Why did greenhouse gas emissions decrease in the EU between 1990 and 2012?

European Environment Agency

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EEA analysis

Contents

Technical summary

1. Total GHG emissions (excluding LULUCF) in the EU-28 decreased 1,082 million tonnes since 1990 (or 19.2%) reaching their lowest level in 2012. This year, the EU emitted 4,544 million tonnes of CO2 eq. in 2012, accounting for less than 10% of global GHG emissions.

2. In 2012, EU-15 emissions were 15.1 % below the base year under the Kyoto Protocol. That constituted a net reduction of 646 million tonnes of CO2-equivalents. The average reduction between 2008 and 2012 compared to base year was 11.8%.

3. Most MS reduced emissions between 1990 and 2012. Almost 50% of the EU net decrease in GHG emissions was accounted for by Germany and the United Kingdom. The main reasons in Germany were increasing efficiency in power and heating plants and the economic restructuring of the five new Länder after the German reunification. Lower GHG emissions in 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.

4. GHG emissions per capita also decreased in almost all MS between 1990 and 2012. For the EU as a whole, per capita emissions stood at about 12 tonnes of CO2 eq. in 1990 and went down to 9 tonnes of CO2 eq. in 2012. Emissions per GDP also decreased substantially during the 22-year period. GDP increased by 45% between 1990 and 2012 whereas total GHG emissions decreased by over 19%. This led to a substantial improvement of the GHG emissions intensity of the economy for the EU as a whole. In addition there has been a convergence of GHG emission intensities across MS, both per-capita and per-GDP, due to the sustained growth in renewables and less carbon intensive fuels in most Member States.

5. In terms of the main GHGs, CO2 was responsible for the largest reduction in emissions since 1990 — currently, 81.6 % of all EU GHG emissions are CO2, excluding LULUCF and international transport. Emissions of CH4 and N2O also fell substantially — CH4 represented 8.9 % of total GHG emissions in 2012 — and N2O — 7.5 % of the total. The reduction in CH4 emissions 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 CH4 emissions from agricultural livestock, due to a reduction in numbers but also to changes in the agricultural management of organic manures. N2O emissions fell because of lower emissions from agricultural soils. 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. HFCs used in refrigeration and air conditioning were the only group of gases for which emissions increased since 1990 and accounted for 2.1% of total EU GHG emissions in 2012. The banning of Montreal-Protocol CFCs, both ozone-depleting substances and potent GHGs, led to new substitutes and their replacement with Kyoto-Protocol HFCs.

6. GHG emissions decreased in the majority of sectors between 1990 and 2012, with the notable exception of transport, including international transport. At aggregate level, reductions were largest for industrial sectors (combustion and processes), electricity and heat production, and residential & commercial combustion. Some of the main findings for these sectors are:

- Manufacturing and construction was the largest source of emission reductions in absolute terms in the EU between 1990 and 2012 (356 million tCO2 eq., including iron and steel). 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 of this sector, with emissions from solid fuels more than halving in 22 years, and structural changes of the economy with a higher share of services and a lower share of industry in total GDP. 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.

- The second largest emission reductions in the EU with 214 million tonnes of CO2 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 2012. In addition to improved energy efficiency there has been a move towards less carbon intensity fuels at EU level. Between 1990 and 2012, the use of solid and liquid fuels in thermal stations decreased strongly whereas natural gas consumption doubled, resulting in reduced CO2 emissions per unit of fossil energy generated. In the last 3 years there has been an increase in the use of solid fuels, hard coal and lignite, for electricity generation in the EU but this has been offset by lower use of natural gas and higher use of biomass.
- Emissions in the residential and commercial sectors decreased by 94 and 24 million tCO2 eq. between 1990 and 2012, respectively, 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 22 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.
- However, CO2 emissions from road transportation increased by 123 million tonnes in the 22-year period. Emissions increased steadily between 1990 and 2007 and have decreased in the last five years. Energy efficiency improvements and to a lesser extent increased used of less carbon intensive fuels 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 19% of total GHG emissions in the EU in 2012. Contributions from international aviation and shipping (not included in national total GHG emissions) increased by over 100 million tonnes between 1990 and 2012. Together, the two sectors in 2012 accounted for about 6 % of total EU GHG emissions.

7. Other key factors underpinning lower GHG emissions in the EU between 1990 and 2012 have been:

- Lower final energy intensity [less final energy per GDP, e.g. less energy used by end users];
- Lower carbon intensity of fossil fuels [less CO2 per primary energy from fossil fuels, e.g. less carbon-intensive fossil fuels];
- Improved energy-transformation efficiency [less primary energy per final energy, e.g. more efficient electricity production]; and,
- Higher non-carbon fuels effect [less fossil fuels in total primary energy]. This has by and large been accounted for by a larger share of renewable energy sources in the fuel mix, and much less so by nuclear which has been declining since 2006.

Overall, the switch to less carbon intensive fuels (mainly to natural gas and renewables) has led to a 16% improvement in the carbon intensity of the whole EU energy sector over the last 22 years.

There were two factors with a negative impact on emissions (i.e. higher CO2):

- The EU population increased by 31 million since 1990; and,
- Higher GDP per capita, with an EU net increase of 36% between 1990 and 2012.

8. A number of policies have also played a key role in GHG emission reductions, including the EU Nitrates Directive, the Common Agricultural Policy, the EU Landfill Directive, the EU Directive on the Energy Performance of Buildings, the EU Large Combustion Plant Directive and more recently the EU Climate and Energy Package. One of the key European success stories has been the deployment of renewable energy sources by Member States, which started well before the adoption of the Directive setting a common EU framework for the promotion of energy from renewable sources. 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 14% in 2012, according to the latest Eurostat figures. Climate and energy policies from the Climate and Energy Package, such as the EU ETS and the Effort Sharing Decision, are projected to have a stronger impact in the run-up to 2020. It is also important to note that many policies at Member State level are additional to EU policies.

9. When comparing the more recent periods before and after the recession that started in 2008, the main findings are:

- Emissions decreased with increasing GDP (per capita) during 2005-2008, whereas emissions and GDP (per capita) decreased during 2008-12. This again shows that emissions can decrease with a growing economy.
- The lower carbon intensity of energy was a key factor underpinning lower emissions in both periods, but even stronger in the period of 2008-12 despite the significant increase in coal use since 2009 and 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.
- The decrease in primary energy intensity was the largest contributing factor to lower CO2 emissions from fossil fuel combustion. 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 period 2005-2008 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.
- 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, not only during the 22-year period, but also during the past 7 years since 2005. This improvement came along with a significant convergence of GHG emission intensities across MS, both per-capita and per-GDP. 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.

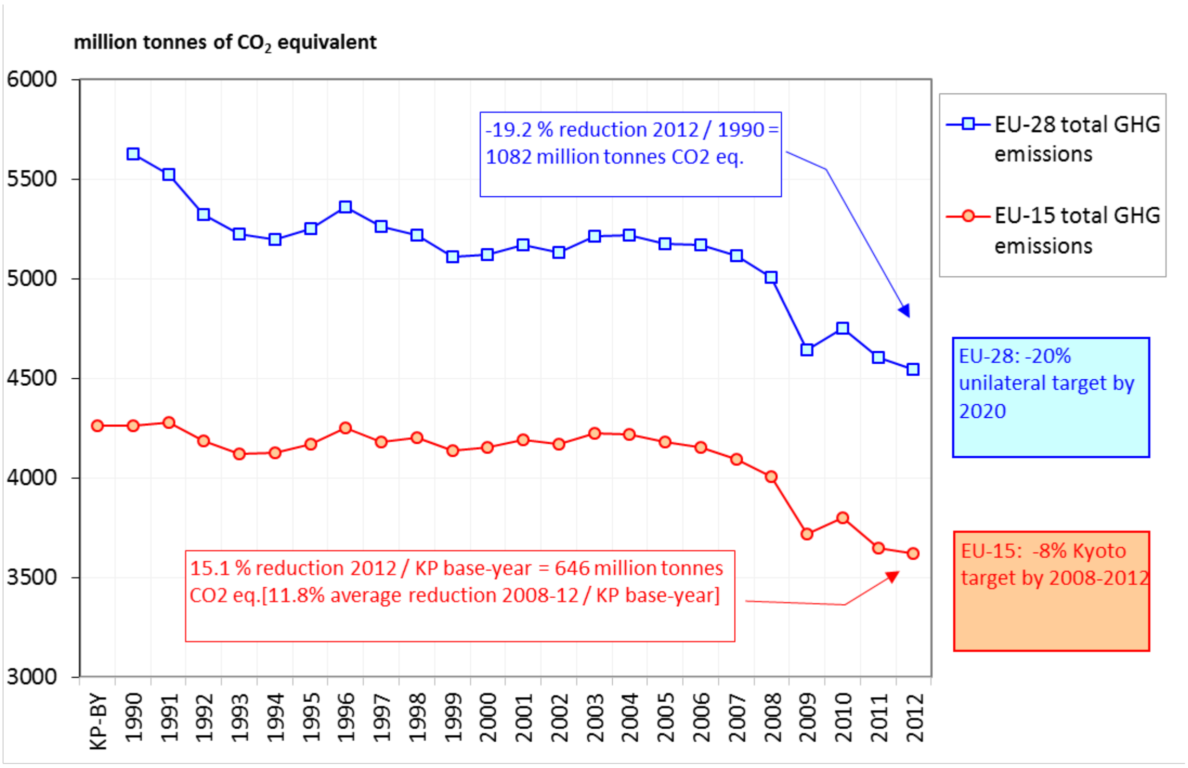
10. Regarding the relationship between GDP and GHG emissions the key findings are:

- There is a positive relationship between changes in GDP and changes in GHG emissions. About one third of the change in total GHG emissions in the EU between 1990 and 2012, on average, can be explained by changes in GDP (both positive and negative).
- Even though the strength of the relationship between GHG emissions and economic growth varies across countries, the relationship is, on average, stronger in periods of economic recession (i.e. negative GDP) than on periods of positive economic growth. For example, in cases where GDP growth has been negative (including the 2008-12 period), the average strength of the relationship between GHG emissions and GDP has ranged between 30% and 50%.
- The current results also suggest that the combined effects of other factors and policies have played at least as important a role as GDP in GHG emission reductions – including indirect effects of economic growth on other variables as well as MS specific factors and policies such as the sustained and strong increases in renewables and significant improvements in carbon intensity and energy efficiency.
- In 37% of all cases where GHG emissions have decreased at Member State level, GDP has been positive. Although the conclusions here should not be read or interpreted as a cause-effect relationship between GDP and GHG emissions, these results show that GHG emission reductions have not been at conflict with economic growth in the last 22 years across the EU.
- GDP is clearly a significant explanatory factor underpinning lower GHG emissions in the EU between 1990 and 2012, albeit not the only one. GDP is also a highly significant factor during the 5-year period that started with the economic recession in the second half of 2008. During this latter period, GHG emissions were more responsive to changes in GDP than during earlier periods, where other factors have played a bigger role in emission reductions.
- The analysis suggests the presence of certain coupling between annual changes in GDP and changes in GHG emissions between 1990 and 2012 for the EU as a whole. This is not at conflict with an absolute decoupling of GDP and GHG emission compared to 1990, with an increase in GDP of 45% alongside a decrease in emissions of 19% over the 22-year period.

1. Overview of EU trends between 1990 and 2012

Total GHG emissions (excluding LULUCF) in the EU decreased substantially since 1990, reaching their lowest level in 2012. The EU emitted 4,544 million tonnes of CO_2 eq. in 2012, accounting for less than 10% of global GHG emissions[1]. Figure 1 shows total greenhouse gas emissions in the period 1990–2012, both in the EU-15 (which is collectively a party to the Kyoto Protocol) and in the EU-28.

Figure 1 EU greenhouse gas emissions relative to 1990 and the EU-15 base year



Source: EEA.

In 2012, EU-15 emissions were 15.1 % below the base year under the Kyoto Protocol ([2]). That constituted a net reduction of 646 million tonnes of CO_2-equivalents. The average reduction between 2008 and 2012 compared to base year stood at 11.8%. Total greenhouse gas emissions in the EU-28 were 19.2 % below 1990 in 2012 — a net reduction of 1082 million tonnes of CO_2-eq ([3]).

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 between 1990 and 2012. The paper commences with an overview of EU trends, followed by summaries of the contributions of individual Member States, greenhouse gas types, and main sectors. This section

(1) This estimate is based on the 49 (±4.5) $GtCO_2eq/yr$ in total anthropogenic GHG emissions in 2010 published by the IPCC WG3 in its latest AR5. In 2010, EU emissions were 4,751 million tonnes of CO2-equivalent. This makes the EU share 9.8% of the global 49 Gt in 2010. This share is likely to have gone down even more by 2012.

(2) Following the UNFCCC reviews of Member States' 'initial reports' during 2007 & 2008 and pursuant to Article 3, para. 7 and 8 of the Kyoto Protocol, the base-year emissions for the EU-15 have been fixed at 4 265.5 Mt CO_2-equivalents.

(3) There is no Kyoto target for the EU-28 during the first commitment period and therefore no applicable base year. The 20 % EU target for 2020 is not directly comparable with the current accounting Kyoto rules due to the different scopes. When CO_2 emissions from international aviation are included (already part of the EU-ETS from 2012), the 19.2 % overall reduction between 1990 and 2012 would be equivalent to a 17.9 % reduction. If international shipping was included, the net emissions reduction between 1990 and 2012 would be 16.9 %.

continues with a more detailed analysis of the main sources of emissions, including the different factors and policies that have contributed to the GHG emission trends in the EU between 1990 and 2012. It then analyses the contribution of other factors such as population levels, economic output, renewable energy consumption, and energy and carbon intensity. It concludes with an overview of the effect of GDP on GHG emissions[4].

This analysis is by and large based on GHG inventory data reported by Member States for the compilation of the EU's GHG inventory. See Annex 6 for an overview on the institutional set up at EU level to ensure compliance with the UNFCCC and the Kyoto Protocol.

2. Overview of EU GHG emission trends by Member State, 1990-2012

EU GHG emissions are the sum of MS emissions. Thus, trends in EU GHG emissions fully reflect emission trends at MS level. Most EU MS reduced GHG emissions between 1990 and 2012 (table 1).

Table 1 Greenhouse gas emissions in CO_2 equivalents (excl. LULUCF)

MEMBER STATE	1990 (million tonnes)	Kyoto Protocol base year (million tonnes)	2012 (million tonnes)	2011–2012 (million tonnes)	Change 2011–2012 (%)	Change 1990-2012 (%)	Change base year–2012 (%)	Targets 2008–12 under Kyoto Protocol and "EU burden sharing" (%)
Austria	78.1	79.0	80.1	-2.7	-3.3%	2.5%	1.3%	-13.0%
Belgium	143.0	145.7	116.5	-3.6	-3.0%	-18.5%	-20.0%	-7.5%
Denmark	68.7	69.3	51.6	-4.9	-8.6%	-24.8%	-25.5%	-21.0%
Finland	70.3	71.0	61.0	-5.9	-8.8%	-13.3%	-14.1%	0.0%
France	557.4	563.9	490.1	0.1	0.0%	-12.1%	-13.1%	0.0%
Germany	1248.0	1232.4	939.1	10.4	1.1%	-24.8%	-23.8%	-21.0%
Greece	104.9	107.0	111.0	-3.7	-3.3%	5.8%	3.7%	25.0%
Ireland	55.2	55.6	58.5	0.8	1.4%	5.9%	5.3%	13.0%
Italy	519.1	516.9	460.1	-26.5	-5.4%	-11.4%	-11.0%	-6.5%
Luxembourg	12.9	13.2	11.8	-0.29	-2.4%	-8.2%	-10.1%	-28.0%
Netherlands	211.8	213.0	191.7	-3.4	-1.7%	-9.5%	-10.0%	-6.0%
Portugal	60.8	60.1	68.8	-0.6	-0.8%	13.1%	14.3%	27.0%
Spain	283.7	289.8	340.8	-5.1	-1.5%	20.1%	17.6%	15.0%
Sweden	72.7	72.2	57.6	-3.2	-5.2%	-20.8%	-20.2%	4.0%
United Kingdom	775.5	776.3	580.8	18.1	3.2%	-25.1%	-25.2%	-12.5%
EU-15	**4262.1**	**4265.5**	**3619.5**	**-30.5**	**-0.8%**	**-15.1%**	**-15.1%**	**-8.0%**
Bulgaria	109.1	132.6	61.0	-5.0	-7.5%	-44.1%	-54.0%	-8.0%
Croatia	31.9	31.3	26.4	-2.1	-7.4%	-17.3%	-15.7%	-5.0%
Cyprus	6.1	n.a.	9.3	-0.4	-4.4%	52.1%	n.a.	n.a.
Czech Republic	196.1	194.2	131.5	-3.8	-2.8%	-33.0%	-32.3%	-8.0%
Estonia	40.6	42.6	19.2	-1.3	-6.3%	-52.8%	-55.0%	-8.0%
Hungary	97.6	115.4	62.0	-4.1	-6.1%	-36.5%	-46.3%	-6.0%
Latvia	26.2	25.9	11.0	-0.2	-1.4%	-58.1%	-57.6%	-8.0%
Lithuania	48.7	49.4	21.6	-0.1	-0.3%	-55.6%	-56.2%	-8.0%
Malta	2.0	n.a.	3.1	0.1	3.7%	57.7%	n.a.	n.a.
Poland	466.4	563.4	399.3	-6.5	-1.6%	-14.4%	-29.1%	-6.0%
Romania	247.7	278.2	118.8	-2.7	-2.3%	-52.0%	-57.3%	-8.0%
Slovakia	73.2	72.1	42.7	-2.0	-4.4%	-41.7%	-40.7%	-8.0%
Slovenia	18.4	20.4	18.9	-0.6	-2.8%	2.5%	-7.1%	-8.0%
EU-28	**5626.3**	**n.a.**	**4544.2**	**-59.0**	**-1.3%**	**-19.2%**	**n.a.**	**n.a.**

Note: Cyprus, Malta and EU-28 do not have CP1 Kyoto Protocol targets, and not applicable Kyoto Protocol base years.

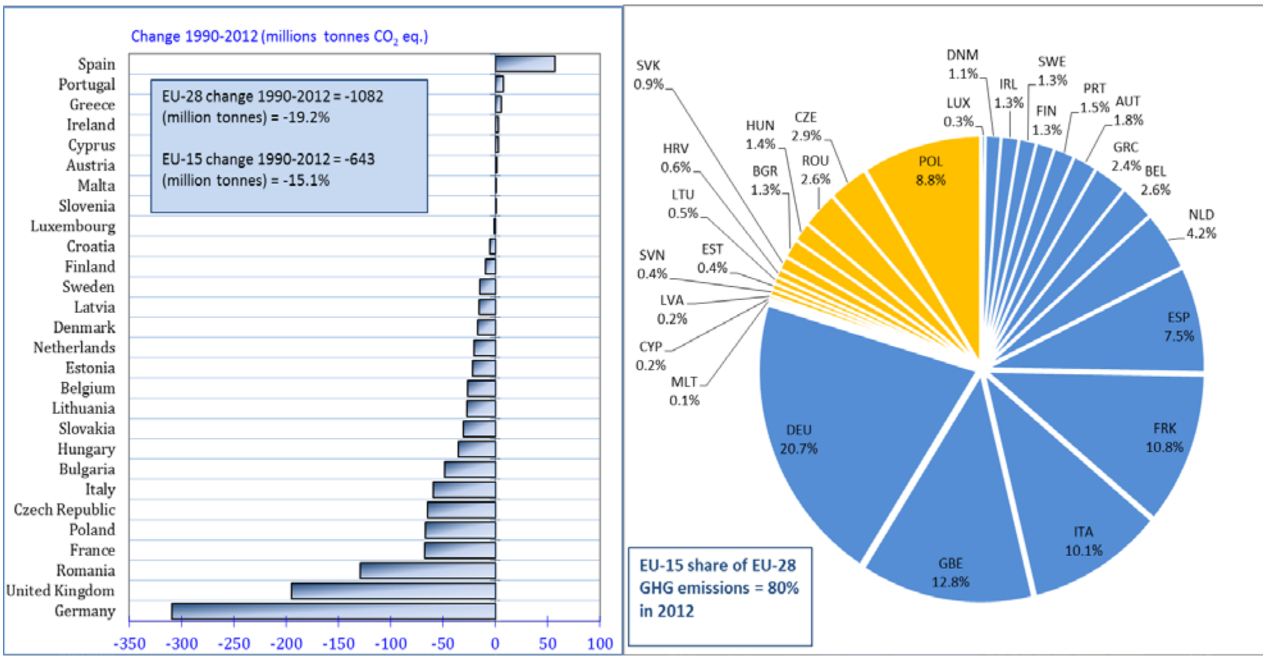
Source: EEA

(4) The effect of some of these policies were already discussed in 'GHG emissions in Europe: a retrospective trend analysis 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 'Sixth National Communication and first biennial report from the EU to the UNFCCC, 2014' http://unfccc.int/files/national_reports/annex_i_natcom_/application/pdf/eu_nc6.pdf

The bars in Figure 2 depict the absolute emission increase or reduction by Member States between 1990 and 2012. The pie chart in Figure 2 shows the percentage contribution of each Member State to total GHG emissions in 2012. The EU-15 as Party to the Kyoto Protocol accounts for 80% of EU-28 GHG emissions. Almost 50% of the EU net decrease in GHG emissions was accounted for by Germany and the United Kingdom. On the negative side, Spain increased emissions significantly despite its rapid deployment of renewable energy technologies. 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. Lower GHG emissions in 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[5].

Figure 2 Greenhouse gas emissions by DU Member State, change 1990-2012 & 2012 shares



Source: EEA.

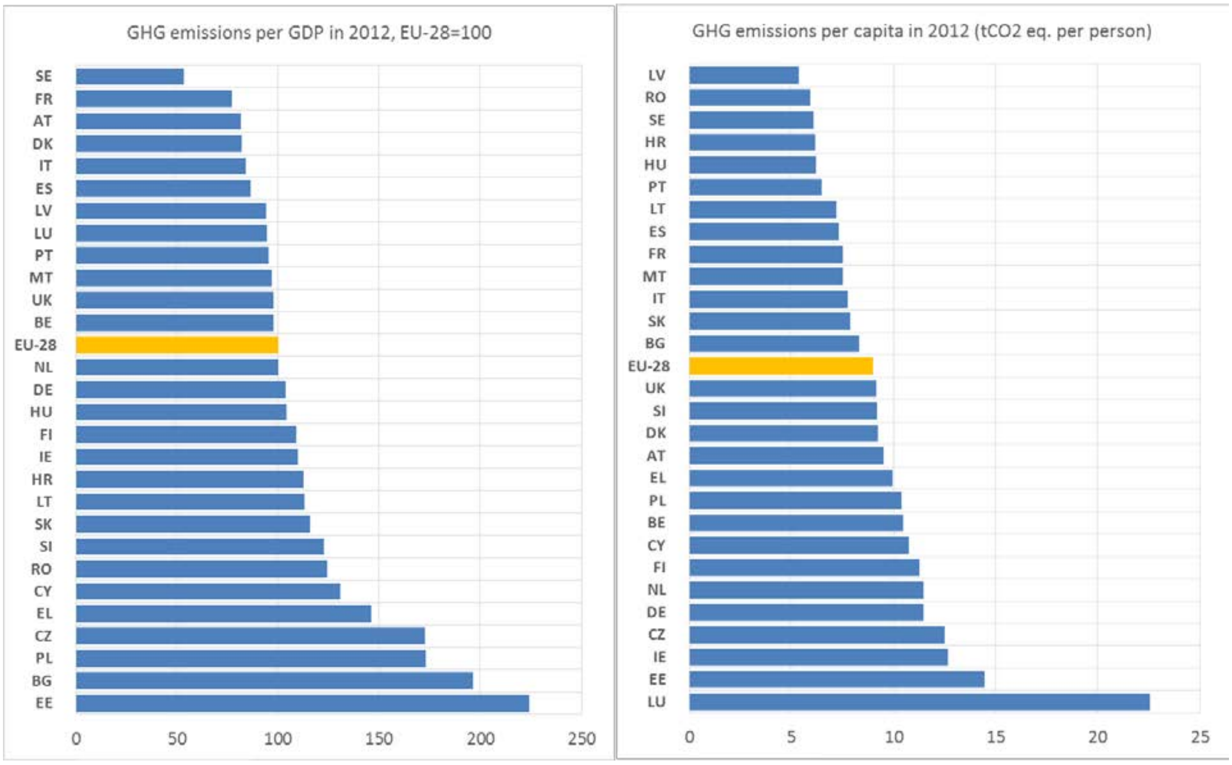
Figure 3 shows total greenhouse gas emissions per capita (right chart) and per GDP relative to the EU-28 in purchasing power standards (left chart) for the year 2012. Differences among countries can be explained by a number of factors, including the carbon intensity of fossil fuel production (i.e. fossil 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.

There have also been reductions in GHG emissions per capita in most MS between 1990 and 2012. For the EU as a whole, per capita emissions stood at about 12 tonnes of CO_2 eq. in 1990 and went down to 9 tonnes of CO_2 eq. in 2012. The average EU citizen emits about 9t CO_2-equivalent (excluding LULUCF), which is above the world average of approximately 7t CO_2-equivalent per person, and similar

(5) 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).

to China's 8t CO_2 eq., but still well below per capita emissions in the United States (21 tCO_2 eq.)[6]. 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, as explained above.

Figure 3 Greenhouse gas emissions per capita and per GDP by EU Member State in 2012



Source: EEA.

In addition to lower GHG emissions per capita, emissions per GDP also decreased substantially during the 22-year period. GDP increased by 45% between 1990 and 2012 whereas total GHG emissions decreased by over 19%. This led to 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 per-capita and per-GDP there has been a convergence of GHG emission intensities across MS, both per-capita and per-GDP (figure 4). One reason for this convergence is the extraordinary growth in renewables in most Member States and a clear move towards less carbon intensive fuels[7].

(6) World per-capita GHG emissions have been calculated based on the IPCC 49 tCO_2 for global GHG emissions in 2010 http://report.mitigation2014.org/spm/ipcc_wg3_ar5_summary-for-policymakers_approved.pdf and the UN estimate of 6.9 billion for the world population for the same year http://esa.un.org/unpd/wpp/unpp/p2k0data.asp.

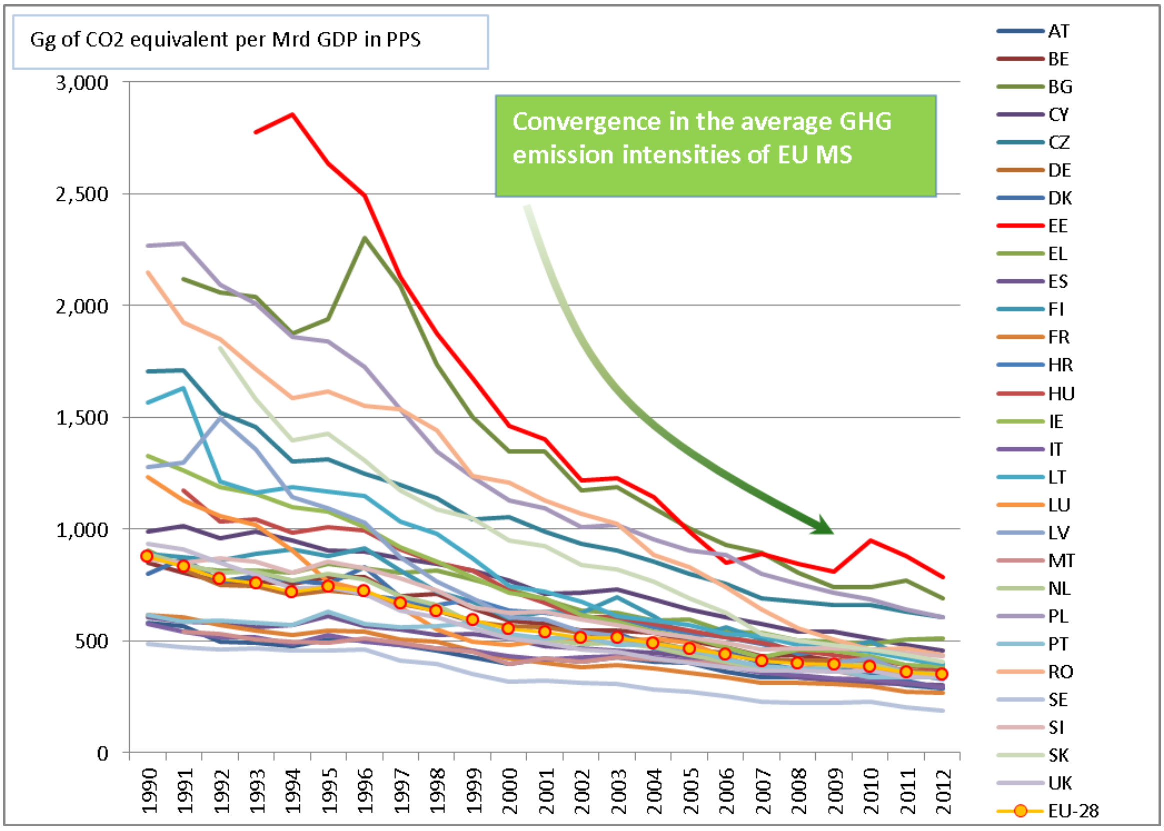
Per capita emissions for the US have been calculated from the US GHG inventory submission to UNFCCC of 15/04/2014, for 2012, http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/8108.php and from World Bank population estimates http://data.worldbank.org/indicator/SP.POP.TOTL.

The EU per capita estimate is based on the 2014 official EU submission to UNFCCC (same link as the US) and population from Eurostat for the year 2012 http://epp.eurostat.ec.europa.eu/portal/page/portal/population/data/database.

Finally, per capita GHG emissions for China are based on the JRC's EDGAR database http://edgar.jrc.ec.europa.eu/overview.php?v=GHGts_pc1990-2010. The latest data available is for the year 2010.

(7) 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 be used. Although the convergence is clearly visible from figure 4, it has also been measured as the reduction in the coefficient

Figure 4 Greenhouse gas emissions intensity of GDP by EU Member State, 1990-2012



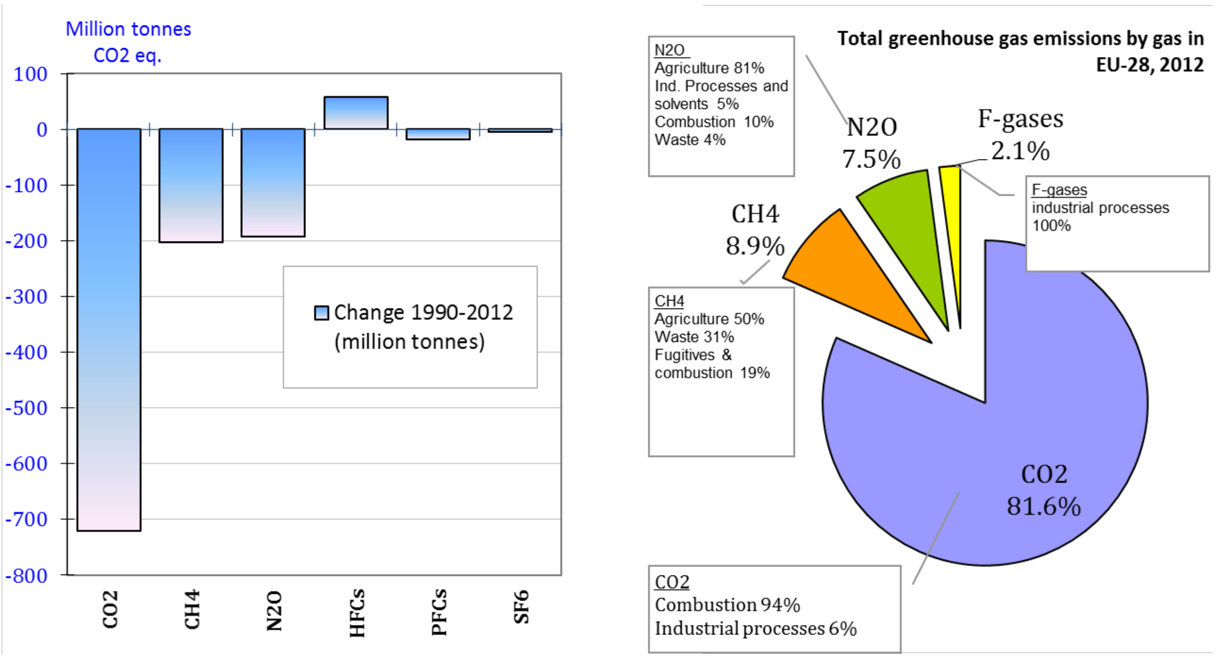
Source: EEA.

3. Overview of EU GHG emission trends by main gas, 1990-2012

In terms of the main GHGs, CO_2 was responsible for the largest reduction in emissions since 1990 (Figure 5) — currently, 81.6 % of all EU GHG emissions are CO_2, excluding LULUCF and international transport. About 94 % of the CO_2 released to the atmosphere originated from the combustion of fossil fuels, and the remaining 6 % from industrial processes. 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 decline 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). The EU Large Combustion Plant Directive, which places limit values on certain pollutants, has also led to a reduction in CO_2 emissions via fossil fuel switching from coal to gas. This also highlights the importance of co-benefits between air pollution and climate policies.

of variation (i.e. standard deviation relative to the EU) of the GHG emissions intensity of the period 2008-12 compared to the average intensity of the period 1995-99. This convergence improved by 40% when comparing the late 1990s with 2008-2012.

Figure 5 Greenhouse gas emissions by main gas in EU-28, change 1990-2012 & 2012 shares



Source: EEA.

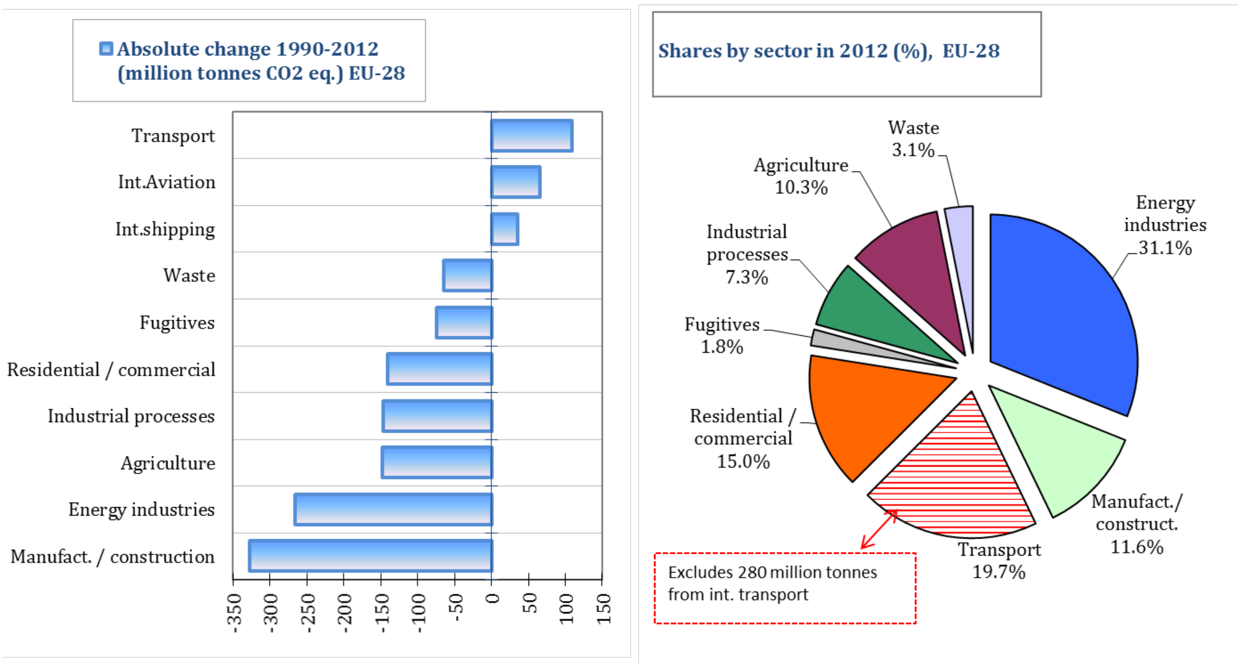
Emissions of CH_4 and N_2O also fell substantially between 1990 and 2012 — CH_4 represented 8.9 % of total GHG emissions in 2012 — and N_2O — 7.5 % of the total. The reduction in CH_4 emissions reflects lower levels of coal mining and post-mining activities as well as lower emissions from managed waste 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 fell because of lower emissions from agricultural soils. 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 impact on greenhouse emissions. The so-called first pillar of the CAP (dealing with market support) also had a strong impact through the milk quota system by reducing animal numbers in the dairy sector to compensate for increasing animal productivity. The Landfill Waste Directive, which requires Member States to reduce the amount of biodegradable waste landfilled has also contributed to an increase in the amounts of waste recycled, composted and an increase in the recovery of landfill gas.

One of the key EU emission sources is the consumption of hydrofluorocarbons (HFCs) used in industrial processes. HFCs were the only group of gases for which emissions increased since 1990 and accounted for 2.1% of total EU GHG emissions in 2012. This increase has been a side effect from the implementation of the Montreal Protocol on ozone depleting substances - one of the most successful multilateral environmental (and indirectly climatic) agreements in history. 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.

4. Overview of EU GHG emission trends by main sector, 1990-2012

GHG emissions decreased in the majority of sectors between 1990 and 2012, with the notable exception of transport, including international transport. Figure 6 shows that, at aggregate level, reductions were largest for industrial sectors (combustion and processes), electricity and heat production, residential & commercial combustion and agriculture.

Figure 6 Greenhouse gas emissions by main sector in EU-28, change 1990-2012 & 2012 shares



Source: EEA.

A detailed analysis of the contribution of key sectors contributing to the largest reductions (and increases) in GHG emissions in the EU between 1990 and 2012 is described in section 5 below.

5. Analysis of key emission sources in the EU, 1990-2012

Table 2 shows the key emission sources explaining the net change in total greenhouse gas emissions in the EU-28 and the EU-15 between 1990 and 2012. The sectors and gases explaining the largest decreases for EU-28 were manufacturing industries and construction (CO_2), public electricity and heat production (CO_2), and households and services (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 22-year period, although they are excluded from the Kyoto targets. A short description of the trends in each of these key sources is presented below.

5.1 Key emission sources and drivers at EU level

A number of factors and policies have contributed to the GHG emission trends in the EU since 1990. The paragraphs that follow are a non-exhaustive list of key drivers underpinning lower GHG emissions in the EU-28 between 1990 and 2012[8].

Table 2 Overview of the EU-28 and EU-15 source categories with the largest emission increases and decreases in the period 1990–2012 (million tonnes CO_2 eq.)

	EU-28	EU-15
➢ Road Transportation (CO_2 from 1A3b)	+123.1	+71.8
➢ Consumptions of halocarbons (HFC from 2F)	+84.9	+70.5
➢ Enteric fermentation (CH_4 from 4A)	-48.2	-21.2
➢ Cement Production (CO_2 from 2A1)	-28.0	-22.6
➢ Production of halocarbons (HFC from 2E)	-26.9	-26.9
➢ Nitric Acid Production (N_2O from 2B2)	-42.1	-30.5
➢ Agricultural soils (N_2O from 4D)	-74.1	-40.8
➢ Fugitive emissions from fuels (CH_4 from 1B)	-72.5	-49.2
➢ Iron and Steel Production (CO_2 from 1A2a +2C1)	-97.6	-53.9
➢ Manufacture of Solid fuels (CO_2 from 1A1c)	-59.2	-57.8
➢ Adipic Acid Production (N_2O from 2B3)	-59.3	-58.4
➢ Public Electricity and Heat Production (CO_2 from 1A1a)	-214.0	-60.8
➢ Solid waste disposal on land (CH_4 from 6A)	-61.3	-65.6
➢ Households and services (CO_2 from 1A4)	-137.2	-77.7
➢ Manufacturing industries (excl. Iron and steel) (Energy-related CO_2 from 1A2 excl. 1A2a)	-258.5	-151.1
Total	**-1082.0**	**-642.6**

Note: The table shows those sources for which emissions have increased/decreased by > 20 million tonnes of CO_2 eq. between 1990 & 2012 in the EU. Therefore, the sum for each country grouping EU-15/EU-28 do not match the total change listed at the bottom of the table.

Source: EEA.

For example, the Montreal Protocol on ozone-depleting substances has been one of the most successful multilateral environmental agreements to date, contributing to substantial 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 significantly since 1990. Indeed, the consumption of HFCs recorded the second largest increase of emissions after CO_2 emissions from road transportation.

The EU Nitrates Directive, preventing water pollution by reducing nitrates from agriculture, 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.

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(8) 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 'Sixth National Communication and first biennial report from the EU to the UNFCCC, 2014' http://unfccc.int/files/national_reports/annex_i_natcom_/application/pdf/eu_nc6.pdf

The EU Common Agriculture Policy 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 EU landfill Waste Directive 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.

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.

At the core of EU climate policy is the Climate and Energy Package adopted in 2009[9]. 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, and agreed to a conditional offer to move to a 30% reduction provided that other developed countries commit themselves to comparable emission reductions and developing countries contribute adequately according to their responsibilities and respective capabilities.

The main instruments to reduce emissions under the Climate and Energy Package are the EU Emissions Trading System[10], covering more than 12,000 power stations and industrial plants in 31 countries, as well as airlines, and the Effort Sharing Decision[11] 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. The non-trading sectors broadly include direct emissions from households and services, as well as emissions from transport, waste, and agriculture. The non-trading sectors currently represent about 60 % of total greenhouse gas emissions.

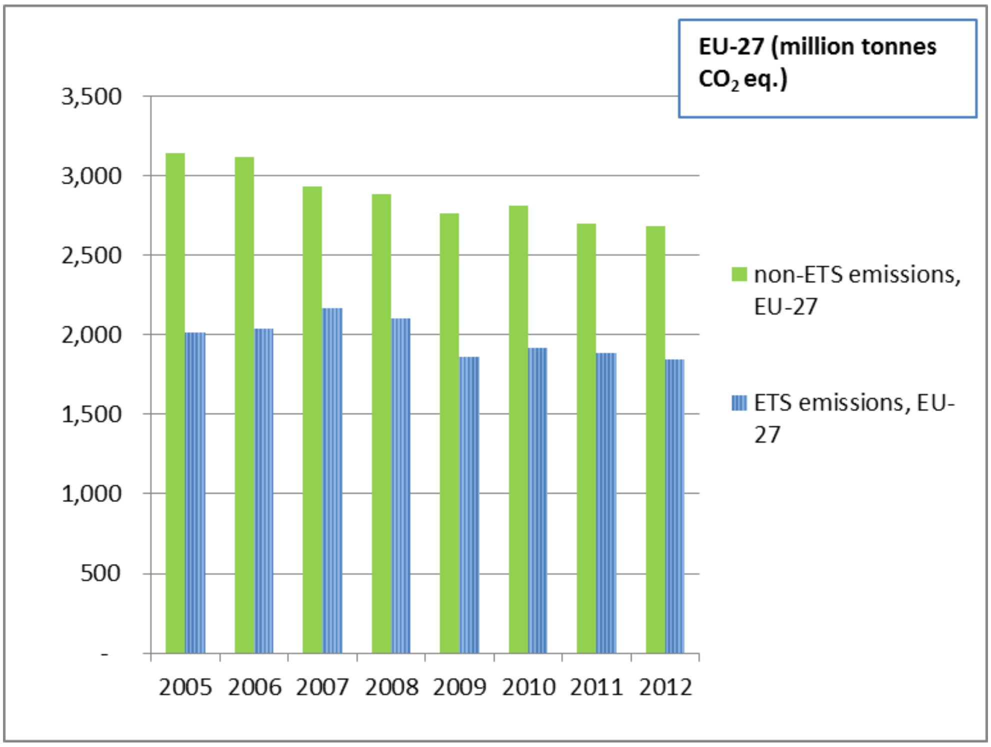
Overall, the sectors covered by the EU Emissions Trading System (EU ETS) contributed more to the overall emissions reduction between 2008 and 2012 than the non-trading sectors (i.e. those outside the EU ETS). The opposite situation occurs when considering the whole period since 2005 (figure 7). This is because ETS emissions increased during the first phase of the EU ETS between 2005 and 2007. 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 emission reductions during 2008-12. 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.

(9) See http://eur-lex.europa.eu/legal-content/en/ALL/?uri=OJ:L:2009:140:TOC

(10) See http://ec.europa.eu/clima/policies/ets/index_en.htm

(11) See http://ec.europa.eu/clima/policies/effort/index_en.htm

Figure 7 Trends in EU ETS and non-ETS emissions between 2005 and 2012



Note: Data only available for EU-27 Member States since 2005. Croatia is not included.

Source: EEA.

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.

Also part of the Climate and Energy Package, is the Directive setting a common EU framework for the promotion of energy from renewable sources[12]: 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 14% in 2012, according to Eurostat figures.

The Climate and Energy package also set the first legally-binding standards for CO_2 emissions from new passenger cars, amended in 2014[13]. According to a recent report by EEA[14], the average CO_2 emissions level of new cars sold in 2013 was 127 gCO_2/km. Thus, in 2013 the European Union fleet already collectively met its legal target of 130 gCO_2/km for 2015. Car manufacturers will have to keep reducing emissions levels to meet the target of 95 gCO_2/km by 2021.

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

(13) See Regulation (EU) No 333/2014 of the European Parliament and of the Council amending Regulation (EC) No 443/2009 to define the modalities for reaching the 2020 target to reduce CO_2 emissions from new passenger cars http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32014R0333

(14) Monitoring CO_2 emissions from new passenger cars in the EU: summary of data for 2013, http://www.eea.europa.eu/publications/monitoring-co2-emissions-from-new-1

As it will be shown in the following sections, there are other factors not necessarily reported in GHG inventories which also contributed to lower GHG emissions in the EU between 1990 and 2012. These include, among others:

Improved energy efficiency in the transformation of primary fuels into electricity, heat and oil products and improvements in energy efficiency from the end user perspective, at consumer level. One example of the latter has been the lower demand for space heating due to better insulation standards in new buildings and the retrofitting of existing buildings, due to policies such as the EU Directive on the Energy Performance of Buildings[15]. The effects of warmer and/or colder winters and of lower and/or higher heat demand are more visible on a year to year basis than over the past 22 years since 1990.

There have also been very substantial improvements in the carbon intensity of energy production and use since 1990, with a strong uptake of natural gas and renewables and a significant decline in solid fuels (despite the increase since 2009) and in oil consumption in the last years..

The decrease in both primary and final energy intensity were also key contributing factors to lower CO_2 emissions from fossil fuel combustion. Energy consumption decreased while GDP increased in the 22-year period, leading to an improvement in the emissions intensity of energy production and use. Lower (primary energy) intensities are linked to improvements in energy efficiency and the strong uptake of renewables, as well as to changes in the structure of the economy and a higher share of the services sector compared to the more energy intensive industrial sector.

The most recent economic recession undoubtedly explains lower energy demand from industry and road transportation since 2008. However, over the long term emissions have decreased with increasing GDP, showing that emissions can decrease with a growing economy (see section 7).

Increasing fuel prices may have also affected the demand from specific sectors. For example, price increases for diesel and gasoline have increased considerably and have outpaced households' disposable income since 2009. Along with the start of the economic recession in the second half of 2008 and the whole of 2009, this may have triggered a fall in freight transport demand.

Obviously, 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.

Climate and energy policies from the Climate and Energy Package, such as the EU ETS and the Effort Sharing Decision, will have a stronger impact in the run-up to 2020. 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.

(15) 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, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:153:0013:0035:EN:PDF

5.2 Analysis of the four largest key emission sources

This section focuses on the four largest key sources in terms of trends in the EU between 1990 and 2012: On the positive emissions side, manufacturing industries and construction (CO_2), public electricity and heat production (CO_2), and residential combustion (CO_2); and, on the negative side, CO_2 emissions from road transportation. The section also includes a short overview of trends in international transport and LULUCF.

5.3.1 Industry-related emissions

Manufacturing and construction was the largest source of emission reductions in absolute terms in the EU between 1990 and 2012 (258 million tCO_2 eq., excluding iron and steel). The reduction in emissions from fuel combustion in iron and steel plants are intertwined with process-related emissions from iron and steel production (together accounting for 98 million tCO_2 eq.) and from the 'manufacture of solid fuels' such as coke production (59 million tCO_2 eq.). Emissions from other industrial processes also declined since 1990. Taken together, industry-related emissions accounted for a reduction of 457 million tonnes in the EU over the 22-year period 2012 (roughly the size of Italy's total emissions in 2012). Most of these emissions fall within the scope of the EU ETS.

A combination of factors explain this trend, such as improved efficiency in restructured iron and steel plants, the increased share of biomass and the lower shares of liquid and solid fuels, and structural changes of the economy with a higher share of services and a lower share of industry in total GDP. The economic recession that began in the second half of 2008 and continued through to 2009 has had a strong impact on overall emissions, particularly from this sector.

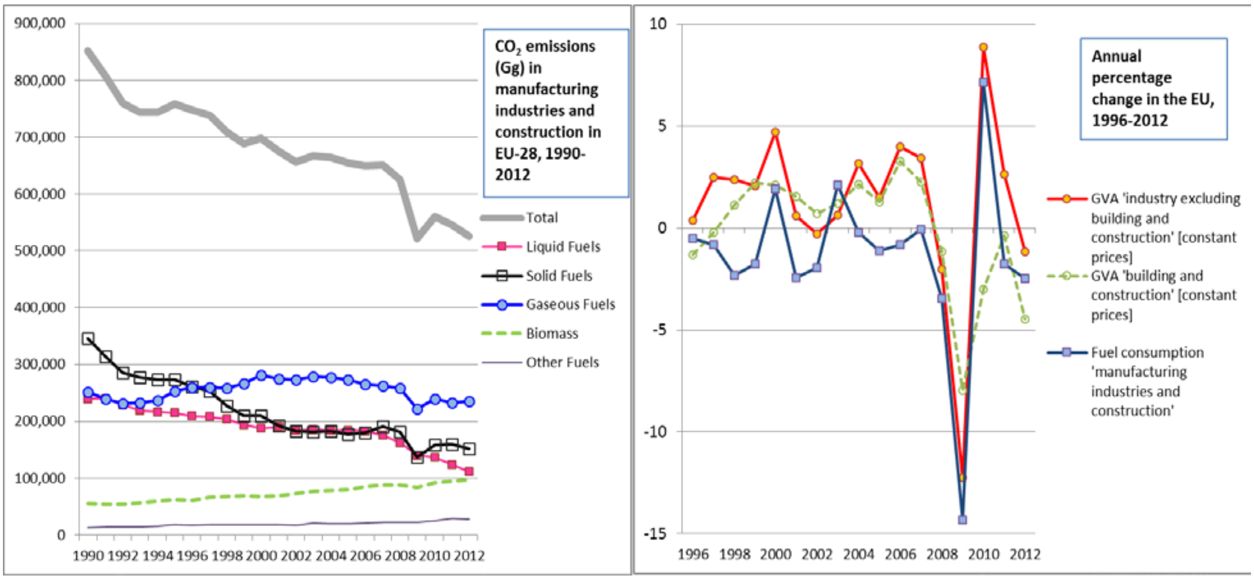
In the early 1990s about 28% of economic output was accounted for by industry in the EU. In 2012, the share of industry in total GDP went down to 22%. The economic restructuring of the Eastern European economies in the early 1990s was a key factor but not the only one. There have been significant changes in the economic structure of other EU MS, with an increasing share of the services sector, both in economic and employment terms in the past 22 years. Overall, these trends can partly explain lower emissions from the more energy-intensive industry in relation to a less energy-intensive services sector. The service sector contributed to almost three quarters of total gross value added (GVA) at EU level in 2012.

In addition to energy efficiency improvements and changes linked to the structure of the economy there have been substantial improvements in the carbon intensity of this sector, with emissions from solid fuels more than halving in 22 years. Figure 8 shows that emissions from manufacturing industries and construction decreased substantially for liquid and solid fuels since 1990. There was a parallel increase in biomass use over the period which clearly contributed to otherwise-higher emissions.

Figure 8 also shows the evolution of GVA in industry alongside fuel consumption in the sector. Indeed, most of the biggest industrial installations are part of the EU ETS and the contraction in gross value added in industry since 2008 appears to have led to a significant reduction in final energy demand and emissions in the sector. On an end-user basis, EEA figures also show that the largest emission reductions from energy combustion in the period that followed the 2008/2009 economic recession were by and large accounted for by industry[16].

(16) 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.

Figure 8 CO₂ emissions, fuel use, and GVA in manufacturing and construction in EU-28



Source: EEA.

Germany, Romania, the UK, Italy and Czech Republic accounted for about 69% of the 258 million tCO_2 eq. reduction in emissions from manufacturing industries and construction (excluding iron and steel) in the EU between 1990 and 2012. The largest emission reductions in iron and steel (both combustion and process-related) took place in Poland, Czech Republic, UK, Belgium, Romania, France and Germany. These MS together accounted for 78% of the 98 million tCO_2 eq. EU-net-reduction since 1990. Regarding the manufacture of solid fuels, 89% of the 59 million tCO_2 eq. emissions reduction was accounted for by Germany.

Finally, world trade developments can also be important for understanding GHG emission trends. The value of exports of goods by EU-28 increased by 60% while that of imports increased by 52% in the period between 2005 and 2012. In 2012, the EU was the largest exporter of goods, followed by China, and second largest importer, after the USA. China has become the EU's first supplier of goods (17% of all imports), with total EU imports from China reaching EUR 280 billion in 2013. Whereas worldwide imports of goods into the EU reached EUR 1.68 trillion in 2013, the value of exports was even higher at EUR 1.73 trillion the same year[17]. So 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.

5.3.2 Electricity and heat production

The second largest emission reductions in the EU with 214 million tonnes of CO_2 eq. were achieved in the production of electricity and heat. This sector is currently the most important source of CO_2 emissions — contributing around 27% of the total — the largest source of sulphur dioxide (SO_2) and second largest of nitrogen oxides (NO_X). Emissions from this sector are by and large covered within the EU ETS.

Fuel input to public electricity and heat production has remained broadly stable, despite some fluctuations in the 22-year period since 1990. Whereas fuel input to conventional thermal stations

(17) European Union in the World, Directorate General for Trade, European Commission, http://trade.ec.europa.eu/doclib/docs/2006/september/tradoc_122532.pdf

remained stable, energy output increased by about 12% in the same period. This has been due to significant improvements in the transformation efficiency of primary energy to final energy. Indeed, energy efficiency in main activity conventional thermal stations (including district heating) improved in the EU-28 from about 45% in 1990 to almost 50% in 2012.

The improvement in the transformation efficiency has to be seen in the context of lower heat production and higher electricity production between 1990 and 2012. At EU level, there has been a downward trend in the production of derived heat (i.e. distributed heat) which was more than offset by an increase in electricity production from electricity plants and combined heat and power plants. Overall, final energy consumption of derived heat decreased by over 10% between 1990 and 2012. Electricity output, however, increased by almost 30% during the same 22-year period since 1990. The improvement in energy efficiency is even more remarkable considering that heat production is more efficient than electricity production, and the latter has increased substantially relative to the former. Viewed over the 22-year period, the increased use of electricity from combined heat and power (cogeneration) and recovery of excess heat have contributed to higher energy efficiencies in the EU. Lower transformation losses have clearly reduced otherwise higher emissions.

In addition to improved energy efficiency there has been a distinct development towards less carbon intensity fuels at EU level. While total fuel input to public electricity and heat production remained somewhat stable between 1990 and 2012 there was a very substantial reduction in emissions over the period which cannot be explained by improvements in energy efficiency alone. Figure 9 shows that CO_2 emissions from heat and power in the EU have generally decreased since 1990, despite a significant increase in fuel use in the sector. The implied emission factor for coal and lignite in the EU-28 in 2012 was on average 101 tonnes of CO_2 equivalent per terajoule in 2012. 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. The EU average implied emission factor for fossil fuels (i.e. excluding biomass) decreased from 92 tCO_2/Tj in 1990 to 87 tCO_2/Tj in 2012.

Between 1990 and 2012, 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. The steady and significant increase in biomass use for electricity and heat production has also served as a substitute for fossil fuels[18]. This improvement in the carbon intensity of combustible fuels, with the switch from coal and oil to natural and biomass, is only part of the story. Some renewables can produce electricity by means of mechanical energy without any combustion. The very 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.

In the last 3 years there has been an increase in the use of solid fuels, hard coal and lignite, for electricity generation in the EU. This development came along with similar reductions in the use of natural gas. Coal imports to the EU also increased significantly, particularly from the United States and Colombia, putting downward pressure on coal prices. In 2012, almost 60% of the fuel used in thermal power stations came from hard coal and lignite. This sector remains the largest contributor to GHG emissions in the EU. This trend may revert once 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.

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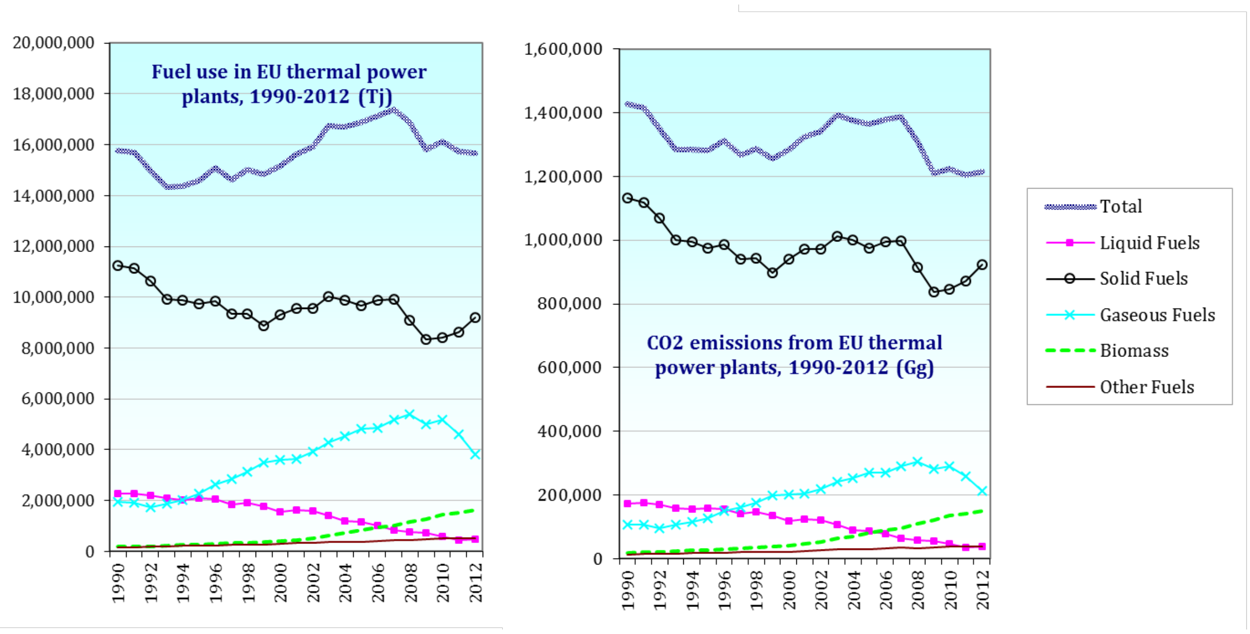
(18) CO_2 emissions from the combustion of biomass (including biofuels in transport) are not included in national GHG emission totals according to UNFCCC Reporting Guidelines. They are reported separately in GHG inventories as a Memorandum item. The reason for this is mainly to avoid double counting 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.

Poland, the UK and Romania accounted for 71% of the 214 million tonnes of CO_2 eq. reduction in the EU between 1990 and 2012. The biggest reduction of all EU MS during the 22-year period was that of Poland, with a net reduction of 67 million tonnes of CO_2 eq. almost fully accounted by lower use of coal. In the UK, the reduction was due to a switch from coal to gas (and biomass) attributed to the liberalisation of the energy markets for electricity generation. In Romania, there was a decrease in emissions in the power sector for all fuels. In 2012, more than 50% of all CO_2 emissions from thermal stations in the EU come from Germany, the UK and Poland.

Figure 9 Fuel use and CO_2 emissions from public electricity and heat production in EU-28



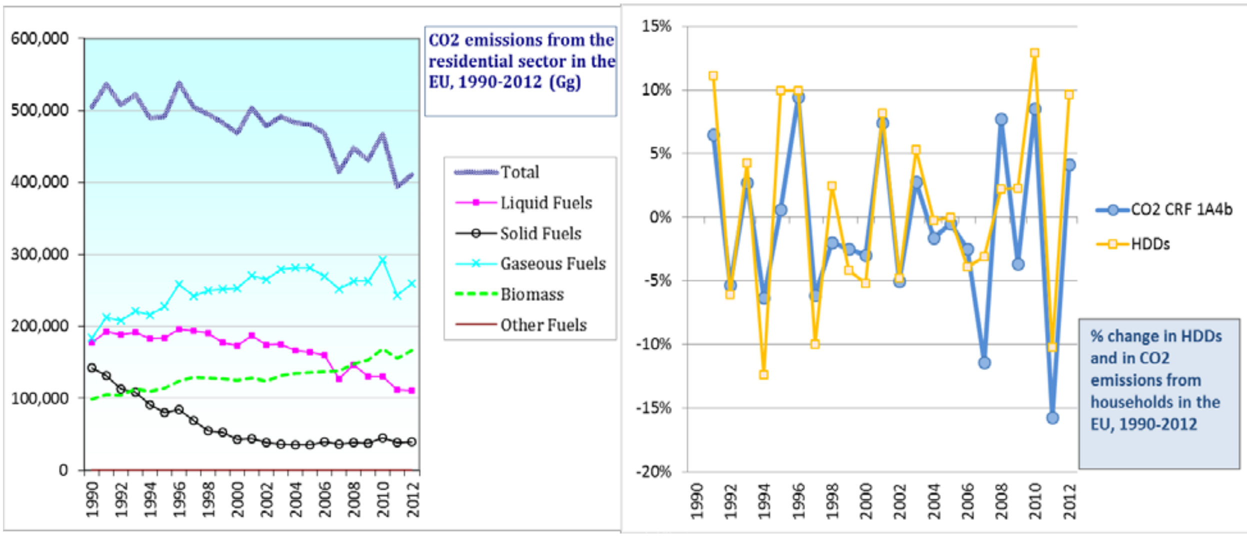
Source: EEA.

5.3.3 Residential combustion

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 such variables 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 and commercial sectors decreased by 94 and 24 million tCO_2 eq. between 1990 and 2012, respectively.

The largest emission reductions occurred in Germany, Czech Republic, Hungary, UK and Sweden, with 72% of the EU net total reduction between 1990 and 2012. Generally, this was due to more gas and biomass used by households and less liquid and solid fuels.

Figure 10 **CO_2 emissions from the residential sector by fuel and heating degree days**



Source: EEA.

While fuel consumption in households has declined only slightly since 1990, there is a distinctive downward trend in emissions which can be partly explained by fuel switching. Figure 10 (left side) shows the development of the fuel mix and related CO_2 emissions in EU households between 1990 and 2012. The most popular fuel in European households is gas, with more than half of all the fuel input in 2012. 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[19].

While total fuel consumption declined only slightly since 1990, one should also take into account that both population and the number of households have increased during the 22-year period and that the average size of a dwelling has also increased. Indeed, there has been an average decrease in the consumption of heat both per dwelling and per square meter, partly offsetting larger dwellings on average. 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

(19) 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 about 20% in the EU between 1990 and 2012. 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. This includes emissions from fuel combustion in commercial and institutional buildings; all emissions from fuel combustion in households; and a smaller source category covering fuel combustion emissions from agriculture, forestry and fishing. Based on GHG inventories, direct heat consumption by the residential sector decreased by less than 1% in the EU between 1990 and 2012. Direct combustion emissions from households 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.

buildings and the diffusion of more efficient heating appliances[20]. 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[21] will continue to play a key role in reducing emissions from the residential sector and contribute to MS targets under the Effort Sharing Decision.

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.

On the one hand, mean land surface temperature is increasing globally, but also in Europe, and has done so particularly in the past 30–40 years, both for summer and winter temperatures. In the last 22 years since 1990 there has been a net warming of the cold months, defined as the average of the first and last quarters of the calendar year, in Europe. However, the variability is very high and the net warming of the winter months is not always clearly evident for Europe as a whole. 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 11.

On the other hand, as shown in figure 10 (right side), there is a clearer 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 (see figure A1 by MS in Annex 1). 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.

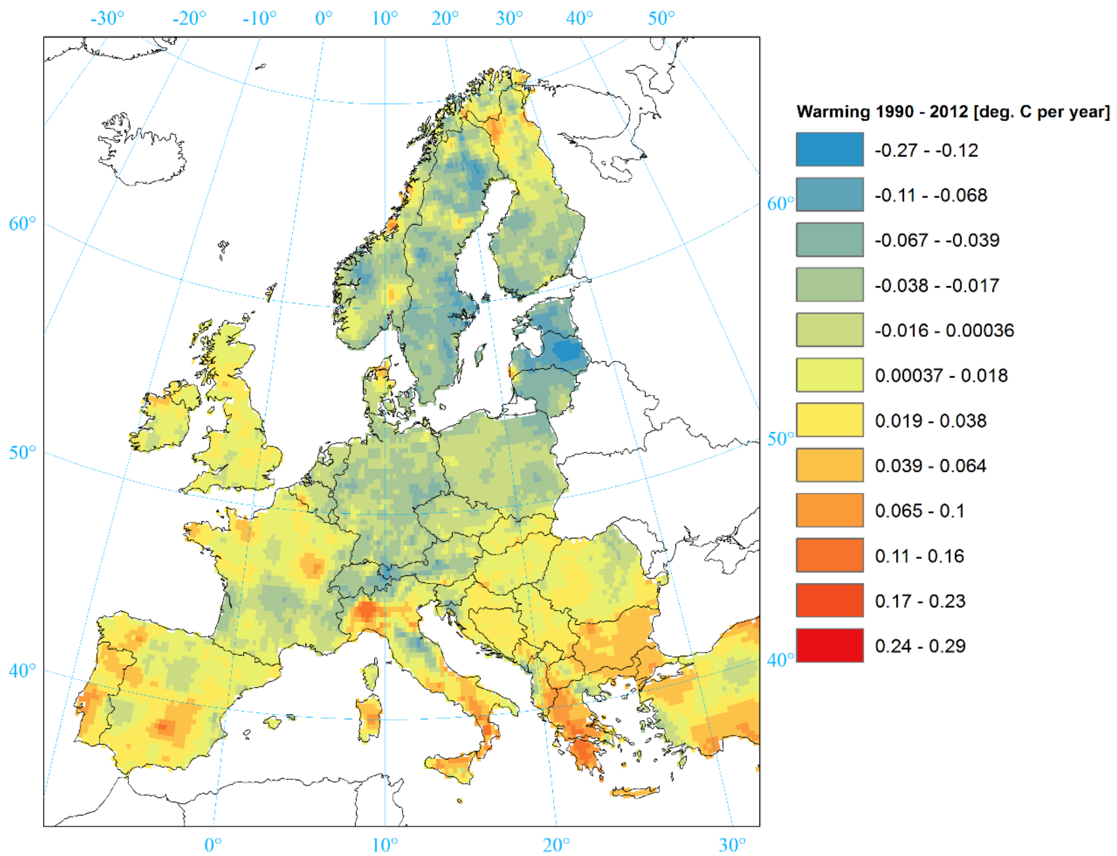
Thus, energy efficiency improvements from better insulation standards in buildings and a lower carbon intensity in the fuel mix can explain lower demand for space heating in the EU as a whole over the past 22 years. These factors have more than offset the effects of a 32 million increase in the population, and in the number and average size of households in the EU. Notwithstanding the different trends by country and region regarding the effect of warmer winters, the positive mean effect for Europe is not

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

(21) 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. Compared to the repealed Directive 2002/91/EC, this Directive has a broader scope and helps citizens to improve the energy efficiency of their houses and the construction industry to build buildings with energy efficient envelope and heating systems. 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. Member States have to develop a methodology to calculate the energy performance of buildings considering, for example, thermal characteristics, heating insulation, hot water supply, air-conditioning installation, but also aspects that have a positive influence on the energy performance such as natural lighting. New buildings have to comply with these requirements and shall undergo a pre-assessment before construction work begins. 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. For a full overview of key policies, including those related to buildings, see the 'Sixth National Communication and first biennial report from the European Union under the UNFCCC, 2014' http://unfccc.int/files/national_reports/annex_i_natcom_/application/pdf/eu_nc6.pdf

clearly visible due to the high regional variability. However, annual variations in winter temperatures do explain changes in fuel use and emissions from the residential sector.

Figure 11 **Mean temperature change between 1990 and 2012 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/ [22]

5.3.4 Road transportation

Transport emissions increased steadily between 1990 and 2007 and have decreased in the last five years. CO_2 emissions increased by 123 million tCO_2 in the 22-year period. Road transport is the second largest source of emissions in the EU, accounting for 18% of total GHG emissions in 2012. Road transportation falls outside the scope of the EU ETS.

Between 1990 and 2012 car ownership levels in the EU increased markedly. Based on Eurostat data, the number of new passenger cars rose by about 86 million in the past 22 years to an estimated 242 million passenger cars in 2012. For the period where data are available (1995-2001), passenger car use (measured in passenger km) and road freight volumes (measured in tonne km) have been increasing at annual average rates of 1.3% and 1.9%, respectively.

Total fuel consumption in the road transportation sector increased by 22% in the EU between 1990 and 2012. Overall, and despite significant improvements in the energy efficiency of new vehicles, emissions from road transport increased by 17% between 1990 and 2012. This increase was fully accounted for by a strong uptake of diesel and a decline in gasoline use. This comes despite the fact

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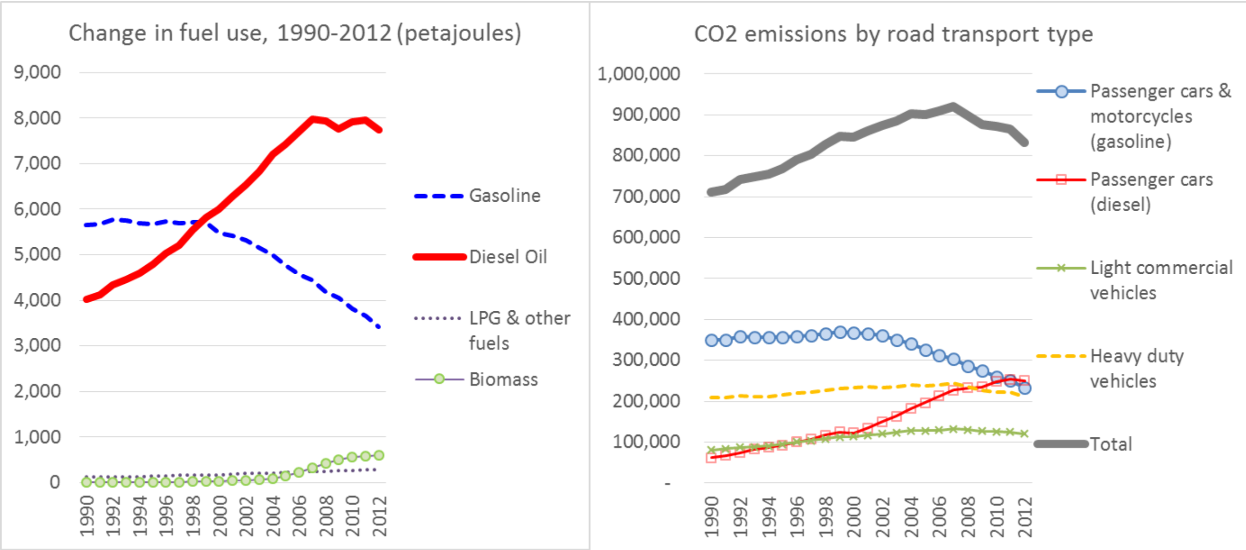
(22) E-OBS dataset from the EU-FP6 project ENSEMBLES (http://ensembles-eu.metoffice.com) and the data providers in the ECA&D project (http://www.ecad.eu) "Haylock, M.R., N. Hofstra, A.M.G. Klein Tank, E.J. Klok, P.D. Jones, M. New. 2008: A European daily high-resolution gridded dataset of surface temperature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

that diesel engines are more energy efficient than similar performance gasoline engines. Gasoline emissions decreased by about 40%, whereas diesel emissions have almost doubled in the 22-year period. Between 1990 and 2012, about almost three quarters of the increase in CO_2 emissions from diesel used in road transportation at EU level was due to passenger cars compared to just over one quarter for freight (i.e. light commercial vehicles and heavy duty).

Figure 12 shows CO_2 emissions from road transport for different vehicle types. In addition to more diesel and less gasoline, less carbon intensive fuels such as LPG and biofuel blends have increased, particularly in the last few years. This has also contributed to otherwise higher emissions in the transport sector.

Figure 12 Fuel use and CO_2 emissions from road transportation in the EU, 1990-2012



Source: EEA

Despite the overall increase in emissions since 1990, EU emissions from transport have decreased for the fifth consecutive year. Fuel price increases for diesel and gasoline have outpaced households' disposable income since 2009. Along with the start of economic recession in the second half of 2008 and the whole of 2009, this appears to have triggered a fall in freight transport demand.

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. In 2009, the EU adopted legislation establishing emission performance requirements for new passenger cars to reduce average emissions to 120 g CO_2/km (130 g through vehicle technology improvements and 10g through more efficient vehicle features such as tyres and air conditioning systems) by 2015, and further to 95 g CO_2/km by 2020 (EU, 2009). Average carbon dioxide emissions per kilometre have continued to fall and already in 2013 the European Union fleet collectively met its legal target for 2015, with an average of 127 g CO_2/km that year[23].

Thus, energy efficiency improvements and to a lesser extent increased used of less carbon intensive fuels have led to levels of road transport emissions that would have been otherwise higher. The economic crisis that started in 2008 has also contributed to lower road transport emissions in the last years. Despite these improvements in efficiency and carbon intensity, demand has grown substantially

(23) 'New cars meet CO_2 target two years ahead of the deadline', EEA. http://www.eea.europa.eu/highlights/new-cars-meet-co2-target

and road transport still represented about 19% (including CO_2, N_2O and CH_4 emissions) of total GHG emissions in the EU in 2012.

A move towards electric vehicles could contribute to lower emissions from road transportation by 'moving' emissions from CRF sector 1A3b, covered under the ESD, to CRF sector 1A1a (public electricity and heat production), broadly included under the EU ETS. The specific effect on overall emission reductions will depend on both the energy mix for power generation and the transformation efficiency, compared to combusting fuel (mostly gasoline and diesel) in a vehicle. In some MS there could be large savings while in other MS emissions would increase, unless electricity production becomes de-carbonised by using more energy from renewable sources.

Finally, and partly related to the transport sector, 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. These emissions have grown at an average rate of 32% 'per year' between 1990 and 2012. 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.

5.3.5 Emission trends in international transport and LULUCF

- **International shipping and aviation**

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 transport increased by over 100 million tonnes between 1990 and 2012. International transport emissions increased constantly between 1992 and 2007. Emissions decreased between 2007 and 2010, and in 2012, partly reflecting the economic recession. EU greenhouse gas emissions from international aviation are lower than for international maritime transport but have been growing more rapidly. Total GHG emissions from international transport altogether reached 280 million tonnes of CO_2 equivalent in 2012 for the EU as a whole. Together, the two sectors in 2012 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.

- **LULUCF and CO2 emissions from biomass combustion**

Finally, CO_2 emissions from biomass combustion increased by 301 million between 1990 and 2012, indicating 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 22-year period[24]. Based on the 2012 EU GHG inventory, net removals increased by about 18% in the EU-28 between 1990 and 2012 and the net sink has increased from 4.6 % of total GHG emissions in 1990 to 6.7 % in 2012. In 2012, net removals from the LULUCF sector in the EU-28 amounted to 303 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 as harvesting only represents approximately 60 % of the annual wood

(24) 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. This has not been the case in the EU so far.

increment. EU 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.

6. Snapshot of EU emission drivers using decomposition analysis

The previous sections of this paper, and in particular section 5, looked at the emission trends in key emission sources in the EU between 1990 and 2012. The main objective of the current section is to provide a snapshot of other factors contributing to lower GHG emissions using a simple 'decomposition-analysis' approach focusing on different time-periods. This section will also summarise the main findings from the annual analysis papers by EEA for the years 2009, 2010, 2011 and 2012.

The economic crisis started in the second half of 2008 and some have argued that GDP is the only factor behind lower GHG emissions in the EU in the past few years. However, as shown by the results of the analysis below and also by those of section 5, other factors than GDP have clearly contributed to this decline in GHG emissions. The note builds from the analytical papers published by EEA which underpin the publication of the annual EU GHG inventory to UNFCCC. The analysis presented below refers to carbon dioxide emissions from fossil fuel combustion, which accounts for about 80% of total GHG emissions[25].

6.1 Decomposition analysis: 1990-2012, 2005-08 & 2008-2012

Figure 13 shows the estimated contributions of the various factors that have affected CO_2 emissions from energy production and consumption in the EU-28 between 1990 and 2012. This approach is often used to portray the primary forces driving emissions and is based on a decomposition analysis[26]. A description of the factors is shown in Annex 2.

Over the 22-year period, four of the factors used in the decomposition analysis have had positive impact on reducing CO_2 emissions:

a) lower final energy intensity [less final energy per GDP, e.g. less energy used by end users];

b) lower carbon intensity of fossil fuels [less CO_2 per primary energy from fossil fuels, e.g. less carbon-intensive fuels];

c) improved energy-transformation efficiency [less primary energy per final energy, e.g. more efficient electricity production]; and

d) higher non-carbon fuels effect [less fossil fuels in total primary energy, e.g. more use of renewables]. The latter has been accounted for by a larger share of renewable energy sources in the fuel mix, and much less so by nuclear which has been declining since 2006.

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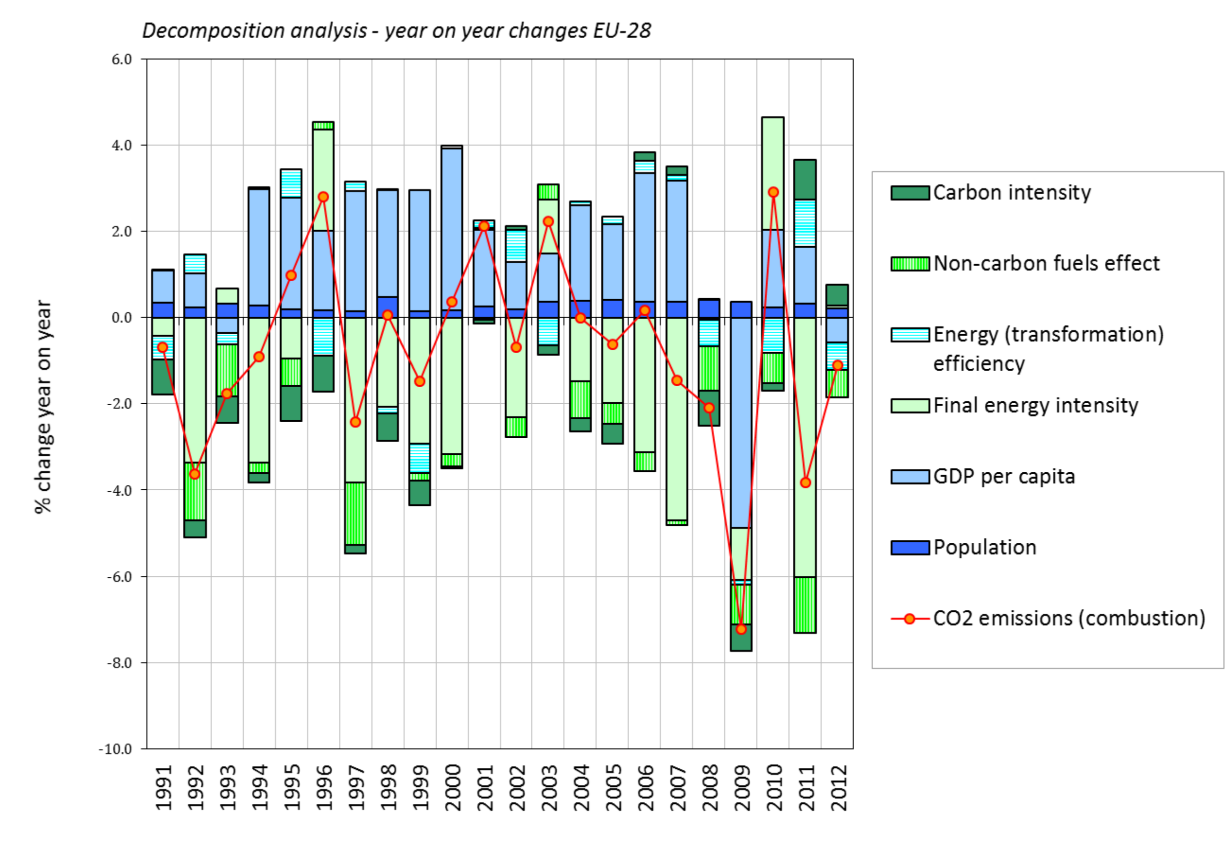
(25) Although the focus of the note is on CO_2 emissions from fossil fuel combustion, there have been substantial emission reductions of both methane and nitrous oxides in other sectors. For methane, these include lower fugitive emissions from coal mining and post-mining activities, managed waste disposal on land and enteric fermentation in the agricultural sector. For nitrous oxides, there were substantially lower emissions from agricultural soils, and lower emissions from adipic and nitric acid production.

(26) It should be noted that while decomposition analysis can be useful for describing some of the primary emission drivers, one should bear in mind its limitations. These limitations include the fact that the equation is an identity where the relationship between the variables is true by definition, allowing no country-specific variation in the data and assuming independence of the factors. However, decomposition analysis can point to interesting findings, which can be explored further using other methods.

There were two factors with a negative impact on emissions (i.e. higher CO_2): a) the EU population increased by 31 million since 1990; and b) higher GDP per capita, with an EU net increase of 36% between 1990 and 2012.

Figure 13 Detailed annual decomposition of the change in total CO2 emissions from fossil fuel combustion in the EU-28, 1990–2012

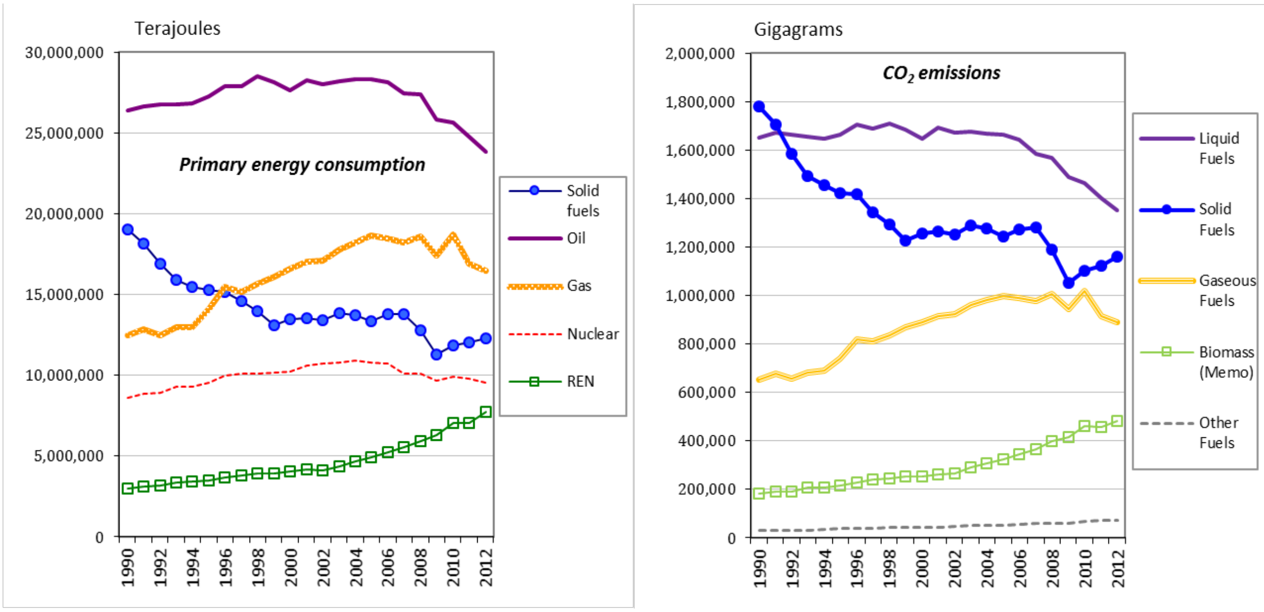


Note: The explanatory factors in this decomposition analysis should not be seen as fundamental factors in themselves nor should they be seen as independent of each other. For definitions see Annex 2.

Source: EEA (CO_2 emissions); Eurostat (population, energy balances); European Commission Ameco database (GDP).

Figure 14 shows primary energy consumption by fuel for the whole energy sector, from Eurostat, and related CO2 emissions from GHG inventories. Total energy consumption increased by less than 1% between 1990 and 2012 whereas CO2 emissions from energy combustion decreased by 15.5%. There have been significant energy efficiency improvements, both in terms of lower transformation losses when converting primary energy, such as crude oil or coal, into final energy, such as gasoline or electricity, and also in terms of lower energy use by the end-users. In addition, there have been very substantial improvements in the overall carbon intensity of energy production and use since 1990, both within carbon fuels (i.e. fossil fuels) and non-carbon fuels (i.e. renewables and nuclear). On the one hand, there has been a strong uptake of natural gas and a significant decline in solid fuels (despite the increase since 2009) and in oil consumption in the last years. This has reduced the carbon intensity of fossil fuels. On the other hand, there has been a very strong uptake of renewables, which has resulted in a higher share of non-carbon fuels in the energy mix.

Figure 14 Total fuel use and CO_2 emissions in the energy sector in EU-28, 1990-2012



Source: EEA (CO_2 emissions); Eurostat (energy balances).

For instance, the implied (i.e. weighted average) emission factor for the combustion of fossil fuels in the EU stood at 78.7 tCO_2/TJ in 1990 and decreased to 74.2 tCO_2/TJ in 2012. This was by and large due to a fuel switch between coal and gas for power generation. However, if one considers the effects of renewable energy, the implied emission factor decreased from 58.9 tCO_2/TJ in 1990 to 49.3 tCO_2/TJ in 2012. This represents an improvement of 16% in the total carbon intensity of the EU energy sector in the last 22 years[27].

Figure 15 illustrates the same information as Figure 13 but averaged over the periods 2005-2008 (growth years 2006, 2007, 2008) and 2008-2012 (growth years 2009, 2010, 2011 and 2012)[28]. The underpinning data is summarised in table 3. CO_2 emissions decreased by about 12% between 2005 and 2012. Most of this reduction took place in the second period (2008-2012) but emissions had been decreasing in the first period, which is characterised by positive economic growth.

The most relevant explanatory factors in 2005-08 were, in order of importance, the lower final energy intensity, the higher GDP per capita and the larger contribution from non-carbon fuels to the fuel mix. The higher GDP per capita was as an offsetting factor to otherwise even-lower emissions. The most

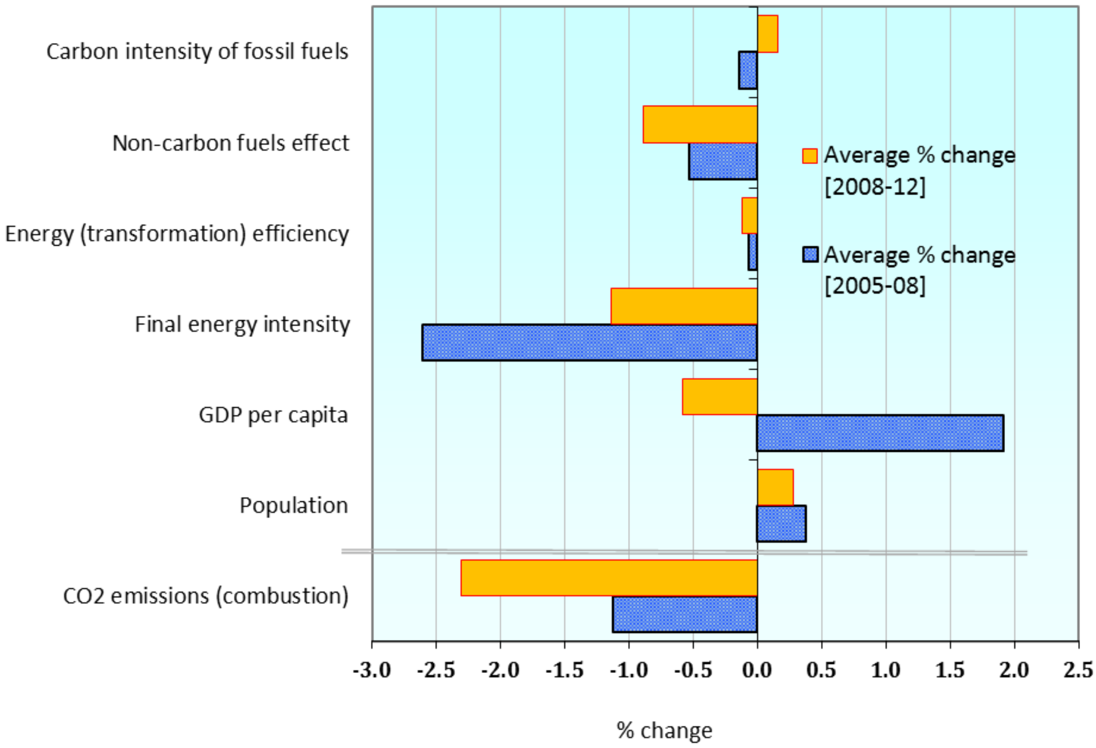
(27) There are two streams of data used to estimate the total carbon intensity of the whole EU energy sector. The first one is the GHG inventory of the EU — an annual submission of national GHG inventories of Annex I Parties under the UNFCCC and the Kyoto Protocol, which the EEA compiles on behalf of the European Commission. The second data source is the annual energy balances reported to Eurostat under the Energy Statistics Regulation. In both cases there are well established QA/QC processes to ensure the highest possible quality of the emissions and energy estimates, respectively. However, differences remain between both sets of data: between fuel/activity data in GHG inventories and energy data in the energy balances, for example. Under the Energy Statistics Regulation, EU Member States are expected to ensure a high degree of consistency between the energy balances reported to Eurostat and the activity data reported under the UNFCCC. The main mismatch occurs at a more detailed sectoral level due to different reporting requirements and/or practices. The treatment of non-energy use, particularly in industrial sectors, can be a source of inconsistencies between the energy balances and national GHG inventories. However, these inconsistencies do not have a significant effect on the trend and the 16% estimate in total carbon intensity improvements.

(28) These two periods have been selected to better show how different factors interact before and after the economic crisis which started in 2008. This distinction will also support the overall findings of this paper that GDP is one of many factors affecting emissions and that the EU has been able to reduce emissions in periods where there has been negative economic growth.

relevant factors in the 2008-12 period were the lower final energy intensity, the higher contribution from renewables and the lower GDP per capita.

Indeed, the most striking difference between both periods is the contribution of GDP per capita to CO_2 emissions. Population increased in both periods by a similar amount. However, while in the first period lower CO_2 emissions came along with positive GDP, in the second period both GDP and emissions were negative. This illustrates that other factors than GDP have played a bigger role and that if GDP was the only factor affecting emissions one could have expected higher, not lower, emissions between 2005 and 2008.

Figure 15 Detailed decomposition of the change in total CO_2 emissions from fossil fuel combustion in the EU-28, 2005-08 & 2008-12



Note: The explanatory factors in this decomposition analysis should not be seen as fundamental factors in themselves nor should they be seen as independent of each other. For definitions see Annex 2.

Source: EEA.

The decrease in final energy consumption was larger in the period 2008-12 because of the effect of the economic recession on energy demand, particularly from the industrial sector. However, the final energy intensity effect was higher in the period 2005-08 because of the relatively small decrease in final energy consumption compared to the much larger increase in GDP. In the period 2008-12, both final energy and GDP decreased.

It should also be noted that nuclear electricity production has been declining since 2005 and therefore the non-carbon fuels effect is accounted for by a higher share of renewables in the energy mix. The sustained growth in renewables since 1990 which was particularly strong after 2000 has clearly contributed to lower emissions in the EU. This effect appears to be stronger in the 2008-12 period than in the 2005-08 period.

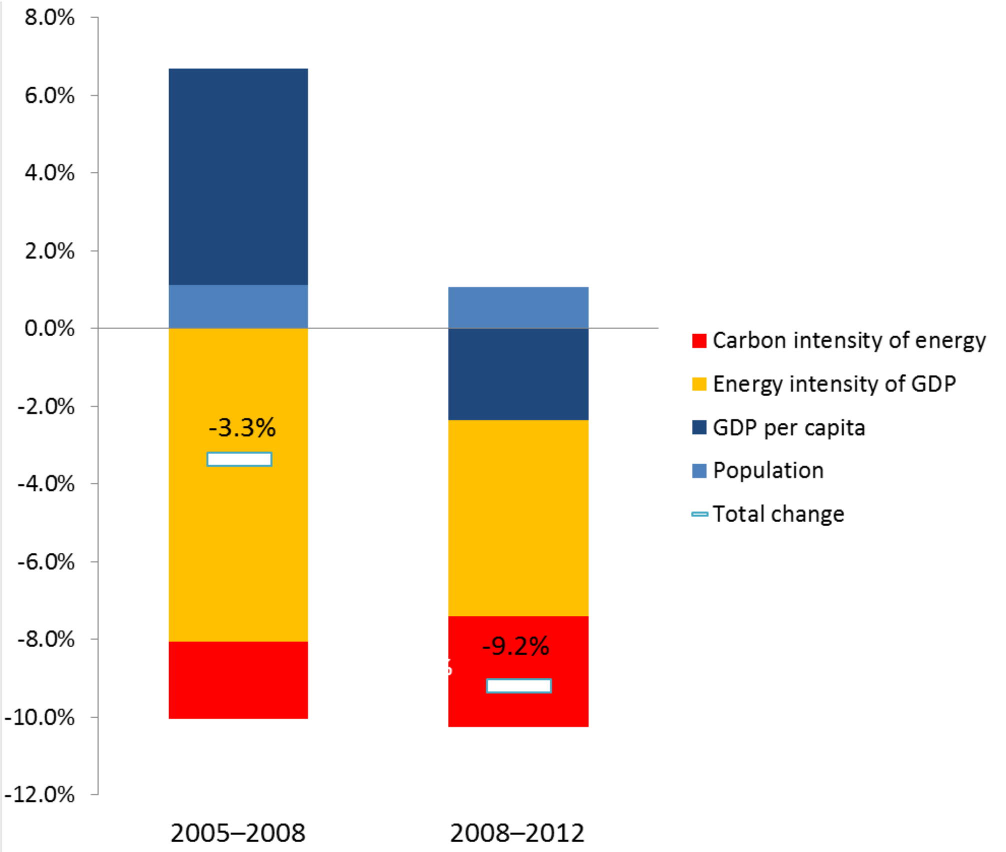
The carbon intensity of fossil fuels effect worsened during 2008-12 and contributed to higher CO_2 emissions. This was due to higher use of hard coal and lignite for heat and power generation. If one considers the total carbon intensity of the entire economy (i.e. not only fossil energy), however, the effect is clearly positive as the growth in renewables outpaced the growth in solid fuel consumption (see also Figure 16).

Figure 16 shows the same information as figure 15 but in a more aggregated way. The selection of factors is also consistent with the decomposition analysis shown in the summary for policy makers of WGIII on Mitigation of the IPCC 5th Assessment Report[29]. The factor 'energy intensity of GDP' combines the 'energy-transformation efficiency' and 'final energy intensity' effects from figure 15. The new aggregated factor refers to the primary energy use per unit of GDP and it is slightly stronger in both periods than final energy intensity because it absorbs the positive contribution from the improved energy-transformation efficiency. The factor 'carbon intensity of energy' combines the 'carbon intensity of fossil fuels' and the 'non-carbon fuels' effects from figure 15. The new aggregated factor refers to the total carbon intensity of the energy sector. The new factor is stronger in the second period (i.e. contributing more to emission reductions) in spite of the increase in coal use, thus worsening the carbon intensity of fossil fuels. During 2005-08 both the non-carbon fuels effect and the carbon intensity of fossil fuels effect decreased (i.e. contributed to emission reductions). However, the increase in renewables in the period 2008-12 was much stronger and more than offset the negative contribution from the higher carbon intensity of fossil fuels. That is, coal use has increased recently but much higher growth in renewables has substantially improved the overall carbon intensity of the whole EU energy sector.

As can be seen from figure 16, in the first period the overall reduction of CO_2 emissions from fossil fuel energy use was 3.3%. 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 very carbon intensity fuels like coal, and a switch to 'cleaner' fuels like gas or renewables. These two factors driving emissions down were partially offset by higher population and mostly by higher GDP per capita. In the second period, the factor GDP per capita played the opposite role. Indeed, as the economy and industrial production contracted, GDP had a negative effect on emissions and contributed further to the decline. Yet, of the 9.2% overall decrease in CO_2 emissions from fossil fuel use, GDP per capita was only one of the three key factors bringing emissions down, with energy intensity and carbon intensity playing a bigger role altogether.

(29) See http://report.mitigation2014.org/spm/ipcc_wg3_ar5_summary-for-policymakers_approved.pdf

Figure 16 Aggregate decomposition of the change in total CO_2 emissions from fossil fuel combustion in the EU-28, 2005-08 & 2008-12



Note: The explanatory factors in this decomposition analysis should not be seen as fundamental factors in themselves nor should they be seen as independent of each other. The bar segments show the changes associated with each factor alone, holding the respective other factors constant. For definitions see Annex 2.

Source: EEA.

Overall, the three main findings from the decomposition analysis of figure 16 are[30]:

i. Emissions decreased with increasing GDP (per capita) during 2005-2008, whereas emissions and GDP (per capita) decreased during 2008-12. This shows that emissions can decrease with a growing economy (see section 7)

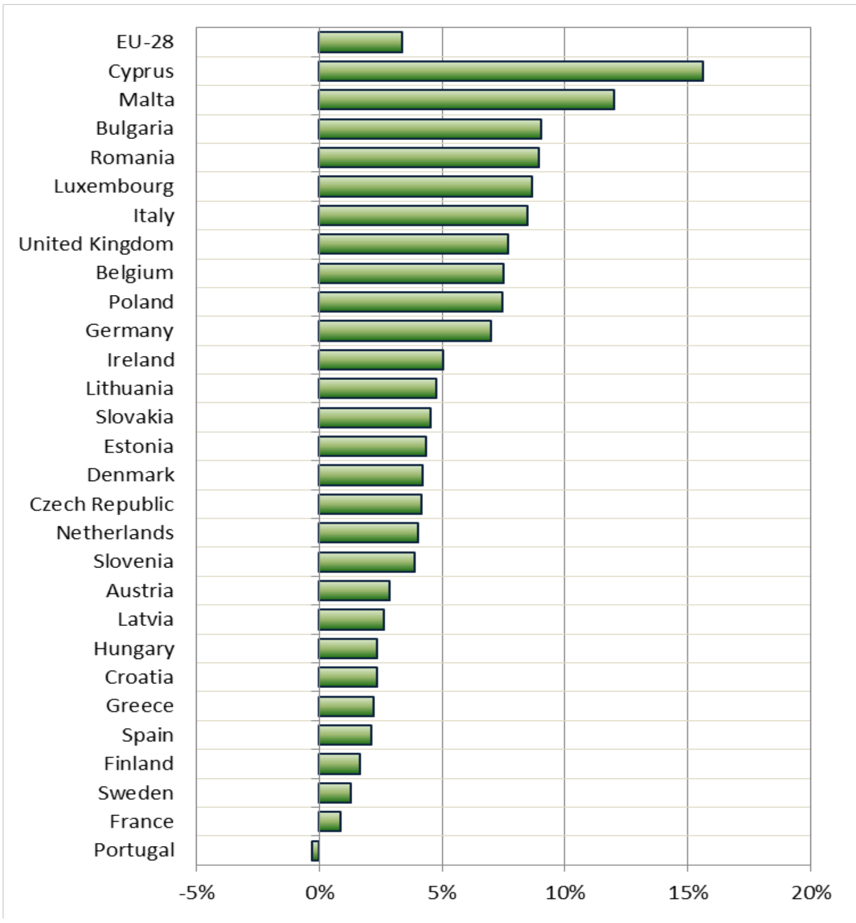
ii. The lower carbon intensity of energy was a key factor underpinning lower emissions in both periods, but even stronger in the period of 2008-12 despite the significant increase in coal use since 2009 and a decline in nuclear electricity production. The lower carbon intensity during both 2005-08 and 2008-12 is by and large accounted for by a higher contribution from renewable energy sources in the fuel mix.

iii. The decrease in primary energy intensity was the largest contributing factor to lower CO_2 emissions from fossil fuel combustion. Total energy consumption has decreased while GDP has increased, leading to an improvement in the emissions intensity of energy production and use. The

(30) 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). Thus, even though the recession has been a very important factor there is also evidence that renewable energy policies have actually made a difference already. The evidence of policies which have contributed to lower emissions would be even more compelling going back 22 years, as already shown in previous sections of the paper.

economic recession partly explains lower energy demand from industry and road transportation since 2008. However, energy intensity also decreased in the period 2005-2008 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 (see figure 17), 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.

Figure 17 Growth in final consumption of renewable energy by EU Member State, 1990-2012 (annualised growth rates)



Source: Eurostat

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 22-year period, including during the past 7 years since 2005. This improvement came along with a significant convergence of GHG emission intensities across MS, both per-capita and per-GDP[31]. 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 summarises the growth rates in the original variables and factors used in the decomposition analysis for the periods 2005-2012, 2005-2008 (growth years 2006, 2007, 2008) and 2008-2012 (growth years 2009, 2010, 2011 and 2012) for the EU-28.

(31) 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 in 5-year periods in the 1990s and in the 2000s.

Table 3 Key statistics for the variables used in the decomposition analysis of figures 15 and 16

% growth rates					
	2012/05	2008/05	2012/08	Annual av. 2008/05	Annual av. 2012/08
Original variables					
CO_2 emissions energy	-12.2%	-3.3%	-9.2%	-1.1%	-2.4%
Population	2.3%	1.1%	1.1%	0.4%	0.3%
GDP constant prices	5.6%	7.0%	-1.3%	2.3%	-0.3%
Total gross inland energy (primary energy)	-7.7%	-1.4%	-6.4%	-0.5%	-1.6%
Total final energy	-7.1%	-1.2%	-6.0%	-0.4%	-1.5%
Fossil fuel primary energy	-12.4%	-2.9%	-9.7%	-1.0%	-2.5%
Decomposition analysis (factors)					
$ln(CO_2) = ln(POP) + ln(GDP/POP) + ln(FEC/GDP) + ln(Primary/FEC) + ln(FF/Primary) + ln(CO_2/FF)$					
CO_2 emissions (CO_2)	-12.2%	-3.3%	-9.2%	-1.1%	-2.4%
Population (POP)	2.1%	1.1%	1.1%	0.4%	0.3%
GDP per capita (GDP/POP)	3.0%	5.6%	-2.4%	1.9%	-0.6%
Final energy intensity (FEC/GDP)	-12.0%	-7.9%	-4.6%	-2.7%	-1.2%
Energy transform. efficiency (Primary/FEC)	-0.7%	-0.2%	-0.5%	-0.1%	-0.1%
Non-carbon fuels effect (FF/Primary)	-4.9%	-1.6%	-3.4%	-0.5%	-0.9%
Carbon intensity of fossil fuels (CO_2/FF)	0.2%	-0.4%	0.6%	-0.1%	0.2%

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 GDP per capita factor contributed to about 2.4 percentage points to the 9.2% reduction in CO_2 emissions in EU-28 between 2008 and 2012 [or 27% of the total net reduction]. For definitions see Annex 2.

To replicate the results of figure 16, the factor 'energy intensity of GDP' is obtained by summing up the factors 'final energy intensity' & 'energy transformation efficiency'. The factor 'carbon intensity of energy' in figure 16 is the sum of the factors 'non-carbon fuels' and 'carbon intensity of fossil fuels'. For definitions see Annex 2.

Source: EEA.

6.2 Annual analysis, 2009, 2010, 2011 and 2012

The period 2008-2012 coincides with the economic recession and/or economic slowdown in EU Member States, which was particularly severe in 2009. Starting in 2009, the EEA started publishing short working papers analysing why emissions increase or decrease in the last year compared to the previous year. These papers underpin the official EU GHG inventory submissions to UNFCCC. The following paragraphs provide a quick snapshot of the key findings for each of the years between 2009 and 2012[32]. More detail information is provided in Annex 2 and Annex 3 (definitions) and Annex 4 (results).

Summary 2009 - The strength of the 2009 recession affected all economic sectors in the EU. Consumption of fossil fuels (coal, oil and natural gas) fell compared to the previous year, mainly due

(32) These analysis were done at the time and changes in definitions and/or in the data (e.g. due to recalculations in GHG inventories or revisions to energy balances and GDP) may marginally change some of the results.

to reduced coal use. The decreased demand for energy linked to the economic recession was accompanied by a strong increase in renewable energy use, which also contributed to lower emissions. Sustained growth in the use of renewables was therefore a key factor explaining the strong decrease in greenhouse gas emissions in 2009.

Summary 2010 - The increase in emissions in 2010 was partly driven by the economic recovery from the 2009 recession in many European countries, which had itself caused substantial emission reductions in 2008 and 2009 in all Member States. Final energy demand increased by 3.8% in 2010, outpacing the increase in economic output (2.0%). In 2010 the winter was also colder than in the previous year, leading to increased demand for heating and higher emissions from the residential and commercial sectors. The continued strong increase in renewable energy use and the improved carbon intensity of fossil fuels - underpinned by strong gas consumption - prevented the increase in GHG emissions from being higher.

Summary 2011 - For the EU as a whole, the 4.1% decrease in CO_2 emissions in 2011 came amid positive economic growth in most EU member states. GDP increased by 1.7%, although economic growth was lower than in 2010, when GDP increased by 2%. A milder 2011 winter compared to 2010 can, to a large extent, explain lower fossil fuel emissions. This is because, on average, the higher winter temperatures led to lower heating demand and lower emissions from the residential and commercial sectors. The increase in coal use did not offset a much larger decrease in the consumption of natural gas, and emissions fell as a result.

Summary 2012 - The 1.1 % decrease in CO_2 emissions from energy in EU-28 in 2012 came along with economic recession across the EU as a whole. Half the EU member states experienced negative economic growth in 2012. In the other half, positive economic growth in 2012 was lower than in 2011. The winter in Europe was on average colder in 2012 than in 2011 leading to higher heating demand and emissions from households. However, higher residential emissions did not offset much lower emissions in other sectors such as transport and industry. Also, the increase in coal use in 2012 did not offset a much larger decrease in the consumption of oil natural gas. There was also a substantial increase in renewable energy in 2012, continuing the long-term trend observed since 1990.

7 The role of economic growth and recession in GHG emission reductions in the EU

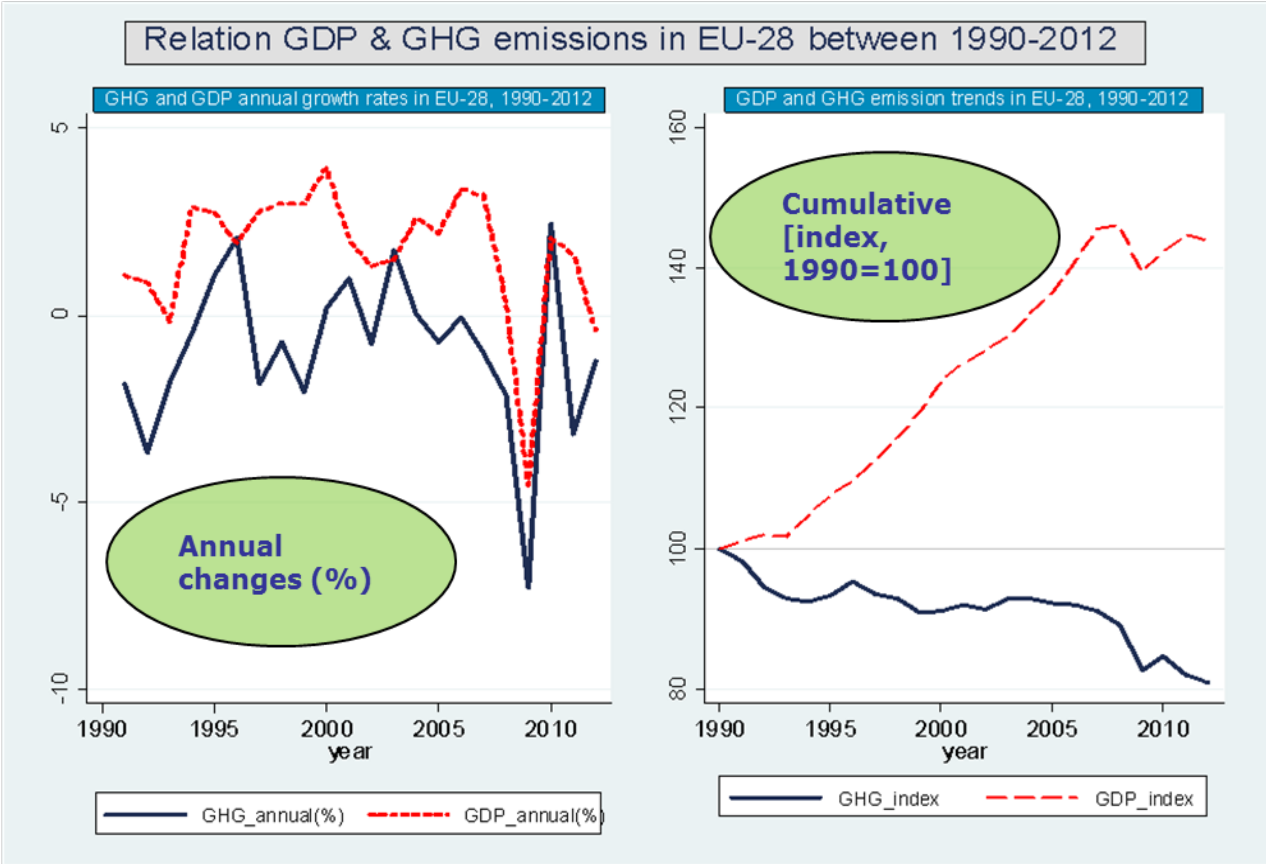
As mentioned in section 6, some have argued the economic crisis that started in the second half of 2008 is the only reason for lower GHG emissions in the EU in the last five years. It has been shown already that other factors and policies have contributed to this decline. In addition, while the last 5 years have clearly contributed to emission reductions in the EU, there have been other periods where the EU has decreased emissions with positive economic growth. This section provides a more statistical approach to the relationship between GDP and GHG emissions, that will help confirm that GDP is a key factor but not the only decisive one.

7.1 The complex link between GHG emissions and GDP growth

The EU-28 has reduced total GHG emissions (excluding LULUCF) by 19.2% between 1990 and 2012, while GDP has increased by 45% (right side of figure 18). However, the apparent decoupling of emissions and GDP (relative to 1990) does not imply that the link between GDP and GHGs is broken (left side of figure 18). There is some degree of correlation or coupling when looking at GDP and GHG emissions on an annual basis, and particularly since the economic crisis started in 2008.

GDP is one factor affecting emissions but not the only one as illustrated in the previous sections of this paper. If GDP was the only factor, or even the main factor, one would see a perfect or almost perfect correlation. This is not the case.

Figure 18 Annual and cumulative changes in GDP & GHG emissions at EU level, 1990-2012



Source: EEA

The relationship between GDP and GHG emissions 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 (see also 5.3.1 on industry-related emissions). 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 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.

The deep economic recession, which commenced at the end of 2008 and continued throughout 2009, was a key factor behind the strong decline in greenhouse gas emissions in 2009. Equally important, however, was the strong increase in the use of renewables in almost all EU countries. In 2010, by contrast, economic growth was positive in the EU as a whole, with GDP increasing by 2.1 % compared to 2009. This economic recovery in the majority of EU Member States in 2010 was a significant factor behind the growth in EU GHG emissions in 2010, albeit not the only one. In 2011, GDP growth was still positive (1.6%), although lower than in 2010, and with the prospect of a worsening of the economic situation in the EU in 2012. Indeed, 2012 was another recession year for the EU as a whole, with GDP contracting by 0.4% compared to 2011. Fourteen MS had negative growth in 2012 whereas in the remaining 14 MS, GDP was positive but the economy slowed down compared to 2011. Despite the importance of the recent economic recession, other factors, mainly related to energy production and use, have contributed to lower GHG emission reductions.

The link between the economy, and economic recession in particular, and GHG emissions is complex. As explained in section 6.1 on decomposition analysis 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' (as defined in figure 16) 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. Figure 19 illustrates changes in GHG emissions and in GDP at MS level over the period 1990-2012. Clearly, the relationships vary across MS partly reflecting specific national circumstances, and reflected in a stronger or weaker link between changes in GDP and changes in GHG emissions.

Figure 19 Annual changes in GDP & GHG emissions by EU Member State, 1990-2012

Trends in GHG emissions and GDP by Member State (annual % change), 1990-2012

Source: EEA (emissions), GDP (based on the Ameco database, European Commission)

7.2 A statistical approach to the link between GHG emissions and GDP

This section will provide a more statistical approach to the link between GHG emissions and GDP growth, by looking at average correlations and estimating model-specific slope coefficients of GDP, taking into account the 28 different country-specific GHG-GDP relationships.

7.2.1 Average statistical relationships between GHG and GDP

The objective of this section is to estimate the correlations between GDP growth and changes in GHG emissions in different time periods and under different assumptions on GDP growth. Table 4 shows the average relationships between annual changes in GHG emissions and GDP growth in constant prices, considering data for all EU 28 MS and between 1990 and 2012. These average relationships have been tested for different scenarios[33].

Table 4 Average relationships between GHG emissions & GDP based on data from 28 MS for the period 1990-2012

Constraints on GDP and time period	Within / Overall R squares=correlations^2 [Goodness of fit]	Number of cases	% of total cases
GDP (all cases)	0.322 / 0.310	616	100.0%
GDP > 0 (positive)	0.018 / 0.016	495	80.5%
GDP < 0 (negative)	0.407 / 0.466	121	19.6%
Year > 2007	0.296 / 0.289	140	22.7&
Year > 2008	0.324 / 0.318	112	18.2%
GDP < 0 & year > 2007	0.390 / 0.344	61	9.9%
GDP < 0 & year > 2008	0.468 / 0.311	50	8.1%
D1.GDP (first difference) <0 & year > 2007	0.405 / 0.326	98	15.9%
D1.GDP (first difference) <0 & year > 2008	0.398 / 0.303	72	11.7%

Note: The R-square 'within' and 'overall are based on the prediction equations: $\widehat{\ddot{y}}_{it} = (\widehat{y}_{it} - \widehat{\bar{y}}_i) = (\mathbf{x}_{it} - \bar{\mathbf{x}}_i)\widehat{\beta}$ and $\widehat{y}_{it} = \widehat{\alpha} + \mathbf{x}_{it}\widehat{\beta}$, respectively.

(33) Recession is defined as two consecutive quarters of negative GDP growth compared to the same quarters of the previous year (i.e. seasonally adjusted). In the current paper, where annual growth rates are used, recession has been defined as negative GDP in one year compared to GDP in the previous year. For hypothesis testing, one could also generalise the definition of recession to refer to any period that, while positive in terms of economic growth, is well below the country's recent historic trend. So for instance while GDP in e.g. 2011 may not be a recession year in strict terms, economic growth may be well below pre-2008 average growth rates. The recession started in the second half of 2008 and was in full force in 2009. The 'constraints' on GDP and years is a way to ensure that all these different definitions and possibilities are taken into account.

The following key messages can be extracted based on table 4:

1. There is a positive relationship between changes in GDP and changes in GHG emissions. About one third of the change in total GHG emissions in the EU between 1990 and 2012, on average, can be explained by changes in GDP (both positive and negative).
2. Over the last 22 years, the economy contracted at EU level in 1993, 2009 and 2012. However, these 3 years represent less than 50% of all cases where GDP was negative at MS level. Even though the strength of the relationship between GHG emissions and economic growth varies across countries, the relationship is, on average, stronger in periods of economic recession (i.e. negative GDP) than on periods of positive economic growth.
3. In cases where GDP growth has been negative (including the 2008-12 period), the average strength of the relationship between GHG emissions and GDP has ranged between 30% and 47%.
4. Although these estimates are not directly comparable to those from the decomposition analysis of section 6, the current results also suggest that the combined effects of other factors and policies have played at least as important a role as GDP in GHG emission reductions – including indirect effects of economic growth on omitted variables as well as MS specific factors and policies.

The conclusions here should not be read or interpreted as a cause-effect relationship between GDP and GHG emissions. Clearly, more work is needed to both understand the relationships between emissions and the economy, and the reasons for the coupling or decoupling at EU and Member State level. Yet, of the 616 cases analysed (28 Member States and 22 years) the following relationships were found:

i. GDP positive & GHG negative: 36.7% of cases

ii. GDP positive & GHG positive: 43.7% of cases

iii. GDP negative & GHG negative: 17.5% of cases

iv. GDP negative & GHG positive: 2.1% of cases

In addition to the main findings from table 4, this simple matrix also shows that GHG emission reductions have not been at conflict with economic growth in the last 22 years. Indeed, whereas the more common outcome has been that emissions would increase with positive GDP growth and would decrease with negative GDP, in 36.7% of all cases where GHG emissions have decreased at Member State level, GDP has been positive.

7.2.2 Model estimation: GDP as explanatory factor of GHG

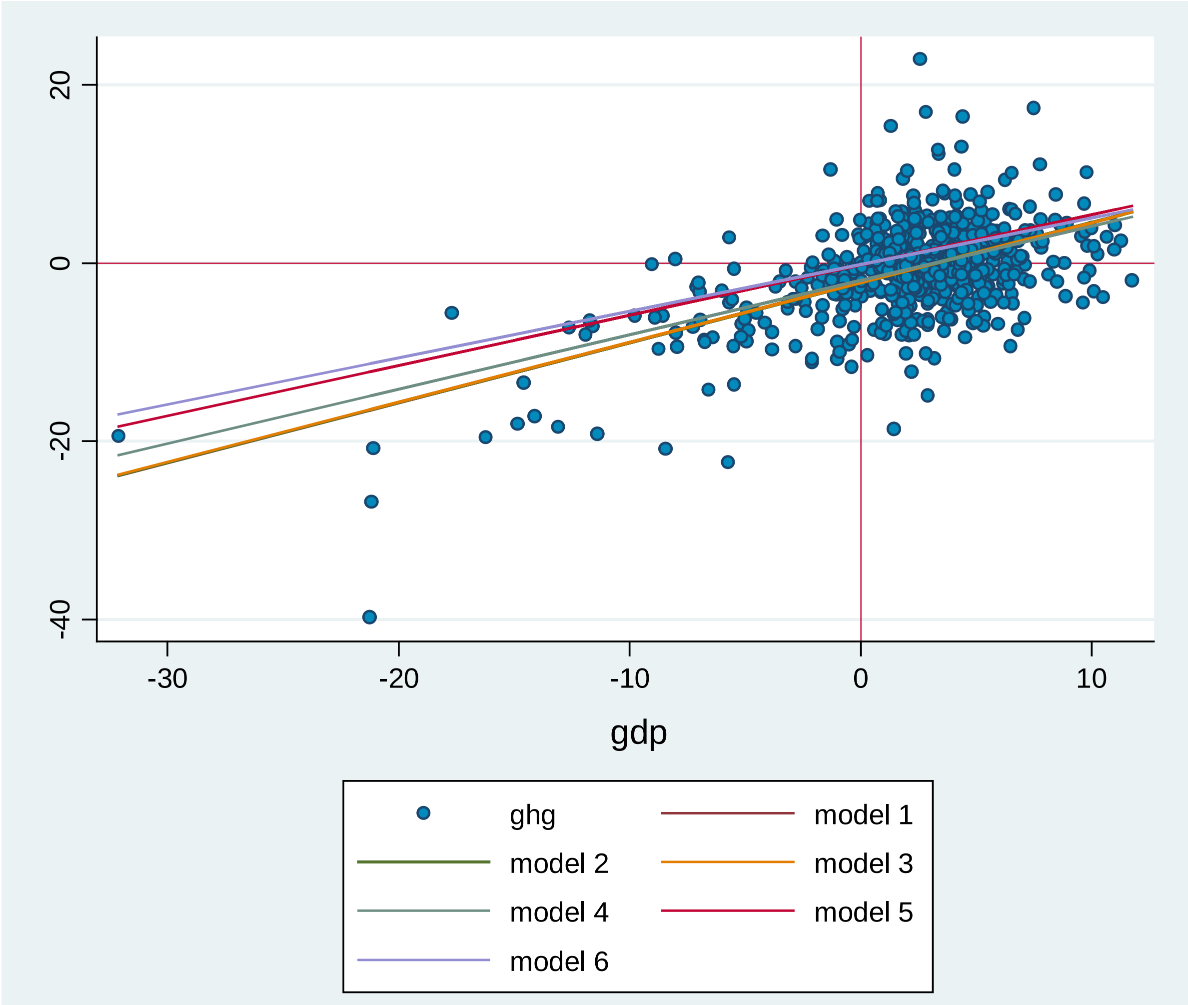
The main objective of this section is to establish the significance and estimate, using alternative models, the slope coefficient of GDP, while taking into account the 28 different country-specific GHG-GDP relationships. The current section summarises the main results only. Annex 5 describes the process to estimate the final regression coefficients, using six different models.

The following key results can be derived from the analysis presented in Annex 5:

1. Overall, evidence suggests the presence of co-integration of the panel as a whole when pooling the data over all cross-sectional units. Notwithstanding specific relationships between GHG and GDP at Member State level, this conclusion suggests the presence of certain coupling between annual changes in GDP and changes in GHG emissions between 1990 and 2012 for the EU as a whole when considering data for all 28 Member States. This is not at conflict with an absolute decoupling of GDP and GHG emission compared to 1990, with an increase in GDP of 45% alongside a decrease in emissions of 19% over the 22-year period. Yet, the link between GDP and GHG emissions is not broken.

2. The general diagnostic tests for cross section dependence suggest the presence of contemporaneous correlations in the variables across MS. Indeed, one can expect this cross-sectional dependence in terms of economic integration and to a lesser extent interconnection in the energy markets. Economic growth or recession in one EU MS will affect other MS, depending on the degree of dependency in terms of e.g. trade of goods and services. In addition, higher or lower emissions in some MS can be linked to weather conditions in other MS with high electricity interconnection. Also a nuclear phase out or the closing of a power plant in a MS could be linked to emissions in other MS, if the importing country e.g. imports electricity from another country with a fossil-fuel dominated energy mix for power generation.
3. GDP is clearly a significant explanatory factor underpinning lower GHG emissions in the EU between 1990 and 2012. The slope coefficients also indicate that when GDP growth increases by 1 percentage point compared to the previous year, the expected mean increase in GHG emissions ranges between 0.5 and 0.7 percentage points, depending on the specific model chosen (see figure 20).
4. GDP is a highly significant factor during the 5-year period that started with the economic recession in the second half of 2008. The slope coefficients are wider due to higher variability from a higher standard error in GDP. Overall, the results indicate that when GDP growth increases by 1 percentage point compared to the previous year, the average increase in GHG emissions would range between 0.6 and 0.8 percentage points, depending on the model estimation. Since the results from table 5 also include the period 2008-12, it would appear that changes in GHG emissions have been more responsive to changes in GDP in this last 5-year period than in the past.

Figure 20 Average predictions for changes in GHG emissions based on changes in GDP, 1990-2012



Notes: Standard errors of the slope coefficients and uncertainty ranges are shown in table 5 of Annex 5.

Source: EEA.

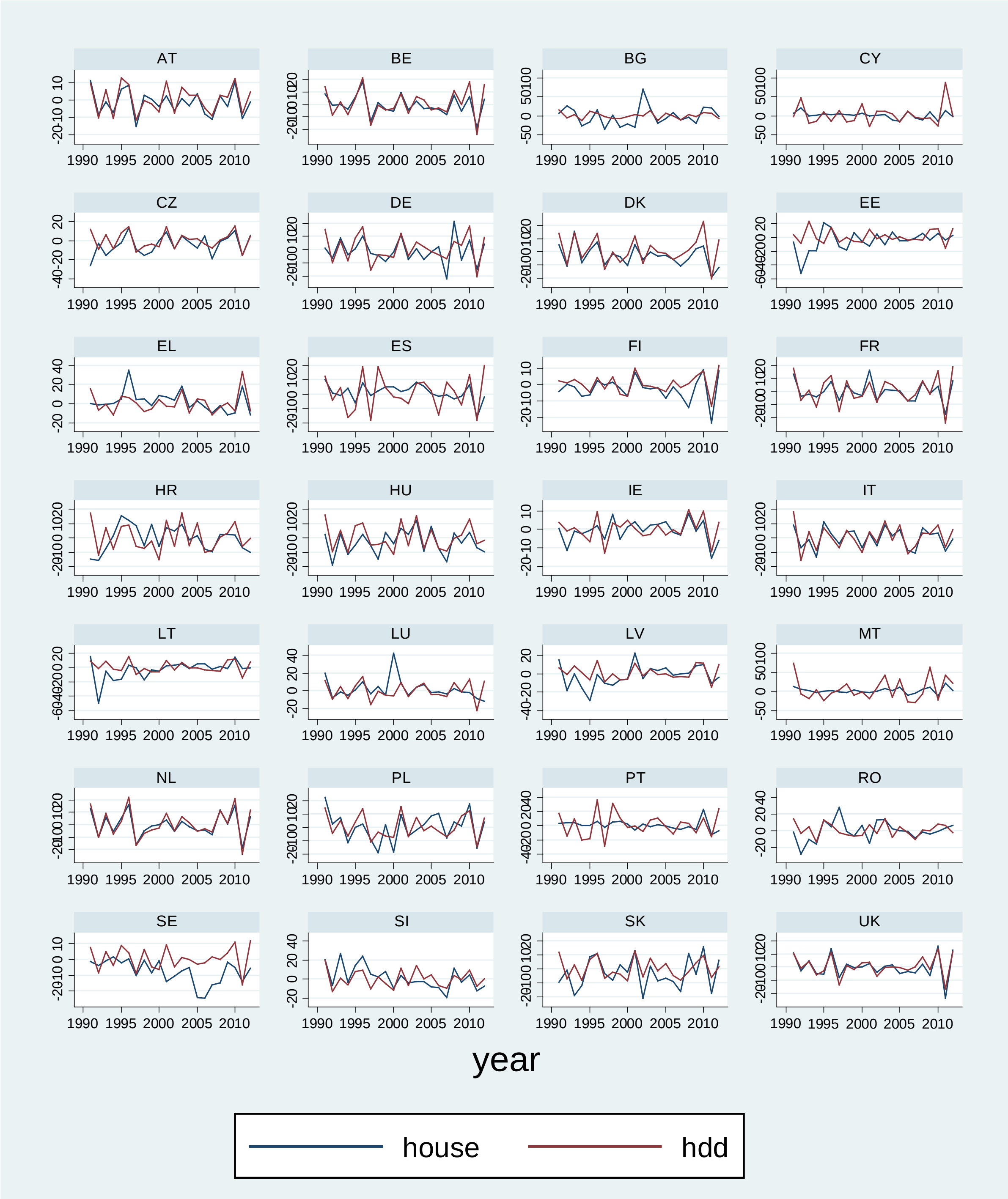
7.3 Final notes

This section has shown that GDP has been an important factor underpinning changes in GHG emissions in the EU between 1990 and 2012, albeit not the only one. About one third of the change in total GHG emissions in the EU between 1990 and 2012 is associated with changes in GDP (both positive and negative). GDP is clearly a significant factor underpinning changes in GHG emissions. In addition, GHG emission reductions have not been at conflict with economic growth in the last 22 years. In some individual Member States, of course, the economic recession has had a larger impact on emissions than the EU average. The recession has affected MS very differently not only in terms of employment, finances and economic performance but also in terms of GHG emissions. The analysis presented in this paper is not an analysis by MS. It is a snapshot for the EU taking into account different relationships between emissions and economic growth across Member States. The results indicate that, on average, about two thirds of the variation at EU level has been due to other factors than GDP – as described in previous sections of this paper.

The paper has also shown that economic recession, defined as negative GDP, can at most explain less than half of the emission reductions over the period considered in the analysis. 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. The combined effects of other factors and policies have played as important a role as GDP, including MS specific factors and policies such as the sustained and strong increases in renewables and significant improvements in the carbon intensity of the economy. It would also appear that changes in GHG emissions have been more responsive to changes in GDP in the last 5-year period which started with the economic crisis in the second half of 2008.

Finally, will emissions increase when the economy starts growing again? Looking back, although emissions have decreased and GDP has increased since 1990, GDP remains a significant factor underpinning GHG emissions in the EU. Since the link between emissions and GDP is not broken one could expect energy use to increase with a growing economy, although not necessarily emissions. This paper has shown that EU economies can grow and emissions decrease, particularly with growing shares of renewables, less carbon intensive fuels in the energy mix and improvements in energy efficiency. This reliance on coal, gas and oil has nevertheless decreased from 83% in 1990 to just about 75% of primary energy in 2012. However, emissions will increase with GDP, on average, if the EU continues relying on fossil fuels to meet the majority of its final energy demand.

Annex 1: figure A1 annual changes in residential emissions and HDDs by EU Member State, 1990-2012



Source: EEA (emissions), Eurostat (HDDs)

Annex 2: Definitions used in the decomposition analysis

Box 1 Factors used in the detailed decomposition analysis

The chosen factors are an extension of the Kaya identity and should be seen as illustrative only since they represent an identity where the dependent variable is not determined stochastically.

The annual decomposition analysis shown in this paper is based on the Logarithmic Mean Divisia Index (LMDI) method.

The **equation for the detailed decomposition analysis** is:

(y) [ln]CO_2 = (x_1) [ln]POP + (x_2) [ln]GDP/POP + (x_3) [ln]FEC/GDP + (x_4) [ln]PEC/FEC + (x_5) [ln]FFC/PEC + (x_6) [ln] CO_2/FFC, where:

The factors are:

(y) CO_2: carbon dioxide emissions from energy combustion processes

(x_1) POP: population (population effect)

(x_2) GDP/POP: GDP per capita (affluence effect)

(x_3) FEC/GDP: final energy intensity of the economy ('final' energy intensity effect)

(x_4) PEC/FEC: primary energy relative to final energy (energy-transformation efficiency effect)

(x_5) FFC/PEC: fossil fuel consumption in total primary energy (non-carbon fuels effect)

(x_6) CO_2/FFC: carbon dioxide emissions in fossil fuel consumption (carbon intensity of fossil fuels effect)

The **equation for the aggregated decomposition analysis** is:

(y) [ln]CO_2 = (x_1) [ln]POP + (x_2) [ln]GDP/POP + (x_3) [ln]PEC/GDP + (x_4) [ln]CO_2/PEC, where:

The factors are:

(y) CO_2: carbon dioxide emissions from energy combustion processes

(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) CO_2/PEC: carbon dioxide emissions in primary energy consumption (total carbon intensity effect)

Note: The definitions for the energy efficiency and non-carbon fuels factors in Box 1 are only relevant for the purpose of the decomposition analysis, without prejudice to the use of different definitions in the EU Energy Efficiency and Renewable Energy Directives.

Source: EEA

Annex 3: Definitions used in the cross-section regression analysis

Box 2 Variables used in the regression analysis — basic model

The variables were derived from the previous decomposition analysis, transforming the deterministic relationship with no error into a stochastic relationship using data from 28 EU Member States.

The **equation** is:

(y) GHG = (x_1)GDP/POP + (x_2)FEC + (x_3)EFF + (x_4)REN + (x_5)CAR + μ, where:

The **variables** are, data source in brackets:

(y) GHG: % change in greenhouse gas emissions from energy combustion including fugitives (EEA).

(x_1) GDP/POP: % change in GDP at constant prices per head of population (European Commission, Ameco database)

(x_2) FEC: % change in final energy consumption (Eurostat's energy balances)

(x_3) EFF: percentage point change in transformation efficiency in main-activity thermal power stations and district heating plants (Eurostat's energy balances)

(x_4) REN: % change in final renewable energy consumption (Eurostat's energy balances)

(x_5) CAR: percentage point change in the average implied CO_2 emission factor of fossil fuel energy, excluding biomass (EEA)

μ: error term

Annex 4: Annual analysis, 2009, 2010, 2011 and 2012

Starting in 2009, the EEA started publishing short working papers analysing why emissions increase or decrease in the last year compared to the previous year. These papers underpin the official EU GHG inventory submissions to UNFCCC. The following sections summarise the key findings for each of the years between 2009 and 2012[34].

6.2.1 Emissions decreased sharply in 2009

i. Results from the decomposition analysis

CO_2 emissions from energy combustion fell by about 7% in 2009 in the EU-27 and accounted for over three quarters of the total reduction in GHG emissions in all sectors. Population increased by about half a percent while GDP contracted by 4.5%, leading to a reduction in GDP per capita of almost 5% in 2009. The negative affluence effect appears quite dominant in 2009 compared to the other explanatory factors.

The energy intensity of the economy improved by about 1% in 2009 compared to 2008. This was mainly because the reduction in final energy demand was more than offset by the reduction in economic growth.

In addition, Eurostat's 2009 energy balances point to a very strong and similar decline in primary and final energy consumption. As a result there was no significant 'energy-transformation efficiency effect' in 2009. Along with the strong decline of primary consumption of fossil fuels (gas, coal, oil) there was a very strong increase in renewable energy, particularly of wind and solar for electricity generation. In absolute terms, biomass still represented over 75% of the increase in renewables in 2009. Nuclear electricity production fell in 2009. Thus, the very positive 'non-carbon effect' is fully accounted for by the increase in renewable energy.

Carbon intensity continued its downward trend in 2009, not so much because of fossil fuel switching but because coal use fell significantly more than oil or gas did. At the EU level, the sector contributing most to the net emission reduction in 2009 was the production of heat and electricity. Despite the relatively colder winter of 2009 emissions also fell in the residential sector. A higher reduction in coal use compared to gas in power plants led to a relatively stronger CO_2 emission reduction per unit of energy. The steady increase in biomass use also provided a substitute for fossil fuels.

ii. Results from the statistical analysis

The results from a cross-section regression showed that the strong decrease in greenhouse gas emissions in 2009 can be explained by both the stark reduction in economic growth and the strong increase in renewable energy consumption. In addition, the analysis suggests that both factors are as important (with GDP ranking just higher than renewables) for understanding why CO_2 emissions fell by 7% and not by less. Clearly, the growth in renewables, both combustible (biomass) and non-combustible (wind and solar) was a common factor in most EU countries.

(34) These analysis were done at the time and changes in definitions and/or in the data (e.g. due to recalculations in GHG inventories or revisions to energy balances and GDP) may change some of the results.

Summary 2009

The strength of the 2009 recession affected all economic sectors in the EU. Consumption of fossil fuels (coal, oil and natural gas) fell compared to the previous year, mainly due to reduced coal use. The decreased demand for energy linked to the economic recession was accompanied by a strong increase in renewable energy use, which also contributed to lower emissions. Sustained growth in the use of renewables was therefore a key factor explaining the strong decrease in greenhouse gas emissions in 2009.

6.2.2 Emissions picked up in 2010

i. Results from the decomposition analysis

Energy combustion accounted for over 90% of the net increase in EU greenhouse gas emissions in 2010. CO_2 emissions from energy combustion increased by almost 3% in the EU-27 in 2010. Population increased by 0.3% while GDP grew by 2.0%, leading to a 1.7% increase in GDP per capita in 2010. The affluence effect was again quite important in 2010, although this time contributing to higher CO_2 emissions.

The energy intensity of the economy deteriorated by almost 2% in 2010 compared to 2009. This was mainly because the strong increase in final energy demand in 2010 outpaced the increase in GDP

There was also a strong increase in primary energy consumption (3.4%) in 2010. This rate was lower than the increase in final energy available to the end-use sectors (3.8%), resulting in an improvement of the 'energy-transformation efficiency effect' in 2010. At least two reasons can explain this improvement. First, there was a strong increase in non-combustible renewables. The avoided transformation losses partly explain why emissions did not increase more. Second, there was also a half percentage point increase in the transformation efficiency in conventional thermal power stations (including district heating) in the EU in 2010. The higher heating demand from the colder 2010 winter, largely met using natural gas, can be seen as a contributing factor to higher emissions despite the improved overall transformation efficiency.

The increase in renewables came primarily from wind, solar and hydro for electricity generation. In absolute terms, however, biomass still represented about 70% of the increase in renewables in 2010. Nuclear electricity production also increased in 2010 but much less than renewables. Thus, the positive 'non-carbon fuels effect' was largely the result of increased renewable energy. The overall increase in emissions in the EU would have been worse if renewable energy use had not continued to expand in 2010.

Finally, the average fossil fuel CO_2 emission factor continued its downward trend in 2010, although at a slower pace. The emission factor for gaseous and liquid fuels remained stable whereas that of solid fuels increased in 2010. Yet the stronger polluting effect from coal was more than offset by a large increase in gas consumption in the EU. The 'carbon intensity effect' improved only slightly compared to 2009 because CO_2 emissions increased almost as fast as the primary fossil fuel input.

ii. Results from the statistical analysis

The regression analysis carried out for the year 2010 indicated that the economic recovery and higher industrial output, more renewable energy in final energy consumption, and the slightly improved carbon intensity were the main (statistical) factors underpinning the change in CO_2 emissions in the EU in 2010. The latter two factors prevented GHG emissions from increasing more in 2010. In addition, the analysis suggests that all three factors were roughly as important in explaining why CO_2 emissions increased by almost 3% on average in the EU in 2010.

Summary 2010

The increase in emissions in 2010 was partly driven by the economic recovery from the 2009 recession in many European countries, which had itself caused substantial emission reductions in 2008 and 2009 in all Member States. Final energy demand increased by 3.8% in 2010, outpacing the increase in economic output (2.0%). In 2010 the winter was also colder than in the previous year, leading to increased demand for heating and higher emissions from the residential and commercial sectors. The continued strong increase in renewable energy use and the improved carbon intensity of fossil fuels - underpinned by strong gas consumption - prevented the increase in GHG emissions from being higher.

6.2.3 Emissions decreased again in 2011

i. Results from the decomposition analysis

CO_2 emissions from energy combustion decreased by 4.1% in the EU-27 in 2011 and accounted for over 95% of the net decrease in total EU GHG emissions that year. Population increased by 0.3% while GDP grew by about 1.7%, leading to a 1.4% increase in GDP per capita in 2011. The positive GDP per capita effect was less influential than in 2010. This was mainly due to the slowdown of the EU economy during 2011.

The final energy intensity of the economy improved substantially in 2011 (by almost 6%), as final energy demand decreased strongly (4.3%) amid positive GDP growth. However, the carbon intensity of the EU economy deteriorated due to increased use of hard coal and lignite in the fossil-fuel mix. As a result, CO_2 emissions decreased less than the primary fossil fuel input in 2011.

Renewable energy use also dropped significantly in 2011. About 60% of the reduction in renewables was accounted for by lower hydro production. Consumption of solar and wind energy, however, continued to grow strongly in the EU in 2011. Consumption of nuclear-generated electricity also decreased in 2011. The contribution of the 'non-carbon fuels' effect was only positive because the consumption of renewables (and of nuclear) fell by less than the consumption of all fossil fuels as a whole.

Eurostat's 2011 energy balances also point to a strong decrease in primary energy consumption (3.5%). This rate was lower than the decrease in final energy consumption (4.3%), resulting in a worsening of the 'energy-transformation efficiency' effect in 2011. Lower heat production in 2011 meant a significant reduction in the average transformation efficiency from conventional thermal power stations, since heat production is more efficient than electricity production. The sharp decrease in hydroelectricity also meant a reduction in the ratio of final to primary energy.

ii. Results from the statistical analysis

The 2011 analysis showed that lower final energy consumption, resulting from lower heat demand, lower energy efficiency and higher carbon intensity were the main (statistical) factors underpinning the change in CO_2 emissions in the EU in 2011. The latter two factors prevented GHG emissions from decreasing more in 2011.

In addition, the analysis suggests that the reduction in final energy consumption was the single most determinant factor of the three in explaining why EU CO_2 emissions decreased by 4.1% in 2011 compared to 2010. A milder 2011 winter compared to 2010 can to a large extent explain lower fossil fuel emissions, as higher winter temperatures, on average, led to lower heating demand and lower emissions from the residential and commercial sectors.

An extended regression model including 'heating degree days' (an indicator of demand for heating by households) confirmed that lower heat consumption was the main reason for lower CO_2 emissions in the EU in 2011 compared to 2010.

Summary 2011

For the EU as a whole, the 4.1% decrease in CO_2 emissions in 2011 came amid positive economic growth in most EU member states. GDP increased by 1.7%, although economic growth was lower than in 2010, when GDP increased by 2%. A milder 2011 winter compared to 2010 can, to a large extent, explain lower fossil fuel emissions. This is because, on average, the higher winter temperatures led to lower heating demand and lower emissions from the residential and commercial sectors. The increase in coal use did not offset a much larger decrease in the consumption of natural gas, and emissions fell as a result.

6.2.4 Emissions continued decreasing in 2012

i. Results from the decomposition analysis

CO_2 emissions from energy combustion decreased by 1.1 % in the EU-28 in 2012 and accounted for two thirds of the net decrease in total EU GHG emissions that year. Population increased by 0.2 % while GDP contracted by 0.4 %, leading to a 0.6 % decrease in GDP per capita in 2012. As in 1993 and 2009, the negative affluence effect contributed to otherwise higher GHG emissions in 2012.

Eurostat's 2012 energy balances point to a significant decrease in primary energy consumption (-1 %). The energy intensity of the economy in 2012 remained somewhat stable compared to 2011. This was mainly because final energy demand decreased by a degree very similar to GDP.

The EU carbon intensity deteriorated in 2012 due to the increased use of hard coal and lignite in the fossil-fuel mix that started in 2009. However, when considering all fuels in the energy mix the carbon intensity of the EU energy sector decreased somewhat in 2012. This was mainly due to a much larger increase in renewable energy in 2012 (+ 3.6 %) after the sharp decline witnessed in 2011. According to Eurostat, the share of renewable energy in gross final energy consumption reached 14.1 % in 2012, up from 12.9 % the year before.

GHG inventory data and energy balances clearly show that, over the long run (1990-2012), there has been a substantial improvement in the carbon intensity of energy production and use in the EU.

ii. Results from the statistical analysis

A preliminary analysis of 2012 data suggest that lower final energy consumption, resulting from lower fuel use by both industry and transport and higher carbon intensity were the main (statistical) factors underpinning the change in CO_2 emissions in the EU in 2012. The latter factor prevented GHG emissions from decreasing more that year.

The 1.1 % decrease in CO_2 emissions from energy in EU-28 in 2012 (1.3% decrease overall) came along with economic recession across the EU as a whole. Half the EU member states experienced negative economic growth in 2012. In the other half, positive economic growth in 2012 was lower than in 2011. Notwithstanding economic developments in specific sectors and countries, there was no apparent correlation between GDP and GHG emissions in the EU in 2012, although emissions did not increase in any MS where GDP was negative.

The winter in Europe was generally colder in 2012 than it was in 2011. Lower winter temperatures led to higher heating demand and higher emissions from the residential and commercial sectors. An extended regression model including ‘heating degree days’ (an indicator of demand for heating by households) confirmed the significance of higher heat consumption from the residential sector. However, higher residential emissions did not offset much lower emissions in other sectors, and as a result, total fossil fuel emissions decreased for the EU as a whole.

Energy prices increased by 7 % on average for the EU in 2012, clearly outpacing the increase in non-energy prices and the gross disposable income of households. Despite lower carbon prices in 2012, energy became relatively more expensive for the average household. This may have also contributed to the decline in GHG emissions in some Member States, particularly in road transportation.

Summary 2012

The 1.1 % decrease in CO_2 emissions from energy in EU-28 in 2012 came along with economic recession across the EU as a whole. Half the EU member states experienced negative economic growth in 2012. In the other half, positive economic growth in 2012 was lower than in 2011. The winter in Europe was on average colder in 2012 than in 2011 leading to higher heating demand and emissions from households. However, higher residential emissions did not offset much lower emissions in other sectors such as transport and industry. Also, the increase in coal use in 2012 did not offset a much larger decrease in the consumption of oil natural gas. There was also a substantial increase in renewable energy in 2012, continuing the long-term trend observed since 1990.

Annex 5: Model estimation cross-sectional time series

The main objective of this section is to establish the significance and estimate the slope coefficients, using alternative models, of GDP as an explanatory factor of GHG emissions over the last 22 years since 1990, while taking into account the 28 different country-specific GHG-GDP relationships.

Figure 20 illustrates the box plots of the dependent (GHG) and explanatory variables (GDP). The plots clearly show the heterogeneity across countries. They also show that GDP is positive in most years for all MS over the 22-year period whereas GHG is negative in most years for more than half of MS.

Figure 20 Annual changes in GDP & GHG emissions by EU Member State, 1990-2012 (Box Plots)

Source: EEA

The Chow test for known breaks suggests that the year 2009 in itself does not constitute a structural break in the time series 1990-2012. However, the same tests points to the existence of a structural break in the regression coefficients before and after 2008. Therefore any conclusions regarding the regression coefficients for the period 1990 to 2012 should take into account that the slope and coefficients of the single linear relationship between GDP and GHG emissions may not as representative for the whole sample as it would be for two separate subsamples before and after 2008.

Three unit root tests are carried out to establish whether the time series of annual changes in GHG emissions and in GDP are stationary. The Im-Pesaran-Shin unit root test, the Fisher-type unit root test and the Hadri Lagrange multiplier stationarity test. The first two tests reject the null hypothesis that all panels contain unit roots at the 5% significance level. This suggests that at least some panels do not contain unit roots and confirms that there is no overall panel unit root for either GHG or GDP. The latter test rejects the null hypothesis that all panels are stationary, implying that at least some panels are not stationary. Thus, all test point to the lack of stationary series in both GHG and GDP. The same unit root tests on the differenced series suggest that both GHG and GDP are stationary series, or integrated of order 1.

The next step is to test whether GHG and GDP are co-integrated series. This is important before estimating the model and avoid the possibility of spurious correlations, and will show whether there is certain coupling between changes in GDP and changes in GHG emissions. The Westerlund co-integration tests for panel data[35] rejects the null hypothesis of no co-integration of the two variables[36]. Overall, evidence suggests the presence of co-integration of the panel as a whole when pooling the data over all cross-sectional units. Notwithstanding specific relationships between GHG and GDP at Member State level, this conclusion suggests the presence of certain coupling between annual changes in GDP and changes in GHG emissions between 1990 and 2012 for the EU as a whole when considering data for all 28 Member States.

We use a fixed effects model to estimate the model parameters with GHG emissions as the dependent variable and GDP as the explanatory variable. The fixed effects model assumes that either the unobserved effects specific to cross-sectional units are constant over time, or the effects specific to time are constant over the cross-sectional units. The unobserved effects are correlated with the explanatory variable. The fixed effects model is estimated using OLS. Table 5 shows that GDP is highly significant at the 5% level (model 1 of table 5)[37].

Differences across MS may also have some influence on the dependent variable. Therefore, we will also estimate a random effects model. The random effects model is estimated using GLS to adjust for heteroscedasticity and autocorrelation in the error terms. This is because there is correlation among the residuals of the same cross-sectional unit. Non-zero correlation indicates the presence of heteroskedastic errors. Again, GDP is highly significant at the 5% level (model 2 of table 5).

To decide between fixed or random effects we run the Hausman test, where the null hypothesis is that the preferred model is the random effects model. The Hausman tests confirms that the difference between the fixed effect and random effects coefficients are not systematic (Prob>chi2 = 0.7099). We fail to reject the null hypothesis and conclude that the unique errors are not correlated with GDP. The random effects model is preferable over the fixed effects model[38].

We also run the Pesaran's test of cross sectional independence (contemporaneous correlation) to establish whether the residuals are correlated across MS. This could lead to bias coefficients. The null of independence is rejected (Pr = 0.0000). There is clear cross-sectional dependence. We can use Driscoll-Kraay standard errors to account for this cross-sectional dependence[39]. The errors are also

(35) Based on Persyn, D. and J. Westerlund. 2008. Error Correction Based Cointegration Tests for Panel Data. Stata Journal 8 (2), 232-241.

(36) One could expect some dynamics in the GHG-GDP relationship, as it may take time for GHG to adjust to changes in GDP. Since overfitting the lags may increase the mean square forecast error and under-fitting may generate autocorrelated errors, the optimal number of lags for each separate time series will be based on the Akaike information criterion.

(37) The fixed effects model assumes time-invariant unobserved effects. We run a joint test to establish if the dummies for all years are equal to zero. The null hypothesis is rejected at the 5% level (Prob > F = 0.0006), indicating that time fixed effects are not needed.

(38) Moreover, to decide between a random effects regression and a simple (pooled) OLS regression, we can run the Breusch and Pagan Lagrange multiplier test for random effects. The null hypothesis is that the variances across MS is zero. We reject the null hypothesis (Prob > chibar2 = 0.0018). That is, there is evidence of significant differences across MS.

(39) Daniel Hoechle, Robust Standard Errors for Panel Regressions with Cross-Sectional Dependence, Stata Journal http://fmwww.bc.edu/repec/bocode/x/xtscc_paper.pdf

robust to heteroskedasticity[40] and autocorrelation[41]. GDP is highly significant at the 5% level (model 3 of table 5).

Since fixed and random effects models could lead to inconsistent and bias results in the presence of heterogeneous slopes, we will also use mean-group estimation[42]. This model allows for different slope coefficients across panels. It basically estimates 28 OLS regressions and then averages the estimated coefficients across MS. GDP is highly significant at the 5% level (model 4 of table 5)

The general diagnostic tests for cross section dependence[43] suggest the presence of contemporaneous correlations in the variables across MS. Indeed, one can expect this cross-sectional dependence in terms of economic integration and to a lesser extent interconnection in the energy markets. Economic growth or recession in one EU MS will affect other MS, depending on the degree of dependency in terms of e.g. trade of goods and services. In addition, higher or lower emissions in some MS can be linked to weather conditions in other MS with high electricity interconnection. Also a nuclear phase out or the closing of a power plant in a MS could be linked to emissions in other MS, if the importing country e.g. imports electricity from another country with a fossil-fuel dominated energy mix for power generation. Thus, there could be unobserved common factors driving GHG emissions in all MS but with differentiated impact across countries. The average correlation coefficients from the Pesaran CD test reject the null hypothesis of cross-section independence for both GHG and GDP, confirming the presence of contemporaneous correlations across MS. This cross-sectional dependence is also found in the residuals of the mean group regression.

A new regression including the common dynamic process as an additional regression confirms the significance of the unobservable common factors. The augmented mean group estimator developed in Eberhardt and Teal (2010)[44] is implemented by imposing the common dynamic process with unit coefficient. GDP is highly significant at the 5% level. The results are shown in table 5 below (model 5 of table 5).

(40) A test of heteroscedasticity available for fixed effect models, based on the modified Wald test for group-wise heteroscedasticity, indicates the presence of heteroscedasticity (Prob>chi2 = 0.0000). The null of homoscedastic errors (or constant variance) is rejected.

(41) We also test for possible autocorrelation of the errors. Serial correlation causes the standard errors of the coefficients to be smaller than they actually. The Wooldridge test for autocorrelation indicates that no first order autocorrelation exits. We fail to reject the null hypothesis and conclude the data does not have first-order autocorrelation (Prob > F = 0.92).

(42) Based on M. Eberhardt. 2012. Estimating panel-time series model with heterogeneous slopes. Stata Journal Volume 12 Number 1.

(43) Based on Pesaran, M. Hashem (2004) General Diagnostic Tests for Cross Section Dependence in Panels' IZA Discussion Paper No. 1240.

(44) Eberhardt, Markus and Francis Teal (2010) 'Productivity Analysis in Global Manufacturing Production', Economics Series Working Papers 515, University of Oxford, Department of Economics.

Table 5 Final model results, 1990-2012

	(1) Fixed effects	(2) Random effects	(3) Pooled OLS (Driscoll-Kraay std errors)	(4) Mean Group estimation	(5) Augmented Mean Group	(6) Robust Augmented Mean Group
Variables	GHG	GHG	GHG	GHG	GHG	GHG
GDP	.676***	.673***	.671***	.610***	.565***	.524***
Standard error	(.040)	(.040)	(.074)	(.056)	(.053)	(.053)
95% confidence interval (high)	.755	.752	.824	.721	.669	.628
95% confidence interval (low)	.596	.595	.519	.500	.461	.421
Constant	-2.201***	-2.196***	-2.191***	-1.959***	-.211	-.173
Standard error	(.200)	(.267)	(.335)	(.285)	(.279)	(.294)
Number of observations	616	616	616	616	616	616
Number of Groups	28	28	28	28	28	28
Observations per group	22	22	22	22	22	22
Root MSE	4.519	4.519	4.606	4.269	3.906	3.906

Standard errors in parentheses
*** p<0.001, ** p<0.01, * p<0.05

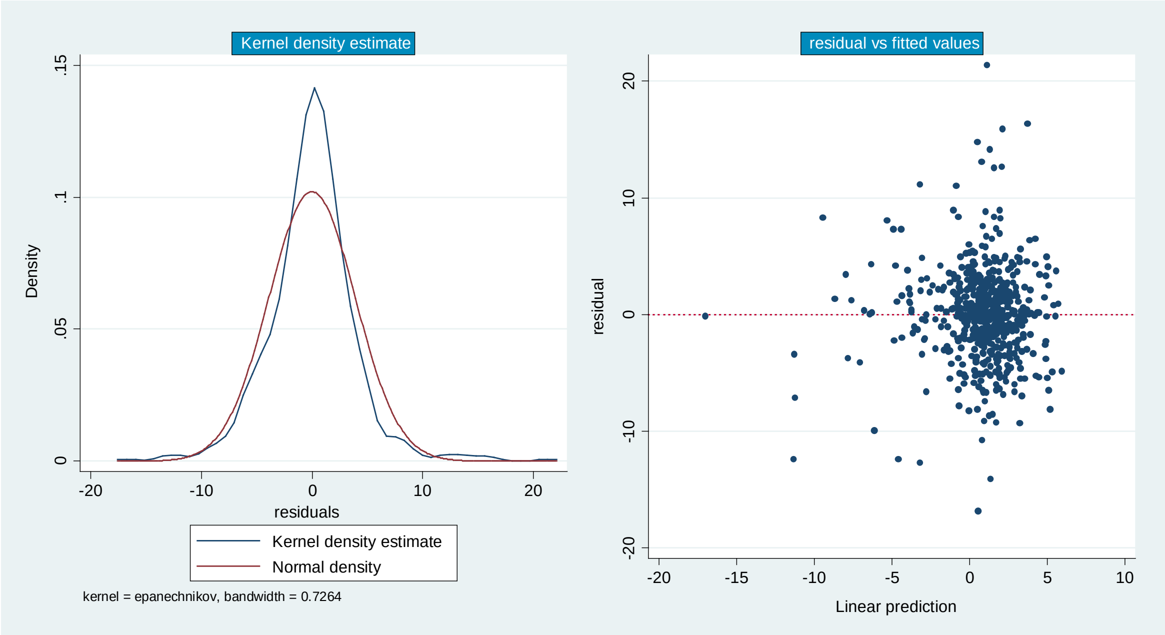
Source: EEA

The plot of the residuals and the fitted values performed on model 5 does not suggest heteroscedasticity of the errors. Although some specific observations could be seen as outliers. We run a final model using robust regression, which estimates the outlier-robust mean of parameter coefficients across groups (model 6 of table 5). The coefficients are not very different from the previous regression, suggesting a small effect from outlier observations in the overall regression coefficients.

The average correlation coefficients from the Pesaran CD test fail to reject the null hypothesis of cross-section independence of the residuals in the final model. The test for serial correlation[45] of the errors is not significant and the null hypothesis not rejected. The Shapiro-Wilk test and the skewness and kurtosis tests for normality seem to reject the null hypothesis of normally distributed residuals. However, the kernel density plot suggest the errors are normally distributed, despite being spikier than the normal (figure 21). Finally, the Fisher-type unit root test based on augmented Dickey-Fuller tests on the residuals confirm the Westerlund co-integration test on the final model.

(45) Based on Drukker, D. M. 2003. Testing for serial correlation in linear panel-data models. The Stata Journal (3)2, 1-10.

Figure 21 Density distribution and residual vs fitted values plot, 1990-2012



Source: EEA

The results from table 5 indicate that GDP is clearly a significant explanatory factor underpinning lower GHG emissions in the EU between 1990 and 2012. The slope coefficients also indicate that when GDP growth increases by 1 percentage point compared to the previous year, the expected mean increase in GHG emissions ranges between 0.5 and 0.7 percentage points, depending on the specific model chosen. One should also take into account the uncertainty ranges around the mean estimates. The table also shows that GHG emissions would decrease by about 2 percentage points when GDP is zero – at least according to the models where the constant terms is significant. The two models using mean group estimation appear to be the best models as reflected in the lower mean square errors.

Finally, the same procedure was performed to the relationships GHG and GDP for the period 2008-12. The results from table 6 indicate that GDP is a highly significant factor during the 5-year period that started with the economic recession in the second half of 2008. The slope coefficients are wider due to higher variability from a higher standard error in GDP. Overall, the results indicate that when GDP growth increases by 1 percentage point compared to the previous year, the average increase in GHG emissions would range between 0.6 and 0.8 percentage points, depending on the model estimation and without factoring in the uncertainty. Since the results from table 5 also include the period 2008-12, it would appear that changes in GHG emissions have been more responsive to changes in GDP in this last 5-year period than in the past. The table also shows that GHG emissions would decrease by about 2 to 4 percentage points when GDP is zero.

Table 6 Final model results, 2008-2012

	(1) Fixed effects	(2) Random effects	(3) Pooled OLS (Driscoll-Kraay std errors)	(4) Mean Group estimation	(5) Augmented Mean Group	(6) Robust Augmented Mean Group
Variables	GHG	GHG	GHG	GHG	GHG	GHG
GDP	.745***	.711***	.711***	.759***	.590***	.680***
Standard error	(.109)	(.095)	(.112)	(.100)	(.109)	(.093)
95% confidence interval (high)	.961	.897	.942	.955	.805	.862
95% confidence interval (low)	.529	.525	.481	.564	.376	.498
Constant	-2.279***	-2.287***	-2.287***	-2.566***	-3.721***	-3.749***
Standard error	(.415)	(.386)	(.552)	(.285)	(.267)	(.278)
Number of observations	140	140	140	140	140	140
Number of Groups	28	28	28	28	28	28
Observations per group	5	5	5	5	5	5
Root MSE	4.902	4.902	4.562	4.038	3.420	3.420

Standard errors in parentheses
*** p<0.001, ** p<0.01, * p<0.05

Source: EEA

Annex 6: Institutional set up in the GHG inventory of the European Union

The European Union (EU), as a party to the United Nations Framework Convention on Climate Change (UNFCCC), reports annually on greenhouse gas (GHG) inventories for the years 1990 to t-2 and within the area covered by its Member States. The legal basis for the compilation of the EU inventory is Regulation (EU) No 525/2013.

Article 5(1) of the Kyoto Protocol requires Parties to establish and maintain a national system for estimating anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol. In doing so, the Union and the Member States apply the guidelines for national systems set out in the Annex to Decision 19/CMP.1 of the Conference of the Parties to the UNFCCC.

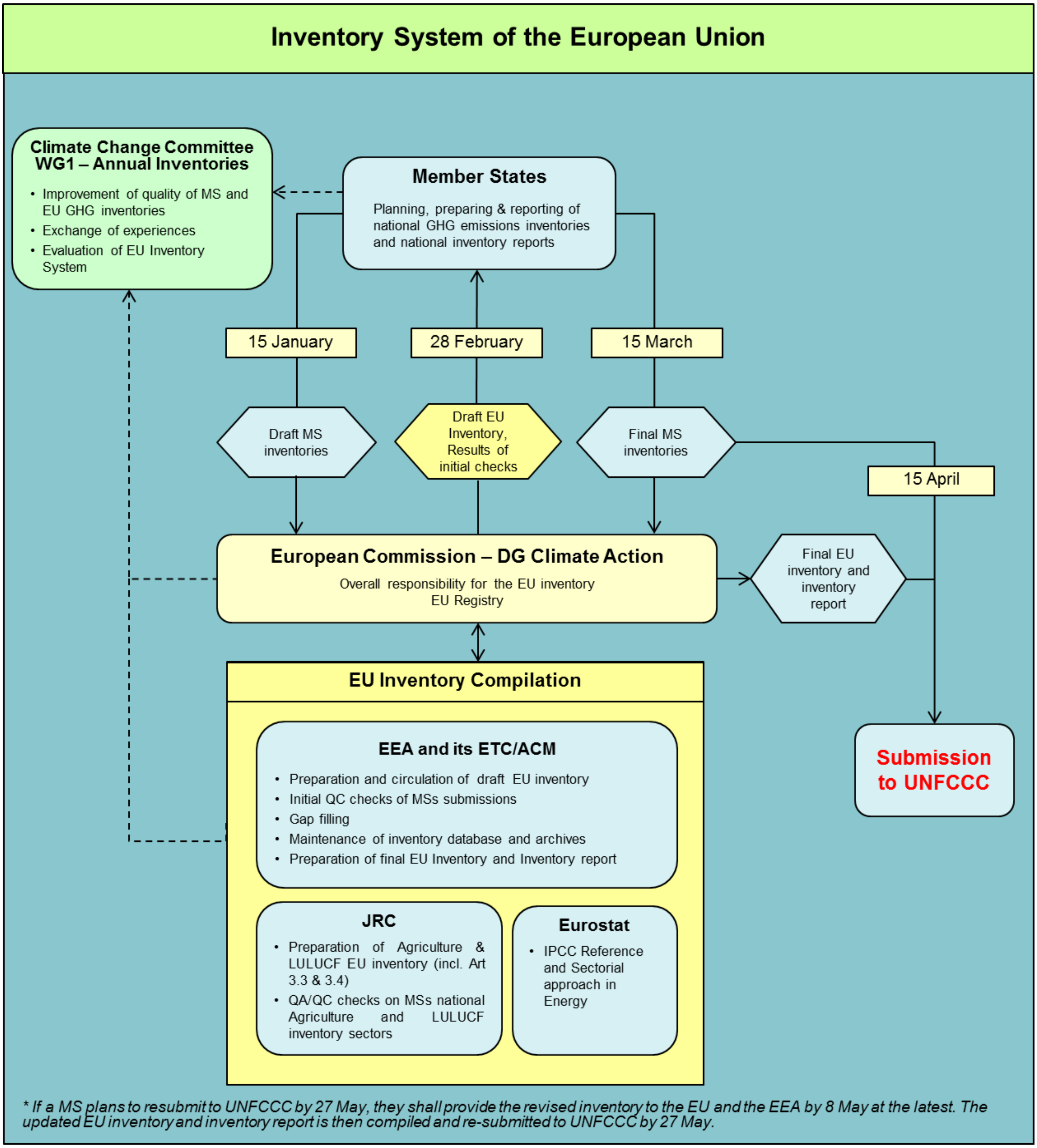
The main institutions involved in the compilation of the EU GHG inventory are the Member States, the European Commission Directorate-General Climate Action (DG CLIMA), the European Environment Agency (EEA) and its European Topic Centre on Air Pollution and Climate Change Mitigation (ETC/ACM), Eurostat, and the Joint Research Centre (JRC). See also flow chart below.

The European Commission's DG Climate Action in consultation with the Member States has the overall responsibility for the EU inventory. Member States are required to submit their national inventories and inventory reports under Decision No 280/2004/EC to the European Commission, DG Climate Action; and the European Commission, DG Climate Action itself submits the inventory and inventory report of the EU to the UNFCCC Secretariat, on behalf of the European Union.

The European Environment Agency is responsible for the compilation of the EU GHG inventory and the implementation of the QA/QC Programme. The EEA assists the European Commission, DG Climate Action, in the compilation of the annual EU inventory through the work of the EEA's European Topic Centre on Air Pollution and Climate Change Mitigation (ETC/ACM), which is an international consortium working with the EEA under a framework partnership agreement. The specific activities of the EEA are outlined in its respective annual management plans, approved annually by its Management Board.

DG ESTAT assists DG CLIMA and cooperates with the EEA in quality assurance and quality control activities of the Union inventory as described in the QA/QC programme, focusing on activity data, in particular energy data. DG ESTAT compiles annual estimates of the Union CO2 emissions from fossil fuels using the IPCC Reference Approach, based on the ESTAT energy balance data. ESTAT collects energy data from EU Member States under Regulation (EC) No 1099/2008 of the European Parliament and of the Council of 22 October 2008 on energy statistics. The specific activities of DG ESTAT are outlined in its annual statistical work programme.

DG JRC assists DG CLIMA and cooperates with the EEA in quality assurance and quality control activities of the Union inventory, focusing on the sectors of land use, land-use change and forestry (LULUCF) and agriculture. JRC performs these activities in close cooperation with the Member States and the research community. The specific activities of DG JRC are outlined in its annual management plan.


Inventory System of the European Union
Climate Change Committee WG1 – Annual Inventories
• Improvement of quality of MS and EU GHG inventories
• Exchange of experiences
• Evaluation of EU Inventory System
Member States
Planning, preparing & reporting of national GHG emissions inventories and national inventory reports
15 January
28 February
15 March
Draft MS inventories
Draft EU Inventory, Results of initial checks
Final MS inventories
15 April
European Commission – DG Climate Action
Overall responsibility for the EU inventory
EU Registry
Final EU inventory and inventory report
EU Inventory Compilation
EEA and its ETC/ACM
• Preparation and circulation of draft EU inventory
• Initial QC checks of MSs submissions
• Gap filling
• Maintenance of inventory database and archives
• Preparation of final EU Inventory and Inventory report
JRC
• Preparation of Agriculture & LULUCF EU inventory (incl. Art 3.3 & 3.4)
• QA/QC checks on MSs national Agriculture and LULUCF inventory sectors
Eurostat
• IPCC Reference and Sectorial approach in Energy
Submission to UNFCCC
* If a MS plans to resubmit to UNFCCC by 27 May, they shall provide the revised inventory to the EU and the EEA by 8 May at the latest. The updated EU inventory and inventory report is then compiled and re-submitted to UNFCCC by 27 May.

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