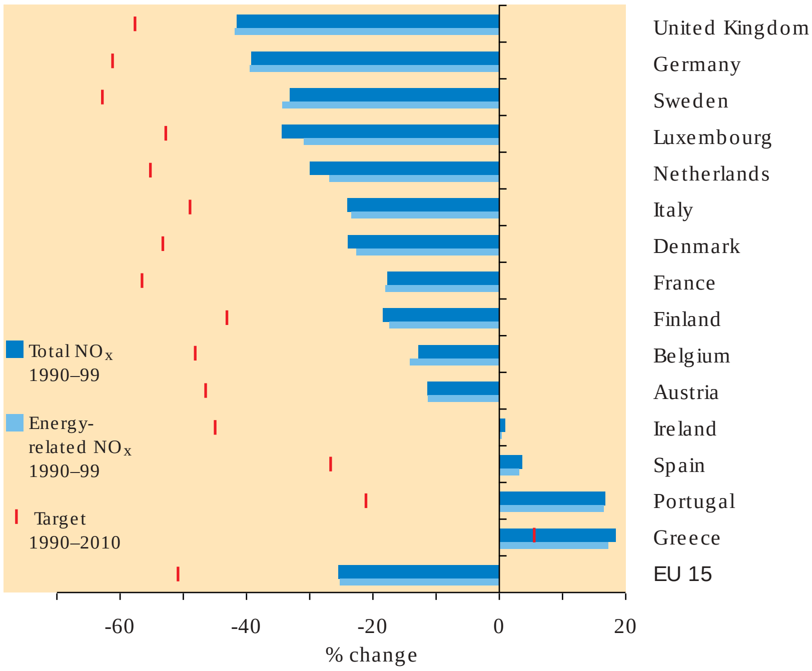
Explanations for the reduction of emissions of sulphur dioxide in the electricity sector



Note: Data and analysis presented here are preliminary results of ongoing work to refine and improve associated statistics and methodology.
Source: EEA.

Energy-related emissions of nitrogen oxides fell, placing the EU and some Member States on track to achieve their 2010 reduction targets for total nitrogen oxide emissions, as set in the national emission ceilings directive.

Figure 6 Change in total and energy-related emissions of nitrogen oxides



Note: Target values are for total emissions.
Source: EEA.

Acidifying nitrogen oxides (NO_x) are produced by the oxidation of nitrogen present in coal and lignite and in combustion air. They have similar impacts on the environment as sulphur dioxide. In addition NO_x is an important precursor for the formation of ground-level ozone, which can have adverse effects on human health and can damage crops and other vegetation.

Energy use accounted for nearly all (97 %) of NO_x emissions in 1999, with over half of this coming from transport (65 %) (see Box 5). Total emissions fell by 25 % between 1990 and 1999, which falls short of the 30 % reduction by 2000 targeted in the fifth EU environment action plan. However, if the rate of improvement is sustained, the national emission ceilings directive (NECD) target for an EU-level cut of total emissions by 51 % (relative to 1990) should be attained by 2010.

The NECD sets targets at Member State level as well as for the EU overall. Germany, Italy, Luxembourg, the Netherlands, Sweden and the UK are currently on track to attain their targets[11]. Other countries need to accelerate the reduction rates achieved between 1990 and 1999, while Greece, Ireland, Portugal and Spain need to reverse their growing emission trends.

Across the EU the greatest absolute reduction came from transport, due mainly to the introduction of catalytic converters on motor vehicles. However, some of the environmental benefit from implementing this technology has been cancelled by the growth in road transport. The energy supply and industry sectors also considerably reduced their energy-related emissions, by 43 % and 23 % respectively. This was achieved through a combination of measures, encouraged by the requirements of the large combustion plant directive (European Parliament and Council, 2001a), including the use of pollution abatement technologies (e.g. low NO_x burners, flue gas treatment and selective catalytic converters) and fuel switching from coal and lignite to natural gas, and by the requirements of the integrated pollution prevention and control directive (European Parliament and Council, 1996a) on the use of best available technology. The reduction in emissions from manufacturing industry was also linked to some structural changes away from energy-intensive industries.

11 This conclusion is based on a ‘distance-to-target’ assessment which measured how far emissions in 1999 were from a linear emission reduction target path from 1990 to 2010, and assessed whether a Member State was on track to meet its target.

The reduction in energy-related emissions of non-methane volatile organic compounds (NMVOCs) has greatly helped to put the EU and some Member States on course to achieve their 2010 targets for reducing total NMVOC emissions, as set in the national emission ceilings directive.

Non-methane volatile organic compounds (NMVOCs) in the atmosphere react with nitrogen oxides in the presence of sunlight to form ozone. Ozone formed by such processes can build up at ground level, particularly in urban areas, having an adverse effect on human health as well as damaging crops and other vegetation.

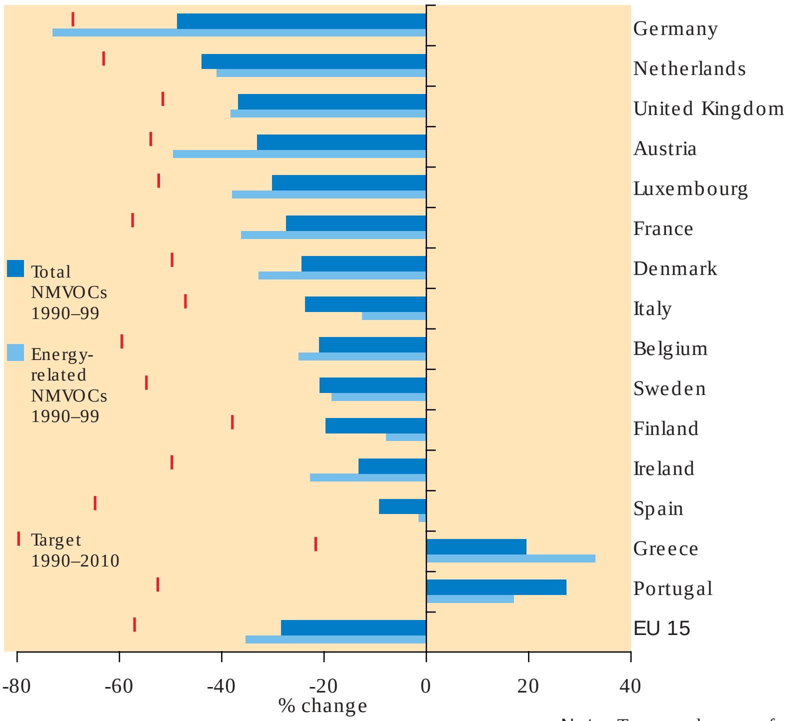
Energy use accounts for about half of NMVOC emissions, with the bulk of this coming from transport (see Box 1). Total EU emissions were reduced by 28 % between 1990 and 1999, which falls short of the 30 % reduction target for 1999 set in the fifth EU environment action plan. However, energy-related emissions were reduced by 35 %. The national emission ceilings directive (NECD) has set a target for a 60 % cut in total emissions, to be attained by 2010, and the EU overall is on course to attain this target[12].

Most Member States, led by Germany, the Netherlands and the UK, have shared in the reduction. Portugal and Greece increased emissions over the 1990 to 1999 period.

The greatest absolute reduction came from transport (38 %), due mainly to the introduction of catalytic converters and other exhaust gas treatments on road vehicles, driven by stricter EU standards for both passenger and commercial vehicle emissions (see Box 5). Nonetheless transport remains the largest source, accounting for 74 % of all energy-related emissions in 1999. Emissions from the energy supply sector were also reduced (37 %), mainly through a cut in fugitive emissions from the storage and distribution of petrol, driven by implementation of the EU directive on the control of volatile organic compound (VOC) emissions from petrol (European Parliament and Council, 1994).

Change in total and energy-related NMVOC emissions

Figure 7



Note: Target values are for total emissions.
Source: EEA.

12 This conclusion is based on a 'distance-to-target' assessment which measured how far emissions in 1999 were from a linear emission reduction target path from 1990 to 2010, and assessed whether a Member State was on track to meet its target.

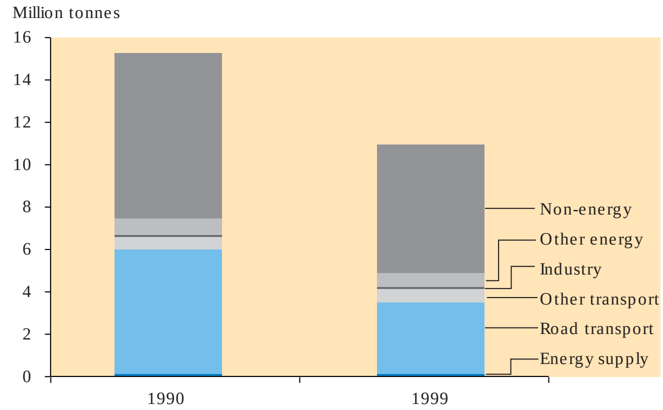
Box 5 What further improvements can be anticipated in emissions of nitrogen oxides and non-methane volatile organic compounds from energy-related activities?

Despite significant improvements between 1990 and 1999, transport remains by far the largest source of NO_x (> 60 % of total emissions) and the main energy-related source of NMVOCs (37 % of total emissions).

The downward trend in road transport emissions should be maintained in the future through the increasingly stringent standards for vehicle exhaust emissions set in the Euro I, II, III and IV standards for cars, goods vehicles and heavy-duty vehicles (European Parliament and Council 1991, 1993b, 1998a and 1999). Non-road transport emissions arise mainly from off-road vehicles and shipping.

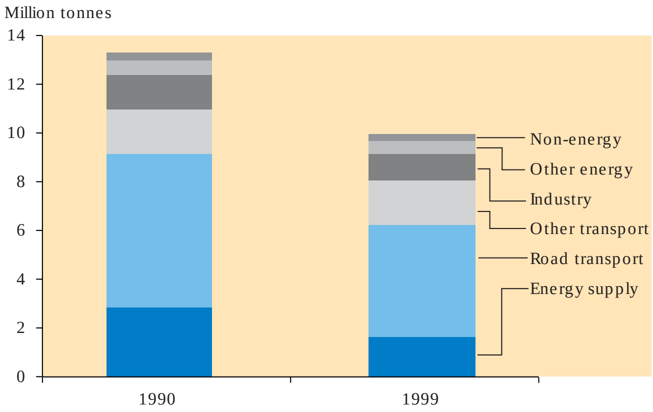
The actual rate of reduction will be determined by the rate of replacement of the EU vehicle fleet and the rate of growth in demand for mobility. Car lifetimes are of the order of 10 to 15 years, so the full benefit of these improved standards will not be gained for some time. Moreover, there are uncertainties over the long-term performance of exhaust catalysts under actual operating conditions. However, in the long term the reduction will be substantial in view of the large improvements in emission standards required for 2000 and 2005 vehicles.

Emissions of non-methane volatile organic compounds



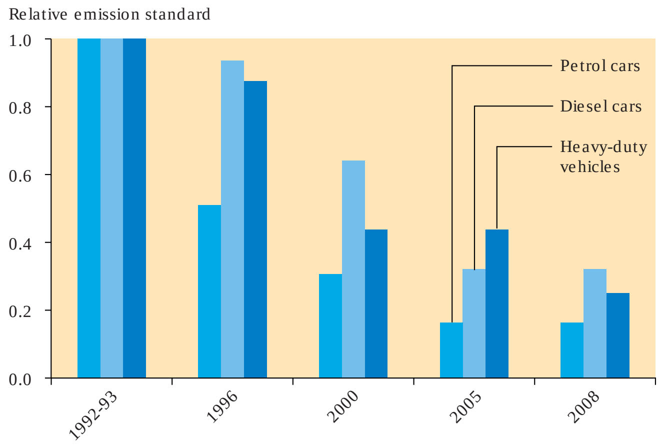
Source: EEA.

Emissions of nitrogen oxides



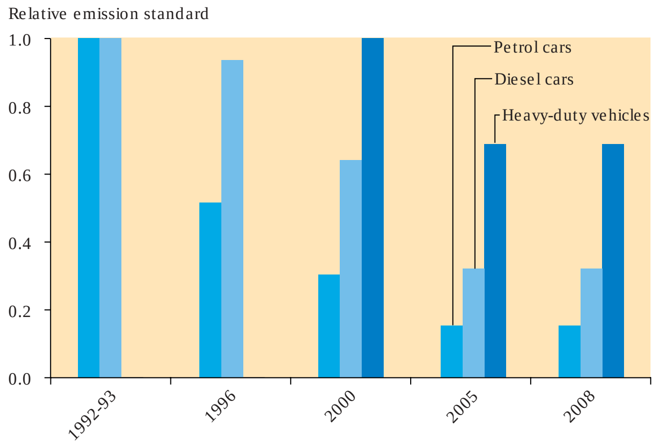
Source: EEA.

Current and future vehicle emission standards for non-methane volatile organic compounds



Note: The relative emission standard shows how the standard has been tightened relative to the first that was set. For example the emission standard for NVMOCs from petrol cars in 2008 is only 16 % of the 1992-93 standard and therefore has a relative emission standard of 0.16.
Source: EEA.

Current and future vehicle emission standards for nitrogen oxides



Source: EEA.

Energy-related emissions of particulates fell by 37 % between 1990 and 1999, mainly as a result of reductions from power plant and road transport.

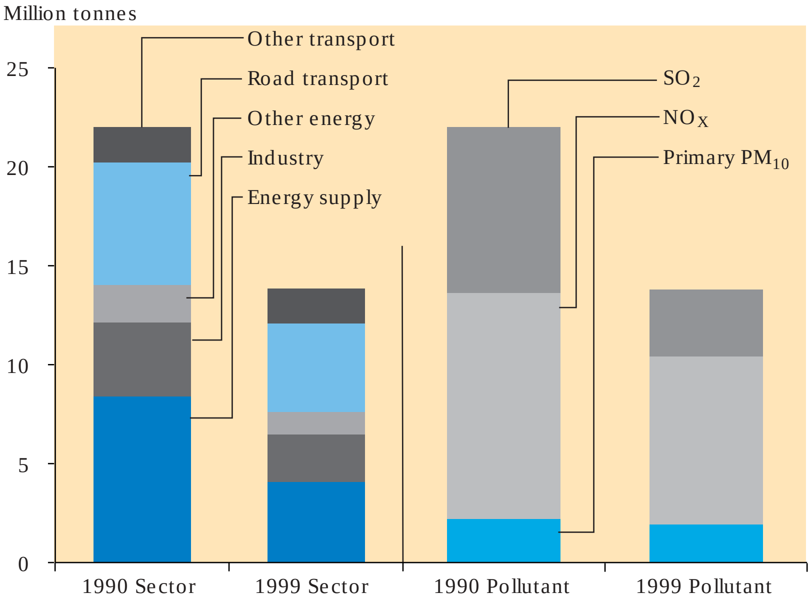
Breathing in fine particulate matter can have an adverse effect on human health. The impact is predominantly associated with PM_{10} (particulate matter with a diameter of 10 µm or less). Inhalation of such particles can increase the frequency and severity of respiratory symptoms and the risk of premature death.

PM_{10} results from direct emissions (primary PM_{10}) and from precursors, such as nitrogen oxides, sulphur dioxide and ammonia, which are partly transformed into particles by chemical reactions in the atmosphere (secondary PM_{10}). Energy-related particulate emissions accounted for 87 % of total EU emissions in 1990, falling to 83 % in 1999. Of these, about 14 % came from primary sources, 61 % from NO_X and 24 % from SO_2. However, these estimates are less accurate than for other pollutants because of uncertainties in emissions of other particulate species, such as organic and inorganic carbon compounds.

Total energy-related PM_{10} emissions are estimated to have fallen by 37 % between 1990 and 1999, with most of the reduction coming from the NO_X (13 %) and SO_2 (23 %) precursors. Energy supply, road transport and industry contributed most to this reduction through fuel switching to lower-sulphur fuels, end-of-pipe treatments in industry and power supply, and increased penetration of catalytic converters in road vehicles.

There are no emission limits or targets for PM_{10} within the EU, although the area benefits from limits to the precursors under the national emission ceiling directive. Air quality concentration limit values are set under the ambient air quality directive (European Parliament and Council, 1996c). Despite the improvements described above, the Auto-Oil II programme (European Commission, 2000c) has estimated that these air quality standards are likely to be exceeded in urban locations, mainly as a result of the continued growth of road transport.

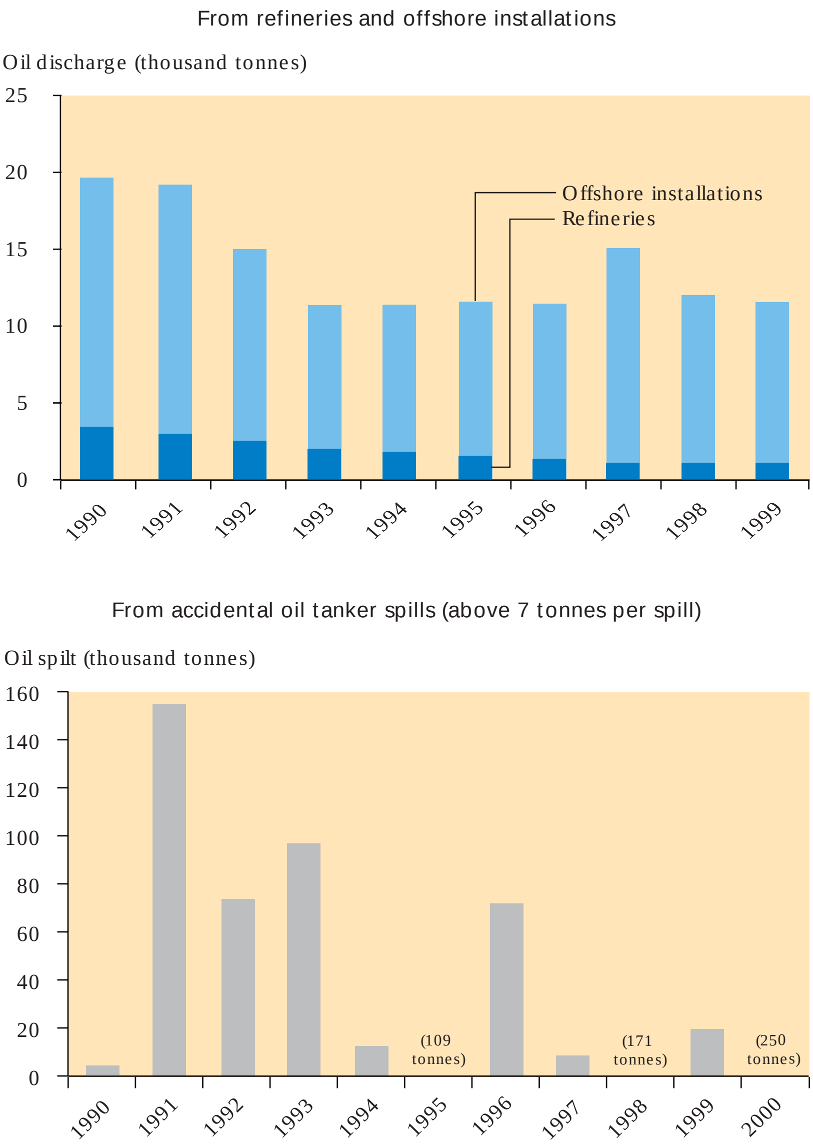
Energy-related primary and secondary particulate emissions — Figure 8



Notes: PM_{10} arising from NH_3 is included in the totals but it is not visible in the graph because it is such a small fraction. Estimates for particulates are much more uncertain than for other air pollutants.
Source: EEA.

Oil pollution from offshore installations and coastal refineries has been reduced, but major oil tanker spills continue to occur.

Figure 9 Marine environment oil pollution



Sources: Eurostat, OSPAR, CONCAWE, DHI, ITOPF.

1.3. Other energy-related pressures

Oil pollution from coastal refineries, offshore installations and maritime transport place significant pressures on the marine environment. Refinery emissions have been controlled under national integrated pollution control regulations and are now also subject to the EU directive on integrated pollution prevention and control, which requires the application of the best available technology to new and refurbished plant. Discharges from offshore installations are regulated by the dangerous substances directive (European Parliament and Council, 1976) and the OSPAR Convention for the Protection of the Marine Environment of the North East Atlantic.

Oil discharges from offshore installations and refineries were reduced by about 40 % between 1990 and 1999. Refineries reduced their discharges by 68 % and offshore installations by 35 %. These reductions were achieved through the increased application of cleaning and separation technologies and despite increasing production.

Tanker oil spills continue, although both the frequency and amounts involved have declined over the past decade. This may reflect the erratic occurrence of such accidents, but it is encouraging that the improvement has come despite increasing maritime transport of oil. Increased safety measures, such as the introduction of double-hulled tankers, have contributed to this improvement. However, the data do not include spills and discharges below 7 tonnes, and therefore underestimate oil pollution from maritime transport.

Highly radioactive waste from nuclear power production continues to accumulate: a generally acceptable disposal route is yet to be identified.

Nuclear power is responsible for a steady accumulation of radioactive waste that poses a potential threat to the environment. The release of radioactivity to the environment can result in acute or chronic impacts that, in extreme cases, can cause loss of biota in the short term and genetic mutation in the longer term, both of which may result in unknown or fatal effects. Increased levels of radioactivity can also be passed up through the food chain and affect human food resources. Radioactive waste consists of three categories:

- Low-level waste (LLW) — slightly radioactive materials, such as safety clothing;
- Intermediate-level waste (ILW) — more radioactive materials such as sludge from water clean-up and some reprocessing and decommissioning wastes;
- High-level waste (HLW) — initially this waste is predominantly spent nuclear fuel (the fuel removed from nuclear power plant after most of its energy has been used up). Some spent fuel is reprocessed to separate plutonium and uranium for reuse as nuclear fuel. The liquid rafinate left over from this process is stored for some years and then vitrified into a solid form, which constitutes the second important source of HLW. Spent fuel and vitrified HLW is the most highly radioactive waste, in many cases taking several hundred thousand years to decay.

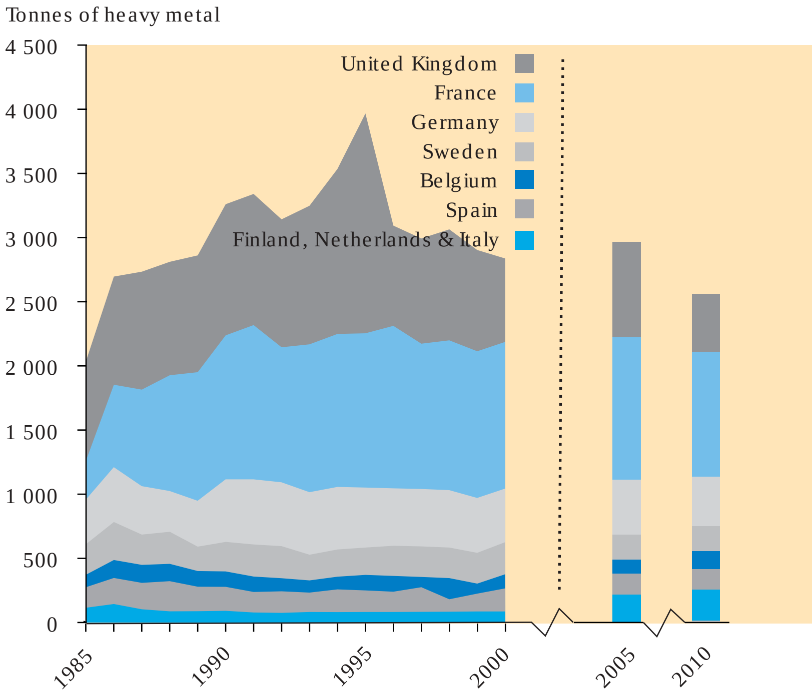
LLW and some ILW is routinely disposed of at surface or near-surface burial sites. Plans for the disposal of ILW not suitable for near-surface disposal and all HLW generally involve deep burial, but at present most waste of this type is held in engineered stores awaiting agreement on the location and design of deep repositories. Progress in identifying suitable sites for deep burial is slow because of a lack of scientific consensus on the methods to be used and public concerns over safety aspects (European Commission, 1998b).

The quantity of spent fuel produced provides a 'reliable representation of the radioactive waste disposal situation and its evolution over time' (OECD, 1993). Nuclear waste data other than for spent fuel are not comprehensive or up-to-date. The total amount of spent fuel discharged from nuclear power plant, measured in tonnes of heavy metal, increased by more than 48 500 tonnes between 1985 and 2000, reflecting the total amount of nuclear power produced over that period (OECD, 1999). With only limited potential for increasing the efficiency with which nuclear heat is converted into electricity in existing power stations or getting more energy out of each tonne of fuel (increased burn-up), a quite similar rate of nuclear fuel discharge can be expected over the next decade for all countries except the UK, reflecting similar rates of nuclear power production. Discharges in the UK are expected to decline from 2000 to 2010 as some plants are retired.

The European Commission has proposed more support for research and development on nuclear waste management in its sustainable development strategy (European Commission, 2001b).

Annual quantities of spent nuclear fuel from nuclear power plant

Figure 10



Note: The vast majority of highly radioactive waste consists of spent fuel and spent-fuel reprocessing wastes. 2000 figures for Spain, Sweden and the UK are based on provisional data. Projected data are taken from national projections with the exception of Sweden for 2010, which is an OECD projection. Austria, Denmark, Greece, Ireland, Luxembourg and Portugal do not have nuclear power plant. Italy phased out commercial nuclear power in 1987. The projected increase attributed to Finland, Italy and the Netherlands is due to a projected increase from Finland only.

Source: OECD.

2. Are we using less energy?

$$\text{PRESSURE} = \text{DRIVER} \times \frac{\text{ENERGY}}{\text{DRIVER}} \times \frac{\text{PRESSURE}}{\text{ENERGY}}$$

Energy consumption is increasing, mainly because of growth in transport but also in the household and services sectors. However, the rate of increase is expected to slow by 2010 as fuel efficiency improvements in transport are realised.

One of the aims of the EU strategy for integrating environmental considerations into energy policy is to increase energy saving (European Commission, 1998a). All things being equal, an increase in energy use will result in a corresponding increase in environmental pressures. Therefore one way of reducing such pressures is to use less energy, by reducing energy demand (e.g. for heat, light, personal mobility, freight delivery), by using more energy-efficient devices (thereby using less energy per unit of demand), or by a combination of the two. This section looks at the overall pattern of energy consumption while section 3 examines whether we are finding ways of improving energy efficiency.

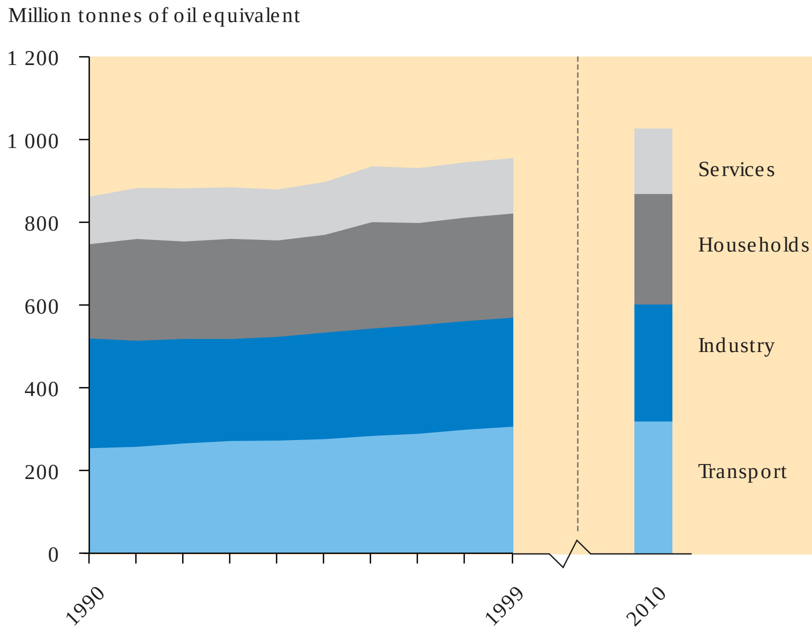
Energy consumption in the EU continued to grow between 1990 and 1999; this trend is expected to continue.

EU final energy consumption[13] grew by an average of 1.1 % per year between 1990 and 1999, compared with average gross domestic product (GDP) growth of 2.1 % per year. It increased in absolute terms in all sectors except manufacturing industry, which had recovered to roughly its 1990 level by 1999. The relative decline in industry's consumption reflects some efficiency improvements but mainly structural changes, including a shift towards less energy-intensive industries, a shift in the location of energy-intensive industries away from industrialised EU countries, and post-unification restructuring of German industry. The fastest growth in demand was for transport, which increased its share from 29.4 % to 32 % over the period. The services sector also had faster-than-average growth, increasing its share from 13.3 % to 14.0 %.

Baseline projections developed for the European Commission[14] (NTUA, 2000a) expect continued growth in consumption from 2000 to 2010, but at a lower rate. Consumption is expected to increase in all sectors. The rate of increase in the transport sector is expected to be less than for 1990 to 1999. This is due to expected improvements in road vehicle fuel efficiencies, stemming from the voluntary agreement between car manufacturers and the EU (the ACEA agreement), rather than to a slowdown in the growth of demand for mobility.

Within this demand pattern, important changes are occurring in the mix of energy sources. Consumption of coal and lignite (outside electricity production) halved between 1990 and 1999, and is expected to decline further. Coal and lignite are major sources of energy-related acidifying gases and particulate emissions, as well as releasing more carbon dioxide per unit of energy consumed than other fuels. As shown in the previous section, the environment has already benefited from the trend away from these fuels. In contrast electricity continues to take an increasing share of the market and, if it is produced with the current fuel mix, the pressure on the environment could increase. Oil-derived fuel consumption (mainly for transport) also grew between 1990 and 1999, and this is expected to continue in absolute terms, although it may take a slightly smaller share of a growing total market by 2010. This reflects the dominance of oil-based fuels in transport, with alternative fuels that could place less pressure on the environment at only an early stage of commercial development.

Final energy consumption — Figure 11



Source: Eurostat.

Percentage shares of energy sources in final energy demand — Table 3

	1990	1999
Coal and lignite	8 %	4 %
Oil	44 %	46 %
Natural gas	18 %	21 %
Electricity	18 %	20 %
Other	12 %	9 %

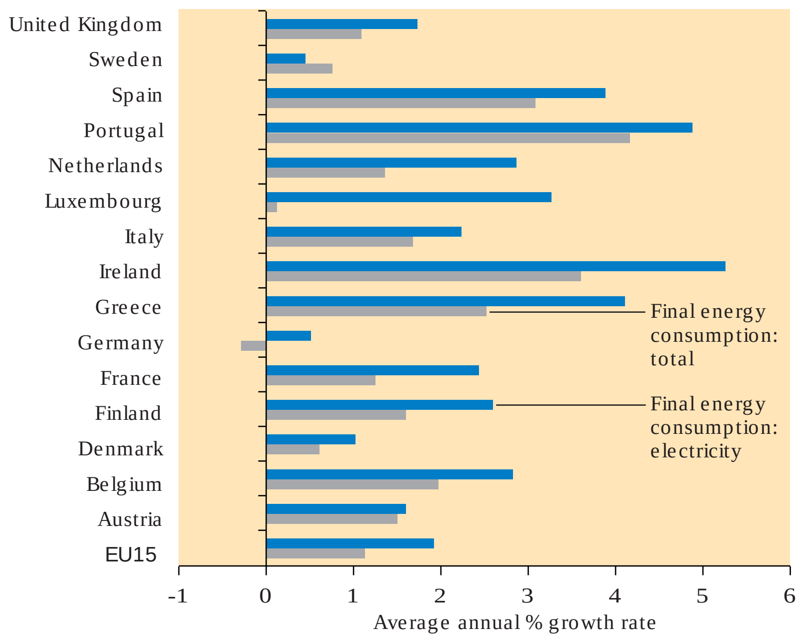
Note: Other energy sources are publicly supplied heat and direct use of renewable energy sources such as solar heat and biomass.

Source: Eurostat.

13 Final energy consumption is the consumption of the transport, industrial, household and services sectors. It includes the consumption of converted energy (electricity, publicly supplied heat, refined oil products, coke, etc.) and the direct use of primary fuels such as natural gas or renewables (e.g. solar heat or biomass).
14 See Annex 1 for information on the baseline projections.

Electricity consumption in the EU grew faster than final energy consumption between 1990 and 1999; this trend is expected to continue.

Figure 12 Growth in final energy consumption and electricity consumption, 1990–99



Source: Eurostat.

Electricity is particularly important to the interaction between energy consumption and the environment for a number of reasons:

- Its flexibility of use and the importance placed by consumers on the energy services it provides mean that demand is growing significantly faster than for total final energy.
- Demand is also being affected by electricity market liberalisation that is tending to drive down prices.
- Because electricity is produced from other fuels with a conversion efficiency of typically 30–50 %, consumption of one unit of electrical energy results in the consumption of two to three units of another energy source. Since most electricity is produced from fossil fuels, growth in electricity consumption without other changes would result in a disproportionate increase in environmental pressures, in particular in carbon dioxide emissions.
- A large proportion of electricity is produced in large centralised plants that provide better economies of scale for pollution abatement measures.
- There is a strong drive for innovation in electricity production to produce cheaper, cleaner and more efficient technologies.
- Combined heat and power offers substantial energy efficiency gains.
- Electricity offers a route for developing and exploiting non-fossil energy sources.

Consequently an increase in electricity consumption is not necessarily bad for the environment, providing this comes from high-efficiency, low-emission technologies that reduce sufficiently the environmental consequences of electricity production.

Electricity consumption across the EU grew at an average annual rate of 1.9 % between 1990 and 1999. This compares with a GDP growth rate of 2.1 % per year and overall final energy growth of 1.1 % per year, which shows that the linkage between electricity consumption and economic growth remains stronger than for overall final energy consumption. Growth in electricity consumption was particularly strong in the services sector followed by the household sector. In both cases this was linked to additional energy demand rather than the substitution of electricity for another fuel.

The use of electrical energy for heating is a particularly inefficient use of the original energy resource, since the vast majority of electrical energy is produced from heat. Member States are finding ways to address this issue. In Denmark, the Electricity Saving Fund, financed by a levy on domestic electricity consumption, enables the government to grant subsidies for the conversion of electrically heated dwellings to district heating or natural gas. The fund is expected to facilitate the conversion of around 50 000 electrically heated dwellings by 2006. Also, natural gas companies encourage customers to choose gas rather than electricity for cooking. Each new installation is supported by a subsidy from the government.

Electricity consumption across the EU is projected to continue to grow to 2010 at an annual average rate similar to that between 1990 and 1999 (NTUA, 2000a). Once again growth in consumption is expected to be strongest in the economically buoyant services area. Transport-related electricity consumption is also expected to grow significantly, driven by further electrification of the rail network, but this will be from a very low base.

Table 4 Electricity consumption by sector (TWh/year)

	1990	1999	Annual growth in demand 1990–99 (%)
Household	45	54	2.2
Industry	69	77	1.2
Services	38	49	2.8
Transport	4	5	2.2
Total	156	185	1.9

Source: Eurostat.

3. How rapidly is energy efficiency being increased?

Improvements in energy efficiency have been slow, but improvements in some Member States are showing the potential benefits of good practices and strategies.

The EU sixth environment action programme identifies the promotion of energy efficiency as a priority action (Council of the European Union, 2002). The Barcelona European Council, March 2002, stressed the need to show substantial progress in energy efficiency by 2010 (European Council, 2002).

Energy efficiency is concerned with minimising the energy needed to meet the demands for energy-related services that originate from economic and social drivers (e.g. economic growth, demand for freight transport, personal mobility, warmth and comfort in the home). Cost-effective improvements in the way we use energy contribute to all three main goals of energy policy: security of supply, competitiveness and environmental protection.

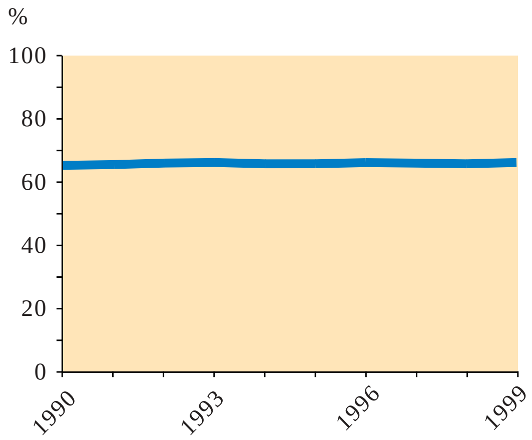
Energy efficiency applies both to the production and the consumption of energy.

Efficiency in the energy supply industries (e.g. electricity production, oil refining) is the ratio of energy input to energy output and thus comparatively easy to measure. Energy intensities are used in this report to measure trends in energy consumption efficiency. Energy intensities measure the energy needed to support economic activity (e.g. energy per unit of gross domestic product (GDP) or value added) or to provide social needs (e.g. energy per capita). They therefore indicate trends in energy efficiency and measure changes arising from both structural and technological change (see Box 7).

The overall efficiency with which energy is converted for final consumption did not improve between 1990 and 1999.

Figure 13 Ratio of final to total energy consumption

Source: Eurostat.



3.1. Efficiency in energy supply

The overall efficiency of conversion of primary into usable or final energy is the ratio of final energy consumption[15] to total energy consumption[16]. The difference between these is the energy used in conversion processes such as electricity generation and oil refining, the energy supply industry's own consumption, and losses in distribution and delivery.

The ratio remained fairly constant at about 65 % between 1990 and 1999. Efficiency gains in conversion processes were offset by converted fuels (e.g. electricity, refined petroleum products) taking a larger share of final energy consumption (see Box 6).

15 Final energy consumption is the energy consumption of the transport, industry, household, agriculture and services sectors. It includes the consumption of converted energy (i.e. electricity, publicly supplied heat, refined oil products, coke, etc.) and the direct use of primary fuels such as natural gas or renewables (e.g. solar heat or biomass).

16 Total energy consumption is also known as gross inland energy consumption (GIEC). It is a measure of the energy inputs to an economy and can be calculated by adding total indigenous energy production, energy imports minus exports and net withdrawals from existing stocks.

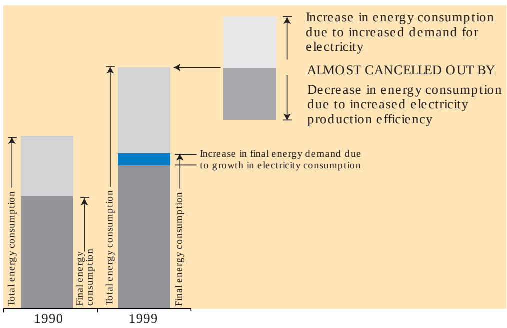
Why is overall EU energy conversion efficiency not improving? — Box 6

The ratio of final to total energy consumption remained almost constant at about 65 % over the period 1990-99 mainly as result of two approximately equal but opposing effects, illustrated in the diagram below. They are:

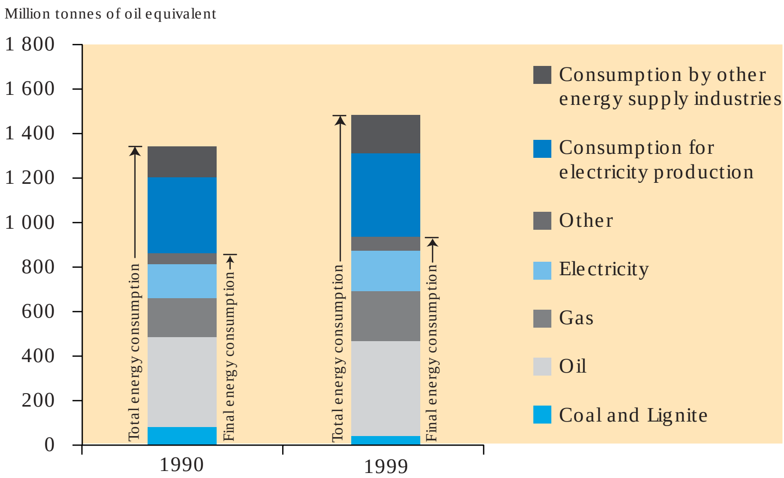
- The overall efficiency of electricity supply (including own use and distribution) improved by about 5 % between 1990 and 1999, so the electricity industry consumed by about 5 % less energy than it would otherwise have consumed. On its own, this would have increased the ratio of final to total energy consumption (i.e. less total energy would be needed to satisfy the demand from final consumers).
- The share of electricity in final consumption increased by 2 % between 1990 and 1999. This increased the amount of energy consumed in electricity production in 1999 by 2 % divided by the overall efficiency of electricity production in 1999 (i.e. about 36 %), which is about 6 % in total. On its own, this would have decreased the ratio of final to total energy consumption (i.e. more total energy would be needed to satisfy the demand from final consumers).

In addition to the changes in electricity production, the efficiency of oil refining fell by about 1 % between 1990 and 1999, reflecting the additional energy needed to produce higher-specification fuels (i.e. low sulphur, unleaded). This on its own would have decreased the ratio of final to total energy. However, less energy was consumed by other energy supply industries, due to factors such as the rundown of coal mining, which on its own would have increased the ratio. Overall these trends again effectively cancelled each other out.

Schematic illustration of the opposing effects of increased electricity demand and improved electricity production efficiency on the ratio of final to total energy consumption



Components of total and final energy consumption



Notes: 1. 'Consumption of other energy supply industries' includes oil refineries, fossil fuel extraction, heat production by public producers, heat and electricity production by autogenerators and the production of other processed fuels such a smokeless solid fuel.
2. The 'Other' category in final energy consumption includes heat and biomass/waste.
Source: Eurostat.

The efficiency of electricity production from fossil fuels improved between 1990 and 1999, but electricity consumption from fossil fuels grew more rapidly, outweighing the benefits to the environment from these improvements.

Figure 14 Improvement in fossil fuel electricity production efficiency

Notes: The calculation of the efficiency of electricity production from fossil fuels includes fuel inputs for both electricity and heat production from public combined heat and power plant, and only electricity output from combined heat and power plant. The fuel input and output data include biomass/waste which accounted for 3 % of electricity production in 1999.
Source: Eurostat.

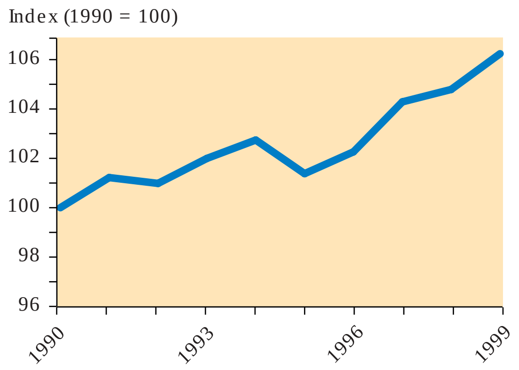


Table 5 Percentage of fossil-fuelled electricity production capacity by technology

	1990	1993	1996	1999
Steam turbines	91 %	88 %	82 %	78 %
Gas turbines (single cycle)	7 %	7 %	8 %	8 %
Gas turbines (combined cycle)	1 %	4 %	8 %	12 %
Oil and gas engines	1 %	1 %	2 %	2 %

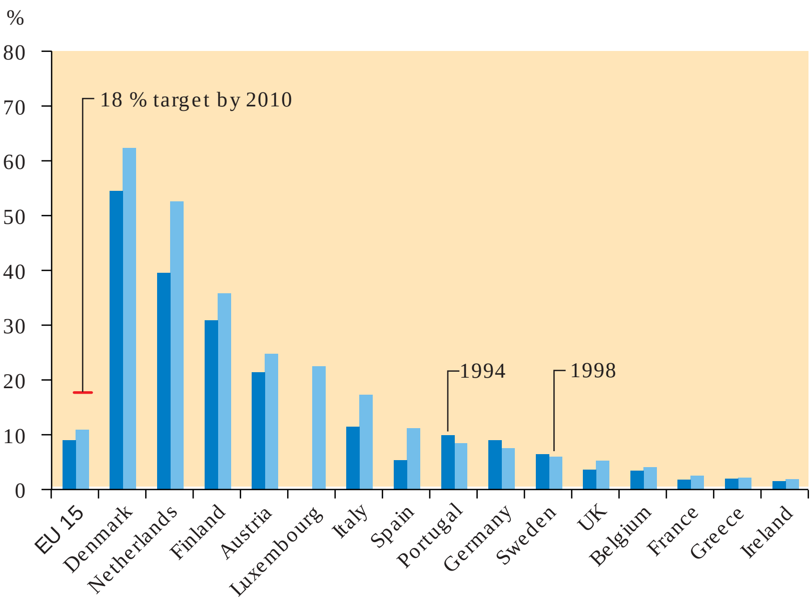
With electricity taking an increasing share of EU energy consumption, it is important for electricity production to operate with maximum efficiency. This is doubly important for fossil-fuelled plant, a major source of greenhouse gases and air pollutants. The share of electricity produced by such plant remained steady at a little over 50 % over the period 1990–99. Some improvement in efficiency can be gained by better operational management, but major improvements come from the retirement of old, inefficient facilities when they reach the end of their design lives (typically 25 to 40 years). Imminent investment decisions on new plant will affect the environmental performance of electricity production for several decades.

Although electricity production from fossil-fuelled plant has remained steady, there have been significant changes to the mix of fuels used (see later indicator) and in the mix of technologies in operation (Table 5). The most important are the switch to gas firing, which increased from 14 % of production in 1990 to 33 % in 1999, and investment in gas-turbine combined-cycle (GTCC) plant. Such plants can achieve conversion efficiencies of the order of 50–60 %, with the prospect of even higher efficiencies in future plant, compared with 36–38 % for the steam turbine plant used with coal and lignite (European Commission, 2002). This made a significant contribution to the overall improvement in the efficiency of electricity production from fossil fuels recorded between 1990 and 1999.

The share of electricity from combined heat and power (CHP) increased across the EU between 1994 and 1998, but faster growth is needed to meet the EU target; preliminary information suggests that the share of electricity produced by CHP declined between 1998 and 2001.

Share of gross electricity production from combined heat and power plant

Figure 15



Source: Eurostat.

Combined heat and power (CHP) technology uses fossil fuels, biomass or waste to generate a mix of heat and electricity. In so doing it avoids much of the waste heat losses associated with normal electricity production, thereby utilising more than 80 % of the energy in the fuel rather than the average of about 36 % in current plant producing only electricity. An expansion of CHP could make an appreciable contribution to energy efficiency and consequently to the environmental performance of electricity and heat production. The EU has set an indicative target to derive 18 % of all electricity production from CHP by 2010 (European Commission, 1997a).

CHP increased its share of electricity production from 9 % to almost 11 % between 1994 and 1998, although this rate of expansion is not sufficient to achieve the EU target.

Growth was strongest in Member States that have ambitious programmes and targets for the technology such as Finland, Denmark, Italy, the Netherlands and Spain. However, progress in other countries with ambitious targets, such as Germany (20 % of power by 2010) and the UK (increase capacity from 3 to 10 GW, 1994–2010) was less.

Concern is raised by preliminary information for 2001, which suggests that the CHP share of production has declined since 1998 (COGEN Europe, 2001). This reverse is spread across the EU, but most severe indications were noted in Germany, the Netherlands and the UK.

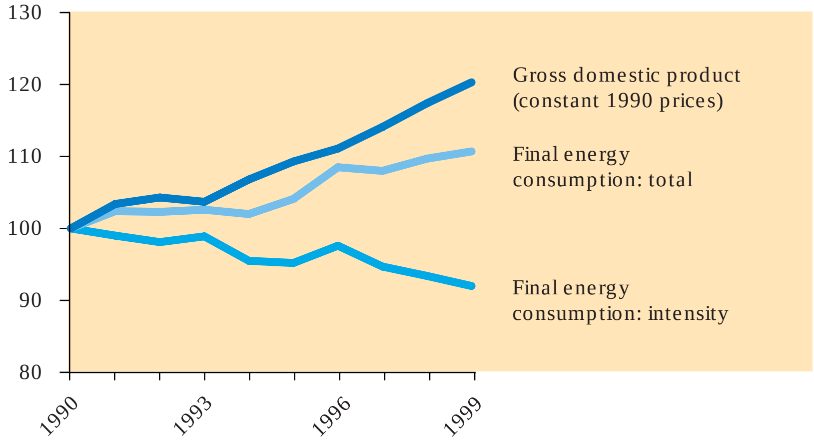
This decline has been caused by a combination of factors.

- Increasing natural gas prices (gas is the preferred fuel for new CHP) have reduced the cost-competitiveness of CHP.
- Falling electricity prices, resulting from market liberalisation and increased competition, have also hit the cost-competitiveness of CHP.
- Uncertainty over the evolution of electricity markets as liberalisation is progressively extended is making companies reluctant to invest in CHP.
- Aggressive pricing has been used by electricity utilities to protect their market.

Clearly further measures are needed across the EU to achieve the target of producing 18 % of electricity from CHP, against a background of growing electricity demand and increasing liberalisation of electricity markets. The German CHP law, passed in early 2002, provides an example of how to alleviate this situation through a number of support mechanisms, including agreed electricity purchase prices fro existing CHP installations and for new, small-scale units.

Economic growth is requiring less additional energy consumption, but energy consumption is still increasing.

Figure 16 | Final energy consumption, gross domestic product and final energy intensity



Source: Eurostat.

3.2. Efficiency in energy consumption

Overall performance in improving energy efficiency can be measured by the final energy intensity indicator (i.e. final energy consumption per unit of GDP) — see Box 7.

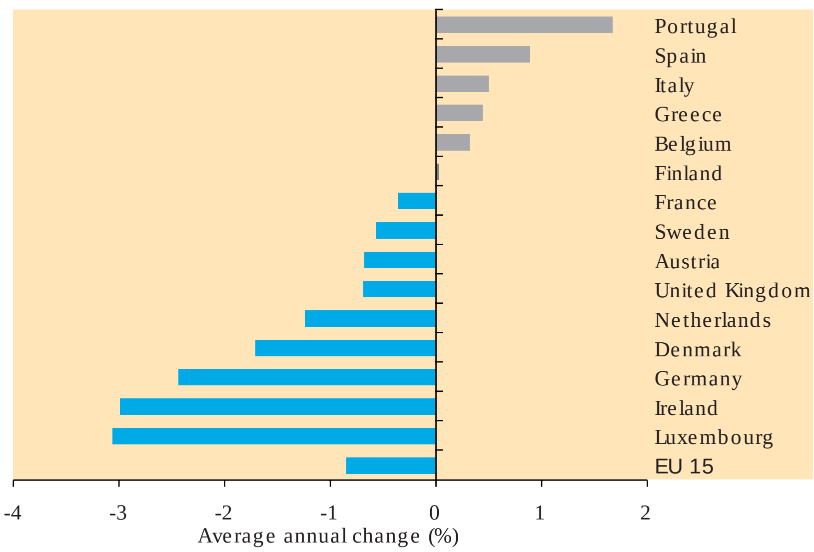
Final energy intensity in the EU fell by an average of 0.9 % per annum between 1990 and 1999. However, this was not sufficient to prevent an increase in final energy consumption because average GDP growth was higher at 2.1 % per year.

The European Commission proposed, and the Council supported, an EU indicative target of reducing final energy intensity by 1 % per year above 'that which would have otherwise been attained' for the period 1998–2010 (Council of the European Union, 1998; European Commission, 2000e). However, 'that which would have otherwise been attained' has not yet been defined, so it is not clear how such a target can be measured and monitored.

The final energy intensity of Member States in 1999 varied by more than a factor of two, reflecting differences in their state of development, the structure of their economies, climate variations and the success of energy efficiency measures. There were impressive reductions between 1990 and 1999 in Luxembourg due to one-off changes and in Ireland due to high growth in low energy-intensive industries and the services sector. The overall intensity for the EU would have increased if it were not for the substantial reduction in Germany helped by energy efficiency improvements. The implementation of energy efficiency policies in Denmark and the Netherlands played an important role in the reductions in these countries.

The rate of improvement in final energy intensity between 1990 and 1999 was less than for earlier years. During the 1973 and 1990 period the EU achieved an average annual reduction of 1.9 %. This was driven by the oil price rises of the 1970s and early 1980s, which prompted energy-saving measures that persisted after oil prices fell again. However, in the 1990s the combination of abundant energy supplies, low fossil fuel prices and a generally low priority for energy saving has resulted in a slower rate of improvement.
EU GDP is expected to grow by an average of 2.3 % per year between 2000 and 2010 (European Commission, 1999a). If final energy intensity continues to improve between 2000 and 2010 at the rate recorded from 1990 to 1999, this rate of economic growth would result in a further energy consumption increase between 2000 and 2010.

Figure 17 | Annual change in final energy intensity, 1990–99



Source: Eurostat.

Table 6 | Average annual rates of change of final energy intensity

	Change in final energy intensity (%/year)
1973-90	- 1.9
1990-99	- 0.9

Source: Eurostat.

With the exception of industry, no EU economic sector has decoupled economic/social development from energy consumption sufficiently to stop growth of its energy consumption.

The linkage between the growth and the energy consumption of a sector can only be broken if the rate of reduction of its energy intensity at least equals its rate of growth.

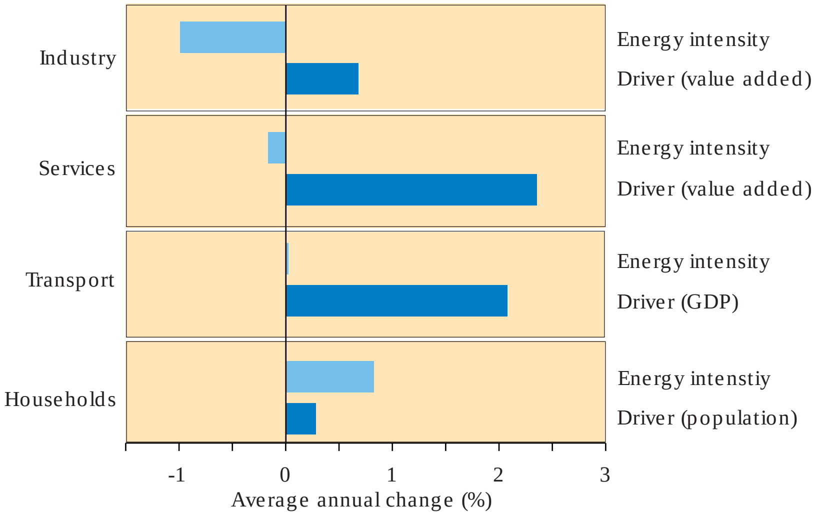
The industry sector has shown a sustained improvement in energy intensity, averaging 1 % per year between 1990 and 1999, which was sufficient to offset the rate of growth in the sector measured in terms of value added. Many factors contributed to this, including structural changes in favour of higher value-added products, changes in some industries to less energy-intensive processes, direct improvements in energy efficiency, and import substitution. There is still a large potential for energy saving in this sector which the EU and national governments are seeking to achieve through voluntary agreements with individual production sectors and the promotion of combined heat and power (European Commission 1997a and 2000d).

The services sector has also shown a reduction in energy intensity, averaging 0.2 % per year between 1990 and 1999. About 84 % of energy consumption in the sector is associated with installed devices such as space heating/cooling, water heating and lighting (European Commission, 2001d) with the remaining 16 % made up mainly of office equipment. Energy saving in these areas will benefit from the proposed directive on the energy performance of buildings, which has suggested that a 22 % reduction on present consumption by installed devices in the service sector and domestic buildings can be achieved by 2010 (European Commission, 2001d). The sector is also leading the growth in electricity demand, particularly for office equipment and lighting. This trend is being addressed through the EU's plans to strengthen the energy-efficiency labelling scheme for office equipment (Council of the European Union, 2001), and the requirement to assess the economic potential for combined heat and power in new buildings and major refurbishments (European Commission, 2001d).

Decoupling transport growth from economic growth is an important objective of the revised Common Transport Policy (European Commission, 2001e) and the EU strategy for

Annual change in sectoral energy intensities and related drivers, 1990–99

Figure 18



sustainable development (European Council, 2001). Overall the energy intensity of the transport sector stayed fairly constant between 1990 and 1999. In 1998, 85 %[17] of transport energy use was associated with roads. Technical developments with passenger cars may have yielded some improvement in fuel efficiency between 1990 and 1999 although this was partly offset by the use of heavier and more powerful vehicles and devices that increase comfort and safety. Passenger car fuel efficiencies should improve further in the next 10 years through the voluntary agreement between the EU and the car manufacturers (the ACEA agreement). This aims to reduce the average carbon dioxide emission of new cars to 140 g CO_2/km by 2008–09 (equivalent to a 25 % fuel efficiency improvement on 1995 vehicles). However, these technical developments alone are not sufficient to yield an improvement in road transport energy intensity (ADEME, 1999). This is because energy consumption also depends on other factors including driver behaviour, congestion, journey types, choice of vehicle, vehicle maintenance and rate of replacement of old cars. Taking account of these factors, and of the expected growth of demand for both passenger and freight transport, energy consumption in the transport sector is expected to continue to increase. More detailed analysis is given in the TERM 2001 indicators report (EEA, 2001b).

Notes: Energy intensities for the industry and services sectors have been calculated as the ratio of final energy demand to value added. Energy intensity in transport is the ratio of final energy demand to gross domestic product, while for households it is final energy demand per capita. The energy intensities are not directly comparable and are shown on the graph for illustrative purposes only.
Source: Eurostat.

17 This figure excludes fuels for international shipping from total transport energy use. Including fuels for international shipping changes this figure to 74 %.

The energy intensity of the household sector, measured as household energy use per capita, increased between 1990 and 1990. This is because improvements in house insulation and the efficiency of appliances were offset by an increase in the number of dwellings (up by 10 % between 1990 and 1999) and their average size, increased comfort levels (e.g. home heating) as living standards improve, and growth in the purchase and use of appliances including televisions, computers, freezers and air conditioning. The potential for energy savings in the household sector is high (~ 22 %), and will be encouraged by the proposed directive on the energy performance of buildings, which includes minimum standards for new buildings and for certain existing buildings when they are renovated, and the requirement for all buildings to have energy performance certificates (European Commission, 2001d). The sector should also benefit from the EU's appliance labelling scheme (European Parliament and Council, 1992). Schemes that call for energy efficiency standards may help to further decrease energy intensity. For example, in the UK energy utilities are obliged to encourage or assist domestic customers to take up energy-saving opportunities such as fitting insulation or converting to more efficient domestic appliances. A small fee is collected from all domestic customers which is pooled and used to fund, partly fund or promote the uptake of more energy-efficient goods and services. By the year 2000, about 3 million households had benefited from the scheme, saving an average of approximately EUR 200 since the scheme began in 1994.

Box 7 How to measure the efficiency of energy consumption

Assessing the efficiency of energy consumption is not simple because there is more than one way to consider and measure energy efficiency. There are two basic sets of indicators for energy efficiency:

- Economic and social: these are energy-intensity indicators and measure the energy needed to support economic activity (e.g. energy per unit of gross domestic product or value added) or to provide social needs (e.g. energy per capita). They measure changes in energy efficiency arising from both structural and technological change.
- Technical: these are specific energy consumption indicators and measure the energy needed to produce a unit of physical output (e.g. one tonne of steel production). They measure changes in energy efficiency arising from technological changes alone.

The economic and social indicators are more broadly based since they measure both technological improvements and those stemming from structural and social change. For example individual citizens could reduce their energy consumption by using public transport in preference to a car, living in smaller, better-insulated houses, or using more efficient appliances. Similarly businesses could use less energy per unit of value added by cutting their energy consumption, or switching production to products that require no more energy but yield a higher added value.

The economic and social indicators measure energy efficiency improvements stemming from deliberate energy-saving actions and policy measures together with improvements driven by factors not related to energy efficiency considerations, such as product development and the impact of foreign competition.

In this report the energy intensity indicators (i.e. economic and social) are used to measure trends in energy consumption efficiency. These indicators are used partly because both EU and Member State policies aim to reduce the environmental pressures associated with energy consumption while maintaining economic development and the prosperity of EU citizens (European Commission, 2001b). At present there are insufficient data to support a comprehensive assessment of technical energy efficiency improvements. Eurostat is currently working to collect such data sets.

4. Are we switching to less-polluting fuels to meet our energy needs?

The EU is switching from coal to the relatively cleaner natural gas, but after 2010 no further switching is expected. Furthermore, some nuclear installations will retire and, if these are replaced by fossil fuel plants, increases in carbon dioxide emissions are likely. This underlines the need to further strengthen support for renewable energy sources.

The European Commission strategy to strengthen environmental integration within energy policy stresses the need to increase the share of production and use of cleaner energy sources (European Commission, 1998a). This is reflected in the sixth environment action programme which encourages renewable and low-carbon fossil fuels for power production, as part of the climate change priority actions (Council of the European Union, 2002).

The main source of environmental pressures from the production and consumption of energy is from fossil fuels that release gaseous, liquid and solid-phase pollutants. The magnitude of these pressures can be reduced by adopting advanced technologies that limit such releases, either by cleaner combustion techniques or with end-of-pipe treatments. An additional, or in some cases alternative approach, is to use cleaner fuels. This section and section 5 examine this second option.

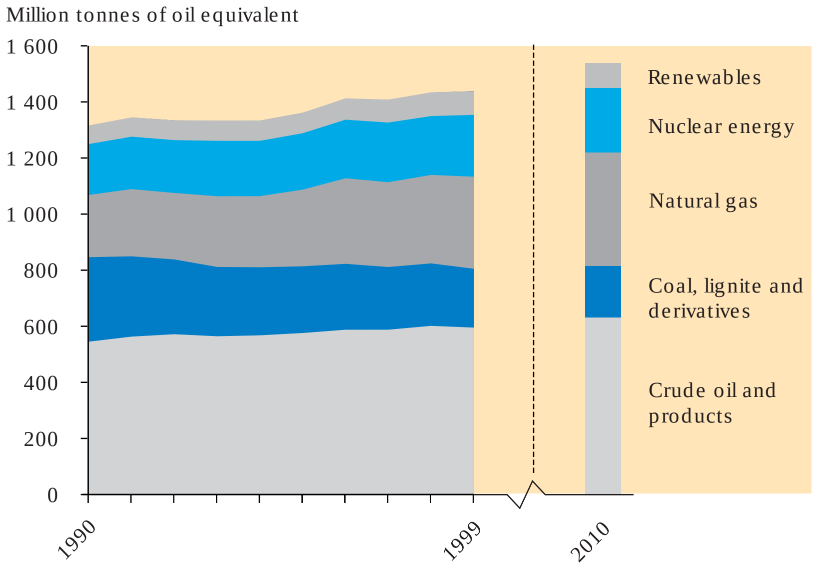
Coal and lignite are generally the most polluting fuels, followed by oil, with natural gas being the cleanest of the fossil fuels. This merit order also applies in relation to greenhouse gas emissions, with natural gas typically producing only 63 % and oil 80 % of the emissions of coal per unit of energy.

Renewable sources such as biomass, wind energy and hydro-power produce comparatively little air pollution or greenhouse gas emissions. Therefore their deployment would have an even greater benefit in reducing pollution than a switch to natural gas, although they can have some adverse impacts on the environment such as loss of natural amenities, loss of habitat, visual intrusion and noise. The EU and most Member States have taken action to support these technologies as discussed in detail in Section 5 of this report.

Nuclear power also produces little pollution under normal operations. However, there is a risk of accidental radioactive releases, and highly radioactive wastes are accumulating for which no generally acceptable disposal route has yet been established. It is also of concern that nuclear energy, which currently accounts for more than 15 % of total energy consumption in the EU, is expected to begin to run down production beyond 2010, and this will result in further growth of emissions, especially carbon dioxide, if it is replaced by fossil fuels.

Fossil fuels continue to dominate energy use, but environmental pressures have been limited by switching from coal and lignite to relatively cleaner natural gas.

Figure 19 Total energy consumption by source



Note: Fuels other than those listed in the legend have been included in the diagram but their share is too small to be visible.
Source: Eurostat, NTUA.

EU total energy consumption continued to increase between 1990 and 1999 at an average of 1 % per year. Moreover, the share taken by fossil fuels declined only slightly, from 81 % in 1990 to 79 % in 1999. This small loss was taken up by increases in nuclear and renewable energy. Although small in terms of market share, there was a 29 % growth in renewable energy over the period (see renewable energy indicator, Figure 21).

Within the share of total energy consumption supplied by fossil fuels, there was a major change in fuel mix, with coal and lignite loosing about one third of their market, and being replaced by natural gas. This was due mainly to fuel switching in power production. Oil retained its share of the energy market, reflecting its continued dominance in road and air transport. This growing dependence on oil and gas, with a substantial share of both being met by imports, resulted in EU dependence on imported fossil fuels increasing between 1990 and 1999.

The baseline projections for the European Commission (NTUA, 2000a) indicate total energy consumption continuing to increase to 2010, but at a reduced rate. Natural gas is expected to continue to replace coal and lignite, but not so rapidly as in the 1990-99 period, while oil products continue to dominate road transport. Renewable energy is also expected to increase, but the rate of growth is not sufficient to increase its share of total consumption.

The baseline projections are based on policies and measures adopted by 1998 (including the ACEA Agreement). The fact that they suggest only limited changes in the energy mix by 2010 underlines the need to strengthen support for renewable energy sources.

Fossil fuels and nuclear power continue to dominate electricity production, but the environment has benefited from the switch from coal and lignite to natural gas.

Electricity production remains a major source of pollution emissions. However, because of the limited number of facilities involved, the rapid rate of technological advance, and opportunities for switching to less-polluting fuels such as natural gas and renewables, it is a key area to achieve improvements in environmental performance.

Between 1990 and 1999 electricity production grew at an annual rate of 2.3 %, and fossil fuels maintained their share of output at a little over 50 %. However, major changes occurred in the mix of fossil fuels used, with coal and lignite, and to a lesser extent oil, being replaced by natural gas. This has yielded environmental benefits, as discussed previously, in terms of reduced emissions of carbon dioxide, acidifying gases and particulates. This trend has been driven by a combination of factors:

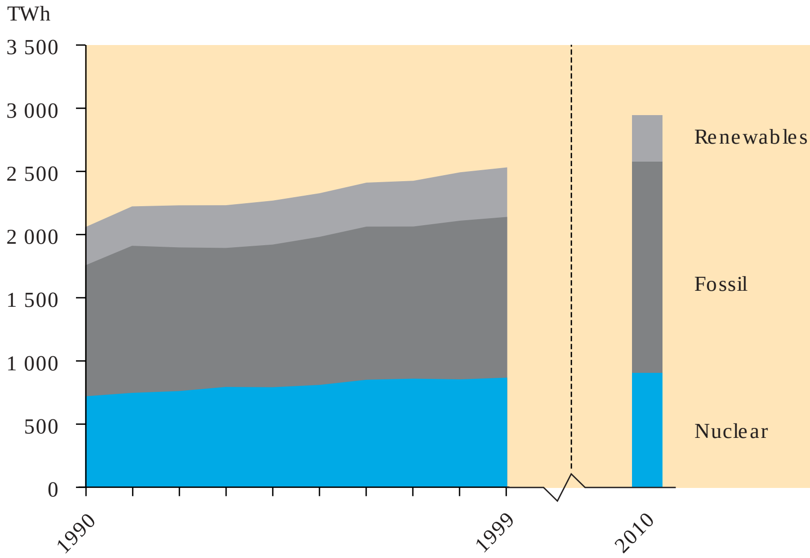
- The high efficiency and low capital cost of gas combined-cycle plant;
- Liberalisation of the electricity supply market bringing in new generators, ready to invest in low capital cost gas plant;
- Low gas prices in the early 1990s;
- The EU large combustion plant directive that sets emissions limits that are more easily attained with modern and cleaner natural gas technologies.

Nuclear power increased its output by an average of 2.1 % per year between 1990 and 1999 through a combination of commissioning of new plant and improved performance of existing facilities. The other major contributor to electricity production was renewable sources, which increased their market share from 14.7 % in 1990 to 15.5 % in 1999[18]. Hydro was by far the largest renewable source accounting for 85 % of renewable electricity production. However, this figure hides remarkable growth in the production from some 'new renewable' sources, discussed in the next section.

Baseline projections (NTUA, 2000b) anticipate fossil fuels taking an increasing share of a market that continues to grow at a similar rate to 2010. This is because the projections are based on the policies and measures in place in 1998, (see Annex 1), and neither nuclear power nor renewable energy sources are expected to expand significantly under these policies. The trend to switch from coal and lignite to natural gas is also expected to continue, although this projection is particularly sensitive to future fossil fuel prices. The switch to natural gas will clearly bring environmental benefits in terms of reduced emissions of carbon dioxide, acidifying gases and particulates.

However, looking beyond 2010 the trend for increased electricity production from fossil fuels, and in particular the slow growth of renewable electricity production, is a matter for concern. After 2010 the switch from coal and lignite to natural gas is not expected to continue and nuclear plant will start to be decommissioned. If nuclear capacity is replaced by fossil plant it seems inevitable that there will be a growth in emissions, especially carbon dioxide emissions. Once again this highlights the importance of policies and measures to stimulate the development and deployment of renewable energy technologies.

Electricity production by source — Figure 20



Source: Eurostat, NTUA.

18 Note that electricity production is equal to electricity consumption less imports plus exports and so the share of renewables in electricity production stated here is not equal to the share of renewables in electricity consumption in Figure 22.

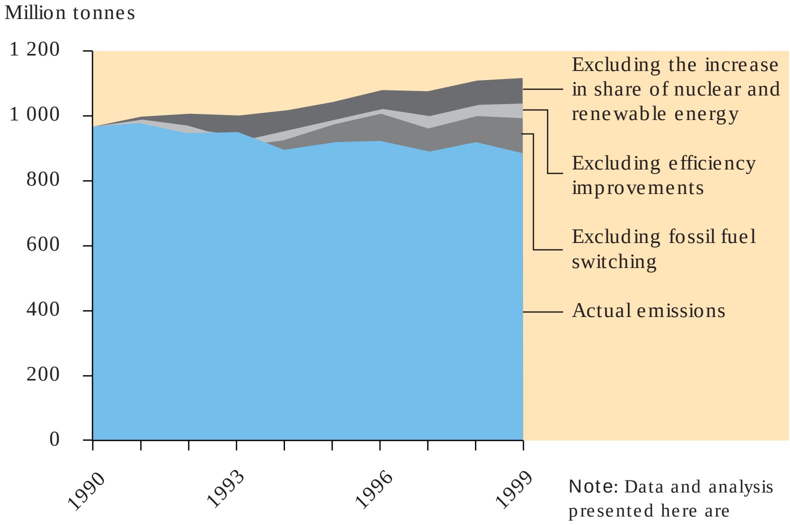
Box 8	How has fuel switching affected carbon dioxide emissions from the electricity production sector?

Carbon dioxide emissions from electricity production fell by 8 % over the period 1990–99, despite a 16 % increase in the amount of electricity produced; 80 % of the decrease is due to fuel switching.

If the structure of electricity production had remained unchanged from 1990, then by 1999 emissions of CO_2 would have increased in line with electricity output by 16 %. In fact, there were a number of changes in the electricity industry in the EU that caused annual emissions of CO_2 to fall by 8 %.

Changes in the fossil fuel mix from coal and lignite to natural gas accounts for 46 % of the reduction. A further 20 % came from an increase in the efficiency of fossil-fuelled electricity production and much of this is also linked to the switch to high-efficiency gas-turbine combined-cycle technology. The remaining 34 % of the reduction is attributable to the increased share of nuclear power and renewable energy sources.

Explanations for the reduction of emissions of carbon dioxide in the electricity sector



Note: Data and analysis presented here are preliminary results of ongoing work to refine and improve associated statistics and methodology.
Source: EEA.

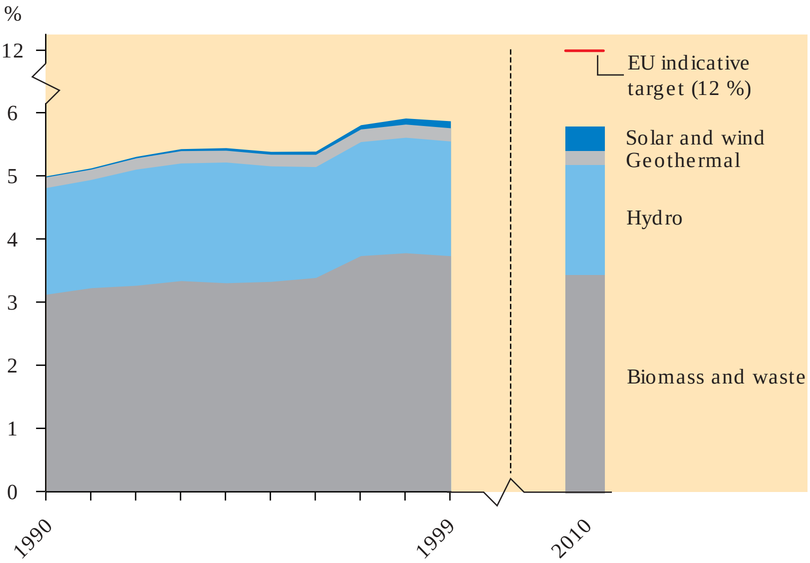
5. How rapidly are renewable energy technologies being implemented?

Renewable energy targets are unlikely to be met under current trends, but experience in some Member States suggests that growth could be accelerated by appropriate support measures.

Renewable energy sources are an important option for reducing the pressures on the environment from energy use. They can also contribute to energy security by replacing imported fossil fuels. The significance of renewable energy has been recognised in a number of EU policy documents concerned with accelerating its deployment, notably the renewable energies White Paper (European Commission, 1997b), which sets an indicative target to derive 12 % of the EU total energy consumption from renewable sources by 2010. Similarly the directive on the promotion of electricity from renewable energy sources (European Parliament and Council, 2001b) sets an indicative target to derive 22.1 % of EU electricity consumption from renewable sources by 2010. The Commission has also proposed a directive on the promotion of biofuels for transport (European Commission, 2001g). However, the promotion of renewable energy is also a matter for Member States since the resources vary between countries as do the infrastructures and market conditions into which they need to fit.

The share of total energy consumption met by renewable energy grew only slightly between 1990 and 1999; projections of future energy demand imply that the growth rate of energy from renewable sources needs to more than double to attain the EU indicative target of 12 % by 2010.

Figure 21 Share of total energy consumption provided by renewable energy sources



Note: Biomass/waste includes wood, wood wastes, other biodegradable solid wastes, industrial and municipal waste (of which only part is biodegradable), biofuels and biogas.
Source: Eurostat, NTUA.

Over the 1990–99 period, renewable energy sources were used mainly to supply heat and electricity, with roughly a 50:50 split. Overall renewable energy output grew by an average of 2.8 % per year over the period, which increased its share of total energy consumption from 5.0 % to 5.9 %. Taking account of the projected expansion in energy consumption, this growth rate needs to be increased to over 7 % per year if the EU indicative target to derive 12 % of total energy consumption from renewable sources is to be met by 2010. However, the baseline projections for the European Commission (NTUA, 2000b) suggest that renewable energy growth will be much less than this, and probably will only be sufficient to maintain current market share to 2010.[19]

The main sources of renewable energy are biomass/waste (63.5 %) and hydro-power (31 %), although wind (1.5 %) and solar energy (0.5 %) recorded the fastest growth rates between 1990 and 1999, albeit from low initial bases. The distribution of renewable energy production is uneven across Member States, mainly reflecting their access to biomass/waste and hydro resources but also the effectiveness of national support measures (EEA, 2001c).

The development of renewable energies has been hindered by financial, fiscal and administrative barriers, the low economic competitiveness of some renewables, and the lack of information and confidence amongst investors. Nevertheless, where the right mix of policies and measures was set up, renewables developed successfully. For example Austria, Germany and Greece contributed about 80 % of new solar thermal installations over the 1990-99 period. Solar thermal developments in Austria and Germany benefited from proactive government policy coupled with subsidy schemes and communication strategies; in Greece the developments were helped by government subsidies. Similarly, Austria and Sweden dominated the increase in output from biomass district heating installations. Due to the high costs of developing heating networks it is common, in Member States such as Austria, to provide considerable financial support towards biomass district heating schemes. In Sweden, biomass district heating expanded, without large direct subsidies, as a result of the introduction of carbon and energy taxes (from which biomass is exempted) and considerable research and development support.

Road transport is a major and growing area for energy consumption and consequently emissions of carbon dioxide and pollutants. However, it is an area which is the almost exclusive preserve of oil-derived fuels, with little substitution from fuel cells or renewable energy sources. In 1999 only 0.1 % of energy consumption by road transport was sourced from renewable biofuels. The European Commission has recently proposed a directive aimed at promoting the use of biofuels in transport (European Commission, 2001g), with an indicative target of replacing 2 % of petrol and diesel consumption with biofuels in 2005, increasing to almost 6 % by 2010. This action highlights the pressing need to begin to replace fossil fuels in road transport; however, there is some concern over a number of environmental impacts associated with the production and consumption of biofuels. This arises because biofuels are energy intensive in their production, requiring a third to half their energy content for cultivation, fertilisers, harvesting, transport, etc. (DTI, 1996). Moreover, there may be competition for land from other energy crops that could be used for electricity or heat production. There is also some concern over the level of nitrougen oxides and particulate emissions from biofuel combustion.

19 These baseline projections missed the trend of increased renewable energy production in the second half of the 1990s. It is likely that the updated, new version of the baseline projections, to be released in the second half of 2002, will show a slight increase in the contribution of renewables to total energy consumption by 2010.

The share of renewable energy in EU electricity consumption grew slightly between 1990 and 1999; projections of future electricity demand imply that the rate of growth of electricity from renewable sources needs to double to attain the EU indicative target of 22.1 % by 2010.

The share of renewable energy in EU gross electricity consumption grew from 13.4 % in 1990 to 14 % in 1999. This was achieved through an average annual growth in output of 2.8 % per year over the 1990–99 period. Renewable electricity was dominated by large hydro-power, which had a 74 % share of output in 1999, followed by small hydro (11 %) and biomass/waste (10 %). Large hydro is an established technology, but its capacity is not expected to increase substantially because of concerns linked to its impact on the environment through the loss of land and the resultant destruction of natural habitats and ecosystems. Growth in renewable electricity will therefore have to come from sources such as wind energy, solar power, biomass and small hydro.

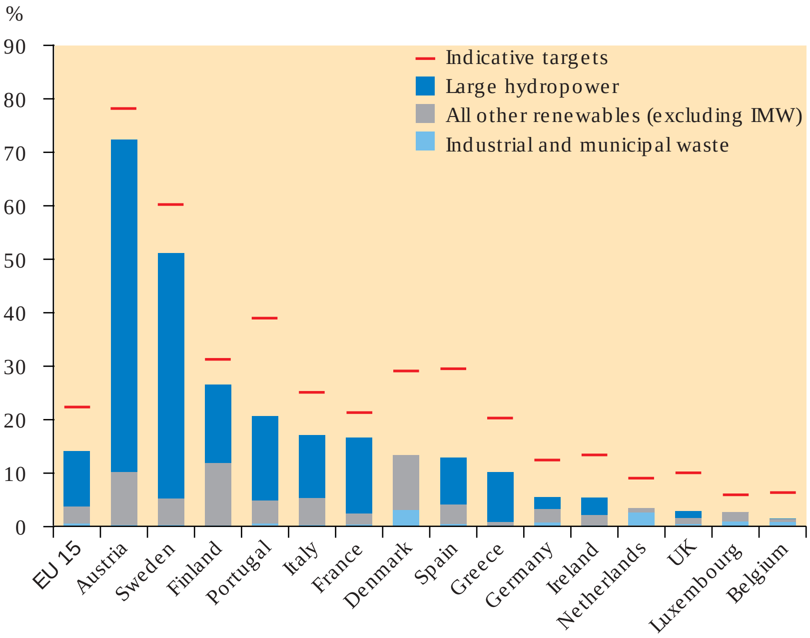
The share of electricity from renewable sources varies considerably among countries, reflecting the resources within their boundaries and the effectiveness of support measures. In its directive on the promotion of electricity from renewable sources the EU proposed indicative targets for Member States and agreed to an EU overall indicative target of 22.1 % of gross electricity consumption from renewable sources by 2010 (European Parliament and Council, 2001b). Taking account of projected growth rates for electricity consumption to 2010, the indicative target will require the rate of growth of renewable electricity supply to roughly double if the target is to be met.

Baseline projections of future electricity production (NTUA, 2000b), based on the policy position in 1998 (see Annex 1), indicate a negligible increase in the share taken by renewable energy sources[20]. Clearly the additional measures contained in the EU directive, together with measures taken at Member State level, need to give a stronger stimulus to the deployment of renewable electricity technologies for the indicative target to be reached.

There are encouraging signs that this may be possible with the right mix of support measures (EEA, 2001c). For example, the rapid expansion of wind power (38 % per year across the EU in the period 1990-99) was driven by Denmark, Germany and Spain, and was the result of support measures including 'feed-in' arrangements that guarantee a fixed favourable price for renewable electricity producers. Similarly, the rapid expansion of solar (photovoltaic) electricity was driven by Germany and Spain, mainly as a result of a combination of 'feed-in' arrangements and high subsidies. Biomass/waste resources have also expanded rapidly, at a rate over 9 % per year, and have the added benefit that they can be used in high-efficiency combined heat and power plant. Finland and Sweden contributed about 60 % of new electricity production from biomass-fuelled power stations. Both countries provided considerable research and development support and subsidies to the biomass power industry. In Sweden, the introduction of carbon dioxide and energy taxes from which biomass is exempted also helped the expansion of biomass power plants.

Share of electricity consumption met by renewable energy sources, 1999

Figure 22



Notes: Industrial and municipal waste (IMW) includes electricity from both biodegradable and non-biodegradable energy sources, as there are no separate data available for the biodegradable part. The EU 22.1 % indicative target for the contribution of renewable electricity to gross electricity consumption by 2010 only classifies biodegradable waste as renewable. The share of renewable electricity in gross electricity consumption is therefore overestimated by an amount equivalent to the electricity produced from non-biodegradable IMW. National indicative targets shown here are reference values that Member States agreed to take into account when setting their indicative targets by October 2002, according to the EU renewable electricity directive.

Source: Eurostat.

20 The baseline projections missed the trend of increased renewable electricity production in the second half of the 1990s. It is likely that the updated, new version of the baseline projections, to be released in the second half of 2002, will show a slight increase in the contribution of renewables to electricity consumption by 2010.

6. Are we moving towards a pricing system that better incorporates environmental costs?

PRESSURE = DRIVER × $\frac{\text{ENERGY}}{\text{DRIVER}}$ × $\frac{\text{PRESSURE}}{\text{ENERGY}}$

Despite increases in energy taxation, most energy prices in the EU have fallen, as a result mainly of falling international fossil fuel prices but also of the liberalisation of energy markets. In the absence of appropriate policies to internalise the external costs of energy and improve energy demand management, reduced prices are likely to act as a disincentive to energy saving and may encourage energy consumption.

The price of energy is an important factor in the interaction between energy and the environment. Energy prices can influence demand, decisions on energy-saving investments and the choice of energy sources (see Box 9).

Other factors remaining unchanged, the environment would benefit from a reduction in energy consumption resulting from high energy prices. However, energy pricing is also important to other policy areas concerned with economic and social development, employment protection and market liberalisation. Generally these policies aim for low energy prices, for example:

- EU and Member State energy policies generally aim to ensure secure supplies of energy at reasonable prices. This is important both to support industrial competitiveness (particularly for energy-intensive industries) and socially, to ensure that all EU citizens can afford the energy services they need.
- Indigenous production of fossil fuels may be supported to contribute to security of supply or to maintain employment in economically depressed areas.
- Market liberalisation aimed at reforming the structure of energy supply has increased competitiveness and resulted in reduced prices to consumers.

Consequently this is an area where environmental concerns can run counter to other issues driving energy policy in the absence of an appropriate policy framework that aims at full internalisation of external costs to the environment and better energy demand management.

Energy prices do not always reflect the full costs of energy to society because they do not, or not completely, take account of the impacts of production and consumption on non-traded factors such as human health and the environment. Strictly these external costs should be included in energy prices to ensure that decisions on the choice and volume of energy consumption take account of all the costs involved. However, there are significant uncertainties in the evaluation of external costs, particularly those linked to environmental impacts, due to factors such as their diversity, geographical variations and the difficulty of setting exact values on non-traded goods. In practice governments therefore seek to introduce external costs associated with energy in less direct ways through regulation, taxation, incentives, tradeable emissions permits, and subsidy review.

The sixth environment action programme stresses the need to internalise the external costs to the environment. It suggests a blend of instruments that include the promotion of the use of fiscal measures, such as environment-related taxes and incentives, a possible use of tradeable emissions permits and emissions trading, and the undertaking of an inventory and review of subsidies that counteract the efficient and sustainable use of energy, with a view to gradually phasing them out.

This section examines the evolution of energy prices over the 1985–2001 period, and considers if this is consistent with the EU's environmental objectives.

Energy prices generally fell between 1985 and 2001, offering little incentive for energy saving.

The real prices of all fuels, with the exception of diesel and unleaded gasoline for transport, fell between 1985 and 2001. The decrease was greatest in the years 1986–87 when the crash in crude oil prices had knock-on effects on natural gas, the price of which tends to be indexed to crude oil. The slower decline since then was sustained by continuing low oil prices, opening-up of additional natural gas supplies to the EU, and progressive liberalisation of the gas and electricity markets leading to greater price competition. This last factor, which is continuing, was driven by the EU electricity and gas directives (European Parliament and Council, 1996b and 1998b). Oil prices increased appreciably in 1999–2000 following an agreement within the Organization of the Petroleum Exporting Countries (OPEC) to restrict production, and this contributed to an increase in the prices of oil products and natural gas in 2000. However, electricity prices were not affected by the oil price rise. This is due to three factors: growing competition in electricity markets, only a small fraction of electricity being generated from oil, and the weakening of the linkage between natural gas and oil prices in a competitive gas market.

End-user energy prices (euro/GJ at 1995 prices) — Table 7

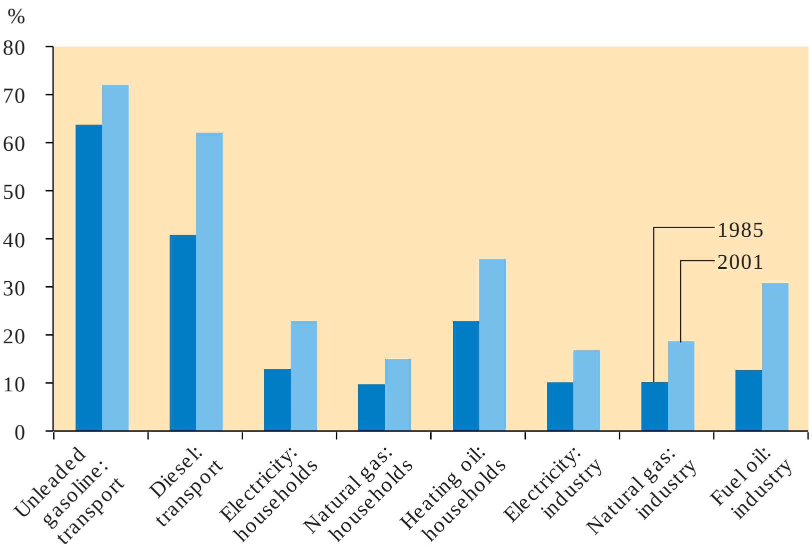
Fuel	Price 1985	Price 2001	Percentage change in price 1985–2001
Heavy fuel oil: industry	11.2	5.1	- 54 %
Natural gas: industry	8.6	5.1	- 41 %
Electricity: industry	26.2	13.6	- 48 %
Heating oil: households	17.0	11.0	- 35 %
Natural gas: households	16.7	12.2	- 30 %
Electricity: households	43.6	30.8	- 29 %
Diesel: road transport	757	772	2.6 %
Unleaded gasoline: road transport	699	922	32 %

Notes: Unleaded gasoline price data are for 1991 instead of 1985. Transport prices are in euro/1 000 litre. Prices are those applicable in January of each year. Industry prices exclude value added tax (VAT).
Source: Eurostat.

Unleaded gasoline was the only fuel to record a substantial increase in price. This was due mainly to moves by Member States to progressively increase taxation on road transport fuels such that tax on unleaded gasoline accounted for 72 % of the price in 2001, an increase from 64 % in 1991. However, much of this tax increase was absorbed by reductions in the non-tax price of unleaded gasoline, and most of the price increase came in 2000, associated with the increase in crude oil prices in that year.

Despite increases in taxation from 1985 to 2001, energy prices for most fuels dropped and the overall demand for energy increased.

Figure 23 Proportion of tax in final energy prices

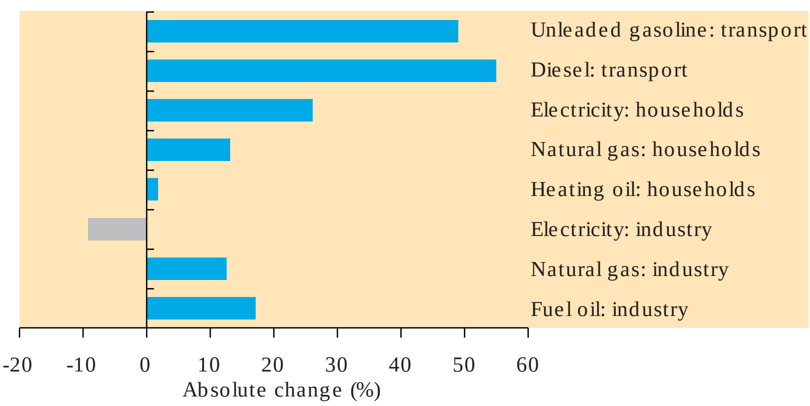


Note: Data for unleaded gasoline are for 1991 instead of 1985.
Source: Eurostat.

Taxation offers one method for internalising the external costs of energy consumption into prices. It also offers a mechanism for introducing price differentials to encourage the use of less-polluting fuels.

The pattern of taxation across the EU between 1985 and 2001 has been to increase the proportion of energy prices accounted for by tax. This has occurred in part through increases in the rate of tax, but it is also linked to a reduction in before-tax energy prices. As discussed in the previous section, this has occurred through a decline in fossil fuel prices combined with greater price competition in the electricity and natural gas markets.

Figure 24 Change in the absolute value of taxation applied to fuels, 1985–2001



Note: Changes for unleaded gasoline are for the period 1991–2001.
Source: Eurostat.

Energy taxation has also increased in absolute terms, but, as shown in the previous section, not sufficiently to prevent overall reductions in energy prices for all but road transport fuels. One important exception is electricity consumption in industry for which taxation in absolute terms has fallen. This is because before-tax prices have been reduced considerably as a result of strong competition between suppliers, and this tax is generally applied as a percentage of the before-tax price.

The European Commission has proposed a directive for restructuring the Community framework for taxing energy products (European Commission, 1997c), which includes suggested minimum tax levels for each fuel. This has not yet been agreed but it is noteworthy that, on average for the EU as a whole, actual taxes on transport fuels, oil-based heating fuels and electricity in 2000 were higher than the proposed minimum tax levels for 2000. Actual taxation on natural gas was about equal to the proposed minimum for the year 2000 for industry and above the minimum for households.[21]

The generally modest increases in tax on industrial energy consumption reflect concerns over the impact of fuel prices on national competitiveness, with Member States seeking to encourage energy efficiency through alternative schemes such as voluntary agreements, awareness campaigns and capital allowances. Some Member States have adopted a 'carrot and stick' approach with energy taxation, combined with the option of significant rebates if energy-efficiency targets are met (DEFRA, 2000; EEA, 2000). Also studies have suggested that a combination of increased energy taxes and reduced employment taxes could yield the double dividends of reduced pollution and increased employment (European Commission, 2000f).

21 These conclusions hold true at the EU overall level. Different conclusions may be drawn for individual Member States.

Taxation of transport fuels increased substantially between 1985 and 2001, but the impact on prices was partially offset by the effects of falling crude oil prices and market competition. Tax rates have been highest in the UK, which from 1993 to 1999 applied a fuel duty escalator that increased taxes by up to 6 % per year. The UK government has estimated that tax increases between 1996 and 1999 will have cut UK transport-related carbon dioxide emissions by between 1 and 2.5 million tonnes of carbon per year by 2010 (i.e. 2 to 5.5 %) (DETR, 2000).

There is concern that fuel taxation is not the most equitable way of taking account of transport impacts. This is because off-peak and rural travel are taxed at the same rate as urban rush-hour travel but, due to their lower volume of activity, do not cause the same damage to health or the environment. Consequently additional forms of taxation may be introduced in future such as road pricing and differential taxation of vehicles according to their energy efficiency.

Taxes on the household consumption of electricity and natural gas have increased significantly, particularly in the last few years of the 1990s. This has had the effect of offsetting price reductions resulting from energy market liberalisation and the increased price competition this causes.

The relationship between energy prices, energy consumption and energy-related environmental pressures — Box 9

The price of energy can have a direct influence on demand and on the pressures placed on the environment from energy consumption. This arises through three mechanisms.

First, price can affect the volume of demand for some energy-related services (i.e. the driver).

Second, price can affect the amount of energy consumed to deliver energy-related services (i.e. energy/driver) through:

- Adopting alternative methods for gaining the energy-related service (e.g. switching between private and public transport);
- Using more efficient devices for converting energy into energy-related services (e.g. more efficient cars, trucks, boilers, lighting);
- Moving to different manufacturing and service activities that require less energy per unit of added value (i.e. structural change).

Other things being equal, people are likely to demand less energy-related services, adopt less energy-intensive lifestyles and business activities, and invest in more efficient devices when the energy price is high.

Third, price may influence the types of energy we buy (coal, gas, oil, electricity, etc.). Again, with all other things being equal, it is logical to select the lowest price source. Since some fuels are more polluting than others it follows that price can directly affect the pressures placed on the environment by energy use (i.e. pressure/energy).

Nonetheless, price is not the only determinant of demand for energy or choice of technologies or fuels. Many other factors affect the decisions of businesses and citizens, in particular the fiscal and regulatory policy framework. Other factors that affect decisions include the availability and reliability of supplies, past experience, existing infrastructure, capital constraints, lack of information, fashion preferences, general affluence and, increasingly, environmental awareness.

With fossil fuels supplying more than half the EU's electricity, price levels would need to be increased to include the estimated external costs of electricity production.

Estimation of the external costs of electricity production (i.e. those associated with impacts on the environment and human health) is complex and needs to take account, for example, of:

- Location—specific impacts determined by factors such as the vulnerability of the environment and the density of population;
- The exact specification of the fuel being used (for example the sulphur content of coal varies appreciably);
- The age of the plant and what emission reduction devices are fitted.

The most comprehensive source of external cost assessments is the European Commission's ExternE project (European Commission, 1999b), which considered a range of electricity generation technologies located across EU Member States. This assessment examined external costs related to impacts on human health, crops, materials, forests and ecosystems, as well as giving separate consideration to climate change; it is the source of the data presented here. The evaluation of climate change was particularly uncertain because of inadequate knowledge of the timing and severity of the impacts, the capacity of systems to adapt, the valuation of impacts in other world regions and the discount rate to apply to impacts occurring well into the future. Mid-range values are included in the data presented here.

The external cost ranges presented in Table 8 reflect the above uncertainties and the differences in the type of location, fuel specification and age of the technologies examined. For example, the comparatively high external cost of coal generation in Belgium arises because an older plant with less pollution control was examined.

Nonetheless the data show the graduation in costs that can be expected, with most lignite and coal having the highest costs and some renewable energy sources offering the lowest. The low nuclear external costs reflect the small health and environmental impacts of this technology under normal operation; however, it is noted that further work is needed to estimate the costs with sufficient reliability because of the complexity of the fuel cycle (European Commission, 1999b).

For the EU, it has been estimated that the external costs of electricity production amount to 1–2 % of GDP, excluding the costs of global warming (European Commission, 2001h).

Comparison of these external costs with the current prices for electricity show that the external costs of coal and lignite electricity production are of the order of 20–120 % of household electricity prices and 50–240 % of industrial electricity prices. For gas-fired electricity production external costs are 7–38 % for households and 13–73 % for industry. Clearly the external costs are greatest for coal and lignite, but they are still significant for gas.

Notes: Electricity prices include all taxes and are those applicable in January 2001. Industrial electricity prices for Austria, Denmark and the Netherlands are those applicable in January 1999.
Source: European Commission, Eurostat.

Table 8 Comparison of estimates of the external costs of electricity production from different fuels with electricity prices (euro cents/kWh at constant 1995 prices)

	External costs							Prices	
	Coal and lignite	Oil	Gas	Nuclear	Biomass	Hydro	Wind	Price of industrial electricity	Price of household electricity
EU	–	–	–	–	–	–	–	5.6	11.1
Austria	–	–	1–3	–	2–3	0.1	–	7.8	12.5
Belgium	4–15	–	1–2	0.5	–	–	–	6.3	12.4
Denmark	4–7	–	2–3	–	1	–	0.05	7.6	16.7
Germany	3–6	5–8	1–2	0.2	3	–	0.1–0.2	6.2	13.9
Spain	5–8	–	1–2	–	–	–	0.2	5.7	8.1
Finland	2–4	–	–	–	1	–	–	4.3	6.7
France	7–10	8–11	2–4	0.3	1	1	–	5.5	10.6
Greece	5–8	3–5	1	–	0–1	1	0.2–0.3	4.0	5.1
Ireland	6–8	–	–	–	–	–	–	4.9	6.6
Italy	–	3–6	2–3	–	–	0.3	–	7.0	16.8
Netherlands	3–4	–	1–2	0.7	0.5	–	–	5.4	14.6
Portugal	4–7	–	1–2	–	1–2	0.2	–	4.7	9.1
Sweden	2–4	–	–	–	0.3	0.03	–	3.3	9.0
UK	4–7	3–5	1–2	0.3	1	0–0.7	0.1–0.2	5.9	7.5

Subsidies continue to distort the energy market in favour of fossil fuels despite the pressures these fuels place on the environment.

Subsidies on energy production and/or consumption change the relative prices of different energy sources, thereby affecting decisions on which should be used. They may also keep prices lower than they would otherwise be, and consequently may encourage increased consumption. Both of these factors affect the pressures of energy-related activities on the environment.

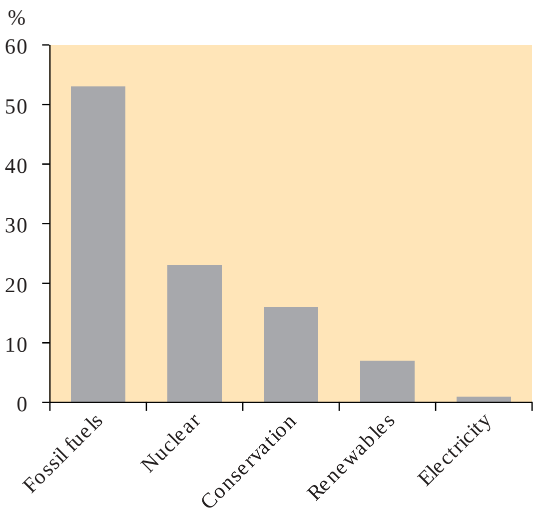
Governments use a broad range of methods to provide subsidies including:

- Direct financial support to particular energy supply industries
- State supply quotas or state obligations to purchase
- Low-cost or underwritten loans
- Limits on the liabilities of particular energy industries
- Price support
- Preferential tax treatment
- Failure to internalise external costs
- Support for research and development.

Consequently it is difficult to develop reliable estimates of the total value of subsidies to particular energy industries, let alone to monitor how these change over time. The data in Figure 25 show the results of one estimate covering the 1990–95 period, which includes only direct subsidies[22]. This shows that most subsidies across the EU are directed at supporting fossil fuels, with much less support for renewable sources or energy conservation. Clearly this distribution of subsidies will not favour the reduction of the environmental pressures caused by energy production and consumption. It is important to determine if this distribution has changed in more recent years.

Subsidies are used as a tool to achieve policy objectives, which in the case of energy may include security of supply, industrial competitiveness and social/employment concerns as well as environmental factors. The challenge is to get an optimal balance between these policy drivers. Moreover, the removal or reduction of subsidies may not yield environmental benefits in the short term if the subsidies have encouraged investment in durable infrastructure and plant that are only replaced over long periods (20 to 40 years).

Estimated distribution of direct energy subsidies (1990–95 average) — Figure 25



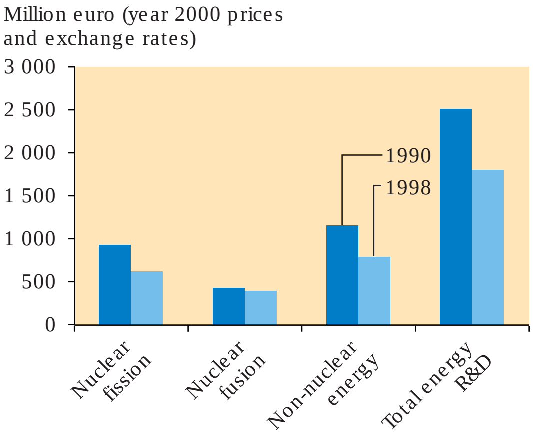
Note: Electricity subsidies include support for research and development on storage methods, combined heat and power, and cross-cutting factors such as power conditioning and load management.
Source: Ruijgrok and Oosterhuis, 1997.

22 Direct subsidies include direct payments from public budgets, tax receipts foregone due to tax reductions, government funded R&D, and payments that reduce the cost of energy production, consumption or conservation.

EU energy research and development expenditure has been reduced at a time when innovation is needed to develop less-polluting technologies.

Figure 26 Energy research and development expenditure

Note: Data are indicative and are the result of combining two data sets that include different methodologies and definitions, covering Member State expenditure and EU-level funding through the R&D European Community framework programmes. Framework programme expenditure has been estimated as an annual average over the duration of the programme. Non-nuclear research includes renewable energy, energy conservation, fossil fuel production, power production and storage technologies, and cross-cutting research.
Source: IEA and European Commission.



The environmental problems associated with energy production and consumption are unlikely to be solved by fiscal and market-based measures alone. Innovative technologies will also be needed to capture less-polluting energy sources such as renewable energy and to use energy with maximum efficiency. This is particularly so in the longer term when substantial reductions in greenhouse gas emissions will be needed to limit climate change to tolerable levels. The longer-term research and development (R&D) needed to produce such innovative technologies is not always attractive to businesses that are required by their shareholders to deliver short-term profitability, and therefore needs to be partially supported by public funds.

Total energy R&D expenditure in the EU fell by about 30 % between 1990 and 1998 (IEA, 1999; European Commission, 2001i). Within this overall budget, expenditure on individual technologies changed less dramatically, with nuclear fission (34 %) and fusion (22 %) R&D still taking more than half the total in 1998. The share of R&D targeted on renewable energy sources and energy conservation increased, but in absolute terms the budgets fell.

Budgets for fossil fuel R&D have declined, which may seem reasonable since these are mature technologies whose future development should be left to industry. However, the major reductions in greenhouse gas emissions needed in the long term may require advanced fossil plant with carbon dioxide abatement technologies at source and carbon dioxide disposal. There is therefore a need for additional research into this area including into the potential environmental pressures associated with options for carbon dioxide disposal, to establish whether they offer an acceptable approach to reducing greenhouse gas emissions.

Annex 1

Background to the baseline energy and greenhouse gas emissions projections

The baseline projections of energy consumption and greenhouse gas emissions used in this report were derived from work carried out for the European Commission in producing the report 'Economic evaluation of sectoral emission reduction objectives for climate change' (Ecofys, 2001).

The energy projections were made with the PRIMES model, and were an update of an earlier baseline projection developed in the shared analysis project (European Commission, 1999a). This earlier set of projections was based on 1995 data and assumed a continuation of 1998 policies over the full modelling period. In the update (NTUA, 2000a; NTUA, 2000b) an additional assumption was made that the EU voluntary agreement with the European, Japanese and Korean car makers (the ACEA Agreement), for a reduction in the average carbon dioxide emissions for all new cars to 140 g/km by 2008-09, would be honoured. Other key assumptions in the baseline projections are:

- EU economic growth in the period 2000 to 2010 is in line with historic trends at around 2.3 % per year.
- The long-established trend of restructuring EU economies towards services and high value-added products continues.
- Liberalisation and integration of the electricity and gas markets are fully developed in the second half of the 2000–10 period.
- Energy taxes remain unchanged in real terms in all Member States.
- Technological improvements in energy supply and demand technologies continue.
- Support continues for renewable energy and combined heat and power.
- There is continued extension of the natural gas infrastructure across Member States.
- Nuclear plant lifetimes are extended to 40 years.

Results from the PRIMES model were also used to project the carbon dioxide emissions attributable to energy use (NTUA, 2000a; NTUA, 2000b). Projections of non-energy related carbon dioxide emissions, and emissions of the other five greenhouse gases covered by the Kyoto Protocol[23], to 2010 were made by a 'bottom-up' modelling approach (Ecofys, 2001), based on emission inventories for either 1990 or 1995, and assuming a 'frozen technology' reference level to 2010 — i.e. no change in the emission level per unit of production compared with the base year, with the following exceptions:

- Industrial emissions of adipic acid take account of reduction measures taken between the base year and 2000.
- Waste sector emissions take account of the effect of abatement measures taken as a result of the landfill directive after the base year.

23 The Kyoto 'basket' of greenhouse gases consists of carbon dioxide, methane, nitrous oxide, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride.

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Acronyms and abbreviations

ACEA	European Automobile Manufacturers Association
BAT	Best available technology
CHP	Combined heat and power
CO_2	Carbon dioxide
CONCAWE	Oil companies' European organisation for environment, health and safety
DG	Directorate General of the European Commission
DG ENV	Directorate General Environment (of the European Commission)
DG TREN	Directorate General Energy and Transport (of the European Commission)
DHI	DHI Water and Environment, Denmark
DPSIR	Driving forces, Pressures, State, Impact and Responses
EEA	European Environment Agency
EIONET	European Information and Observation Network
ETC	European Topic Centre
ETC-ACC	European Topic Centre on Air and Climate Change
EU	European Union
Eurostat	Statistical Office of the European Union
ExternE	Externalities of fuel cycles project
FCCC	Framework Convention on Climate Change (UN)
FGD	Flue gas desulphurisation
GDP	Gross domestic product
GIEC	Gross inland energy consumption
GJ	Gigajoule
HFCs	Hydrofluorocarbons
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IPPC	Integrated pollution prevention and control
ITOPF	International Tankers Owners Pollution Federation
JAMA	Japanese Automobile Manufacturers Association
KAMA	Korean Automobile Manufacturers Association
km	Kilometre
ktonnes	Thousand tonnes
kWh	Kilowatt hour
MS	Member State (of the European Union)
Mt	Million tonnes
Mtoe	Million tonnes of oil equivalent
N_2O	Nitrous oxide
NMVOC	Non-methane volatile organic compounds
NECD	National emission ceiling directive
NO_X	Nitrogen oxides, including nitric oxide (NO) and nitrogen dioxide (NO_2)
NTUA	National Technical University of Athens
OECD	Organisation for Economic Co-operation and Development
OPEC	Organization of the Petroleum Exporting Countries
OSPAR	Joint Oslo and Paris Commissions
PFCs	Perfluorocarbons
PM	Particulate matter
SO_2	Sulphur dioxide
TERM	Transport and Environment Reporting Mechanism of the EU
toe	Tonnes of oil equivalent
TWh	Terrawatt hour
UNFCCC	United Nations Framework Convention on Climate Change
WHO	World Health Organization

European Environment Agency

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