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Greenhouse gas emissions in Europe: a retrospective trend analysis for the period 1990–2008

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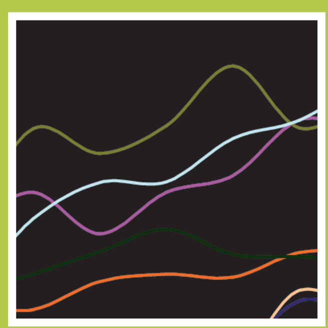

European Environment Agency

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Foreword: cross-sector linkages

The EEA's 'The European environment — State and outlook 2010 (SOER 2010)' report highlights that many of today's main environmental challenges are systemic in character and cannot be tackled effectively in isolation. This holds for linkages between environmental issues but also across environment and sector policy domains.

Furthermore, many links between environmental issues and socio-economic activities, go beyond linear cause-effect relationships. Often several activities combine to exacerbate environmental problems: this is well recognised, for example, in the context of greenhouse gas emissions, which stem from a wide range of sectoral activities. Where environmental pressures correspond to multiple, often interlinked sources and economic activities, the coherence between approaches to tackle related problems becomes increasingly important.

Frequently, multiple sources and economic activities interact to either enhance or counteract their respective environmental impacts — resulting in clusters of environmental pressures. Addressing such clusters (rather than merely addressing individual sources separately) can offer opportunities for more cost-effective responses. The potential co-benefits between climate mitigation and air quality improvements provide an example. Conversely, if not addressed coherently, the interaction within such clusters carries the risk that environmental action in one sector counteracts efforts made in another.

The need to integrate environmental concerns into sectoral activities and other policy domains has long been acknowledged — for example through the EU Cardiff integration process since 1998. As a result, many EU-level policies explicitly take into account environmental considerations to some degree; for example the Common Transport Policy and the Common Agricultural Policy (CAP). There are also specific reporting initiatives for several sectors, such as the Transport and Environment Reporting Mechanism (TERM). Such approaches, however, generally look at one sector only — and do not address cross-sectoral links.

If coherent policies across several sectoral and environmental domains are to be further developed the right analytical tools and approaches need to be available. This means more integrated analysis of environmental, economic and social impacts, trade-offs and costs as well as policy effectiveness. Integrated assessment tools, combining modelling and qualitative methods, new platforms for displaying analytical results to policy makers, and the use of environmental accounting techniques, for example, can help to bring this about. The EEA seeks to provide targeted analysis to support policy decisions at the interface between different policy areas and to further analytical approaches that look across several sectors and environmental issues.

Executive summary

This report presents a retrospective overview of the greenhouse gas (GHG) emission trends in Europe from 1990 to 2008, with a particular focus on the underpinning drivers and the influence of EU policies. The analysis is based on the combination of decomposition analyses to identify the respective influence of each identified driver and an overview of the main EU policies and their likely effects on these drivers. The period covered by the analysis stops in 2008. As a result, the analysis does not address the effects of the recent economic crisis on GHG emissions. This reinforces the conclusion on long-term emission drivers. The report covers the EU-27 and presents results for the other European Environment Agency (EEA) member countries (Iceland, Liechtenstein, Norway, Switzerland and Turkey) and Croatia (EU candidate country, together with Turkey) as far as data are available.

Overall GHG emission trends

EU GHG emissions were reduced between 1990 and 2008. Most of the reductions took place in the 1990s, but emissions have also been decreasing every year from 2003 until the last year considered in this report, 2008.

In 2008, GHG emissions in the EU-27 were 11.1 % below their 1990 level. Much of this reduction took place during the 1990s. After a steep increase between 1999 and 2003, the EU-27's emissions declined again from 2003, to reach 4 969 million tonnes (Mt) carbon dioxide (CO_2)-equivalent in 2008.

Between 1990 and 2008, the largest absolute emission reductions took place in Germany, the United Kingdom and most EU-12 Member States, while emissions increased most (in absolute terms) in southern EU-15 Member States (Greece, Spain, Italy and Portugal). Outside the EU, all the other EEA member countries except Switzerland experienced an increase in their total GHG emissions between 1990 and 2008, including a doubling of total emissions in Turkey.

Between 1990 and 2008, per gross domestic product (GDP) emissions decreased by 38 % in the EU-27 (GDP increased by 44 % while emissions decreased by 11 %), and by 34 % in the EU-15 (GDP increased by 43 % with a 6 % reduction in GHG emissions). GHG emissions per capita show significant differences across European countries, depending on national circumstances. Between 1990 and 2008, per capita emissions decreased by 16 % in the EU-27.

Predominant drivers

For the most part, the GHG emission trends observed in the EU between 1990 and 2008 resulted from economic factors. However, EU policies, some of which did not directly target GHG emissions, as well as national policies set up by some front-runner countries, also played a role in these trends.

GHG emissions in the EU during the period from 1990 to 2008 were significantly affected by economic or macroeconomic factors. Emission levels varied considerably in the 1990s under the influence of the political and economic process taking place in eastern Europe following the collapse of the Soviet Union. This led to the restructuring of the economies of these countries, including that of the reunified Germany. In the energy and industry sectors, a number of heavily polluting plants were closed and the structure of industry was subsequently modified. In the agriculture sector, decollectivisation resulted in a radical restructuring with very large decreases, for example, in the number of cattle. Across the energy, industry and agriculture sectors, the economic trends resulted in significant reductions in GHG emission levels. At the other end of the spectrum, the sustained economic development of southern European countries during the period from 1990 to 2008, accompanied by rising incomes, higher living standards and, consequently, higher energy demand, resulted in significant increases in emissions. For example, growing mobility of persons and increasing globalisation of trade led to an overall increase in transport emissions across the whole of Europe.

One should not assume that the predominant influence of economic factors shaping GHG emission trends between 1990 and 2008 detracts from the important role played by policies. Although climate policies were not fully developed yet at EU level during the 1990s, they had started to be implemented in some EU Member States by means of national climate strategies or policies and measures such as energy or CO_2 taxation (e.g. in Denmark, Germany and Sweden). Other policies, including some not primarily designed to reduce GHG emissions, also played a role in reducing emissions during the period. Besides early energy efficiency policies, air pollution mitigation policies (such as Directive 88/609/EEC, the Large Combustion Plant (LCP) Directive) were particularly effective. Primarily aimed at limiting the pollution of large industrial installations, these policies targeted emissions of acidifying substances, ozone precursors and particles in the air. However, by placing emission limits on those pollutants, the policies resulted in efficiency improvements and provided further incentives to shift fuel sources, thereby indirectly reducing GHG emissions. Energy efficiency policies had a similar impact.

In the agriculture sector, the 1991 Nitrates Directive (Directive 91/676/EEC), which was initially aimed at limiting and reducing water pollution from agriculture practices, achieved significant reductions of nitrous oxide (N_2O) emissions from agricultural soils in the course of the 1990s by addressing the use of nitrogen-based fertilisers. The successive reforms of the CAP also had an influence on agricultural emissions.

Impacts of EU policies

Between 2000 and 2008, emission trends were more directly targeted by a range of energy and climate policies, e.g. the implementation of the European Climate Change programme. However, the steady increase in energy demand during this period — particularly electricity — outweighed the considerable EU-wide savings generated by energy efficiency improvements and the development of renewable energy.

Since 2000, the energy sector (both supply and use), which represents about 80 % of total GHG emissions, has seen a number of policy developments at EU level targeting reduction of emissions. The impact of these policies is difficult to distinguish from the overall impact of GHG emission trends. It can also be subject to varying interpretations due, for example, to the fact that EU policies cannot always be distinguished from the effects of policies implemented at national level.

Despite strong growth in the use of renewable energy sources (RES) for electricity generation between 2000 and 2008, particularly in the form of wind and biomass energy, promoted by Directive 2001/77/EC, the RES-E Directive, the share of renewable energy sources in total electricity generation in the EU has only slightly increased to between 16 % and 17 %. This relatively small market share is attributable to the parallel increase in thermal electricity generation that was necessary in order to absorb the steep rise in EU electricity demand. However in some EU Member States, the share of renewable energy increased strongly in absolute, as well as in relative, terms.

Likewise, the improvements in power generation efficiency were mostly offset by the negative consequences of increasing electricity demand. Despite a relative success in actually pushing a number of Member States to adopt energy taxation measures, the minimum taxation levels set at EU level were generally too low to induce a visible change in consumer behaviour with regard to energy demand over the years from 1990 to 2008.

In the freight transport sector, the constant growth in freight volume — at a rate faster than that of the GDP — has by and large outweighed the limited improvements in engine efficiency. Furthermore, the share of road transport in intra-EU and domestic transport increased compared with less carbon-intensive transport modes, from around 42 % in 1995 to 46 % in 2008. Policy initiatives were not sufficient to reverse this trend and only succeeded in keeping the share of railways in intra-EU freight transport roughly the same since 2001, at close to 11 %. In intra-EU passenger transport, railways also kept their market share of slightly more than 6 % that they had at the beginning of the decade.

Co-benefits

Taking example from the positive benefits on GHG emissions that resulted from the implementation of non-climate-related policies, systematically identifying, analysing and monitoring the impacts of measures in other policy areas would contribute towards better policy integration and coherence across different sectors.

The climate mitigation co-benefits obtained from the implementation of policies such as the LCP Directive, the Integrated Pollution Prevention and Control (IPPC) Directive (Directive 96/61/EC), the Nitrates Directive, the CAP reforms or even the Landfill Directive (Directive 1999/31/EC) constitute important examples of how co-benefits can be harvested across different sectors through the implementation of integrated policies. Whether these co-benefits from non-climate-related policies were intended or not is not really relevant. More important for today's policymaker is the question of how such co-benefits — or any cross-cutting impact or side effect, positive or negative — might be identified, analysed and monitored in a systematic manner in order to maximise the benefits of new policies. In the end, further integration of policies across sectors will be crucial in achieving further emission reductions.

The following paragraphs provide more detailed results of the analyses carried out by sector in the report for the periods from 1990 to 2000 and from 2000 to 2008.

Transport

The **transport sector** (Chapter 4) experienced by far the largest increase in EU-27 GHG emissions between 1990 and 2008 (+ 24 % excluding international aviation and navigation, + 34 % when included). This is largely due to increasing mobility of persons and products in the context of globalised trade. A total of 94 % of the transport emissions are attributable to road transport. Road transport emissions fell by almost 2 % in 2008 as a result of very high international oil prices alongside the economic recession and increased fuel efficiency of vehicles. Passenger cars account for 60 % of road transport's final energy demand, while freight transport accounts for 36 %. Between 1990 and 2008, both **passenger** and **freight transport** demand increased due to economic growth and rising income levels. While the pace of the increase significantly slowed down for passenger transport during the period from 2000 to 2008, freight transport showed no sign of such slowing down — except in 2008, as a consequence of the economic recession. Recent trends show that international oil prices and the global economic situation exert the largest influence on the demand for transport.

CO_2 emissions from **passenger cars increased** steadily in the period from 1990 to 2000 owing to a sustained growth in transport demand and an increasing share of road transport compared with other modes. Between 2000 and 2008, the growth in transport demand — in particular road transport — was significantly reduced, and its effects on CO_2 emissions were further offset by fuel efficiency improvements due to the combined effects of technological improvements, dieselisation and, more recently, biofuel blending. Part of this trend can be attributed to the effects of voluntary commitments by car manufacturers, obligatory labelling of new passenger cars (Directive 1999/94/EC) and promotion of the use of biofuels. However, the voluntary commitments of car manufacturers and the Biofuels Directive (Directive 2003/30/EC) have fallen short of their initial objectives in terms of fuel efficiency and biofuel share in transport fuels, respectively.

Large increases in CO_2 emissions from **road freight transport** were observed in the period from 1990 to 2008, despite technical improvements in the fuel efficiency of truck engines. This was largely owing to the increasing prevalence of road over less carbon-intensive modes such as rail. Emissions continued growing faster than GDP during the period from 2000 to 2008. The various policy initiatives promoting alternative, generally less carbon-intensive transport modes, such as the first and second Marco Polo Programmes (Regulations (EC) No 1382/2003 and No 1692/2006) and the first and second Railway Packages (including Directives 2001/14/EC, 2001/16/EC, 2004/49/EC and Directive 2004/50/EC), were not sufficient to reduce the share of road in total freight transport and achieve the necessary decoupling of emissions from increased activity levels.

Agriculture

EU-27 GHG emissions from **agriculture** (Chapter 5) accounted for 10 % of total GHG emissions in 2008. Between 1990 and 2008, they decreased by 20 %. Cattle husbandry and the application of fertiliser to soils are the most important sources of GHG emissions from agriculture. Emissions from both sources decreased between 1990 and 2008. GHG emission drivers were primarily affected by macroeconomic factors such as intensification of the sector, which led to important GHG emission reductions. However, it is worth highlighting the role played by policies that were not specifically designed to reduce GHG emissions such as the CAP and the Nitrates Directive, in further reducing emissions in this sector.

Between 1990 and 2008, methane (CH_4) emissions from **cattle** decreased continually due to a declining number of cattle. In the early 1990s, this was largely a consequence of the restructuring and modernisation of the agriculture sector in eastern Europe, but the trend has since continued. Several aspects of the CAP, and its successive reforms, have indirectly affected GHG emissions from cattle: the combination of overproduction control through milk quotas (initiated in 1984), the successive reductions of intervention prices (in 1992 and 2000) and the introduction of the Single Farm Payment (SFP) (under the 2003 CAP reform). These limited the economic attractiveness of cattle production in Europe, incentivised higher milk yield (to sustain production levels with less cattle) and therefore contributed to limiting or even decreasing cattle numbers, thereby limiting GHG emissions from this sector.

Between 1990 and 2008, N_2O emissions from **agricultural soils** were significantly reduced due to the lesser use of fertiliser per cropland, combined with a decreasing cropland area. Various national and EU policies aimed at reducing the amount of synthetic fertilisers applied to agricultural soils contributed to this decrease, in particular the Nitrates Directive. Its impact was the largest in the reduction of synthetic fertiliser application, but it also contributed to reducing input of organic fertilisers. The set-aside rules introduced in 1992 led to a significant but varying share of arable land being set aside, which is likely to have reduced GHG emissions associated with arable production. However, assessing the impact of the set-aside rule on GHG emissions is difficult, given the importance of other socio-economic factors for cropping decisions, in particular links between input and output costs. The SFP combined with rural development measures, in particular agri-environment schemes, also provided incentives to limit overproduction of arable crops and other agricultural commodities, leading, in turn, to reduced GHG emissions from agricultural soils. Cross-compliance requirements, progressively introduced since 2000, contributed to better management of organic and mineral fertilisers.

Waste

EU-27 GHG emissions from **waste** (Chapter 6) experienced the largest decrease in relative terms (– 30 %) among the main GHG-emitting sectors between 1990 and 2008. They accounted for 3 % of total GHG emissions in 2008 (this does not include emissions from waste incineration with energy recovery, which are reported under the energy sector). A total of 75 % of GHG emissions from waste (mainly CH_4) arise during solid waste disposal on land. These emissions decreased by 35 % between 1990 and 2008. Intensified separate collection, recycling and pretreatment of waste as well as landfill gas recovery were the major reasons for the strong decline. The Landfill Directive has exerted an important influence on these GHG drivers. The recovery of CH_4 from landfills played the most important role in reducing emissions from solid waste management between 1990 and 2008. The existence of national policies at Member State level contributed to important emission reductions prior to adoption of the Landfill Directive. The directive has furthered this trend since its entry into force in 1999.

Energy industry

EU-27 GHG emissions from the **energy supply sector** (Chapter 7) accounted for 33 % of the total GHG emissions in 2008 and decreased by 12 % from 1990 to 2008. Within this sector, the **production of public electricity and heat**, the single greatest source of CO_2 emissions in 2008, contributed 27 % of the total GHG emissions in the EU-27. CO_2 emissions from public electricity and heat production decreased by 9 % between 1990 and 2008. This overall reduction was achieved despite an increased demand for electricity in the EU during the whole period. The reduction was driven mostly by the closure of inefficient coal-fired power plants in the early 1990s (following the restructuring of eastern Europe economies), a fuel shift from coal and oil to gas and biomass, and an increased share of combined heat and power (CHP) for heat production. Despite this overall reduction, between 2000 and 2008, CO_2 emissions from the sector increased slightly, by 2 %. In the EU-15, the implementation of air pollution control measures for large combustion plants (the LCP Directive, later reinforced by the IPPC Directive) produced important co-benefits for GHG emissions, by encouraging efficiency improvements and fuel switching to cleaner fuels. These positive developments took place despite the fact that such policies were not specifically designed to reduce GHG emissions. Their effects added to those of energy policies specifically promoting energy efficiency.

More recently, setting a price signal for carbon emissions through the EU Emissions Trading System (EU ETS) within the EU-27 has now established a foundation for the implementation of further efficiency improvements and fuel switching, under the condition of meaningful carbon prices. The development of renewable energy sources to produce electricity led to important visible emission reductions, in particular during the 1990s (because the share of renewables in electricity production actually increased, as opposed to the overall trend in the period from 2000 to 2008 — despite a strong development in renewable production in absolute terms).

Between 2000 and 2008, the increase in electricity demand was mostly satisfied through increased production from gas-fired thermal power plants. This reduced the effects on total emissions of the relative growth of renewables, in particular biomass and wind, reduced the share of nuclear power in total electricity generation, and led to the observed increase in emissions. However, in certain EU Member States, GHG emissions from this sector have decreased since 2000, mainly as a result of an increased use of RES. Despite the relative success of policies aiming to improve energy efficiency at consumer level, and thereby reduce the overall energy demand (e.g. the Energy Labelling Directive (Directive 92/75/EEC) and its subsidiary directives, the Energy Performance of Buildings Directive (Directive 2002/91/EC) and the Energy Services Directive (Directive 2006/32/EC)), their effects are masked by increased electricity demand.

Energy use from manufacturing and construction industry

Energy use — and thus also CO_2 emissions — from the EU **manufacturing and construction industry sector** fell between 1990 and 2008, while the gross value added (GVA) of products and services increased significantly. Most of the 25 % reduction in CO_2 emissions from this sector was achieved between 1990 and 2000, mainly due to energy efficiency improvements and further developments within industry. Part of these improvements actually reflected the closure of energy-intensive industries in eastern Europe in the early 1990s. Fuel shifting from coal to gas also delivered significant emission reductions. Since 2000, the rising share of biomass and the increased reliance on power generated from public electricity power plants (for which GHG emissions are reported under the sector 'Energy supply') have also contributed to reducing direct CO_2 emissions from the manufacturing industries sector. As was noted for the public electricity and heat plants, the LCP Directive and, to a lesser extent, the IPPC Directive resulted indirectly in GHG emission reductions by driving efficiency improvements and further incentivising fuel switching, in addition to energy policies specifically promoting energy efficiency. The EU ETS is also estimated to have driven some efficiency improvements in this sector.

Energy use from households

Between 1990 and 2008, CO_2 emissions from **households** in the EU-27 decreased by 11 %. The main reasons for this reduction were a fuel shift for domestic heating from coal and oil to gas in the 1990s, coupled with reduced energy demand in households due to efficiency improvements and improvements in household insulation between 2000 and 2008. Several EU directives contributed to reducing energy use in the households sector. As is the case with electricity production, the minimum levels of energy taxation set at EU level in the period considered did not represent a significant enough share of energy prices (in most Member States) to drive consumption levels down. Switching from fossil fuels to public electricity as an energy source, both for industrial users and for households, results in a transfer of the emissions linked to electricity or heat use from these sectors to the energy supply sector. Since 2005, this shift has also resulted in the transfer of emissions into a sector covered by the EU ETS. On the other hand, the reduction of electricity demand by households — or any other electricity end user not producing their own electricity — due, for example, to the implementation of energy efficiency measures, may have impacted the demand for allowances in the EU ETS. This provides an example of the importance of monitoring the impacts of measures across sectors.

1 Introduction

The developments of anthropogenic GHG emissions are linked to a number of drivers, such as population, economic development, production and consumption patterns, climatic conditions, energy supply infrastructures, etc. With the raising awareness about the potential catastrophic consequences of climate change, an increasing number of policies and measures (PAMs) have been adopted and implemented at EU and national levels in order to target these drivers and reduce greenhouse gas emissions.

The EU has taken various climate related initiatives in the past 20 years. Most of the EU policies take the form of directives (which must be transposed by Member States into national legislation) and regulations (directly applicable in all Member States). Voluntary commitments are also used in specific areas. The first Community strategy to limit carbon dioxide (CO_2) emissions and improve energy efficiency was issued by the European Commission in 1991 and included a directive to promote electricity from renewable energy, voluntary commitments by car makers to reduce CO_2 emissions by 25 % and proposals on the taxation of energy products. A decade later, the first European Climate Change Programme (ECCP I) (European Commission, 2000) was launched to identify and develop a number of EU-wide policies to implement the Kyoto Protocol. The second European Climate Change Programme (ECCP II) (European Commission, 2005), launched in October 2005, focused on reviewing the ECCP I, exploring new policy areas including climate change adaptation, and identifying further cost-effective options for reducing greenhouse gas emissions in synergy with the EU's Lisbon strategy for increasing economic growth and job creation. Specific areas for which additional emission reduction measures for 2008–2012 were developed include aviation, carbon capture and storage. Following an agreement between the European Parliament and the European Council on a climate and energy package in December 2008, a set of legislative measures was adopted in April 2009, including a strengthened and expanded EU ETS, national 2020 targets for emissions not covered by the EU ETS and national 2020 targets for renewable energy.

Since 1990, GHG emission levels in the EU have undergone significant changes, which have been measured annually through national greenhouse gas inventory reports. The EEA reports on 2010 GHG emissions in the EU and on GHG emission trends and projections in Europe, published in October 2011, show that the EU-15 is well on track to meet its emission targets under the UNFCCC and the Kyoto Protocol and that the EU-27 achieved a total reduction of 15.5 % compared to 1990 levels. Which sectors witnessed the strongest reductions? Are there still increasing emission trends in specific sectors or countries? Which were the most significant drivers in the different GHG-emitting sectors and what was their respective influence on sectoral and total GHG emissions? Ultimately, is it possible to attribute certain observed emission trends to the effects of EU and national PAMs?

The report presents first an overview of the main GHG emission trends in Europe until 2008, with a description of the main trends by sector, gas and country. It also briefly looks at emission intensities, both per capita and per gross domestic product (GDP).

The report then assesses GHG emission trends in Europe in four important sectors since 1990, identifies the driving forces and the magnitude of their respective contribution to observed GHG trends and, to the extent possible, explores the links between these trends and a number of PAMs implemented in the EU. The report focuses on emissions from the main source sectors that are energy, transport, agriculture and waste.

Given the importance of the energy sector in terms of GHG emissions compared with other sectors, a more detailed analysis is provided separately for GHG emissions from energy industries (mostly public electricity and heat production), and for GHG emissions from energy use by other industries as well as by households. In the transport sector, a distinction in the analysis is made for road passenger and for freight transport. In the agriculture sector, emissions are split between methane emissions from enteric fermentation and nitrous oxide emissions from agricultural soils. In 2008, about 60 % of total EU emissions were not covered by the EU ETS. Such emissions come from the transport, agriculture and waste sectors as well as part of the energy sector. For this reason, these sectors are analysed first. This is also of particular relevance for all Member States, which will have to implement measures at national level in order to achieve their individual 2020 target set under the 2009 Effort Sharing Decision, as part of the EU climate and energy package. The extended analysis in the energy sector remains essential due to the important share of this sector in total GHG emissions.

The report focuses on some of the policies to analyse GHG emission trends but does not aim to look at the entire body of EU legislation that may have consequences on GHG emission developments. Other policies may still be relevant to some of the issues analysed but were not further explored here. EU cohesion funds, for example, which may contribute to modal shift in the transport sector, are not analysed here. Furthermore, the conclusions on the effects of policies across Europe reflect the results achieved by the combination of EU PAMs, as well as national measures implemented either as a consequence of these EU policies or as individual Member States' initiatives. An indicative (and non-exhaustive) list of EU legislative texts (or supporting documents), identified as relevant in terms of potential impacts on GHG emissions, is provided at the end of each of the four sectoral chapters.

The analysis covers the time period 1990 to 2008, with a split between 1990–2000 and 2000–2008. This allows for distinguishing and analysing emissions trends during two periods where economic conditions in the EU were markedly different, with important political developments in Europe in the early 1990s, which have indirectly but strongly affected GHG emissions over the whole decade, and relatively stable economic conditions across Europe after 2000 (until the recent recession), which have shaped emission trends differently.

The geographical scope of this report corresponds to the European Union (EU-27). The main report focuses solely on EU-27. Its annex presents complete data sets and analyses for the EU-15 and all individual Member States of the EU-27. It also presents results for the other European Environment Agency (EEA) member countries (Iceland, Liechtenstein, Norway, Switzerland and Turkey) and Croatia (EU candidate country together with Turkey) as far as data are available.

2 Methodology

2.1 Sectoral classification

The report is based on an analysis of GHG emissions as reported annually by Member States under EU legislation (EU, 2004) and international requirements under the UNFCCC. These emissions are reported in a consistent way, using a nomenclature defined in the Revised 1996 Intergovernmental Panel on Climate Change (IPCC) Reporting Guidelines to categorise anthropogenic GHG emissions (IPCC, 1996). GHG emissions are classified according to their emitting sector, consistently with a common reporting format (CRF) used to report GHG emissions internationally. The definition of the four sectors (and their relevant subsectors) analysed in the report is provided in Table 2.1.

Table 2.1 Sector definitions

Sector or sub sector name	IPCC sector	Definition	Comment
Transport	1A3	Emissions from the combustion and evaporation of fuel for all transport activity, regardless of the sector, specified by subsectors as followed.	Emissions from fuel sold to any air or marine vessel engaged in international transport (bunker, i.e. fuel used in international aviation and maritime transport) are excluded from the totals in this category and reported separately by countries. Emissions due to electricity use by rail transport and electric vehicles are also not reported in this category, but allocated instead to the energy supply sector.
Agriculture	4	All anthropogenic emissions from this sector except for fuel combustion and sewage emissions, which are covered in the Energy (1A1) and Waste (6B) sectors, respectively.	The uncertainty of GHG emission estimates is relatively high compared to other sectors. See for example, emissions from enteric fermentation (CRF 4A1). CO_2 emissions related to land use, land-use change and forestry (LULUCF) are not included here but reported under the IPCC category 5.
Enteric fermentation	4A1	Methane production from herbivores as a by-product of enteric fermentation, a digestive process by which carbohydrates are broken down by micro-organisms into simple molecules for absorption into the bloodstream. Both ruminant (e.g. cattle, goat, sheep) and non-ruminant animals (e.g. pigs, horses) produce CH_4, although ruminants are the largest source (per unit of feed intake). This includes enteric fermentation of cattle producing milk and non-dairy cattle (beef production).	CH_4 emissions from enteric fermentation reported under the UNFCCC are calculated on the main basis of the number of cattle. However, several other factors which are not accounted for in the estimates of emissions (e.g. breed, size of animal, amount of time raised on grass versus amount of compound feed, age at first calving, longevity of animals) may also influence the actual level of emissions.
Agricultural soils	4D	Emissions and removals of CH_4 and N_2O from agricultural soil/land and NMVOCs from crops. N_2O emissions from the use of nitrogen-based fertilisers in rice cultivation are also reported here.	
Waste	6	GHG emissions resulting from solid waste disposal on land, waste water, waste incineration (without energy recovery) and other waste management activity (biological treatment of waste).	CO_2 from organic waste handling and decay are not reported here. CO_2 emissions from fossil-based products (incineration or decomposition) are accounted for here, excluding waste incineration with energy recovery (those emissions are reported under the Energy supply sector. Emissions from recycling, waste transport are reported under energy sectors. Therefore the GHG emissions covered here represent only part of all emissions from the waste sector as defined in EU waste legislation.

Table 2.1 Definition of the sectors used (cont.)

Sector or sub sector name	IPCC sector	Definition	Comment
Solid waste disposal on land	6A	CH_4 produced from anaerobic microbial decomposition of organic matter in solid waste disposal sites.	CO_2 is also produced but only CO_2 from non-biogenic waste is reported.
Energy supply	1A1+ 1B	Emissions from fuels combusted by the fuel extraction or energy-producing industries (1A1) and fugitive emissions from the production, processing, transmission, storage and use of fuels (1B).	This category covers all emissions resulting from electricity consumption by households and industry (non autoproducers).
Energy use	1A2 + 1A4 + 1A5	Emissions from fuel combustion in industry including combustion for the generation of electricity and heat by the industry (except energy industries), in commercial and institutional buildings and in households, from agriculture, forestry and fishing and all remaining emissions (except transport) from non-specified fuel combustion.	This category corresponds to direct emissions from fuel combustion only. This means that emissions due to electricity consumption are not reported here, but under category 1A1 (emissions from energy industries).
Energy use from manufacturing and construction industries	1A2	Emissions from combustion of fuels in industry including combustion for the generation of electricity and heat.	Emissions related to the production of public electricity or heat used by the manufacturing and construction industries are covered under the Energy supply sector.
Energy use from households	1A4B	All emissions from fuel combustion in households. Emissions from electricity consumption are not included under households.	Emissions related to the production of public electricity or heat used by households are covered under the Energy supply sector.

Source: IPCC, 1996.

2.2 Overall method

This report presents a new approach of directly linking and comparing emission trends and related PAMs, especially from Chapter 4 onward (sectoral analyses). This is done by carrying out a decomposition analysis on the GHG trend, in order to determine the influence of drivers on emissions, followed by a mapping of qualitative assessments of PAMs with the emission drivers used in these decomposition analyses. The decomposition analysis, as a tool itself for analysing trends, has already been widely used in other studies. In particular, it has already been used in past EEA reports on GHG trends and projections in Europe for the explanation of selected sectoral emission trends. In this report, the analyses have been extended to cover four main emitting sectors: energy supply and use, transport, agriculture and waste. The quantifications and interpretations have to be undertaken carefully to reflect specific circumstances.

The procedure foresees the following steps for each of the main GHG-emitting sectors analysed in the report.

1. Identification of underlying factors and resulting drivers: Factors that are assumed to be key in influencing emission trends have been identified. These factors are then combined with each other into emission drivers.

2. Decomposition analysis — analysis of the relative influence of drivers on GHG trends: It represents one starting point for analysing emission trends.

3. Identification and description of the relevant PAMs affecting emissions from the analysed sector and of the main links with the drivers used in the decomposition analysis.

4. Overall assessment of emission trends, taking into account the relative impact of the different drivers from the decomposition analysis and of the potential effects of the relevant PAMs.

Two periods within the whole 1990–2008 period are considered: 1990–2000 and 2000–2008. This allows for a more detailed description of the effects of emission drivers and policies. It also allows for capturing the diverse significance of economic change in both periods.

2.3 General description

The two main elements of the method adopted in the present analysis are described here. Overall, the decomposition analysis and policy analysis are performed sequentially and the results of both analyses are combined in a conclusive section for each of the sectors investigated.

2.3.1 *Decomposition analysis*

The designs of new policy instruments as well as the assessment of implemented measures in the field of climate change mitigation require knowledge of the factors and drivers influencing GHG emissions levels. A first step therefore consists in identifying these drivers, an exercise that can be informed by identifying the main GHG sources at global or sectoral level. In order to determine the respective contribution of these drivers to changes in GHG emissions, a decomposition analysis can then be carried out, in which GHG emissions are decomposed into a product of factors involving the 'underlying causes' of these emissions. The choice of the factors depends on the 'conceptual model' ('Which factors can reasonably be considered to have an impact on the interesting variable?'), on feasible or non-feasible interpretation within the formula, and on data availability.

In a following step, a change in GHG emissions over a determined period is decomposed into a sum of individual changes attributed to each driver. Each individual emission change represents the contribution of a driver while leaving all other independent variables unchanged. In the following example, four drivers of total GHG emissions are selected and combined to perform a decomposition analysis. Such analysis could be done with any selection of drivers and for any specific sector. The relevance of its result will depend on the appropriateness of the selected drivers for the sector chosen.

The effect of a certain driver within the chosen period is quantified by calculating the single effect of a change of this driver on total GHG emissions, while leaving all other drivers constant. When all drivers follow the change over time, the result has to be equivalent to the overall change in GHG emissions, and represents the sum of the effects of all drivers.

The effect of the first driver is estimated by taking the last value available for this factor (e.g. 2008) while all the other factors remain equal to their values of the starting year (e.g. 1990). The magnitude of change of GHG emissions caused by this driver in the period is therefore evaluated by assuming that all other drivers would remain constant. In the following, the 2008 value is used for one factor after

Box 2.1 Example of decomposition analysis applied to total GHG emissions, using four selected underlying factors:

Example of underlying factors:
- population
- gross domestic product (GDP)
- energy consumption
- fossil fuel use.

Decomposition:

*GHG = [population] * [GDP per capita] * [energy consumption/GDP] * [fossil fuel use/energy consumption] * [GHG/fossil fuel use]*

Resulting drivers:
- population
- economic development (GDP per capita)
- energy intensity of the economy (energy consumption/GDP)
- share of fossil fuels in final energy consumption (fossil fuel use/energy consumption)
- content in GHG emissions of the fossil fuels used (GHG/fossil energy use).

Followed by:

Total GHG change = Δ GHG due to change of population
+ Δ GHG due to economic development
+ Δ GHG due to change in energy intensity
+ Δ GHG due to change in fossil fuel share in final energy consumption
+ Δ GHG due to change in emission content of fossil fuels used.

the other. For the second driver this implies that all factors but the first two are equal to 1990 emissions. This intermediary result shows the combined influence of the first two drivers. The difference between the first and this intermediary result gives the individual influence of the second factor. The single values show the effect of each factor on emissions during the period considered. The last step is to apply the 2008 value to all factors. The result of this last equation should conform to the actual emissions in 2008.

For certain sectors, a relevant decomposition analysis requires splitting the emissions to be analysed into a sum of two (or more) elements, each element being itself a combination of drivers. For example in the agriculture sector, emissions from cattle are first split between emissions from dairy cattle and emissions from non-dairy cattle. Each of these two elements is then decomposed, introducing the relevant drivers. Once they are estimated, the effects of all drivers can be combined to obtain the overall trend in emissions from cattle. The decomposition formulas used for each analysis are presented in the relevant sections of the report, next to the identification of the relevant factors affecting sectoral (or total) emissions trends.

2.3.2 Assessment of policies and measures

Selection of EU policies influencing GHG emission trends

For each sector, a number of relevant EU policies having potentially affected the emission drivers used in the decomposition analysis is identified and examined. Most of these key policies were already identified in the 'GHG emission trends and projections in Europe' report (EEA, 2009). Certain policies have been included because of their impact on specific sectoral drivers. Furthermore, policies that have been amended/incorporated by recent frameworks or other policies, where considered appropriate, have been analysed on an individual basis prior the amendment (e.g. Boiler Efficiency Directive (Directive 92/42/EEC) amended by the Ecodesign Directive (Directive 2005/32/EC)). Other potentially relevant policies have not been included for various reasons.

- Since the sector of industrial processes and related fluorinated gas (F-gas) emissions have not been included in the analysis, the F-gas Regulation (Regulation (EC) No 842/2006) and the Mobile Air Conditioning (MAC) Directive (Directive 2006/40/EC) have not been considered.

- New policies which entered into force post the last year covered in the decomposition analysis (2008) have in general not been discussed. In case they have been discussed, this has not been done in depth (e.g. the Carbon Capture and Storage (CCS) Directive (Directive 2009/31/EC) and the revised RES Directive (Directive 2009/28/EC) which both entered into force in 2009).

- Overarching and cross-sectoral policies with broad objectives have not been considered (e.g. Kyoto Protocol project mechanisms, EU structural funds).

Impacts of selected policies on GHG emission drivers

In addition to GHG reductions resulting from the adoption and/or transposition of EU policies, savings may also result from PAMs implemented by Member States as a result of national policy objectives. The focus of this study is placed on the EU-wide policies. A large majority of these policies consist of directives, which must be transposed by Member States into national law.

Based on available analyses of the effects of the policies selected, in particular the study carried out for the European Commission between 2007 and 2010: 'Quantification of the effects on greenhouse gas emissions of policies and measures' (AEA et al., 2009), these impacts are reported in qualitative terms and linked with the drivers used in the decomposition analysis so as to obtain a policy perspective on the trends in GHG affected by each single driver.

For each sector, the policies linked to the sectoral drivers are analysed. Each analysis includes a description of the policy and a description of the likely impact of the policy on the various drivers. Due to the number of sectors and policies examined in this report, not all aspects of each policy are covered in detail. The qualitative analysis of the impacts of policies is based on a number of criteria.

- The alignment between the aims and objectives of the policy and the driver. If the objective of the policy aligns well with the driver the policy would place a direct impact on the driver, which may result in a strong impact. In other cases, the scope of the driver is broad whereas the policy targets a specific activity. For example, the Packaging and Packaging Waste Directive (Directive 94/62/EC) is linked to the driver 'Incineration of MSW' (municipal solid waste). However, since the policy only targets packing waste, which accounts for 17 % of total MSW, the alignment between the policy objective and the driver is considered weak. This could also be considered vice versa, in particular when the policy sets a general framework as opposed to having a specific objective.

- Literature review including assessments from other studies. Findings from literature reviews of other studies and Commission documents that analyse the policy effectiveness are used. The status of the transposition of the policy in Member States is also used to determine whether the policy has had a strong impact on the driver.

- Change observed in indicators associated with the policy. The AEA et al. report (2009) identified 'simplified policy effectiveness indicators' for the EU-level policies studied. These indicators do not provide an accurate representation of the policy impacts, or replace the results from the policy evaluation. They do, however, give a quick overview of the emissions causing activity that the policy acts upon and of the overall trend in the activity since the policy has been in place. This can help to determine the strength of the policy on the driver. In some instances, the indicator matches the factor of the drivers or the driver itself in the decomposition analysis. In this case, the same data source is used for consistency.

- The time frame of the policy target and type of policy instrument used. Certain policies set targets that Member States must meet by a certain time period. Whether these targets are mandatory or indicative and whether they are stringent compared to the circumstances before the policy introduction influences the effect of the policy on the driver.

- Time elapsed since the policy's entry into force. If the policy has only been introduced in recent years of the period covered by the decomposition analysis, the policy is considered to have not had enough time to make a significant impact on the driver.

- Strength of the autonomous change. For some drivers, strong autonomous progress can be identified and explained. This influences the assessment of the influence of a policy linked to this driver. Autonomous change may in particular be due to national policies implemented prior to the EU policy.

- Other background information. Background information related to the policy is analysed. This includes aspects such as the consideration of the impacts of other policies in the same sector.

A number of policies have been amended or recast during the time series covered by the decomposition analysis. In this instance, the strength of the policy impact on the driver may differ for the two time periods discussed (1990–2000 and 2000–2008).

2.4 Data source

Performing a decomposition analysis across the EU requires comparable and time consistent data sets. For each driver, one single data source for all countries and for the full time period analysed is used. The availability of the required data determines to a large extent which factor is to be used in the decomposition analysis. National statistics are not considered due to inconsistencies across countries. The data used for the decomposition analyses are taken from acknowledged sources:

- official national inventories submitted to the United Nations Framework Convention on Climate Change (UNFCCC) for GHG emissions and driving factors in the agriculture and waste sector;

- data from the statistical office of the European Commission (Eurostat) for driving factors in the energy and industry-related sectors;

- in certain cases, macro-economic assumptions used in the 2009 Energy baseline of the European Commission (based on the PRIMES model) were used.

The PAMs assessment is carried out only at the EU-27 level. A wide number of datasets and documents have been used.

2.5 Limitations and uncertainties

The analyses presented in the report are restricted to the trends of GHG emissions produced within EU territory during the period from 1990 to 2008.

The decomposition analysis is based on a tautology (whatever factors are selected, the formula combining these factors will always be true). Its relevance is entirely dependent on the appropriate choice of drivers. Therefore it provides more a description than an explanation of emission trends.

The uncertainty of the results of the decomposition analysis depends on the uncertainty inherent to the methodology chosen and to the underlying data (which includes the uncertainty of emission trends themselves).

- The formula requests both terms of the equation to be equal, which sets limitations on the selection of factors as the selected factors must be transferable to meaningful drivers, describing the change in GHG emissions.

- The quantitative results of the analysis depend on the order of mathematical terms within the formula. The drivers have to be analysed one after the other as they follow logical dependencies. A different order of driver analysis would lead to different and potentially misleading results. The sensitivity of the results to a change in the order of the drivers has not been assessed.

- The period chosen for the decomposition analysis also impacts the results. It is fixed at an initial point in 1990 and ends in 2008, regardless of the exact year a policy is implemented. Consequently, specific developments occurring within this period, e.g. between 1997 and 2003, cannot be pictured adequately. The time period has been adjusted accordingly for direct comparisons with the quantitative analysis of emission savings due to a certain policy.

- With regard to the uncertainty of the underlying data, it is important to note that input data is taken from different sources. This is relevant for drivers that link, for example, fuel data reported in national inventory reports to Eurostat data on final energy consumption, i.e. in particular the driver 'fuel efficiency'. In addition, data from the PRIMES model was used in a few cases: this data is not directly taken from actual statistics and is only available for 2005 and 2010 (projection). Linear interpolation is used in order to obtain values for the years 2006, 2007 and 2008, which introduces additional uncertainties.

- To eliminate the influence of weather conditions on energy consumption, the time series has to be temperature corrected from 1990 on. The result shows a national final energy consumption, fuel consumption and emissions based on yearly average temperature corresponding constantly to the long-term average.

The results of the decomposition analysis should therefore be interpreted with care (in the magnitude of kilo tonnes) rather than being taken as accurate quantification of the effect of each individual driver. A sensitivity analysis of the impacts of drivers has not been undertaken. Furthermore, the fact that a quantity appears in a decomposition analysis does not mean that this quantity is proportional to emissions.

The impact of policies on the various drivers is based on expert judgement using the criteria listed previously. Thus, an uncertainty arises as a result of the accuracy of the methodology used in any referenced documents used for judgement, depth of understanding of the policy objectives, the strength of the autonomous effects and alignment with emission drivers.

The policy assessment identifies the role policies play in influencing emission trends in the EU. In an ideal scenario, the GHG emission drivers resulting from the decomposition analysis align well with one or more policy objectives. If this is the case and if emission savings of the policies can be quantified, the emission change due to the driver can be split between the autonomous change (price effects, structural changes, etc.) and the proportion attributed to the policy. However, the quantification of policy impacts (both *ex ante* and *ex post*) is complex for several reasons, and in particular those set out below.

- For some policies, the link to GHG emissions is more direct than others. For example, in the analysis of the RES-E Directive, the emission savings arise from the electricity that would have been generated from fossil fuels in the absence of the directive. However, the CAP covers a wide range of emission sources not directly linked to GHG emissions. In addition, the CAP addresses sources whose uncertainty levels are considered high in the EU GHG National Inventory Report (NIR). This makes a reliable quantification of emission savings complex.

- A number of policies may have the same objective and consequently decomposition drivers are often impacted by a number of policies. In this case, distinguishing the contribution of individual polices to a change in the driver is complex.

- The availability of the datasets containing key parameters required for the analysis is often limited.

An additional issue arises when analysing the impact of policies based around the UNFCCC reporting because PAMs are often cross-cutting and target more than one source in multiple sectors. This means that a policy may trigger emissions to decrease in one sector but may have the opposite effect in another.

The policy will only impact those Member States that were part of the EU in the specific year. In this report the driver is presented at the EU-27 level and thus the impact of the policy due to the changing number of EU Member States has not been considered apart from the CAP.

3 Total GHG emissions, 1990–2008

Summary

In 2008, CO_2 emissions represented 82 % of total GHG emissions in the EU (excluding land use, land-use change and forestry (LULUCF) and international bunkers). About 93 % of this CO_2 originated from the combustion of fossil fuels, and the remaining 7 % from specific industrial processes (e.g. production of cement, chemicals, iron and steel). The three activities with the largest shares in GHG emissions were the production of public electricity and heat from fossil fuel combustion by the energy industry, road transportation (freight and passenger), and iron and steel production. The five largest GHG emitters in the EU-27 were Germany, the United Kingdom, Italy, France and Spain (in decreasing order of emissions). Together these countries, which are all EU-15 Member States, accounted for more than 60 % of EU-27 GHG emissions. The sixth largest GHG emitter was Poland, the largest emitter in the EU-12.

Between 1990 and 2008, EU-27 GHG emissions decreased by 11.3 %, a large part of these reductions taking place during the 1990s. The EU-27's emissions declined steadily between 2003 and 2008, reaching 4 940 million tonnes CO_2-equivalent in 2008. The main reasons for the reduction were decreases in energy and carbon intensity, and switching to less intensive fuels, which overcompensated for emission increases due to rising populations, economic development and, more generally, increasing energy demand. The sector with the highest GHG emission increase was transport. The largest absolute emission reductions took place in Germany, the United Kingdom and in most EU-12 Member States, while emissions increased most in southern EU-15 Member States (in decreasing order of absolute emission change: Spain, Italy, Greece and Portugal). All the other EEA member countries except Switzerland experienced an increase in their total GHG emissions between 1990 and 2008, including a doubling of total emissions in Turkey during the period.

Between 1990 and 2008, per GDP emissions decreased by 38 % in the EU-27 (GDP increase of 44 % while emissions decreased by 11 %), and by 34 % in the EU-15 (GDP increase of 43 % with a 6 % reduction in GHG emissions). GHG emissions per capita show significant differences across European countries, depending on national circumstances. Between 1990 and 2008, per capita emissions decreased by 16 % in the EU-27.

This chapter presents a general description of GHG emission trends, emissions per capita and emissions intensity in Europe between 1990 and 2008. The analysis of the drivers and effects of EU policies on these total GHG emission trends is presented in Chapter 8.

3.1 Emission levels in 2008

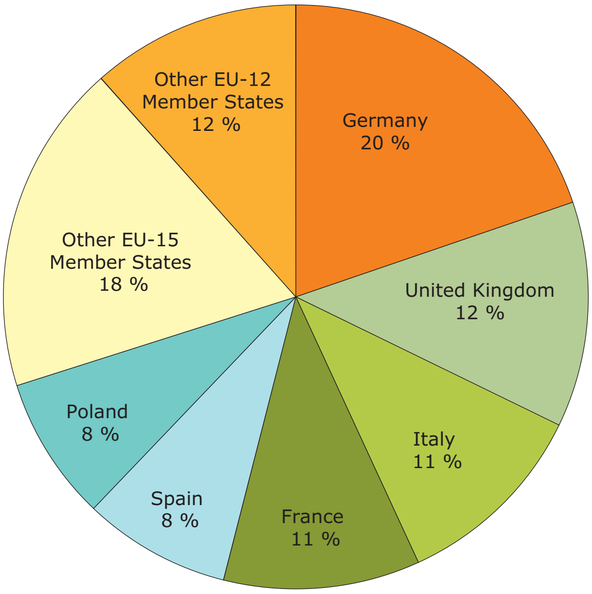
In 2008, the EU-27 emitted 4 940 Mt CO_2-equivalent, excluding net CO_2 removals from LULUCF and emissions from international bunkers (international aviation and international maritime transport), 627 Mt CO_2-equivalent less compared to 1990 (– 11 %). Total GHG emissions in 2008 present the lowest emission level achieved in the EU-27 between 1990 and 2008.

Eighty per cent of total EU-27 GHG emissions are generated in the EU-15 also representing the EU-15 share on the whole EU-27 population. The five largest GHG emitters in the EU-27 were, in decreasing order of emissions: Germany, the United Kingdom, Italy, France and Spain. Together they accounted for more than 60 % of EU-27 GHG emissions. Poland was the largest GHG emitter in the EU-12 (Figure 3.1).

The three activities with the largest shares in GHG emissions were the production of public electricity and heat from fossil fuel combustion by the energy industry, road transportation (freight and passenger), and iron and steel production (Table 3.1). More details on drivers responsible for emission trends in these sectors are presented from Chapter 4 to Chapter 7. Energy-related emissions account for about 79 % of total GHG emissions in the EU-27 (80 % in the EU-15).

As a consequence of the role played by fossil fuel combustion, CO_2 is the predominant GHG emitted, accounting for 82 % of total GHG emissions (excluding LULUCF and international bunkers). About 93 % of this CO_2 originates from the combustion of fossil fuels, and the remaining 7 % from specific industrial processes (e.g. production of cement, chemicals, iron and steel). Methane (CH_4) and nitrous oxide (N_2O), mainly due to agriculture and waste management, account for about 9 % and 7 %, respectively, of total emissions, while fluorinated gases (F-gases) from industrial processes represent 2 % of total emissions (Figure 3.2).

Figure 3.1 GHG emissions in the EU-27 by main emitting countries, 2008



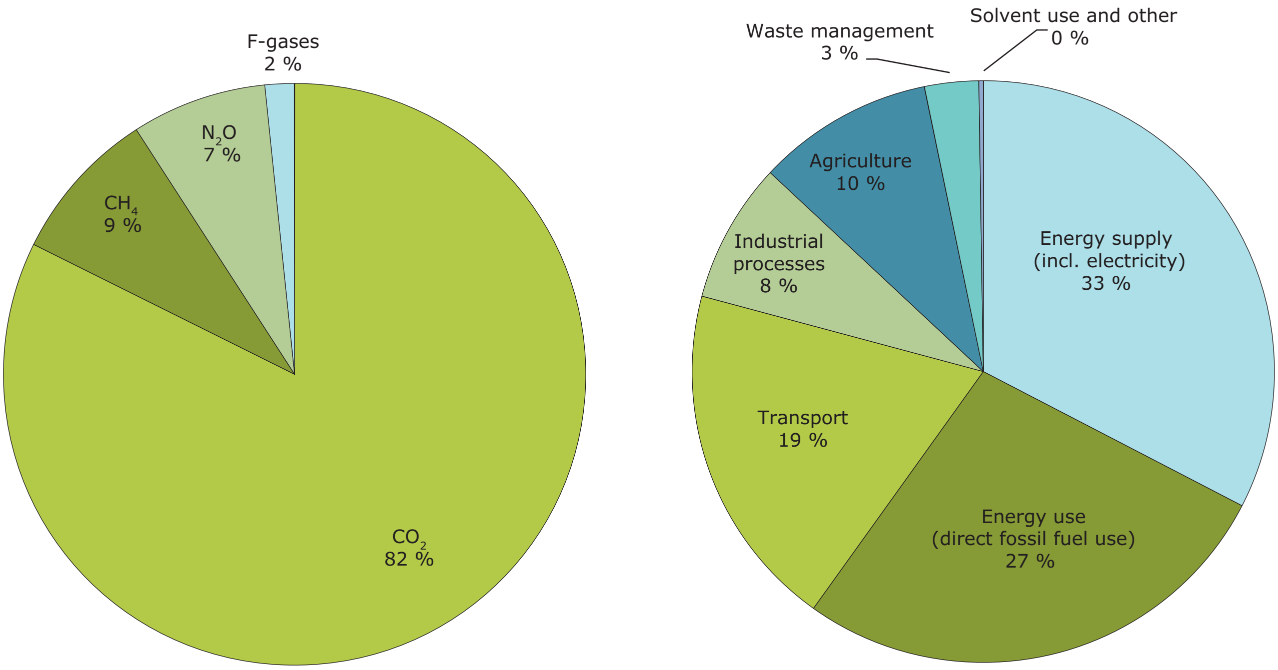
Source: EEA, 2011. See www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer.

Table 3.1 GHG emission in the EU-27 by main source activity, 2008

Key source (CRF category)	Gas	Share in 2008
Production of public electricity and heat (1A1a)	CO_2	26.6 %
Road transport (1A3b)	CO_2	17.9 %
Energy use by manufacturing industries excluding iron and steel production (1A2 excluding 1A2a)	CO_2	10.3 %
Energy use by households (1A4b)	CO_2	8.9 %
Soil emissions from fertiliser use (4D)	N_2O	5.0 %
Iron and steel production (1A2a+2C1)	CO_2	3.6 %
Energy use by tertiary sector (1A4a)	CO_2	3.6 %
Enteric fermentation (4A)	CH_4	3.0 %
Petroleum refining (1A1b)	CO_2	2.7 %
Solid waste disposal (6A)	CH_4	2.3 %
Cement production (2A1)	CO_2	2.0 %
Energy use in primary sector (1A4c)	CO_2	1.5 %
Consumption of halocarbons (2F)	HFC	1.4 %
Fugitive emissions from fuels (1B)	CH_4	1.3 %
Other sources	CO_2-equivalent	9.9 %

Source: EEA, 2011. See www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer.

Figure 3.2 GHG emissions in the EU-27 by gas and by sector, 2008



Note: Emissions from international aviation and international maritime navigation, which are not covered by the Kyoto Protocol, are not included here. Net emissions from LULUCF are not included either. Emissions related to the use of public electricity and heat (generated from fossil fuel combustion) are included in the category 'energy supply'.

Source: EEA, 2011. See www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer.

3.2 GHG emission trends 1990–2008

Between 1990 and 2008, total EU-27 GHG emissions (without LULUCF) decreased by 11.1 %. This overall change is the result of GHG emission reductions of 6.3 % in the EU-15 and emission reductions of 26.7 % in the EU-12. A large part of these reductions took place during the 1990s (Figure 3.3).

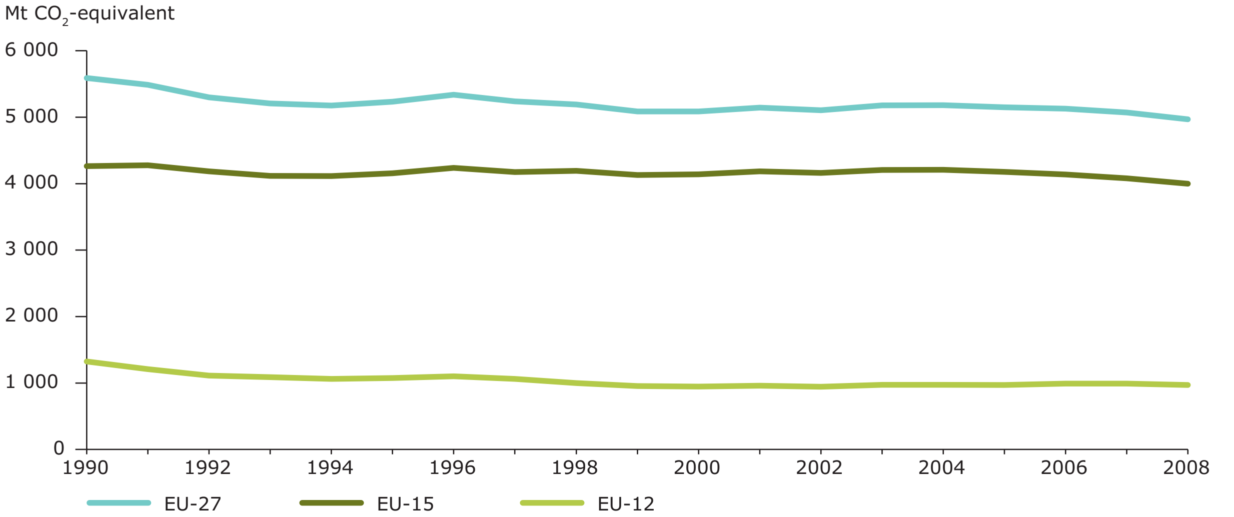
GHG emission reductions between 1990 and 2008 can be observed in all IPCC sectors except for transport. Regarding the development of gases, all GHGs decreased except F-gases (Figure 3.4). However, CH_4 and N_2O emissions decreased to a much larger extent than CO_2, which can be attributed to chemical industry and the agriculture and waste sector.

The nature of the factors affecting GHG emission trends can be very diverse although some of these are interlinked (such as socioeconomic, demographic, climatic, technological and structural). Most of these factors are related to the levels of fossil fuel combustion, the main source of GHG emissions in Europe, as the analysis of 1990–2008 GHG trends in Europe shows:

- EU-27 emissions decreased by 9 % between 1990 and 2000 due to the economic decline that affected mostly eastern Europe during the early 1990s and a following period of restructuring. Heavily polluting and energy-intensive industries were closed and energy efficiency improvements in power and heating plants were achieved. Romania was responsible for about half of the total EU-27 change between 1990 and 1991. The emission reductions that took place in (former Eastern) Germany in the early 1990s accounted for a significant part of the reductions observed at EU-15 level. Important emission reductions also took place in France and the United Kingdom during that period, in particular in energy industries, manufacturing industries and other energy sectors. In the United Kingdom this reduction in emissions was due to a switch from solid fuels to gaseous fuels.

- In 1996, an emission increase was recorded in most EU Member States. This was due to a particularly severe winter, which led to increased energy consumption from households for heating. In Italy, this emission peak from households was counterbalanced by a strong

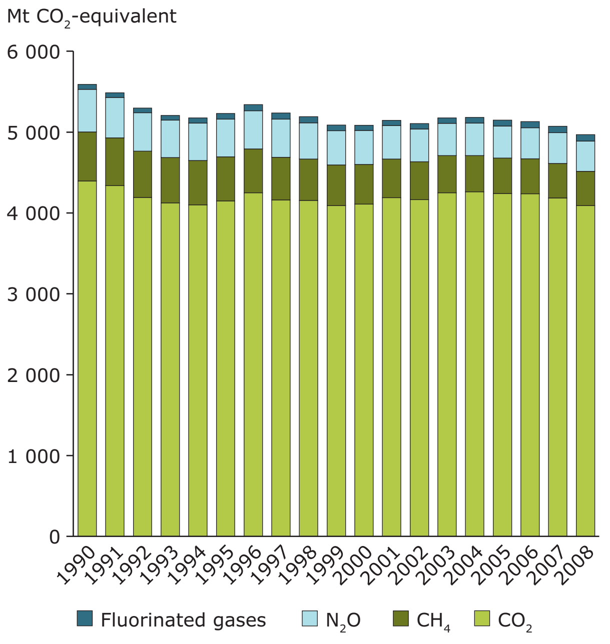
Figure 3.3 Greenhouse gas emission trends in the EU-27, the EU-15 and the EU-12, 1990–2008

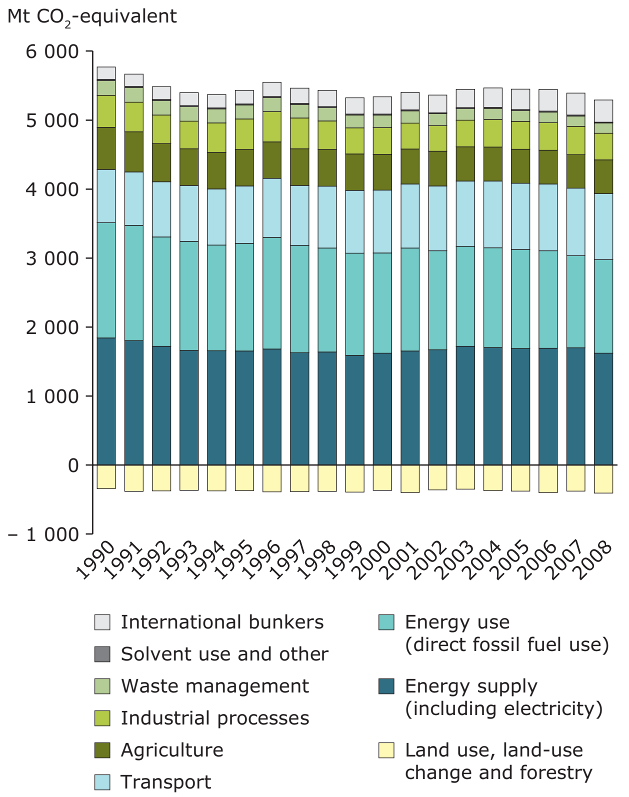


Note: Emissions from international aviation and international maritime navigation, which are not covered by the Kyoto Protocol, are not included here. Net emissions from LULUCF are not included either.

Source: EEA, 2011. See www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer.

Figure 3.4 Total EU GHG emissions by sector and by gas, 1990–2008





Note: The sectors presented here correspond to the following IPCC categories: Land use, land-use change and forestry: 5; Energy supply (including electricity): 1A1a+1B; Energy use (direct fossil fuel use): 1A2+1A4+1A5; Transport: 1A3; Agriculture: 4; Industrial processes: 2; Waste management: 6; Solvent use and other: 3+7. Emissions related to the use of public electricity and heat (generated from fossil fuel combustion) are included in the category 'energy supply'. Emissions from international aviation and navigation are not included in the transport sector.

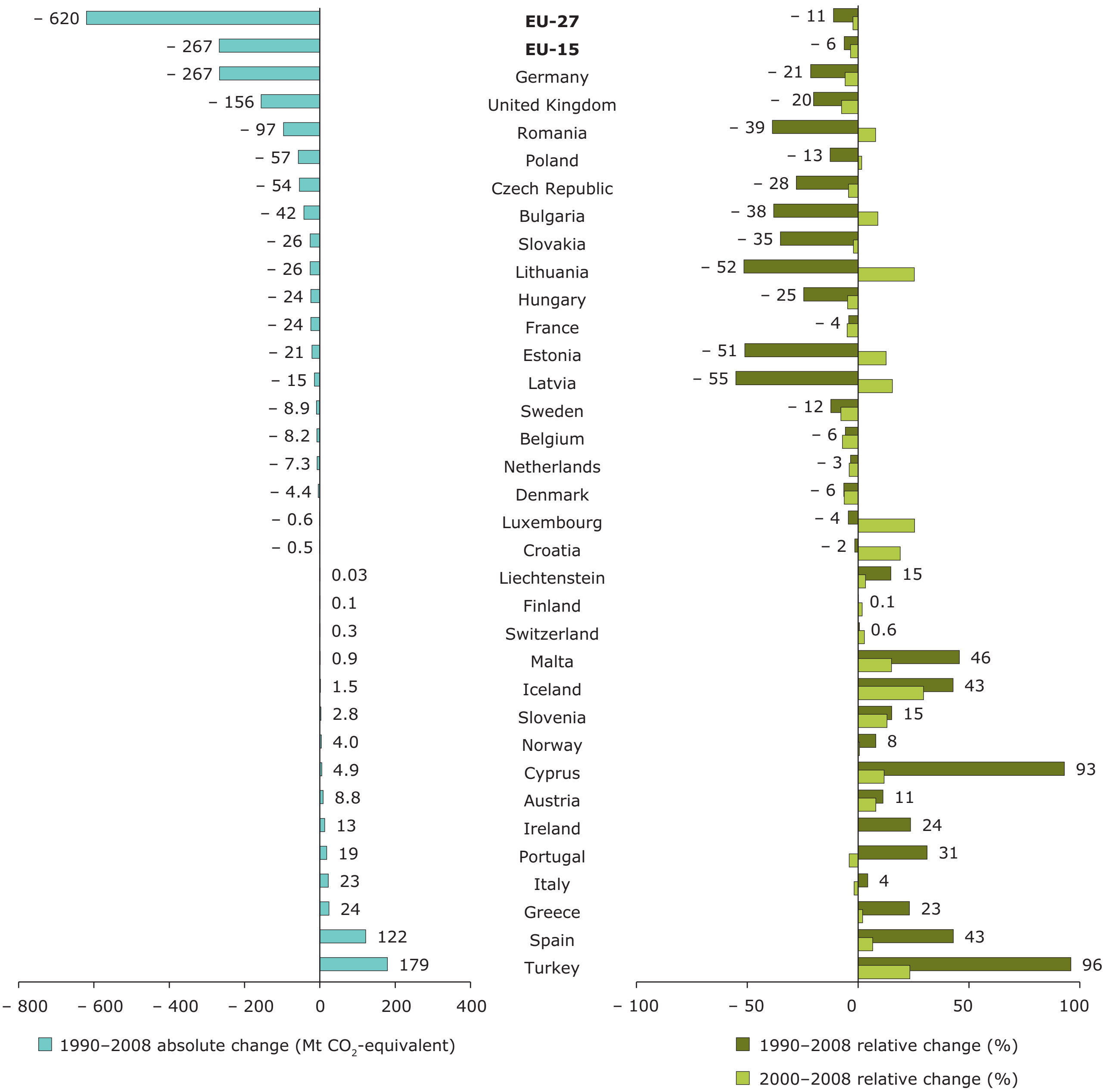
Source: EEA, 2011. See www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer.

decrease in emissions from energy industries, which resulted in an overall decrease in total emission in Italy.

- Between 1996 and 1999, emissions in the EU-15 decreased, mainly due to reductions in emissions from chemical industries (adipic acid production) in Germany, France and the United Kingdom, and from production of halocarbons in the Netherlands and the United Kingdom. Emissions in Italy increased during this period due to considerable increased emissions from the energy sector. Between 1997 and 1998, emission reductions in Poland were responsible for most of total EU-27 emission reductions. Emissions peaked in France in 1998, as all emissions from fuel combustion in the energy sector increased despite reduced emissions from chemical industries.

- Between 1999 and 2004, emission trends in the EU-15 and EU-12 were comparable. The

Figure 3.5 Absolute change and average annual relative change of total GHG emissions in the EU, 1990–2008



Source: EEA, 2011. See www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer.

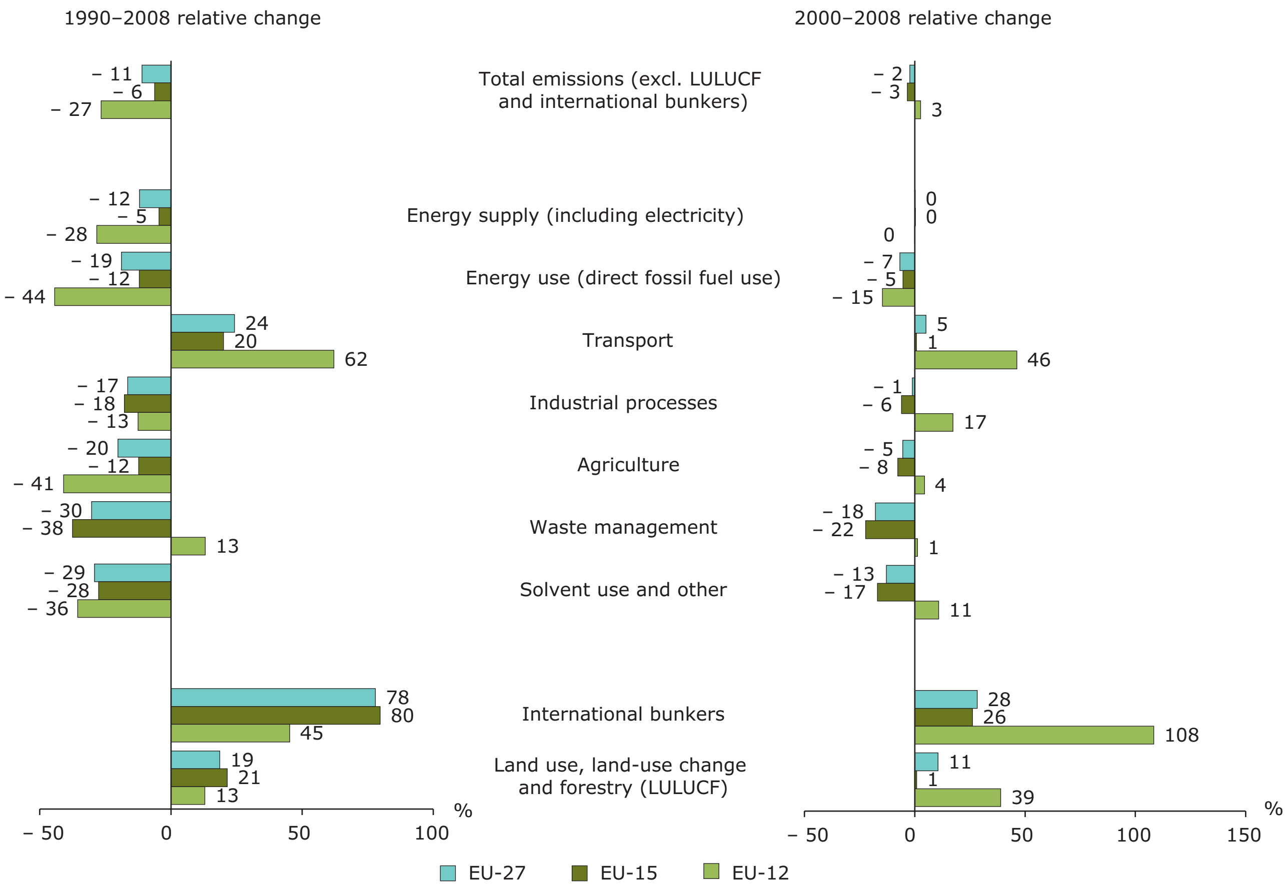
overall increase in emissions was mainly driven by increasing energy consumption from final users. The hot and dry summer in 2003 was responsible for high emissions because it reduced hydropower availability, which led to an increased output from thermal power production.

- Since 2004, final energy demand in the households sector and the tertiary sector in the EU-15 has been decreasing, which has resulted in decreasing total emissions. Belgium, Germany, France, Italy and the Netherlands made significant contributions to this overall EU-15 trend. On the other hand, emissions have been increasing since 2004 in the EU-12. This was mostly due to transport and industrial processes. These countries seem to be repeating the experience of countries like Ireland, Spain and Portugal which, starting from a relatively low transport level, experienced high economic growth accompanied by strong growth in transport and related GHG emissions.

- The overall EU GHG emission trend between 1990 and 2008 was dominated by the two largest emitters, Germany and the United Kingdom, which together achieved GHG emission reductions of more than 50 % of the absolute total emission reduction (Figure 3.5). Important absolute emission reductions were also achieved by EU-12 Member States Bulgaria, Czech Republic, Poland and Romania. These decreases were partly offset by striking emission increases in Spain and, to a lesser extent, in Italy and Greece.

- All the other EEA member countries except Switzerland experienced an increase in their total GHG emissions between 1990 and 2008, including a doubling of total emissions in

Figure 3.6 Total and sectoral changes in total GHG emissions for EU-27, EU-15 and EU-12



Note: The sectors presented here correspond to the following IPCC categories: Land use, land-use change and forestry: 5; Energy supply (including electricity): 1A1a+1B; Energy use (direct fossil fuel use): 1A2+1A4+1A5; Transport: 1A3; Agriculture: 4; Industrial processes: 2; Waste management: 6; Solvent use and other: 3+7. Emissions related to the use of public electricity and heat (generated from fossil fuel combustion) are included in the category 'energy supply'. Emissions from international aviation and navigation are not included in total emissions or in the transport sector.

Source: EEA, 2011. See www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer.

Turkey during the period. This last increase is mainly attributed to the country's important demographic growth (+ 25 % over the period) and economic development. However, emissions per capita of 5.2 Mt CO_2-equivalent in 2008 are still relatively low compared to other European countries. After a sharp decrease observed between 1990 and 1994, GHG emissions in Croatia increased until 2007 to reach a level 2 % above 1990 levels. In 2008, emissions decreased by 4 % compared to 2007.

- The emission sources contributing most to a decrease concern fuel combustion (Table 3.2). The highest reductions were achieved in the sector energy use in manufacturing industries and households, and in public energy supply. Along with these changes in the energy sector the closely related fugitive emissions also decreased. Strong increases in emissions occurred in the sector road transport and production of halocarbons. The latter increase occurred as they replaced chlorofluorocarbons (CFCs), the manufacture of which is being phased out due to their contribution to ozone depletion. In contrast to this, reductions were achieved in the production of halocarbons, mainly due to reduction measures in the United Kingdom between 1998 and 1999, and the decrease in the Netherlands and Sweden between 2000 and 2001.

Over the period 1990–2008, the changes in emissions were most significant before 2000, especially in EU-12 Member States (Figure 3.6). In the EU-27, the sector with the highest GHG emission increase was transport. GHG emissions from waste went in opposite directions, as in the EU-15 emissions decreased and in the EU-12 they increased.

Further background information and analysis of sectoral trends are to be found from Chapter 3 to Chapter 8.

3.3 GHG emissions per capita, GHG intensity relative to GDP

Between 1990 and 2008, per GDP emissions decreased by 38 % in the EU-27 (GDP increase of 44 % while emissions decreased by 11 %) and by 34 % in the EU-15 (GDP increase of 43 % with a 6 % reduction in GHG emissions). Between 1990

Table 3.2 GHG emission sources with changes higher than 20 Mt CO_2-equivalent between 1990 and 2008

Source (CRF category)	Change 1990–2008 (Mt CO_2-equivalent)
Manufacturing industries (excluding iron and steel) (energy-related CO_2 from CRF category 1A2 excluding 1A2a)	– 161.8
Public electricity and heat production (CO_2 from CRF category 1A1a)	– 129.1
Households and services (CO_2 from CRF category 1A4)	– 95.4
Agricultural soils (N_2O from CRF category 4D)	– 68.7
Fugitive emissions (CH_4 from CRF category 1B)	– 66.9
Solid waste disposal (CH_4 from CRF category 6A)	– 61.3
Iron and steel production (CO_2 from CRF categories 1A2a+2C1)	– 51.5
Adipic acid production (N_2O from CRF category 2B3)	– 51.3
Manufacture of solid fuels (CO_2 from CRF category 1A1c)	– 46.9
Enteric fermentation (CH_4 from CRF category 4A)	– 37.2
Nitric acid production (N_2O from CRF category 2B2)	– 23.9
Production of halocarbons (HFC from CRF category 2E)	– 25.6
Consumption of halocarbons (HFC from CRF category 2F)	+ 67.8
Road transport (CO_2 from CRF category 1A3b)	+ 188.5
Total change 1990–2008	– 619.7

Source: EEA, 2011. See www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer.

and 2008, remarkable increases in GDP occurred in parallel with significantly lower increases or even decreases in GHG emissions, especially in Ireland, Latvia, Lithuania and Slovakia. In 2008, the economies of most EU-12 Member States were more intensive in emissions than in EU-15 Member States (Figure 3.8, left graph).

Per capita GHG emissions decreased by 16 % (– 1.9 tonne CO_2-equivalent per capita) between 1990 and 2008 (Figure 3.7). Absolute GHG emissions in the EU-27 declined by 11.1 % while population grew by 5.7 %. Consequently, This decrease mostly occurred during the 1990s. Between 2000 and 2008, per capita emissions decreased by 7.6 % in the EU-15, while they rose by 4.9 % in the EU-12. Between 1990 and 2008, per capita GHG emissions increased most in Spain, Portugal, Cyprus and Malta (in decreasing order of relative change). However, in all these countries per capita emissions have remained below the EU-27 average (except in Cyprus, which had higher than average per capita emissions in 2008). Of EEA member countries, Turkey experienced the largest increase (54 %).

All the other EEA member countries except Switzerland have experienced an increase in their total GHG emissions between 1990 and 2008, including a doubling of total emissions in Turkey during the period. This last increase is mainly attributed to the country's important demographic growth (+ 27 % over the period) and economic development. However, emissions per capita of 5.2 t CO_2-equivalent are still relatively low compared to other European countries.

3.3.1 GHG per capita

Greenhouse gas emissions per capita show significant differences across European countries. Emissions per capita are correlated to the primary energy consumption per capita and the energy mix (affecting the level of emissions by energy unit produced) of each country. Croatia, Latvia, Romania, Sweden, Switzerland and Turkey have the lowest GHG emissions per capita among all EEA member countries. This can be explained by low levels of final energy use per capita in some of these countries (Turkey having the lowest) (EEA, 2008b). In Latvia and in Switzerland, about 55 % of the electricity produced comes from hydropower. In Sweden, the high share of nuclear, hydropower and bioenergy in the energy mix explains the low per capita emissions, despite relatively high energy consumption per capita. The relatively high levels of GHG emissions per capita observed in Estonia, Finland, Iceland, Ireland and Luxembourg can be explained by:

- the high level of 'road fuel exports' ([1]) from Luxembourg to neighbouring countries;
- the importance of the agriculture sector and related CH_4 and N_2O emissions in Ireland, and the relatively low share of renewable energy for energy supply;
- the severe climatic conditions requiring a significant use of energy per capita, combined with low energy prices in Finland and Iceland, despite a significant use of renewable energy sources (and nuclear energy in Finland) for energy supply in both countries.

3.3.2 Emission intensity

The emissions intensity of a country, measured as the level of emission per unit of economic output (measured in GDP), reflect a country's:

- level of energy efficiency;
- overall economic structure (including the carbon content of goods imported and exported);
- carbon content of the energy consumed in the country.

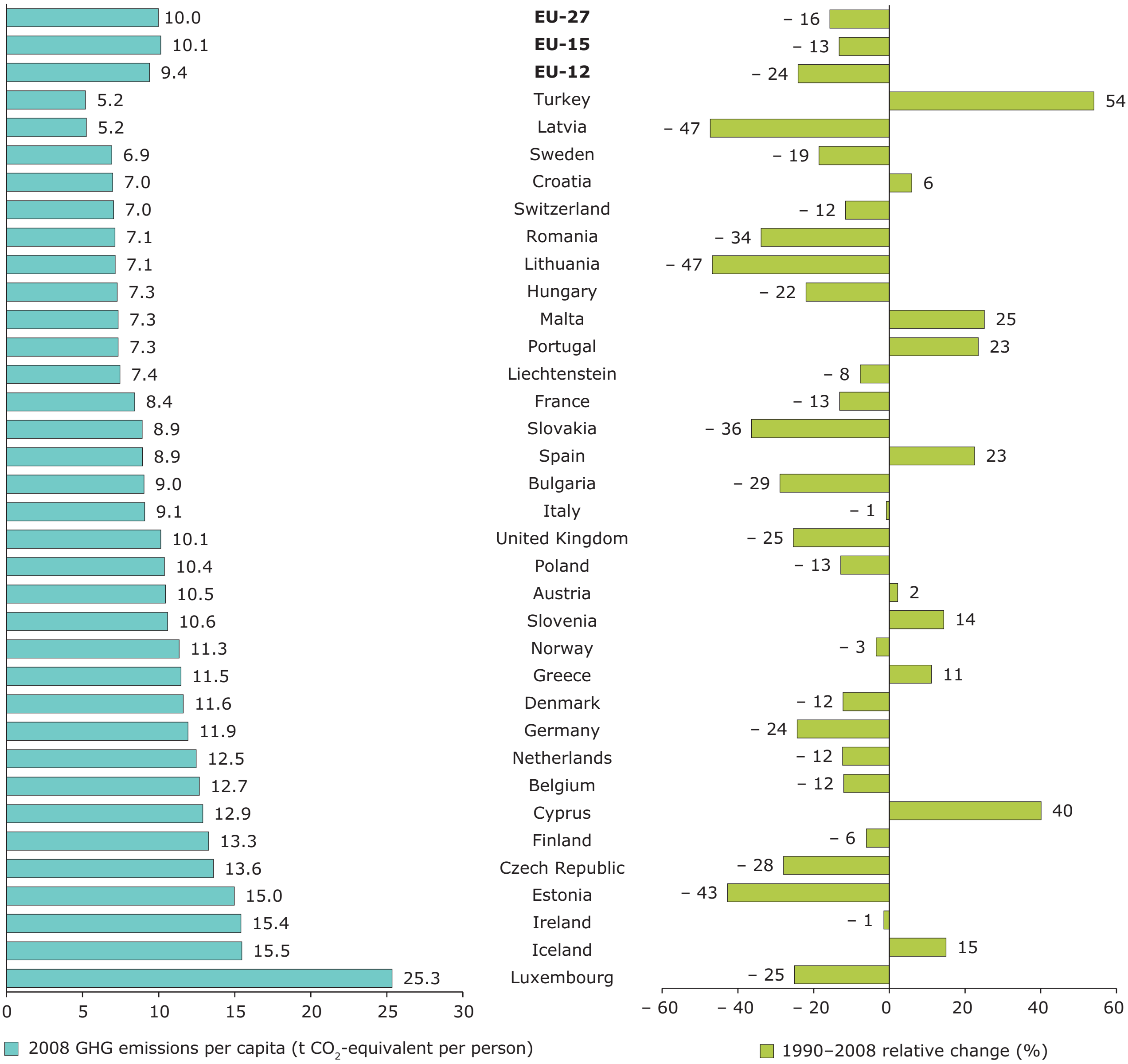
Emission intensities differ greatly among EU Member States ([2]). The six Member States with the lowest emission intensities are all EU-15 Member States, while the seven Member States with the highest emission intensities are all EU-12 Member States. This regional difference could be explained by deindustrialisation and offshoring in the traditional (labour-intensive) manufacturing sectors affecting the majority of EU-15 Member States, transitions towards low-carbon economies, reflected

([1]) Fuel bought in Luxembourg but burned outside the country by people and by truck drivers crossing the countries as well as by the relatively important cross-border commuting workforce (more than 25 % of the resident population), because of lower fuel taxes compared to neighbour countries. Luxembourg estimates that fuel exports could be responsible for up to 40 % of its total greenhouse gas emissions. Other countries, such as Austria and Ireland, also experience fuel tourism and road fuel export.

([2]) To eliminate the differences in price levels among countries, allow meaningful volume comparisons of GDP across European countries and benchmark country performance in a particular year, GDP at market prices is converted to purchasing power standard (PPS). The currency conversion rates both convert to a common currency and equalise the purchasing power of different currencies.

to some extent in low levels of energy use per GDP (Italy, Austria and the United Kingdom) and the share of renewable energy sources and nuclear energy in the fuel mix. France and Sweden have high shares of renewable and nuclear energy, while Austria relies strongly on hydropower; this results in the lowest levels of GHG emission per GDP in the EU. Liechtenstein, Norway and Switzerland also have low emission intensities compared to other European countries. The importance of the low-carbon financial sector in the economies of Liechtenstein and Switzerland explains the relatively low emission intensities compared to other European countries. In Norway, the large share of hydropower for electricity production explains the low GHG emission intensity.

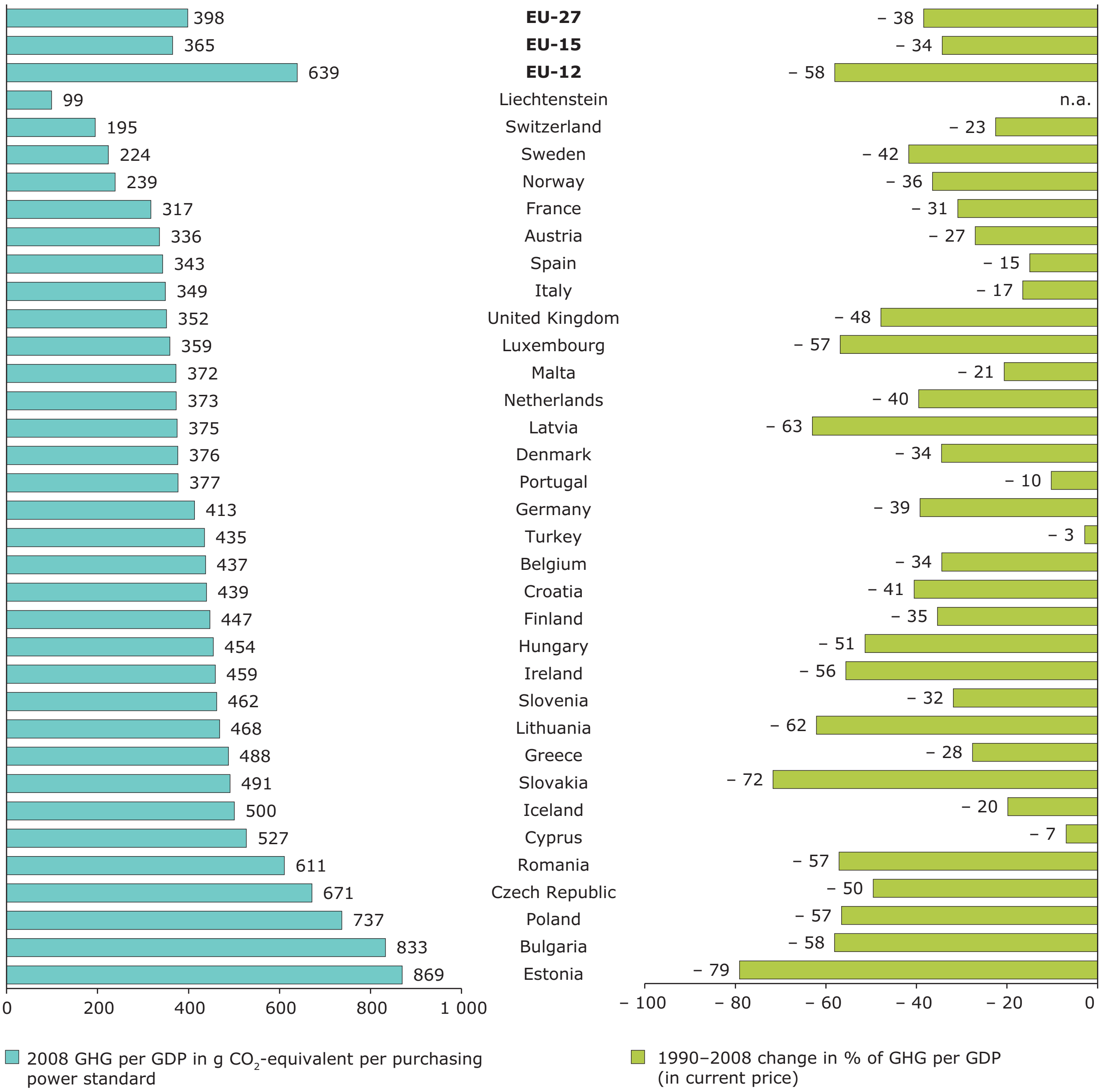
Figure 3.7 GHG emission per capita in Europe 2008 and relative change between 1990 and 2008



Note: Population on 1 January. 1990 population data for France corrected to include population from overseas departments.

Source: Eurostat, 2011a; EEA, 2011.

Figure 3.8 GHG emission intensity of European economies (GHG emissions per GDP) in 2008 and changes in economic intensity, 1990–2008



Note: The left graph uses GDP at market prices, current prices, converted to PPS (purchasing power standard), which allows meaningful volume comparisons of GDP across European countries and benchmark country performance in a particular year. The right graph refers to GDP at constant market prices, which allows consistent GDP time series in a particular country.

Source: Eurostat, 2011a; EEA, 2011.

4 Transport

Summary

The transport sector is by far the sector that experienced the largest increase in EU-27 GHG emissions between 1990 and 2008 (+ 24 % excluding international aviation and navigation, + 34 % when it is included). This is in large part attributable to increasing mobility of persons and growing globalisation of trade. Road transport is responsible for 94 % of the transport emissions. Road transport emissions fell by almost 2 % in 2008 as a result of very high international oil prices along with economic recession and increased fuel efficiency of vehicles. Of road transport's final energy demand, 60 % is due to passenger cars, and 36 % to freight transport.

Between 1990 and 2008, both **passenger** and **freight transport** demand increased because of economic growth and rising income levels. While the pace of the increase has significantly slowed down for passenger transport, the trend observed in freight transport has not showed any loss of steam during the period from 2000 to 2008 compared with that from 1990 to 2000 — except in 2008, as a consequence of the economic recession. Recent trends show that international oil prices and the global economic situation exert the largest influence on the demand for transport.

CO_2 emissions from passenger cars increased steadily in the period from 1990 to 2000, on account of a sustained growth in transport demand and an increasing share of road compared with other modes. Between 2000 and 2008, the growth in transport demand was significantly reduced and its effects on CO_2 emissions were offset by fuel efficiency improvements due to the combined effects of technological improvements, dieselisation and, more recently, biofuel blending. Part of this trend can be attributed to the effects of voluntary commitments by car manufacturers, obligatory labelling of new passenger cars and promotion of the use of biofuels. However, the agreements with the European Automobile Manufacturers Association (ACEA), Japan Automobile Manufacturers Association (JAMA) and Korea Automobile Manufacturers Association (KAMA), and the Biofuels Directive have fallen short of their initial objectives in terms of fuel efficiency and biofuel share in transport fuels, respectively.

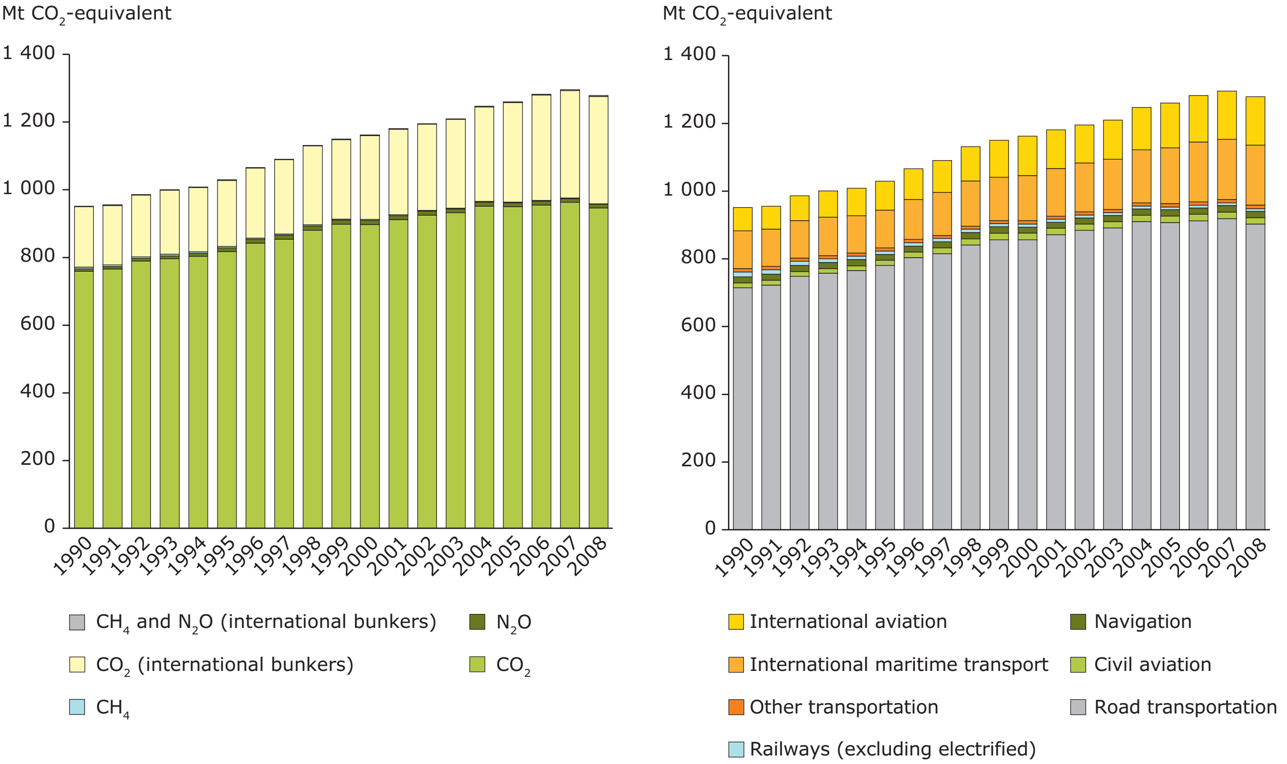
Large increases in CO_2 emissions from road freight transport were observed in the period from 1990 to 2008. This was attributable to continuing growth in demand for the transport of freight and the increasing prevalence of road over less carbon-intensive modes (such as rail), despite technical improvements in the fuel efficiency of truck engines. Emissions continued growing faster than GDP during the period from 2000 to 2008. The various policy initiatives to promote alternative, generally less carbon-intensive transport modes, such as the 2003 and 2006 Marco Polo Programmes and the 2001 and 2004 Railway Packages, were not sufficient to reduce the share of road in total freight transport and achieve the necessary decoupling of emissions from increased activity levels.

4.1 Emission trend

In 2008, emissions from the transport sector accounted for 19 % of total EU-27 GHG emissions. Apart from the aviation and maritime shipping sectors, road transport is the sector which experienced the largest increase in emissions over the period 1990 to 2008 (+ 24 %). However, transport emissions decreased by 2 % between 2007 and 2008.

Most emissions originate from road transport (94 %), whereas emissions from national civil aviation and railways contribute with only 2 %, respectively, to total emissions from transport (Figure 4.1). Since 1990, nearly all subsector GHG emissions from transport have increased, while only emissions from railways (direct fossil fuel combustion, excluding emissions from electricity production) have decreased significantly (– 44 %).

Figure 4.1 GHG emissions from the transport sector per subsector and per gas, 1990–2008 in the EU-27



Note: The sectors presented here correspond to the following CRF categories: Road transportation: 1A3b; Civil aviation: 1A3a; Navigation: 1A3d; Railways: 1A3c; Other transportation: 1A3e. Emissions related to electricity use by electric trains are not included here, but reported under the Energy supply sector (1A1a). Emissions from international aviation and navigation are not included in total transport emissions under the UNFCCC. These emissions are reported separately as memo items.

Source: EEA, 2011. See www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer.

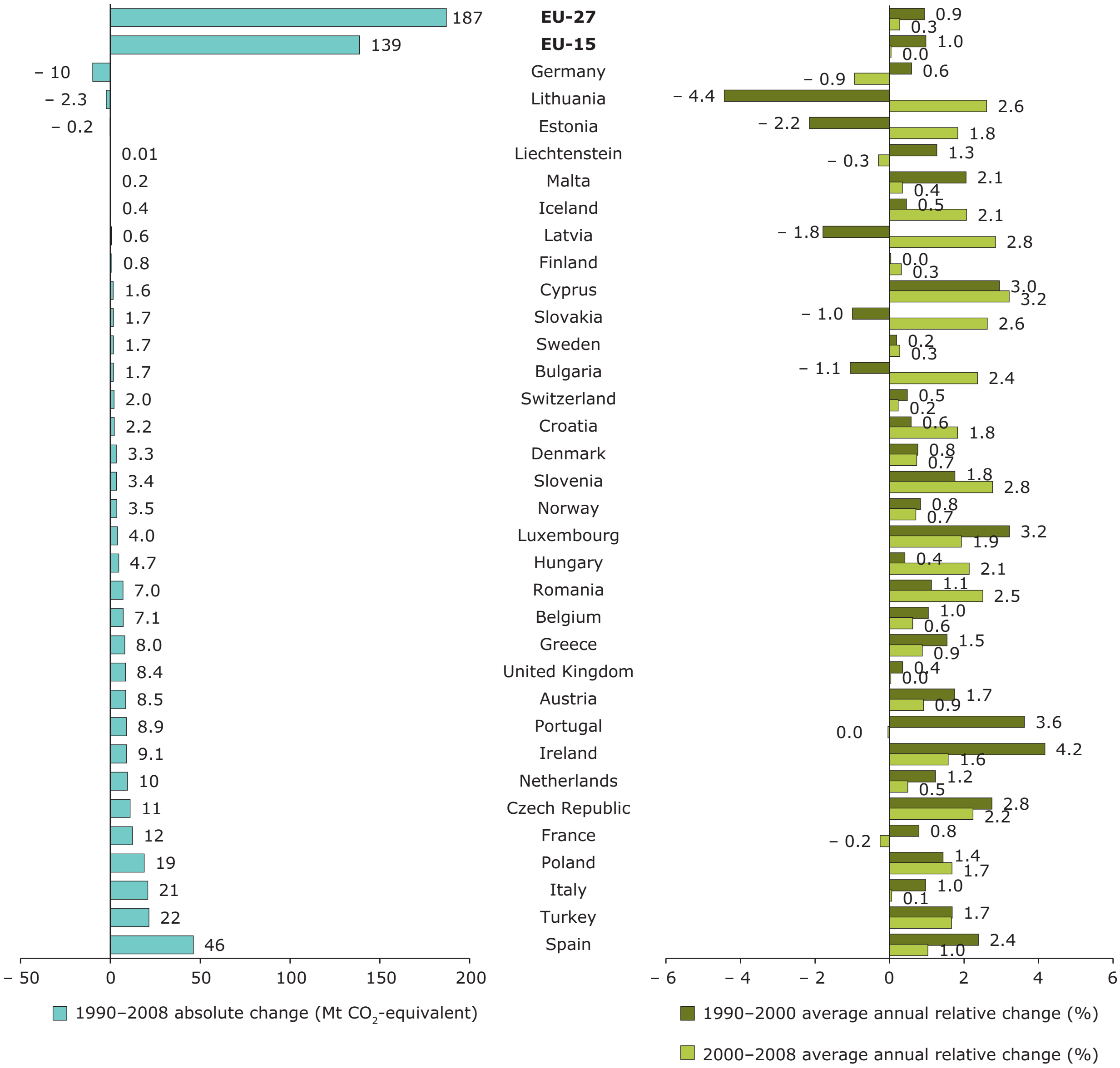
Emissions from international aviation and navigation are reported under the UNFCCC but are not included in national totals and do not accounted under the Kyoto Protocol. When these emissions are taken into account in EU-27 GHG emissions, they account for 5.9 % of the total. Emissions from international aviation more than doubled between 1990 and 2008. However, in 2008, EU-27 emissions from international aviation and especially navigation fell for the first time after 1992, mainly due to the economic recession.

CO_2 is the predominant greenhouse gas (98.7 % of total transport GHG). N_2O emissions increased by 76 % between 1990 and 1998 due to the implementation of the catalytic converter in the early Euro vehicles (mainly Euro 1), but decreased thereafter (for post Euro 2 vehicles).

In 2008, the largest emitters in the transport sector were Germany, France, Italy, the United Kingdom and Spain (in decreasing order of emissions). Estonia, Germany and Lithuania are the only EU-27 Member States that have managed to reduce their GHG emissions from transport between 1990 and 2008. In Germany, the reduction was mainly due to the increased share of diesel-powered cars and increasing fuel prices (including effects of the eco-tax).

Figure 4.2 shows that most EU-15 Member States reduced their average annual relative change of emissions in the transport sector in the 2000–2008 period compared to 1990–2000. However, while the rate decreased in these countries, absolute emissions still increased in the 2000–2008 period, except for Germany, France and Portugal. All EU-12 Member States (except the Czech Republic and Malta), on the other hand, increased their emission growth rate. In absolute figures, the EU-15 accounted for 74 % of the EU-27 emission increase between 1990 and 2008.

Figure 4.2 Absolute change and average annual relative change of GHG emissions from transport in the EU, 1990–2008



Note: Emissions from international aviation and navigation are not included in total transport emissions under the UNFCCC. These emissions are reported separately as memo items.
Countries sorted according to absolute change between 1990 and 2008.
Average annual relative change (%) = (last year/base year)$^{(1/\text{number of years})}$ – 1.

Source: EEA, 2011.

4.2 Effects of drivers on CO_2 emissions from road transport

The analysis of emissions requires the examination of underlying drivers and components whose development steers the trend in GHG emissions. The decomposition analysis focuses on CO_2 emissions from passenger cars and road freight transport, which represent approximately 60 % and 36 %, respectively, of the total final energy demand in road transport. Road transport itself accounts for 94 % of total transport emissions (excluding international bunkers).

4.2.1 Passenger cars

Five relevant factors were identified as affecting CO_2 emissions from passenger cars in the EU-27

(Figure 4.3). In the 1990s, all factors affecting CO_2 emissions increased steadily. Since 2000, a break in the trend of fossil fuel consumption by private cars seems to have resulted in a more reduced growth — or even a decrease — in CO_2 emissions, due to efficiency improvements and biofuel blending.

The decomposition analysis interlinks these factors to six emission drivers influencing CO_2 emissions from road passenger transport (Table 4.1, Figure 4.3, Figure 4.5).

The continued growth in transport demand over the whole 1990–2008 period has been the main driver for increased EU CO_2 in transport (Figure 4.5). As a result of increasing household revenues, the share of private cars on roads also increased. These negative effects on emissions were only partly offset by reduced fuel intensity, due to engine improvements in fuel efficiency.

The overall stable 2000–2008 trend in CO_2 emissions was due to a slower growth of transport demand (compared to the previous decade), combined with the effects of continuing efficiency improvements. The increasing use of biofuels in private cars and a slight reduction in the share of road transport in total passenger transport made rather limited contributions to the limitation of CO_2 emissions between 2000 and 2008. Modal shift did not take place towards public road transport or rail, but towards aviation.

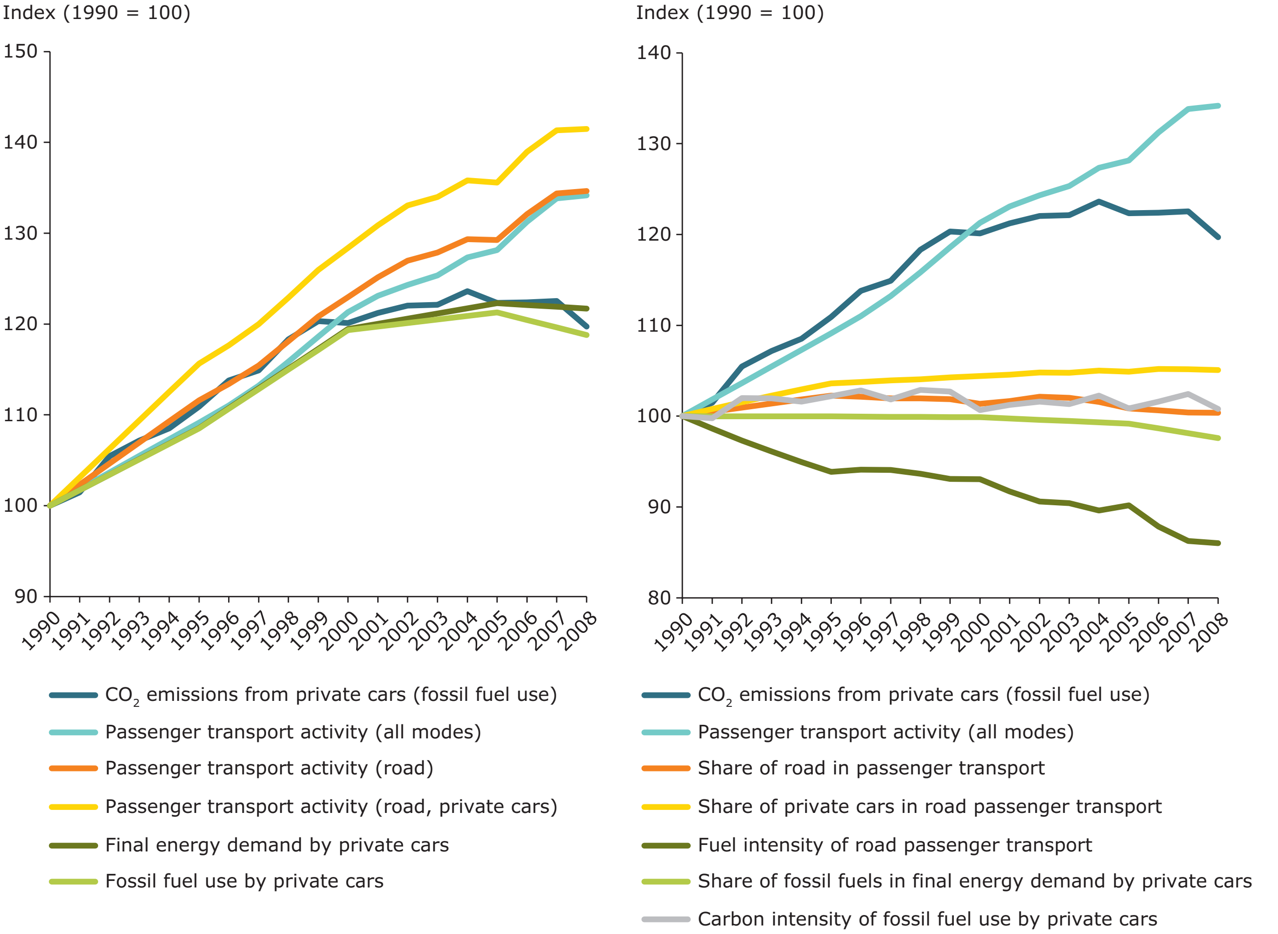
The main reason for the increase in passenger transport in the 1990s was the increase in distances driven by private cars. This trend was caused by the growth in incomes coupled with a tendency to spend more or less the same share of disposable income on transport. Additional income therefore means additional travel budget, which allows more frequent, faster, farther and more luxurious

Table 4.1 Identification of drivers influencing CO_2 emissions from passenger cars

Drivers influencing emissions	Description	Input of factors to decomposition analysis as	Unit
Passenger transport demand (pkm)	The activity in passenger transport is measured as the product of the distance a vehicle travels times the number of occupants travelling that distance. It is expressed in passenger-kilometre and covers all modes: public road transport, private cars, motorcycles, rail, aviation (including international aviation) and inland navigation. This driver is influenced by income level and oil price.	Passenger km	Gpkm
Share of road transport in total passenger transport	The share of road transport represents the share of passenger transport on road (public road transport, private cars, motorcycles) compared to all transport modes (road, rail, aviation and inland navigation). The effectiveness of policies aiming at encouraging the shift to less carbon-intensive transport modes is reflected here.	Passenger km on road/ Passenger km = share of road transport	Gpkm/Gpkm
Share of private cars in total road passenger transport	The share of private cars represents the passenger km driven by private cars compared to total road transport (coaches, buses, powered two-wheelers and private cars). An increasing share often correlates with income growth.	Passenger km by private cars/Passenger km on road = share of private cars	Gpkm/Gpkm
Fuel intensity of road passenger transport	The fuel intensity of transport is expressed as fuel consumption per km driven by private cars. A decrease in intensity can be explained by improvements in motor efficiency, different driving behaviour, use of smaller cars or a shift from gasoline-driven cars to more efficient diesel-driven cars of the same size. All these factors can reduce the fuel consumption per km and hence also CO_2 emissions. The fuel intensity is also sensitive to occupancy rate of cars: higher rates result in less vehicle-kilometres being needed to transport the same number of passengers and consequently less fuel used for that transport. Present data availability is not sufficient to support quantitative analysis at EU level.	Total fuel used for private cars/Passenger km by private cars = fuel intensity	ktoe/Gpkm
Share of biofuels in private cars	The share of biofuels in private cars indicates the share of biofuel use in the total fuel consumption of private cars (mostly gasoline and diesel). For the purposes of this decomposition, biofuels are assumed to be emission neutral *.	Fossil fuel use by private cars/Total fuel used by private cars = 1 – share of biofuels in private cars	ktoe/ktoe
Carbon intensity of fossil fuels use by private cars	Carbon intensity is defined as the amount of CO_2 emitted per unit of fossil fuel consumed by private cars and is mainly dependent on the type of fossil fuel used (gasoline has a lower CO_2 emission factor than diesel).	CO_2 emissions from private cars/Fossil fuel use by private cars	Mt CO_2/ktoe

Note: * Kyoto accounting where emissions from land use, land-use change, cultivation, processing, etc. are accounted under the relevant sectors and/or outside the EU in the case of imported biofuels.

Figure 4.3 Drivers of CO_2 emissions from passenger cars in the EU, 1990–2008



Note: Passenger km: the number of km covered by people is represented as passenger km, and includes road, rail, air and ship transport of passengers.

Passenger km on road: passenger km on road do not include passenger km on rail, air and ship transport of passengers.

Source: EEA, 2010a; European Commission, 2010a; Eurostat, 2011b.

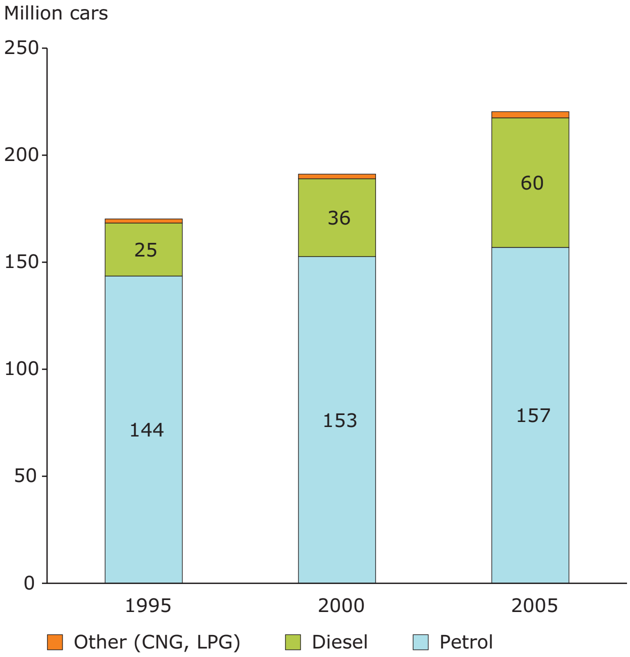
travelling (EEA, 2009). Germany contributed most to the increased CO_2 emissions from rising passenger transport demand, followed by Italy, Spain and France. However, all of these countries managed to stabilise the amount of kilometres driven on the road between 2000 and 2008 (mainly since 2003), whereas Ireland doubled its passenger kilometres. Poland contributed most to the increased share of private cars in the 1990s, followed by Bulgaria, Germany and Italy. Between 2000 and 2008, however, the share of private cars levelled off, mainly due to saturation and followed by economic recession.

Additionally, a small increase in emissions as a result of carbon intensity can be seen for passenger transport. Diesel is a more carbon-intensive fuel than gasoline and therefore results in more CO_2 per energy unit (5.5 %) and per volume unit (almost 15 %). However, diesel vehicles used to be significantly more efficient by 20–30 %; hence, fuel consumption and CO_2 emissions are reduced. The ongoing shift from gasoline to diesel cars is why carbon intensity has increased and it also explains increasing fuel efficiency (Figure 4.4).

Germany was most efficient in decreasing the amount of fuel consumed per kilometre driven. This was partly due to a shift from gasoline to diesel-driven cars, which are more fuel efficient, but also a consequence of the fact that German car users purchased some of their fuel in neighbour countries where fuel was cheaper ('tank tourism').

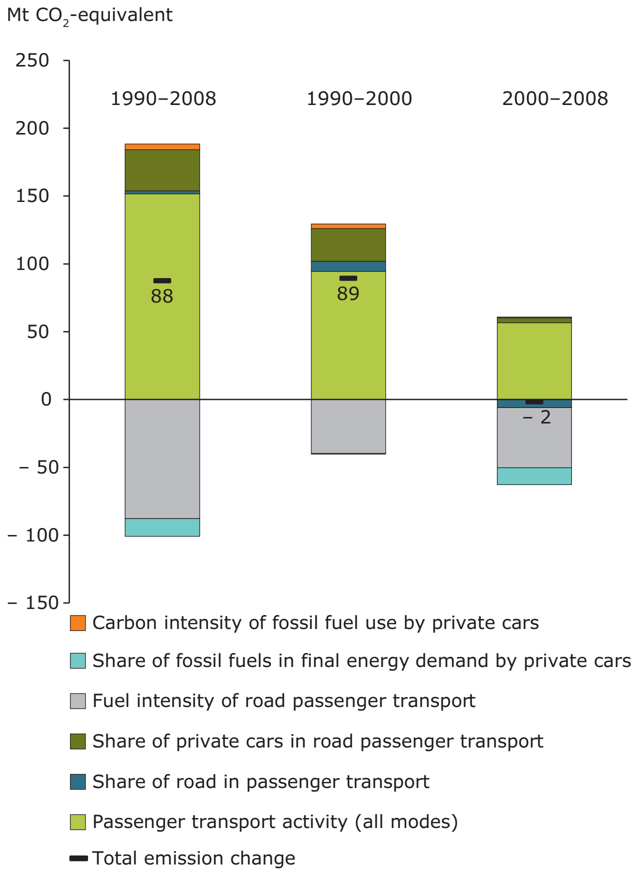
More than a third of the EU-27 CO_2 reduction due to biofuel addition was accomplished by Germany. The share of biofuels (mainly biodiesel) in 2008 was 6.5 % in Germany and 5.8 % in France, compared to 3.4 % in the EU-27.

Figure 4.4 Change in the gasoline and diesel car stock between 1995 and 2005



Source: Tremove, 2009.

Figure 4.5 Decomposition analysis of CO_2 emission trends from passenger cars in the EU, 1990–2008



Note: Each bar shows the contribution of a single driver to GHG emission trends during a determined period. The thick short black lines indicate the combined effect of all emission drivers, i.e. the overall GHG emission trend during the period considered.
Different data sources have been used for the calculation of carbon intensity, which may result in a relatively high uncertainty of the results for this driver.

Source: Own calculations, based on EEA, 2010a; European Commission, 2010a; Eurostat, 2011b.

4.2.2 *Road freight transport*

Figure 4.6 shows the relative change of factors relevant for road freight transport between 1990 and 2008. All factors increased during this period but to a lesser extent from 2000 onwards. Achievements for freight transport were much smaller than for passenger transport, partly because of the linkage to GDP. The demand for freight transportation, the share of freight transported by trucks, the fuel efficiency and the type of fuel used are the most important drivers of CO_2 emissions from freight transport.

Due to economic growth, the demand for freight transportation has increased since 1990. Up to 2008, the shift from road transport to generally less carbon-intensive transport modes has not been achieved.

The decomposition analysis interlinks these factors to five emission drivers to CO_2 emissions from road freight transport (Table 4.2, Figure 4.8). The trend of these drivers between 1990 and 2008 is shown in Figure 4.6.

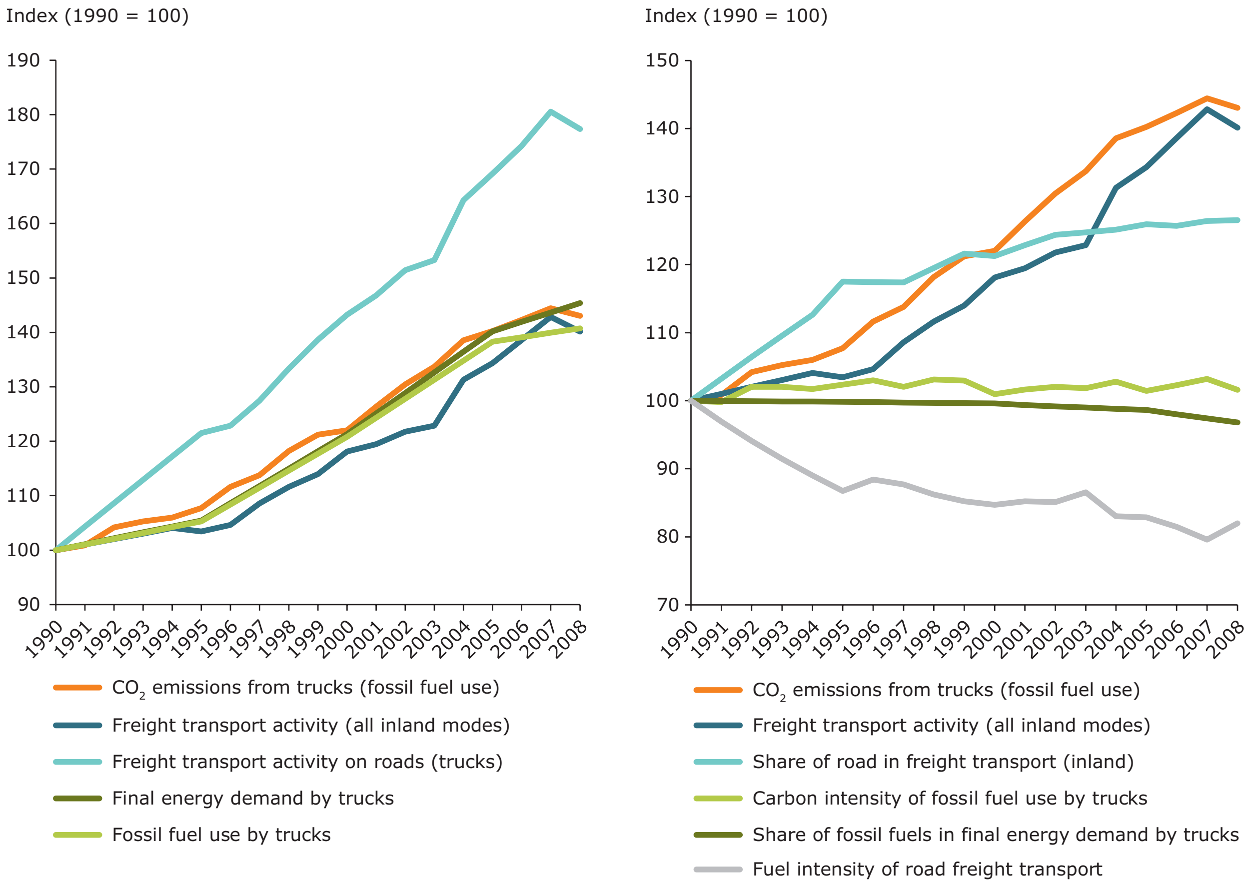
As with passengers, the main driver of CO_2 emissions from freight transport between 1990 and 2008 has been a continuing growth in freight transport demand. However, contrary to the situation observed with passenger road transport, there has been no slowing down of this growth after 2000, except in 2008, when freight transport started decreasing across the EU, due to the economic crisis. Spain contributed most to the increase in freight kilometres and the share of road transport between 1990 and 2008, followed by Germany. In relative terms, Ireland more than tripled its freight transport due to its rapidly growing economy.

Road has also increasingly been prevailing over less carbon-intensive modes such as rail. The volume of

Table 4.2 Identification of drivers influencing CO_2 emissions from road freight transport

Drivers influencing emissions	Description	Input of factors to decomposition analysis as	Unit
Freight transport demand (tkm)	Tonnes of goods transported/km is represented as tonne km. It includes freight transported on road, rail, air and ship freight transport. It reflects the demand for freight transportation and often correlates with economic growth.	Tonne km	Gtkm
Share of road transport in total freight transport	Share of road transport represents the share of freight transport on road compared to total freight transport (road, rail, inland navigation). The modal choice of operators and the effectiveness of policies aiming at encouraging the shift to generally less carbon intensive transport modes is reflected here.	Tonne km on road/ Tonne km	Gtkm/Gtkm
Fuel intensity of road freight transport	Fuel intensity is expressed as the fuel consumption per km driven by trucks. A decrease in intensity (= increasing efficiency) suggests that technical improvement and/or increasing load factors reduced the fuel consumption per km and hence also CO_2 emissions. The fuel intensity is also sensitive to load factors: efficient loading of trucks results in less vehicle-kilometres being needed to transport the same number of tonnes and consequently less fuel used for that transport. Present data availability is not sufficient to support quantitative analysis at EU level.	Total fuel for trucks/ Tonne km on road	ktoe/Gtkm
Share of biofuels in road freight transport	The driver biofuels compares biofuel consumption with total fuel consumption (mostly gasoline and diesel). Increased use of biofuels replaces fossil fuels and thereby reduces emissions.	Fossil fuel for trucks/ Total fuel for trucks = 1 − share of biofuels	ktoe/ktoe
Carbon intensity of fossil fuels use by road freight transport	Carbon intensity is defined as the amount of CO_2 emitted per unit of fossil fuel consumed by trucks.	CO_2 emissions from fossil fuel used by trucks/Total fossil fuel used by trucks	Mt CO_2/ktoe

Figure 4.6 Drivers of CO_2 emissions from road freight transport in the EU, 1990–2008



Source: EEA, 2010a; European Commission, 2010a; Eurostat, 2011b.

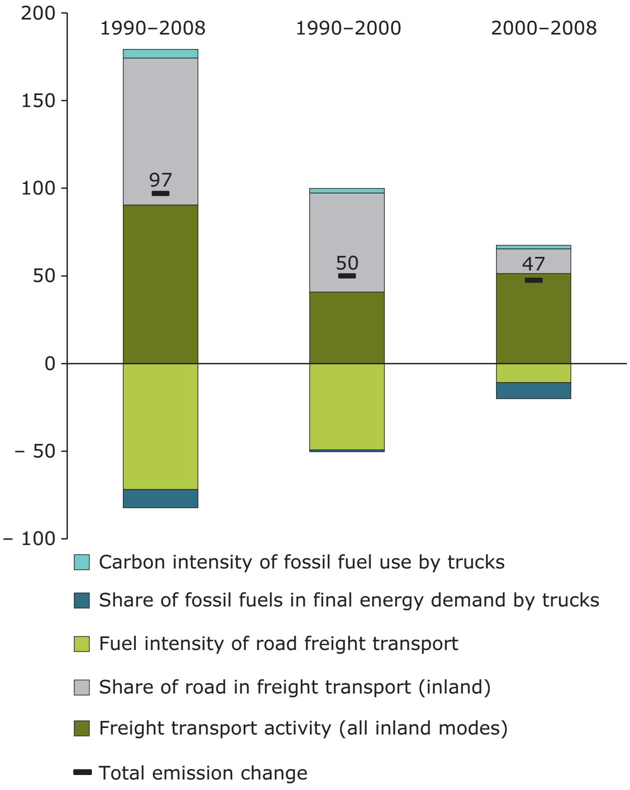
freight transported by road vehicles in the EU-27 was about four times higher than the volume transported by rail in 2008 ([3]) (Figure 4.7).

Fuel efficiency improvements and the blending of biofuels on the other hand decreased emissions from freight transport. Fuel efficiency increased mainly during the 1990s. Spain contributed most to the related emission decrease, followed by Germany and France.

The increased use of biofuels after the implementation of the Biofuel Directive in 2003 (Section 4.3) affected CO_2 emissions from freight transport only slightly. With a relative emission decrease of 7 %, Germany contributed most to the EU-27 emission trend.

Overall, despite technical improvements in engine efficiency achieved mainly during the 1990s and a slow penetration of biofuels after 2000, the effects of an increasing demand in freight transport and the increasing prevalence of road over other modes resulted in a strong increase of CO_2 emissions from freight in the 1990–2008 period.

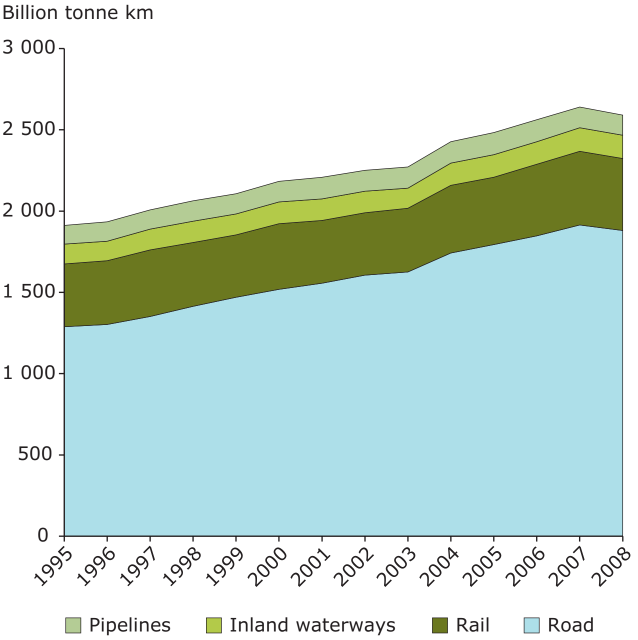
Figure 4.8 Decomposition analysis of CO_2 emissions from road freight transport in the EU, 1990–2008



Note: Each bar shows the contribution of a single driver to GHG emission trends during a determined period. The thick short black lines indicate the combined effect of all emission drivers, i.e. the overall GHG emission trend during the period considered.
Different data sources have been used for the calculation of carbon intensity, which may result in a relatively high uncertainty of the results for this driver.

Source: Own calculations, based on EEA, 2010a; European Commission, 2010a; Eurostat, 2011b.

Figure 4.7 EU freight transport by inland modes in the EU, 1995–2008



Source: Eurostat, 2011b.

([3]) Road freight statistics are compiled according to the nationality principle and those for rail according to the territoriality principle, meaningful conclusions cannot be directly drawn at country level from the comparison of freight statistics by mode and by country.

4.3 Main links between EU policies and observed GHG emission trends from road transport between 1990 and 2008

This section outlines the EU energy and transport policies that might have influenced the environmental performance of road passenger and freight transport during the period 1990–2008 (Table 4.3). These policies affect emissions mainly by reducing energy/fuel consumption and increasing efficiency, for example:

- promoting the use of biofuels or other renewables for transport fuels;
- setting emission performance standards for vehicles;
- increasing the energy efficiency and the reduction of pollutant emissions (of road passenger and freight transport);
- tightening the environmental quality standards of fuels used for transport;
- encouraging modal shift to passenger and freight transport with lower emissions;
- ensuring environmental information (including the fuel consumption and CO_2 emissions of new passenger cars) is made available to consumers;
- setting minimum rates of fuel taxation.

The main EU policies with an objective of reducing GHG emissions from road transport sector were adopted and implemented after 1998. Overall, these policies have not been able to prevent the steady increase of road transport emissions across Europe between 1990 and 2008.

Concerning the policies linked to both passenger and freight road transport, the Biofuels Directive achieved limited results in raising the relative contribution of biofuels in the overall petrol and diesel fuel consumption between 2003 and 2008. Only a few Member States were on track to meet their 5.75 % target of biofuels by 2010. The introduction of common minimum taxation levels through the Energy Taxation Directive (Directive 2003/96/EC) led several Member States, in particular in the EU-12 and in Spain, to introduce taxation. However, because such minimum taxation levels remain low, their effects on consumer behaviour, and thereby on fuel transport consumption, could not be observed at EU level between the introduction of the directive, in 2003, and 2008.

If the efficiency of new passenger cars did improve between 1998 and 2008, the voluntary agreements between the European Commission and car manufacturers associations proved to be unsuccessful in achieving their objectives. Signed in 1998, the agreements sought to achieve a 25 % reduction of average specific CO_2 emissions for new passenger cars compared to 1995 levels, but did not manage to reduce these emissions down to the target level of 140 g CO_2/km by 2008 (the average for the ACEA manufacturers for 2008 was 152.3 g CO_2/km) and by 2009 (the JAMA average was 142.6 g CO_2/km; the KAMA average was 141.8 CO_2/km). Assessing the exact impact of the agreement is also difficult due to the constant improvements brought to car engines by manufacturers, even in the absence of any policy incentive (autonomous progress), as observed before 1998. The impact of the Car Labelling Directive (Directive 1999/94/EC), introduced in complement to the voluntary commitments from car manufacturers, is also difficult to apprehend at EU level, due to the diversity among Member States in the ways the directive was implemented. The directive is

Table 4.3 Link between EU policies and GHG emission sources

IPCC sector	Actors	EU policy potentially affecting GHG emissions
Road transport (1A3B)	Passengers	Fuel Quality Directive (1998) Voluntary commitments (ACEA, KAMA, JAMA) (1998, 2000) Car Labelling Directive (1999) Biofuels Directive (2003) Energy Taxation Directive (2003)
	Freight	Fuel Quality Directive (1998) First and second Railway packages (2001, 2004) and Railway Interoperability Directives Energy Taxation Directive (2003) Biofuels Directive (2003) First and second Marco Polo Programmes (2003, 2006)

considered a useful tool in raising awareness and possibly helping the manufacturers to sell more fuel-efficient cars but it is difficult to objectively assess its direct impact. Between 1995 and 2003, the average specific CO_2 emissions were reduced by 11.8 % from 186 g/km to 164 g/km. Since in the same time period the share of diesel cars sold in the European passenger car fleet increased from 22.2 % in 1995 to 44.4 % in 2003, the share of diesel cars (as well as the improvements in diesel technology) has to be considered as an important element in the average decrease of specific CO_2 emissions. Furthermore, in 2008 a preference of buyers for smaller cars, as a consequence of the economic crisis, combined with the introduction of scrappage schemes in certain countries, resulted in a clear improvement of fuel efficiency of road.

In the freight sector, road transport has become more prominent than before. Attempts have been made to promote intermodality through incentive programmes such as Marco Polo (2003–2006) and Marco Polo II (2007–2009), which co-fund modal shift or traffic avoidance projects. Although the first Marco Polo Programme did realise a modal shift of about 31 billion tkm off the road from 2003 to 2006 and the second Programme had the ambition of doubling this amount in the 2007–2009 period, the amount of freight shifted through these programmes has represented a small fraction of the total international road freight transport in Europe. These initiatives were therefore not sufficient to reverse the increasing trend in the share of freight transported by trucks, which increased by + 5 % between 2000 and 2008.

Table 4.4 includes a general description of the link between the effects of these policies, in particular in relation to the drivers identified in the previous section.

4.4 Sectoral synthesis: road transport

Apart from the aviation and maritime shipping sectors, road transport is the sector which experienced the largest increase in emissions over the period 1990 to 2008. This is for a large part due to increasing mobility of persons and increasing globalisation of trade. The effects of this increasing demand in transport have been only partly offset by

Table 4.4 EU policies affecting GHG emissions from road transport between 1990 and 2008

EU legislation	Objectives	Actors concerned	Impact on identified drivers
Voluntary agreements with car manufacturers from EU (ACEA), Japan (JAMA) and Korea (KAMA), (1998, 2000)	Reduce average CO_2 emissions from new passenger cars sold in the EU to 140 g/km by 2008/2009 through a voluntary agreement with car manufacturers from EU, Japan and Korea.	Passenger cars	The target of reducing CO_2 emissions from passenger cars to an average of 140 g/km of CO_2 by 2008 represented a 25 % reduction from the 1995 level of 186 g/km. Although average CO_2 emissions from new passenger cars did fall significantly during the period covered by the ACEA agreement signed in 1998, the final objective was not achieved. The agreement affected directly the fuel efficiency of private cars, but in 2008 the EU-15 average of new passenger car CO_2 emissions was still about 10 % above the 140 g CO_2/km target at 153.6 g CO_2/km. In 2007 the Commission, taking note of the failure of car manufacturers to fulfil their commitments, put forward further EU-wide policies to speed up car emission reduction with a legally binding target for new cars' emissions (Regulation 443/2009).
Car Labelling Directive Directive 1999/94/EC relating to the availability of consumer information on fuel economy and CO_2 emissions in respect of the marketing of new passenger cars	Ensures that the information relating to the fuel economy and the CO_2 emissions of new passenger cars for sale or lease is made available to consumers.	Passenger cars	The Car Labelling Directive is mainly related to the driver 'Fuel efficiency' of private cars. It has been a useful tool in raising awareness but its impact has not been clearly visible, with labels of strongly varying quality being used in different Member States.
Biofuels Directive Directive 2003/30/EC on the promotion of the use of biofuels or other renewable fuels for transport	Promotion of biofuels or other renewables for transport fuels. Set indicative targets for the contribution of biofuels to overall petrol and diesel fuel consumption: 2 % by 2005 and 5.75 % by 2010.	Passenger cars Freight	Biofuels achieved only a share of 3.4 % in the EU in 2008, compared to the 5.75 % target for 2010, with progress still slow in a third of Member States. The share of biofuels grew by 1.6 percentage points between 2005 and 2007, compared with 0.5 percentage points between 2003 and 2005. Yet, in 2008, only four Member States had already met their 2010 target. The recent growth in biofuels is linked to a widespread development of support systems, such as tax relief and biofuels obligations, to promote biofuels at Member State level. Overall, the Biofuels Directive seems to have been the main driver behind the growth in biofuels use, although it achieved limited results compared to the overall target.

Table 4.4 EU policies affecting GHG emissions from road transport between 1990 and 2008 (cont.)

EU legislation	Objectives	Actors concerned	Impact on identified drivers
Marco Polo Programme: Regulation (EC) No 1382/2003 on the granting of Community financial assistance to improve the environmental performance of the freight transport system (Marco Polo Programme). Marco Polo Programme II Regulation (EC) No 1692/2006	Reduce road congestion, improve the environmental performance of the freight transport system within the Community and enhance intermodality through project funding. The Marco Polo Programme II develops the above with a larger budget and broader project and geographical focus.	Freight	This policy seeks to decrease the amount of freight transport on the roads by shifting it to other modes. It should therefore impact the 'Share of road transport (trucks)'. The first Programme which went from 2003 to 2006 had the objective of moving 12 billion tkm per year off the road. While the contracts concluded did meet that target on paper, not all projects succeeded. With altogether about 31 billion tkm shifted over four years, the overall target has been missed by more than a third. The second Programme has so far been somewhat more active: The planned amount of freight to be shifted from projects funded in the first three years (2007–2009) is 61.8 billion tkm. The total amount of funding available for Marco Polo is 450 million € for the 2007–2013 period. Although the first Marco Polo Programme did realise a modal shift of freight off roads, it was not sufficient to reverse the increasing trend in the share of freight transported by trucks, which increased by + 5 % between 2000 and 2008.
First and second Railway Packages (2001, 2004) Directive 2001/14/EC on the allocation of railway infrastructure capacity and the levying of charges for the use of railway infrastructure — Amended by Directive 2004/49/EC and Directive 2007/58/EC Directive 2001/16/EC on the interoperability of the trans-European conventional rail system — Amended by Directive 2004/50/EC, repealed by Directive 2007/58/EC	The three railway packages adopted in 2001, 2004 and 2007 included the most important initiatives at EU level aiming to revitalise the rail sector. This was to be achieved essentially by opening up the rail market in the EU, by introducing common safety rules and standards and by improving the interoperability of national railway networks. The packages also aimed at moving to modal shift of freight from road to rail and inland waterway.	Freight	The two first packages of 2001 and 2004 did not deliver the desired results in terms of moving towards a modal shift, as demonstrated by the steady increase in the share of road freight transport compared to other modes, in particular rail. After losing one percentage point between 1998 and 2001, the share of railways in intra-EU freight transport remained roughly the same at close to 11 %. In intra-EU passenger transport, railways also kept their market share of slightly more than 6% which they had at the beginning of the decade. This result was also not been evenly spread. Between 2000 and 2008, rail freight transport activity rose by 54 % in the Netherlands, by 40 % in Germany and by 37% in the United Kingdom while it shrank by 30 % in France.
Energy Taxation Directive: Directive 2003/96/EC: restructuring the Community framework for the taxation of energy products and electricity	Minimum rates of taxation set for energy products when used as motor, heating fuel and electricity. It encourages more efficient use of energy so as to reduce dependence on imported energy products and limit GHG emissions.	Passenger cars Freight	The fiscal arrangements made in connection with the implementation of the EU framework for the taxation of energy products and electricity (including transport fuels) are a matter for each Member State to decide on and therefore differ among countries. Many Member States have set their tax levels for transport fuels higher than the levels stipulated by the directive. The introduction of minimum taxation levels through the Energy Taxation Directive led several Member States to introduce taxation only as a consequence of common minimum rates, in particular in the EU-12. The impacts of such minimum taxation levels on consumer behaviour, and thereby on passenger transport demand, is not yet clearly demonstrated at EU level.
Fuel Quality Directive: Directive 98/70/EC relating to the quality of petrol and diesel fuels and amending Directive 93/12/EEC	Set EU-wide specifications for petrol, diesel and gas-oil used in cars, trucks and other vehicles — including inland waterway barges, tractor locomotives and machinery — in order to protect human health and the environment.	Passenger cars Freight	The focus of the 1998 directive was placed on banning the marketing of leaded petrol and controlling the sulphur content of diesel. The impact of the directive on GHG emission drivers was not significant. An objective to reduce the GHG intensity of energy supplied for use in road vehicles and non-road mobile machinery was only introduced in the revised Fuel Quality Directive (Directive 2009/30/EC).

Source: Data: Eurostat, 2011b; part of the analysis based on European Commission, 2010b; European Commission, 2011a; European Commission, 2011b.

improvements in the efficiency of vehicles and the relative shift towards more diesel-fuelled vehicles. While the pace of the increase has significantly slowed down for passenger transport, partly due to visible improvements in car efficiency and an increasing share of biofuels in private cars, the trend observed in freight transport has not showed any loss of steam during the period 2000–2008 (except for the year 2008, due to the economic recession), compared to 1990–2000. Road freight transport is actually increasing faster than GDP and the various policy initiatives to promote alternative, generally less carbon-intensive transport modes have not been sufficient to achieve the necessary decoupling of emissions from increased activity levels. Recent trends show that international oil prices and the global economic situation exert the largest influence on the demand for transport.

Road passenger transport in private cars (passenger cars)

The strong increase in transport demand resulted in an important increase in car fuel consumption over the whole period. This increase, however, was significantly less in the second half of the period (2000–2008), possibly due to the combined effects of a saturation of consumer demand and increasing fuel prices. Continuous efficiency improvements in car efficiency were observed over the whole period 1990–2008, as a combined result of improvements in engine efficiency during the period 1990–2000 and high fuel prices, leading customers to buy more efficient cars — in particular diesel. Although they are likely to have contributed towards these improvements after 1998, the voluntary agreements with car manufacturers from the EU, Japan and Korea did not reach their assigned objective, which was to reduce average CO_2 emissions from new passenger cars sold in the EU to 140 g/km by 2008/2009. The share of road use compared to the use of other transport modes by passengers remained relatively stable over the period and did not result in important GHG emission changes.

The development of biofuel use has had a limited impact on CO_2 emissions from passenger cars between 1990 and 2008, the share of biofuels in 2008 remaining well below the indicative target of 5.75 % set in the 2003 Biofuels Directive for 2010. The Fuel Quality Directive (Directive 98/70/EC), which aimed to ban the marketing of leaded petrol and control the sulphur content of diesel, did not affect the carbon intensity of fossil fuel use by private cars (Table 4.5).

Road freight transport

Despite technical improvements in engine efficiency achieved mainly during the 1990s, the continuing growth in demand for the transport of freight, linked to economic growth and the internationalisation of trade, and the increasing prevalence of road over less carbon-intensive modes, such as rail, has been resulting in large increases in CO_2 emissions from freight in the 1990–2008 period. These increases have been only partly offset by fuel efficiency improvements of truck engines. Overall, existing policies (the 2003 Energy Taxation Directive, the Marco Polo Programmes and the Railway Packages) have shown limited success in limiting transport demand or driving modal shift towards generally less carbon-intensive modes than road during the period from 2000 to 2008, as the continuing increase in the share of road in total freight transport demonstrates.

With most of the truck fleets equipped with diesel engines and a slow penetration of biofuels, the overall carbon intensity of road freight transport has not changed significantly over the period, which resulted in a slight increase in emissions between 1990 and 2000 and small CO_2 emission reductions between 2000 and 2008 (Table 4.6).

Table 4.5 Changes in drivers influencing CO_2 emissions from passenger cars in the EU and effects on emissions, 1990–2008

Group of drivers	Drivers	Change in driver (%)		Effect on GHG emissions (Mt CO_2-equivalent)		Assessment
		1990–2000	2000–2008	1990–2000	2000–2008	1990–2008
Amount of fuel	Passenger transport demand (pkm)	+ 21 %	+ 11 %	95	57	The strong growth in total passenger transport demand between 1990 and 2008 drove upward fuel combustion and emissions. The increase was the strongest between 1990 and 2000, mostly due to longer distances. Saturation and increasing oil price led to a more moderate increase between 2000 and 2008. While setting minimum tax levels through the Energy Taxation Directive led several Member States to introduce taxation of vehicle fuels, these minimum levels do not seem to have been sufficiently meaningful to modify consumer behaviour in a visible manner in these countries.
	Share of road transport in total passenger transport	+ 1 %	− 1 %	7	− 6	The share of road transport in total passenger transport has remained relatively stable over the whole period and had only a limited impact on GHG emissions. The motorisation level in the EU has continued to increase, mainly boosted by developments in the EU-12 where it has grown by almost 60 % since 1998. More than 4 million cars have been added to the vehicle stock in the EU every year between 2005 and 2008. At the same time, measured in passenger-kilometres, high speed rail traffic has more than doubled between 1998 and 2008 and air passenger transport has continued its steady increase, resulting in a marginally decrease in the share of road transport compared with other modes between 2000 and 2008.
	Share of private cars in total road passenger transport	+ 4 %	+ 1 %	24	4	In the 1990s, the increasing share of private cars was a result of income growth. Between 2000 and 2008, passengers have kept using private cars at a stable level, as a possible result of a saturation of consumer demand and increasing fuel prices.
	Fuel intensity of road passenger transport	− 7 %	− 8 %	− 40	− 44	The decrease of fuel intensity of road passenger transport during the whole period 1990–2008 resulted in important CO_2 emission reductions. This was a combined result of improvements in engine efficiency, in particular during the period 1990–2000, and high fuel prices, leading customers to buy more efficient cars, in particular shifting from gasoline to diesel-driven cars. Fuel efficiency of new passenger cars has constantly increased over the period 1990 to 2008. This trend may have been further helped after 1998 by the voluntary agreements with car manufacturers. The labelling of new passenger cars provided for by the 1999 Car Labelling Directive has not shown any visible effect over the period. This driver also depends on the occupancy rates of cars, which decreased over the period and therefore led to a limited increase in the fuel consumed per passenger km. For example, a decrease in the average occupancy rate from approximately 1.61 to 1.57 persons per car was observed in Denmark, the Netherlands and the United Kingdom between 1995 and 2008.
Type of fuel	Share of fossil fuels in private cars	− 0.1 %	− 2 %	− 1	− 12	The trend in the share of fossil fuels in total fuel consumption reflects the share of biofuels in private cars, which increased during the period 1990–2008 from almost zero to 2.4 %. This increase accelerated after 2000 and may have been stimulated by the Biofuels Directive after 2003, but the impact of the directive on the development of this driver is not clearly demonstrated and the directive has failed to drive this increase to the policy objective of 5.75 % by 2010. Only four Member States had already met their 2010 target in 2008.
	Carbon intensity of fossil fuels use by private cars	+ 1 %	+ 0.1 %	4	1	When the impact of biofuels use is excluded, the carbon intensity of private cars slightly increased between 1990 and 2000, due to dieselisation (diesel is a more carbon-intensive fuel than petrol), and has remained relatively constant between 2000 and 2008. The development of this driver had therefore very limited consequences on road passenger transport GHG emissions. The 1998 Fuel Quality Directive, which aimed to ban the marketing of leaded petrol and control the sulphur content of diesel, did not affect the carbon intensity of fossil fuel use by private cars.

Source: Own calculations, based on EEA, 2010a; European Commission, 2010a; Eurostat, 2011b.

Table 4.6 Changes in drivers influencing CO_2 emissions from road freight transport in the EU and effects on emissions, 1990–2008

Group of drivers	Drivers	Change in driver (%)		Effect on GHG emissions (Mt CO_2-equivalent)		Assessment
		1990–2000	2000–2008	1990–2000	2000–2008	1990–2008
Amount of fuel	Freight transport demand (tkm)	+ 18 %	+ 19 %	41	51	Between 1990 and 2008 demand for freight transportation grew steadily, mostly in correlation with economic growth. The increase between 2000 and 2008, however, was smaller than between 1990 and 2000, partly due to economic recession which showed its first effects on the transport of merchandise already in 2008.
	Share of road transport (trucks) in total freight transport	+ 21 %	+ 4 %	57	14	The share of freight transported by trucks increased significantly in the 1990s and, to a lesser extent, between 2000 and 2008. In 2008, the volume of freight transported on road in the EU-27 was about four times higher than the volume transported by rail. Existing policies such as the Railway Interoperability Directives, the first and second Marco Polo Programmes and the first and second Railway Packages have shown limited success in driving modal shift towards generally less carbon-intensive modes than road during the period 2000–2008.
	Fuel intensity of freight road transport	– 15 %	– 3 %	– 49	– 11	Autonomous technical improvements in trucks (mainly in engine efficiency) resulted in lower fuel consumption per km and decreased emissions between 1990 and 2008. No policy has been identified as having impacted the fuel efficiency of trucks, although a new policy (Regulation on light-duty vehicles) is now directly targeting this driver.
Type of fuel	Share of fossil fuels in freight road transport	– 0.4 %	– 3 %	– 1	– 9	The share of fossil fuels in total fuel consumption decreased between 2000 and 2008, but the observed effect was slightly lesser than in the passenger transport sector. This development is likely to have been influenced by the Biofuels Directive.
	Carbon intensity of fossil fuels use by freight road transport	+ 1 %	+ 1 %	3	2	Carbon intensity has slightly increased between 1990 and 2008, thereby contributing towards a small increase in GHG emissions.

Source: Own calculations, based on EEA, 2010a; European Commission, 2010a; Eurostat, 2011b.

4.5 Indicative list of relevant legislative texts

Council Directive 93/12/EEC of 23 March 1993 relating to the sulphur content of certain liquid fuels (OJ L 74, 27.3.1993, p. 81–83) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31993L0012:en:NOT).

Council Directive 96/48/EC of 23 July 1996 on the interoperability of the trans-European high-speed rail system (OJ L 235, 17.9.1996, p. 6–24) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31996L0048:EN:NOT).

Directive 98/70/EC of the European Parliament and of the Council of 13 October 1998 relating to the quality of petrol and diesel fuels and amending Council Directive 93/12/EEC (OJ L 350, 28.12.1998, p. 58–68) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31998L0070:EN:NOT).

Communication from the Commission to the Council and the European Parliament — Implementing the Community strategy to reduce CO_2 emissions from cars: an environmental agreement with the European automobile industry, COM(1998) 495 final. (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:51998DC0495:EN:NOT).

Directive 1999/94/EC of the European Parliament and of the Council of 13 December 1999 relating to the availability of consumer information on fuel economy and CO_2 emissions in respect of the marketing of new passenger cars (OJ L 12, 18.1.2000, p. 16–23) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31999L0094:EN:NOT).

Commission Recommendation 2000/303/EC of 13 April 2000 on the reduction of CO_2 emissions from passenger cars (KAMA) (notified under document number C(2000) 801) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32000H0303:EN:NOT).

Commission Recommendation 2000/304/EC of 13 April 2000 on the reduction of CO_2 emissions from passenger cars (JAMA) (notified under document number C(2000) 803) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32000H0304:EN:NOT).

Directive 2001/14/EC of the European Parliament and of the Council of 26 February 2001 on the allocation of railway infrastructure capacity and the levying of charges for the use of railway infrastructure and safety certification (OJ L 75, 15.3.2001, p. 29–46) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32001L0014:EN:NOT).

Directive 2001/16/EC of the European Parliament and of the Council of 19 March 2001 on the interoperability of the conventional rail system (OJ L 110, 20.4.2001, p. 1–27) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32001L0016:EN:NOT).

Regulation (EC) No 1382/2003 of the European Parliament and of the Council of 22 July 2003 on the granting of Community financial assistance to improve the environmental performance of the freight transport system (Marco Polo Programme) (OJ L 196, 2.8.2003, p. 1–6) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32003R1382:EN:NOT).

Directive 2003/30/EC of the European Parliament and of the Council of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport (OJ L 123, 17.5.2003, p. 42–46) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32003L0030:EN:NOT).

Council Directive 2003/96/EC of 27 October 2003 restructuring the Community framework for the taxation of energy products and electricity (OJ L 283, 31.10.2003, p. 51–70) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32003L0096:EN:NOT).

Directive 2004/49/EC of the European Parliament and of the Council of 29 April 2004 on safety on the Community's railways and amending Council Directive 95/18/EC on the licensing of railway undertakings and Directive 2001/14/EC on the allocation of railway infrastructure capacity and the levying of charges for the use of railway infrastructure and safety certification (Railway Safety Directive) (OJ L 164, 30.4.2004, p. 44–113) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32004L0049:EN:NOT).

Directive 2004/50/EC of the European Parliament and of the Council of 29 April 2004 amending Council Directive 96/48/EC on the interoperability of the trans-European high-speed rail system and Directive 2001/16/EC of the European Parliament and of the Council on the interoperability of the trans-European conventional rail system (OJ L 164, 30.4.2004, p. 114–163) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32004L0050:en:NOT).

Regulation (EC) No 1692/2006 of the European Parliament and of the Council of 24 October 2006 establishing the second Marco Polo programme for the granting of Community financial assistance to improve the environmental performance of the freight transport system. (Marco Polo II) and repealing Regulation (EC) No 1382/2003 (OJ L 328, 24.11.2006, p. 1–13) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32006R1692:EN:NOT).

Directive 2007/58/EC of the European Parliament and of the Council of 23 October 2007 amending Council Directive 91/440/EEC on the development of the Community's railways and Directive 2001/14/EC on the allocation of railway infrastructure capacity and the levying of charges for the use of railway infrastructure (OJ L 315, 3.12.2007, p. 44–50) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32007L0058:EN:NOT).

Directive 2008/57/EC of the European Parliament and of the Council of 17 June 2008 on the interoperability of the rail system within the Community (OJ L 191, 18.7.2008, p. 1–45) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32008L0057:EN:NOT).

5 Agriculture

Summary

EU-27 GHG emissions from agriculture accounted for 10 % of total GHG emissions in 2008. Between 1990 and 2008, they decreased by 20 %. Cattle husbandry and the application of fertiliser to soils are the most important sources of GHG emissions from agriculture. Emissions from both sources decreased between 1990 and 2008. GHG emission drivers were primary affected by the influence of macroeconomic factors such as intensification of the sector, which led to important GHG emission reductions in this sector. However, it is worth highlighting the role played by policies that did not have the reduction of GHG emissions as a primary objective, such as the CAP and the Nitrates Directive, in further reducing emissions in this sector.

Between 1990 and 2008, CH_4 emissions from **enteric fermentation of cattle** decreased continually due to a declining number of cattle. This was, in the early 1990s, a consequence of the restructuring and modernisation of the agriculture sector in eastern Europe, but this trend has since continued. Several aspects of the CAP and especially its successive reforms have indirectly affected GHG emissions from cattle: the combination of overproduction control through milk quotas (initiated in 1984), the successive reductions of intervention prices (in 1992 and 2000) and the introduction of the SFP (under the 2003 CAP reform) limited the economic attractiveness of cattle production, incentivised higher milk yield (to sustain production levels with less cattle), and therefore contributed to limiting or even decreasing cattle numbers, thereby limiting GHG emissions from this sector.

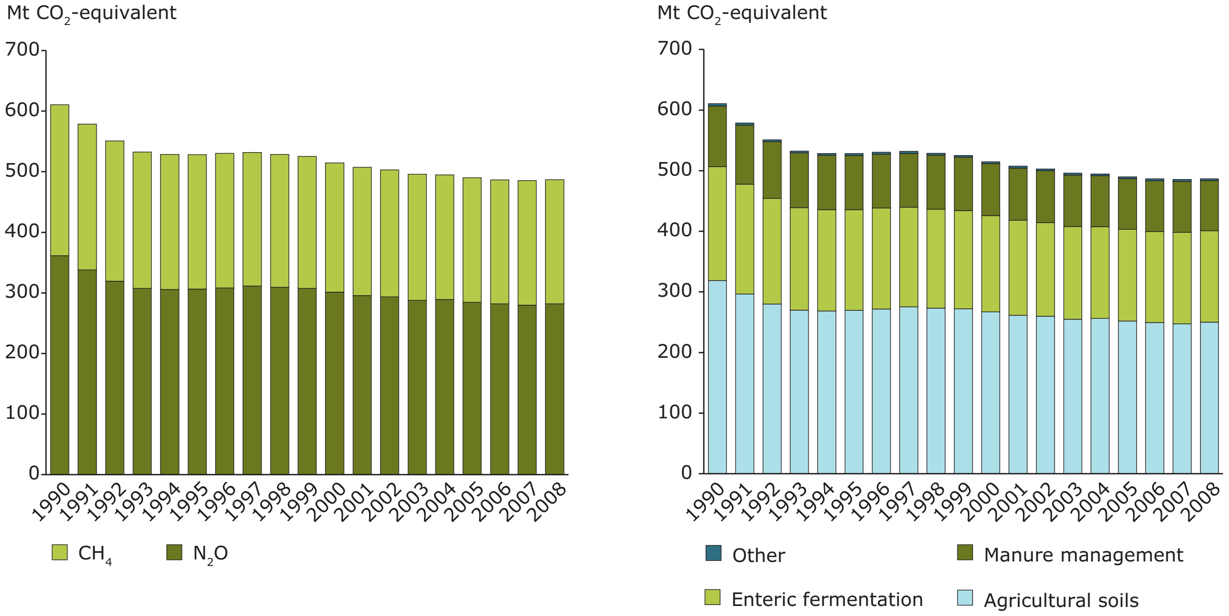
Between 1990 and 2008, N_2O emissions from **agricultural soils** were significantly reduced due to the lesser use of fertiliser per cropland, combined with a decreasing cropland area. Various national and EU policies aimed at reducing the amount of synthetic fertilisers applied to agricultural soils contributed to this decrease, in particular the Nitrates Directive. Its impact was the largest in the reduction of synthetic fertiliser application, but it also contributed to reducing input of organic fertilisers. The set-aside rules introduced in 1992 led to a significant but varying share of arable land being set aside, which is likely to have reduced GHG emissions due to arable production. However, assessing the impact of the set-aside rule on GHG emissions is difficult, given the importance of other socio-economic factors for cropping decisions, in particular links between input and output costs. The SFP combined with rural development measures, in particular agri-environment schemes, also provided incentives to limit overproduction of arable crops and other agricultural commodities which, in turn, led to reduced GHG emissions from agricultural soils. Cross-compliance requirements that were progressively introduced since 2000 contributed to better management of organic and mineral fertilisers.

5.1 Emission trend

GHG emissions from agriculture accounted for 10 % of total GHG emissions in 2008. Contrary to the energy-related sectors, which are dominated by CO_2 emissions, N_2O (58 %; mainly from plant production) and CH_4 (42 %; mainly from animal husbandry) are the predominant GHGs in agriculture. Half of the emissions are estimated to derive from microbiological activities in agricultural soils, 31 % from enteric fermentation and 17 % from manure management (Figure 5.1). In 2008, France (20 %), Germany (15 %) and the United Kingdom (9 %) contributed most to total GHG emissions in the EU-27.

Methane is emitted from three sources within livestock production systems: digestive processes

Figure 5.1 EU GHG emissions from agriculture per subsector and per gas, 1990–2008



Note: The sectors presented here correspond to the following IPCC categories: Agricultural soils: 4D; Enteric fermentation: 4A; Manure management: 4B; Other (rice cultivation and field burning of agricultural residues): 4C+4F. Emissions from fuel combustion in the agriculture sector are reported under the energy sector (1A4c).

Source: EEA, 2011. See www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer.

in animals (enteric fermentation); anaerobic decomposition processes in animal manure; and anaerobic decomposition processes of waste products from animal processing. The latter often occur when large numbers of animals are managed in confined areas (e.g. dairy farms, beef feedlots, and pig and poultry farms). The production of methane is therefore closely related to livestock production, and to a certain extent, to the production type.

Nitrous oxide is emitted during manure storage when the nitrogen in manure is converted to nitrous oxide, and by the conversion of nitrogen in the soil. These are natural processes, which are enhanced by agriculture. The sources of these emissions include synthetic fertilisers, animal waste, sewage sludge applications, biological nitrogen fixation and crop residues.

EU-27 GHG emissions from agriculture decreased by 124 Mt CO_2-equivalent (– 20 %) between 1990 and 2008. Emissions from all subsectors, except for rice cultivation, decreased significantly. The decreases achieved between 1990 and 2000 were highest in the Baltic countries and Bulgaria while the same countries had the highest relative increases between 2000 and 2008 (Figure 5.2).

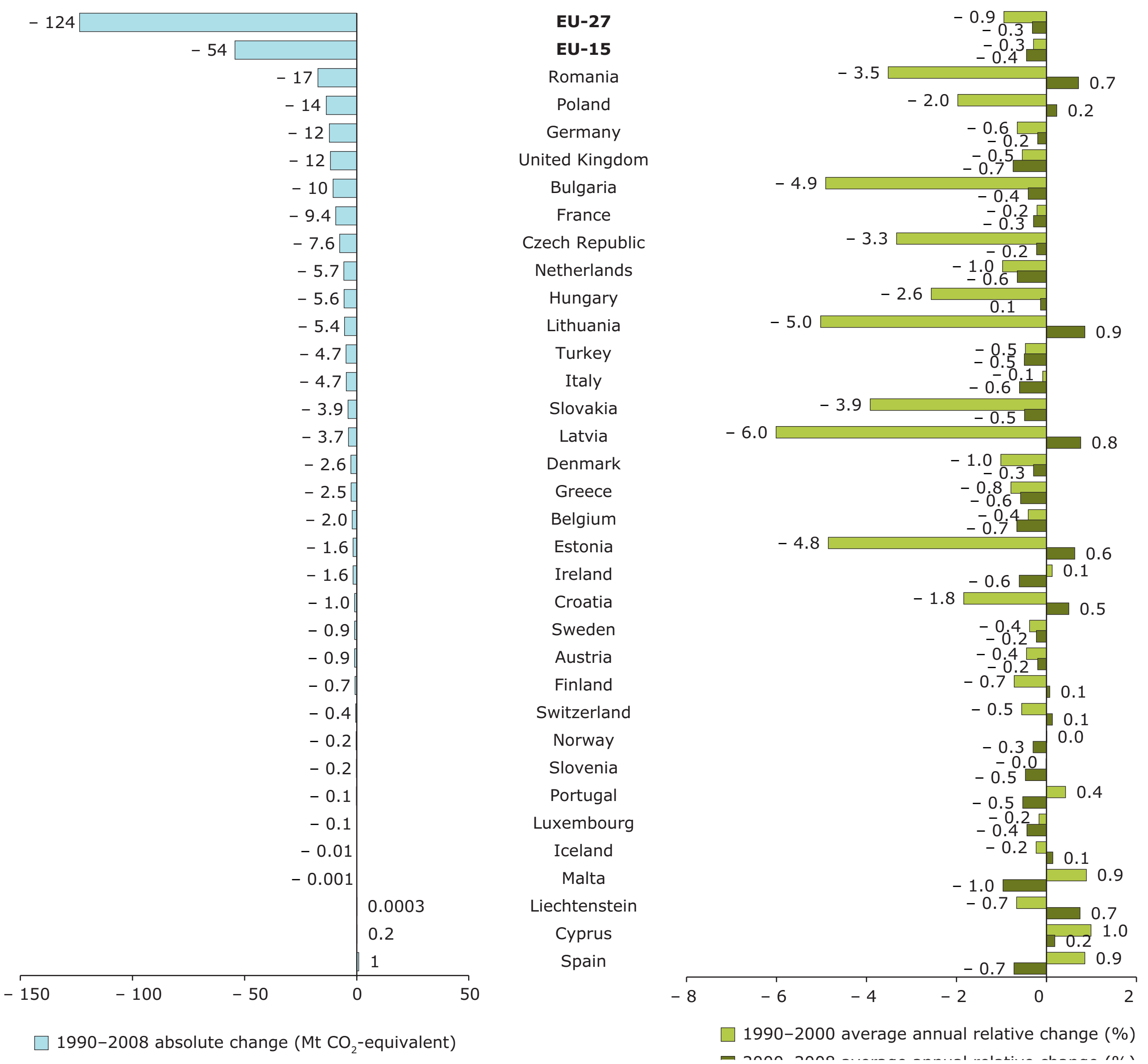
5.2 Effects of drivers on GHG emissions from agriculture

Cattle farming and the application of fertiliser to soils are the most important sources of GHG emissions in agriculture. These sources are analysed in detail in the two following sections.

5.2.1 *Enteric fermentation by cattle*

Enteric fermentation of cattle is the largest source of CH_4 emissions in the EU-27 and represented 31 % of total GHG emissions from the agriculture sector in 2008. It is directly related to the number of dairy and non-dairy cattle. The decomposition analysis examines the influence of five drivers of CH_4 emissions from enteric fermentation of cattle, covering 25 % of total GHG emissions from the agriculture sector (Table 5.1, Figure 5.3). Before decomposing CH_4 emissions into a number of factors according to the decomposition formula presented in Chapter 1, a first split is operated between CH_4 emissions from dairy cattle and CH_4 emissions from non-dairy cattle:

Figure 5.2 Absolute change and average annual relative change of GHG emissions from agriculture in the EU, 1990–2008



Note: Countries sorted according to absolute change between 1990 and 2008.
Average annual relative change (%) = (last year/base year)$^{(1/\text{number of years})}$ – 1.

Source: EEA, 2011.

$CH_{4\ \text{enteric fermentation}} = CH_{4\ \text{dairy cattle}} + CH_{4\ \text{non-dairy cattle}}$

With: [$CH_{4\ \text{dairy cattle}}$ = milk production * 1/milk yield * emission intensity of dairy cattle] and [$CH_{4\ \text{non-dairy cattle}}$ = number of non-dairy cattle * emission intensity of non-dairy cattle].

Once the effects of each individual driver on CH_4 trends have been calculated, these are combined together to allow a meaningful analysis (Figure 5.4).

In the EU-27, the number of cattle decreased more or less continually during the 1990–2008 period analysed here. After a period of decrease following the introduction of milk quotas in the 1980s, milk stabilised around 1994 and began to slightly increase thereafter. Following a long-term trend of intensification of cattle husbandry, milk productivity increased continuously during the period, with increases in milk yield ranging from 20 % (Ireland) to 97 % (Spain) (EEA, 2010).

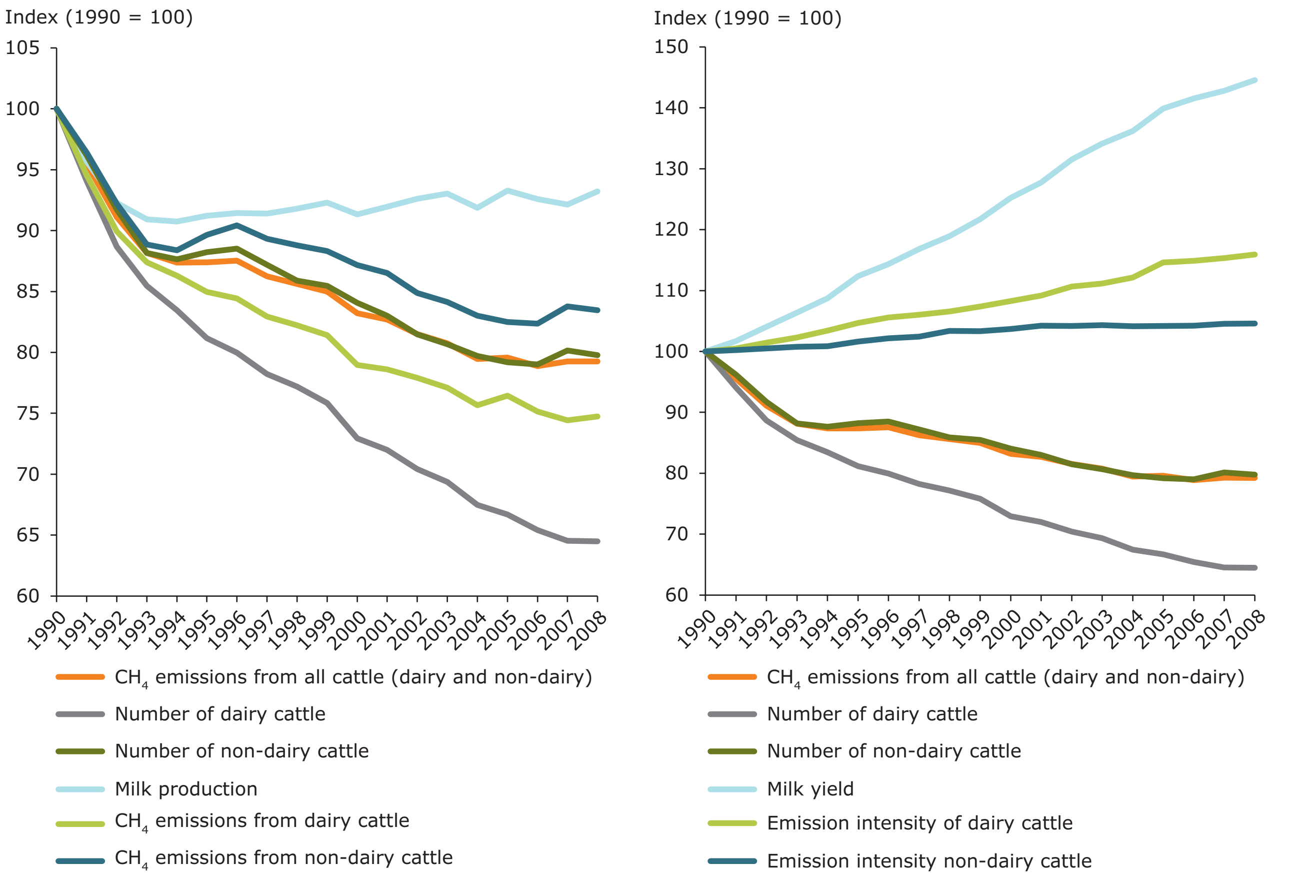
Table 5.1 Identification of drivers influencing CH_4 emission from enteric fermentation of cattle

Drivers influencing emissions	Description	Input of factors to decomposition analysis	Unit
Milk production	Milk production is one of the main drivers on CH_4 emissions from enteric fermentation of dairy cattle.	Milk production	T
Milk yield	The milk yield represents the quantity of milk produced each year by a cow. This driver reflects the 'productivity' of dairy cattle.	Dairy cattle/milk production = 1/milk yield	head/t
Emission intensity of dairy cattle	The emission intensity of dairy cattle reflects the level of emissions per cattle. It depends mainly on the type of feed (energy intake and digestibility).	CH_4 emissions from dairy cattle/number of dairy cattle	Mt CH_4/head
Number of non-dairy cattle	Non-dairy cattle cause fewer emissions than dairy cattle, mainly due to different feeding.	Number of non-dairy cattle	head
Emission intensity of non-dairy cattle	The emission intensity of non-dairy cattle depends on the type of feed (energy intake and digestibility).	CH_4 emissions from non-dairy cattle/number of non-dairy cattle	Mt CH_4/head

Although higher milk yields were achieved through increased energy intake per cattle, among other measures, which resulted in a higher amount of CH_4 emitted per cow (emission intensity), the decrease in the number of cattle within the EU had a larger effect on total CH_4 emissions and drove down emissions from this sector (Figure 5.4).

As regards non-dairy cattle (for beef production), here again the intensification of this sector resulted in a decrease in cattle number, which largely outweighed the effects of increased CH_4 intensity due to higher energy intake. This also resulted in an overall decrease in CH_4 emissions from this type of cattle.

Figure 5.3 Drivers of CH_4 emissions from enteric fermentation of cattle in the EU, 1990–2008

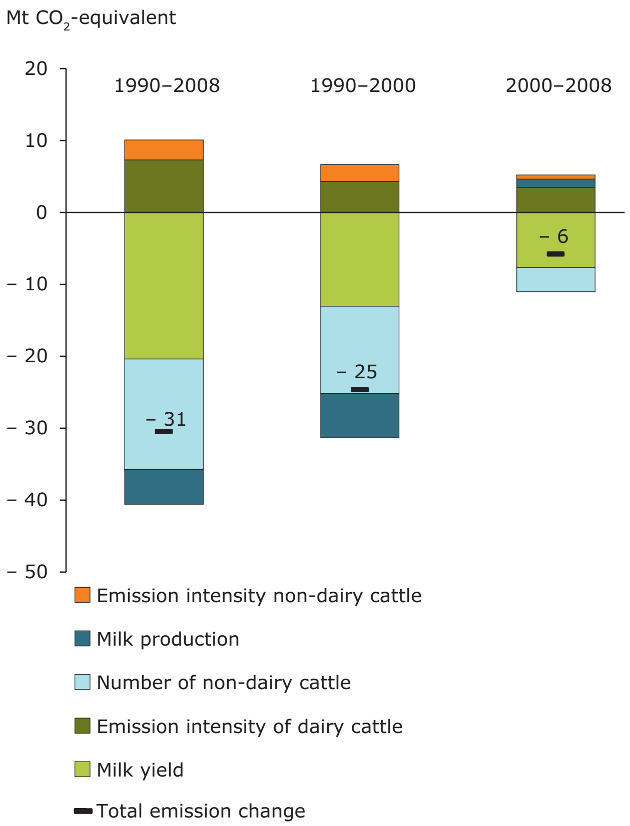


Source: EEA, 2010a.

The long-term decrease in the number of cattle reflected primarily the restructuring of the European agricultural sector in order to remain economically competitive on world food markets. This trend, however, was exacerbated in the early 1990s by the decollectivisation occurring in eastern Europe, which participated to the wider restructuring of eastern Europe economies during that period. The latter also strongly affected energy-related emissions (see Chapter 7). This was particularly visible in Germany, Poland and Romania, where the largest absolute reductions were observed across the EU.

Germany had the largest decrease of non-dairy cows in absolute terms between 1990 and 2008 (– 4 million cows; – 33 %). The reduction of animal numbers since 1990, and in particular between 1990 and 1991, was a consequence of the German unification causing decollectivisation. In the Czech Republic, Poland and Romania, the number of dairy and non-dairy cattle decreased (together with milk production), mainly in the 1990s, due to restructuring and modernisation of agricultural techniques. Between 2000 and 2008, the number of dairy cattle decreased further. In Poland in particular this was due to the need for adjustments and investments required by EU regulations and consequent increasing operational costs. This could only be afforded by the most efficient large agricultural holdings and processing industries, whereas the small ones stopped to produce for the market.

Figure 5.4 Decomposition analysis of CH_4 emission trends from enteric fermentation of cattle in the EU, 1990–2008



Note: Each bar shows the contribution of a single driver on GHG emission trends during a determined period. The thick short black lines indicate the combined effect of all emission drivers, i.e. the overall GHG emission trend during the period considered.

Source: Own calculations, based on EEA, 2010a.

Besides such important economic and structural factors, the number of cattle was also affected by EU policy such as milk quota (as mentioned above), suckler cow premia, but also environmental legislation linked to agricultural policy through cross compliance and rural development. Animal development was also determined by epidemics such as the avian flu (reducing for example the number of poultry in the Netherlands in 2003), the Foot and Mouth Disease (FMD) or the bovine spongiform encephalopathy (BSE or 'mad cow disease') second crisis between 2001 and 2003 (EEA, 2010).

5.2.2 *Agricultural soils*

N_2O emissions may be related to the use of both organic and inorganic fertilisers, biological nitrogen fixation, and return of crop residues to the field or to animal production. Non-CO_2 greenhouse gas emissions associated with the use of compost and human waste as fertilisers are also recorded in this category. Emissions of N_2O from sewage are to be reported under Waste (IPCC sector 6B) and N_2O emissions from animal waste management systems other than grazing under manure management (IPCC sector 4B). Emissions of N_2O from manure and biomass used for fuel are reported under the section on Energy supply (IPCC sector 1A). CO_2 emissions due to land-use change in the agriculture sector are reported under the LULUCF sector. These emissions occur in particular with the internal turn over between grassland (IPCC sector 5C) and cropland (IPCC sector 5B). The former releases carbon when ploughed up, which has occurred a lot in the last 10–15 years.

The application of nitrogen containing fertilisers is the major component leading to N_2O emissions from soils. Beside the amount of applied nitrogen, the amount of N_2O emitted is also influenced by nitrogen application and irrigation practices, climatic variables, soil temperature and humidity. Additionally, cultivation techniques also lead to N_2O emissions from soil due to the mineralisation of organic matter. Since 1990, N_2O emissions from agricultural soils were reduced by about 20 %. The amount of synthetic fertiliser applied to cropland decreased primarily in the early 1990s and to a lesser extent between 2000 and 2008. By contrast, the area used as cropland has decreased only slightly. An overview on how these factors are interlinked in the decomposition analysis to drivers influencing the trend of N_2O emissions from agricultural soils, covering 28 % of total GHG emissions from the agriculture sector, is shown in Table 5.2. Here, the decomposition formula applied is:

N_2O $_{\text{agricultural soils}}$ = cropland area * [animal manure per cropland area + synthetic fertiliser per cropland area + other fertiliser per cropland area]
* N_2O emissions per fertiliser applied

Over the period 1990 to 2008, the reduced use of fertiliser per cropland combined with a decreasing cropland area resulted in an overall reduction of N_2O emissions from agricultural soils. The reduced application of synthetic fertiliser to cropland contributed most to the reduction (Figure 5.5, Figure 5.6). Nitrogen-containing fertilisers applied to cropland are subject to microbiological transformations causing N_2O emissions, nitrate leaching and ammonia volatilisation. The availability of mineral nitrogen forms facilitates these processes. Consistent with the decrease of animal numbers in Europe and the decrease of nitrogen content in manure (see Section 5.2.1), the input of nitrogen to agricultural soils also decreased considerably between 1990 and 2008. The input of manure decreased by 8 %, and the input of mineral fertiliser decreased even more, by 24 %.

The area used as cropland decreased in Germany, France and Italy, especially between 2000 and 2008, whereas in the United Kingdom increases were observed. The increased emission intensity in the early 1990s was mainly due to an increased emission factor from animal manure in the Netherlands (Figure 5.5). To reduce ammonia volatilisation, the ammonia policy led to a shift from the surface spreading of manure to the incorporation of manure into soil which reduced ammonia volatilisation but increased N_2O emissions.

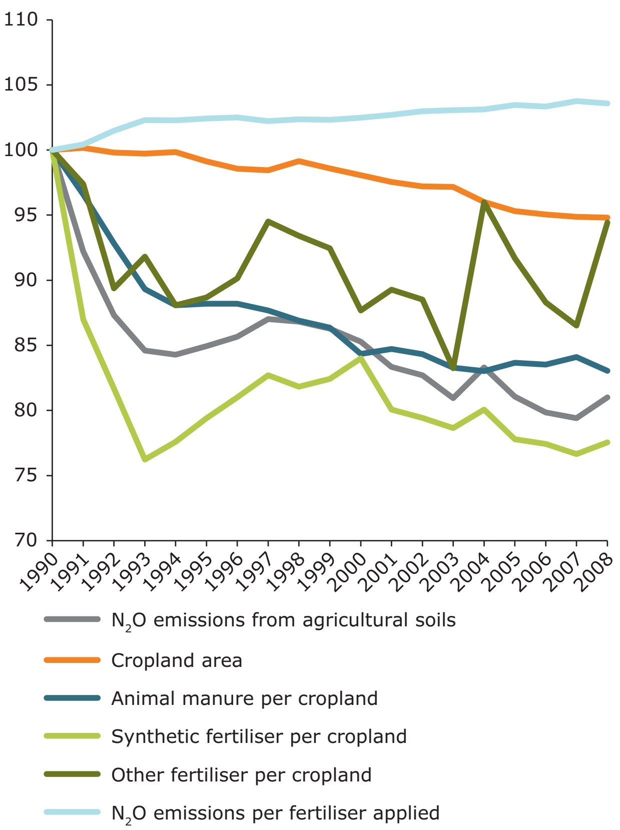
The overall decrease of N_2O emissions in the EU-27 between 1990 and 2008 was driven by Germany, France, Poland, Romania and the United Kingdom.

Poland and Romania decreased N_2O emissions from agricultural soils in the 1990s, but increased them between 2000 and 2008; Poland mostly by increasing the rate of synthetic fertiliser application whereas Romania increased the rate of crop residues applied per area cropland.

Table 5.2 Identification of drivers influencing N_2O emissions from agricultural soils

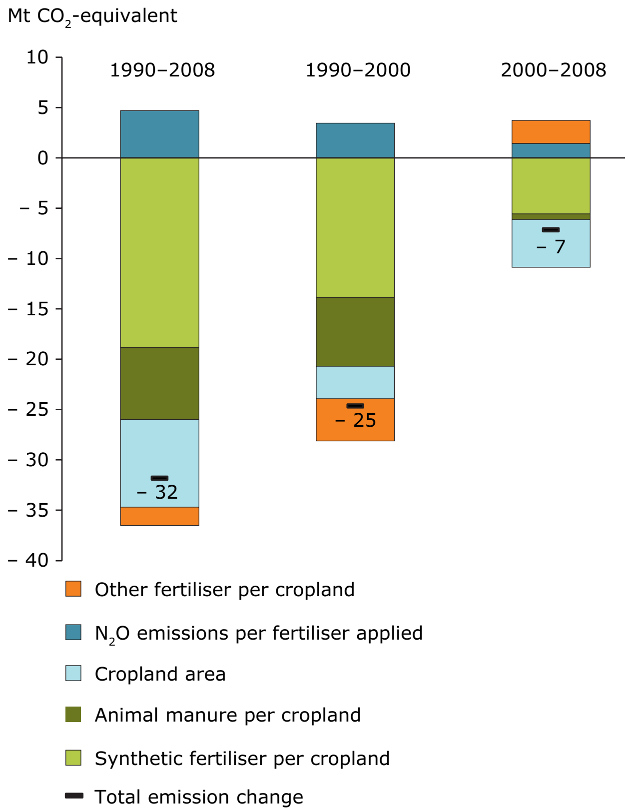
Drivers influencing emissions	Description	Input to decomposition analysis	Unit
Cropland area	Area of land that is used for growing crops. This area is a primary factor determining the amount of animal manure and fertiliser used in agriculture.	Cropland area	kha
Animal manure per cropland area	The amount of animal manure applied per cropland area is directly related to the number of animals farmed.	Animal manure/ Cropland area	kt N/kha
Synthetic fertiliser per cropland area	Mineral nitrogen (N) fertiliser is subject to rapid microbiological transformation to N_2O and to nitrate leaching. Various national and EU policies therefore aim at reducing the use of synthetic fertiliser.	Synthetic fertiliser/ Cropland area	kt N/kha
Other fertiliser per cropland area	Other fertilisers comprise nitrogen-fixing crops and crop residues, but also the cultivation of histosols (mainly organic soils) in Scandinavian countries.	Other fertiliser/ Cropland area	kt N/kha
N_2O emissions per fertiliser applied	The amount of N_2O emissions per amount of fertiliser applied to soils depends on the nitrogen content, the type of nitrogen application, irrigation practices, soil cultivation, climatic variables, soil humidity and temperature.	N_2O emissions/Total fertiliser use	kt N_2O/kha

Figure 5.5 Drivers of N_2O emissions from EU agricultural soils, 1990–2008



Source: EEA, 2010a.

Figure 5.6 Decomposition analysis of N_2O emission trends from EU agricultural soils, 1990–2008



Note: Each bar shows the contribution of a single driver on GHG emission trends during a determined period. The thick short black lines indicate the combined effect of all emission drivers, i.e. the overall GHG emission trend during the period considered.

Source: Own calculations, based on EEA, 2010.

In France the cropland area decreased by 4 % in the 1990s and contributed the most to decreased N_2O emissions; also the reduced use of nitrogen fixing crops showed effect.

The United Kingdom decreased its N_2O emissions from agricultural soils despite the highest absolute increase of cropland area in the EU-27 between 1990 and 2008. However, the absolute decrease of synthetic fertiliser application per area cropland was also highest in the United Kingdom (– 30 % relative change).

5.3 Main links between EU policies and observed GHG trends in the agriculture sector between 1990 and 2008

Two important policies adopted at the EU level have affected, indirectly but significantly, GHG emissions from the agriculture sector: the CAP and the Nitrates Directive (Table 5.3). Although the objective of both these policies was not primarily to reduction GHG emissions, they have impacted a number of agricultural practices that drive emissions

Table 5.3 Link between EU policies and GHG emission sources

IPCC sector	EU Directive potentially affecting GHG emissions
Cattle (enteric fermentation) (4A1)	Common Agricultural Policy (CAP) and its successive reforms (1992, 2000, 2003, 2008)
Agricultural soils (4D)	Common Agricultural Policy (CAP) and its successive reforms (1992, 2000, 2003, 2008) Nitrates Directive (1991)

in this sector, and some aspects of these policies have driven GHG emission changes. The objectives of the two policies and the effects of their various aspects on GHG emission drivers are summarised in Table 5.4. Other policies, often linked to the CAP and the Nitrates Directive, have also played a role in decreasing GHG emissions from agriculture, although they are not analysed in detail here.

Common Agricultural Policy

The CAP is a system of European Union agricultural subsidies and programmes that combines a direct subsidy payment for crops and land which may be cultivated with price support mechanisms, including guaranteed minimum prices, import tariffs and quotas on certain goods from outside the EU, as well as support for rural development measures. The CAP went through a number of important reforms since its creation:

- milk quotas (introduced in 1984 and due to be progressively phased out by 2015);
- 1992: move from price support per product to direct support per hectare linked to type of production;
- 1992: compulsory set-aside rule and its abolishment in 2008 (CAP 'health check' reform);
- 2000: further move to direct support;
- 2000 and 2003: cross compliance including improving the welfare of animals and land use change;
- 2003: decoupling of direct support from production, including SFP;
- 2008: further decrease of price support (intervention mechanism as safety-net).

The Milk Quota regime was introduced in 1984 to curb the rising milk production by placing a limit on the amount of milk that could be produced by each Member State. With such limit on milk production, the intensification of dairy cattle husbandry, which sought to increase the production of milk per head of cattle, resulted indirectly in a decrease in the number of cattle. The CAP reforms of 2003 began the process of gradually increasing milk quotas with a view to their eventual removal. The initial introduction of the milk quota led to the reduction in milk production, although the majority of the trend was observed prior to the period 1990–2008 (as mentioned above, milk production actually stopped decreasing in 1994 and increased slowly thereafter).

The successive reductions of intervention prices in 1992 and 2000 also represented an incentive to improve the competitiveness of further increase milk yield and more generally to shift the market towards more efficient milk producers since low milk yield became less profitable.

The set-aside measure was introduced through the MacSharry reform of 1992 as a control against over production of cereal in the EU. The percentage of compulsory set aside was set up each year. The set-aside rules led to a significant but varying share of arable land being set aside, which is likely to have reduced GHG emissions due to arable production. Although intervention stocks of products were reduced and an increase in the area of land set aside was clearly visible, assessing the impact of the set-aside rule on cropland area is particularly difficult, because of the important role of other socio-economic factors for cropping decisions, in particular links between input and output costs. As such, the variation of the percentage of compulsory set-aside between 2000 and 2008 are not reflected in the trend of cropland area.

Generally speaking, it is considered that the 1992 reform of the CAP was a major, but insufficient, step towards a better integration of environmental demand and sustainability in the CAP. Several aspects of the 2003 CAP reform had direct links to drivers affecting GHG emissions from agriculture, in particular from enteric fermentation and/or agricultural soils.

The SFP introduced, as part of the 2003 reform, the decoupling from production of direct aids. Combined with rural development measures, in particular agri-environment schemes, it has led to a reduction in the over production of certain crops and other commodities which, in turn, has led to reduced GHG emissions from agricultural soils. The SFP also further limited the economic attractiveness of cattle production, incentivised higher milk yield and contributed therefore to limiting or even decreasing cattle numbers, thereby limiting GHG emissions from this sector.

Cross compliance was also introduced as an optional control-and-sanction system in the 2000 reform and was made compulsory for all Member States with the 2003 reform to ensure that aid to farmers was linked to the aspects of animal welfare and good environmental practices. Although the link between cross compliance, improved animal welfare standards and GHG emissions is currently uncertain, it is generally considered that some aspects of welfare do affect GHG emissions. For example, high roughage as in grass leads to higher methane emissions as compared to more concentrated feed.

Nitrates Directive

N_2O emissions from agricultural soils accounted for 4.8 % of the EU-27's total emissions in 2008. Although the main aim of the 1991 Nitrates Directive was to protect water quality across Europe by promoting use of good farming practices, thus reducing run-off of nitrates from agricultural soils (which pollute ground and surface waters), the policy has also exerted a significant downward pressure on N_2O emissions by limiting the application of fertilisers. The reduced use of synthetic fertilisers, in particular, drove important relative emission reductions. The specific aspects of the policy that impact the N_2O emissions from soils are:

- designation of Nitrate Vulnerable Zones (NVZs), which are areas of land which drain into polluted or threatened waters and which contribute to nitrogen pollution;

- establishment of Code(s) of good farming practices (GFP) limiting the time and the conditions when fertiliser can be applied;

- implementing limits to application of fertilisers taking into account crop needs. Maximum animal manure application rate is set at 170 kg N organic/hectare/year.

Codes of good farming practice (GFP) are a key policy response to encourage the promotion of better management practices, including nutrient management. Member States have to define codes of good farming practice at national or regional level in their rural development programmes. These codes correspond to the type of farming that a reasonable farmer would follow in the region concerned. This includes at the very least, compliance with general statutory environmental requirements, such as the Nitrates Directive. Codes of GFP include therefore relevant standards regarding manure and slurry management and storage. Included in these codes are eligibility conditions for support under agri-environment programmes and the Less Favoured Area scheme. However, a substantial part of intensive livestock farms do not participate in these schemes and do not need to respect such codes, although they have to comply with the legal provisions of the Nitrates Directive.

Agri-environment schemes are designed to encourage farmers to protect and enhance the environment on their farmland by paying them for the provision of environmental services. These schemes were first introduced into EU agricultural policy during the late 1980s as an option to be applied by Member States. Since 1992, the application of agri-environment programmes has been compulsory for Member States in the framework of their rural development plans, whereas they remain optional for farmers. These schemes led to important benefits in terms of GHG emission reductions through improved nutrient management, long-term set-aside of sensitive cropland, etc.

5.4 Sectoral synthesis: agriculture

Between 1990 and 2008, GHG emissions decreased in two of agriculture's main subcategories: CH_4 emissions from cattle due to enteric fermentation and N_2O emissions from agricultural soils due to the application nitrogen-based fertilisers. The decrease in CH_4 emissions was primarily driven by the reduction in the number of dairy and non-dairy cattle, as a result of restructuration and gains in competitiveness of European agricultural sectors in a more globalised and market-driven economy. The combination of a number of policies aiming to reduce the impacts of agriculture practices on the environment resulted in significant reduction of fertilizer use, which in turn led to important N_2O reduction in this sector. This is particularly the case for the Nitrates Directive, despite the fact that its first objective was not to reduce GHG emissions but to limit and reduce water pollution. Generally speaking, it is considered that the 1992 reform of the CAP was a major, but insufficient, step towards a better integration of environmental demand and sustainability in the CAP. Several aspects of the 2003 CAP reform had direct links to drivers affecting GHG emissions from agriculture, in particular from enteric fermentation and/or agricultural soils.

Enteric fermentation

The decrease in the number of cattle, a long-term trend that had been taking place for several decades, was by far the largest factor behind the decrease in CH_4 emissions from cattle. This decrease was steepest in the early 1990s, as a direct consequence of decollectivisation, i.e. the restructuring and

Table 5.4 EU policies affecting emissions from agriculture between 1990 and 2008

EU legislation	Objectives	Main aspect of the policy	Main sector affected	Impact on identified drivers
Common Agricultural Policy (CAP): MacSharry reforms (1992) & Agenda 2000. Regulation (EC) 1782/2003 establishing common rules for direct support schemes for farmers under the Common Agricultural Policy and establishing certain support schemes for farmers. The regulation associated with the 2003 reform has now been repealed. Council Regulation (EC) 73/2009 establishing common rules for direct support schemes for farmers under the common agricultural policy and establishing certain support schemes for farmers replaces the former regulation and its amendments.	**1992 MacSharry reforms**: limit rising production, while at the same time adjusting to the trend toward a more free agricultural market. Change the cereals regime by reducing the internal (intervention) price from 155 ecu/tonne to 90 ecu/tonne and replacing the support with fixed area payments and the requirement that any farmer claiming the area payments should also comply with any set-aside restrictions. **Agenda 2000** (second pillar of the CAP taking into account the 'multifunctionality' of farming activities): further reduce the intervention prices for cereals and oilseeds, as well as for beef and sheep. Some reduction in support prices for milk, with quotas in place until 2006, as well as pig and poultry to reflect the lower prices for cereal feeds. **2003 reform**: ensure, through the 'decoupling'of support payments, that farmers no longer need to manage their businesses with the aim of maximising their subsidies from the CAP, but could focus their production and management practices on market demand.	Introduction of milk quota	Cattle (enteric fermentation)	Milk quotas had a significant impact on milk production and the number of dairy cows after 1984. A drop between 30 % and 40 % in the number of dairy cows was recorded in Denmark, France and Luxembourg between 1975 and 1995, although in Ireland the reduction was only 13 %. The observed reduction in milk production halted in 1992. As milk yield increased due to intensification of the sector, the limitation of milk production affected indirectly the number of dairy cattle. By limiting production, the quotas indirectly affected the number of cattle. The CAP reforms of 2003 began the process of gradually decreasing milk quotas with a view to their eventual removal.
		Reduction of intervention prices (1992 MacSharry reform, Agenda 2000) and Single Farm Payment (2003 reform)	Cattle (enteric fermentation)	The reduction of intervention price played a strong role to increase the production of dairy products other than butter and skimmed milk (production of the latter two decreased as a result of Agenda 2000). It also represented an increased incentive to further increase milk yield and more generally to shift the market towards more efficient milk producers since low milk yield became less profitable. Assessing the specific effects of this measures on milk yield is however difficult, because milk yields have constantly increased over the whole period considered 1990–2008, mainly due to improved feedstock and machinery. The number of non-dairy cattle does not seem to have been directly affected by the reduction of intervention prices, in particular in the 1990s. The EU-12 entry into the CAP has contributed to the increase in production-based drivers since 2004.
			Agricultural soils	Cropland area decreased during the period following the 1992 MacSharry reform where intervention prices decreased significantly. Some of the decrease could be attributed to this reform, while the increase in crop yield is also thought to have played an important role. The decoupling of price support may also have led to a reduction in the number of animals being farmed, which might have resulted in less animal manure available for use as fertiliser on cropland. The SFP introduced the decoupling from production of direct aids and led to reduce the over production of arable crops and other commodities which, in turn, has led to reduced GHG emissions from agricultural soils.
		Set-aside land	Agricultural soils	The set-aside rules introduced in 1992 led to a significant but varying share of arable land being set aside, which is likely to have reduced GHG emissions due to arable production. However, assessing the impact of the set-aside rule on GHG emissions is difficult, given the importance of other socio-economic factors for cropping decisions, in particular links between input and output costs.
		Cross compliance	Cattle (enteric fermentation)	Genetic selection for high 'milkers'often has detrimental effects on other aspects of the cow's physiology. These reduce the welfare of the animals as they suffer from increased health complaints. Overall, although the link between cross compliance, improved animal welfare standards and GHG emissions is currently uncertain, it is generally considered that some aspects of welfare do affect GHG emissions. The consequences of better animal welfare on emission intensities of both dairy and non-dairy cattle are not determined, as they can be positive or negative. For example, high roughage as in grass leads to higher methane emissions as compared to more concentrated feed.

Table 5.4 EU policies affecting emissions from agriculture between 1990 and 2008 (cont.)

EU legislation	Objectives	Main aspect of the policy	Main sector affected	Impact on identified drivers
			Agricultural soils	Cross-compliance requirements that were progressively introduced since 2000 contributed to better management of organic and mineral fertilisers. Many land-use changes have also been more strictly controlled via cross compliance since 2005 and there are incentives to maintain the total grassland area within Member States and regions. This may result in an increase in carbon sinks being maintained in the agriculture sector. However, the impact of this is not observed in the time series that stop in 2008.
Nitrates Directive: Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources.	Prevent nitrogen loading of water bodies stemming from agricultural waste and the excessive use of fertilisers.	Designation of NVZs	Agricultural soils	By 2000, all EU Member States had transposed the directive and designated NVZs. From 1999 to 2003, the area of land in the EU-27 covered by NVZs expanded over 10-fold, which led to a reduction in the loss of N_2O from soil to atmosphere.
		Code(s) of good agricultural practice	Agricultural soils	Codes of GFP include relevant standards regarding manure and slurry management and storage. Included in these codes are eligibility conditions for support under agri-environment programmes and the Less Favoured Area scheme. However, a substantial part of intensive livestock farms do not participate in these schemes and do not need to respect such codes, although they have to comply with the legal provisions of the Nitrates Directive.
		Limits to application of fertilisers	Agricultural soils	The directive implemented limits to the application of fertilisers taking into account crop needs. The use of synthetic fertiliser per cropland decreased by 14 % between 1990 and 1993 and the use of manure and other fertilisers also decreased in the early 1990s — although the observed decrease was not as important as for synthetic fertilisers. The directive set an upper limit for manure per cropland of 170 kg N organic/hectare/year. The use of manure decreased in the early 1990s, however not as strongly compared to synthetic fertilisers. The directive is estimated to have had an important effect on the use of fertilisers, in particular synthetic ones.

modernisation of the agriculture sector in eastern Europe. One of the aspects of the sector's intensification was an increase in cattle's energy feed (in order to increase its productivity), which also increased its CH_4 intensity (especially dairy cattle). The effects of such increased intensity on CH_4 emissions were largely outweighed by the effects of the reduction in cattle numbers. Several aspects of the CAP and especially its successive reforms have indirectly affected GHG emissions from cattle: the combination of overproduction control through milk quotas (initiated in 1984), the successive reductions of intervention prices (1992, 2000) and the introduction of the Single Farm Payment (SFP) (under the 2003 CAP reform) limited the economic attractiveness of cattle production, incentivised higher milk yield (to sustain production levels with less cattle) and contributed therefore to limiting or even decreasing cattle numbers, thereby limiting GHG emissions from this sector (Table 5.5).

Agricultural soils

Over the period 1990 to 2008, the reduced use of fertiliser per cropland combined with a decreasing cropland area resulted in an overall reduction of N_2O emissions from agricultural soils. The reduced application of synthetic fertiliser to cropland contributed most to the reduction. Various national and EU policies aiming at reducing the amount of synthetic fertilisers applied to agricultural soils (e.g. nitrate leaching) contributed to this trend. Despite the fact that its primary objective was to reduce water pollution, the Nitrates Directive played an important role in this trend by limiting the amount of nitrogen input to agricultural soils. Consistent with the decrease of animal numbers in Europe and the decrease of nitrogen content in manure, the input of nitrogen to agricultural soils also decreased considerably between 1990 and 2008. The input of manure decreased by 8 %, and the input of mineral fertiliser decreased even more, by 24 %. The set-aside rules introduced in 1992 led to a significant but varying share of arable land being set aside, which is likely to have reduced GHG emissions due to arable production. However, assessing the impact of the set-aside rule on GHG emissions is difficult, given the importance of other socio-economic factors for cropping decisions, in particular links between input and output costs. The SFP combined with rural development measures, in particular agri-environment schemes, also provided incentives to limit over-production of arable crops and other agricultural commodities which, in turn, led to reduced GHG emissions from agricultural soils. Cross-compliance requirements that were progressively introduced since 2000 contributed to better management of organic and mineral fertilisers. Agri-environment schemes led to important benefits in terms of GHG emission reductions through improved nutrient management or long-term set-aside of sensitive cropland. Finally, by leading to a reduction in the over production of certain crops and other commodities, the SFP also contributed to further reducing GHG emissions from agricultural soils (Table 5.6).

Table 5.5 Changes in drivers influencing CH_4 emissions from enteric fermentation of cattle in the EU and effects on emissions, 1990–2008

Group of driver	Driver	Change in driver (%)		Effect on GHG emissions (Mt CO_2-equivalnt)		Assessment
		1990–2000	2000–2008	1990–2000	2000–2008	1990–2008
Number of cattle	Milk production	– 9 %	2 %	– 6	1	Milk production decreased in the 1990s as a consequence of the restructuring and modernisation of the agriculture sector in eastern Europe. It stabilised in the mid-1990s and slowly increased thereafter. Milk quotas had strong effects on milk production until the early 1990s. As a result of Agenda 2000, butter and skimmed milk powder production decreased. However, milk production is heavily influenced by demand for other dairy products (e.g. cheese). Hence, although reduction in intervention price under the CAP reform has had a strong impact on the specific products, the net milk production remained relatively static between 2000 and 2008. The EU-12 entry into CAP and other reasons such as the increase in milk price due to a supply shortage have contributed to the increase in production-based drivers since 2004.
	Milk yield	+ 6 %	+ 3 %	– 13	– 8	The milk yield increased very significantly in the 1990s, enabling the farming industry to maintain production levels while the number of cattle strongly decreased — thereby inducing important GHG emissions reductions. Improved feedstock and machinery are thought to have played a significant role in influencing this trend, although it may also have been further pushed by successive reductions of the intervention price (MacSharry reform and Agenda 2000), which further incentivised milk yield increases.
	Number of non-dairy cattle	– 16 %	– 5 %	– 12	– 3	The number of non-dairy cows decreased in the 1990s, leading to emission decreases.
Type of feed	CH_4 emission intensity dairy cattle	+ 8 %	+ 7 %	4	3	CH_4 emissions per dairy cattle have been increasing, mainly due to the higher energy intake through feeding which goes along with higher milk yields, but also higher emissions per head of cattle.
	CH_4 emission intensity non-dairy cattle	+ 4 %	+1 %	2	1	CH_4 emissions per cattle have been increasing, mainly due to the higher energy intake through feeding which goes along with higher emissions.

Source: Own calculations, based on EEA, 2010a.

Table 5.6 Changes in drivers influencing N_2O emissions from EU agricultural soils and effects on emissions, 1990–2008

Group of drivers	Driver	Change in driver (%)		Effect on GHG emissions (Mt CO_2-equivalent)		Assessment
		1990–2000	2000–2008	1990–2000	2000–2008	
Amount of fertiliser	Cropland area	– 2 %	– 3 %	– 3	– 5	The area of cropland decreased in most countries between 1990 and 2008, mainly due to increases in crop yields (in particular after 2000), CAP reforms and market adjustments from EU enlargement or international trade agreements. Cropland has increased only in the United Kingdom. Since compensatory payment due to the reduction of the intervention price was based on the existing cropland area, the impact of lowering the intervention price had only a weak effect on this driver. In the absence of the set-aside land, the rate of reduction of cropland area may also have been slower in the 1990s.
	Animal manure per cropland area	– 16 %	– 2 %	– 7	– 1	The amount of animal manure applied to agricultural soil decreased due to decreasing animal numbers. Part of this trend may be attributed to the decoupling of price support. Limits on the use of organic nitrogen set by the Nitrates Directive may also have contributed to the decrease observed in the 1990s.
	Synthetic fertiliser per cropland area	– 16 %	– 8 %	– 14	– 6	Synthetic fertiliser contains mineral nitrogen that is subject to leaching, volatilisation and transformation to N_2O. Mineral nitrogen fertilisation decreased in almost all EU-27 Member States, except in Poland where emissions increased by 17 % between 2000 and 2008 (but remained below EU average levels). The Nitrates Directive is estimated to have played an important role in reducing the use of synthetic fertilisers since 1991.
	Other fertiliser per cropland area	– 12 %	+ 8 %	– 4	2	France (decreased use of nitrogen fixing crops), Poland and Romania (reduced application of crop residues) were mainly responsible for the decreased application of other fertiliser types. Here again, the Nitrates Directive may have contributed to the trend observed in the 1990s.
Amount of N_2O per fertiliser	N_2O emissions per fertiliser applied	+ 2 %	+ 1 %	3	14	Ammonia policies — such as in the Netherlands in the early 1990s — led to a shift from the surface spreading of manure to the incorporation of manure into soil, which reduced ammonia volatilisation but increased N_2O emissions.

Source: Own calculations, based on EEA, 2010a.

5.5 Indicative list of relevant legislative texts

Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources (OJ L 375, 31.12.1991, p. 1–8) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31991L0676:EN:NOT).

Council Regulation (EEC) No 1765/92 of 30 June 1992 establishing a support system for producers of certain arable crops (OJ L 181, 1.7.1992, p. 12–20) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31992R1765:EN:NOT).

Council Regulation (EEC) No 3950/92, of 28 December 1992, establishing an additional levy in the milk and milk products sector (OJ L 405, 31.12.1992, p. 1–5) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31992R3950:EN:NOT).

Communication from the Commission to the Council and the European Parliament — Agenda 2000 — Vol. I: For a stronger and wider Union — Vol. II: The challenge of enlargement, COM(97) 2000. (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:51997DC2000:EN:NOT).

Communication from the Commission to the Council and the European Parliament — Proposals for Council Regulations (EC) concerning the reform of the common agricultural policy, COM(1998) 158 final. (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:1998:0158:FIN:en:PDF).

Council Regulation (EC) No 1251/1999 of 17 May 1999 establishing a support system for producers of certain arable crops (OJ L 160, 26.6.1999, p. 1–14) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31999R1251:en:NOT).

Council Regulation (EC) No 1252/1999 of 17 May 1999 amending Regulation (EC) No 1868/94 establishing a quota system for the production of potato starch (OJ L 160, 26.6.1999, p. 15–17) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31999R1252:en:NOT).

Council Regulation (EC) No 1253/1999 of 17 May 1999 amending Regulation (EEC) No 1766/92 on the common organisation of the market of cereals and repealing Regulation (EEC) No 2731/75 fixing standard qualities for common wheat, rye, barley, maize and durum wheat (OJ L 160, 26.6.1999, p. 18–20) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31999R1253:en:NOT).

Council Regulation (EC) No 1254/1999 of 17 May 1999 on the common organisation of the market in beef and veal (OJ L 160, 26.6.1999, p. 21–47) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31999R1254:EN:NOT)

Council Regulation (EC) No 1255/1999 on the common organisation of the market in milk and milk products (OJ L 160, 26.6.1999, p. 48–72) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31999R1255:EN:NOT).

Council Regulation (EC) No 1256/1999 of 17 May 1999 amending Regulation (EEC) No 3950/92 establishing an additional levy in the milk and milk products sector (OJ L 160, 26.6.1999, p. 73–79) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31999R1256:EN:NOT).

Council Regulation (EC) No 1259/1999 of 17 May 1999 establishing common rules for direct support schemes under the common agricultural policy (OJ L 160, 26.6.1999, p. 113–118) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31999R1259:en:NOT).

Council Regulation (EC) No 1782/2003 of 29 September 2003 establishing common rules for direct support schemes under the common agricultural policy and establishing certain support schemes for farmers and amending Regulations. (EEC) No 2019/93, (EC) No 1452/2001, (EC) No 1453/2001, (EC) No 1454/2001, (EC). 1868/94, (EC) No 1251/1999, (EC) No 1254/1999, (EC) No 1673/2000, (EEC) No 2358/71 and. (EC) No 2529/2001 (OJ L 270, 21.10.2003, p. 1–69) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32003R1782:EN:NOT).

Council Regulation (EC) No 1234/2007 of 22 October 2007 establishing a common organisation of agricultural markets and on specific provisions for certain agricultural products (Single CMO Regulation) (OJ L 299, 16.11.2007, p. 1–149) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32007R1234:EN:NOT).

6 Waste

Summary

EU-27 GHG emissions from waste experienced the largest decrease in relative terms (– 30 %) among the main GHG-emitting sectors between 1990 and 2008. They accounted for 3 % of total GHG emissions in 2008 (this does not include emissions from waste incineration with energy recovery, which are reported under the energy sector). A total of 75 % of GHG emissions from waste (mainly CH_4) arise during **solid waste disposal on land**. These emissions decreased by 35 % between 1990 and 2008. Intensified separate collection, recycling and pretreatment of waste as well as landfill gas recovery were the major reasons for the strong decline. The Landfill Directive has exerted an important influence on these GHG drivers. The recovery of CH_4 from landfills played the most important role in reducing emissions from solid waste management between 1990 and 2008. The existence of national policies at Member State level contributed to important emission reductions prior to adoption of the Landfill Directive. The directive has furthered this trend since its entry into force in 1999.

6.1 Emission trend

Emissions from waste accounted for 3.0 % of total GHG emission in 2008. It is the sector where emissions have decreased most (– 33 %) (Figure 6.1). As CO_2 emissions deriving from biogenic waste are not accounted under this sector according to the IPCC classification, methane (CH_4) emissions are dominating the emission trend; N_2O emissions resulting mainly from waste water treatment contribute less to the overall GHG emissions than CH_4 emissions from solid waste disposal.

The sector waste includes GHG emissions from a number of areas.

- Solid waste disposal (CRF 6A), which contributed with 77 % to total waste emissions in 2008, and decreased strongly by 35 % between 1990 and 2008. In this category, CH_4 from anaerobic microbial decomposition of organic matter in solid waste disposal sites (managed and unmanaged landfill sites) is accounted for. CO_2 is also produced but only CO_2 from non-biogenic waste is included.

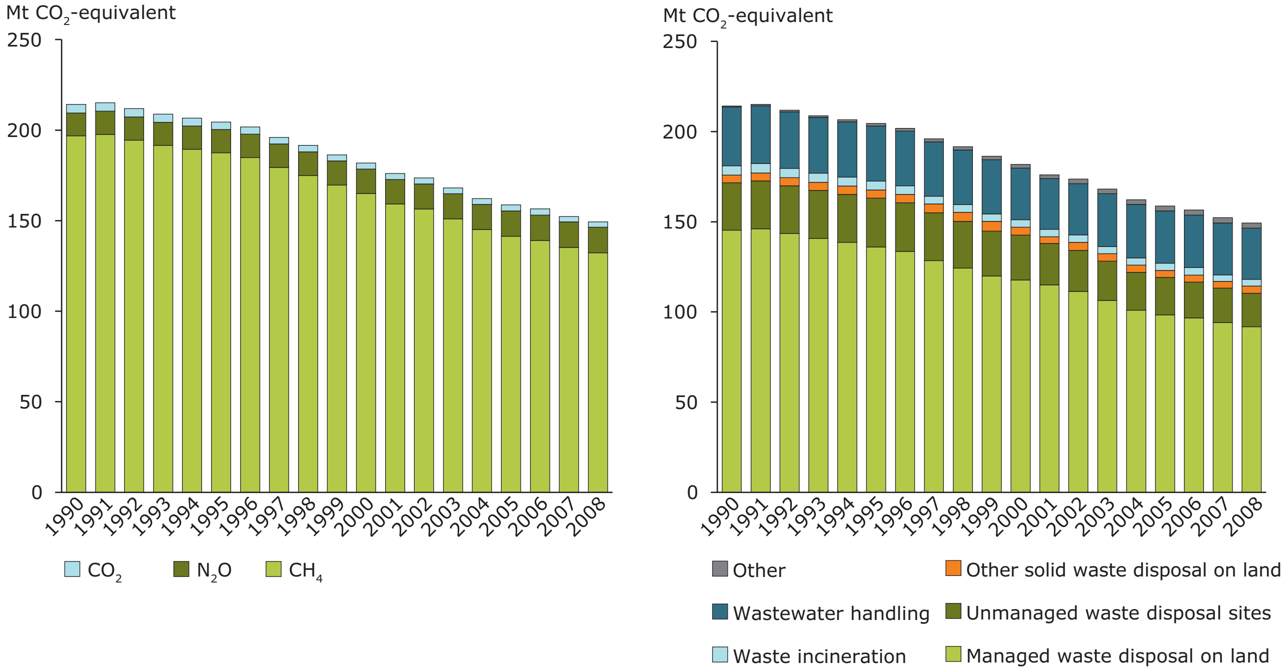
- Waste water treatment (CRF 6B), which contributed with 19 % to total waste emissions in 2008, and decreased by 13 % between 1990 and 2008. This includes CH_4 and N_2O produced during decomposition of organic matter by bacteria in sewage facilities (waste water treatment plants) and septic tanks, and from food processing and other industrial facilities in the course of waste water handling.

- Waste incineration (excluding waste-to-energy facilities) (CRF 6C), which contributed with only 2 % to total waste emissions in 2008, and decreased by 29 % between 1990 and 2008. Emissions from waste burnt with energy recovery are reported under the Energy sector (1A), but all non-CO_2 GHG gases from incineration are reported under sector 6C as well as CO_2 from non-biogenic waste.

- Other waste treatment (CRF 6D), includes other waste handling activities such as biological treatment (composting, mechanical-biological treatment) of biogenic waste.

The largest decreases occurred in Belgium, Germany, the Netherlands and the United Kingdom (Figure 6.2). The decreasing trend in the EU-27 is mainly attributable to the EU-15 Member States, whereas emissions in the EU-12 have not changed much between 1990 and 2008. In most countries, the decreases achieved during the 8-year period 2000–2008 were larger than in the 10 previous years (1990–2000).

Figure 6.1 GHG emissions from the waste sector per subsector and per gas, 1990–2008



Note: The sectors presented here correspond to the following CRF categories: Solid waste disposal: 6A; Waste water treatment: 6B; Waste incineration: 6C, Other waste treatment: 6D; Emissions from waste burnt with energy recovery are reported under the Energy sector (1A).

Source: EEA, 2011.

6.2 Effects of drivers on CH_4 emissions from municipal solid waste management

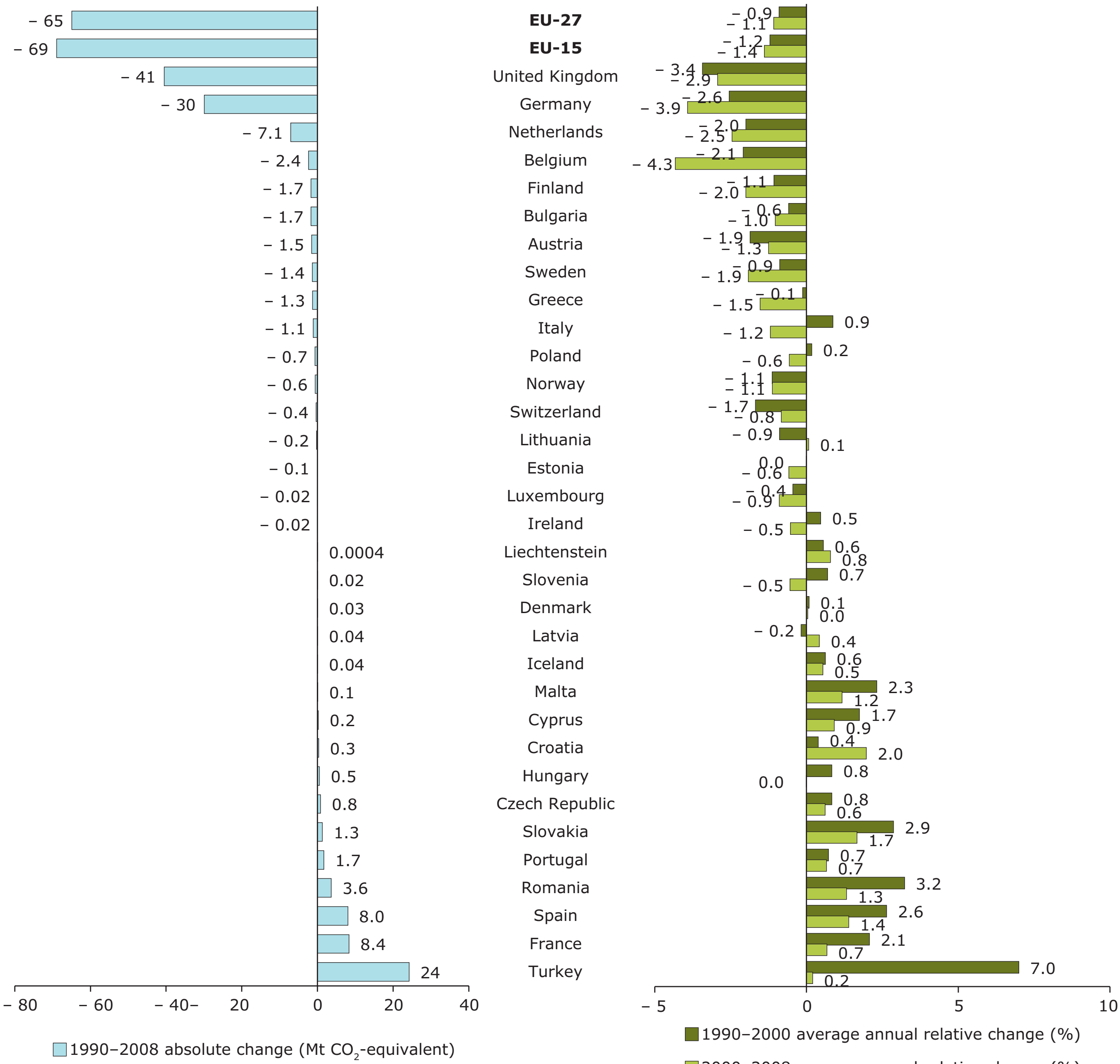
This analysis focuses on CH_4 emissions from the disposal on land of municipal solid waste. The total amount of solid waste disposed on land cover 77 % of total GHG emissions from the waste sector. Emissions from the incineration of solid waste with energy recovery are not accounted for, as they are reported under the energy supply sector. Furthermore, although municipal solid waste contributes only around 9 % to total solid waste, it has a high relevance for GHG emissions due to its high content of biodegradable carbon. Besides, the available data for other waste types does not allow for a trend analysis. Consistent data sets for the period 1990 to 1994 are not available; therefore the decomposition analysis could only be carried out for the years 1995–2008.

Municipal solid waste consists of waste collected by or on behalf of municipal authorities and disposed of through the waste management system. The bulk of this waste stream is from households, though similar wastes from sources such as commerce, offices and public institutions are included.

Five relevant factors were identified to affect CH_4 emissions from MSW landfilling. These factors are presented in (Table 6.1). The decomposition analysis interlinks these factors to six emission drivers (Table 6.1, Figure 6.3).

The amount of municipal waste generated increased faster than the population of the EU-27, especially between 1995 and 2000. This can partly be explained by higher incomes and increased lifestyle leading to more consumption — and consequently more waste generation — per capita. Yet, emissions from solid waste disposal decreased, due to an overall improvement of municipal solid waste management practices across the EU: intensified separate collection, recycling and pre-treatment of waste. As the amounts of waste incinerated, treated in mechanical-biological treatment plants, composted or recycled increased, less waste was directly disposed of and consequently less CH_4 was emitted. Moreover, the total organic carbon (TOC) content of the waste disposed decreased due to these pre-treatment operations. The increasing collection of CH_4 arising from disposal sites (landfill gas recovery), for energy purposes for example, provided further reductions.

Figure 6.2 Absolute change and average annual relative change of GHG emissions from waste in the EU, 1990–2008



Note: Countries sorted according to absolute change between 1990 and 2008.
Average annual relative change (%) = (last year/base year)$^{(1/\text{number of years})}$ – 1.

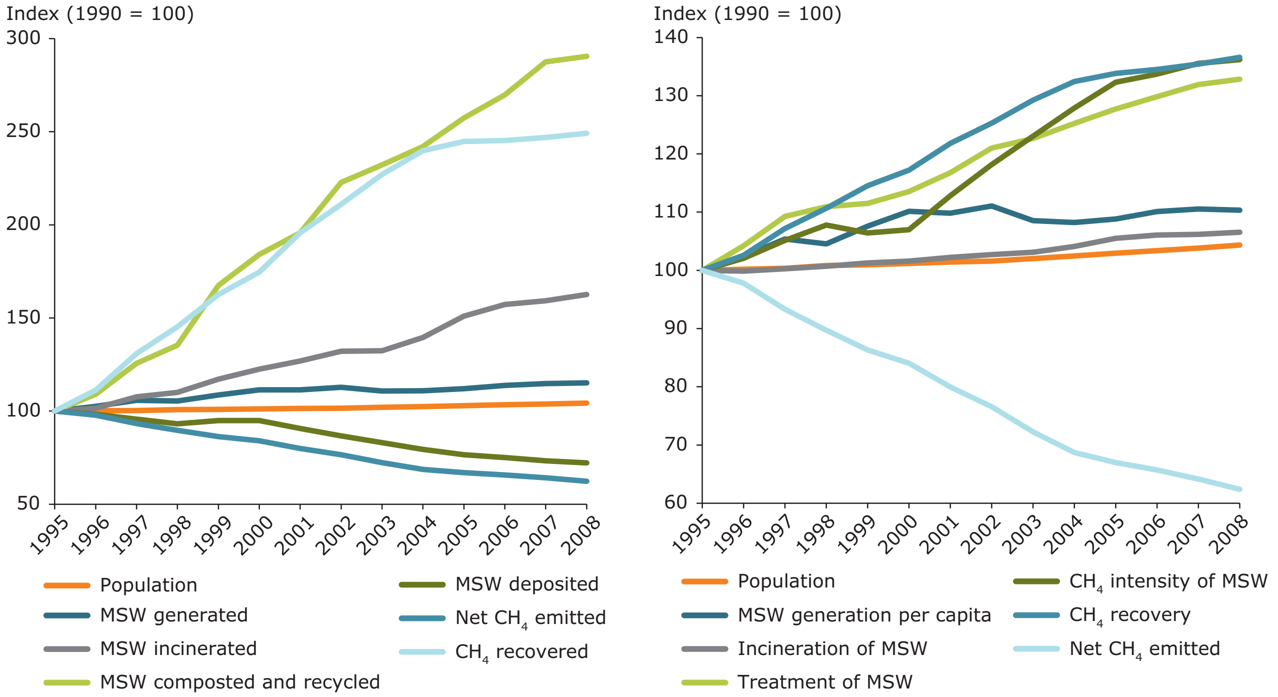
Source: EEA, 2011.

The recovery of CH_4 at the disposal sites and the treatment of waste both increased significantly since 1995. Increased waste treatment and increased use of waste as an energy source had the largest impact in decreasing emissions (Figure 6.5). Besides the slight increase in the share of MSW incineration between 1995, 2008 (from 15 % to 20 %), the share of MSW recycled and composted more than doubled, which was the main factor behind the significant reduction in the share of MSW landfilled (Figure 6.4). The majority of MSW incineration is now carried out with energy recovery, the emission reductions taking place in the waste sector also resulted in parallel in emission increases in the energy supply sector (although from a life cycle perspective, this can be considered as a substitution of fossil fuels, which overall reduces total emissions).

Table 6.1 Identification of drivers influencing CH_4 emission from municipal solid waste disposal

Drivers influencing emissions	Description	Input of factors to decomposition analysis	Unit
Population	The quantity of waste generated is directly dependent on population.	Population	heads
MSW per capita	Amount of MSW generated per capita, including household waste, waste from institutional/commercial institutions and litter from streets and parks.	MSW generated/ Population	kt/head
Share of MSW incinerated with energy recovery	Waste can be used as an energy source (incineration with energy recovery). In that case, emissions are not allocated to the waste sector: GHG emissions from the combustion of non-biogenic waste are accounted for under the sector 'public electricity and heat production', while biogenic waste emissions are considered as carbon neutral. In case the energy produced from municipal waste replaces a fossil fuel power plant, total emissions (across the energy and waste sectors) will decline, because 50 % of the energy content of municipal solid waste is of biogenic origin.	MSW generated excluding MSW incinerated/MSW generated = 1 – share of MSW incinerated with energy recovery	kt/kt
Share of MSW landfilled in MSW not incinerated with energy recovery	Apart from incineration with energy recovery, waste can be landfilled (solid waste disposal sites) — which may emit CH_4 — or undergo other types of treatment: pre-treatment (e.g. mechanical-biological), recycling or composting.	MSW landfilled/MSW generated excluding MSW incinerated	kt/kt
CH_4 intensity of landfills	CH_4 is generated from degradation of waste. This process spans over several years. The amount of CH_4 emitted depends on the composition of the waste landfilled.	CH_4 generated/MSW landfilled	Mt/kt
CH_4 recovery in landfills	The installation of CH_4 recovery systems allows for burning of CH_4 (global warming potential (GWP) equal to 21 or more) and transforming it into CO_2 (GWP equal to 1), with or without energy recovery.	CH_4 emitted/CH_4 generated = 1 – CH_4 recovery	Mt/Mt

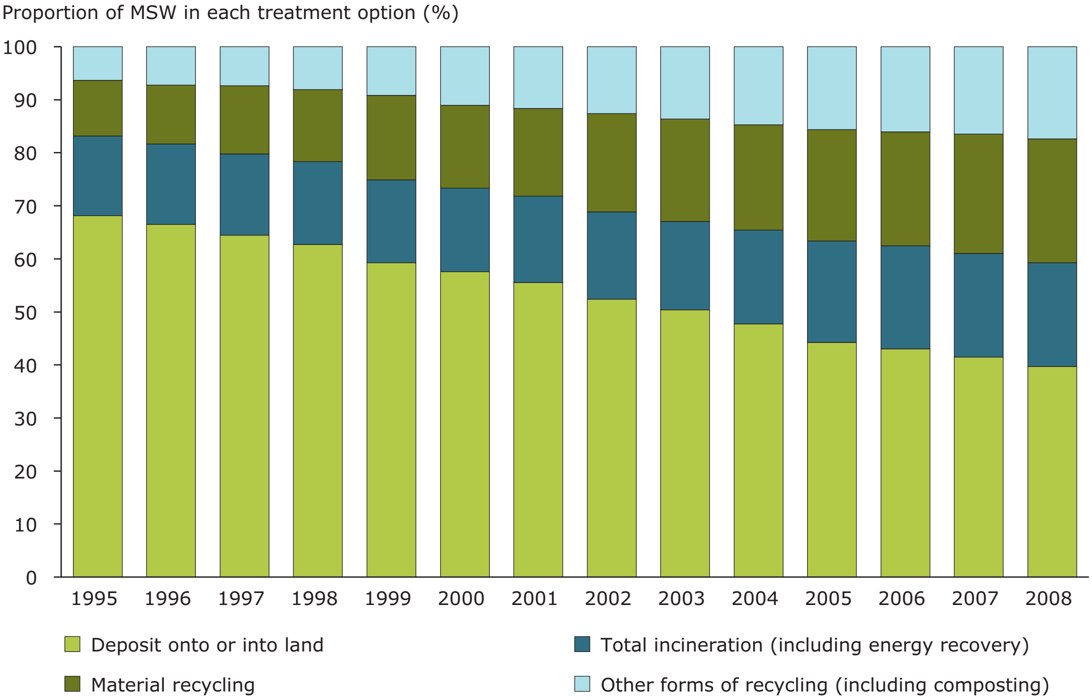
Figure 6.3 Drivers of CH_4 emissions from municipal solid waste in the EU, 1995–2008



Note: Figure does not include data before 1995, as consistent data sets for the time 1990 to 1995 are not available for all Member States.
MSW deposited = MSW generated – MSW incinerated – MSW recycled and composted
Data for MSW generated, MSW incinerated and MSW recycled and composted are from national GHG inventory submissions and other data are from Eurostat, 2010.

Source: EEA, 2010a; Eurostat, 2011a.

Figure 6.4 MSW treatment in the EU-27



Source: Eurostat, 2011a.

The observed increase in CH_4 intensity (CH_4 emitted per MSW disposed) drove emissions upward, due to the degradation process of waste, responsible for a delay between the moment biodegradable waste is landfilled and the moment CH_4 is emitted (not all potential CH_4 is released in the year the waste is disposed of). Therefore, although landfilled waste quantities decrease, CH_4 emission may still increase for a certain period due to previously higher waste quantities landfilled.

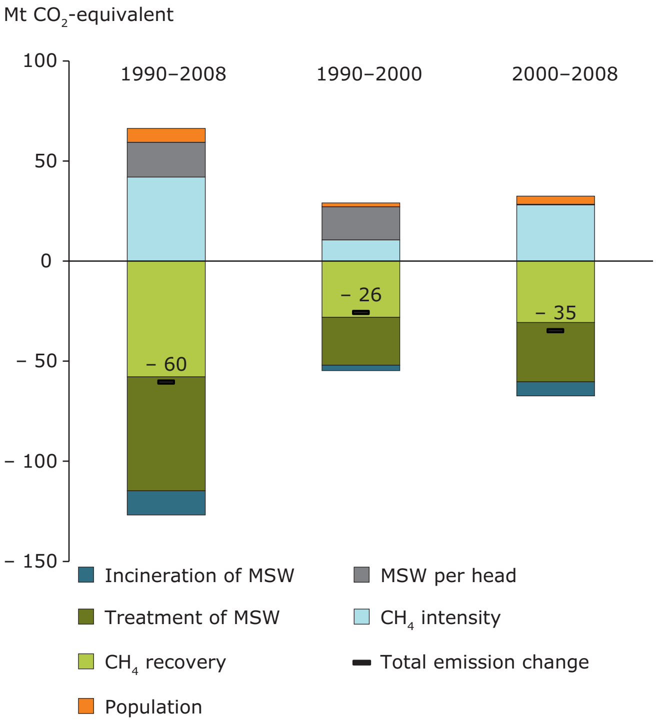
The decomposition analysis does not make directly apparent the decrease in biodegradable content of MSW resulting from improved waste recovery and pre-treatment, which results in less CH_4 emissions from landfills. It is in fact indirectly expressed in the increasing (pre-) treatment of MSW, which has the objective of minimising the amount of MSW and reducing the carbon content in waste before being landfilled.

Overall, the reduction in CH_4 emissions was larger during the 2000–2008 period than during the 1995–2000 period. This was mainly due to the stabilisation of MSW generation per capita.

The overall emission decrease in the EU-27 (– 2.9 Mt CO_2 equivalents between 1995 and 2008, see Figure 6.5) was mainly driven by developments in Bulgaria, Germany, the Netherlands and the United Kingdom, where the largest absolute decreases in emissions from waste were observed between 1995 and 2008. Spain showed the highest absolute increase between 1995 and 2008, followed by Romania and Portugal.

- In Germany, emissions decreased steadily until 2005, partly due to an increase of CH_4 recovery. Facilities for gas collection were installed on almost all landfill sites and the collected landfill gas increased continuously since 1995. At the same time, the generation of landfill gas decreased, thus the collected gas volumes were also reduced for several years (EEA, 2010). Germany's reductions can further be attributed to increased composting and recycling of MSW. It is also one of the few countries where the generation of MSW has decreased. CH_4 intensity of landfilled waste was a strong increasing factor, as the disposal of MSW almost stopped, whereas emissions are still arising due to the degradation process over time. Since June 2005, MSW in Germany has to be pre-treated by incineration or mechanical biological treatment before being disposed of in a landfill.

Figure 6.5 Decomposition analysis of CH_4 emission trends from solid waste management in the EU, 1990–2008



Note: Each bar shows the contribution of a single driver on GHG emission trends during a determined period. The thick short black lines indicate the combined effect of all emission drivers, i.e. the overall GHG emission trend during the period considered.

Source: Own calculations, based on EEA, 2010a; Eurostat, 2011a.

- In the United Kingdom the decrease can be attributed to increased treatment of MSW (composting and recycling) and installation of CH_4 recovery systems, which reached a maximum in 2005. The picture for emission intensity is similar to Germany.
- In the Netherlands the strong increase in recycling (93 % between 1995 and 2008) is mostly responsible for the strong decrease in emissions from solid waste disposal.
- In Bulgaria the main reason is the decrease in MSW generation by 39 % between 1995 and 2008, although some of this might be explained by uncertainty in the data, especially in the 1990s. In particular, the decrease might partly be explained by the introduction of weighting stations at the landfills whereas before, the waste amounts were estimated.
- In Spain the main reasons for increasing emissions were an increased waste generation and disposal (although a decrease was observed after 2003) and therefore higher emission intensity.
- In Romania, the low rate of composting and recycling was reflected in rising trends.
- In Portugal, rising waste generation and emission intensity explain the increasing emissions, although the rate of increase in emission intensity was reduced to only 1 % between 2007 and 2008, due to elevated biogas flaring in landfills; four new CH_4 recovery systems were established in 2005 and 2007 (EEA, 2010).

6.3 Main EU legislation potentially linked to GHG emissions from the waste sector between 1990 and 2008

Several PAMs adopted at EU level influence GHG emissions from the waste sector, both directly and indirectly (Table 6.2). These policies primarily affect emissions by:

Table 6.2 Link between EU Directives and GHG emission sources

IPCC sector	EU Directive potentially affecting GHG emissions
Solid waste disposal on land (6A)	• Waste Framework Directive (1975) • Packaging and Packaging Waste Directive (1994) • Landfill Directive (1999) • Waste Incineration Directive (2000) • Ecodesign Directive (2005)

- reducing GHG emissions from landfills by placing technical requirements on how they manage and treat waste;
- reducing the pollution caused from the process of waste incineration;
- limiting waste to landfill by placing restrictions on the waste that can be managed at landfill sites;
- promoting the ecodesign of energy-using and energy-related products;
- ensuring the better management of packaging waste through recycling, treatment and incineration;
- providing a framework for reducing the environmental and human health impacts of waste generation and management.

The objectives of these policies and their effects on GHG emission drivers are summarised in Table 6.3.

6.4 Sectoral synthesis

Municipal solid waste disposal on land

CH_4 emissions from MSW management decreased strongly between 1990 and 2008, mostly driven by the increasing diversion of waste away from landfills (for incineration and recycling), combined with better recovery of landfill gas. The share of landfilling in the EU-27 dropped from 68 % in 1995 to 38 % in 2008.

The Landfill Directive played a major role in this development by setting targets on the amount of biodegradable municipal waste going to landfills, forcing municipalities to find alternative, less carbon-intensive treatment solutions, as well as promoting the recovery of landfill gas. This trend was further enhanced by the Packaging and Packaging Waste Directive, which targets on average about 17 % of total municipal waste.

The significant improvements in the recovery of landfill gas (CH_4) may be attributed to national policies in place before the Landfill Directive, but the adoption of the directive contributed to reducing landfill gas emissions in countries without such policies in place (Table 6.4).

Table 6.3 EU policies affecting emissions from the waste sector between 1990 and 2008

EU legislation	Objectives	Impact on identified drivers
Landfill Directive: Directive 99/31/EC on the landfill of waste	Prevent/reduce as far as possible the negative effects on the environment from the landfilling of waste by introducing stringent restrictions on waste that can be landfilled as well as technical requirements for landfills.	The Landfill Directive diverts MSW away from landfills through setting a target on the percentage reduction of biodegradable municipal waste going to landfill. The average annual reduction in the percentage of MSW landfilled between 2001 and 2008 was 27 % higher than between 1995 and 2001, which indicates that the directive accelerated the reduction of the percentage of waste landfilled, although the emission reduction due to the driver 'Treatment of MSW' was also driven by autonomous change. Most of the reduction in landfill of waste prior to 2001 was driven by a small number of Member States. The continued reduction of the proportion of landfill MSW required the imposition of EU level regulation to ensure remaining Member States embarked on a similar trajectory, which it has succeeded in achieving. Incineration is one of the waste management options used to divert waste from landfills. Between 1995 and 2008, the proportion of MSW incinerated increased. The biggest increase took place between 2000 and 2005 in line with the timeline of the Landfill Directive. The directive may therefore have contributed to the increasing rate of incinerated waste. The increase in the MSW incinerated can also be partly attributed to the 2001 RES-E Directive because incineration of biodegradable municipal waste with energy recovery is considered a RES, which contributes to achieving renewable targets. There is no evidence that the Landfill Directive has lessened municipal waste generation.
Waste Framework Directive: Directive 75/442/EEC on waste	This directive establishes a legal framework for the treatment of waste within the Community. It aims to protect the environment and human health through prevention of the harmful effects of waste generation and management.	The directive laid out the framework for waste management in the EU, including key elements regarding prevention, reuse, recycling and recovery of waste, and the sound disposal of waste. Still, the quantity of MSW per capita in the EU-27 has increased from 1995 to 2008. Other non-policy factors, such as GDP per capita, have had a stronger impact on the MSW per capita than the directive.
Packaging and Packaging Waste Directive: Directive 94/62/EC on packaging and packaging waste	Harmonisation of national measures concerning the management of packaging and packaging waste to provide a high level of environmental protection and ensure the functioning of the internal market.	The directive aims to divert packaging waste (which represents up to 17 % of the municipal waste stream) away from landfill through recycling and recovery treatment (including incineration). As a result of targets set in 1994 under this directive, the policy has had time to impact the recycling and recovery of packaging waste within the timeframe of the decomposition analysis up to 2008. By the year 2001, the Member States had to recover a minimum of 50 % of all packaging put on the market and 60 % by 31 December 2008. Recycling and recovery of packaging waste has increased considerably and a significant number of countries met their targets in 2008. In general, the Packaging and Packaging Waste Directive has led to the increase of recycling and recovery of packaging waste, diverting waste from landfill. Due to the relatively small share of packaging waste in municipal waste, the overall effect of the directive on total waste management GHG emissions is somewhat limited.

Table 6.3 EU policies affecting emissions from the waste sector between 1990 and 2008 (cont.)

EU legislation	Objectives	Impact on identified drivers
Waste Incineration Directive: Directive 2000/76/EC on the incineration of waste	Prevent or reduce as far as possible air, water and soil pollution caused by the incineration or co-incineration of waste, as well as the resulting risk to human health. These measures include a prior authorisation requirement for incineration and co-incineration plants, and emission limits for certain pollutants released to air or to water.	Incinerating waste generates less GHG emissions than landfilling, both directly (CO_2 emission instead of CH_4 from decomposition) and indirectly, since the energy generated from the waste combustion in many cases replaces energy that would have otherwise been derived from fossil fuel combustion (this may depend on the comparative conditions, including whether energy recovery is used at landfills). The mass of MSW incinerated has steadily increased for the EU-27, whereas the energy recovered from the incineration process has fluctuated since 2002 after a steep rise in the five years beforehand. However, any emissions from waste incineration are accounted for in the energy sector. Any increase in the share of incinerated waste actually results in a shift of emissions from one sector to another (covered by the EU ETS Directive). The measures associated to the Waste Incineration Directive include emission limits for certain pollutants released into the air or water, but the directive does not target specifically the quantity of waste incinerated. Therefore it did not directly result in GHG reductions between 2000 and 2008.
Ecodesign Directive: Directive 2005/32/EC establishing a framework for the setting of ecodesign requirements for energy-using products	By taking the lifecycle of products into account the directive aims to encourage development of products that create less waste, can be recycled and are made from reused products. This directive has subsequently been repealed by Directive 2009/125/EC, the Energy-related Products (ErP) Directive, which is a recast and increases the scope from energy-using products to energy related products.	This directive provides clear EU-wide rules for ecodesign, aimed at avoiding disparities in regulation amongst individual Member States, which could impede the free movement of products within the internal market. The entire supply chain of products is influenced by this policy, contributing to potential emissions savings from the more efficient production and disposal of products. However, the potential savings from this policy are extremely difficult to estimate as they depend on a plethora of variables, including the original lifecycle emissions of a product, the scale of lifecycle changes and the secondary impacts of new procedures, for example recycling more products may increase energy demand for recycling and therefore impact upon GHG emissions outside the waste category. The specific impact of this directive on waste generation was therefore not possible to assess.

Table 6.4 Changes in drivers influencing GHG emissions from solid waste disposal and effects on emissions, 1995–2008

Group of Drivers	Drivers	Change in driver (%)		Effect on GHG emissions (Mt CO_2- equivalent)		Assessment
		1995–2000	2000–2008	1995–2000	2000–2008	1995–2008
Amount of waste	Population	+ 1 %	+ 3 %	2	4	Between 1995 and 2008 population grew steadily, which drove upward GHG emissions from waste.
	MSW per capita	+ 10 %	+ 0.2 %	16	0	The relative increase in MSW generated was higher than the relative increase in population, which further increased GHG emissions. However the amount of waste per capita stabilised resulting in no further pressure on waste quantities.
	All drivers related to amount of waste			18	4	The increase in the production of waste per capita between 1995 and 2000, combined with increasing population over the whole period, were two drivers of emission increase.
Type of waste treatment	Share of MSW incinerated with energy recovery	+ 10 %	+ 29 %	– 3	– 7	The share of MSW incinerated has been constantly increasing since 1995, thereby reducing the share of waste to be treated or landfilled and driving down CH_4 emissions from landfilled MSW.
	Treatment of MSW other than incineration and landfilling	+ 40 %	+ 40 %	– 24	– 30	The reduction of the carbon content of MSW (in the course of pre-treatment) leads to a reduction in GHG emissions.
	CH_4 recovery of landfills	+ 72 %	+ 47 %	– 28	– 31	The increasing recovery of landfill gas, combined with the decreasing organic fraction in landfilled MSW, resulted in direct reductions of CH_4 emission into the atmosphere.
	CH_4 intensity in landfills	+ 7 %	+ 27 %	11	28	CH_4 per MSW disposed is a factor for increasing GHG emissions due to a time delay in CH_4 emissions. This has occurred as a result of the decrease in landfilled waste quantities and the time shift in the evolution of CH_4 in landfills, as a result of the decay of waste disposed in landfill sites earlier. The Landfill Directive has contributed to a reduction in the amount of MSW landfilled but the emission reduction due to the reduction in the MSW landfilled is felt over a long period of time.

Source: Own calculations, based on EEA, 2010a; Eurostat, 2011a.

6.5 Indicative list of relevant legislative texts

Council Directive 75/442/EEC of 15 July 1975 on waste (OJ L 194, 25.7.1975, p. 39–41) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31975L0442:EN:NOT).

European Parliament and Council Directive 94/62/EC of 20 December 1994 on packaging and packaging waste (OJ L 365, 31.12.1994, p. 10–23) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31994L0062:EN:NOT).

Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste (OJ L 182, 16.7.1999, p. 1–19) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31999L0031:EN:NOT).

Directive 2000/76/EC of the European Parliament and of the Council of 4 December 2000 on the incineration of waste (OJ L 332, 28.12.2000, p. 91–111) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32000L0076:EN:NOT).

Directive 2005/32/EC of the European Parliament and of the Council of 6 July 2005 establishing a framework for the setting of ecodesign requirements for energy-using products and amending Council Directive 92/42/EEC and Directives 96/57/EC and 2000/55/EC of the European Parliament and of the Council (OJ L 191, 22.7.2005, p. 29–58) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32005L0032:EN:NOT).

Directive 2006/12/EC of the European Parliament and of the Council of 5 April 2006 on waste (OJ L 114, 27.4.2006, p. 9–21) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32006L0012:EN:NOT).

7 Energy (excluding transport)

Summary

Production of public electricity and heat

EU-27 GHG emissions from the energy supply sector accounted for 33 % of the total GHG emissions in 2008. Within this sector, the **production of public electricity and heat**, the single greatest source of CO_2 emissions in 2008, contributed 27 % of the total GHG emissions in the EU-27. CO_2 emissions from public electricity and heat production decreased by 9 % between 1990 and 2008. This overall reduction was achieved despite an increasing demand for electricity in the EU during the whole period. It was driven mostly by the closure of inefficient coal-fired power plants in the early 1990s (following the restructuring of eastern Europe economies), a fuel shift from coal and oil to gas and biomass, and an increased share of CHP for heat production. Despite this overall reduction, between 2000 and 2008, CO_2 emissions from the sector increased slightly, by 2 %.

In the EU-15, the implementation of air pollution control measures for large combustion plants (the LCP Directive, later reinforced by the IPPC Directive) produced important co-benefits for GHG emissions by encouraging efficiency improvements and fuel switching to cleaner fuels. These positive developments took place despite the fact that such policies were not specifically designed to reduce GHG emissions. Their effects added to those of specific energy policies promoting energy efficiency. More recently, setting a price signal for carbon emissions through the EU ETS within the EU-27 has now established a foundation for the implementation of further efficiency improvements and fuel switching, under the condition of meaningful carbon prices. The development of renewable energy sources to produce electricity led to important emission reductions, in particular during the 1990s. This occurred because the share of renewables in electricity production actually increased, as opposed to the overall trend in the period from 2000 to 2008 period — despite a strong development in renewable production in absolute terms).

Between 2000 and 2008, the increase in electricity demand was mostly satisfied through increased production from gas-fired thermal power plants. This reduced the effects on total emissions of the relative growth of renewables, in particular biomass and wind, brought down the share of nuclear power in total electricity generation, and led to the observed increase in emissions. However, in certain EU Member States, GHG emissions decreased since 2000, mainly as a result of an increased use of RES. Despite the relative success of policies aiming to improve energy efficiency at consumer level and thereby reduce the overall energy demand (e.g. the Energy Labelling Directive and its subsidiary directives, the Energy Performance of Buildings Directive and the Energy Services Directive), their effects have been masked by the opposed effects of increasing electricity demand.

Manufacturing and construction industry

Energy use, and thus also CO_2 emissions from the EU **manufacturing and construction industry sector,** fell between 1990 and 2008, while the GVA of products and services increased significantly. Most of the 25 % reduction in CO_2 emissions from this sector was achieved between 1990 and 2000, mainly due to energy efficiency improvements and further developments within industry. Part of these improvements actually reflected the closure of energy-intensive industries in eastern Europe in the early 1990s. Fuel shifting from coal to gas has also delivered significant emission reductions. Since 2000, the rising share of biomass and the increased use of power generated from public electricity power plants have also contributed to reducing direct CO_2 emissions from the manufacturing industries sector. As was noted for the public electricity and heat plants, the LCP Directive and, to a lesser extent,

Summary (cont.)

the IPPC Directive resulted indirectly in GHG emission reductions by driving efficiency improvements and further incentivising fuel switching. The EU ETS is also estimated to have driven some efficiency improvements in this sector.

Households

Between 1990 and 2008, CO_2 emissions from **households** in the EU-27 decreased by 11 %. The main reasons for this reduction were a fuel shift for domestic heating from coal and oil to gas in the 1990s coupled with reduced energy demand in households, due to efficiency improvements and improvements in household insulation between 2000 and 2008. Several EU directives have contributed to reducing energy use in the households sector. As in the case of electricity production, the minimum levels of energy taxation set at EU level do not represent a significant enough share of energy prices (in most Member States) to drive consumption levels down. Switching from fossil fuels to public electricity as an energy source, both for the cases of industrial users and households, results in a transfer of the emissions linked to electricity or heat use from these sectors to the energy supply sector. Since 2005, this shift has also resulted in the transfer of emissions to a sector covered by the EU ETS. In opposition, the reduction of electricity demand by households — or any other electricity end user not producing their own electricity — due, for example, to the implementation of energy efficiency measures, results in the freeing up of allowances in the EU ETS. This provides an example of the importance of monitoring the impacts of measures across sectors, including trade-offs and costs as well as policy effectiveness.

7.1 Emission trends from energy supply and use (excluding the transport sector)

7.1.1 *Energy supply*

GHG emissions from the energy supply sector accounted for 33 % of total GHG emissions in 2008. The production of public electricity and heat represented the single greatest source of all CO_2 emissions in the EU in 2008, contributing 27 % to total GHG emissions in the EU-27 (25 % in the EU-15). This activity contributes to 82 % of all GHG emissions from the energy supply sector.

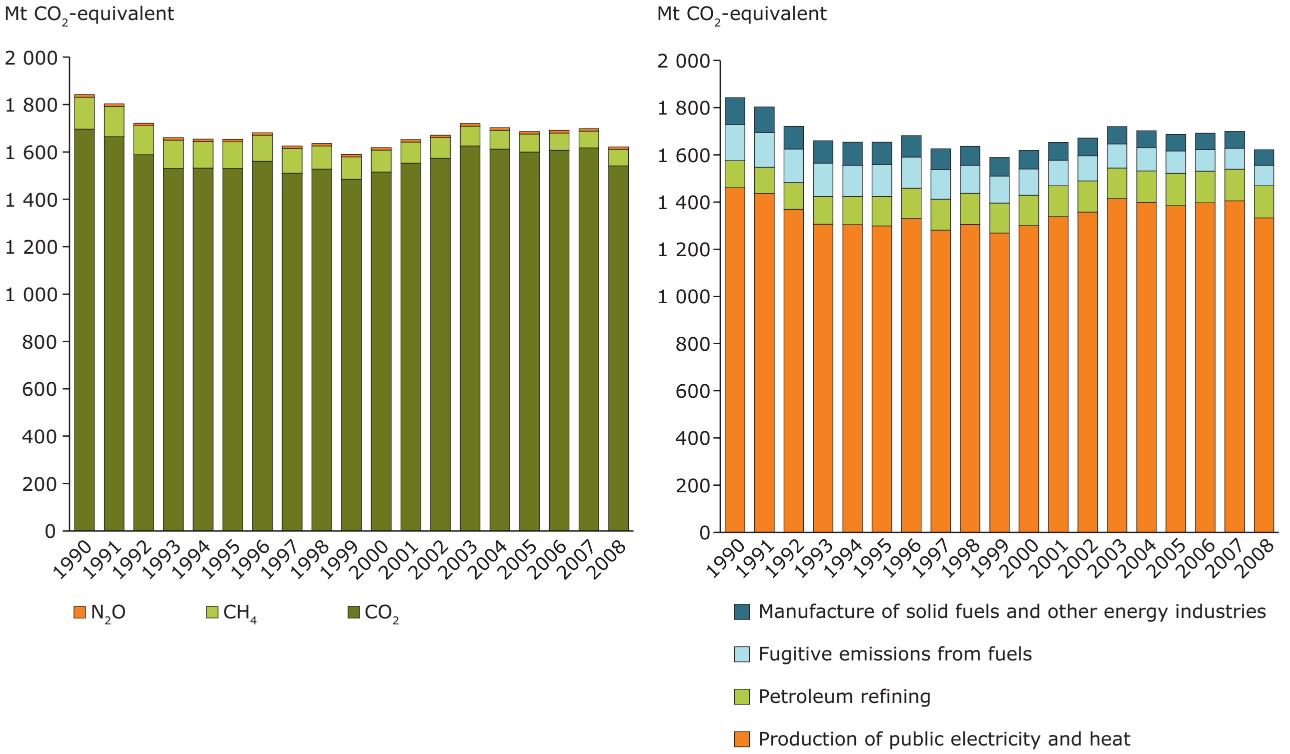
Between 1990 and 2008 emissions from public electricity and heat production decreased by 133 Mt CO_2-equivalent (– 9 %). This decrease occurred mostly in the early 1990s, whilst emissions increased between 1999 and 2008 (Figure 7.1). The decrease was mainly driven by the closure of inefficient coal power plants especially in eastern European countries and a fuel shift from coal to gas. Between 1999 and 2003, emissions increased by 11 %; mainly because of a rising use of brown coal in Germany due to an increased electricity demand of the industry.

Emissions from petroleum refining increased by 15 % between 1990 and 2008 (basically due to increased refining of liquid fuels in Italy and Germany), whereas emissions from the manufacture of solid fuels (e.g. hard coal mining, coking and briquetting plants) decreased by 40 %. Also, fugitive emissions from fuel production and use declined gradually by 45 % between 1990 and 2008. Emissions from energy supply are projected to decrease by 11 % between 2008 and 2015; for the following five years, however, an increase of 8 % is projected.

Compared to 2007, CO_2 emissions from electricity and heat production decreased sharply by 6 % in the EU-27. Spain (– 17 Mt CO_2-equivalent) and Germany (– 19 Mt CO_2-equivalent) contributed most to this decrease, but all other Member States, except Ireland, also reported decreases. In Spain, the main reason was a significant change from coal to gas use for power generation; while in Germany electricity generation by conventional thermal power plants was partly offset by nuclear electricity generation.

Germany, Poland and the United Kingdom account for 54 % of EU-27 emissions from energy supply. In Luxembourg, the remarkable emission decrease of more than 15 % in the 1990s was due to the closure of blast furnace steel production and consequently electricity generation in 1997. In 2002, a gas-driven power station came into operation to reduce dependency on imports which led to an increase of emissions. On the other side, emissions in Latvia

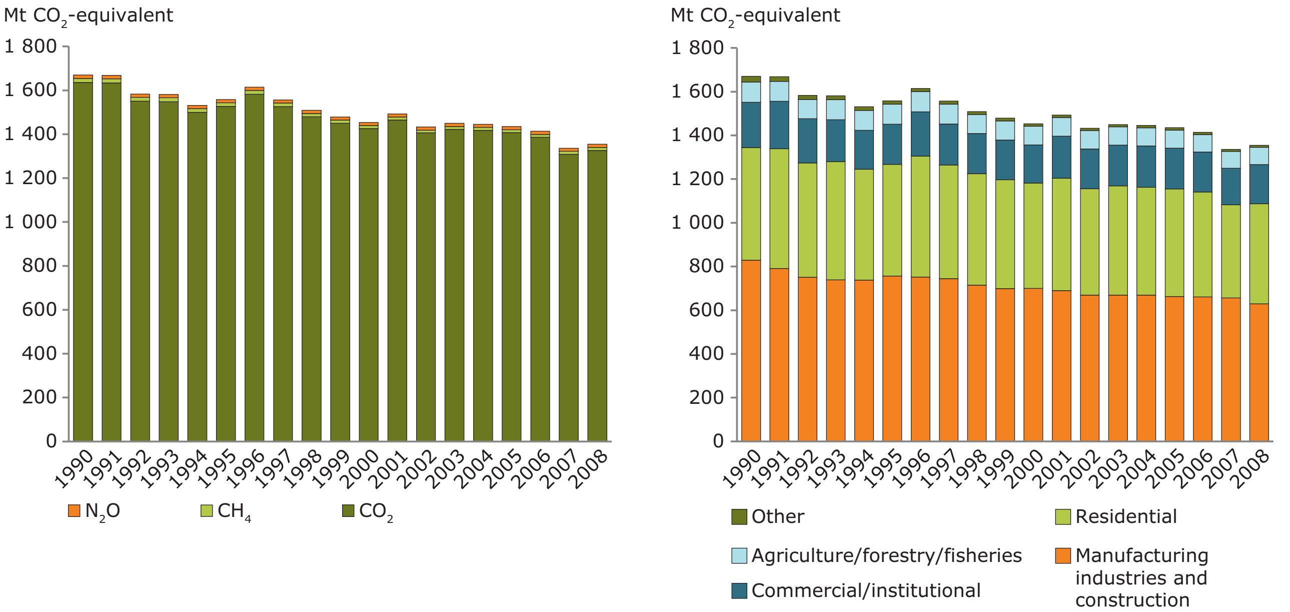
Figure 7.1 GHG emission trends from the energy supply sector per subsector and per gas, 1990–2008



Note: The sectors presented here correspond to the following CRF categories: Public electricity and heat production: 1A1a; Manufacture of solid fuels: 1A1b; Petroleum refining: 1A1c; Fugitive emissions: 1B; Energy supply: 1A1+1B.

Source: EEA, 2011.

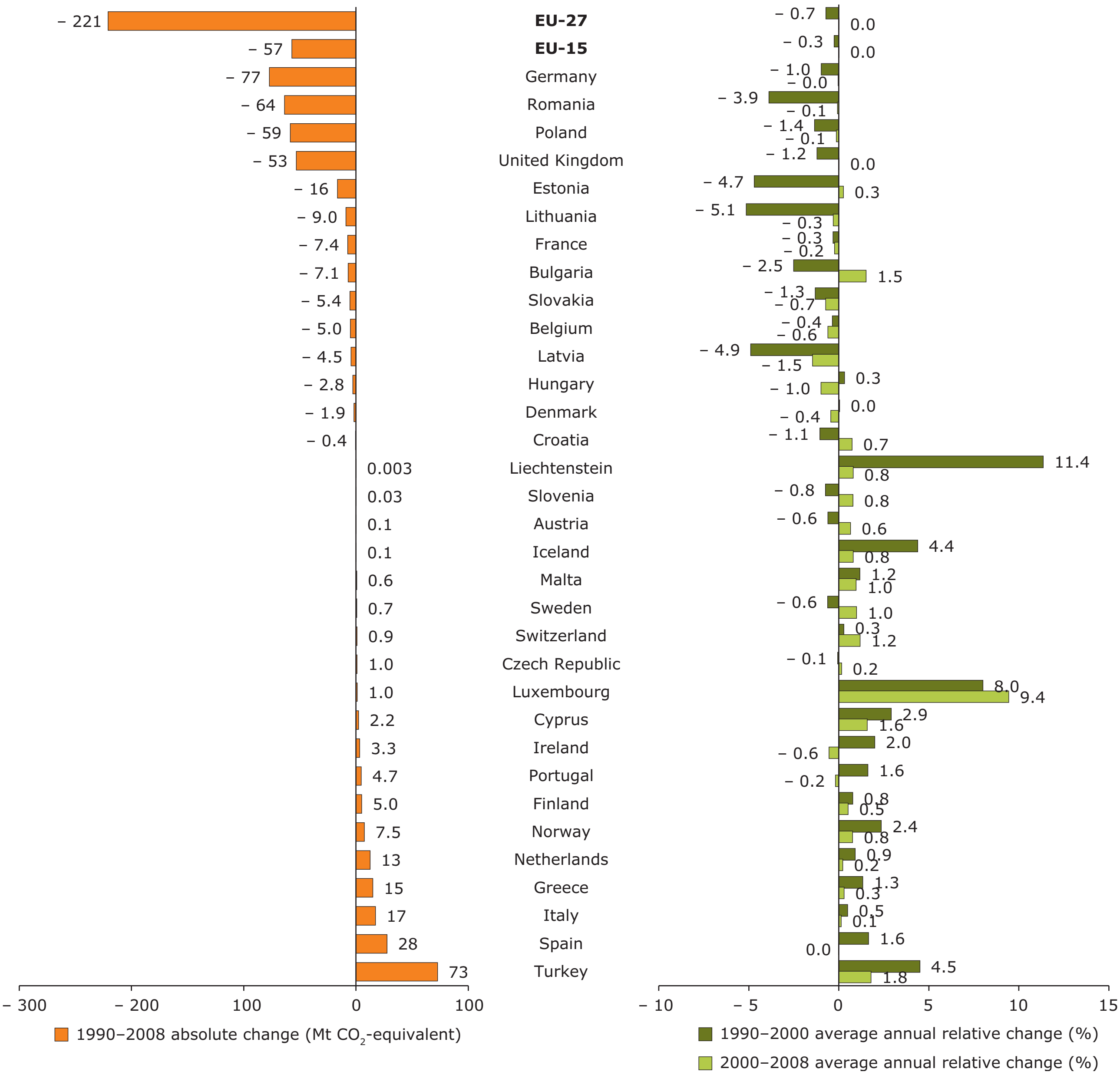
Figure 7.2 GHG emission from energy use per subsector and per gas, 1990–2008



Note: The sectors presented here correspond to the following CRF categories: Manufacturing industries and construction: 1A2; Primary and tertiary sector: 1A4a+1A4c+1A5; Households: 1A4b. Emissions generated from the use of public electricity and heat are not included. These emissions are reported under CRF category 1.A.1a (Public electricity and heat production). See Figure 7.1.

Source: EEA, 2011.

Figure 7.3 Absolute change and average annual relative change of GHG emissions from energy supply in the EU, 1990–2008



Note: Countries sorted according to absolute change between 1990 and 2008.
Average annual relative change (%) = (last year/base year)$^{(1/\text{number of years})}$ – 1.

Source: EEA, 2011.

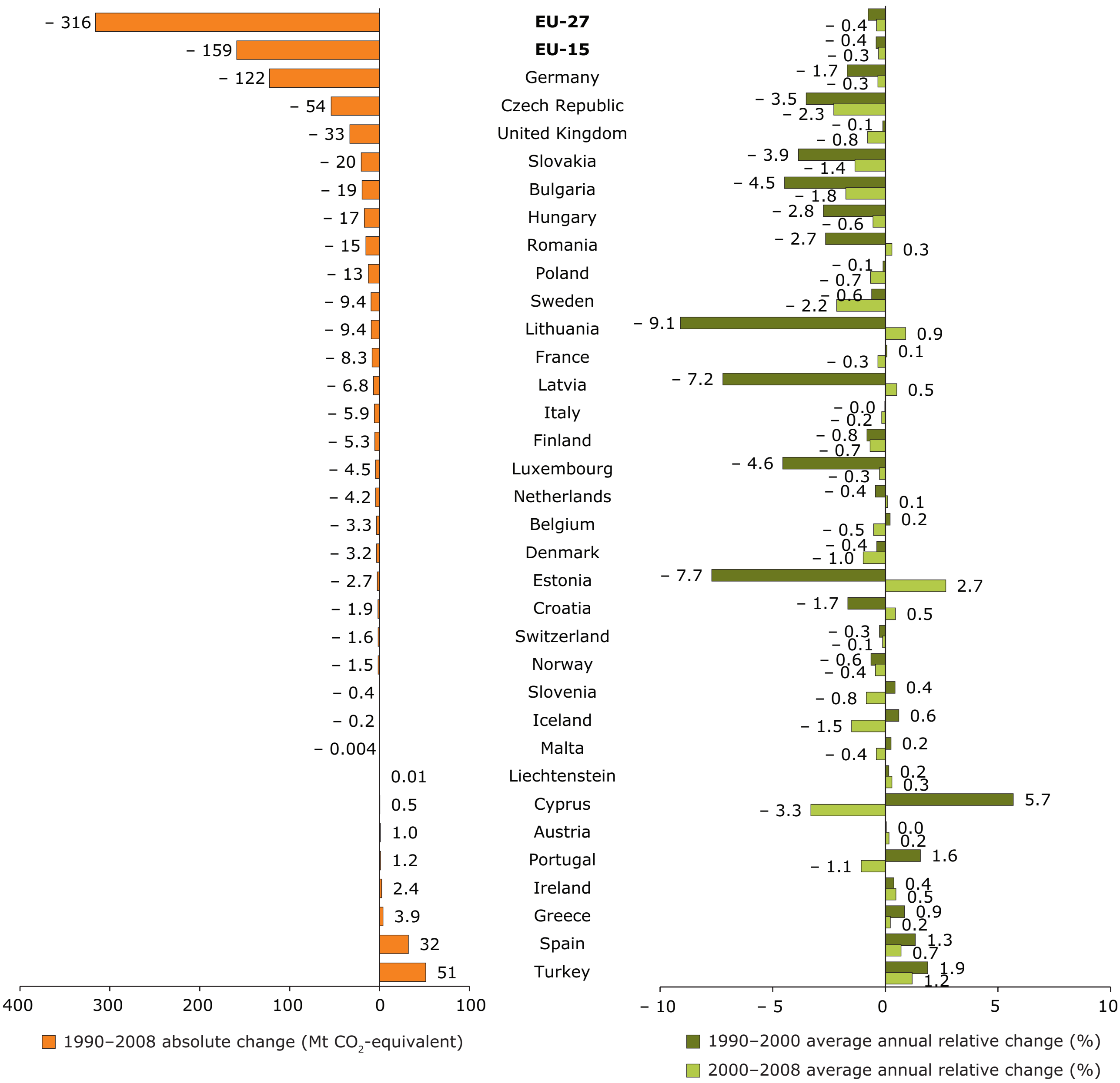
decreased due to the period of economic difficulties in this country in the early 1990s and in Russia (on which Latvia is highly economically dependent) in the late 1990s (Figure 7.3).

7.1.2 *Energy use (direct fuel combustion by industry, households and services)*

Fuels are mainly consumed by manufacturing industries, households, the primary and tertiary sectors and by transport (see Chapter 6). GHG emissions from energy use (excluding transport) accounted for 27 % of total GHG emissions in 2008, whereby the share continually decreased from 30 % in 1990.

EU-27 GHG emissions from energy use (excluding transport) have fallen by 19 % since 1990. Emissions from energy consumption decreased in all subsectors (Figure 7.2).

Figure 7.4 Absolute change and average annual relative change of GHG emissions from energy use (excluding transport) in the EU, 1990–2008



Note: Countries sorted according to absolute change between 1990 and 2008. Average annual relative change (%) = (last year/base year)$^{(1/\text{number of years})}$ – 1.

Source: EEA, 2011.

The sector of 'manufacturing industries and construction' (IPCC sector 1A2) is the third largest key source for CO_2 emissions in the EU-27 accounting for 12 % of total GHG emissions in 2008. The iron and steel industry and the chemical industry represent the largest sources within this sector.

Since 1990 emissions have been constantly decreasing (– 25 %). The primary and tertiary sector decreased by – 18 % since 1990 but increased between 2007 and 2008 (+ 6 %). About 40 % of this increase was due to Germany. Many end consumers did not restock their oil tanks in 2007 because of high outdoor temperatures and rising oil prices. It is assumed that the circumstances were similar for other Member States (e.g. Austria).

In the EU-27, CO_2 emissions resulting from fuel combustion in households (mainly for heating purposes) accounted for 9 % of total GHG emissions in 2008. These emissions have been decreasing since 1990 (– 11 %); between 2007 and 2008, however, a sharp increase (8 %) occurred mainly due to filling up of fuel stocks.

In 2008, Germany (19 %) had the highest share of total GHG emissions from energy use (excluding transport) within the EU-27 followed by the United Kingdom (14 %), France (13 %) and Italy (12 %). Between 2000 and 2008 most Member States reported decreasing emissions (Figure 7.4).

The high decreases in GHG emissions in the 1990s in Estonia, Latvia and Lithuania were mainly caused by economic restructuring during the early 1990s.

7.2 Effects of drivers on GHG emissions from energy supply and use (excluding transport)

This section presents a decomposition analysis for the following three sectors:

- energy supply (public electricity and heat production);
- energy use by manufacturing and construction industries (direct fuel combustion);energy use by households (direct fuel combustion).

7.2.1 Energy supply (public electricity and heat production)

For the decomposition analysis of emission trends in the electricity and heat production sector, eight factors were identified as affecting GHG emissions from the production of public electricity and heat. These factors are related to the amount of electricity consumption and production (including trade of electricity) and the type of electricity generation. Electricity produced in nuclear power plants and from renewable energy sources do not, per definition, cause end-of-pipe GHG emissions. Combined together, these factors result in nine emission drivers. Table 7.1 provides an overview of how factors and drivers are linked in the decomposition analysis.

Figure 7.5 and Figure 7.7 indicate an increasing use of renewables for electricity generation over the period 1990–2008. In 2007, increased installed capacity of wind turbines allowed wind electricity generation to exceed for the first time the electricity generation from biomass. Wind energy has become the largest renewable electricity source at EU-level. Figures 7.6 and 7.7 show the replacement of oil by gas during the same period. Coal use was reduced during the period 1990–2008, but has roughly stagnated since.

Between 1990 and 2008, electricity demand increased by 29 %. This, in combination with the minor effects of a reduced share of electricity generation from autoproducers (mainly France, Italy and Sweden) was the main cause of an important increase in public electricity generation within the EU-27 and was consequently an important driver of CO_2 emissions from the production of public electricity and heat, in particular from thermal power plants.

In the 1990s, the effects of this negative driver were largely offset by the combined effects of efficiency improvements in electricity production (e.g. closure of inefficient coal power plants, in particular in eastern Europe and technological improvements), the development of renewable (and nuclear) electricity generation (Figure 7.8) as well as a fuel switch from coal and oil to gas in thermal power plants. These developments led to an important overall decrease of CO_2 emissions from public electricity and heat production between 1990 and 2000.

However, between 2000 and 2008, the effects of these positive (GHG-reducing) emission drivers (in particular an important development of electricity production from biomass and from CHP) were not sufficient to counteract the combined effects of a continuing rise in electricity demand and of a reduced share of electricity generation from nuclear power plants (mainly in Germany and Spain), which resulted in an increase in CO_2 emissions from public electricity and heat production during that period.

Country analysis

The relative overall increase of biomass used in public power plants was mainly due to Germany. The countries contributing most to the decrease in EU-27 GHG emissions (– 225 Mt) from energy supply between 1990 and 2008 were Germany (– 79 Mt), Romania (– 65 Mt), Poland (– 58 Mt), and the United Kingdom (– 55 Mt). Countries showing the highest increases in emissions from energy supply are Spain (+ 27 Mt), Italy (+ 19 Mt), Greece (+ 15 Mt) and the Netherlands (+ 12 Mt).

The trend in Germany was determined by a shift from fossil fuel to renewable electricity production (including biomass) between 2000 and 2008. Between 1990 and 2008, the share of renewable

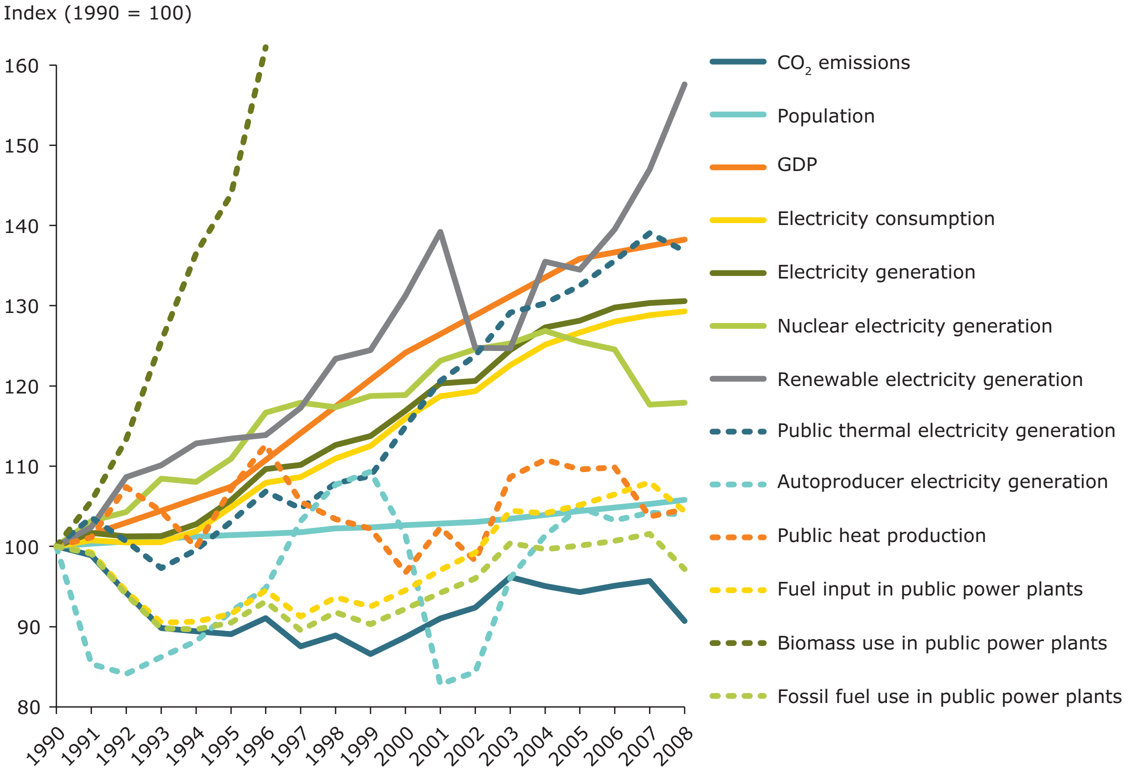
Table 7.1 Identification of drivers influencing CO_2 emissions from the production of public electricity and heat

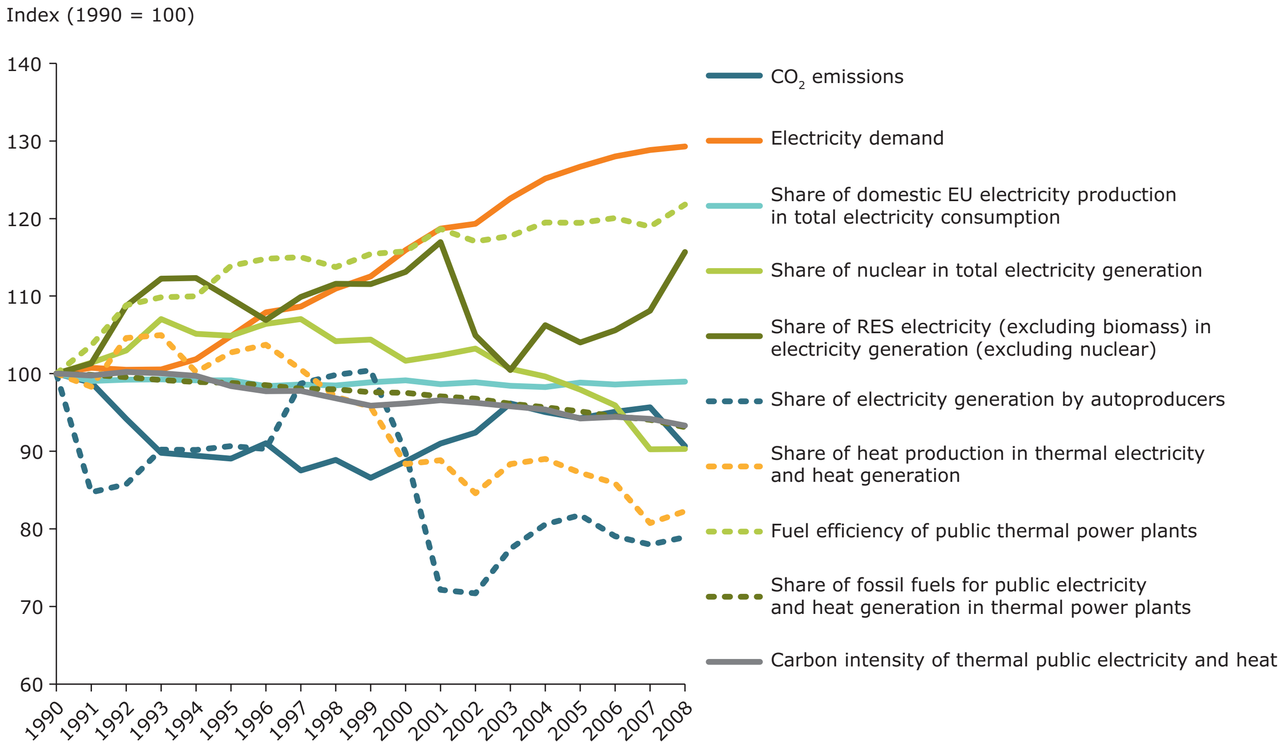
Drivers influencing emissions	Description	Input of factors to decomposition analysis	Unit
Electricity demand	Electricity consumption from all sectors of economy, as well as households. It reflects population and economic growth as well as efficiency improvements.	Electricity consumption	GWh
Share of domestic EU electricity production in total electricity consumption	The amount of electricity generated depends on electricity demand (electricity consumption) as well as imports and exports of electricity. Higher imports reduce the share of domestic electricity production in total consumption, thereby resulting in lower GHG emissions.	Total electricity generation/Electricity consumption = 1 – share of net electricity trade in total electricity consumption (%)	GWh/ GWh
Share of nuclear in total electricity generation	Electricity generated by nuclear power plants does not cause end-of-pipe GHG emissions. A high share of nuclear electricity generation in total electricity generation contributes to reduced GHG emissions reductions.	Electricity generation excluding nuclear/Total electricity generation = 1 – share of nuclear in total electricity generation (%)	GWh/ GWh
Share of RES electricity (excluding biomass ([a]) in electricity generation (excluding nuclear)	Electricity generation from energy sources like geothermal, hydropower, photovoltaic and wind turbines does not cause GHG emissions. A high share of renewable electricity generation in total electricity generation contributes to lower GHG emissions. The use of biomass as a renewable energy source is reflected in the driver 'Share of biomass for public electricity and heat in thermal power plants' (see below).	Thermal electricity generation ([b])/ Electricity generation excluding nuclear = 1 – share of RES electricity (excluding biomass) in electricity generation (excluding nuclear) (%)	GWh/ GWh
Share of electricity generation by autoproducers	In the IPCC nomenclature, emissions from autoproducers are not accounted for under the energy supply sector. An increase in autoproducers' electricity generation means that public electricity generation is decreasing under the condition that electricity demand is constant. Emissions from autoproducers are accounted for in the sector where their electricity is produced in (e.g. manufacturing industries). Consequently, increasing electricity produced by autoproducers only decreases emissions from the energy supply sector, but not necessarily total emissions.	Thermal electricity generation in public thermal power plants/ Thermal electricity generation = 1 – share of electricity generation by autoproducers (%)	GWh/ GWh
Share of heat production in thermal electricity and heat generation	Heat can be generated together with electricity, either by CHP systems or by separate district heating plants. Any increase of CHP is reflected in the trend of the driver 'Fuel efficiency'.	Thermal electricity and heat generation in public power plants/ Thermal electricity generation in public thermal power plants = 1/(1 – share of heat in thermal electricity and heat generation (%))	GWh/ GWh
Fuel efficiency of public thermal power plants	The output of electricity and heat compared to input of fuel to thermal power plants describes the efficiency. A higher input of fuels does not always have to lead to higher emissions, as fuel type, technology and equipment influence fuel efficiency. An increased share of CHP leads to a higher heat output with the same amount of fuel input.	Fuel input to thermal public power plants/Thermal electricity and heat generation in public power plants (%) = 1/fuel efficiency (%)	TJ/GWh
Share of biomass for public electricity and heat in thermal power plants	The use of biomass in public electricity and heating power plants has a decreasing effect on GHG emissions as it reduces the use of fossil fuels. CO_2 emissions resulting from the combustion of biomass are not accounted for as they are considered carbon neutral and a renewable resource.	Fossil fuel input to thermal public power plants/Fuel input to thermal public power plants = 1 – share of biomass for public electricity and heat production in thermal power plants (%)	TJ/TJ
Carbon intensity of thermal public electricity and heat generation	Each type of fossil fuel has a different emission factor (with solid fuels having the highest one). Shifting from coal to oil, to gas, to biomass increasingly reduces emissions.	CO_2 emissions from thermal public electricity and heat generation/Fossil fuel input to thermal public power plants	Mt CO_2/TJ

Note: ([a]) This driver determines the effect of renewable electricity generation in contrast to electricity produced in thermal power plants. The effect of the share of biomass used in thermal power plants is determined separately.

([b]) Including biomass used in thermal power plants.

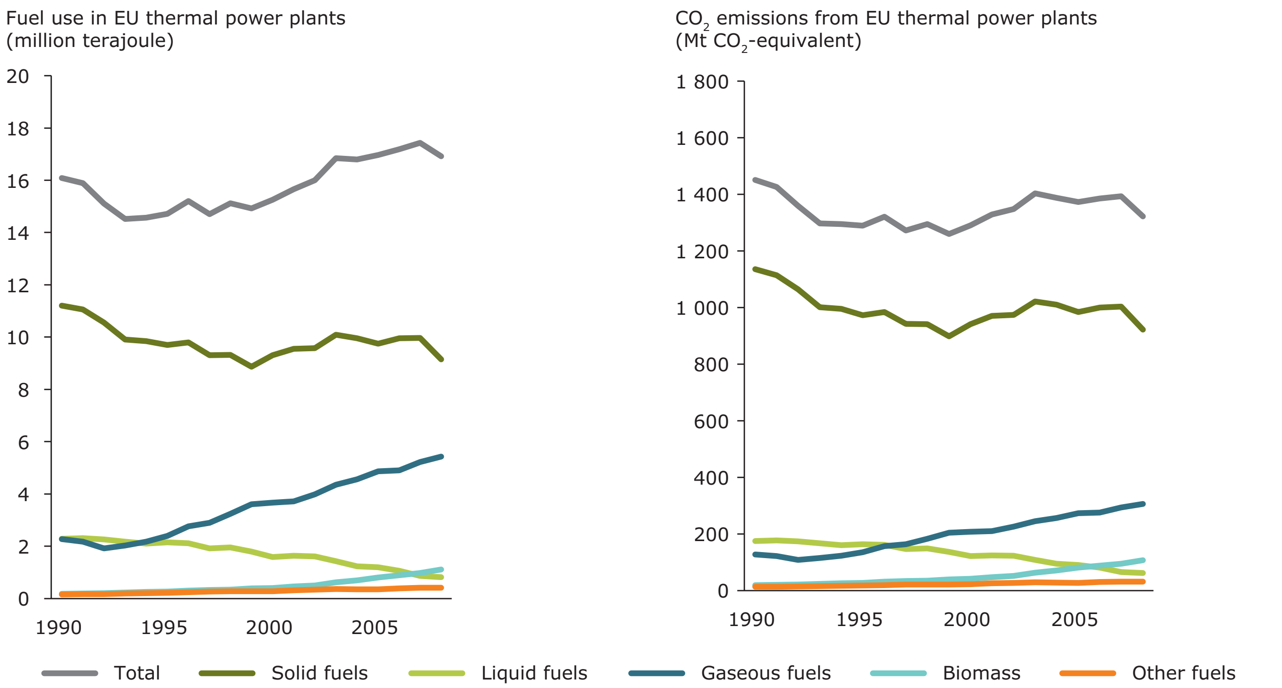
Figure 7.5 Drivers of EU GHG emissions from energy supply, 1990–2008





Source: EEA, 2010a; Eurostat, 2011a.

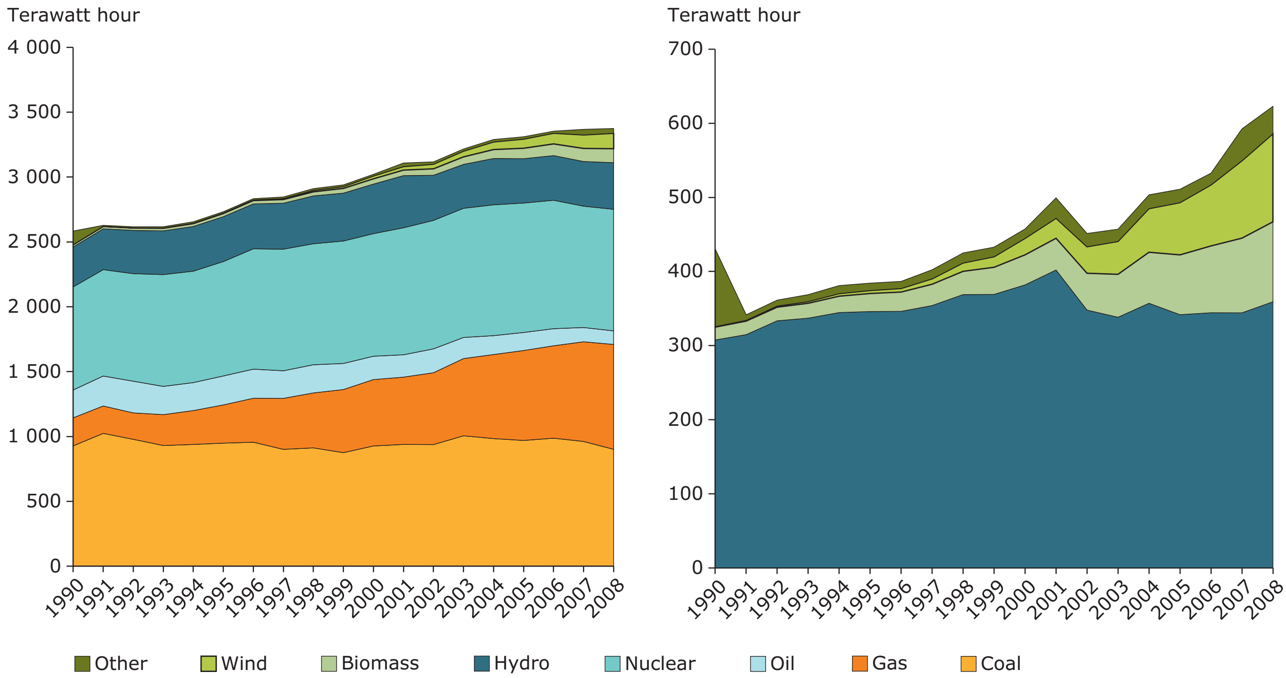
Figure 7.6 Change in the fossil fuel mix in conventional thermal power stations, 1990–2008



Note: The data presented as provided in the EU GHG inventory report. Although biomass emissions are not included in national totals or under the energy sector, they reported as a memorandum item.

Source: EEA, 2011.

Figure 7.7 Gross electricity generation by fuel in the EU

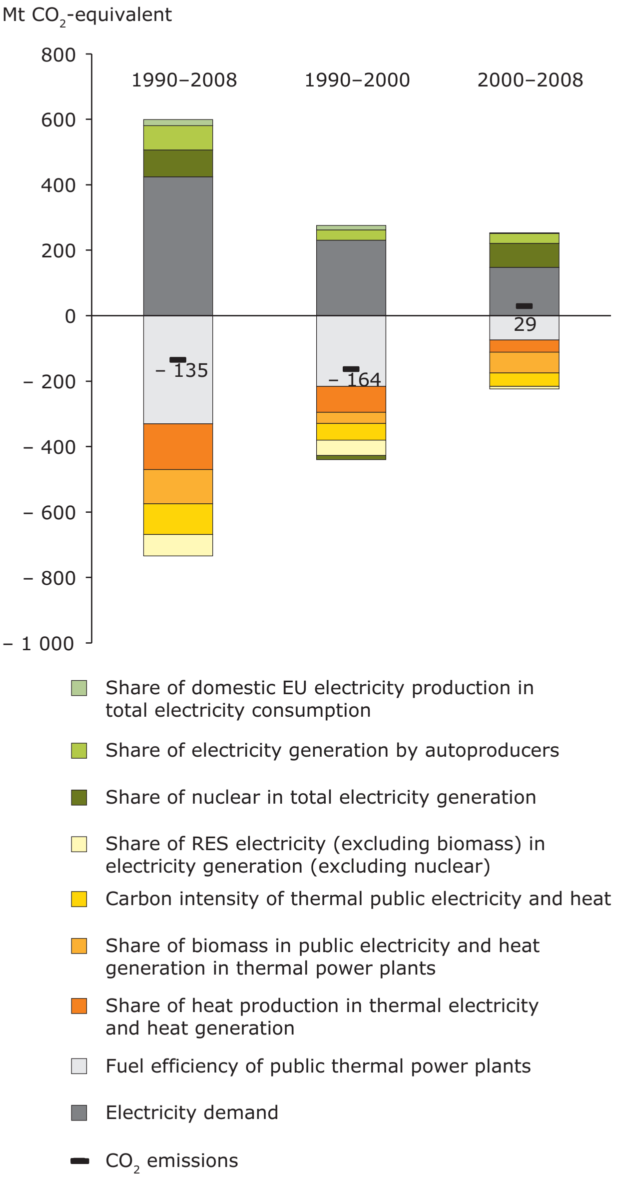


Note: The figure on the right represents a zoom of the figure on the left, for renewable sources only.

Source: EEA, 2010a; Eurostat, 2011a.

energy more than tripled. On the other hand, reduced share of nuclear and autoproducers in total electricity production (– 8 %) were positive drivers of emissions from public thermal power plants.

Figure 7.8 Decomposition analysis of CO_2 emission trends from public electricity and heat production in the EU, 1990–2008



Note: Each bar shows the contribution of a single driver on GHG emission trends during a determined period. The thick short black lines indicate the combined effect of all emission drivers, i.e. the overall GHG emission trend during the period considered.

Source: Own calculations, based on EEA, 2010a; Eurostat, 2011a.

Romania was most successful in improving the energy efficiency of power plants in the EU-27, both in absolute and relative terms. In addition, in 2003/2004 more than 20 % of the district heating plants were closed down, which decreased emissions.

Poland's CO_2 emissions from public electricity and heat production decreased due to efficiency improvements in the 1990s and reductions in heat production both from district heating and CHP. Heat consumption in Poland decreased due to an increase in heat price as a result of withdrawal of state subsidies at the beginning of the 1990s, restructuring of energy intensive industries for reason of market forces, and increased support for energy efficiency investments in buildings, resulting in low heat losses.

In the United Kingdom, emissions decreased mainly due to a shift from solid and liquid fossil fuels to gas and biomass and efficiency improvements. These indicators offset increases in electricity consumption and heat production. After a peak of nuclear power production in the United Kingdom in 1997 (26 % share), a number of stations were closed, leading to an increase of CO_2 emissions from public electricity and heat production between 2000 and 2008.

In Spain and Greece, increasing electricity consumption due to economic growth and increasing living standards was the main driver for the emission increase. Also, Italy increased its emissions due to increased electricity consumption and heat production.

7.2.2 *Energy use (direct fuel combustion by manufacturing and construction industries)*

EU-level analysis

Emissions due to the direct combustion of fuel by manufacturing industries and construction represented 46 % of total CO_2 emissions from energy use (excluding electricity consumption and the transport sector) in 2008.

Four relevant factors were identified for the decomposition analysis (Table 7.2). While GVA has been constantly increasing since 1990, final energy consumption, fuel consumption, fossil fuel consumption and CO_2 emissions were reduced. An overview on how these factors are interlinked in the decomposition analyses to the five drivers influencing the emission trend is shown in Figure 7.9.

Table 7.2 Identification of drivers influencing direct CO_2 emissions from manufacturing and construction industries

Drivers influencing emissions	Description	Input of factors to decomposition analysis	Unit
Gross value added (manufacturing and construction)	Gross value added (GVA) is a key economic indicator to measure the performance of a sector and reflects the level of economic activity of the manufacturing sector. It is strongly linked to GHG emissions. Here, GVA is the value of goods and services produced by the manufacturing and construction sector minus the cost of the raw materials and other inputs used to produce them.	Gross value added of manufacturing and construction sector	EUR million
Energy intensity of manufacturing and construction industries	The energy used to produce industrial goods is a determining factor of emission levels in this sector. A decreasing energy intensity may reflect an improvement in energy efficiency, i.e. less use of energy to produce the same product (constant GVA), or a move to the production of less energy-intensive goods with higher value added.	Final energy consumption/Gross value added	TJ/EUR million
Share of public electricity and district heat in manufacturing industry's energy use	The fuel consumed by manufacturing industrial plants compared to the total final energy consumption describes the share of public electricity and district heat used. The emissions resulting from the production of public electricity and district heat are not accounted for in the industrial sector. Therefore, an increase in this driver results in decreasing emissions from this sector (but it can also result in increasing emissions in the electricity generation sector).	Fuel consumption/Final energy consumption = 1– share of electricity and district heat	TJ/TJ
Share of fossil fuels in direct fuel combustion by manufacturing industry	Biomass is considered here as the main non-fossil fuel source. Its share in the total fuel consumption reflects the level of independence of manufacturing processes from fossil fuels. An increasing share of biomass leads to decreasing emissions.	Fossil fuel consumption/ Fuel consumption = 1 – share of renewables including biomass	TJ/TJ
Carbon intensity of direct fuel combustion by manufacturing and construction industries	The combustion of fossil fuels results in direct GHG emissions. Switching to less carbon-intense fossil fuel (e.g. from coal to gas) drives emissions down.	CO_2 emissions/Fossil fuel consumption	Mt/TJ

The decomposition analysis shows that despite sustained economic activity and performance of the sector, reflected by an increasing GVA, the EU manufacturing industry has significantly reduced its energy use and CO_2 emissions between 1990 and 2008 (Figures 7.9 and 7.12).

Most of the reduction in CO_2 emissions (201 Mt CO_2-equivalent) was achieved between 1990 and 2000, mainly caused by a reduced energy intensity — the consequence of both energy efficiency improvements (Figure 7.11) and a shift of EU industry towards the production of less energy-intensive goods, which includes moving the manufacturing of certain products outside EU — as well as a fuel shift from coal to gas use (Figure 7.10). Since 2000, the rising shares of biomass and public electricity use in energy consumption have also contributed to reduced CO_2 emission from manufacturing industries.

Overall, the emission reductions achieved in the sector between 1990 and 2000 were higher than those observed in the energy supply sector.

Country analysis

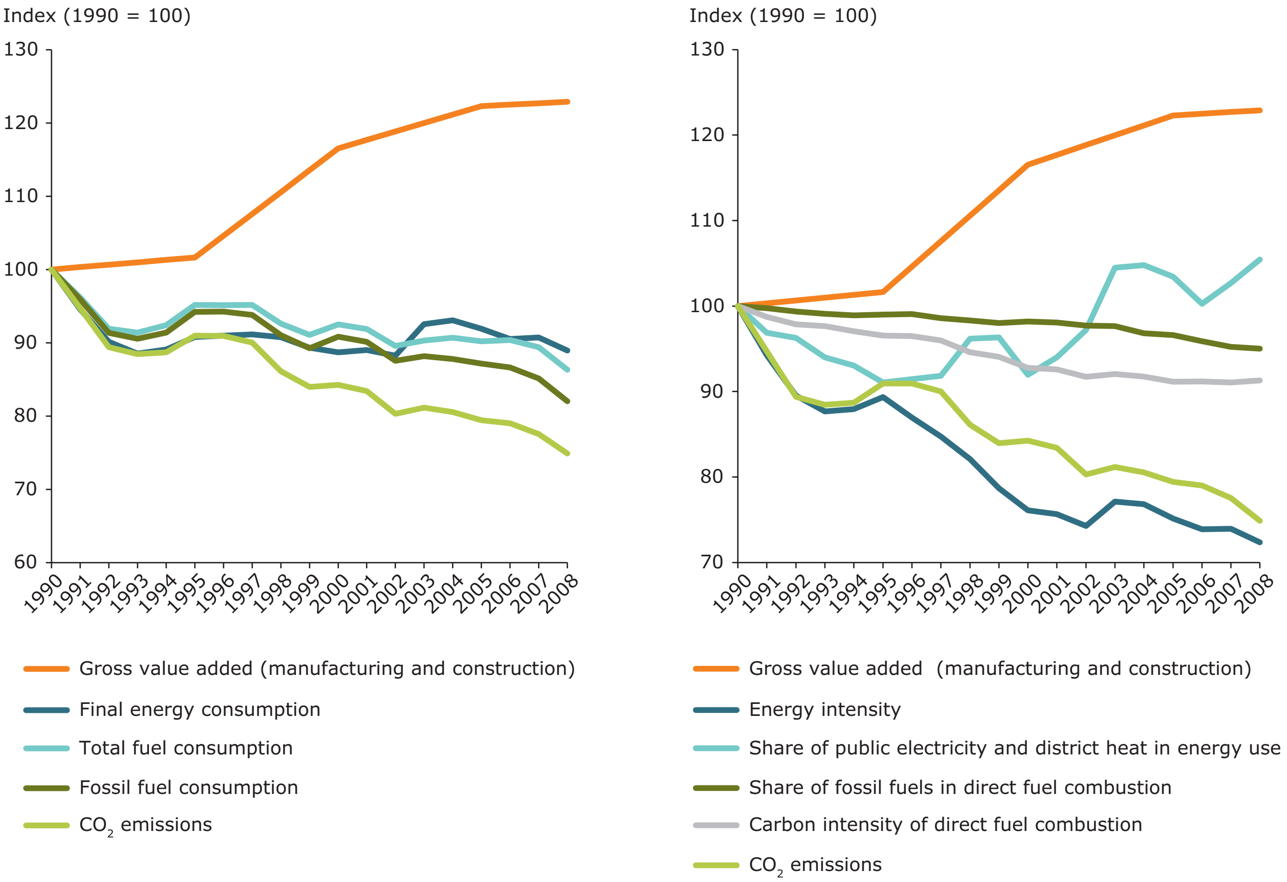
Germany (– 60 Mt CO_2-equivalent), the Czech Republic (– 31 Mt CO_2-equivalent) and the United Kingdom (– 24 Mt CO_2-equivalent) contributed most to the decrease in EU-27 CO_2 emissions from manufacturing industries and construction between 1990 and 2008. The substantial decreases in CO_2 emissions in several new Member States were caused by efficiency improvements due to economic restructuring.

The main reason for the large decline in **Germany** was the restructuring of the industry and efficiency improvements after German reunification.

The **Czech Republic's** CO_2 emissions from manufacturing industries and construction decreased due to economic changes but have remained relatively stable since 2000. The decrease was mainly caused by energy efficiency improvements.

In the **United Kingdom** significant emission reductions were achieved mainly due to increased

Figure 7.9 Drivers of direct GHG emissions from EU manufacturing and construction industries, 1990–2008



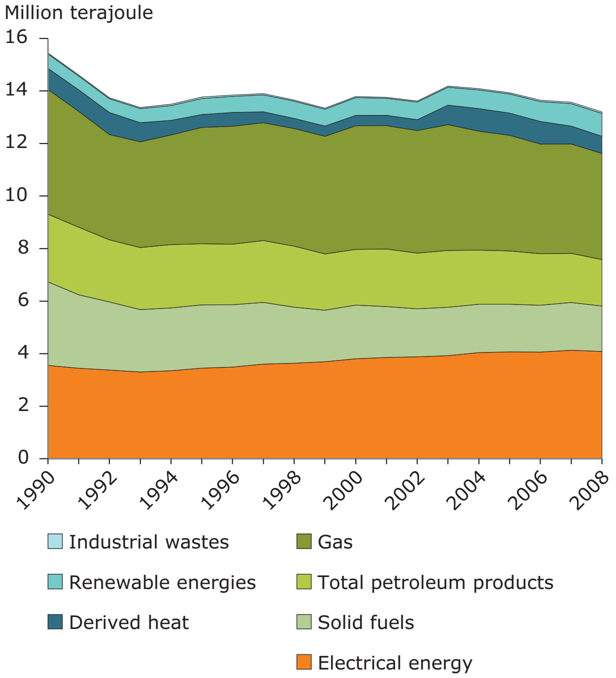
Note: Indirect emissions, related to the production of public electricity or heat used by the manufacturing and construction industries, are not included.

Source: EEA, 2010a; European Commission, 2010a; Eurostat, 2011a.

share of electricity and district heat and — to a much smaller extent — due to fuel switching from coal to gas.

Contrary to the general trend in the EU-27, **Spain** had the highest increase in emissions from manufacturing industries and construction (+ 20 Mt), due to its sustained economic growth.

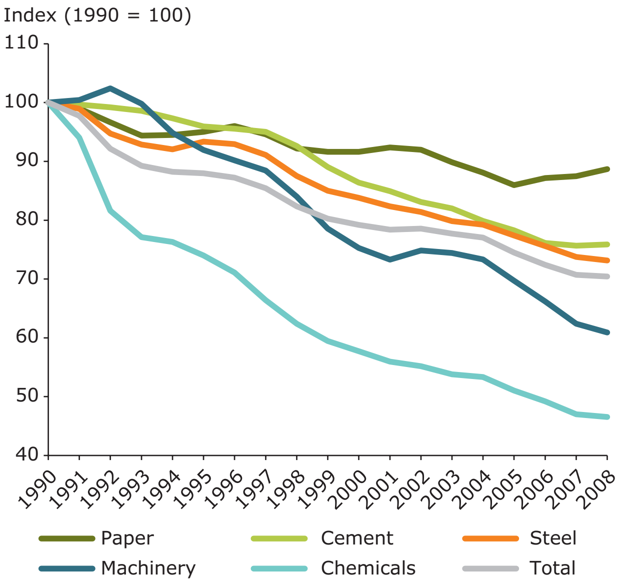
Figure 7.10 Final energy consumption in EU industry, 1990–2008



Note: GHG emissions resulting from the consumption of electrical energy and derived heat, do not count towards direct emissions of the industry, but are accounted in the sector 1A1 'Energy supply'.

Source: Eurostat, 2011a.

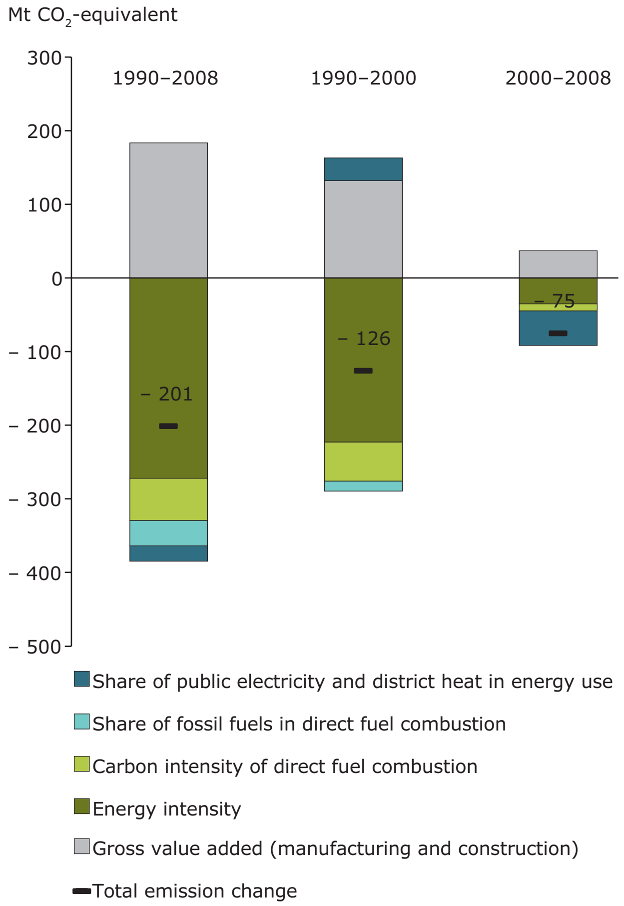
Figure 7.11 Energy efficiency index (ODEX) in industry in EU-27



Note: The industry ODEX represents a weighted average of indices of energy efficiency progress at the level of manufacturing branches. Each index is calculated from variations of unit energy consumption indicators, measured in physical units and selected so as to provide the best 'proxy' of energy efficiency progress.

Source: Odyssee database, 2010. See www.odyssee-indicators.org.

Figure 7.12 Decomposition analysis of direct CO_2 emission trends from EU manufacturing and construction industries, 1990–2008



Note: Each bar shows the contribution of a single driver on GHG emission trends during a determined period. The thick short black lines indicate the combined effect of all emission drivers, i.e. the overall GHG emission trend during the period considered.

Source: Own calculations, based on EEA, 2010a; European Commission, 2010a; Eurostat, 2011a.

7.2.3 *Energy use (direct fuel combustion by households)*

EU-level analysis

Emissions due to the direct combustion of fuel by households represented 34 % of total CO_2 emissions from energy use (excluding electricity consumption and the transport sector) in 2008.

Six factors were identified for the decomposition analysis (Table 7.3): population, number of households, final energy consumption, fuel consumption, fossil fuel consumption and temperature.

Table 7.3 Identification of drivers influencing direct CO_2 emissions from households

Drivers influencing emissions	Description	Input of factors to decomposition analysis	Unit
Population	Emissions are directly linked to population.	Population	Million
Number of persons per household	The number of households is increasing in most countries and contributes to higher emissions, especially if the number of people per household is decreasing at the same time.	Number of households/Population = 1/number of persons per household	Million/ Million
Energy use per household	The energy used per households for heating, warm water, cooking, electric appliances, etc. Changes in this driver can indicate increased energy savings or increasing number of single households.	Temperature-corrected final energy consumption/Number of households	PJ/Million
Share of electricity and district heat in households' energy use	The fuel consumed by households compared to the total final energy consumption, describes the share of public electricity and district heat used. The emissions resulting from the production of public electricity and district heat are not accounted for in the households sector. Therefore, an increase in this driver results in lower emissions from this sector (but it can also result in increasing emissions in the electricity generation sector).	Temperature corrected fuel consumption/Temperature-corrected final energy consumption = 1 – share of electricity and district heat in households' energy use	PJ/PJ
Share of biomass in direct fuel combustion by households	Biomass is considered here as the main non-fossil fuel source. Its share in the total fuel consumption reflects the level of independence of manufacturing processes from fossil fuels. An increasing share of biomass leads to decreasing emissions.	Temperature-corrected fossil fuel consumption/Temperature-corrected fuel consumption = 1 – share of biomass	PJ/PJ
Carbon intensity of direct fuel combustion by households	The emissions resulting from the combustion of fossil fuels depend on the type of fuel used. A switch to less-carbon-intense fossil fuels can be monitored.	Temperature-corrected CO_2 emissions/Temperature-corrected fossil fuel consumption	Mt/PJ
Temperature	The temperature influences heating demand and thereby constitutes an important emission driver. To describe the energy consumption independently from temperature fluctuations, the energy data have been adjusted to allow a more meaningful trend analysis for years with different temperature conditions.	Temperature	Celsius degrees

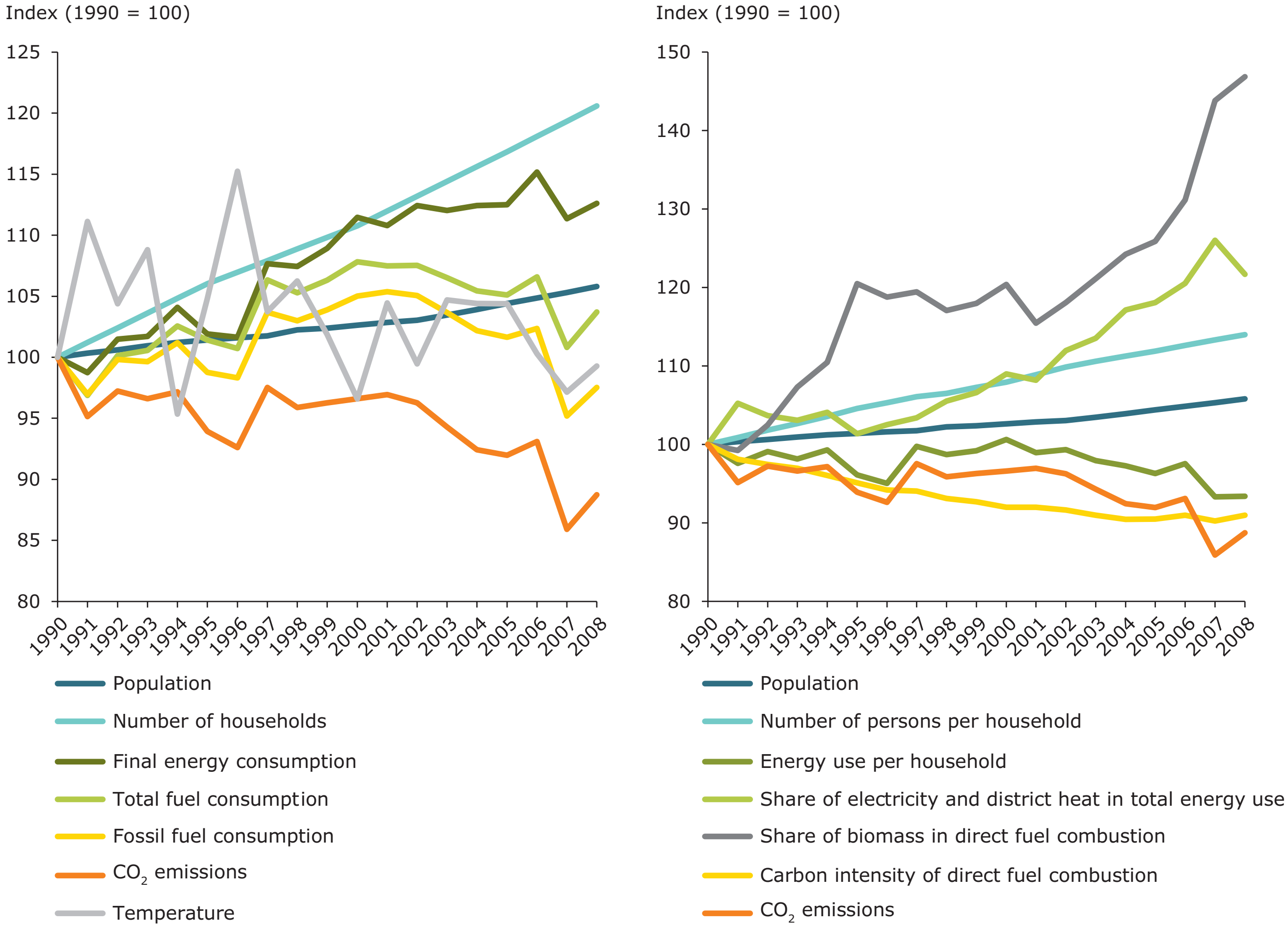
An overview on how these factors are interlinked in the decomposition analysis to drivers steering the GHG emission trend of the households sector is shown in Figure 7.13.

In order to observe the trend of energy consumption independent from variations in temperature, several factors (final energy consumption, fuel consumption, fossil fuel consumption and CO_2 emissions) have been temperature corrected before being used in the decomposition analysis. The results represent trends in energy consumption that would occur if annual mean temperature was constant and equal to the long-time mean temperature over the period 1990–2008. A rise in population, households per capita (number of people living per household) and energy use per household increased CO_2 emissions, whereas the increasing share of electricity and district heat and of biomass in total final energy consumption and the switch to less-carbon-intense fuels (e.g. from solid to gaseous fuels) had a reducing effect on CO_2 emissions.

Between 1990 and 2008, CO_2 emissions from households in the EU-27 decreased by 54 Mt CO_2-equivalent (Figure 7.15). The main reasons for this reduction were a fuel shift from coal and oil to gas in the 1990s and reduced energy demand in households due to efficiency improvements and better insulation between 2000 and 2008. In addition, the increased use of electricity and district heating and — to a lesser extent — of biomass contributed to declining CO_2 emissions from households (Figure 7.14). Annual temperature variations also have significant consequences on energy use by households and related CO_2 emission trends.

Compared to 2007, CO_2 emissions from households increased sharply in 2008. At least two reasons account for this. Firstly, households used more fuel for heating purposes, partly due to lower temperatures than in 2007. This is confirmed by the increase in the number of 'heating degree days' (an indicator of household demand for heating) compared to 2007. The second reason for increased emissions from households and services in 2008, compared to 2007, was refilling of fuel stocks. Fuel purchases were avoided in 2007 because of the high prices, particularly in Germany.

Figure 7.13 Drivers of direct CO_2 emissions from EU households, 1990–2008



Note: Final energy consumption, fuel consumption, fossil fuel consumption and CO_2 emissions are temperature corrected. Indirect emissions, related to the production of public electricity or heat used by households, are not included.

Source: EEA, 2010a; European Commission, 2010a, Eurostat, 2011a.

Country analysis

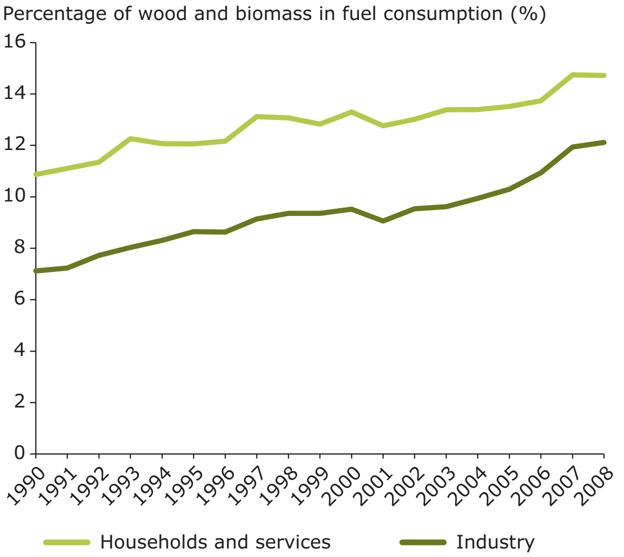
The highest emission reduction (– 30 % of total EU-27 gross reduction) was achieved by **Germany** (– 25 Mt CO_2-equivalent), due to efficiency improvements, increased use of district heating and a fuel switch in Eastern German households (mainly in the 1990s). Other significant decreases occurred in the **Czech Republic** (– 14 Mt CO_2-equivalent) and **Hungary** (– 6 Mt CO_2-equivalent).

The **Czech Republic's** CO_2 emissions from households decreased sharply in the 1990s due to economic changes. The decrease was mainly caused by efficiency improvements and by switching from coal to natural gas. Further decreases achieved since 2000 were mainly due to a replacement of fossil fuels by biomass.

In **Hungary**, CO_2 emission reductions in the early 1990s were also caused by economic restructuring. In the years of economic transformation, energy demand was significantly reduced and the fuel composition changed, with solid fuels being mostly replaced by natural gas.

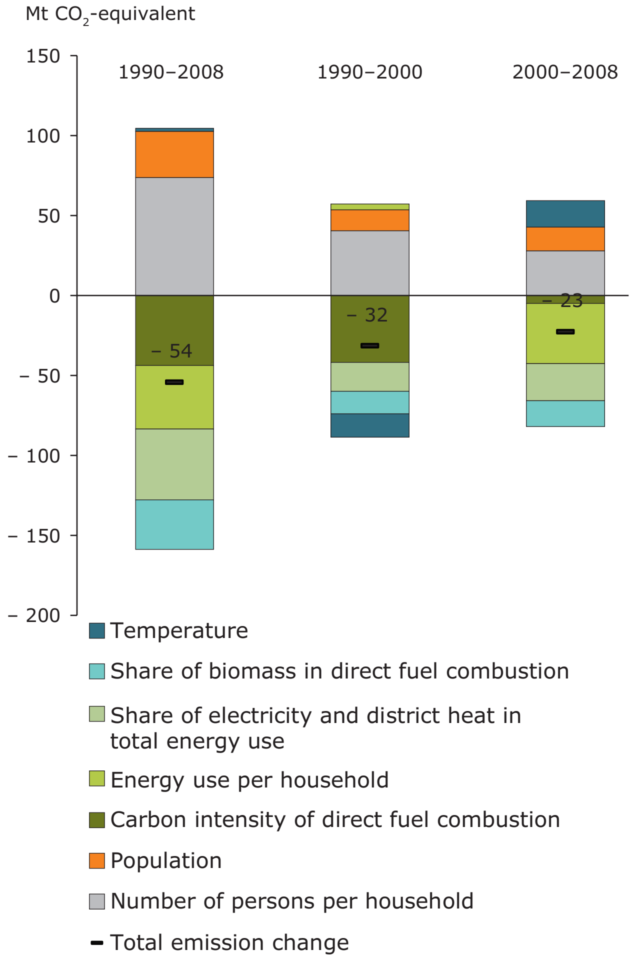
Within the EU-27, **Spain and France** had the highest absolute increase in GHG emissions from households (+ 6 Mt CO_2-equivalent each). This trend was caused by sustained economic growth. In particular, the use of gas increased (in Spain, the use of gas for residential heating purposes in 2008

Figure 7.14 Share of wood and biomass use in fuel consumption by industry, households and the services sector



Source: Eurostat, 2011a.

Figure 7.15 Decomposition analysis of direct CO_2 emission trends from EU households, 1990–2008



Note: Each bar shows the contribution of a single driver on GHG emission trends during a determined period. The thick short black lines indicate the combined effect of all emission drivers, i.e. the overall GHG emission trend during the period considered.

Source: Own calculations based on EEA, 2010a; European Commission, 2010a; Eurostat, 2011a.

was nearly 9 times higher than in 1990), whereas the use of all other fuel types decreased between 1990 and 2008.

7.3 Main links between EU legislation and observed GHG emission trends from energy supply and use between 1990 and 2008

This section presents a synthetic description of a number of EU directives which can have potential effects on various drivers of GHG emissions from the energy supply sector (IPCC sector 1A1), the combustion of fuels by industry (1A2), households (1A4a) or services (1A4b), or a combination of these sectors (Table 7.4). Such policies can affect GHG emissions directly or indirectly and in several ways, such as:

- using a price signal to limit energy/electricity demand (e.g. taxation of energy products) or CO_2 emissions (e.g. EU ETS);
- promoting the use of renewable energy sources to produce heat and electricity;
- promoting efficient production of electricity and heat (e.g. promotion of co-generation);
- promoting an efficient use of energy, either for the production of electricity and heat or for direct use (e.g. fuel efficiency of combustion in power plants, promotion of co-generation, energy efficiency of boilers);
- promoting energy-efficient products through better conception (ecodesign), standards (e.g. energy efficiency of buildings structures), consumer information (e.g. energy labelling of electricity-using products), etc.

Table 7.4 Link between EU directives and GHG emission sources

IPCC sector	Actors	EU directive potentially affecting GHG emissions
Energy supply (1A1)	Energy industries	LCP Directive (1988, 1994, 2001) IPPC Directive (1996, 2008) RES-E Directive (2001) EU ETS Directive (2003) CHP Directive (2004)
	Heat and electricity end users	EU Electricity Directive (1996, 2003) Energy Labelling Directive (1992) and subsidiary directives Energy Taxation Directive (2003) Ecodesign Directive (2005)
Energy use (excluding public electricity and heat) (1A2) (1A4)	Industry	LCP Directive (1988, 1994, 2001) SAVE Directive (1993)/Energy Services Directive (2006) IPPC Directive (1996, 2008) Energy Taxation Directive (2003) EU ETS Directive (2003) CHP Directive (2004) Ecodesign Directive (2005)
	Households	Boiler Efficiency Directive (1992) SAVE Directive (1993)/Energy Services Directive (2006) Energy performance of buildings Directive (2002) Energy Taxation Directive (2003) CHP Directive (2004) Ecodesign Directive (2005)

In addition, regulating air pollutants (such as NO_X and SO_2) emitted during the combustion of fossil fuels incentivises efficient use of fuel and fuel switching from coal to gas, which can consequently impact GHG emissions.

During the period 1990 to 2000, GHG emissions in the energy sector have been impacted by a limited number of policies. A number of these were implemented to promote energy efficiency through minimum requirements for boilers (the Boiler Efficiency Directive), information on household appliances (the Energy Labelling Directive and its subsidiary directives) and measures in buildings (Directive 93/76/EEC, the SAVE Directive); although some positive effects could be observed — in particular a shift towards more efficient appliances — the results fell overall short of expectations and did not succeed in sufficiently curbing the rising demand in energy and electricity (Table 7.5). Air pollution control policies also seem to have been particularly important in the 1990s. These policies were actually not directly targeting GHG emissions but aimed to limit the quantity of air pollutants (such as NO_X and SO_2) emitted during the combustion of fossil fuels by large industrial plants. The 1988 LCP Directive, further strengthened in 1996 by the IPPC Directive, incentivised efficient use of fuel and fuel switching from coal to gas (thereby reducing carbon intensity) across industrial sectors, which consequently impacted GHG emissions — especially in the energy supply sector but also in the manufacturing industry sector. Some EU Member States started implementing climate policies already during the 1990s by means of national climate strategies or policies and measures such as energy or CO_2 taxation (e.g. in Denmark, Germany and Sweden).

Since 2000, more policies have been implemented to reduce emissions from electricity generation and energy use. The promotion of renewable energy, in particular through the 2001 RES-E Directive, seem to have significantly contributed to the development of renewables in the EU, in particular wind energy and biomass, the latter being used both in electricity generation as well as for direct fuel combustion by the industry. Still, the parallel rise of electricity demand — and consequent electricity generation from thermal power plants — has limited the penetration of renewables in national energy mixes (apart from a few exceptions). Consequently, the share of renewables has not grown to the expected levels and policy objectives have been reached only in rare cases. Likewise, the objectives of the CHP Directive (Directive 2004/8/EC), aiming at improving electricity and heat generation efficiency, have not been achieved. The introduction of the EU ETS in 2003 and its implementation in 2005 showed the EU's resolution to introduce and explore new policy instruments to tackle emissions from large point sources. The first trading period delivered many lessons regarding allocation and the effect of a carbon price signal, although actual emission reductions during its first phase were difficult to demonstrate clearly. For some of the more recent policies, there is not enough time yet to look back and be able to assess whether these policies have been successful.

As regards the use of electricity, despite the success achieved by the Energy Labelling Directive in shifting the market of electric appliances towards more efficient appliances through consumer information, the EU has not managed to curb its rising energy — and in particular electricity — demand over the period 1990–2008. Minimum taxation levels imposed by the Energy Taxation Directive also remain too low to play any significant role in energy pricing across the EU and have an impact on consumption.

Table 7.5 includes a general description of the link between the effects of these policies, in particular in relation to the drivers identified in the previous section.

7.4 Sectoral synthesis

Energy-related emissions have decreased over the period 1990–2008. The largest trends in absolute terms were observed during the 1990s. For each of the three subsectors considered, two main factors with opposite effects emerge: the first is related to energy demand and drives emissions up, while the second one relates to efficiency or carbon intensity and drives emissions down:

- Energy supply (public electricity and heat generation): the effects of the strong rise in electricity demand (+ 29 % between 1990 and 2008) were almost fully counterbalanced by large fuel efficiency improvements in thermal plants for the production of public electricity and heat. In this sector, emission trends show an actual increase in emissions during the period 2000–2008 (due to steep rising trends between 1999 and 2003), while they had decreased during the period 1990–2000, despite the additional positive effects of increasing use of renewable energy sources.

- Energy use (direct fuel combustion) by industry: the effects of economic activity growth have in principal been totally offset by strong reductions in energy intensity. The switch to electricity has also de facto transferred some emissions to the energy supply sector and has had a significant influence on emissions in the last years.

- Energy use (direct fuel combustion) by households: more dwellings but less people living in each household have on average exacerbated the demand in energy, in particular for heating. Here, switching to less carbon-intensive fossil fuels is the response that has provided the largest emission savings, in addition to higher electricity use (partly in replacement of fossil fuels) and higher biomass use. Emission changes in this sector remain of much lower magnitude than in the two previous industry-related subsectors.

The emission trend during the 1990s was mainly a result of the economic restructuring in Eastern Europe. Thus, emission decreases in the industry sector (including energy industries) in the 1990s were mostly the result of an exceptional economic situation. This large effect effectively masked the contribution of more dedicated energy and/or climate policies also had on emissions, although their effects were significantly more reduced in comparison. Besides energy efficiency policies, other policies aiming at reducing air pollution have also had co-benefits in terms of reduced CO_2 emissions. Another important factor during the second half of the 1990s and resulting in large emission reductions was also a primary effect of fuel prices and of the lower cost of electricity produced from gas-fired efficient plants compared to coal or oil-fired plants, making gas more favourable.

The trends observed between 2000 and 2008 clearly represent the opposition between the effects of increasing energy demand due to higher living standards and of economic growth on one hand; and on the other hand the benefits coming from efficiency improvements in electricity and heat generation (with support from policies such as the CHP Directive), increased use of renewable energy sources, in particular biomass and wind (the RES-E Directive), improvements in energy efficiency such as in the building sector (the Energy Performance of Buildings Directive), and in the efficiency of products and appliances (which has improved through a number of dedicated policies on labelling or efficiency standards). In the current situation, positive and negative drivers counteract each other. This shows the necessity of both tackling efficiently the growth in energy demand, while enhancing policies on energy efficiency and renewable energy.

Energy supply (public electricity and heat production)

The overall decrease of emissions from the production of public electricity and heat during the full period from 1990 to 2008 is the result of an important decrease in the 1990s and a moderate increase between 2000 and 2008. The observed absolute effects of GHG emission drivers, either positive or negative, were larger during the 1990s than after 2000. Energy supply represents the sector that has been affected by the largest number of

Table 7.5 EU policies affecting emissions from energy supply and use (excluding transport) between 1990 and 2008

EU legislation	Objectives	Actors concerned	IPCC sector affected	Impact on identified drivers
Large Combustion Plant (LCP) Directive: Directive 88/609/EEC on the limitation of emissions of certain pollutants into the air from large combustion plants – Amended by Directive 2001/80/EC	Reduce emissions of acidifying pollutants, particles and ozone precursors from large combustion plants, as part of the overall EU strategy to reduce air pollution. The 2001 directive also encourages the combined production of heat and electricity (co-generation).	Energy industries Industry	Energy supply Manufacturing and construction industry Industrial processes	Although the primary objective of the LCP Directive was to reduce pollution from acidifying emissions, ozone precursors and particles, it has led plants to achieve compliance through measures such as efficiency improvements to reduce fuel use or fuel switching, which have resulted in CO_2 emission reductions in parallel with NO_x and SO_2 emission reductions. The LCP Directive impacted the drivers 'Fuel efficiency' and 'Carbon intensity' in the energy supply sector, especially during the 1990s in the EU-15 (although a range of other policies are also likely to have contributed to GHG reductions from these drivers). Due to the much smaller number of equipment concerned (boilers and process heaters) in the manufacturing industry, the impact of the LCP Directive was less important on the relevant drivers of this sector (energy intensity and carbon intensity).
Integrated Pollution Prevention and Control (IPPC) Directive: Directive 96/61/EC concerning integrated pollution and prevention and control – Amended by Directive 2008/1/EC	Minimising pollution from various industrial sources (including energy industries, production and processing of metals, mineral industry, chemical industries, waste management, livestock farming).	Energy industries Industry	Energy supply Manufacturing and construction industry Industrial processes	Like the LCP Directive, the IPPC Directive contributed to improve energy efficiency of large scale industrial combustion, impacting the two drivers related to energy use: 'Fuel efficiency' and 'Carbon intensity' in the public power sector and, to a lesser extent, 'Energy intensity (efficiency)' and 'Carbon intensity' in the industry sector. Overall, the impacts of the IPPC Directive were not as important as those of the LCP, as the latter first tackled emissions from the most inefficient plants.
Boiler Efficiency Directive: Directive 92/42/EEC on efficiency requirements for new hot-water boilers fired with liquid or gaseous fuels	Promote energy efficiency in the Community through minimum efficiency requirements applicable to new hot-water boilers fired by liquid or gaseous fuels with a rated output of no less than 4 kW and no more than 400 kW.	Households	Households	The star rating system introduced by the Boiler Efficiency Directive did not prove to deliver the expected results. The directive had a limited effect on the overall GHG trend due to the GHG driver 'Energy use per household' in the households sector. The reduced amount of fossil fuel used for heating resulted in an increase in the share of electricity in households' total energy use, but this increase was primarily due to an overall increase in electricity consumption by households, due in particular to the increase in the number of electrical appliances and the number of households. The role of the directive in the change of emissions due to this driver was therefore very limited.
Energy Labelling Directive and subsidiary directives: Directive 92/75/EEC on the indication by labelling and standard product information of the consumption of energy and other resources by household appliances	Harmonise information on the consumption of energy and of other essential resources by household appliances to allow consumers to choose appliances on the basis of their energy efficiency.	Heat and electricity end users	Energy supply	The Energy Labelling Directive and its subsidiary directives affecting various appliances succeeded in realising a shift towards more efficient appliances. It helped improve the energy efficiency of household appliances and reduce the growth in electricity consumption per households but was overall not sufficient to significantly limit the growth in total electricity consumption of EU households (and thereby the electricity output of energy industries).

Table 7.5 EU policies affecting emissions from energy supply and use (excluding transport) between 1990 and 2008 (cont.)

EU legislation	Objectives	Actors concerned	IPCC sector affected	Impact on identified drivers
SAVE Directive/Energy Services Directive: Directive 93/76/EEC to limit CO_2 emissions by improving energy efficiency (SAVE) – Repealed by Directive 2006/32/EC on energy end-use efficiency and energy services	**SAVE:** require Member States to introduce measures such as: energy certification of buildings; billing of heating, air conditioning and hot water costs according to consumption; thermal insulation of new buildings; regular inspection of boilers. **Energy services:** make energy end use more cost effective and efficient through indicative targets, incentives and removal of market barriers and imperfections; promote energy services, energy-saving programmes and other measures aimed at improving end-use energy efficiency.	Industry Households	Manufacturing and construction industry Households	The SAVE Directive had some significant but non-quantifiable impact on national programmes but also had many shortcomings. In particular, it did not enforce measurable objectives and the lack of focus reduced its overall impact. Accordingly, the directive was a low priority for Member States. The SAVE therefore did not significantly impact the driver 'Energy use per households'. The Energy Services Directive covers a nine year timeframe (2008–2012). It requires Member States to draw up National Energy Efficiency Action Plans (NEEAPs). It could therefore not affect emissions during the period 1990–2008.
Ecodesign Directive for energy-using products: Directive 2005/32/EC establishing a framework for the setting of ecodesign requirements for energy-using products and amending Directives 92/42/EEC (Boiler Efficiency Directive), 96/57/EC (energy efficiency requirements for household electric refrigerators, freezers and combinations) and 2000/55/EC (energy efficiency requirements for ballasts for fluorescent lighting)	Improving the environmental performance of energy-related products (ERPs) through setting minimum efficiency performance standard requirements. No binding requirements on products, but a framework (rules and criteria) for setting such requirements through implementing measures (prepared only for products which have significant sales and trade in the EU, a significant environmental impact and potential for improvement).	Heat and electricity end users Industry Households	Energy supply Manufacturing and construction industry Households	The Ecodesign Directive came into force in 2007 and the majority of the existing implementing measures became applicable only in 2009 or 2010. They have had, therefore, a very limited impact on electricity consumption (although there may have been an announcement effect in some cases). On the other hand, Directives 92/42/EEC (ecodesign of boilers — cf. Boiler Efficiency Directive), 96/57/EC (energy efficiency requirements for household electric refrigerators and freezers) and 2000/55/EC (ecodesign of ballasts for fluorescent lighting) have been in force for a number of years and are expected to have had a certain impact on emissions. The 2005 directive was further amended by Directive 2009/125/EC.
EU Electricity Directive: Directive 96/92/EC concerning common rules for the internal market in electricity, repealed by Directive 2003/54/EC and subsequently Directive 2009/72/EC	Allow electricity consumers to choose their suppliers so that companies benefit from competition (increased efficiency and lower prices) and consumers benefit from market opening (lower domestic bills for electricity). Ensure a level playing field among Member States in terms of market opening.	Heat and electricity end users	Energy supply	There is no clear impact of liberalising the internal market on GHG emission drivers, due to large uncertainties. It has been argued that the process of liberalisation may generate risks for the creation of a sustainable power sector in the short term, while in the long term liberalisation could drive efficiency gains and facilitate the transition to a sustainable power sector.
RES-E Directive: Directive 2001/77/EC on the promotion of electricity produced from renewable energy sources in the internal electricity market – Amended by Directive 2009/28/EC on the promotion of the use of energy from renewable sources	Promote renewable energy sources for electricity production (RES-E), set an indicative 21 % objective for renewable energy sources contribution to electricity production and lay down specific measures relating to evaluation of the origin of the electricity, connection to the grid and administrative measures, among others.	Energy industries	Energy supply	The RES-E Directive had a large estimated impact on RES-E generation, which is consistent with observed increases in the share of renewable energy for the production of public electricity and heat since 2001. Two GHG emission drivers identified for this sector were affected: 'Share of renewables excl. biomass' and 'Share of biomass'. However, this impact was somewhat lessened by the parallel rise in fossil-based electricity generation, driven by an important electricity demand within the EU. In the absence of the directive, the increase in RES-E would have been slower than the increase in fossil-fuel based electricity, which would have resulted in a decrease in the RES-E share.

Table 7.5 EU policies affecting emissions from energy supply and use (excluding transport) between 1990 and 2008 (cont.)

EU legislation	Objectives	Actors concerned	IPCC sector affected	Impact on identified drivers
Energy Performance of Buildings Directive: Directive 2002/91/EC on the energy performance of buildings	Reducing the energy losses in existing, renovated and new residential and service buildings through minimum efficiency standards for buildings, introducing a labelling system for existing buildings and setting up a system for regular boiler and air conditioning inspection.	Households	Households	The reduction in emissions from fossil fuel combustion by households, which corresponds to the two drivers 'Energy use per household' and 'Share of public electricity and heat', was more important between 2000 and 2008, in line with the time frame and objectives of the Energy Performance of Buildings Directive. The directive is expected to have impacted these two drivers, although it is also likely that the increase in and shift to electricity as an energy source for households will have had a greater impact on these drivers.
EU ETS Directive: Directive 2003/87/EC establishing a scheme for GHG emission allowance trading within the Community – Amended by Directive 2009/29/EC	Helping EU Member States achieve their commitments to limit or reduce GHG emissions in a cost-effective way by allowing participating companies to buy or sell emission allowances.	Energy industries Industry	Energy supply Manufacturing and construction industry Industrial processes	Abatement has been estimated to have been modest during the first trading period of the EU ETS (2005–2008), but emissions were nevertheless reduced as a result of the scheme, in particular within the EU-15. Firms responded to the relatively high carbon prices at the beginning of the trading phase (before over-allocation became clear and EU allowance prices collapsed) and included it in their long-term investment decisions, both in the electricity generation sector and in industrial facilities. The EU ETS predominantly resulted in some fuel switching (to gas and biomass), despite high natural gas prices, thereby affecting the drivers 'Carbon intensity' and 'Share of biomass'. Energy efficiency also improved, both in industrial facilities and in power plants.
Energy Taxation Directive: Directive 2003/96/EC on restructuring the community framework for the taxation of energy products and electricity	Minimum rates of taxation set for energy products when used as motor and heating fuel and for electricity, to encourage more efficient use of energy so as to reduce dependence on imported energy products and limit GHG emissions.	Heat and electricity end users Industry Households	Energy supply Manufacturing and construction industry Households	The Energy Taxation Directive appears to be driving the taxation of electricity in many Member States, but the minimum level of taxation is very low and is likely to constitute only a small portion of the price of electricity. In other Member States, the significantly higher rates observed imply that the directive has not driven the level of taxation, while other Member States do not tax electricity use at all due to derogations. In the industry and households sectors, minimum levels of taxation imposed by the directive are very low in comparison with energy prices and constitute a small portion of the total price in most Member States. Therefore, the Energy Taxation Directive does not affect the driver 'Electricity consumption' or other drivers of energy-related emissions.
Combined Heat and Power (CHP) Directive: Directive 2004/8/EC on the promotion of co-generation based on a useful heat demand in the internal energy market	Facilitating the installation and operation of electrical co-generation plants (producing heat and electricity in one process). Overall indicative target of doubling the share of electricity production from co-generation to 18 % by 2010.	Energy industries Industry Households	Energy supply Manufacturing and construction industry Households	Despite the development of co-generation since the implementation of the CHP Directive in 2004, the low share of CHP in electricity generation (in the public power sector as well as other industrial facilities), the slow progress towards policy objectives and the remaining barriers to further CHP penetration demonstrate a limited impact of the CHP Directive on the GHG emission driver 'Fuel efficiency of public power production' (which also covers electricity-only plants), especially in comparison with the LCP Directive, the IPPC Directive and the EU ETS, which also tackle the efficiency of large-scale combustion plants. Micro CHP remains very marginal in the households sector.

Source: EEA, 2011.

policies adopted at EU level, which can be explained by the high share of total GHG emissions this sector accounts for. In addition, emissions from this sector mostly come from large point sources, where implementation of policies is relatively easier than for diffuse emissions. Although climate policies were not fully developed yet at EU level during the 1990s, they had started to be implemented in some EU Member States by means of national climate strategies or policies and measures such as energy or CO_2 taxation (e.g. in Denmark, Germany and Sweden).

CO_2 emissions from the production of public electricity and heat within the EU-27 were mainly driven upward by rising electricity demand, observed particularly in the 1990s. This growth in electricity demand slowed down slightly after 2000, possibly due to the increasing efficiency of electrical appliances introduced on the market after the implementation of energy labelling polices (the Energy Labelling Directive and subsidiary directives). EU minimum electricity taxation levels are not currently considered to affect electricity consumption levels.

At the same time, efficiency improvements resulted in important GHG reductions across the EU between 1990 and 2008. Between 1990 and 2000, these improvements, which were the consequence of the closure of old inefficient plants, resulted in emissions reductions larger than the increases due to rising electricity demand. Further emission reductions came from improvements in existing technologies, often combined with a switch from coal power plants to more efficient combined cycle gas-turbines (CCGTs) and, especially between 2000 and 2008, an increase in the use of co-generation by public thermal power plants. In the EU-15, the early implementation of air pollution control measures for large combustion plants (the LCP Directive, later reinforced by the IPPC Directive) produced important co-benefits on GHG emissions through efficiency improvements. More recently, establishing a price signal for carbon emission (through the EU ETS) has shown that it could also stimulate efficiency improvements.

The development of renewable energy sources to produce electricity also led to important emission reductions in the 1990s, combined with an overall increase in the share of nuclear between 1990 and 2000. Between 2000 and 2008, however, the effects of a continued increase in electricity generation from renewable sources (in particular from wind energy and biomass), supported by new policies such as the RES-E Directive were offset by the relative decrease in nuclear electricity generation. As a result, the rising electricity demand in the EU was overall satisfied with additional thermal power production within the EU.

Finally, switching from coal or oil to gas has led to continuous reductions in emissions between 1990 and 2008. External factors played a key role in the emission reduction resulting from this driver, such as fuel prices and the lower cost of electricity produced from gas-fired efficient plants compared to coal or oil-fired plants, making gas more favourable. Fuel shift was also partly driven by air pollution mitigation policies in the 1990s (the LCP and IPPC Directives). Introducing a carbon price signal through the EU ETS has also shown it could contribute to further fuel switching (Table 7.6).

Energy use by manufacturing and construction industry (direct fuel combustion, excluding public electricity consumption)

The increase in GVA observed between 1990 and 2008 took place while the need for final energy use decreased by 28 %. In the 1990s, the restructuring of the industrial sector in eastern Europe, a general shift of EU industry towards the production of less energy-intensive goods (e.g. services) as well as efficiency improvements had larger effects than the negative effects of increasing economic growth and a decreasing share of public electricity use.

Between 2000 and 2008, the increase of GVA slowed down; the effects of this development were opposite, but equal in absolute value, to those of further efficiency improvements, while the increased share of public electricity use, reflecting the growth in electricity consumption, drove emissions further down. The efficiency improvements were driven by a number of external factors and policies. In the 1990s, the low price of gas also contributed to the development of high-efficiency CCGTs. The LCP Directive and — to a lesser extent — the IPPC Directive resulted indirectly in GHG emission reductions. From 2000 onwards, further efficiency improvements were achieved through policies and initiatives such as the motor challenge and European Committee of Manufacturers of Electrical Machines and Power Electronics (CEMEP) voluntary agreement as well as through the development of co-generation (the CHP Directive). The EU ETS is also estimated to have driven some efficiency improvements in this sector under the condition of meaningful carbon prices.

The fuel switch to less carbon-intensive fossil fuels (gas, biomass) has also driven emissions from manufacturing industries down. The largest effects occurred in the 1990s, with an important switch from coal to oil and gas. This switch was mainly a result of low gas prices, although the LCP and IPPC are also expected to have played some role in this trend in the 1990s. Between 2000 and 2008, biomass use continued to grow strongly under the possible stimulation of the RES-E Directive. Fuel switch may also have been driven — for a short period — through relatively high carbon prices in the context of the EU ETS (Table 7.7).

Energy use by households (direct fuel combustion, excluding electricity consumption)

Between 1990 and 2008 the increase in emissions were driven by the increased number of households, which grew faster than the increase of the EU population. Energy efficiency improvements and better insulation have helped to limit these negative factors since 2000. Furthermore, the constant increase in the share of electricity and district heat in households' energy use has also contributed to reducing emissions (the emissions resulting from public electricity and heat use being accounted for in the energy supply sector), due to a switch from fossil fuel use to electricity (for the same energy service), the autonomous increase in the number of electrical appliances used by households and — probably to a more limited extent — policy impacts. Here, several EU directives have contributed to reducing energy use in the households sector. The Boiler Efficiency Directive, the SAVE Directive and more recently the Energy Performance of Buildings Directive have helped in reducing fuel use for space heating (the largest share of energy use in households) by improving the efficiency of houses and boilers, although final results appear limited when compared to initial objectives (in the case of 'old' directives). Due to their recent entry into force, the Ecodesign Directive and the Energy Services Directive have not had time to deliver any noticeable effect at EU level. The development of micro CHP remains too insignificant to affect this driver at EU level. As for electricity, energy taxation levels do not represent any significant share in energy prices (in most Member States) to drive consumption levels down.

The overall switch to less carbon-intensive fuels (in particular biomass and gas) has resulted in a decrease of household emissions, especially between 1990 and 2000. During that period, it was the switch from coal to gas that resulted in the largest emission reduction (Table 7.8).

Table 7.6 Changes in drivers influencing EU CO_2 emissions of public electricity and heat production, and effects on emissions, 1990–2008

Group of drivers	Drivers	Change in driver (%)		Effect on GHG emissions (Mt CO_2- equivalent)		Assessment — GHG emission trends from public electricity and heat production
		1990–2000	2000–2008	1990–2000	2000–2008	1990–2008
Amount of total electricity generation	Electricity demand	+ 16 %	+ 12 %	+ 231	+ 148	A 29 % increase in electricity demand was observed between 1990 and 2008, which was satisfied by increasing public electricity generation. This rising demand followed the trends of economic growth and increasing electrification in the EU, as well as an increasing number of appliances per household. The GHG trend was observed despite the effects of a number of energy policies, in particular the 1992 Energy Labelling Directive and its subsidiary directives promoting efficient end-use of electricity, which resulted in a clear shift towards more efficient electrical appliances. The minimum tax level imposed by the Energy Taxation Directive on electricity is low and is likely to constitute a small portion of the price of electricity to affect its consumption. Demand has slightly slowed down after 2000.
	Share of net electricity trade in total electricity consumption	– 56 %	– 25 %	+ 14	+ 2	Between 1990 and 2008, the decrease in the (very low) share of net traded electricity to Europe in overall European electricity consumption had only limited effects on emissions from electricity generation within the EU, which were not significantly affected by this driver ([a]).
	Share of autoproducers in total thermal power production	– 10 %	– 12 %	+ 31	+ 30	Electricity generation by autoproducers did not evolve much while electricity generation in public thermal power plants grew steadily, which means that the share of electricity produced by autoproducers decreased, thereby driving emissions from public electricity generation upwards.
	Share of heat production in thermal electricity and heat generation	– 12 %	– 7 %	– 79	– 37	The decrease in the share of heat production from district heating between 1990 and 2008 drove emissions from public electricity and heat production down. This decrease was mainly driven by market forces towards lower district heating, in particular in eastern Europe in the 1990s.
Type of electricity generation	Share of nuclear electricity generation	+ 2 %	– 11 %	– 13	+ 73	After a slight increase in the share of nuclear generation in the 1990s, the decommissioning of old nuclear power plants between 2000 and 2008 contributed to a large increase in emissions. Over the whole period, electricity generation from nuclear power plants increased slower than total electricity generation; the gap has been filled mostly with increased output from conventional thermal power plants, thereby leading to an increase in total emissions from public electricity generation.
	Share of RES electricity (excluding biomass) in total electricity generation (excluding nuclear)	+ 13 %	+ 2 %	– 47	– 8	The share of renewable electricity generation (wind, solar, hydro, etc.) increased in the 1990s, which decreased the share of electricity produced in thermal power plants and consequently reduced emissions. Germany contributed by far the most to the increased share of renewable electricity. After 2000, the implementation of the RES-E Directive drove renewable electricity generation upward, but the rising electricity demand, satisfied through increased thermal electricity generation within Europe, offset these positive effects on EU level. However in some Member States the growth of renewable energy exceeded the rising electricity demand.
	Share of biomass for public electricity and heat production in thermal power plants	+ 119 %	+ 97 %	– 34	– 64	The share of biomass used in public thermal power stations increased between 1990 and 2008, reducing emissions. Germany increased its electricity generation from biomass by more than 5 times between 2001 and 2008 and contributed most to the EU-27 trend. Biomass has developed most after 2000 (at a faster rate than other renewables), notably under the influence of the RES-E Directive. The EU ETS is also estimated to have stimulated the use of biomass in the first half of the first trading period due to the monetary value placed on carbon making low-carbon electricity generation more economically attractive.

Table 7.6 Changes in drivers influencing EU CO_2 emissions of public electricity and heat production, and effects on emissions, 1990–2008 (cont.)

Group of drivers	Drivers	Change in driver (%)		Effect on GHG emissions (Mt CO_2- equivalent)		Assessment — GHG emission trends from public electricity and heat production
		1990–2000	2000–2008	1990–2000	2000–2008	1990–2008
Amount of fuel used for public thermal electricity generation	Fuel efficiency of public thermal power plants	+ 16 %	+ 5 %	– 216	– 74	Efficiency improvements across the EU between 1990 and 2008 resulted in important GHG reductions. These improvements, which resulted in very large emissions reductions in particular between 1990 and 2000, were the consequence of the closure of old inefficient plants in the 1990s, improvements in existing technologies, often combined with a switch from coal power plants to more efficient combined cycle gas-turbines and, especially between 2000 and 2008, an increase in the use of co-generation by public thermal power plants. In the EU-15, in addition to existing energy efficiency policies, the early implementation of air pollution control measures for large combustion plants (the LCP Directive, later reinforced by the IPPC Directive) produced important co-benefits on GHG emissions through efficiency improvements. More recently, establishing a meaningful price signal for carbon emission (through the EU ETS) has shown that it could also stimulate efficiency improvements.
Type of fossil fuel used for electricity generation	Carbon intensity of public power production	– 4 %	– 3 %	– 51	– 40	A fuel switch from coal or oil to gas has led to continuous reductions in emissions between 1990 and 2008. External factors played a key role in the emission reduction resulting from this driver, such as fuel prices and the lower cost of electricity produced from gas-fired efficient plants compared to coal or oil-fired plants, making gas more favourable. Fuel shift was also partly driven by air pollution mitigation policies in the 1990s (in particular the LCP Directive and the IPPC Directive), initially aimed at reducing NO_x and SO_2 emissions. The carbon price signal in the EU ETS (at the beginning of the first trading phase) also contributed. Germany, Spain and Italy contributed most to this trend. Italy switched from oil to gas, and Germany and Spain from coal to gas. In Spain, electricity production from gas has increased significantly since 2000 due to increased gas imports from Algeria.

Note: ([a]) Emissions related to electricity imports into the EU-27 are allocated to the country that generates the electricity, not to the country that imports or consumes that electricity.

Source: Own calculations, based on EEA, 2010a; European Commission, 2010a; Eurostat, 2011a.

Table 7.7 Changes in drivers influencing direct CO_2 emissions of EU manufacturing and construction industries, and effects on emissions, 1990–2008

Group of drivers	Drivers	Change in driver (%)		Effect on GHG emissions (Mt CO_2- equivalent)		Assessment — GHG emission trends from manufacturing and construction industries (direct fuel combustion)
		1990–2000	2000–2008	1990–2000	2000–2008	1990–2008
Amount of fuel used	Gross value added (manufacturing and construction)	+ 17 %	+ 5 %	+ 132	+ 37	Between 1990 and 2008, the GVA from manufacturing and construction industries and construction increased by 23 %, which reflects a steady development of economic activity. Sustaining such growth required use of more resources and more energy, which resulted in important GHG emissions — this driver resulting in the largest effect on GHG emissions. The GVA increase, however, was significantly slower between 2000 and 2008 compared to the 1990s.
	Energy intensity of manufacturing and construction industries	– 24 %	– 5 %	– 223	– 35	The reduction of EU energy intensity was responsible for the largest emission savings in this sector between 1990 and 2000 and offset the emission increase due to the economic growth from 2000 to 2008. This was the consequence of the closure of a large number of heavily polluting plants in the 1990s in eastern Europe, a result of energy efficiency improvements and the sign of a shift of the European industry towards less energy-intensive activities. Efficiency improvements were driven by a number of policies. In the 1990s, air pollution control measures (the LCP and IPPC Directives) produced co-benefits in terms of GHG emission reductions (especially in the EU-15 during the 1990s). The LCP Directive is particularly important, as it was one of the first EU-level policies regulating industrial emission. The low price of gas also contributed to the development of high-efficiency CCGTs. From 2000 onwards, further efficiency improvements were achieved through policies and initiatives (such as the motor challenge and CEMEP voluntary agreement, which improved the energy efficiency of electricity motors) through the (somewhat limited) development of co-generation (the CHP Directive). The EU ETS is also estimated to have driven some efficiency improvements in this sector.
	Share of electricity and district heat in manufacturing industry energy use	– 8 %	+ 15 %	+ 31	– 47	The share of electricity in the industry's energy mix decreased in the 1990s but increased after 2000. This is a combined result of reduced fossil fuel use and a shift towards public electricity and heat as an energy source, due to its flexibility of use and the variety of energy services it provides. This trend had an important effect on industry's GHG emissions after 2000, in comparison with the other identified drivers. Furthermore, the liberalisation of the power sector market might have resulted in the decrease of electricity prices, although they started to rise again in the last few years.
Type of fuel used	Share of biomass (and other renewables) in direct fuel combustion by manufacturing industry	+ 37 %	+ 47 %	– 13	– 20	The share of biomass in total fuel consumption in manufacturing industries and construction increased significantly between 1990 and 2008, which reduced emissions from industry. The sustained increase of biomass use after 2000 may have been strengthened by the RES-E Directive. Some additional use of biomass may have occurred at the time CO_2 prices were relatively high under the EU ETS. The share of biomass in industry's energy use was also stimulated by the development of incineration with energy recovery as a consequence of the Landfill Directive.
	Carbon intensity of direct fuel combustion by manufacturing industry	– 7 %	– 2 %	– 53	– 10	Due to a fuel switch from coal to oil and gas, CO_2 emissions from manufacturing industries and construction decreased continuously between 1990 and 2008. This switch was mainly a result of low gas prices in the 1990s, although the LCP and IPPC Directives are also expected to have played some role in this trend in the 1990s. Fuel switch may also have been driven for a short period through relatively high carbon prices in the context of the EU ETS.

Source: Own calculations, based on EEA, 2010a; European Commission, 2010a; Eurostat, 2011a.

Table 7.8 Changes in drivers influencing direct CO_2 emissions from EU households and effects on emissions, 1990–2008

Group of drivers	Drivers	Change in driver (%)		Effect on GHG emissions (Mt CO_2- equivalent)		Assessment — GHG emission trends from households (direct fuel combustion)
		1990–2000	2000–2008	1990–2000	2000–2008	1990–2008
Amount of fuel used	Population	+ 3 %	+ 3 %	+ 13	+ 15	The population in the EU-27 grew steadily between 1990 and 2008, which drove upward emissions from households.
	Number of persons per household	– 7 %	– 5 %	+ 41	+ 28	Since 1990 the number of households has been increasing more rapidly than population, which resulted in less people per household and consequently in increasing emissions.
	Energy use per household	+ 1 %	– 7 %	+ 3	– 38	After a slight increase in the 1990s, the final energy consumption per household declined between 2000 and 2008. This may primarily be due to the smaller number of people per household. A number of policies have also potentially affected this emission driver, in particular those targeting energy use for space heating (the largest share of energy use in households), such as the Boiler Efficiency Directive and the Energy Performance of Buildings Directive — after 2000. Due to their recent entry into force, the Ecodesign Directive and the Energy Services Directive have not had time to deliver any noticeable effect at EU level. Like for electricity, energy taxation levels do not represent any significant share in energy prices (in most Member States) to drive consumption levels down.
	Share of electricity and district heat in households' energy use	+ 9 %	+ 12 %	– 18	– 23	Since 1990, the share of electricity and district heat has been increasing constantly, which has resulted in a decrease of emissions attributed to households, since emissions resulting from electricity and heat production are accounted for in the energy supply sector. This trend results from a combination of a switch from fossil fuel use to electricity for the same energy service, the autonomous increase in the number of electrical appliances used by households overall and — probably to a much more limited extent — policy impacts, such as those of the Boiler Efficiency Directive, the SAVE Directive or more recently from the Energy Performance of Buildings Directive, which may have driven reductions in fuel consumption by improving the efficiency of houses and boilers. The development of micro CHP remains too insignificant to affect this driver at EU level.
Type of energy used	Share of biomass (and other renewables) in direct fuel combustion by households	+ 20 %	+ 22 %	– 14	– 16	The share of biomass on total fuel consumption has been continually increasing since 1990, which is providing a continuous reduction of household emissions.
	Carbon intensity of direct fuel combustion by households	– 8 %	– 1 %	– 42	– 5	The switch to less carbon-intensive fuels (e.g. from coal to gas) led to decreasing emissions especially between 1990 and 2000, under the main influence of low gas prices.
	Temperature			– 15	+ 17	Annual temperature variations have significant consequences on energy use by households.

Source: Own calculations, based on EEA, 2010a; European Commission, 2010a; Eurostat, 2011a.

7.5 Indicative list of relevant legislative texts

Council Directive 88/609/EEC of 24 November 1988 on the limitation of emissions of certain pollutants into the air from large combustion plants (OJ L 336, 7.12.1988, p. 1–13) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31988L0609:EN:NOT).

Council Directive 92/42/EEC of 21 May 1992 on efficiency requirements for new hot-water boilers fired with liquid or gaseous fuels (OJ L 167, 22.6.1992, p. 17–28) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31992L0042:en:NOT).

Council Directive 92/75/EEC of 22 September 1992 on the indication by labelling and standard product information of the consumption of energy and other resources by household appliances (OJ L 297, 13.10.1992) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31993L0076:EN:NOT).

Council Directive 93/76/EEC of 13 September 1993 to limit carbon dioxide emissions by improving energy efficiency (SAVE) (OJ L 237, 22.9.1993, p. 28–30) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31993L0076:EN:NOThttp://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31993L0076:EN:HTML).

Commission Directive 94/2/EC of 21 January 1994 implementing Council Directive 92/75/EEC with regard to energy labelling of household electric refrigerators, freezers and their combinations (OJ L 45, 17.2.1994, p. 1–22) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31994L0002:EN:NOT).

Council Directive 94/66/EC of 15 December 1994 amending Directive 88/609/EEC on the limitation of emissions of certain pollutants into the air from large combustion plants (OJ L 337, 24.12.1994, p. 83–85) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31994L0066:EN:NOT).

Commission Directive 95/12/EC of 23 May 1995 implementing Council Directive 92/75/EEC with regard to energy labelling of household washing machines (OJ L 136, 21.6.1995, p. 1–27) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31995L0012:EN:NOT).

Commission Directive 95/13/EC of 23 May 1995 implementing Council Directive 92/75/EEC with regard to energy labelling of household electric tumble driers (OJ L 136, 21.6.1995, p. 28–51) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31995L0013:EN:NOT).

Directive 96/57/EC of the European Parliament and of the Council of 3 September 1996 on energy efficiency requirements for household electric refrigerators, freezers and combinations thereof (OJ L 236, 18.9.1996, p. 36–43) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31996L0057:en:NOT).

Commission Directive 96/60/EC of 19 September 1996 implementing Council Directive 92/75/EEC with regard to energy labelling of household combined washer-driers (OJ L 266, 18.10.1996, p. 1–27) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31996L0060:EN:NOT).

Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control (OJ L 257, 10.10.1996, p. 26–40) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31996L0061:EN:NOT).

Directive 96/92/EC of the European Parliament and of the Council of 19 December 1996 concerning common rules for the internal market in electricity (OJ L 27, 30.1.1997, p. 20–29) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31996L0092:EN:NOT).

Commission Directive 97/17/EC of 16 April 1997 implementing Council Directive 92/75/EEC with regard to energy labelling of household dishwashers (OJ L 118, 7.5.1997, p. 1–25) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31997L0017:EN:NOT)

Commission Directive 98/11/EC of 27 January 1998 implementing Council Directive 92/75/EEC with regard to energy labelling of household lamps (OJ L 71, 10.3.1998, p. 1–8) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31998L0011:EN:NOT).

Directive 2000/55/EC of the European Parliament and of the Council of 18 September 2000 on energy efficiency requirements for ballasts for fluorescent lighting (OJ L 279, 1.11.2000, p. 33–39) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32000L0055:EN:NOT).

Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market

(OJ L 283, 27.10.2001, p. 33–40) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32001L0077:EN:NOT).

Directive 2001/80/EC of the European Parliament and of the Council of 23 October 2001 on the limitation of emissions of certain pollutants into the air from large combustion plants (OJ L 309, 27.11.2001, p. 1–21) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32001L0080:EN:NOT).

Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings (OJ L 1, 4.1.2003, p. 65–71) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32002L0091:EN:NOT).

Commission Directive 2002/31/EC of 22 March 2002 implementing Council Directive 92/75/EEC with regard to energy labelling of household air-conditioners (OJ L 86, 3.4.2002, p. 26–41) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32002L0031:EN:NOT).

Commission Directive 2002/40/EC of 8 May 2002 implementing Council Directive 92/75/EEC with regard to energy labelling of household electric ovens (OJ L 128, 15.5.2002, p. 45–56) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32002L0040:EN:NOT).

Directive 2003/54/EC of the European Parliament and of the Council of 26 June 2003 concerning common rules for the internal market in electricity and repealing Directive 96/92/EC (OJ L 176, 15.7.2003, p. 37–56) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32003L0054:EN:NOT).

Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC (OJ L 275, 25.10.2003, p. 32–46) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32003L0087:EN:NOT).

Council Directive 2003/96/EC of 27 October 2003 restructuring the Community framework for the taxation of energy products and electricity (OJ L 283, 31.10.2003, p. 51–70) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32003L0096:EN:NOT).

Directive 2004/8/EC of the European Parliament and of the Council of 11 February 2004 on the promotion of cogeneration based on a useful heat demand in the internal energy market and amending Directive 92/42/EEC (OJ L 52, 21.2.2004, p. 50–60) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32004L0008:EN:NOT).

Directive 2005/32/EC of the European Parliament and of the Council of 6 July 2005 establishing a framework for the setting of ecodesign requirements for energy-using products and amending Council Directive 92/42/EEC and Directives 96/57/EC and 2000/55/EC of the European Parliament and of the Council (OJ L 191, 22.7.2005, p. 29–58) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32005L0032:EN:NOT).

Directive 2006/32/EC of the European Parliament and of the Council of 5 April 2006 on energy end-use efficiency and energy services and repealing Council Directive 93/76/EEC (OJ L 114, 27.4.2006, p. 64–85) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32006L0032:EN:NOT).

Directive 2008/1/EC of the European Parliament and of the Council of 15 January 2008 concerning integrated pollution prevention and control (OJ L 24, 29.1.2008, p. 8–29) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32008L0001:EN:NOT).

8 Conclusion

8.1 Top down decomposition analysis of GHG emission trends in EU-27

As has been done for various GHG-emitting sectors, a 'top down' decomposition analysis can be done for total EU-27 greenhouse gas emissions, using the factors seen as the most important in driving GHG emissions. The merit of this approach lays in its simplicity, as it reduces GHG emission trends to the influence of a limited number of drivers. Its downside is to assume that all emissions are dependent on these drivers, which is not the case in reality. Taking into account the following, energy consumption and CO_2 emissions are logically central in selection of the top down drivers:

- about 80 % of total emissions are related to energy supply and use;
- CO_2 emissions contribute with about 80 % to total GHG emissions;
- more than 90 % of all CO_2 emissions stem from fuel combustion.

Final energy consumption is primarily affected by population and the level of economic output, and drives primary energy use, which contributes directly to GHG emissions to a level depending on the carbon content of the primary energy. Any increase in these factors results in higher GHG emissions.

Table 8.1 Main factors influencing total GHG emissions

Drivers influencing emissions	Description	Input of factors to decomposition analysis as	Unit
Population	Population seen as a basic driver for emissions.	Population	Million
Economic output per capita	The gross domestic product per capita reflects the economic output within a country and is an indicator for national wealth.	GDP/Population	EUR billion '05/ Capita
Final energy intensity	The final energy intensity reflects the efficiency of energy use at end-user level, e.g. industry, households and transport. It also reflects the structure of an economy, whereby producing industries are of more relevance than services in terms of emissions.	Final energy consumption/ GDP	TJ/EUR billion '05
Fuel conversion efficiency	This driver represents a combined measure of fuel conversion efficiency (how effectively fuel is transformed into usable energy, in particular in power production) and of the share of electricity use in energy consumption from final users (final energy consumption). Efficiency improvements result in a decrease of GHG emissions, while a higher share of electricity increases the weight of transformation losses in gross inland consumption.	Gross inland energy consumption/Final energy consumption	TJ/TJ
Carbon intensity	Change in carbon intensity reflects fuel shifts from carbon-intensive fuels (e.g. coal) to gas and a changed share of renewables used for electricity generation. The lower the carbon intensity the less CO_2 is emitted per energy consumed.	CO_2 emissions/Gross inland energy consumption	Mt CO_2-equivalent/ TJ
Share of CO_2	This driver describes the importance of CO_2 compared to non-CO_2 gases (CH_4, N_2O, F-gases) in total GHG trends. It represents the extent to which the five previous drivers describe total GHG trends. It can be influenced by CO_2 trends as well as changes in GHG from chemical processes, agricultural activities and waste handling, etc.	Total GHG emissions/CO_2 emissions = 1/Share of CO_2	Mt CO_2-equivalent/ Mt CO_2-equivalent

Note: Definitions (Eurostat, 2011a): Gross inland energy consumption, sometimes abbreviated as gross inland consumption, is the total energy demand of a country or region. It represents the quantity of energy necessary to satisfy inland consumption of the geographical entity under consideration. Final energy consumption is the total energy consumed by end users, such as households, industry and agriculture. It is the energy which reaches the final consumer's door, including electricity, and excludes that which is used by the energy sector itself.

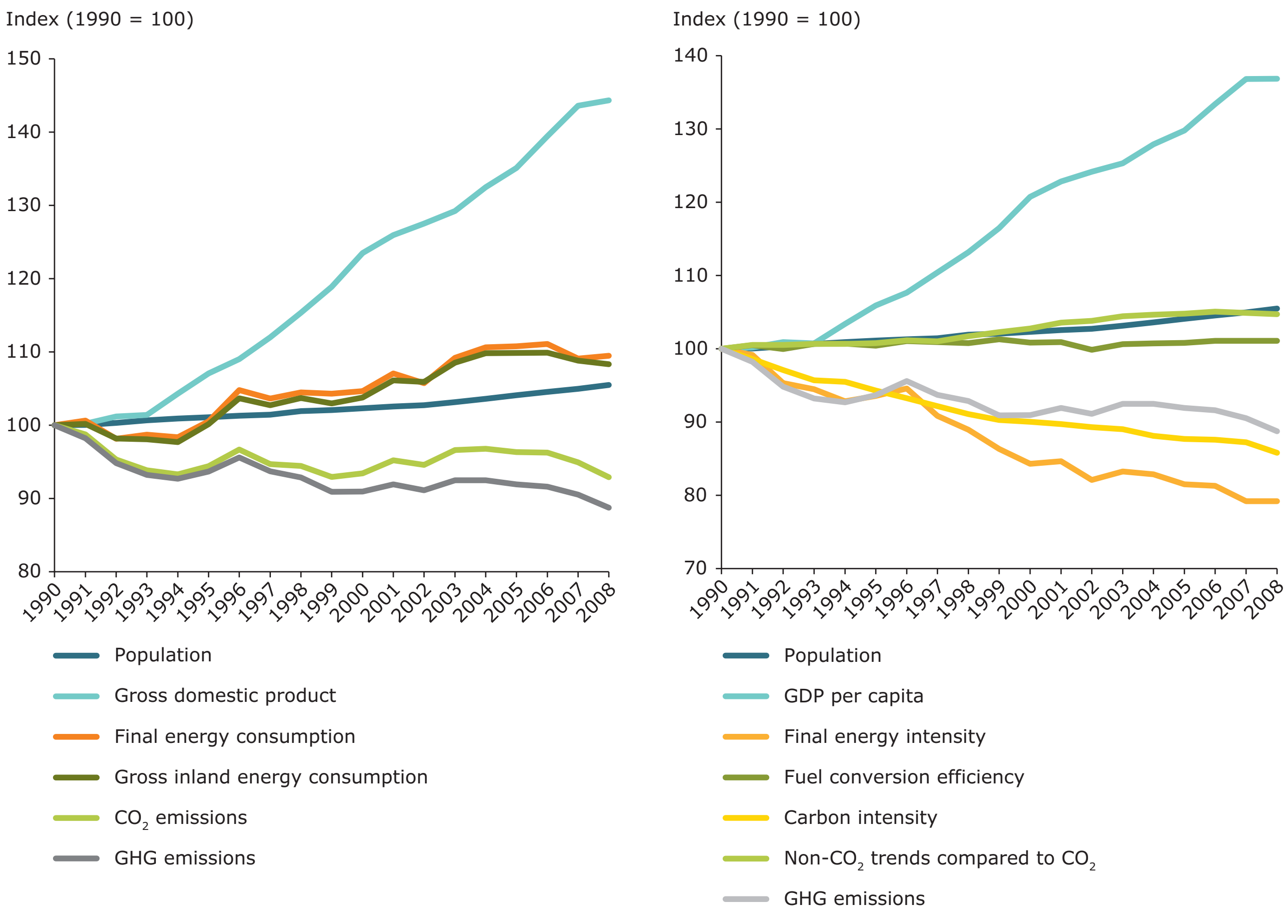
Combining these five factors into policy-relevant emission drivers allows for a top-down decomposition analysis of total GHG emissions (Table 8.1). Such top down analysis provides a general overview of the impacts of the developments of these main drivers on total emissions between 1990 and 2008 (Figure 8.1).

Despite strong economic growth during 1990 and 2008, as well as increases in EU population, energy production and energy consumption, GHG emissions decreased during this period. Final energy consumption and gross inland energy consumption follow very close trends. They both grew over the period 1990–2008, apparently due to the transport sector (Figure 8.2). Short-term variations in energy consumption were mostly due to the households sector, which adjusts its energy demand to the annual variations of climatic conditions. During the period, the share of coal was significantly reduced, while gas became dominant (Figure 8.3).

A first observation shows that the largest changes in emissions and the largest effects of the drivers, in absolute terms, occurred during the 1990s, except for the effects of population growth. This is particularly the case for the economic output increase and the reductions in energy and carbon intensity. Absolute trends were much reduced between 2000 and 2008 compared to 1990–2000 (even if the last period counts two years less than the earlier) (Figure 8.5 and Table 8.2).

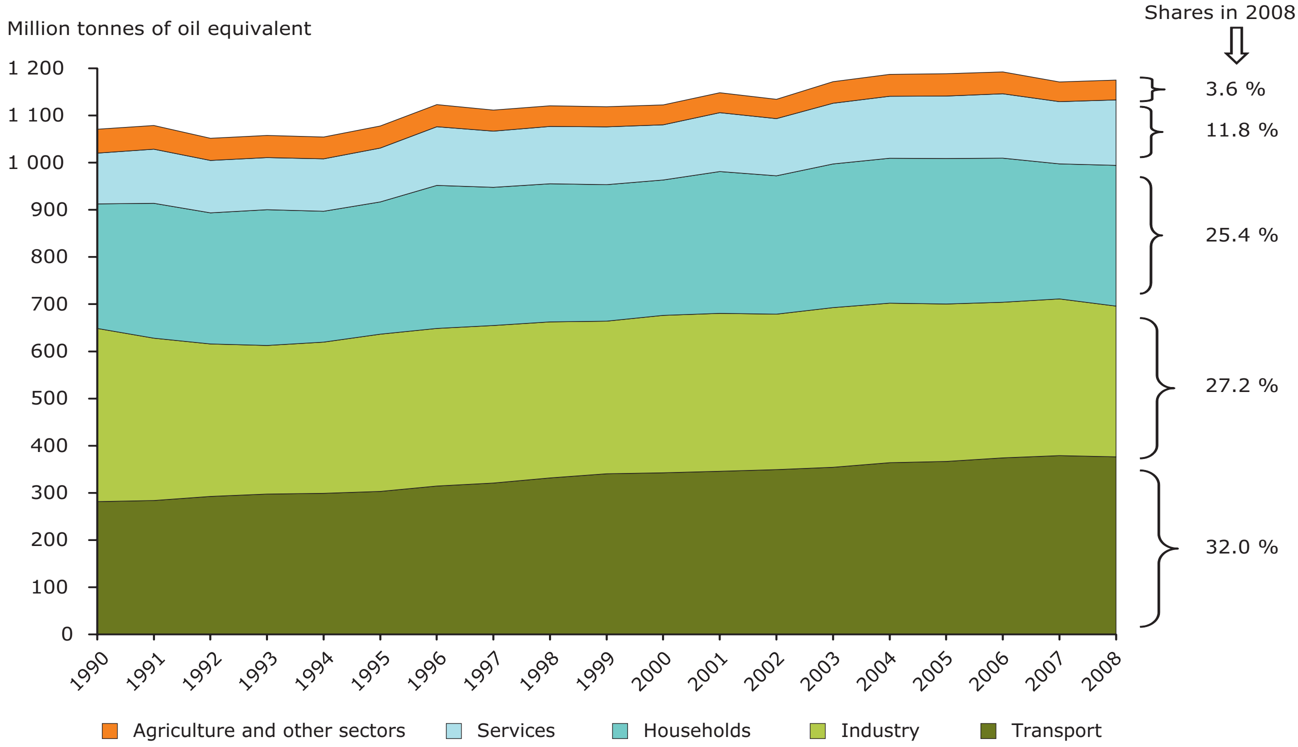
Population and economic output (GDP per capita) are basic drivers of resource and energy use related to human activities. The increase in GDP per capita had the largest effect contributing to increased emissions over the period 1990 to 2008 — especially during the first half of the period. The effects of this driver should be seen in conjunction with the development of energy intensity, the decrease of which provides opposite effects. For example, the influence of an increasing GDP per capita on GHG emissions can be reduced by a shift towards a more services-oriented economy.

Figure 8.1 Main drivers of total GHG emissions in the EU, 1990–2008



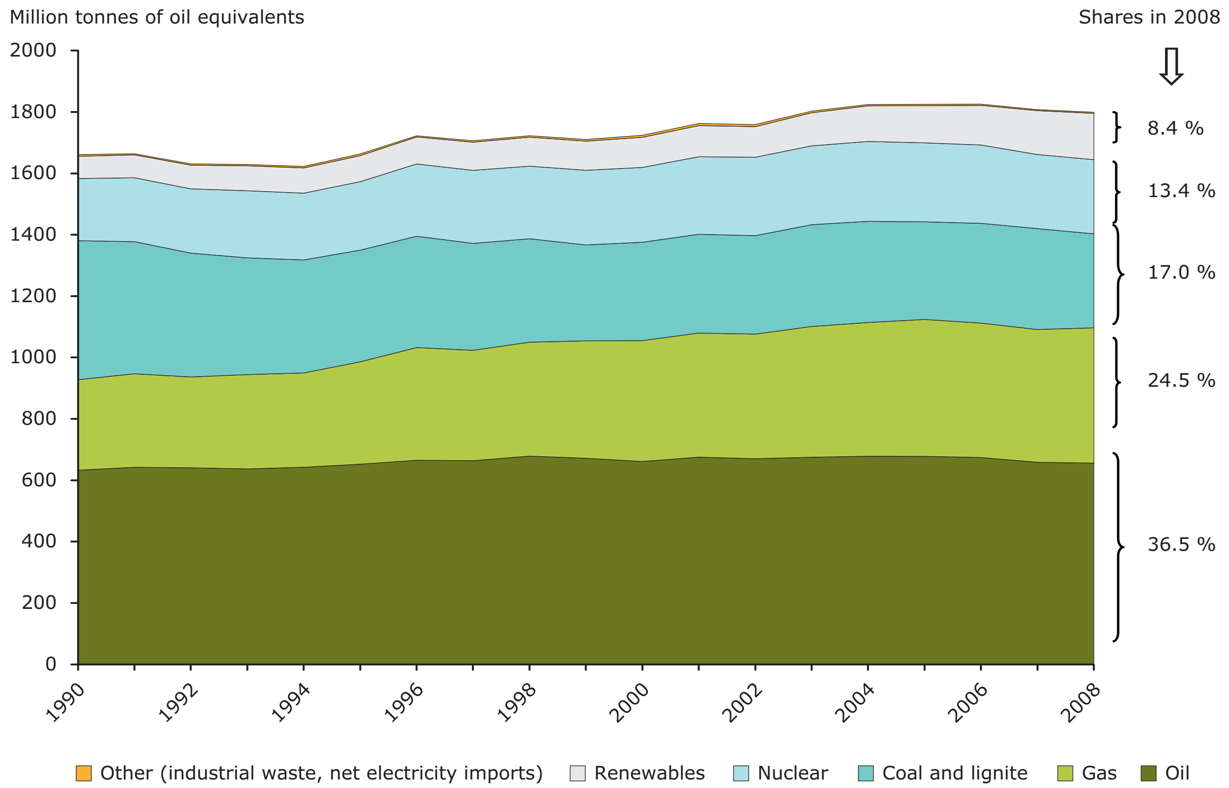
Source: EEA, 2010a; Eurostat, 2011a.

Figure 8.2 Final energy consumption by sector in the EU-27, 1990–2008



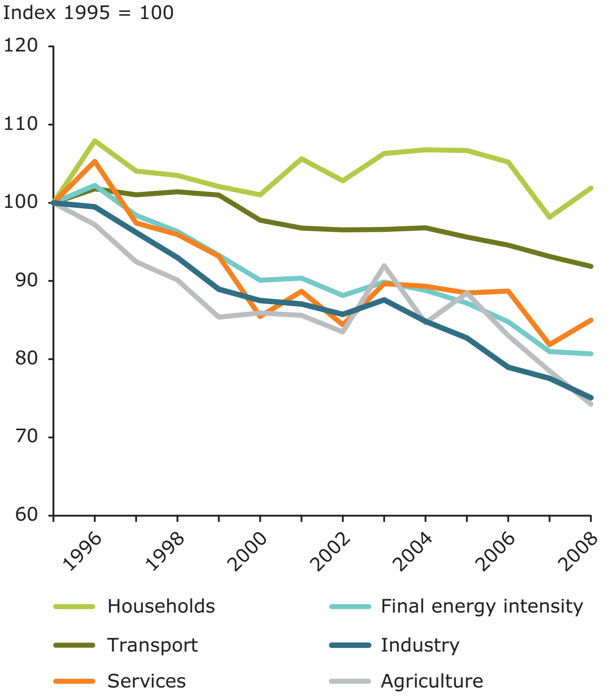
Source: Eurostat (Energy statistics: Supply, transformation, consumption — all products — annual data), 2011. See http://epp.eurostat.ec.europa.eu/portal/page/portal/energy/data/database.

Figure 8.3 Primary energy consumption by fuel in the EU-27, 1990–2008



Source: Eurostat (Energy statistics: Supply, transformation, consumption — all products — annual data), 2011. See http://epp.eurostat.ec.europa.eu/portal/page/portal/energy/data/database.

Figure 8.4 Final energy intensity by sector in the EU-27, 1990–2008



Note: Gross value added (GVA) is not available for all the countries before 1995 (as well as for EU-27 as a whole). Final energy intensities between sectors, and also the total final energy intensity, are not comparable, because the normalising variables are not the same. The indicator serves to highlight the evolution in energy intensity within each sector. The denominators for the sectoral energy intensities are, respectively: GDP for total, transport, population for households, GDP, GVA in industry for industry and GVA in services for tertiary and GVA in agriculture for agriculture.

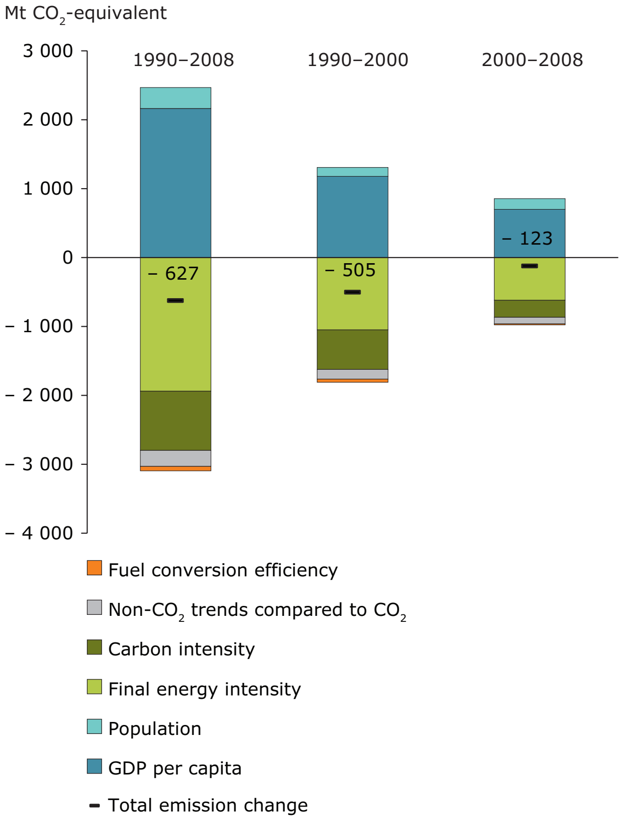
Source: EEA, 2011; Eurostat, 2011a. See www.eea.europa.eu/data-and-maps/figures/index-of-final-energy-intensity-3.

The reduction of the EU's final energy intensity had the largest impact on emissions, especially in the 1990s. The development of this driver reflects the modifications in the structure of the economy, depending on the relative importance of the different economic sectors, with varying energy intensities (Figure 8.4). A large part of this trend can be explained by the 'economic restructuring' following the collapse of the Soviet Union and its consequences in eastern Europe, which led in particular to the closure of heavily polluting industrial plants. Further improvements in energy intensity can be observed after 2000 albeit at a lower pace.

The final energy consumption is based on the total energy consumed by end users, such as households, industry and agriculture (it is the energy that reaches the final consumer's door and excludes that which is used by the energy sector itself).

The substitution of carbon-intensive fossil fuels (e.g. coal and oil) by other fuels, such as gas and renewable energy sources, has resulted in a decrease in EU's carbon intensity, thereby driving emissions down. As the conversion efficiency associated with less-carbon intensive fuels is generally higher than that for coal, the observed fuel switch — in combination with the economic restructuring of eastern Europe in the 1990s — has resulted in large improvements in fuel conversion efficiency for electricity generation. However, the decomposition analysis also shows that the driver 'fuel conversion efficiency', defined here as the ratio between gross inland energy consumption and final energy consumption, has not significantly changed during

Figure 8.5 Top-down decomposition analysis of total GHG emission trends in the EU, 1990–2008



Note: Each bar shows the contribution of a single driver on GHG emission trends during a determined period. The thick short black lines indicate the combined effect of all emission drivers, i.e. the overall GHG emission trend during the period considered.

Source: Own calculations, based on EEA, 2010a; Eurostat, 2011a.

the period from 1990 to 2008 and had therefore no significant effect on total GHG emissions. Over the period, the EU's final energy consumption remained largely equal to approximately 65 % of its gross inland energy consumption. This can be explained by the counterbalancing effects of increased electricity use by end users. In other words, over the whole period, the rising demand in electricity has been constantly offsetting the benefits coming from conversion efficiency improvements in electricity generation.

The influence of energy trade is reflected in the decomposition analyses of the energy supply sector. An import of electricity has positive effects on national emissions, as the emission caused by the production of energy (e.g. in thermal power plants) are attributed to the country providing electricity.

The contribution of non-CO_2 greenhouse gases towards total GHG emissions has decreased, which indicates that emissions from sources like agriculture, chemical industry and waste handling decreased faster than CO_2 emissions from fuel combustion.

Developments on Member State level

Population increased in most EU-27 Member States (+ 6 % between 1990 and 2008 in the EU-27). Only in the Baltic countries, Romania and Bulgaria, population decreased due to emigration waves in the early 1990s and demographic processes.

Gross domestic product per capita increased in all Member States between 1990 and 2008, which was a major driving force of GHG emissions in the EU-27.

Table 8.2 Changes in the main drivers influencing total EU GHG emissions and effects on emissions (top down decomposition analysis), 1990–2008

Group of Driver		Change in driver (%)		Effect on GHG emissions (Mt CO_2-equivalent)		Assessment
		1990–2000	2000–2008	1990–2000	2000–2008	1990–2008
Macroeconomic parameters	Population	+ 2 %	+ 3 %	129	156	Between 1990 and 2008, population increased in most countries, which leads primarily to higher emissions. If the use of energy becomes more efficient then GHG emissions per capita decrease, which was observed in many countries.
	Economic output	+ 21 %	+ 13 %	1 179	698	GDP per capita increased in all EU-27 Member States, indicating increasing national wealth. The influence of GDP on emissions was particularly significant in the 1990s.
Energy-related parameters	(Final) energy intensity	– 15 %	– 10 %	– 1 050	– 621	The EU's final energy intensity decreased due to the closure of heavily polluting industries in the 1990s, technical improvements in energy efficiency, as well as structural changes (shift towards more services, possibly coupled with the exporting of some manufacturing activities outside the EU). GDP increased considerably between 1995 and 2005 while final energy consumption increased at a lower rate.
	Fuel conversion efficiency	+ 1 %	0 %	– 48	– 13	About 65 % of the energy provided to end users is part of the gross inland energy consumption. The remaining share is the energy consumed by the energy sector plus distribution and transformation losses. Efficiency improvements reduced these losses, but their effects were offset by an increasing share of electricity in final energy consumption.
	Carbon intensity	– 10 %	– 5 %	– 576	– 249	Carbon intensity is steadily decreasing because of several reasons, such as a shift to less carbon-intensive fuels and the development of renewable energy sources.
Emissions-related parameters	Share of CO_2	+ 3 %	+ 2 %	– 139	– 94	The share of CO_2 emissions in total emissions increased, which means that non-CO_2 emissions decreased more rapidly than CO_2 emissions over the period. This was mainly achieved in the chemical industry due to N_2O abatement techniques in the adipic acid production, and in the waste and agriculture sector due to several PAMs.

Source: Own calculations, based on EEA, 2010a; Eurostat, 2011a.

This trend is dominated by the EU-15 Member States where it was stronger between 1990 and 2000. In eastern European countries, GDP per capita grew most after 2000, after significant restructuring had taken place. This was particularly the case in Bulgaria, Estonia, Latvia, Lithuania and Romania, which experienced a drop in economic output in the 1990s. Between 2000 and 2008, Poland experienced the largest increase in emissions due to its GDP increase. Almost all EU-27 Member States (except Spain and Portugal) managed to reduce their energy intensity from 1990 levels, especially in the EU-12 Member States, where structural changes within the economy occurred and heavily polluting industries were shut down. Denmark is by a long way the country with the lowest energy intensity, followed by the United Kingdom and Ireland. Denmark has decreased its energy intensity by 15 % since 1996 due to energy-saving measures in various sectors (however, imported coal is still the most important fuel in electricity generation). Finland's energy intensity is highest in the EU-15, which is due to the cold climate, long distances to be covered and the presence of energy-intensive industries.

Carbon intensity decreased in most countries in the 1990s and to a lesser extent between 2000 and 2008. Germany, France and the United Kingdom contributed most to the decreased carbon intensity in the EU in absolute terms since 1990. In Germany, this is mainly due to reunification with East Germany and subsequent restructuring of the economy in the early 1990s. The United Kingdom decreased between 1990 and 2008 its use of carbon-intense liquid fuels by 80 % and of solid fuels by 40 % for public electricity and heat production, and switched to gaseous fuels. Beside fuel shifts, the switch to renewable energy sources or the use of nuclear energy also contributed to decreasing carbon intensities. The highest relative reductions in carbon intensity since 2000 were achieved by the Czech Republic, Hungary and Sweden (more than 10 % each). The Czech Republic almost doubled its nuclear energy generation between 2000 and 2008, whereas a switch to natural gas-fired power stations occurred in Hungary.

8.2 Bottom-up synthesis of sectoral analyses

8.2.1 Main trends at sector level

The sectors for which a decomposition analysis was carried out in this report (Chapters 4 to 7) represented altogether about 72 % of total EU GHG emissions in 2008, and contributed to about half of the change in total EU-27 GHG emissions between 1990 and 2008 (Table 8.3).

For all these sectors — except solid waste management — the absolute trends from 1990 to 2008 were much more significant between 1990 and 2000 than between 2000 and 2008. This observation holds both for emission decreases and for emission increases. On average, the 1990-to-2000 trends

Table 8.3 Overview of sectors analysed through decomposition analysis

Analysed sectors	Share of EU-27 GHG emissions in 2008 (%)	Absolute change in GHG emissions		
		1990–2008	1990–2000	2000–2008
Road transport (CO_2)	17 %	184	139	46
Freight	7 %	97	50	47
Passenger cars	11 %	88	89	– 2
Agriculture (CH_4 and N_2O)	5 %	– 62	– 49	– 13
Cattle (enteric fermentation) (CH_4)	2 %	– 31	– 25	– 6
Agricultural soils (N_2O)	3 %	– 32	– 25	– 7
Solid waste management (CH_4)	2 %	– 66	– 31	– 35
Energy supply (CO_2)	27 %	– 135	– 164	29
Energy use (excluding electricity) (CO_2)	21 %	– 255	– 158	– 98
Manufacturing and construction industry	12 %	– 201	– 126	– 75
Households	9 %	– 54	– 32	– 23
All analysed sectors	**72 %**	**– 328**	**– 258**	**– 71**
Other GHG sources	28 %	– 299	– 247	– 52
Total GHG emissions (EU-27)	**100 %**	**– 627**	**– 505**	**– 123**

Source: Own calculations, based on EEA, 2010a; European Commission, 2010a; Eurostat, 2011a.

were about four times larger (in absolute terms) than the 2000-to-2008 trends. Considering the fact that dedicated climate policies started being implemented only after 2000, this means that the largest effects observed on GHG emissions are due either to external/macroeconomic factors (e.g. the collapse and restructuring of eastern economies in the early 1990s) or to the effects of policies not directly targeting GHG emission reductions.

Of the different sectors analysed, the road transport sector is the only one where significant growth in emissions has been recorded over the whole period from 1990 to 2008, both for passenger cars and freight. Although the trend in CO_2 emissions from passenger cars seems to have taken a positive turn during the period from 2000 to 2008 (overall stable trend compared with an increase during the previous period), road freight emissions represent the main trend observed that causes concern.

In the energy supply sector (public electricity and heat generation), emissions increased very steeply between 1999 and 2003, which resulted in an overall emission increase between 2000 and 2008 despite the fact that emissions from this sector had been decreasing since 2003.

Given their low share in total GHG emissions, emission reductions achieved in the agriculture and waste sectors over the full period are remarkable. In the waste sector, the reduction was even larger after 2000, potentially as a result of the Landfill Directive.

8.2.2 *Main types of drivers*

A presentation of the GHG emission drivers by type completes this assessment at sector level. The emission drivers used in the sectoral decomposition analyses of the previous chapters can be grouped in several different ways. Comparing the various drivers identified in the different sectors shows that some common features are repeated from one sector to another. Within each sector, drivers can be grouped according to:

- their influence on demand, in particular the amount of energy needed to provide heat or electricity to energy end users (this includes efficiency of combustion by industry and households);

- the amount of other resources directly linked to the production of GHG emissions (e.g. agriculture products, cattle and waste to be disposed of);

- the type of input used in a GHG-generating processes: coal, gas, renewables, nuclear, etc. for transformation into electricity or heat and cattle feed for enteric fermentation;

- other drivers.

Albeit subject to interpretation, this classification allows the grouping of all of the drivers used in the sectoral decomposition analyses into a reduced number of categories.

Table 8.3 confirms the strong influence of increasing electricity demand and road transport demand on GHG emissions. When grouped together, the drivers related to energy demand, energy efficiency and energy intensity become less prominent as their effects roughly offset each other (although efficiency improvements and intensity reductions overall remain dominated by rising energy demand). On the other hand, the role played by the type of energy source used to generate heat or electricity, including biomass and other RES, is clearly outlined. One can see in particular the very important impacts across several energy sectors that the fuel shift had on emissions. In the 1990s, this shift consisted mainly of a decrease in coal and oil use and an increase in gas, due to low gas prices, and biomass. After 2000, the increasing use of biomass and other renewables further contributed to savings. This shows, indirectly, the importance of the policies that contributed or contribute to fuel switching (e.g. the LCP and IPPC Directives in the 1990s, EU ETS after 2005) or promoted the use of biomass and other renewable energies (e.g. the RES-E Directive).

Table 8.4 also outlines the importance of improved waste management: increased waste recovery for recycling and incineration resulted in very significant emission savings, especially considering the relatively small share of emissions from this sector compared with total GHG emissions. Such improvements also provide additional benefits as they result in reducing the use of fossil fuels to produce electricity (in the case of incineration with energy recovery) and the use of raw materials for manufacturing activities (in the case of recycling).

8.2.3 *Conclusions*

A selection of the drivers that had the largest effects on sectoral emission trends shows the large dominance of energy-related drivers on GHG emissions (Table 8.5).

Rising energy demand — particularly electricity — from industrial users and households, due to

Table 8.4 Main GHG drivers aggregated by type

Sector	Drivers aggregated by main type	Effect on GHG emissions ($Mt\ CO_2$-equivalent)		
		1990–2008	1990–2000	2000–2008
All sectors	Overall energy demand, including electricity and energy efficiency/intensity	97	58	48
	Other demand-related drivers (agriculture products, waste)	– 53	– 41	– 14
	Other drivers	– 68	– 49	– 17
	Type of energy source used, including renewables	– 360	– 271	– 98
Energy supply	Amount of electricity generated	377	197	143
Road transport — freight	Amount of fuel used	102	48	55
Road transport — passengers	Amount of fuel used	96	86	10
Waste management	CH_4 intensity in landfills	42	11	28
Waste management	Amount of solid waste produced	24	18	4
Energy use — households	Amount of fuel	19	39	– 18
Agriculture — cattle	Type of feed for cattle	10	7	4
Agriculture — soils	N_2O emissions per fertiliser applied	5	3	1
Energy use — households	Temperature	2	– 15	17
Road transport — freight	Type of energy source used	– 5	2	– 7
Road transport — passengers	Type of energy source used	– 9	3	– 12
Agriculture — soils	Amount of fertiliser	– 37	– 28	– 9
Agriculture — cattle	Number of cattle	– 41	– 31	– 10
Energy use — households	Type of fuel combustion	– 75	– 56	– 21
Energy supply	Type of electricity generation	– 88	– 93	0
Energy use — industry	Type of energy source used	– 92	– 66	– 30
Energy supply	Type of energy source used	– 94	– 51	– 40
Energy use — industry	Amount of fuel used	– 110	– 60	– 45
Waste management	Type of waste treatment	– 127	– 55	– 67
Energy supply	Fuel efficiency of public thermal power plants	– 330	– 216	– 74

Source: Own calculations, based on EEA, 2010a; European Commission, 2010a; Eurostat, 2011a.

economic growth and overall wealthier population had by far the largest negative impacts on GHG emissions, necessitating energy industries' raising of their output through increased thermal power production, with direct consequences on GHG emissions. Electricity increasingly became a substitution product to fossil fuels for a number of energy end users. The rate of increase in electricity demand clearly slowed down during the 2000-to-2008 period compared with the previous one, which one may see as a positive sign resulting from the implementation of energy savings and energy efficiency policies such as the Energy Labelling Directive (1992) and its subsidiary directives promoting efficient end use of electricity.

Tackling electricity demand through a homogeneous price signal across Europe remains an unattained objective, because the minimum tax levels imposed by the 2003 Energy Taxation Directive on electricity are low and are likely to constitute too small a portion of the price of electricity to affect its consumption. It may also be too early to judge the effects of more recent policies adopted in past years, such as the 2005 Ecodesign Directive, where implementing directives were adopted only in the last few years.

Part of these consequences were counterbalanced by important improvements in the efficiency of electricity and heat generation and the decoupling of economic output (GVA) with energy demand in the manufacturing industry. These were, for the most part, driven by political and economic factors in the 1990s (the situation in eastern Europe). Still, to some extent, efficiency improvements also took place as a result of energy efficiency policies as well as of early policies aiming firstly to reduce air pollution from large industrial facilities (the LCP and IPPC Directives). Despite policy support at EU level after 2000, the development of renewables has only begun to appear as a major GHG-reducing factor compared with these drivers at EU level and therefore represents an important future challenge for further reducing EU emissions from energy supply. However in some Member States, renewable energy already contributes considerably to national GHG emissions reductions.

In the households sector, however, a shift to gas in the 1990s and to electricity after 2000, combined with reduced energy use per household, are offsetting the effects of an increasing number of dwellings.

Road transport demand also appears to constitute a major concern for total GHG emissions, in particular in the freight sector where the negative effect of increasing transported volumes is adding up to the increasing share of road compared with other less carbon-intensive modes, despite some policy initiatives to promote a modal shift. Between 1997 and 2007, road freight volumes increased by 43 %, while volumes transported by rail freight and on inland waterways increased by only 10 % during this period, thereby reducing their market share. As freight transport is continuing to grow slightly faster than the economy, no policy has proved successful in curbing this trend, despite efforts to promote modal shift through policy initiatives such as the first and second Railway packages or the first and second Marco Polo Programmes. Although the recent economic downturn has had a short-term impact on growth rates, the overall trend suggests that the least energy-efficient modes of travel will continue to increase in the long term (EEA, 2010b).

For road passenger transport, the effects of car efficiency improvements and of a higher share of diesel cars are starting to level off with the effects of the rising passenger transport demand — which was cut by two in the period from 2000 to 2008, compared with the previous decade.

In the agriculture and the waste sectors, no driver is responsible for large emission increases, while a number of elements contribute to reduce emissions significantly: decrease in cattle numbers, in cropland area and in fertiliser use, and in landfilled waste, and increased recovery of landfill gas. Some of the EU policies are no stranger to these developments: the CAP reforms, through milk quotas, reduced intervention prices and single farm payments, set-aside land, the Nitrates Directive and the Landfill Directive made remarkable contributions to these observed sectoral trends.

As was the case with the LCP Directive and the IPPC Directive, which primarily targeted air pollution (the LCP Directive) or various pollutants from several media (the IPPC Directive) but not directly GHG emissions, the observed effects of the Nitrates Directive on GHG emission show the merits of integrated mitigation approaches. Imposing strict limits on emissions of air, water or soil pollutants other than GHGs can therefore be used as a means to control GHG emissions in various sectors.

A number of policies were implemented in recent years in several domains including transport, renewables or ecodesign, and may result in future GHG emission savings. However, observing their effects on GHG emission trends until 2008 is difficult due to the brief observation period. Initial studies of the EU ETS have shown that it can achieve emission reductions through efficiency improvements and fuel switching under relatively high carbon prices. The role of the EU ETS in EU climate policy has become increasingly important as demonstrated by the revision of the EU ETS Directive (Directive 2003/87/EC) in the climate and energy package, setting now linear ETS targets beyond 2020.

Several EU directives have contributed to reducing energy use in the households sector. As is the case of electricity production, the minimum levels of energy taxation set at EU level did not in the period considered represent a significant enough share of energy prices (in most Member States) to drive consumption levels down. Switching from fossil fuels to public electricity as an energy source, both for the cases of industrial users and households, results in a transfer of the emissions linked to electricity or heat use from these sectors to the energy supply sector. Since 2005, this shift has also resulted in the transfer of emissions into a sector covered by the EU ETS. On the other hand, the reduction of electricity demand by households — or any other electricity end user which does not produce its own electricity — due, for example, to the implementation of energy efficiency measures, may have impacted the demand for allowances in the EU ETS. This provides an example of the importance of monitoring the impacts of measures across sectors.

Table 8.5 Effects of significant GHG emission drivers and main factors underpinning these changes between 1990 and 2008

Sector	Largest emission drivers by sector	Change in driver (%)		Effect on GHG emissions (Mt CO_2-equivalent)			Main underpinning factors Linked policies (1990–2008)
		1990–2000	2000–2008	1990–2008	1990–2000	2000–2008	
Electricity generation	Electricity demand	+ 16 %	+ 12 %	425	231	148	Economic growth, increasing electrification in the EU and increasing number of appliances per household Energy Labelling Directive and subsidiary directives, Energy Taxation Directive (no impact)
	Share of biomass for public electricity and heat production	+ 119 %	+ 97 %	− 104	− 34	− 64	Autonomous development RES-E Directive, EU ETS (with meaningful carbon prices)
	Fuel efficiency of public thermal power plants	+ 16 %	+ 5 %	− 330	− 216	− 74	Closure of old inefficient plants in the 1990s, improvements in existing technologies, switch from coal power plants to combined cycle gas-turbines and increase in the use of co-generation LCP Directive, IPPC Directive, CHP Directive, EU ETS
Energy use (manufacturing and construction industry)	Gross value added	+ 17 %	+ 5 %	184	132	37	Economic development
	Carbon intensity of direct fuel combustion	− 7 %	− 2 %	− 57	− 53	− 10	Fuel switch from coal to oil and gas due to low gas price in the 1990s LCP Directive, IPPC Directive, EU ETS (with high carbon prices)
	Energy intensity	− 24 %	− 5 %	− 272	− 223	− 35	Closure of a large number of heavily polluting plants in the 1990s in eastern Europe, energy efficiency improvements, shift towards less energy-intensive economic activities, low gas prices (for CCGTs) LCP Directive, IPPC Directive, EU ETS (with high carbon prices), motor challenge and CEMEP voluntary agreement, CHP Directive
Energy use (households)	Number of persons per household	− 7 %	− 5 %	74	41	28	
	Energy use per household	+ 1 %	− 7 %	− 40	3	− 38	Smaller number of people per household Boiler Efficiency Directive, Energy Performance of Buildings Directive, Ecodesign Directive, Energy Services Directive
	Share of electricity and district heat in households' energy use	+ 9 %	+ 12 %	− 44	− 18	− 23	Switch from fossil fuel use to electricity, autonomous increase in the number of electrical appliances used by households overall Boiler Efficiency Directive, SAVE Directive, Energy Performance of Buildings Directive
	Carbon intensity of direct fuel combustion	− 8 %	− 1 %	− 44	− 42	− 5	Switch to less carbon-intensive fuels (e.g. from coal to gas) due to low gas prices
Passenger transport	Passenger transport demand	+ 21 %	+ 9 %	138	92	46	Longer travelled distances Energy Taxation Directive (no impact)
	Fuel intensity	− 6 %	− 6 %	− 72	− 36	− 33	Efficiency improvements in cars, fuel prices, shift from gasoline to diesel-driven cars (vs. reduction of occupancy rates of cars) Voluntary agreements with car manufacturers, Car Labelling Directive

Table 8.5 Effects of significant GHG emission drivers and main factors underpinning these changes between 1990 and 2008 (cont.)

Sector	Largest emission drivers by sector	Change in driver (%)		Effect on GHG emissions (Mt CO_2-equivalent)			Main underpinning factors Linked policies (1990–2008)
		1990–2000	2000–2008	1990–2008	1990–2000	2000–2008	
Freight transport	Freight transport demand	+ 19 %	+ 18 %	91	42	50	Economic growth
	Share of road transport (trucks) in total freight transport	+ 21 %	+ 5 %	84	55	16	Lower price compared to other modes (e.g. rail) Marco Polo Programmes (I and II), first and second Railway packages
	Fuel intensity	– 15 %	– 3 %	– 73	– 49	– 12	Autonomous technical improvements in trucks (mainly in engine efficiency)
Agriculture (cattle)	Milk yield	+ 6 %	+ 3 %	– 20	– 13	– 8	Decollectivisation (affecting cattle number) Improved feedstock and machinery CAP reforms: successive reductions of the intervention price (MacSharry reform and Agenda 2000)
	Number of non-dairy cattle	– 16 %	– 5 %	– 15	– 12	– 3	Decollectivisation Reductions of the intervention price under the CAP
Agriculture (soils)	Cropland area	– 2 %	– 3 %	– 9	– 3	– 5	Increases in crop yields CAP reforms (reduction of intervention prices, set-aside land) and market adjustments from EU enlargement or international trade agreements
	Synthetic fertiliser per cropland area	– 16 %	– 8 %	– 19	– 14	– 6	Nitrates Directive
Solid waste disposal	Treatment of MSW other than incineration and landfilling	+ 40 %	+ 40 %	– 57	– 24	– 30	Landfill Directive
	CH_4 recovery of landfills	+ 72 %	+ 47 %	– 58	– 28	– 31	
	CH_4 intensity in landfills	+ 7 %	+ 27 %	42	11	28	Decreasing trend in the disposal of waste to landfills combined with decay of landfilled waste Landfill Directive

Source: Own calculations, based on EEA, 2010a; European Commission, 2010a; Eurostat, 2011a.

9 Acronyms and abbreviations

ACEA	Association des Constructeurs Européens d'Automobiles (European Automobile Manufacturers Association)
CAP	Common Agricultural Policy
CCGT	Combined cycle gas turbine
CEMEP	Comité Européen de Constructeurs de Machines Electriques et d'Electronique de Puissance (European Committee of Manufacturers of Electrical Machines and Power systems)
CH_4	methane
CHP	combined heat and power
CO_2	carbon dioxide
CO_2–eq.	carbon dioxide equivalent
CRF	common reporting format
ECCP	European Climate Change Programme
EEA	European Environment Agency
ERP	Energy-related product
EU	European Union
EU ETS	European Union Emissions Trading System
EU-12	Bulgaria, Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia, Slovenia
EU-15	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom
EU-27	EU-12 + EU-15
EuP	Energy-using products
ETC/ACM	European Topic Centre on Air pollution and Climate change Mitigation
F-gas	fluorinated greenhouse gas
GDP	gross domestic product
GFP	good farming practice
GHG	greenhouse gas
GVA	gross value added
GWP	global warming potential
IPCC	Intergovernmental Panel on Climate Change
IPPC	integrated pollution prevention and control
JAMA	Japan Automobile Manufacturers Association
KAMA	Korea Automobile Manufacturers Association
LCP	large combustion plant
LULUCF	land use, land-use change and forestry
MAC	Mobile air-conditioning system
Mt	Mega (million) tonnes
MSW	municipal solid waste
N_2O	nitrous oxide
NIR	national inventory report
NVZ	nitrate vulnerable zone
ODEX	Energy efficiency index

OJ	Official Journal of the European Union
PAMs	policies and measures
Pkm	passenger kilometre
PPS	purchasing power standard
RES	renewable energy source
RES-E	electricity generation from renewable energy sources
SFP	Single Farm Payment
TERM	Transport and Environment Reporting Mechanism
Tkm	tonne kilometre
Toe	tonne of oil equivalent
UNFCCC	United Nations Framework Convention on Climate Change

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