Analysis of key trends and drivers in greenhouse gas emissions in the EU between 1990 and 2014

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European Environment Agency

European Environment Agency
Kongens Nytorv 6
1050 Copenhagen K
Denmark

Tel.: +45 33 36 71 00
Web: eea.europa.eu
Enquiries: eea.europa.eu/enquiries

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This paper briefly analyses the major factors that accounted for decreased greenhouse gas (GHG) emissions excluding land use, land use changes and forestry (LULUCF) in the EU-28. It consists of two parts: the first part looks at the year 2014 compared to 2013 and the second part looks at the whole period between 1990 and 2014. The data is based on the EU's GHG inventory submission to UNFCCC in 2016[1]. The paper ends with a quick overview of emission estimates for 2015 from other sources.

Contents

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[1] The EU GHG inventory comprises the direct sum of the national inventories compiled by the EU Member States making up the EU-28. In addition, the European Union, its Member States and Iceland have agreed to jointly fulfil and report on their quantified emission limitation and reduction commitments for the second commitment period to the Kyoto Protocol. In this paper the analysis is based on the EU-28 reporting under the UNFCCC (i.e. Convention reporting).

The main institutions involved in compiling the EU GHG inventory are the Member States, the European Commission Directorate-General Climate Action (DG CLIMA), the European Environment Agency (EEA) and its European Topic Centre on Air Pollution and Climate Change Mitigation (ETC/ACM), Eurostat, and the Joint Research Centre (JRC). More information on the EU GHG inventory, including the GHG data viewer can be found on the EEA's website at: http://www.eea.europa.eu/publications/european-union-greenhouse-gas-inventory-2016

1 GHG emissions in 2014 compared to 2013

1.1 Summary (last year)

Total GHG emissions (excluding LULUCF) decreased by 185 million tonnes, or 4.1% compared to 2013[2] to reach their lowest level in 2014 (4282 Mt CO_2 eq.). This significant decrease in emissions in 2014 came with an increase in GDP of 1.4 %. This resulted in a lower GHG-emission intensity of GDP in the EU in 2014, which can be attributed to the sharp decline in the consumption of heat and electricity. This was in turn triggered by the lower heat demand by households due to the milder winter conditions in Europe. The sustained increase in non-combustible renewables, particularly wind and solar, for electricity generation also contributed to lower emissions in 2014. Over 80 % of the total GHG emissions reduction in 2014 was accounted for by lower CO_2 emissions from gas and solid fuels from thermal power stations as well as by lower CO_2 emissions from gas in the residential and commercial sectors. Primary energy consumption declined overall, with fossil emissions decreasing for all fuels, particularly for natural gas, but also for hard coal and lignite. The consumption of renewables increased in terms of primary energy. This led to a further improvement of the carbon intensity of the EU energy system in 2014. Germany and the United Kingdom accounted for about 45% of the total GHG-emissions reduction at EU level in 2014.

1.2 Overall results at EU level

Total GHG emissions (excluding LULUCF) in the EU decreased again in 2014 reaching their lowest level since 1990 (4282 Mt CO_2 eq.). In 2014, EU emissions were 4.1% below 2013 levels and accounted for a net reduction of 185 million tonnes of CO_2-equivalents. Compared to 1990, total GHG emissions were 24.4% lower in 2014 (23% lower when including international aviation).

Figure 1 breaks down the 4.1% overall reduction in GHG emissions compared to 2013 into several factors using the Kaya decomposition identity[3]. Of these, the lower energy intensity of GDP played the biggest role (yellow section) in bringing emissions down, as the economy required less primary energy per unit of GDP. The carbon intensity of energy also improved in 2014 (red section), which reflects the lower use of very carbon intensive fuels like coal, and of fossil fuels in general, and an increase in the (primary) consumption of renewables. The two factors driving emissions down were partially offset by higher population and GDP as well as by a higher share of non-combustion (i.e. non-energy related) emissions in total GHG emissions.

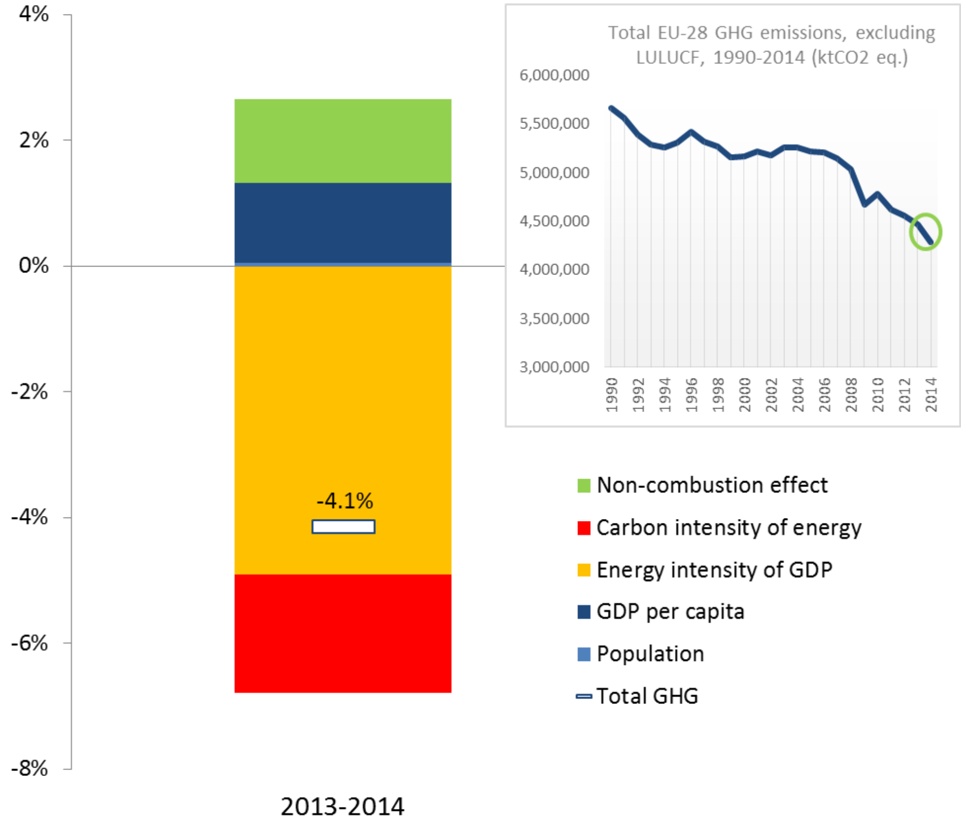
[2] The current analysis focuses on GHG emission trends in the EU-28 and is based on Member States' GHG inventories by 15/04. Thus, some of the country data in this paper may be slightly different from the latest inventory submissions to UNFCCC.

[3] The chosen factors are an extension of the Kaya identity. The annual decomposition analysis shown in this paper is based on the Logarithmic Mean Divisia Index (LMDI) method. The equation for the aggregated decomposition analysis is:

(y) [ln]GHG = (x_1) [ln]POP + (x_2) [ln]GDP/POP + (x_3) [ln]PEC/GDP + (x_4) [ln]GHG_en/PEC + (x_5) [ln]GHG/GHG_en, where:

(y) GHG: total GHG emissions; (x_1) POP: population (population effect); (x_2) GDP/POP: GDP per capita (affluence effect); (x_3) PEC/GDP: primary energy intensity of the economy (primary energy intensity effect); (x_4) GHG_en/PEC: energy-related GHG emissions in primary energy consumption (carbon intensity effect); (x_5) GHG/GHG_en: total GHG emissions in energy-related GHG emissions (non-combustion effect).

Figure 1 Decomposition of the annual change in total GHG emissions in the EU-28 in 2014



Note: The explanatory factors should not be seen as independent of each other. The bar segments show the changes associated with each factor alone, holding the respective other factors constant.

Source: EEA.

Overall, the four main findings from the decomposition analysis of figure 1 are:

i. The reduction of 4.1% in total GHG emissions came along with an increase in GDP of 1.4% in 2014, showing that emission improvements are not necessarily at odds with a growing economy[4]. As it will be shown, however, weather factors, which are independent of economic growth, are broadly responsible for the substantial reduction in emissions in 2014.

ii. The decrease in total GHG emissions was almost fully-driven by emission reductions in the energy sector, particularly in electricity and heat production and in the residential and commercial sectors. As explained below this was due to significantly warmer conditions in Europe in 2014 and by the increase in non-combustible renewables for electricity generation. The relative weight of non-combustion emissions, such as those from industrial processes, agriculture and waste, increased in 2014. For industrial processes and agriculture, emissions did increase in 2014.

iii. The lower carbon intensity of energy was a key factor underpinning lower emissions in 2014 in spite of the decline in nuclear electricity production. Fossil fuel consumption fell substantially for all fuels. Thus, the lower carbon intensity is by and large accounted for by a higher relative-contribution from renewable energy sources in the fuel mix. According to Eurostat, the share of renewable energy in gross final energy consumption (normalised to even out the annual variability in hydro and wind production) reached 16% in 2014, up from 15% the year before. In fact, the carbon intensity of fossil fuels for the whole energy-combustion sector (i.e. excluding renewables and

[4] For an overview of the effect of GDP on GHG emissions, see section 7 of 'Why did GHG emissions decrease in the EU between 1990 and 2012' published in 2014 http://www.eea.europa.eu/publications/why-are-greenhouse-gases-decreasing

nuclear) increased as gas consumption fell faster than coal consumption. Thus, the contribution from renewables, and the stagnation in nuclear electricity production, led to an overall improvement of the carbon intensity of energy production and use in the EU.

iv. The decrease in primary energy intensity was the largest contributing factor to lower GHG emissions. Total energy consumption decreased while GDP increased, leading to an improvement in the energy intensity of the EU economy as a whole. As it will be shown, this improvement in energy intensity was largely driven by lower heat demand. The improvement occurred in spite of a worsening of the energy efficiency of the overall EU economy due to the lower heat to electricity ratio. The lower efficiency was partly offset by an increase in non-combustible renewables, particularly from wind and solar electricity production, and in non-energy use. The moderate increase in gross value added in the industrial sector compared to pre-2008 levels, where growth was faster, also contributed to lower consumption of electrical output in 2014.

1.3 Largest emission changes by sector at EU level

We now look deeper into the sectors accounting for the largest reduction in emissions. These sectors were also the main contributors to the lower energy intensity and lower carbon intensity of the EU economy in 2014. Table 1 shows that the largest reductions in emissions occurred in electricity and heat production and in the residential and commercial sectors.

The combined CO_2-emission reduction from these sectors represented around 94% of the total EU net-reduction in 2014. Why these sectors? The common denominator in both sectors is heat consumption, which is either distributed, such as in the case of main-activity electricity and heat production, or direct (heat) consumption in the case of residential and commercial.

Table 1 Overview of the largest emission changes by key sector in EU-28, 2013-2014

Source category	**Million tonnes (CO_2 equivalents)**
Road Transportation (CO_2 from 1.A.3.b)	6.6
Iron and steel production (CO_2 from 1.A.2.a +2.C.1)	5.6
Cement Production (CO_2 from 2.A.1)	3.4
Chemicals: Fuels (CO_2 from 1.A.2.c)	-3.1
Petroleum Refining (CO_2 from 1.A.1.b)	-4.2
Managed Waste Disposal Sites (CH_4 from 5.A.1)	-4.6
Manufacturing industries (excl. Iron and steel) (Energy-related CO_2 from 1.A.2 excl. 1.A.2.a)	-18.1
Commercial/Institutional (CO_2 from 1.A.4.a)	-22.5
Residential (CO_2 from 1.A.4.b)	-65.6
Public Electricity and Heat Production (CO_2 from 1.A.1.a)	-85.1
Total	-185.0

Note: The table shows only those sectors where emissions have increased or decreased by at least 3 million tonnes of CO_2 equivalent between 2013 and 2014. The table reflects the emission reductions according to the EU's geographical scope under KP and includes Iceland.

Source: EEA.

GHG inventories provide evidence of the fuel input and the emissions output from electricity and heat production, but without distinguishing between emissions from heat and from electricity. Solid fuels and natural gas accounted for the bulk of the reduction in fuel input to the energy-transformation process in 2014. The reduction in the consumption of solid fuels in the heat and power sector was twice as strong as the reduction in natural gas use. This lead to a sharp reduction in CO_2 emissions from main-activity heat and electricity plants, which was 7.4% lower than in 2013 for the EU as a whole. The question is whether the trigger for such large reduction was lower heat output or electricity, or both.

According to energy statistics reported to Eurostat, there was a sharp decline in both heat output and electricity output from main-activity conventional thermal power stations (including district heating). The reduction in distributed/derived heat production was one of the largest of the past 24 years since 1990. The reduction in electricity production continues the downward trend that started in 2008 and can partly be explained by the sustained strong increase in electricity from renewable energy sources, particularly of wind and solar, as well as by moderate (as opposed to strong) economic activity in the industrial sector compared to pre-2008 levels. In addition, electricity in some countries is also used for heating purposes, so part of the reduction in electricity in 2014 may also be attributed to lower heat demand in these countries.

Most of the heat consumption in the EU is not supplied via distributed systems from thermal stations but occurs as a process of direct combustion in buildings. The consumption and emissions of the residential and commercial sectors reported in GHG inventories capture by and large the bulk of heat consumption and emissions from fossil fuels. The year 2014 represents both the lowest-ever heat consumption by households in the EU and the largest decline from year to year. Overall, the reduction in CO_2 emissions in the residential and commercial sectors reached a staggering 15% in 2014.

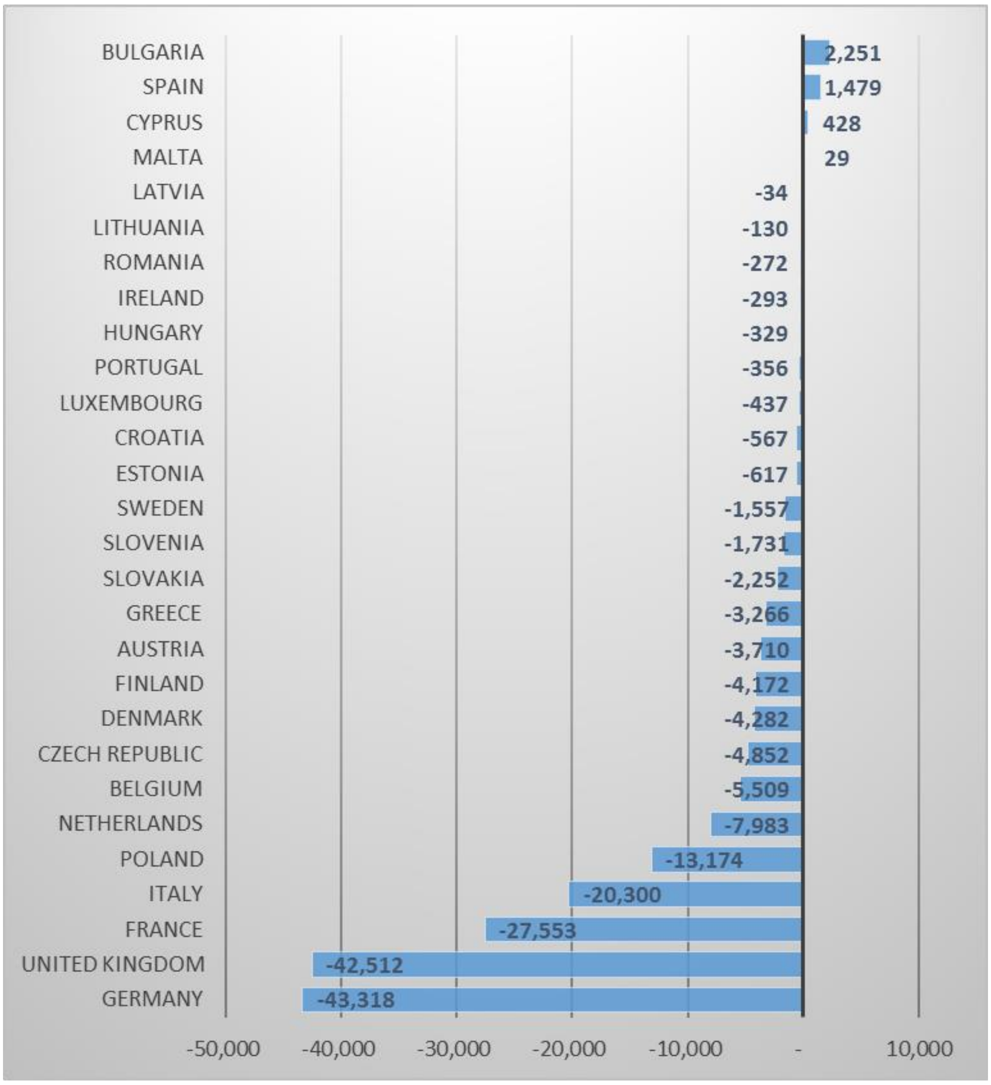
It is worth noting that CO_2 emissions from road transportation increased in 2014 after 6 years of consecutive reductions.

All in all, there is evidence that lower heat demand and consumption is one of the key reasons for the strong decrease in emissions in 2014. The continued increase in renewables for electricity generation also contributed to this decline in emissions as well as to lowering the dependence on fossil fuel generation.

1.4 Largest Member State contributions to the positive EU performance

Figure 2 shows the absolute change in total GHG emissions, excluding LULUCF, by Member State (MS) between 2013 and 2014. Emissions decreased in almost all Member States. Six MS [DE, UK, FR, IT, PL and NL] accounted for almost 85% of the EU total net reduction of 185 million tonnes of CO_2 eq. in 2014. The two largest emission reductions occurred in Germany and the United Kingdom, which combined represented about 45% of the EU reduction in 2014. The main reasons for the decrease in emissions in Germany are linked to a substantial decrease in electricity generation, in spite of a positive export balance, the increase in renewables, particularly from wind and photovoltaics, and the milder weather conditions which led to lower heat demand in commercial buildings and homes. In the case of the UK, the strong reduction in emissions was primarily due to the extraordinary warm 2014 year, which reduced demand for heating, as well as to the increase in renewables for electricity generation.

Figure 2 Change in total GHG emissions, excluding LULUCF, between 2013 and 2014 by EU Member State [kt CO_2 equivalent]



Source: EEA.

As shown in the previous section, the largest reductions in emissions at EU level occurred in electricity and heat production and in the residential and commercial sectors. A closer analysis at country level shows that the top 10 contributors to the reduction in GHG emissions in the EU in 2014 were: a) lower coal use in heat and electricity plants in DE, FR, UK and PL; b) lower use of natural gas in heat and electricity plants in IT; and c) lower use of natural gas in the residential sector in DE, FR, UK, IT and NL. All these together can explain almost 60% of the total reduction in EU emissions in 2014. This is shown in table 2.

Table 2 Top 10 contributors to the total GHG emission reduction in the EU in 2014

Ranking in top 10	Member State	Sector	Gas	Fuel	Reduction (kt)	% total EU reduction
1	United Kingdom	Electricity & Heat Production	CO2	Solid fuels	-26,192	14.2%
2	Germany	Electricity & Heat Production	CO2	Solid fuels	-14,512	7.8%
3	United Kingdom	Residential combustion	CO2	Gaseous fuels	-11,861	6.4%
4	Germany	Residential combustion	CO2	Gaseous fuels	-10,061	5.4%
5	France	Electricity & Heat Production	CO2	Solid fuels	-9,903	5.4%
6	Poland	Electricity & Heat Production	CO2	Solid fuels	-9,235	5.0%
7	Italy	Residential combustion	CO2	Gaseous fuels	-7,572	4.1%
8	France	Residential combustion	CO2	Gaseous fuels	-6,423	3.5%
9	Italy	Electricity & Heat Production	CO2	Gaseous fuels	-5,393	2.9%
10	Netherlands	Residential combustion	CO2	Gaseous fuels	-5,183	2.8%
Sum of top 10	-	-	*CO2*	-	*-106,334*	*57.5%*
EU total net reduction	-	*all sectors excluding LULUCF*	*GHG*	-	*-185,026*	*100.0%*

Note: The emissions-threshold to achieve the top 10 was set at 5 million tonnes. Table 2 (at MS level) builds from the two largest emission sources shown in table 1 (EU level).

Source: EEA.

Clearly, there are strong indications that lower heat demand and consumption is the key determinant for the decrease in emissions in 2014, not only in the EU as a whole but also at MS level. Other reasons can indeed be at play, including the continued increase in renewable energy for electricity generation. The next section will show that milder winter conditions in 2014 can by and large explain the reduction of 185 million tonnes of CO_2 equivalent in the EU.

1.5 Weather conditions as a key driver of emissions in 2014

There is evidence of significantly lower heat consumption and heat demand in the residential and commercial sectors, and partly in the power sector, due to warmer weather conditions in Europe during 2014 compared to 2013. In fact the year 2014 was the hottest year on record in Europe with mean annual near-surface temperatures over land 2.11 to 2.16 °C higher than the pre-industrial average[5].

Based on data for Europe from the UK's Met Office Hadley Centre, the average monthly near-surface temperatures over land were substantially higher in most months where heating is usually needed[6]. Furthermore, according to Eurostat and EEA data, there was a 13% decrease in the number of heating degree days (an indicator of household demand for heating) in the EU in 2014 compared to 2013. This affected almost every month of the autumn and winter seasons. Thus, mean temperatures for Europe as well as heating degree days strongly suggest that warmer winter conditions in 2014 are largely responsible for the decrease in fuel use and emissions from buildings (residential, commercial and

[5] http://www.eea.europa.eu/data-and-maps/indicators/global-and-european-temperature-1/assessment

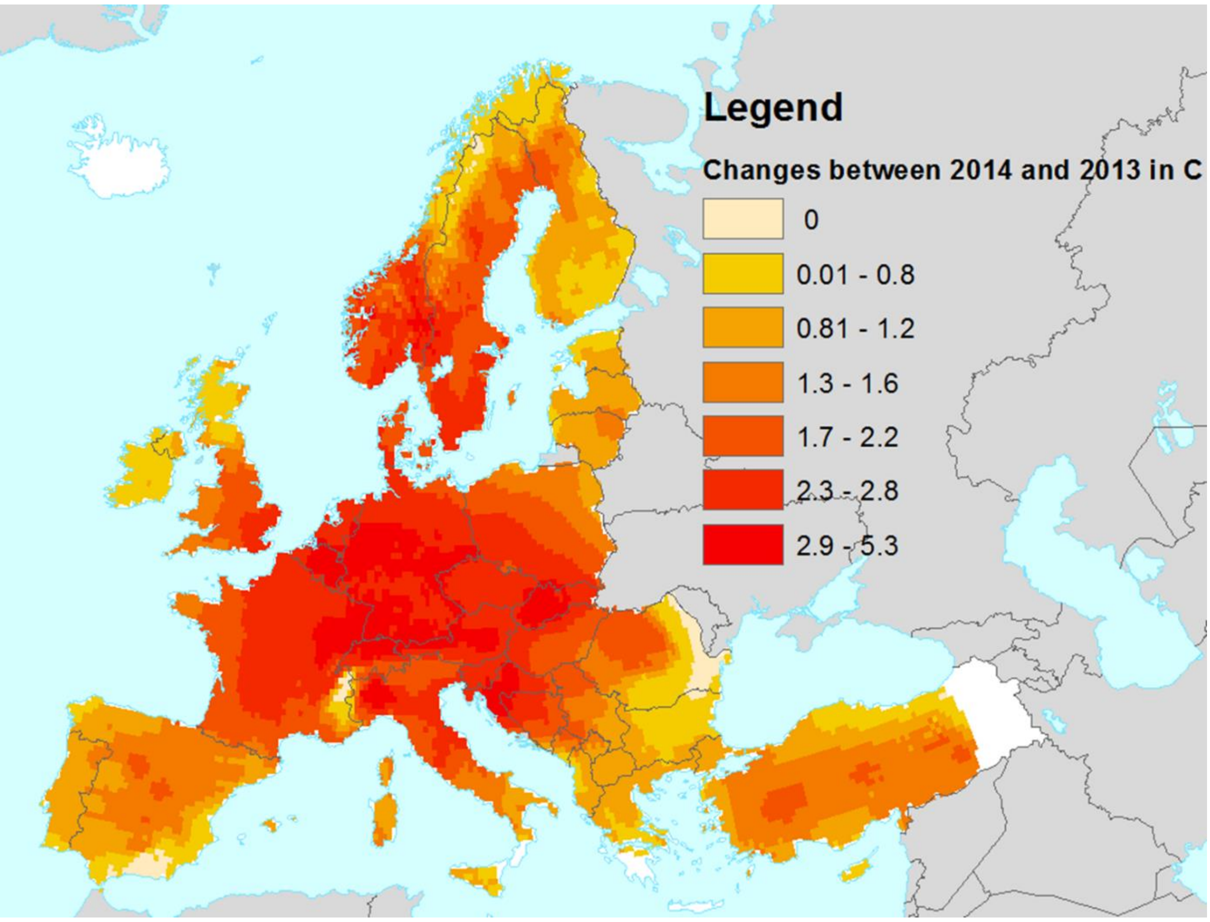
[6] Other international sources, such as the National Aeronautics and Space Administration Goddard Institute for Space Studies (NASA's GISS) and the National Oceanic and Atmospheric Administration's National Climatic Data Centre (NOAA's NCDC), also confirm average warmer conditions in Europe in 2014 compared to 2013.

institutional) that year. This result is statistically significant on average for the EU, when considering the evolution of HDDs and GHG emissions in 2014 in all MS.

Figure 3 below, which is based on daily gridded data (E-OBS)[7], illustrates the difference in average annual near-surface temperatures in Europe between 2013 and 2014. The map shows that, notwithstanding regional variability, mean temperatures in most parts of the continent were higher, or much higher, in 2014 compared to 2013.

All in all, the lower emissions in the EU in 2014 can be attributed to the sharp decline in the consumption of heat and electricity. This was due to lower heat demand from the milder winter/autumn conditions and to the continued increase in renewables for electricity generation, particularly of wind and solar.

Figure 3 Mean near-surface temperature change between 2013 & 2014 in Europe: average temperature of the season January, February, March, October, November and December



Source: EEA. Data source for the underpinning daily gridded temperatures, http://www.ecad.eu/

7 The European Climate Assessment & Dataset (ECA) contains series of daily observations at meteorological stations throughout Europe and the Mediterranean. E-OBS dataset from the EU-FP6 project ENSEMBLES (http://ensembles-eu.metoffice.com) and the data providers in the ECA&D project (http://www.ecad.eu). Haylock, M.R., N. Hofstra, A.M.G. Klein Tank, E.J. Klok, P.D. Jones, M. New. 2008: A European daily high-resolution gridded dataset of surface temperature and precipitation. J. Geophys. Res (Atmospheres), 113, D20119, doi:10.1029/2008JD10201

2 GHG emissions trends between 1990 and 2014

2.1 Summary (last 24 years)

Total GHG emissions (excluding LULUCF) in the EU-28 decreased by 1383 million tonnes since 1990 (or 24.4 %) reaching their lowest level during this period in 2014 (4282 Mt CO_2 eq.). The EU-28 reduction including international aviation was 23%, or 1317 Mt CO_2 eq. There has been a progressive decoupling of gross domestic product (GDP) and GHG emission compared to 1990, with an increase in GDP of about 47 % alongside a decrease in emissions of over 24 % over the period. The reduction in greenhouse gas emissions over the 24-year period was due to a variety of factors, including the growing share in the use of renewables, the use of less carbon intensive fuels and improvements in energy efficiency, as well as to structural changes in the economy and the economic recession. Demand for energy to heat households has also been lower, as Europe on average has experienced milder winters since 1990, which has also helped reduce emissions.

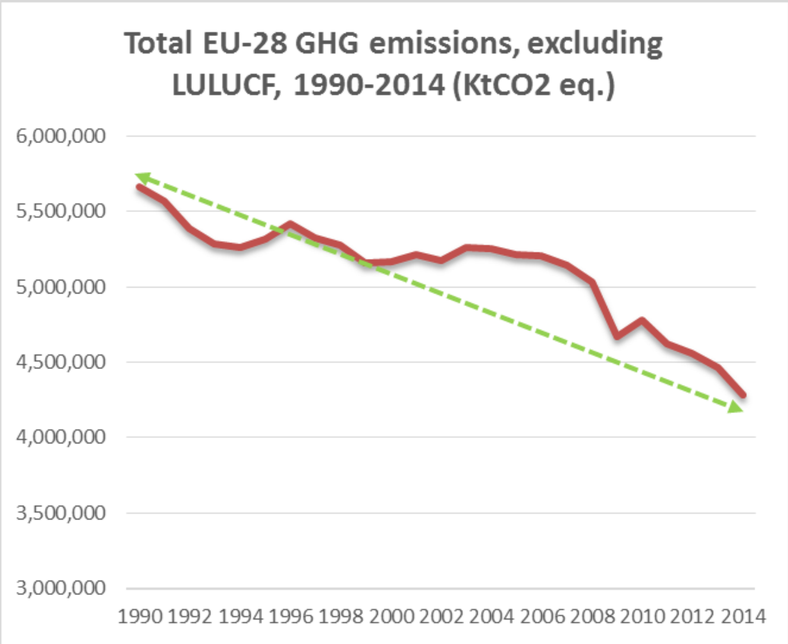
GHG emissions decreased in the majority of sectors between 1990 and 2014, with the notable exception of transport, including international transport, and refrigeration and air conditioning. At the aggregate level, emission reductions were largest for manufacturing industries and construction, electricity and heat production, and residential combustion. A combination of factors explains lower emissions in industrial sectors, such as improved efficiency and carbon intensity as well as structural changes in the economy, with a higher share of services and a lower share of more-energy-intensive industry in total GDP. The economic recession that began in the second half of 2008 and continued through to 2009 also had an impact on emissions from industrial sectors. Emissions from electricity and heat production decreased strongly since 1990. In addition to improved energy efficiency there has been a move towards less carbon intense fuels. Between 1990 and 2014, the use of solid and liquid fuels in thermal stations decreased strongly whereas natural gas consumption doubled, resulting in reduced CO_2 emissions per unit of fossil energy generated. Emissions in the residential sector also represented one of the largest reductions. Energy efficiency improvements from better insulation standards in buildings and a less carbon-intensive fuel mix can partly explain lower demand for space heating in the EU as a whole over the past 24 years. The year 2014 was also the hottest year on record, leading to substantially lower heat demand. Since 1990 there has been a warming of the autumn/winter in Europe; although there is high regional variability. The very strong increase in the use of biomass for energy purposes has also contributed to lower GHG emissions in the EU – since CO_2 emissions from biomass combustion are excluded from national totals under UNFCCC reporting.

In terms of the main GHGs, CO_2 was responsible for the largest reduction in emissions since 1990. Reductions in emissions from N_2O and CH_4 have been substantial, reflecting lower levels of mining activities, lower agricultural livestock, as well as lower emissions from managed waste disposal on land and from agricultural soils. A number of policies (both EU and country-specific) has also contributed to the overall GHG emission reduction, including key agricultural and environmental policies in the 1990s and climate and energy policies in the 2000s. Finally, in spite of the good progress in reducing the GHG emissions intensity and decarbonising the EU economy, fossil fuels still represent the largest source of energy and emissions in the EU. The more a country relies on fossil fuels, and particularly the more carbon-intensive fuels, the more difficult will be to completely decouple (break the link between) GHG emissions from economic growth. This also means the higher the contribution from renewable energy sources the easier will be to break the link between economic growth, energy demand and GHG emissions, other things equal.

2.2 Overall results at EU level

The recently adopted Paris Agreement sets out a global action plan to keep global temperature rise to below 2°C and to drive efforts to limit the increase even further to 1.5°C above pre-industrial levels. It is the first multilateral agreement on climate change covering almost-all of global emissions and is coherent with the EU's path to a low carbon economy by 2050. Already in the past 24 years, total GHG emissions (excluding LULUCF) in the EU decreased substantially since 1990, reaching their lowest level in 2014 (figure 4). The EU emitted 4,282 million tonnes of CO_2 eq. in 2014, which is 24% less than in 1990, and currently accounts for less than 8% of global GHG emissions.

Figure 4 Total GHG emission trend in the EU-28, 1990-2014

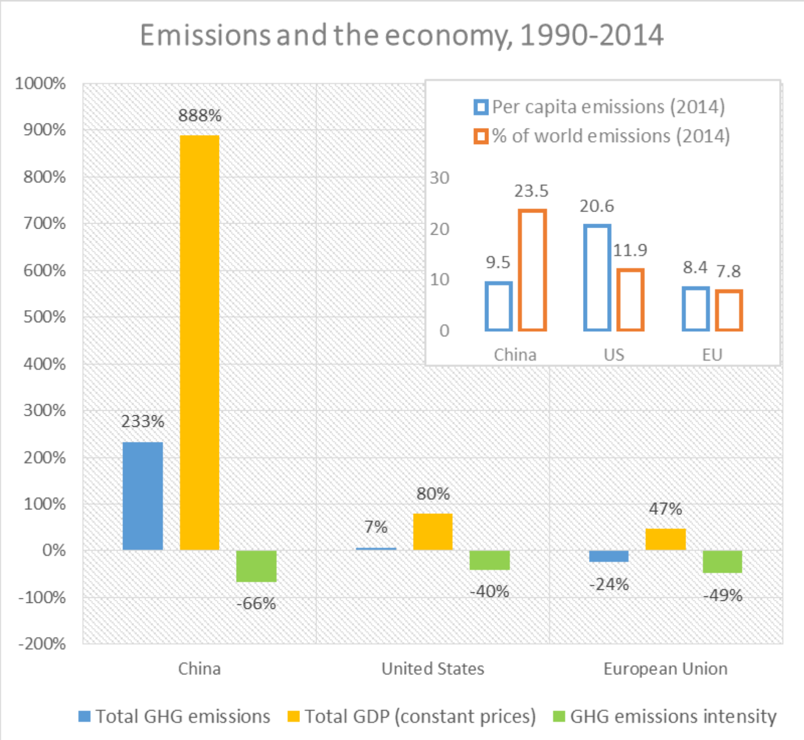


Source: EEA

Figure 5 shows total greenhouse gas emissions, GDP in constant prices and the GHG intensity of the economy during the period 1990–2014, for the EU, the US and China. In all three regions, the GHG emissions intensity of the overall economy decreased over the 24-year period. In the European Union, and using standard terminology, there was an absolute decoupling of emissions from economic growth, whereas in both the US and China there was a relative decoupling, with emissions increasing less rapidly than economic growth.

EU's per capita emissions stood at about 12 tonnes of CO_2 eq. in 1990 and went down to 8 tonnes of CO_2 eq. in 2014. The average EU citizen emits about 8t CO_2-equivalent (excluding LULUCF), which is above the world average of approximately 7.5t CO_2-equivalent per person, just below China's 9t CO_2 eq. and well below per capita emissions in the United States (21 tCO_2 eq.). Greenhouse gas emissions per capita also vary widely between European countries, mainly reflecting differences in the fuel mix for the conversion of primary fuels to heat and electricity (see table 7 in section 2.6).

Figure 5 GHG emissions, GDP and intensity in the EU, US & China



Notes: GHG emissions intensity is defined as total GHG emissions excluding LULUCF divided by total GDP in constant prices. Per capita emissions is measured in tonnes of CO_2 equivalent per person.

Source: EEA, based on data from EEA, JRC's EDGAR, Eurostat, UNPD and DG ECFIN's AMECO.

Figure 6 breaks down the 24-year 24.4% overall reduction in GHG emissions, for the 3 different periods, into several factors using the Kaya decomposition identity[8]. In the first period (1990-2000) the overall reduction of GHG emissions from fossil fuel energy use was 8.8%. Of this, lower energy intensity of GDP played the biggest role (yellow section) in bringing emissions down, as the economy required less energy per unit of GDP. The carbon intensity of energy also improved during this period, which reflects the lower use of more carbon-intensive fuels like coal, and a switch to less carbon intensive fuels like gas or renewables. The reduction in emissions from non-combustion sectors, such as agriculture, industrial processes and waste also contributed to the overall positive trend. These three factors driving emissions down were partially offset by higher population and by higher GDP per capita. The second period (2000-2008) was also characterised by high economic growth and lower GHG emissions. The reduction in GHG emissions was lower than during the 1990s, as the improvement in the carbon intensity slowed due to less substantial reductions in coal use and declining nuclear production. In the third period (2008-2014), the factor GDP per capita played the opposite role. Indeed, as the economy and industrial production contracted, GDP had a positive effect on emissions and contributed further to the decline. Yet, of the 15.0% overall decrease in GHG emissions from fossil fuel use, GDP per capita was only one of the three key factors bringing emissions down, with energy

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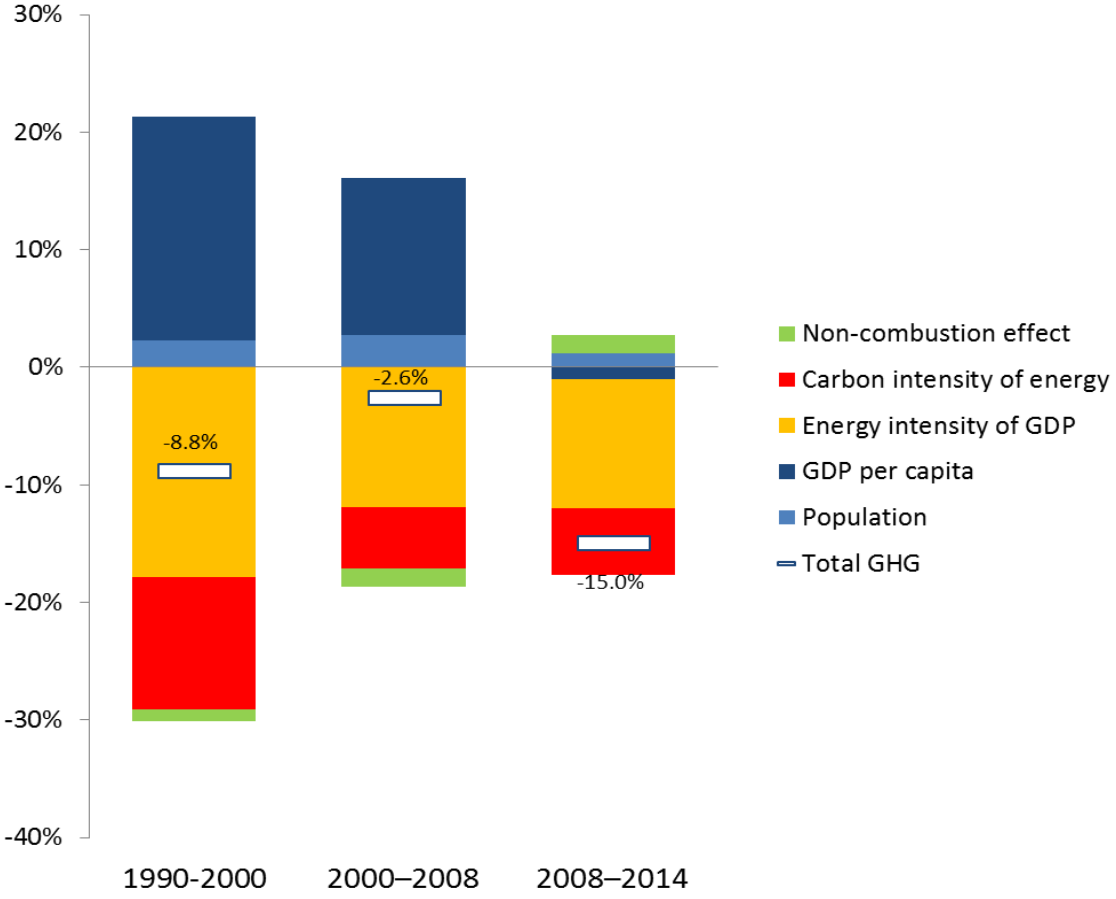
8 The chosen factors are an extension of the Kaya identity. The annual decomposition analysis shown in this paper is based on the Logarithmic Mean Divisia Index (LMDI) method. The equation for the aggregated decomposition analysis is:

(y) [ln]GHG = (x_1) [ln]POP + (x_2) [ln]GDP/POP + (x_3) [ln]PEC/GDP + (x_4) [ln]GHG_en/PEC + (x_5) [ln]GHG/GHG_en, where:

(y) GHG: total GHG emissions; (x_1) POP: population (population effect); (x_2) GDP/POP: GDP per capita (affluence effect); (x_3) PEC/GDP: primary energy intensity of the economy (primary energy intensity effect); (x_4) GHG_en/PEC: energy-related GHG emissions in primary energy consumption (carbon intensity effect); (x_5) GHG/GHG_en: total GHG emissions in energy-related GHG emissions (non-combustion effect).

intensity and carbon intensity playing a bigger role altogether. The reduction in energy-related emissions in this last period was stronger than for non-combustion sectors.

Figure 6 Decomposition of the cumulative changes in total GHG emissions in the EU-28 in three different periods: the 1990s, the 2000s before the recession, and post-2008



Note: The explanatory factors should not be seen as independent of each other. The bar segments show the changes associated with each factor alone, holding the respective other factors constant.

Source: EEA.

Overall, the four main findings from the decomposition analysis of figure 6 are[9]:

i. Emissions decreased with increasing GDP (per capita) during both 1990-2000 and 2000-2008, whereas emissions and GDP (per capita) decreased during 2008-14. This shows that emissions can decrease with a growing economy. But it also shows that emissions can decrease faster with a declining economy, as concluded by previous EEA work[10] . The economic recession has resulted in substantial emission reductions in the 2008-2014.
ii. The lower carbon intensity of energy was a key factor underpinning lower emissions in all three periods. This factor has been slightly stronger in the period of 2008-14 than in the period 2000-

9 When interpreting the results from this decomposition analysis, one should be careful not to extrapolate everything that is not GDP to policies or other factors which are assumed to be independent from the economy. Recession is broader than GDP, and there is a recession effect in 'energy intensity' (e.g. lower fuel use by industry), or in 'carbon intensity' (e.g. if recession affected relative fuel prices).

10 See section 7 'The role of economic growth and recession in GHG emission reductions in the EU 'of 'Why did GHG emissions decrease in the EU between 1990 and 2012', published in 2014 http://www.eea.europa.eu/publications/why-are-greenhouse-gases-decreasing

08, despite a decline in nuclear electricity production. The lower carbon intensity during both 2005-08 and 2008-12 is by and large accounted for by a higher contribution from renewable energy sources in the fuel mix. In the 1990s, renewables, although still positive, contributed less to emissions reductions compared to nuclear; however, the largest factor of emission reductions was the switch between more carbon-intensive coal to less carbon intensive gas.

iii. The decrease in primary energy intensity was the largest contributing factor to lower CO_2 emissions from fossil fuel combustion in all three periods. In the last period 2008-14, total energy consumption decreased while GDP increased, leading to an improvement in the emissions intensity of energy production and use. The economic recession partly explains lower energy demand from industry and road transportation since 2008. However, energy intensity also decreased in the periods 1990-2000 and 2000-2008 where energy demand was high. Lower energy intensity of GDP can be explained by improvements in energy efficiency (transformation and end-use) and the strong uptake of renewables, as well as by changes in the structure of the economy and a higher share of the services sector compared to the more energy intensive industrial sector.

iv. The largest emission reductions occurred in the energy-combustion sector. Contributions from other sectors, particularly industrial processes, waste and agriculture have also been important. In the last period, non-energy emissions decreased, though at a lower rate than energy-related'.

Table 3 Key statistics for the variables used in the decomposition analysis of figure 6

	% growth rates					
	2000/1990	2008/2000	2014/2008	annual average 2000/1990	annual average 2008/00	annual average 2014/08
<u>Original variables</u>						
Total GHG (million tonnes)	-8.8%	-2.6%	-15.0%	-0.9%	-0.3%	-2.7%
POP (millions)	2.4%	2.8%	1.3%	0.2%	0.3%	0.2%
GDP (Mrd Euro at 2005 market prices)	24.2%	17.8%	0.4%	2.2%	2.1%	0.1%
Total Primary Energy Supply (TJ)	3.7%	4.4%	-11.0%	0.4%	0.5%	-1.9%
GHG energy (million tonnes)	-7.8%	-1.0%	-16.3%	-0.8%	-0.1%	-2.9%
<u>Decomposition analysis (factors)</u>						
ln(total GHG) = ln(POP) + ln(GDP/POP) + ln(PEC/GDP) + ln(GHG energy/PEC) + ln(total GHG/GHG energy)						
Total GHG (million tonnes)	-8.8%	-2.6%	-15.0%	-0.9%	-0.3%	-2.7%
Population	2.3%	2.7%	1.2%	0.2%	0.1%	0.7%
GDP per capita	18.4%	13.4%	-0.9%	1.1%	1.0%	3.8%
Primary energy intensity	-17.2%	-11.9%	-11.1%	-1.1%	-0.8%	-4.4%
Carbon intensity (energy sector)	-11.3%	-5.2%	-5.7%	-1.0%	-0.5%	-2.5%
Non-combustion	-1.0%	-1.5%	1.5%	-0.1%	-0.1%	-0.3%

Note: The decomposition analysis used in table 3 is based on an extension of the original IPAT and Kaya identities, which are often used to illustrate the primary forces of emissions. The most important limitation from this method is that the relationship between the variables in the equation is true by definition, allowing no country-specific variation and assuming independence between the different factors. Therefore, one should avoid over-interpretation of the different effects. However, decomposition analysis can point to interesting findings, which can be explored further using other methods. The table shows the results of the multiplicative decomposition analysis where the factors are (almost) additive. For example, the carbon intensity factor contributed to 5.7 percentage points to the 15% reduction in GHG emissions in EU-28 between 2008 and 2014 [or 38% of the total net reduction in GHG emissions].

Source: EEA.

In addition to the reduction of the energy intensity of GDP there has been a substantial improvement of the GHG emissions intensity of the EU economy as a whole. Emissions per GDP decreased substantially in all MS during the 24-year period. This improvement came along with a significant convergence of GHG emission intensities across MS, both per-capita and per-GDP[11]. One reason for this convergence has been the extraordinary growth in renewables in most Member States and a clear move towards less carbon intensive fuels.

Table 3 above summarises the growth rates in the original variables and factors used in the decomposition analysis for the periods 1990-2000, 2000-2008 and 2008-2014 for the EU-28.

2.3 Largest emission changes by sector at EU level

Table 4 shows the largest emission changes by key source in the EU-28 between 1990 and 2014. GHG emissions decreased in the majority of sectors between 1990 and 2014, with the notable exception of transport, including international transport. The sectors and gases[12] explaining the largest decreases for EU-28 were manufacturing industries and construction (CO_2), public electricity and heat production (CO_2), and residential combustion (CO_2). The sectors and gases with the largest increases over the period were road transportation (CO_2) and the consumption of HFCs in industrial processes. CO_2 emissions from international aviation and shipping also increased very rapidly during the 24-year period, although these emissions are excluded from the Kyoto targets.

Manufacturing and construction was the largest source of emission reductions in absolute terms in the EU between 1990 and 2014 (370 million tCO_2 eq.)[13]. A combination of factors explain lower emissions in industrial sectors, such as improved efficiency in restructured iron and steel plants, substantial improvements in the carbon intensity, with emissions from solid fuels more than halving in 24 years, and structural changes of the economy with a higher share of services and a lower share of more-energy-intensive industry in total GDP. Trade is also important for understanding GHG emission trends. While Europe may be indirectly generate some of the emissions elsewhere — exported EU emissions — a share of Europe's own emissions can be traced to consumption of European goods in some of Europe's main trading partners — imported EU emissions. The energy and carbon intensity of the production of goods and services will by and large determine the real shares of exported and imported emissions. Finally, the economic recession that began in the second half of 2008 and continued through to 2009 also had a substantial impact on emissions from this sector.

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11 This convergence has been calculated on the basis of GDP in purchasing power standards and refers to the reduction in the coefficient of variation of Member States GHG emissions intensities.

12 Overall, emissions from CO_2 (81% of total GHG emissions in 2014) decreased by 22% since 1990 and accounted for 72% of the total net reduction in GHG emissions in the EU-28 between 1990 and 2014. N_2O emissions (6% of the total in 2014) decreased by 38%, and accounted for 11% of the net reduction, whereas CH_4 emissions (11% of the total) fell by 39% and represented 21% of the total reduction. F-gases (3% of the total) actually increased by 71% over the 24-year period.

13 In 2012, the EEA published the technical report 'End-user GHG emissions from energy: Reallocation of emissions from energy industries to end users 2005–2010'. The report's objective was to help improve understanding of past greenhouse gas (GHG) emission trends in the energy sector from the demand or end-user side. To do this, the report developed a methodology to redistribute emissions from energy industries to the final users (by sector) of that energy. This reallocation is done on the basis of Eurostat's energy balances and GHG inventories for the energy sector, as reported to the United Nations Framework Convention on Climate Change (UNFCCC), for the period 2005–2010.

Table 4 Overview of the largest emission changes by key source in the EU, 1990-2014

Source category	**Million tonnes (CO_2 equivalents)**
Road Transportation (CO_2 from 1.A.3.b)	124
Refrigeration and Air conditioning (HFCs from 2.F.1)	99
Aluminium Production (PFCs from 2.C.3)	-20
Fugitive emissions from Natural Gas (CH_4 from 1.B.2.b)	-20
Enteric Fermentation: Dairy Cattle (CH_4 from 3.A.1)	-21
Agricultural Soils: Direct N_2O Emissions From Managed Soils (N_2O from 3.D.1)	-25
Cement Production (CO_2 from 2.A.1)	-28
Fluorochemical Production (HFCs from 2.B.9)	-29
Nitric Acid Production (N_2O from 2.B.2)	-45
Enteric Fermentation: Cattle (CH_4 from 3.A.1)	-47
Commercial/Institutional (CO_2 from 1.A.4.a)	-56
Adipic Acid Production (N_2O from 2.B.3)	-57
Manufacture of Solid Fuels and Other Energy Industries (CO_2 from 1.A.1.c)	-62
Coal Mining and Handling (CH_4 from 1.B.1.a)	-75
Managed Waste Disposal Sites (CH_4 from 5.A.1)	-76
Iron and steel production (CO_2 from 1.A.2.a +2.C.1)	-105
Residential: Fuels (CO_2 from 1.A.4.b)	-140
Manufacturing industries (excl. Iron and steel) (energy-related CO_2 1.A.2 excl. 1.A.2.a)	-299
Public Electricity and Heat Production (CO_2 from 1.A.1.a)	-346
Total	**-1382**

Note: The table shows only those sectors where emissions have increased or decreased by at least 20 million tonnes of CO_2 equivalent between 1990 and 2014. Emissions from manufacturing and construction decreased by 370 million tonnes of CO_2 equivalent between 1990 and 2014. The distinction with iron and steel responds to internal consistency issues of the EU inventory and reflects different reporting of activity data by Member States. The table reflects the emission reductions according to the EU's geographical scope under KP and includes Iceland.

Source: EEA.

The second largest emission reductions in the EU with 346 million tonnes of CO_2 eq. were achieved in the production of electricity and heat. Emissions from electricity and heat production decreased strongly since 1990. The improvement in the transformation efficiency has to be seen in the context of lower heat production and higher electricity production between 1990 and 2014. In addition to improved energy efficiency there has been a move towards less carbon intensity fuels at EU level. Between 1990 and 2014, the use of solid and liquid fuels in thermal stations decreased strongly whereas natural gas consumption doubled, resulting in reduced CO_2 emissions per unit of fossil energy generated[14]. The steady and significant increase in biomass use for electricity and heat production has also served as a substitute for fossil fuels. This improvement in the carbon intensity of combustible fuels, with the switch from coal and oil to natural gas and biomass, is only part of the story. Some renewables can produce electricity by means of mechanical energy without any combustion. The very

[14] The implied emission factor for coal and lignite (combined) in the EU-28 in 2014 was on average 101 tonnes of CO_2 equivalent per terajoule in 2014. The emission factor for liquid fuels was 76 t CO_2 / Tj and for gaseous fuels it was 56 t CO_2/ Tj. This means that coal releases around 80 % more CO_2 than gas to deliver the same amount of energy.

strong increase in other renewables, such as wind power, has led to both an improvement in transformation efficiency of the whole energy system and have also contributed positively to the reduction in emissions. Nuclear generation of electricity has increased since 1990 although its share in total electricity production has fallen since 2005. This sector remains the largest contributor to GHG emissions in the EU. This trend could revert if gas prices become more attractive compared to coal. A higher carbon price (or prospects for it) should also affect the relative demand of coal to gas for power generation in the EU. Currently about 78% of emissions from power plants come from coal, compared to 16% for gas.

Emissions in the residential sector decreased by 140 million tCO_2 eq. between 1990 and 2014 and represented the third largest reduction. Energy efficiency improvements from better insulation standards in buildings and a less carbon-intensive fuel mix can explain lower demand for space heating in the EU as a whole over the past 24 years. These factors have more than offset the effects of a 32 million increase in the population, and in the number and average size of households in the EU. Emissions from the residential sector fluctuate according to weather conditions and heat demand. The year 2014 was the hottest year on record in Europe with mean annual land temperatures 2°C higher than the pre-industrial average (see figure 3). In the last 24 years since 1990 there has been a warming of the winter/autumn months in Europe which has partly contributed to lower heat demand by households and therefore to lower GHG emissions (see figure 12).

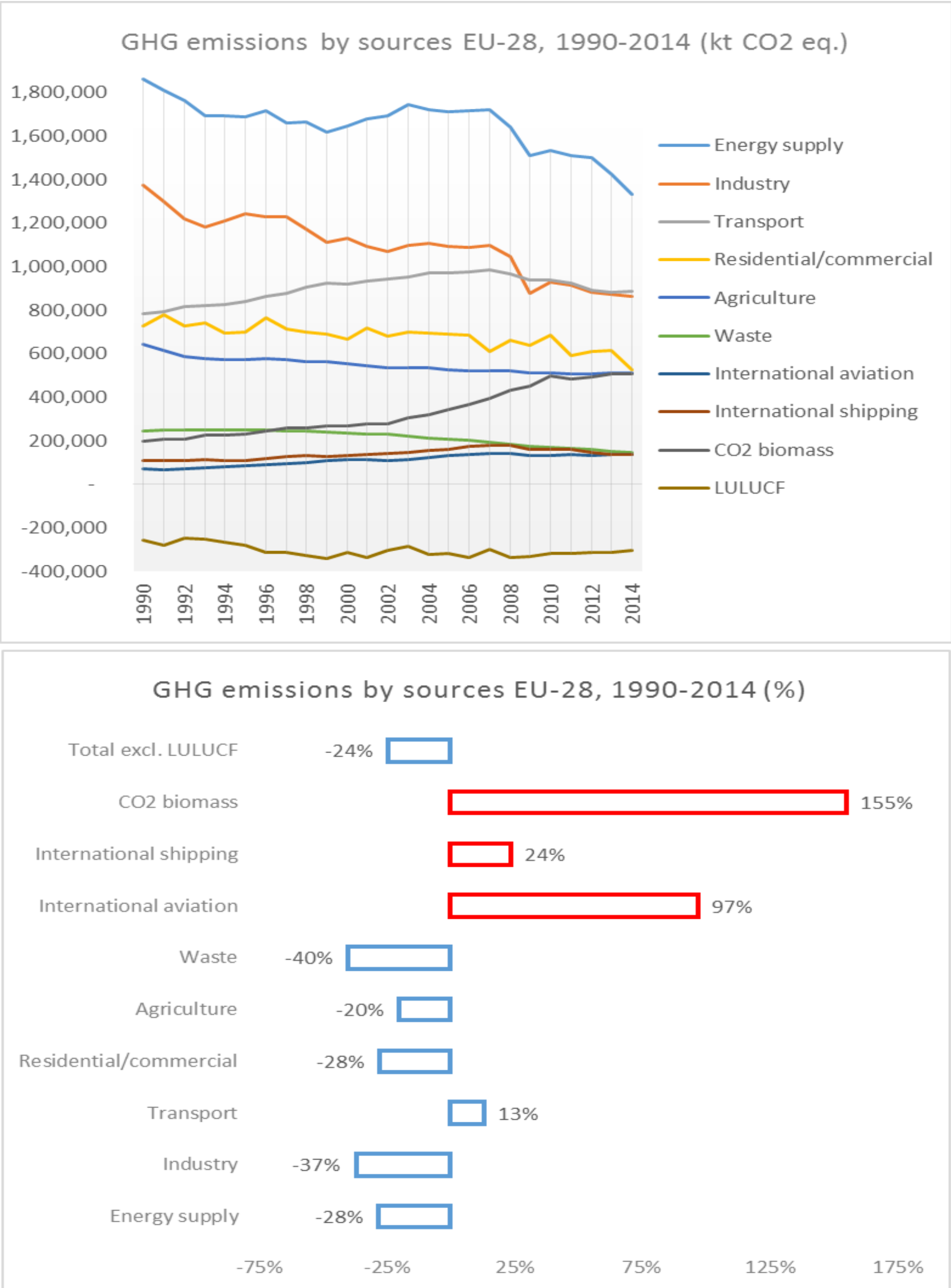
On the negative side, CO_2 emissions from road transportation increased by 124 million tonnes in the 24-year period. Emissions increased steadily between 1990 and 2007, decreased up to 2013 and increased again in 2014. The overall net increase was fully accounted for by a strong uptake of diesel and a decline in gasoline use. Energy efficiency improvements and to a lesser extent increased used of less carbon intensive fuels, such as LPG and biofuel blends, have led to levels of road transport emissions that would have been otherwise higher. The economic recession that started in 2008 has also contributed to lower road transport emissions (for freight and passenger) in the last years. Despite these improvements in efficiency and carbon intensity, demand has grown substantially and road transport still represented about 20% of total GHG emissions in the EU in 2014. Transport roughly represents about one third of emissions from the sectors not covered by the EU ETS. Thus, transport emissions would need to fall significantly if Member States are to meet their limitation targets under the Effort Sharing Decision for non-trading sectors by 2020 compared to 2005.

The second largest increase came from hydrofluorocarbons (HFCs) used in industrial processes. These were the only group of gases for which emissions increased since 1990 and accounted for 2.6% of total EU GHG emissions in 2014. This increase has been a side effect from the implementation of the Montreal Protocol on ozone depleting substances. The banning of Montreal-Protocol CFCs, both ozone-depleting substances and potent GHGs, led to new substitutes and their replacement with Kyoto-Protocol HFCs. HFCs are used in the production of cooling devices such as air conditioning systems and refrigerators and the increase is consistent with both warmer climatic conditions in Europe (i.e. summers) and higher standards of comfort demanded by citizens.

Figure 7 shows GHG emissions by sources and sinks in the EU-28 between 1990 and 2014. The top chart shows the emissions by sector over the 24-year period for the EU-28. The effect of the economic recession is clearly visible in energy supply and industry from 2008 onwards. The downward emission trend in the residential and commercial sectors fluctuates over the time series, generally reflecting the effect of warmer or colder winters on heat demand. In the case of transport, emissions increased substantially until 2007 and have declined somewhat in the past years, although they increased again in 2014.

Of all trends, perhaps the most interesting ones are the increase in emissions from international aviation and international shipping as well as the stark increase in CO_2 emissions from biomass. The increase in these three emission sources is more visible from the bottom chart. In common, they have that they are not included in national GHG totals and are excluded from Kyoto targets (depicted by the red bars), and that their emissions have increased more than the sectors included in national GHG totals (depicted by the blue bars).

Figure 7 GHG emissions by aggregated sector in EU-28, 1990-2014



Notes: indirect CO_2, sector CRF 1A5 (mostly including emissions from military use) and sector 6 'other' are not included in the graph and represented a combined 0.2% of total GHG emissions in 2014. The red bars denote items not included in national GHG totals and therefore excluded from Kyoto targets. The sectoral aggregations in the top chart are: Energy supply: CRF 1A1 (energy industries) + 1B (fugitives); industry: CRF 1A2 (manufacturing industries and construction) + CRF 2 (industrial processes); transport: CRF 3; residential and commercial: CRF 1A4a (commercial) + CRF 1A4b (residential); agriculture: CRF 1A4c (agriculture, forestry and fishing) + CRF 3 (agriculture); waste: CRF 5 (waste); LULUCF: CRF 4 (LULCUF); international aviation, international shipping and CO_2 biomass are Memorandum items not included in national totals.

Source: EEA.

Emissions from international aviation and maritime transport are not relevant for Kyoto compliance. They are reported in greenhouse gas inventories as Memorandum items. Contributions from international aviation and shipping increased by over 90 million tonnes between 1990 and 2014. Together, the two sectors in 2014 accounted for about 6 % of total EU GHG emissions. Emissions from international aviation have been included in the EU ETS since 2012. A decision on the inclusion of greenhouse gas emissions from international maritime transport has not been taken so far.

CO_2 emissions from biomass combustion increased by 308 million between 1990 and 2014, highlighting the rapidly increasing importance of bioenergy in replacing fossil fuel sources. In addition, net removals from land use, land use change and forestry (LULUCF) increased in the EU over the same 24-year period[15]. Based on the 2014 EU GHG inventory, net removals increased by about 19% in the EU-28 between 1990 and 2014 and the net sink has increased from 4.7 % of total GHG emissions in 1990 to 7.6 % in 2014. In 2014, net removals from the LULUCF sector in the EU-28 amounted to 302 million tonnes of CO_2-equivalent. The key driver for the increase in net removals is a significant build-up of carbon stocks in forests. Environmental policies have also resulted in less intensive agricultural practices and an increase in forest and woodland conservation areas for the purpose of preserving biodiversity and landscapes.

However, biomass can only reduce GHG emissions effectively if it is produced in a sustainable way. There is growing concern about the environmental and climatic integrity of biomass as a source of energy, with consumption from both domestic production and imports from third countries growing very rapidly. According to Eurostat's energy statistics, solid biomass represents about three quarters of all biomass consumed in the EU, with both biogas and liquid biofuels accounting for the remaining 25%. Almost 90% of all biomass consumed in Europe is produced in Europe. However, biomass imports are growing very rapidly, not only for liquid biofuels, where there are mandatory sustainability criteria[16], but also for woody biomass, where such binding criteria are yet to be agreed at EU level. The European Commission is currently preparing a sustainable bioenergy policy as part of the EU renewable energy package expected by end of 2016.

2.4 EU policies and GHG emission reductions

In addition to key drivers such as improved energy efficiency, improved GHG intensity and the strong increase in renewables, a number of policies have also played a key role in GHG emission reductions[17]. The paragraphs that follow are a non-exhaustive list of EU-wide policies underpinning lower GHG emissions in the EU-28 between 1990 and 2014.

The Montreal Protocol on ozone-depleting substances has been one of the most successful multilateral environmental (and indirectly climatic) agreements to date, contributing to substantial

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15 Net LULUCF emissions and/or removals and CO_2 emissions from the combustion of biomass (including biofuels in transport) are not included in national GHG emission totals according to UNFCCC Reporting Guidelines. They are reported separately in GHG inventories as a Memorandum item. The reason for this is mainly to avoid double counting emissions from a reporting perspective. It should not be linked to sustainability and/or to carbon neutrality. The assumption is that harvesting does not outpace annual regrowth, and that unsustainable biomass production would show as a loss of biomass stock in the LULUCF sector.

16 The Renewable Energy Directive provide a sustainability framework at EU level for liquid biomass used for transport, electricity, heating and cooling. Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC (OJ L 140, 5.6.2009, p. 16).

17 The effect of some of these policies were already discussed in 'Greenhouse gas emissions in Europe: a retrospective trend analysis for the period 1990 – 2008', EEA http://www.eea.europa.eu/publications/ghg-retrospective-trend-analysis-1990-2008 For a more recent overview of key policies, see the 'Second Biennial Report' from the EU to the UNFCCC, http://unfccc.int/national_reports/biennial_reports_and_iar/submitted_biennial_reports/items/7550.php

GHG emissions reductions in Europe and worldwide. Many of the substances addressed in the Montreal protocol such as chlorofluorocarbons (CFCs) are also potent GHGs. The banning of CFCs led to an increase in the consumption of substitute gases such as HFCs, regulated under the Kyoto Protocol, and where emissions at EU level have increased substantial since 1990. Indeed, the consumption of HFCs recorded the second largest increase of emissions after CO_2 emissions from road transportation[18], even though they remain small in relation to other GHGs.

The two largest non-CO_2 GHGs are CH_4 and N_2O. The reduction in CH_4 emissions over the past 24 years reflects lower levels of coal mining and post-mining activities as well as lower emissions from managed waste disposal on land. There has also been a very significant reduction in CH_4 emissions from agricultural livestock, due to a reduction in numbers but also to changes in the agricultural management of organic manures. N_2O emissions decreased substantially in adipic acid production (a precursor in the production of nylon) due to abatement techniques implementing by industry and in adipic acid production (used in the production of fertilisers). There were also substantial reductions in N_2O emissions from agricultural soils and nitric acid production.

Key EU polices such as the Nitrates Directive, the Common Agriculture Policy (CAP) and the Landfill Waste Directive have been successful in reducing greenhouse gas emissions from methane and nitrous oxides. The EU Nitrates Directive which aims at reducing and preventing water pollution caused by nitrates from agricultural sources has had a significant positive impact on greenhouse emissions. The Directive addresses the use of synthetic and nitrogen-based fertilisers. Lower use of fertilisers per cropland combined with lower cropland area has led to substantial reductions in N_2O emissions from agricultural soils.

The so-called first pillar of the EU Common Agriculture Policy (CAP), dealing with market support, had a strong impact through the milk quota system by reducing animal numbers in the dairy sector to compensate for increasing animal productivity. The CAP also had a very strong effect on emissions, particularly of CH_4 from enteric fermentation. Overproduction control through 'milk quotas' has limited the economic attractiveness of cattle production in the EU and has incentivised higher milk yield to sustain production levels with less cattle. The so-called 'agro-environmental schemes' have also provided incentives to limit overproduction of arable crops.

The Landfill Waste Directive, which requires Member States to reduce the amount of biodegradable waste landfilled, has intensified separate collection, recycling and pre-treatment of waste, as well as landfill-gas recovery by Member States. This has led to significant reductions in CH_4 emissions from solid waste disposal of biodegradable waste on land.

As described in the EU's National Inventory Report to UNFCCC, the EU agricultural and environmental policies have been the major driver of land use and land use change in Europe, and particularly since 1990. The Common Agricultural Policy and rural development programs have stimulated less intense agricultural practices and a general decrease of area of the utilized arable land, compensated by the increase in forest and urban areas. In addition, the EU environmental policy (e.g. Natura 2000 network) has also stimulated the increase of forest and woodlands area under conservation regime with the purpose of preserving biodiversity and landscapes. Currently, at EU level, around 25% of total forest and woodland areas are excluded from harvesting. Felling accounts for only about 60% of the net annual wood increment, which explains the significant build-up of biomass (i.e. carbon removal) in the forests. To minimise the impacts of unstainable biomass production and use the European

[18] HFC emissions from air-conditioning systems in motor vehicles are of concern because HFC-134a is the largest contributor to total HFCs emissions and has a global warming potential (GWP) about 1 400 times stronger than CO_2. In Europe, however, the use of HFC-134a for mobile air-conditioning in new cars will be phased out between 2011 and 2017. From January 2011, EU Member States will no longer grant EC type-approval or national type-approval for a type of vehicle fitted with an air conditioning system designed to contain fluorinated GHGs with a GWP higher than 150, and from January 2017, Member States will have to refuse registration and prohibit the sale of such new vehicles.

Commission is currently preparing a sustainable bioenergy policy post-2020 as part of the EU renewable energy package expected by end of 2016.

Even though the reduction in N_2O and CH_4 emissions in the EU have been large, the largest reduction in GHG emissions was in terms of CO_2, which was mainly linked to improve GHG intensity, less carbon intensive fossil fuels and renewables, as well as improvements in energy efficiency. In terms of more recent climate and energy policies, the key strategy for Europe to bring about the transition to a low-carbon, secure and competitive economy is the Energy Union Framework Strategy[19], which include the objectives of reducing energy demand, improve energy efficiency and decarbonise the energy mix. Already as part of the 'climate and energy package' and the 'Europe 2020 strategy', the EU committed to a reduction of 20% in its GHG emissions[20], a 20% share of renewables and a 20% improvement in energy efficiency by 2020 compared to 1990. Building from the climate and energy package, the European Council recently adopted the '2030 climate and energy framework', which sets a target of a 40% reduction in GHG emissions compared to 1990 as well as renewable energy and energy efficiency targets of at least 27% by 2030. The 2030 framework is an EU priority in follow up to the Paris Agreement and is consistent with the longer term objective of the '2050 low-carbon economy roadmap', which sets the EU ambition to reduce its GHG emissions by 80% compared to 1990, with milestones of 40% by 2030 and 60% by 2040. Essentially, the EU's climate change mitigation policy framework is based on a distinction between GHG emissions from large industrial sources, which are governed by the EU emissions trading system (ETS), and emissions from the other sectors, covered by the Effort Sharing Decision (ESD) and where national targets apply.

Overall, the sectors covered by the EU Emissions Trading System (EU ETS) contributed more to the overall emissions reduction, particularly between 2008 and 2012 (i.e. during the first commitment period under the Kyoto Protocol) than the non-trading sectors (i.e. those outside the EU ETS). ETS emissions increased faster than non-ETS' during the first phase of the EU ETS between 2005 and 2007 (figure 8). This period also coincided with larger consumption of hard coal and lignite for power generation. The overall EU ETS cap for the period 2008–2012 put a limit to emissions from installations by setting the maximum amount of emissions allowed during the 5-year period. By design, the EU ETS has contributed to the overall GHG emission reductions. The effects of the economic crisis which resulted in even lower emissions than expected also resulted in the accumulation of a large surplus of allowances. In comparison, the bulk of the decrease in non-ETS emissions in this period was due to lower consumption of gas and liquid fuels in the residential sector, and lower consumption of gasoline and diesel in road transportation.

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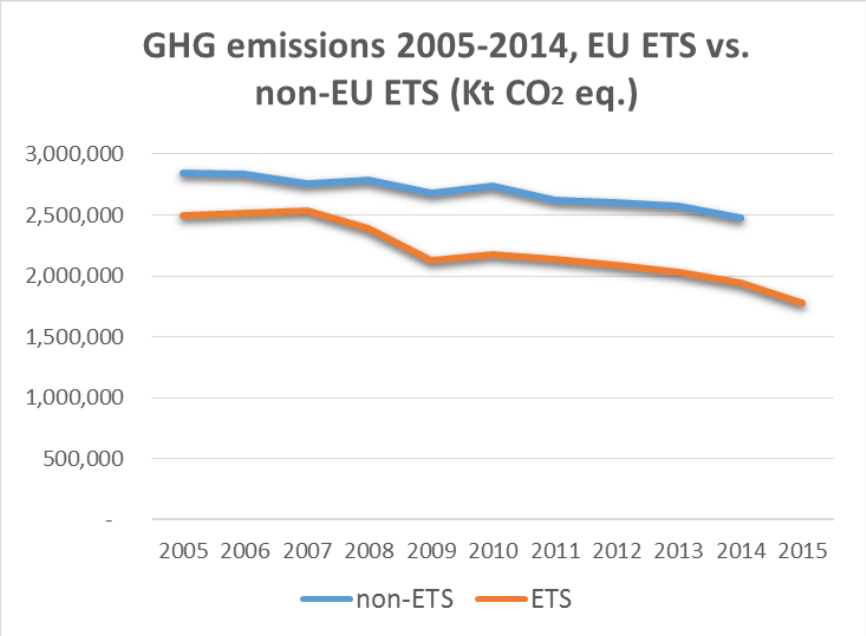
[19] European Commission Communication 'A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy' http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2015%3A80%3AFIN

[20] At the core of EU climate policy is the Climate and Energy Package adopted in 2009. The package underlines the objective of limiting the rise in global average temperature to no more than two degrees Celsius above pre-industrial levels. To achieve this goal, the EU committed to a unilateral emission reduction target of 20% by 2020, compared with 1990 levels. The main instruments to reduce emissions under the Climate and Energy Package are the EU Emissions Trading System, covering more than 12,000 power stations and industrial plants in 31 countries, as well as airlines, and the Effort Sharing Decision for sectors not included under the EU ETS. Both trading (i.e. EU ETS) and non-trading sectors are to contribute to the 20 % objective. Minimising overall reduction costs implies a 21 % reduction in emissions from EU ETS sectors compared to 2005 by 2020, and a reduction of approximately 10 % compared to 2005 by 2020 for non-EU ETS sectors. Emissions from international aviation have been included in the EU ETS since 2012. A decision on the inclusion of greenhouse gas emissions from international maritime transport has not been taken so far. The non-ETS sectors fall under the scope of the so called Effort Sharing Decision, which establishes binding annual greenhouse gas emission targets for Member States for the period 2013–2020. These targets concern emissions from most sectors not included in the EU Emissions Trading System, such as transport (except aviation and international maritime shipping), buildings, agriculture and waste. The non-trading sectors currently represent almost 60 % of total greenhouse gas emissions.

Figure 8 GHG emissions in the EU ETS and non-ETS sectors in the EU-28 between 2005 and 2014



Note: Non-ETS emissions have been calculated by subtracting scope-corrected ETS emissions, CO_2 from domestic aviation and NF_3 emissions from total GHG emissions excluding LULUCF and including indirect CO_2 emissions. International aviation has been included in the ETS (using GHG inventory data). The data across different ETS trading-periods are comparable. A scope-correction has been applied since 2005 to reflect the current scope of the EU ETS, incorporating successive changes in terms of countries, activities and gases. More information can be found on the EEA website http://www.eea.europa.eu/data-and-maps/data/data-viewers/emissions-trading-viewer

Source: EEA.

Also part of the Climate and Energy Package, is the Directive setting a common EU framework for the promotion of energy from renewable sources[21]: One of the key European success stories has been the deployment of renewable energy sources by Member States, which started well before the Directive was adopted. There has been a strong uptake of renewables for electricity, heating and transport, which have doubled since 1990. The share of renewables in gross final energy consumption (normalised to even out the annual variability in hydro & wind production) stood at 16% in 2014, according to Eurostat figures. However, growing concern about the environmental/climatic integrity of (all types) of biomass as a source of energy and the very rapid growth in the use of biomass, including of imports from third countries, has led the European Commission to prepare a sustainable bioenergy policy as part of the EU renewable energy package expected by end of 2016.

The Climate and Energy package also set the first legally-binding standards for CO_2 emissions from new passenger cars. The first Regulation [(EC) No 443/2009] introduced mandatory CO_2 emission performance standards for new passenger cars, with the setting of a CO_2 emission target of 130 g CO_2/km by 2015 and of 95 g CO_2/km to be phased in from 2020. These targets refer to the average value for the fleet of newly registered passenger cars in the EU. A more recent Regulation (EU) No 510/2011 introduced mandatory CO_2 emission performance standards for new vans, with a CO_2 emission target of 175 g CO_2/km by 2017 and of 147 g CO_2/km by 2020. These targets refer to the

(21) See http://register.consilium.europa.eu/doc/srv?l=EN&f=ST%203736%202008%20INIT

average value for the fleet of newly registered vans in the EU. According to a recent report by EEA[22], the average CO_2 emissions level of new cars sold in 2014 was 123.4 g CO_2/km. Thus, in 2014 the European Union fleet already collectively met its legal targets of 130 g CO_2/km for 2015. The average emission of new light commercial vehicles in 2014 was 169.1 g CO_2/km, which is also below the 2017 target of 175 g CO_2/km by 2017. Car and van manufacturers will have to keep reducing emissions levels to meet the targets of 95 g CO_2/km and 147 g CO_2/km, respectively.

The EU Large Combustion Plant Directive also had a significant effect on lower emissions, not only of air pollutants but also of greenhouse gases. The setting up of limit values on certain pollutants (i.e. gases which may be acidifying substances, ozone-precursors and/or particles) has encouraged efficiency improvements and fuel switching from solid fuels to cleaner fuels. These improvements have also highlighted the co-benefits of air pollution and climate policies.

Of course, Member States' own policies are additional to EU policies. The effects of EU policies cannot always be distinguished from the effects implemented at national level. Also, the integration/mainstreaming of environmental and climate concerns into the design and implementation of other policies makes it difficult to quantify the individual effects of each policy because of confounding effects.

Finally and more forward looking, much of the CO_2 emitted in Europe nowadays comes from combustion and industrial installations under the European Trading Scheme (EU ETS). Emissions are expected to continue declining as a result of improvements in energy efficiency and fuel switch motivated by the restricted supply of emission allowances. The implementation of the EU Climate and Energy Package should also lead to a reduction in emissions from sectors outside the EU ETS, such as transport and buildings (residential and commercial). According to the information reported to the EEA by Member States, a number of EU policies, in particular the climate and energy package, are expected to deliver significant emission savings through implementation at national level. The Directive promoting renewables and the legislation targeting industrial emissions (in particular the EU ETS) are considered important. In the sectors not covered by the EU ETS, for which Member States have national annual targets under the Effort Sharing Decision (ESD), energy efficiency measures are expected to play an important role in reducing emissions. Of course, effective and full implementation of policies and measures is key to the delivery of these emission reductions. Some Member States will rely on the implementation of planned policies that have not yet been adopted to ensure they reach their annual objectives under the ESD.

2.5 Largest Member State contributions to the positive EU performance

Figure 9 shows the absolute emission increase or reduction by Member States between 1990 and 2012. About 45% of the EU net decrease in GHG emissions was accounted for by Germany and the United Kingdom.

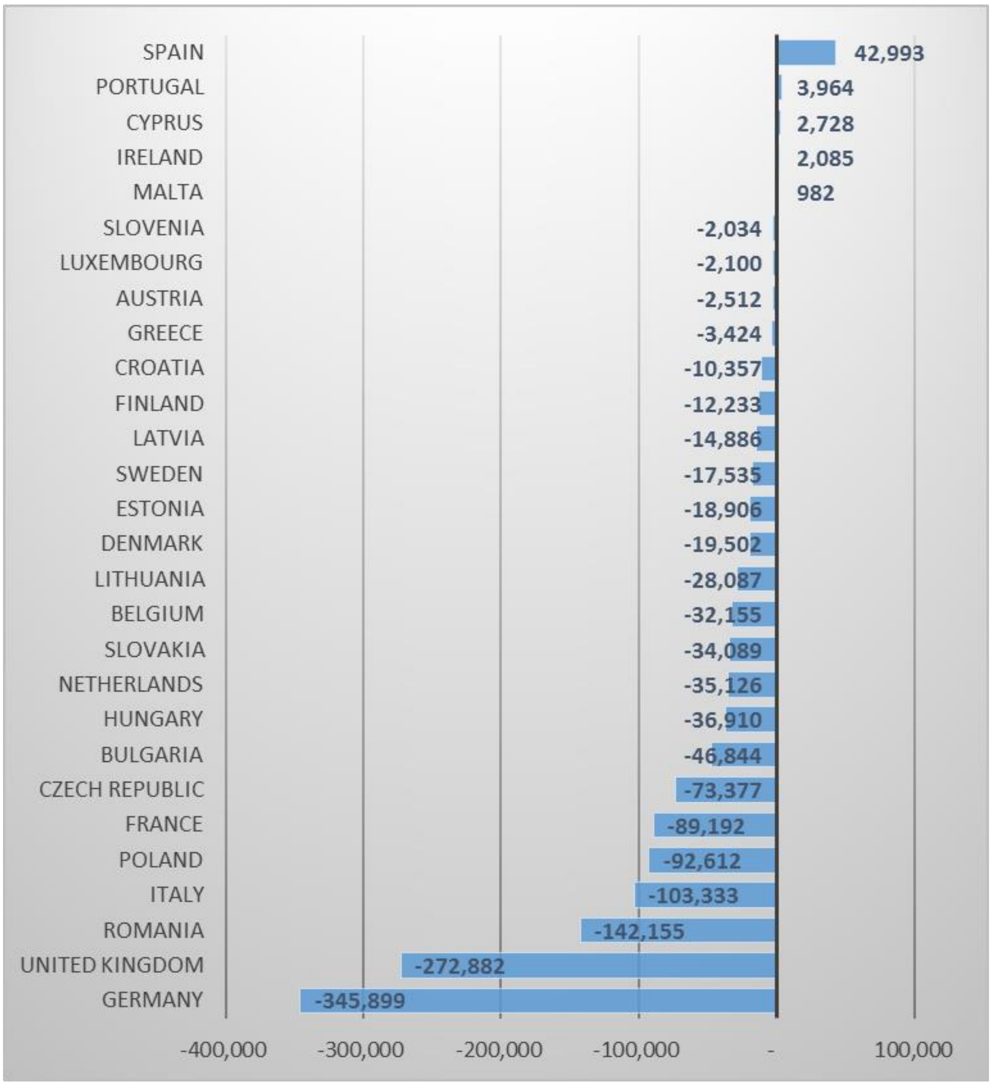
The main reasons for the favourable trend in Germany were increasing efficiency in power and heating plants and the economic restructuring of the five new Länder after the German reunification, particularly in the iron and steel sector. Other important reasons include the improvement in the carbon intensity of fossil fuels (from coal to gas), the strong increase in renewable energy use, and waste management measures that reduced the landfilling of organic waste[23]. Lower GHG emissions in

(22) Monitoring CO_2 emissions from new passenger cars and vans in 2014, http://www.eea.europa.eu/publications/monitoring-emissions-cars-and-vans

23 These are just some of the many drivers of lower GHG emissions in Germany. As in other Member States, the economic recession also had a significant effect in GHG emissions. Other relevant emission drivers can be found in Germany's National Inventory Report submitted to UNFCCC in 2016 http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/9492.php

the United Kingdom were primarily the result of liberalising energy markets and the subsequent fuel switch from oil and coal to gas in electricity production[24]. Other reasons include the shift towards more efficient combined cycle gas turbine stations (CCGT), decreasing iron and steel production and the implementation of methane recovery systems at landfill sites[25].

Figure 9 Change in total GHG emissions, excluding LULUCF, between 1990 and 2014 by EU Member State [kt CO_2 equivalent]



Source: EEA.

Table 5 shows the top 25 contributors to the reduction in GHG emissions at country level in the EU in 2014. All these together can explain 60% of the total reduction in EU emissions in 2014. One should inevitable analyse the reasons underpinning the reduction in emissions in the sectors and countries

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24 For more detailed descriptions and analysis of GHG emission trends in EU Member States, see the official GHG inventory submissions to UNFCCC (e.g. chapter 2 'Trends in GHG emissions' and under the respective sectoral chapters of the National Inventory Reports).

25 For a more detailed description of emission drivers, see the UK's 2016 National Inventory Report submitted to UNFCCC http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/9492.php

mentioned in table 5 to better understand the reasons underpinning the reduction in GHG emissions in the EU as a whole. This goes beyond the scope of this paper[26].

Table 5 Top 25 contributors to the total GHG emission reduction in the EU between 1990 and 2014

Ranking in top 10	Member State	Sector	Gas	Reduction (kt)	% total EU reduction
1	United Kingdom	Electricity & Heat Production	CO2	-80,013	5.8%
2	Poland	Electricity & Heat Production	CO2	-75,461	5.5%
3	Germany	Industrial combustion (excl. iron/steel)	CO2	-64,970	4.7%
4	Germany	Manufacture of solid fuels	CO2	-55,039	4.0%
5	Romania	Industrial combustion (excl. iron/steel)	CO2	-54,532	3.9%
6	United Kingdom	Managed waste disposal	CH4	-49,159	3.6%
7	Germany	Residential combustion	CO2	-44,328	3.2%
8	Italy	Electricity & Heat Production	CO2	-35,779	2.6%
9	United Kingdom	Industrial combustion (excl. iron/steel)	CO2	-32,982	2.4%
10	Germany	Commercial combustion	CO2	-31,545	2.3%
11	Czech Republic	Industrial combustion (excl. iron/steel)	CO2	-28,248	2.0%
12	Italy	Industrial combustion (excl. iron/steel)	CO2	-27,563	2.0%
13	Germany	Electricity & Heat Production	CO2	-25,155	1.8%
14	Romania	Electricity & Heat Production	CO2	-25,098	1.8%
15	Germany	Managed waste disposal	CH4	-24,325	1.8%
16	Germany	Coal mining	CH4	-22,752	1.6%
17	France	Electricity & Heat Production	CO2	-21,476	1.6%
18	United Kingdom	Coal mining	CH4	-20,117	1.5%
19	France	Industrial combustion (excl. iron/steel)	CO2	- 18,520	1.3%
20	Germany	Adipic acid production	N2O	- 17,864	1.3%
21	United Kingdom	Residential combustion	CO2	-17,334	1.3%
22	Czech Republic	Iron and steel production	CO2	-15,873	1.1%
23	Estonia	Electricity & Heat Production	CO2	-14,444	1.0%
24	United Kingdom	Fluorochemical production	HFCs	-14,376	1.0%
25	France	Adipic acid production	N2O	-14,090	1.0%
Sum of top 25	-	-		*-831,045*	*60.0%*
EU total net reduction	-	*all sectors excluding LULUCF*	*GHG*	*-1,383,971*	*100.0%*

Source: EEA.

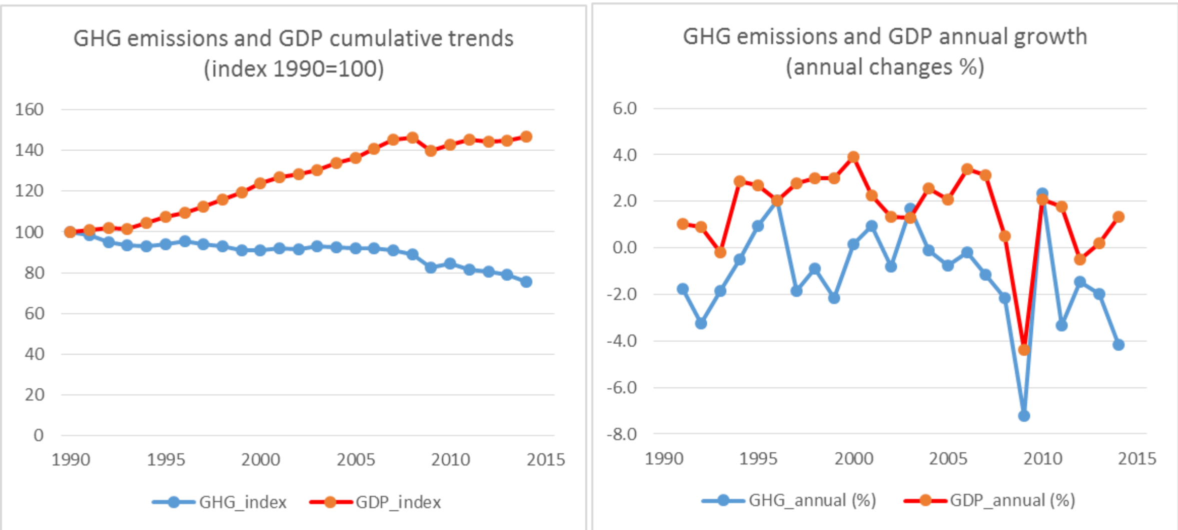
[26] Whereas the EU GHG inventory is a bottom up process starting from Member States' GHG inventories, the analysis of emission trends at EU level is a top-down process. The effect of drivers, including policies, on EU GHG emissions is larger the bigger the Member State. Table 5 shows indeed that the majority, although not only, of the top-25 contributors is accounted for by the larger EU Member States. Some of the drivers may be common across Member States (e.g. implementation of EU legislation, economic crisis, weather patterns, energy prices, etc). However, there are also country-specific drivers, policies and measures at play that need a more detail analysis to understand both the cause and effect on total EU emission reductions.

2.6 Weather conditions and the economy as drivers of emissions

2.6.1 The economy

The EU-28 has reduced total GHG emissions (excluding LULUCF) by 24.4% between 1990 and 2014, while GDP has increased by 47% (left side of figure 10). However, the apparent decoupling of emissions and GDP (relative to 1990) does not imply that the link between GDP and GHGs is broken (right side of figure 10). There is some degree of correlation or coupling when looking at GDP and GHG emissions on an annual basis. In a previous EEA-analysis[27], it was shown that GDP is a key driver of GHG emissions but not the only decisive one, with other factors and policies contributing to the decline. The 2014 analysis also showed that the strength of the relationship between GHG emissions and economic growth varies across countries but this relationship is, on average, stronger in periods of economic recession than on periods of positive economic growth.

Figure 10 Annual and cumulative changes in GDP & GHG emissions at EU level, 1990-2014



Source: EEA and AMECO database, European Commission.

Notwithstanding the complexity in causal inference at country-level[28], EU economies can grow and emissions decrease, with growing shares of renewables, less carbon intensive fuels in the energy mix

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27 For an overview of the effect of GDP on GHG emissions, see section 7 of 'Why did GHG emissions decrease in the EU between 1990 and 2012' http://www.eea.europa.eu/publications/why-are-greenhouse-gases-decreasing .

28 The link between the economy, and economic recession in particular, and GHG emissions is complex. Economic recession is broader than GDP. For example, there is a recession effect in the 'energy intensity' factor due to, for example, low demand from manufacturing industries or from transport by individuals and/or companies. There could also be an effect on 'carbon intensity' if e.g. the recession affected relative fuel prices between coal and gas (and/or renewables), or if less final energy was consumed because of higher fuel prices relative to income/salaries. Even population growth can be affected by economic recession (e.g. lower birth rates and/or net migration rates). Therefore, one should not extrapolate any conclusions regarding the average relationship between GHG emissions and GDP to the causal relationship, without considering that other factors are also at play. Some of these factors are indeed country specific and may be as important as economic growth. The relationship between GDP and GHG emissions also depends on the type of economic sector. For instance, there is clearer link between industrial economic activity and energy use and emissions from industrial sectors such as those included in the EU ETS. For other sectors, such as residential, the link to GDP is not as clear and other factors, such as warmer or colder winters, or better insulation standards in buildings, would have a much bigger effect on emissions. In addition, the link between GHG emissions and GDP also varies widely across Member States, partly reflecting the fact that the energy mix is different from country to country. Clearly, energy demand which is met by fossil fuel combustion should

and improvements in energy efficiency. The reliance on coal, gas and oil remains high but has decreased from 83% in 1990 to about 73% of primary energy in 2014. Even though the trends are encouraging, emissions will increase alongside GDP, on average, if the EU continues relying on fossil fuels to meet the majority of its final energy demand. Shifting relative prices between gas and coal can reduce and/or emissions due to the very different carbon intensities, but fossil energy demand can remain unaffected[29].

Table 6 GHG equilibrium in a fossil economy

Cointegrating relationship[30]: d.ln(ghg) f{d.ln(gdp) d.ln(ff) l.res}		Test results [coefficients & standard errors]
Variable names	Variables model	D.ln(ghg)
GDP in constant prices (first difference of the log)	D.ln(gdp)	0.173**
		(0.0790)
Fossil-fuel energy use (first difference of the log)	D.ln(ff)	0.688***
		(0.0485)
Residual (lagged error correction)	L.res	-0.458***
		(0.133)
Intercept	Constant	-0.00908***
		(0.00183)
F test	Prob > F	0.0000
Adjusted R squared	Adj. R^2	0.941
Root mean square error	Root MSE	.00523

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: EEA

There is some evidence of a long-run equilibrium between GHG emissions, economic growth and fossil-energy use. Table 6 below illustrates the results of a cointegration analysis using the Engle and Granger method[31]. The short-run elasticities for economic growth ('gdp D1)) and energy consumption ('ff D1') are highly significant at the 5% significance level. The coefficient for economic growth is significantly lower than that of energy consumption, as the EU has indeed been able to reduce

have a larger effect on GHG emissions that energy demand which is by and large met by renewables. And even yet, coal will have a larger effect on emissions than natural gas due to its higher carbon intensity. Thus, economic growth that increases demand for electricity that is largely generated by burning hard coal and/or lignite will have a larger effect on emissions than less carbon intensive fuels, other things being equal. Therefore, the more a country relies on fossil fuels, and particularly the more carbon-intensive fuels, the more difficult will be to completely decouple GHG emissions from economic growth.

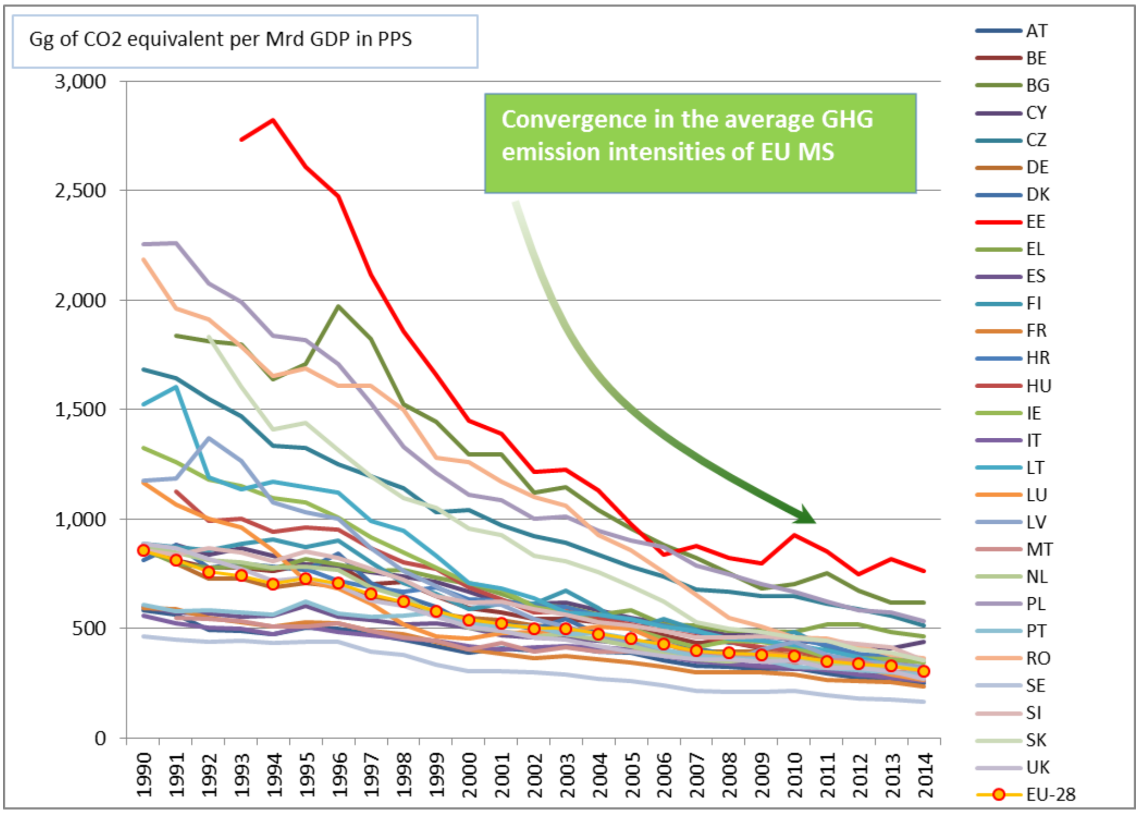
29 It is difficult to predict the effect of energy prices on energy demand and GHG emissions. According to the European Commission's Communication 'Energy prices and costs in Europe' there have been significant increases in retail prices for gas and electricity for households and industry in Europe, on average, in spite of market liberalisation. Yet, wholesale prices declined for electricity and remained stable for gas. Some of the reasons for these trends are explained in the report and are linked to both global developments and an incomplete internal energy market, as well as to the different components of the energy bill, including the fuel price, the network costs and the taxes and levies.

30 The 3 variables (total GHG emissions excluding LULCUF, GDP in Euro in 2010 market prices and primary energy fossil-fuel consumption) have been transformed into logs and were tested for unit roots using the Augmented Dickey-Fuller test. All 3 variables are integrated of order 1 (i.e. stationary in the first difference). The residuals from the OLS regression are stationary, suggesting a cointegrating relationship between the variables. These residuals entered the error correction model that incorporates the equilibrium relationship in modelling the short-term dynamics. The results of the full regression model including the lagged residuals are shown in table 6. The Johannsen's approach can be used to test the number of cointegrating relationships. In this paper, the relationship of interest was unidirectional with GHG emissions as the dependent variable and GDP and fossil fuel consumption as explanatory variables.

31 Engle, Robert F.; Granger, Clive W. J. (1987). "Co-integration and error correction: Representation, estimation and testing". Econometrica 55 (2): 251–276. JSTOR 1913236.

emissions in years of positive economic growth. When the consumption of fossil fuels increase, GHG emissions would generally increase – unless there is a substitution effect between gas and coal. In any case, both drivers are positively correlated with GHG emissions. The error correction term ('res L1') is also highly significant and has a 'speed of adjustment' coefficient of -.458. The results from the model suggest the existence of a) a long-run equilibrium between the variables, and b) a short-run disequilibrium, half of which is corrected within one year. Thus, it takes just over two years to return to the equilibrium where fossil fuels and GDP drive emissions in a predictable way. This pattern can be broken with lower levels of fossil fuels in the economy, as non-carbon fuels do not affect GHG emissions. Assuming no change in energy efficiency, the higher the share of renewables in the energy mix, the more decoupling one should expect between emissions and economic growth – understanding decoupling in the strict sense as lack of cointegration. There cannot be a complete decoupling of emissions from economic growth in a fossil-fuel economy (i.e. understood as breaking the link), since energy demand, by and large driven by fossil fuels, remains connected to economic growth.

Figure 11 Greenhouse gas emissions intensity of GDP by EU Member State, 1990-2014



Source: EEA.

A fossil economy still today is not at odds with the strong reduction in the GHG emission intensity in the EU since 1990. Because GHG emissions decreased and GDP increased, there has been a substantial improvement of the GHG emissions intensity of the economy for the EU as a whole. In addition to these improvements of total GHG emissions there has been a convergence of GHG emission intensities across MS (figure 11). One reason for this convergence is the extraordinary growth in renewables in most Member States and a move towards less carbon intensive fuels[32].

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32 Convergence 'across countries' for any given year of the time series has been analysed in GDP in purchasing power standards. To look at the reduction in GHG emissions intensity over time for a given country, GDP in constant prices should

Due to this strong convergence, GHG emissions per capita and per GDP are more similar now across Member States than they were back in 1990. Table 7 shows total greenhouse gas emissions per capita and per GDP relative to the EU-28 in purchasing power standards for the year 2014. A quick comparison between table 7 and figure 5 of section 1.1 shows that, while China improves GHG emissions intensity faster than the EU, 18 EU countries had in 2014 per-capita emissions below those of China. All 28 Member States had per-capita emissions below the US'. Differences among countries can be explained by a number of factors, including the carbon intensity of fossil fuel production (i.e. fossil fuel mix), the penetration of renewables, the existence of nuclear power for electricity generation, the efficiency in the transformation of primary energy into useful energy as well as the penetration of combined heat and power, the actual energy demand of end users, and energy efficiency improvements (and savings) linked to that demand. Other factors arising from specific climatic conditions (i.e. wind, hydro, average temperature) and the economy (i.e. fuel prices and economic growth) may also affect the ranking of countries in specific years, sometimes significantly.

Table 7 Greenhouse gas emissions per capita & GDP in 2014 (sorted)

GHG emissions per GDP in 2014 [PPS, EU-28=100]		**GHG emissions per capita in 2014 [tCO_2 eq. per person]**	
Sweden	54.2	Romania	5.5
France	77.2	Sweden	5.6
Austria	82.1	Latvia	5.7
Italy	85.2	Croatia	5.8
Luxembourg	86.1	Hungary	5.8
Denmark	86.4	Portugal	6.2
United Kingdom	88.3	Lithuania	6.5
Spain	92.2	Italy	6.9
Portugal	94.6	France	6.9
Malta	96.5	Malta	7.0
EU-28	**100.0**	Spain	7.1
Netherlands	100.7	Slovakia	7.5
Hungary	101.4	Bulgaria	7.9
Belgium	102.2	Slovenia	8.0
Lithuania	102.5	United Kingdom	8.1
Germany	105.0	**EU-28**	**8.4**
Latvia	105.3	Austria	8.9
Ireland	111.9	Denmark	9.1
Slovenia	115.9	Greece	9.3
Slovakia	116.0	Cyprus	9.9
Finland	116.5	Poland	10.0
Croatia	116.9	Belgium	10.1
Romania	118.5	Finland	10.8
Cyprus	143.7	Netherlands	11.1
Greece	152.2	Germany	11.1
Czech Republic	168.0	Czech Republic	12.0
Poland	173.5	Ireland	12.6
Bulgaria	201.6	Estonia	16.0
Estonia	249.4	Luxembourg	19.4

Source: GHG emissions, EEA. Average population, Eurostat. GDP, Ameco database, European Commission.

be used. Although the convergence is clearly visible from figure 11, it has also been measured as the reduction in the coefficient of variation (i.e. standard deviation relative to the EU).

2.6.2 *The weather*

Emission reductions from the residential (i.e. households) and commercial (i.e. services) sectors are one of the key reasons for lower greenhouse gas emissions in the EU. Emissions from households, and to a lesser extent from the services sector, have decreased substantially since 1990, despite the growth in the number of private households and the increase in population. Households represent one of the largest sources of GHG emissions and are affected by variables such as climatic conditions, fuel prices, the existence of district heating, energy efficiency in buildings and the fuel mix for heat generation. Emissions in the residential sector alone decreased by 140 million tCO_2 eq. between 1990 and 2014 and represented the third largest reduction of all sectors in the EU.

Energy efficiency improvements from better insulation standards in buildings and a less carbon-intensive fuel mix can partly explain lower demand for space heating in the EU as a whole over the past 24 years. These factors have more than offset the effects of a 32 million increase in the population, and in the number and average size of households in the EU.

Fuel consumption by the residential sector decreased by over 10% between 1990 and 2014. The most popular fuel in European households is gas, with more than half of all the fuel input in 2014. Biomass is the second and oil the third most widely-used fuels for heating. The use of gas has increased significantly since 1990. In parallel there has been a steady increase in the use of biomass. Coal use in households has declined throughout the period and represents less than 5 % of the fuel mix nowadays. As a result, the change in the fuel mix in households has led to important savings in CO_2 emissions because of the better emission intensity per unit of energy of the fuels being replaced[33].

One of the explanations for somewhat decreasing overall fuel use has been the lower demand for space heating due to better insulation standards in new buildings, the retrofitting of existing buildings and the diffusion of more efficient heating appliances[34]. Whereas energy efficiency improvements from new and better buildings should not affect heat demand substantially from one year to another, the increasing size of the new housing stock relative to the existing stock and improvements in existing buildings will reinforce this positive effect. Policies such as the EU Directive on the Energy Performance of Buildings[35] should continue to play a key role in reducing emissions from the residential sector and contribute to Member States' targets under the Effort Sharing Decision.

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[33] Not all the heat consumption by households is included under residential combustion in GHG inventories. Part of the heat is supplied via distributed systems from district heating and combined heat and power thermal stations. The primary energy to generate distributed heat (mainly from coal and gas) is reported under 'public electricity and heat production' in greenhouse gas inventories (by and large under the EU ETS). According to Eurostat, derived heat consumption in the residential sector decreased by over 25% in the EU between 1990 and 2014. The other part of the heating consists of non-distributed heat, which is generated directly by households/services (mainly from gas and biomass) and is reported under 'residential and commercial' in greenhouse gas inventories. Based on GHG inventories, direct heat consumption by the residential sector decreased by over 10% in the EU between 1990 and 2014. These emissions are by and large outside the EU ETS and account for about 90% of total heat consumption compared to distributed heat (10%). Fuel changes in derived heat have a larger effect on GHG emissions because of the higher carbon intensity used compared to direct heat combustion. In addition, some Member States (also) use electrical energy for heating purposes; however, it is not possible at this stage to quantify this heat using Eurostat's energy balances without more detail in final energy consumption by specific end-use.

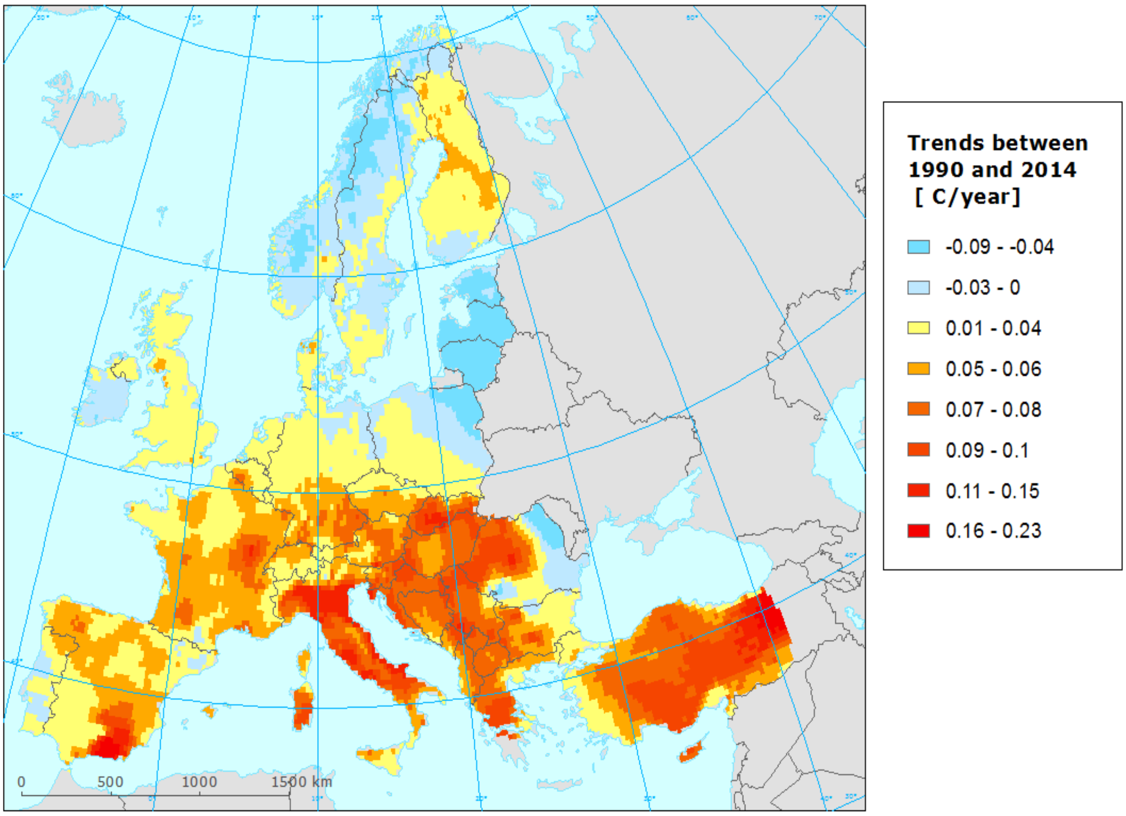
[34] Energy efficiency trends in the EU, Odyssee-Mure 2013, http://www.odyssee-mure.eu/publications/br/energy-efficiency-trends-in-Europe.html

[35] Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings was adopted in 2010 and repeals Directive 2002/91/EC on the energy performance of buildings. The Buildings Directive is one of the main instruments which have been put in place to reach the EU's 20% reduction target for primary energy consumption by 2020. The Directive obliges Member States to set minimum standards for the energy performance of new buildings and for existing buildings that are subject to major renovation work to achieve cost optimal levels. By 31 December 2020, all new buildings shall be 'nearly zero-energy buildings'. New buildings occupied and owned by public authorities shall comply with the same criteria by 31 December 2018.

The other factor that helps explain the changes in fuel use (and emissions) from the residential sector is weather related. There are two aspects to consider: a) possible long term effects from warmer winter conditions in Europe; and b) short-term effects from annual variations in winter temperatures.

Mean near-surface temperature over land has been increasing globally, and also in Europe, in the past 30–40 years and has done so both for summer and winter temperatures. Since 1990 there has been a warming of the autumn/winter months, defined as the average of the first and last quarters of the calendar year, in Europe. However, spatial variability is very high and the warming of the winter months is not always clearly evident across Europe. In some regions of Europe the trend is more visible, particularly in the South East and parts of the Iberian Peninsula as shown in figure 12. Notwithstanding the different trends by country and region regarding the effect of warmer winters, one can say that Europe is experiencing milder winters on average since 1990.

Figure 12 Trends in mean near-surface temperature between 1990 and 2014 in Europe: average temperature of January, February, March, October, November and December



Source: EEA. Data source for the underpinning daily gridded temperatures, http://www.ecad.eu/ [36]

Annual variations in winter temperatures also explain changes in fuel use and emissions from the residential sector. The year 2014 was the hottest year on record in Europe with mean annual land temperatures about 2°C higher than the pre-industrial average. As shown in section 1 of this paper, the warmer winter conditions in 2014 were the key factor underpinning the strong reduction in

36 E-OBS dataset from the EU-FP6 project ENSEMBLES (http://ensembles-eu.metoffice.com) and the data providers in the ECA&D project (http://www.ecad.eu) "Haylock, M.R., N. Hofstra, A.M.G. Klein Tank, E.J. Klok, P.D. Jones, M. New. 2008: A European daily high-resolution gridded dataset of surface temperature and precipitation. J. Geophys. Res (Atmospheres), 113, D20119, doi:10.1029/2008JD10201"

emissions that year. There is also a clear positive correlation between heating degree days (HDDs), an indication of heat demand based on outdoor temperatures, and fuel use and emissions from the residential sector. HDDs fluctuate annually depending on the prevailing weather conditions in a specific year, and this is translated into a lower or higher heat consumption by households. According to Eurostat data, the current heat demand in Europe is below its long-term average (defined as 1980–2004). Although there is no consistent trend in the number of HDDs, the average number of HDDs in the 1980s was higher than the average in the 1990s (i.e. less heat demand in the 1990s), and the average number of HDDs in the 1990s was higher than the average in the 2000s (i.e. less heat demand in the 2000s). Despite the lack of a long-term trend in the number of HDDs, there is strong evidence that annual changes in HDDs can explain annual changes in residential CO_2 emissions.

3 Early indications of 2015 emissions

The most recent official data available for total EU GHG emissions is the GHG inventory 1990-2014.

Verified 2015 emissions from the EU ETS decreased by about 0.8% compared to 2014. The EU ETS covers more than 12 000 power plants and industrial installations, as well as aircraft operators, in the 28 EU member states plus Iceland, Norway and Liechtenstein. As from 2013, the scope of the ETS is being extended to include other sectors and greenhouse gases. In 2014, emissions from stationary installations under the EU ETS represented approximately 42% of total GHG emissions in the EU.

In addition, early Eurostat estimates of CO_2 from fossil fuel combustion point to a 0.7% increase in emissions between 2014 and 2015. Eurostat's estimates are based on the IPCC Reference Approach. CO_2 emissions from fossil fuel combustion represent about 80 % of total GHG emissions in the EU.

By 30 September, the EEA will finalise its annual Approximated GHG inventory for 2015. The EEA's Approximated GHG inventory covers all major sectors reported under the UNFCCC and is consistent with a full emissions inventory, therefore covering 100 % of total GHG emissions.

The final 2015 GHG emissions for the EU and its Member States will be submitted to the UNFCCC in the spring of 2017 according to the new UNFCCC Reporting Guidelines and the 2006 IPCC Guidelines.

Other EU bodies also publish emission estimates, with a somewhat different scope in terms of methods, sectors, gases and/or geographical coverage. For more details see the paper 'different emission estimates by EU bodies/institutions', which is updated and publish regularly as a joint collaboration between EEA, JRC, Eurostat and DG CLIMA.

European Environment Agency
Kongens Nytorv 6
1050 Copenhagen K
Denmark

Tel.: +45 33 36 71 00
Web: eea.europa.eu
Enquiries: eea.europa.eu/enquiries

European Environment Agency