European Environment Agency

Why did greenhouse gas emissions fall in the EU in 2009?

EEA analysis in brief

This paper briefly analyses the major factors that accounted for reduced greenhouse gas emissions in the EU-27 between 2008 and 2009. 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. It then analyses the contribution of other factors such as population, economic growth, renewables, energy and carbon intensity, and concludes with a brief overview of 2010 emissions from the EU Emissions Trading System.

Contents

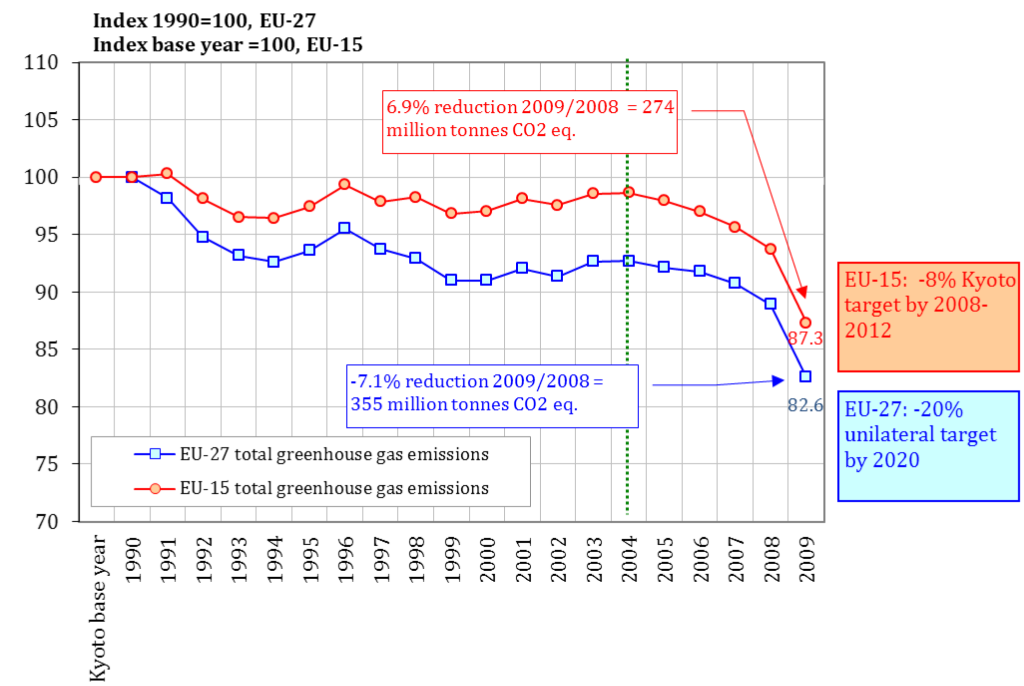
Summary overview for the EU

Greenhouse gas emissions in the EU have fallen consistently since 2004. The sharp decline in 2009 accelerated the downward trend already observed in previous years. Figure 1 shows total greenhouse gas emissions in the period 1990–2009, both in the EU-15, as a party to the Kyoto Protocol, and in the EU-27.

In 2009, EU-15 emissions were 12.7 % below the base year under the Kyoto Protocol. That constituted a net reduction of 542 million tonnes of CO_2 equivalents, of which 274 million occurred in 2009 alone.

Total greenhouse gas emissions in the EU-27 were 17.4 % below 1990 in 2009 ([1]) — a net reduction of 974 million tonnes of CO_2 eq., of which 355 million took place in 2009.

Figure 1 EU greenhouse gas emissions relative to 1990/base year



Source: EEA.

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.

Despite the relatively colder winter of 2009 emissions fell in the residential sector. In relative terms, the largest emission reductions occurred in industrial processes reflecting lower activity levels in the cement, chemical and iron and steel industries. The 2009 verified emissions from the sectors covered by the EU Emission Trading Scheme (EU-ETS) decreased by more than 11 % compared to 2008.

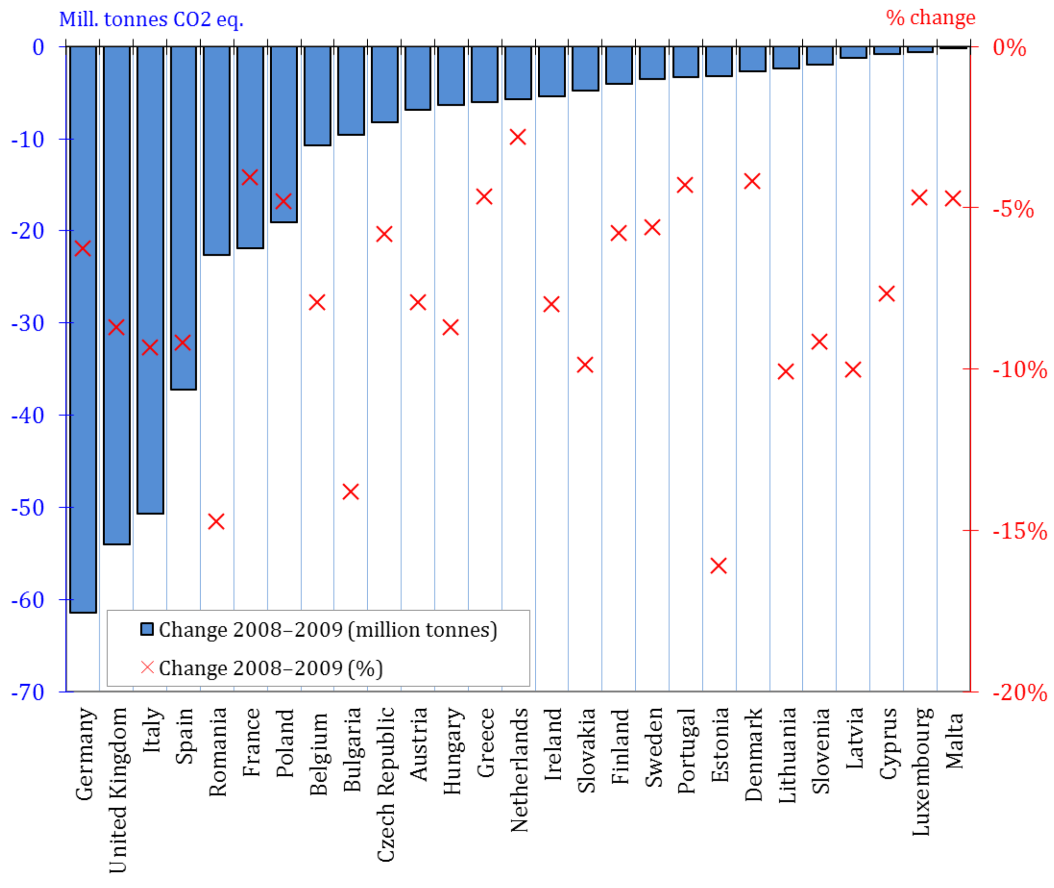
(1) There is no Kyoto target for the EU-27 and therefore no applicable base year. The 20 % EU-27 target for 2020 is not directly comparable with the current accounting Kyoto rules due to the different scopes. When international aviation is included (already part of the EU-ETS from 2012) the 17.4 % overall reduction between 1990 and 2009 would be equivalent to a 16.1 % reduction. If international shipping is included, the net emissions reduction between 1990 and 2009 would be 14.9 %.

The recession in 2009 accelerated, temporarily, the downward trend in total greenhouse gas emissions. Sustained growth in the use of renewables was the other key factor explaining the strong decrease in greenhouse gas emissions in 2009.

Overview by Member State

At the Member State level, all countries reduced greenhouse gas emissions in 2009. The blue bars in Figure 2 (scaled to the left axis) depict the absolute emission reduction by member state between 2008 and 2009. Germany, United Kingdom and Italy accounted for almost half of the net EU-27 reduction. The red crosses of Figure 2 (scaled to the right axis) show the relative emission reduction in 2009 compared to 2008 in percentage terms. Estonia, Romania and Bulgaria recorded the largest relative emission reductions — about 15 % on average —in 2009 compared to 2008.

Figure 2 Greenhouse gas emissions by EU Member State



Source: EEA.

The deep economic recession, which had its first impact at the end of 2008 and continued throughout 2009, has been one common factor behind the strong decline in greenhouse gas emissions in 2009. As will be explained later, however, the strong increase in the use of renewables in almost all EU countries was as important as the economic recession in explaining the positive 2009 result.

Overview by greenhouse gas type

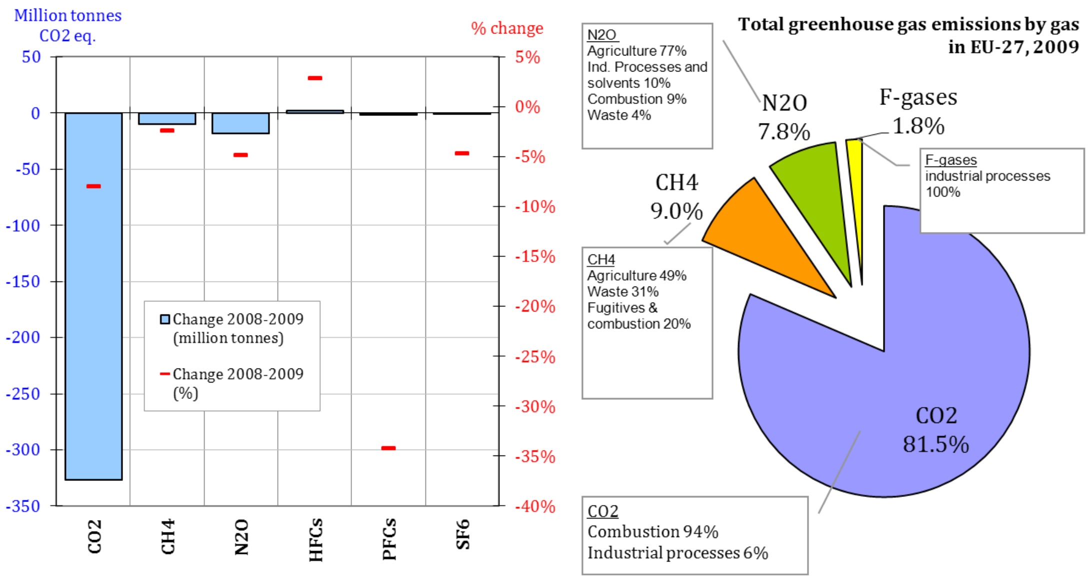
Of the Kyoto greenhouse gases, CO_2 accounted for the largest reduction in emissions in 2008 (Figure 3). This was mainly due to the contraction in economic growth, lower use of fossil fuels (particularly coal), and greater use of renewables.

In 2009, almost 82 % of all EU greenhouse gas emissions were CO_2 related. About 94 % of the CO_2 released to the atmosphere stemmed from combusting fossil fuels and the remaining 6 % from industrial processes. Emissions also declined for methane (which accounted for 9 % of total greenhouse gas emissions in 2009) and nitrous oxide (7.8 % of the total).

The fall in methane emissions in the period 1990–2009 resulted from lower fugitive emissions from coal mining and post-mining activities, and lower emissions from managed waste disposal on land. Methane from enteric fermentation in the agricultural sector also fell significantly, partly due to reduced livestock numbers but also due to changes in the agricultural management of organic manures. Nitrous oxide emissions also fell because of lower emissions from agricultural soils.

HFCs from industrial processes were the only group of greenhouse gases that increased in 2009, continuing the long trend observed since 1990. HFCs are used in producing cooling devices such as air conditioning and refrigeration. The increase is consistent with both warmer climatic conditions in Europe and higher comfort standards.

Figure 3 Greenhouse gas emissions by main gas in the EU-27



Source: EEA.

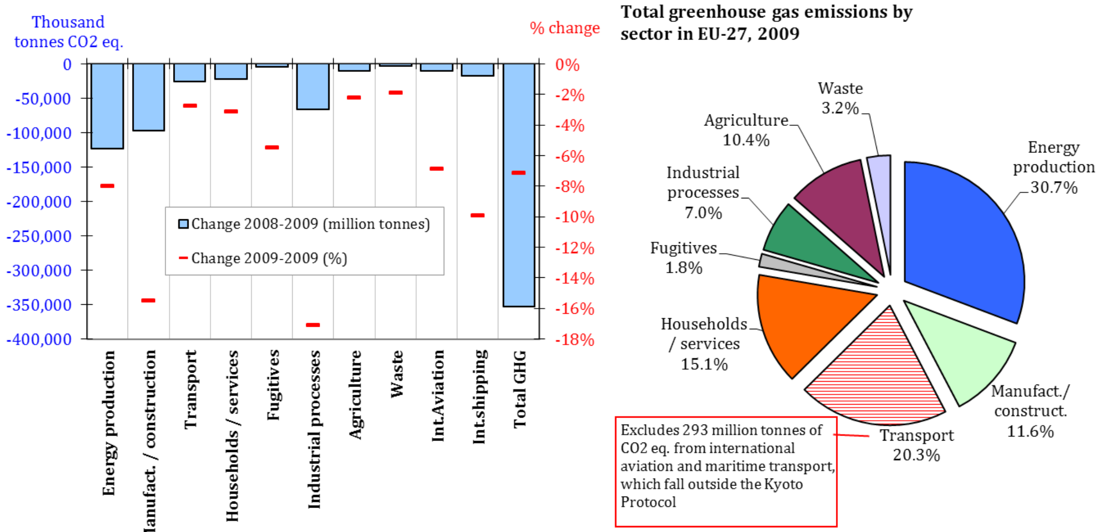
Overview by main sector

All the main sectors reduced their greenhouse gas emissions in 2009 (Figure 4). This is also true for households (and services)despite the colder winter ([2]).There was an increase in the number of 'heating degree days' in most European countries (an indicator of household demand for heating) compared to 2008. Eurostat's energy balances confirm a significant increase in derived heat in EU-27 households during 2009. However, this increase has been more than offset by lower use of fuel in non-distributed heat in the residential sector, particularly liquid fuels. As a result, household emissions fell in 2009 even though the winter was on average colder than 2008.

Viewed over a longer period, emission reductions from households (and services) are one of the key reasons for lower greenhouse gas emissions in the EU. One driver has been generally warmer winters in Europe and, correspondingly, less demand for heating. Even though 2009 was colder than 2008, it was still among the warmest years since 1850 and the number of heating degree days was still below the average for 1980–2004.

In the energy production/transformation sector, emissions declined by around 8 % in 2009. Fossil fuel energy consumption decreased for all fuels (coal, oil and gas) but particularly for coal. The reduction in the use of coal for heat and power generation in the EU-27 accounted for two thirds of the net reduction in emissions from energy industries. Despite the economic crisis, the use of biomass for heat and power increased significantly in 2009 and continued the upward trend observed since 1990 ([3]).

Figure 4 Greenhouse gas emissions by main sector in EU-27



Source: EEA.

Energy prices have increased very rapidly in the past decade, outpacing prices for other goods and household disposable income. Energy prices in the EU-27 had increased twice as rapidly as the harmonised consumer price index up to 2008. In 2009, however, there was a marked

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([2]) 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. It should be noted that greenhouse gas emissions from households and services do not include indirect emissions. That is, greenhouse gas emissions resulting from the production of heat and electricity supplied to households and services are included under public electricity and heat production. Direct combustion emissions from households are outside the EU ETS.

(3) CO_2 emissions from the combustion of biomass (including biofuels in transport) are considered neutral for IPCC/UNFCCC reporting purposes.

decline in real energy prices which has to be seen in the context of lower final energy demand and the economic recession.

Lower final energy demand and fuel prices can also be reflected in the price of carbon in the EU ETS, which had reached EUR 30 per tonne at the end of June 2008, before falling to a level of about EUR 15 per tonne by the end of 2008 and down to between EUR 10-15 per tonne by the end of 2009.

Emissions for sectors which are part of the EU ETS declined more than the so-called non-trading sectors. Most of the biggest industrial installations are part of the EU ETS and the stark contraction in gross value added in industry during 2009 appears to have led to a sharp reduction in final energy demand and emissions in the sector. Emissions fell particularly for manufacturing industries and construction, as well as for key industrial processes, such as iron and steel and cement production. The 2009 energy balances and the verified 2009 emissions from the EU ETS published last year also confirm significantly lower energy use and lower emissions in all industrial sectors.

Road transport emissions fell by almost 3 % in 2009. Gasoline emissions continued their downward trend, whereas diesel emissions fell for the second time since 1990. Diesel price inflation has outpaced the rapidly increasing gasoline prices. Along with the start of economic recession in the second half of 2008 and the whole of 2009, this could have triggered a fall in freight transport demand. To a lesser extent, increased use of biofuels has also contributed to the lower road transport emissions in 2009.

Other factors explaining the change in greenhouse gas emissions

A number of factors outside formal GHG inventory reporting can help explain the sharp reduction in greenhouse gas emissions in the EU in 2009. Two approaches to understand emission drivers are presented below:

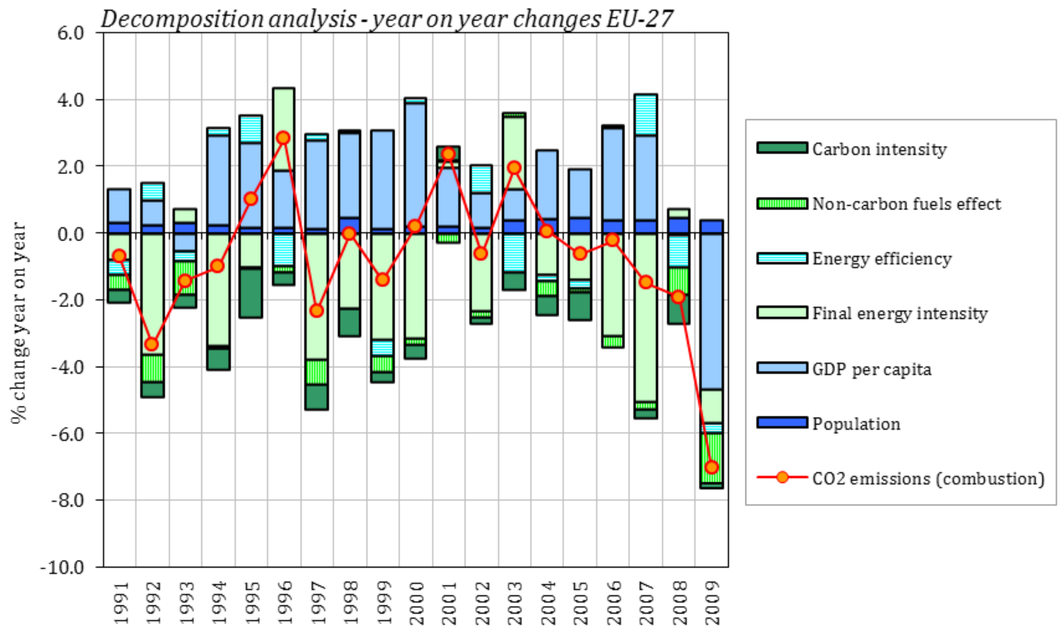
1. decomposition analysis based on an extension of the original Kaya identity;

2. regression analysis using both standard and robust methods.

1. Decomposition analysis

Energy combustion (i.e. the production and consumption of energy by all sectors, including transport) accounts for much of the reduction in EU-27 greenhouse gas emissions in 2009. Figure 5 shows a breakdown of the factors that help explain or illustrate year-on-year changes in CO_2 emissions from the combustion of fossil fuels. For definitions see Box 1.

Figure 5 Explanatory factors for CO_2 emissions from energy combustion in EU-27, 1990–2008



Note: The chart shows the estimated contributions of the various factors that have affected CO_2 emissions from energy production and consumption in the EU-27. This approach is often used to portray the primary forces driving emissions. The explanatory factors should not be seen as fundamental factors in themselves nor should they be seen as independent of each other.

Source: EEA (greenhouse gas emissions); Eurostat (population and energy balances); European Commission Ameco database (GDP).

CO_2 emissions from energy combustion fell by 7 % (267 million tonnes) in the EU-27 in 2009. A growing population and GDP generally contribute to higher CO_2 emissions. The population increased by 0.4 % (2 million people) while GDP contracted by 4.2 %, leading to a 4.6 % reduction in GDP per capita in 2009. The negative affluence effect appears quite dominant in 2009.

The energy intensity of the economy improved by 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.

Box1 Factors used in the decomposition analysis

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

The *equation*is:

(y)CO_2= (x1)POP * (x2)GDP/POP * (x3)FEC/GDP * (x4)PEC/FEC * (x5)FFC/PEC * (x6)CO2/FFC, where:

The *factors* are:

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

(x1)POP: population (population effect)

(x2)GDP/POP: GDP per capita (affluence effect)

(x3)FEC/GDP: final energy intensity of the economy (energy intensity effect)

(x4)PEC/FEC: primary energy relative to final energy (energy efficiency effect)

(x5)FFC/PEC: fossil fuel consumption in total primary energy (non-carbon fuels effect)

(x6)CO_2/FFC: carbon dioxide emissions in fossil fuel consumption (carbon intensity effect)

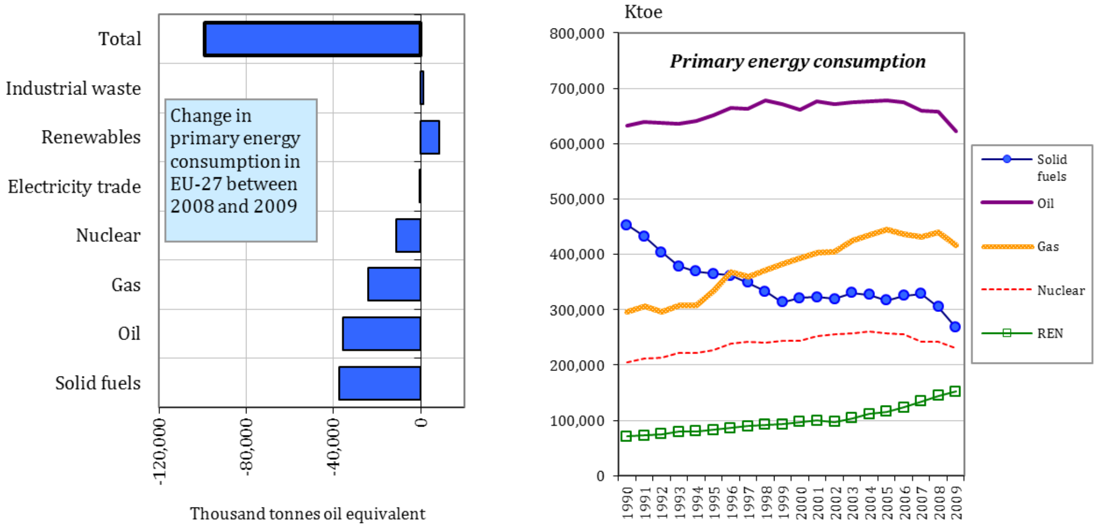
In addition, Eurostat's 2009 energy balances point to a very strong decline in primary energy consumption, outpacing the decrease in the final energy available to the end-use sectors ([4]). The main reason for this was the increase in renewables, some of which can produce electricity by means of mechanical energy without any combustion. The avoided transformation losses in thermal power stations partly explain why emissions fell even more. The transformation efficiency in conventional thermal power stations (including district heating) in the EU remained somewhat stable at about 50 % in 2009. Over the long period, the increased use of electricity from combined heat and power (i.e. cogeneration) and recovery of excess heat has also contributed to higher energy efficiencies in the EU.

Along with the strong decline of primary consumption of fossil fuels (gas, coal, oil) the energy balances also show 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 (Figure 6).Thus, the '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. Less fossil fuels, particularly coal, and more combustible renewables (i.e. biomass) explain why this sector emitted 103million tonnes of CO_2 less than in 2008 (Figure 7).

([4]) It is worth noting that not all primary energy is available to the end users of energy such as industry, transport, households, services and agriculture. This is because various losses occur within the energy system to transform primary energy (e.g. coal and lignite, natural gas and crude oil) into useful energy (i.e. heat, electricity, gasoline etc.). In addition to transformation losses, there are additional losses related to energy distribution and consumption of energy by the energy-production sector itself. In the case of non-combustible renewables such as wind, hydro (without pumping) or photovoltaics, mechanical energy is used to transform primary energy into useful energy.

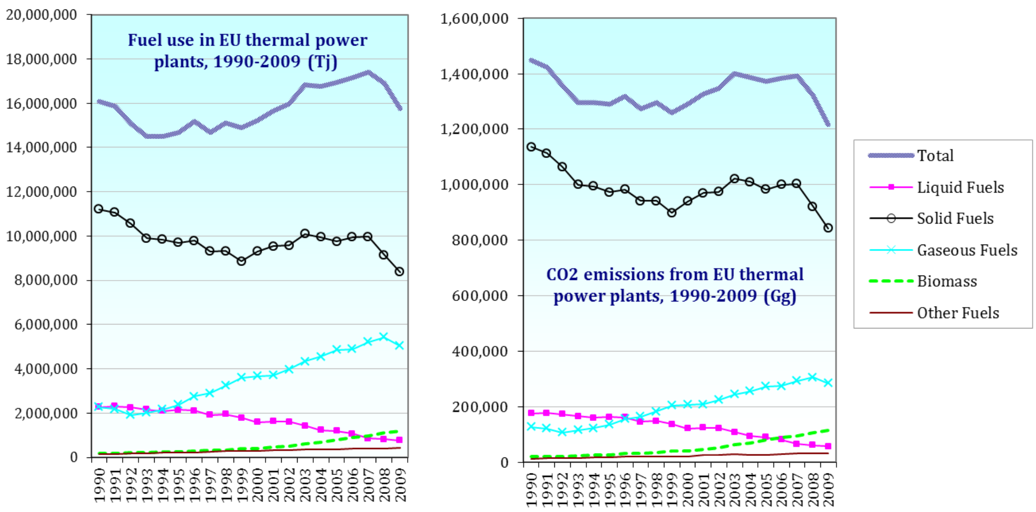
Figure 6 Primary energy consumption by main fuels in the EU-27, 1990–2009



Source: Eurostat energy balances

Figure 7 also shows that the fall in CO_2 emissions from EU-27 public electricity and heat production in 2009 was greater than the drop in fuel use in the sector. The implied emission factor for coal and lignite in the EU-27 was on average 101 tonnes of CO_2 per Terajoule in 2009. 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 75 % more CO_2 than gas to deliver the same amount of energy. Therefore, a higher reduction in coal use compared to gas has led to a relatively stronger CO_2 emission reduction per unit of energy. The steady increase in biomass use is also providing a substitute for fossil fuels.

Figure 7 Fuel use and CO_2 emissions from electricity and heat production in the EU-27



Source: EEA

2. Regression analysis

This section presents a cross-sectional statistical analysis of greenhouse gas emission drivers in 2009. The variables have been selected from the decomposition analysis of the previous section so far as possible (Box 2). The objective is to determine the statistical significance and importance of each of the predictors on the dependent variable. The variables are allowed to vary stochastically using data for 27 EU countries and their significance will be determined using standard and robust regression methods.

The OLS (ordinary least squares) coefficients in the full regression model strongly suggest collinearity between some of the independent variables. The full model (F-value) is highly significant even though almost all predictors have non-significant p-values([5]).The correlation matrix of the dependent and all independent variables shows high correlations between GHG and GDP (0.63) and between GHG and REN (0.64) (see also Figure 8). POP and the interaction term have significantly lower correlations but will be retained in the model. The last two variables, REN and EFF, are discarded because of the very low correlation coefficients.

Box 2 Variables used in the regression analysis

The variables have been derived from the previous decomposition analysis, while transforming the deterministic relationship with no error into a stochastic additive relationship using data from 27 EU member states.

The *equation* is:

(y)GHG= (x1)POP +(x2)GDP +(x3)GDP*POP + (x4)EFF+(x5)REN+(x6)CAR + μ, where:

The *variables* are:

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

(x1) POP: % change in population

(x2) GDP: % change in GDP at constant prices

(x3) GDP*POP: interaction between GDP and POP

(x4) EFF: change in percentage terms in the efficiency of transformation in public thermal power stations and district heating plants

(x5) REN: change in percentage terms in the share of renewable energy in final energy consumption taking into account distribution losses and own energy consumption

(x6) CAR: change in percentage terms in the average implied CO_2 emission factor of fossil fuel energy (excludes biomass)

μ: error term

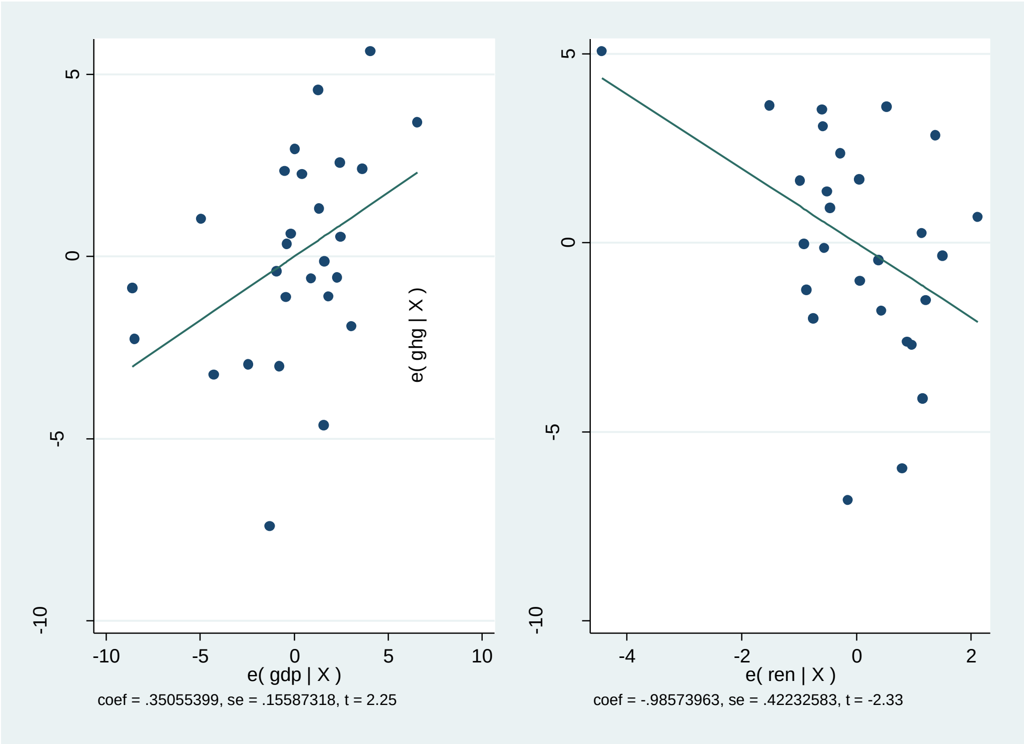
The coefficients from the reduced regression model suggest that collinearity is no longer a problem. The change in greenhouse gas emissions can therefore be written as a function of the individual and combined effects of economic growth and population as well as the higher share of renewables in final energy in 2009. The OLS regression coefficients of both the interaction term and population are not significant at the 5 % level and are dropped from the model. The

([5]) Only REN would be significant at the 5 % level (not at 1 %).Collinearity is a problem because the standard errors are inflated and one would more often than otherwise fail to reject the null hypothesis of non-significant coefficients. Before running the regression, a first explorative analysis had revealed potential multicollinearity problems for some of the independent variables. The first method used was principal components analysis, excluding factors (combination of variables) with Eigen values lower than 1. Two factors were retained, the first one with an Eigen value > 2, with both GDP and POP loading strongly. The second factor had an Eigen factor very close to 1. The second method used maximum likelihood. The hypothesis that a one-factor model was better than a saturated model was not rejected at 5 % significance level. The pattern matrix showed that both GDP and POP load heavily on this factor.

final model consists of two independent variables (REN and GDP). Based on this final model, the strong decrease in greenhouse gas emissions in 2009 can be explained by the stark reduction in economic growth and by the strong increase in renewable energy consumption (see model 1 in Table 1).

There is however some evidence that the variance of the residual errors is not constant, which may be due to potential outliers or extreme observations in some countries. This in turn could lead to biased standard errors and inference (6).

Figure 8 Added-variable plots (GHG emissions against the predictor variables)



A closer look at the influence of specific observations shows that Romania, particularly, and Bulgaria are statistical outliers because of their large residuals of more than two standard deviations from the mean of expected predicted values ('large residual effect'). Indeed GHG reductions in these two countries were among the largest in the EU given similar GDP and REN values.

In addition, Finland, Lithuania and Latvia have extreme values on at least one of the predictor variables ('high leverage effect'). Finland's share of renewables fell in contrast to what occurred in most other EU countries, whereas Latvia had the largest increase. Meanwhile, the contractions in GDP in both Lithuania and Latvia were among the largest in the EU.

Some of these countries also have a significant effect on the regression coefficients ('high influence effect'). In Latvia there is overall influence from both GDP and REN. In Lithuania and Portugal the influence is mostly triggered by GDP values, whereas in Romania it is mainly caused by a very large residual.

(6) The Breusch-Pagan / Cook-Weisberg test for heterocedasticity rejects the null hypothesis of homocesdatic errors at the 5 % significance level (but not at 1 %). White's test, however, does not reject the null hypothesis of constant errors. Cameron and Triveldi's decomposition of IM-test does not suggest the presence of heterocedastic errors. There is mixed evidence of the presence of heterocedasticity.

None of the observations are removed from the model as they just represent the country-specific changes in the dependent variable (GHG) to changes in the two explanatory variables (REN, GDP). A robust specification of the standard errors from the OLS regression can help remove the bias in the variance of the residuals from the OLS regression (model 2 of Table 1). This only affects the confidence interval around the mean estimates but does not affect the regression coefficients ([7]).

To test whether heterocedasticity substantially affects the OLS estimates we run a robust regression ([8])and compare the regression coefficients (model 3 of Table 1). The coefficients of model 3 are very similar to models 1 and 2, suggesting only a small 'gain' from using robust regression compared to OLS regression.

Table 1 Final model results

		Model 1 Least Squares Regression	**Model 2** OLS with Robust standard errors	**Model 3** Robust regression	**Model 4** Weighted Least Squares
VARIABLES		GHG	GHG	GHG	GHG
GDP		0.351*	0.351*	0.331*	0.635**
		(0.156)	(0.125)	(0.159)	(0.182)
	Beta coef.	*0.394*	*0.394*	*0.372*	*0.491*
RENEWABLES		-0.986*	-0.986**	-0.999*	-1.574**
		(0.422)	(0.306)	(0.431)	(0.477)
	Beta coef.	*-0.409*	*-0.409*	*-0.414*	*-0.463*
Constant		-3.751***	-3.751***	-3.648***	-2.217*
		(0.900)	(0.729)	(0.919)	(0.987)
Observations		27	27	27	27
R-squared		0.51	0.51	0.49	0.54
Adj. R-squared		0.47	0.47	0.45	0.50
Mean Square Error		189.59	189.59	182.09	134.70
Residual Square Error		181.02	181.02	188.87	113.87
Root MSE		2.75	2.75	2.81	2.18

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

([7]) The standard errors are estimated using Huber-White sandwich estimators and can deal with some minor problems of failure to meet the Gauss-Markov assumptions, in our case the lack of homocedastic errors potentially triggered by some extreme observations.

([8]) Robust regression basically uses iteratively reweighted least squares by assigning a weight to each observation, with lower weights given to less well-behaved observations. (Extreme observations can be excluded where Cook's D is greater than 1, which is not the case in our sample.)

A final model takes into account the relative contributions of member states in the regression coefficients, using greenhouse gas emissions as analytical weights (model 4). The regression coefficients in model 4 are larger, particularly for GDP. Compared to the other 3 models, this suggests both a greater (positive) response in greenhouse gas emissions due to economic growth, and a greater (negative) response due to renewables. The WLS coefficients indicate that when the share of renewables in final energy increases by 1 percentage point greenhouse gas emissions are expected to decrease by about 0.5 % (holding GDP constant). Also, if GDP increases by 1 % greenhouse gas emissions are expected to increase by about 0.6 % (holding renewables constant). Method 4 using weighted least squares may be preferable as it takes into account country-size effects on the dependent variable. Standard regression diagnostics have been applied iteratively to confirm the residuals meet Gauss-Markov conditions ([9]).

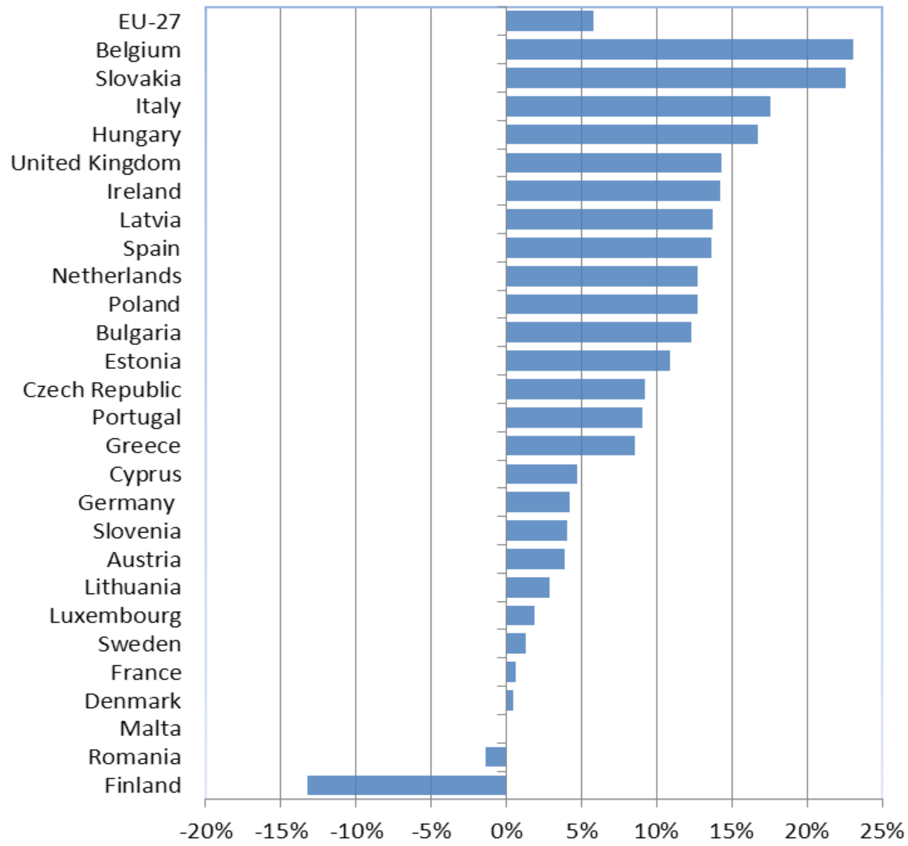
All 4 methods are in good agreement and both explanatory variables are significant at 5 % level. That is, the increase in renewable energy consumption and the economic recession are the main factors underpinning the stark reduction in greenhouse gas emissions in the EU in 2009.

In addition, the analysis suggests that both factors are equally important (similar beta coefficients) for understanding why emissions fell by 7 % and not by less[10]. Clearly, the growth in renewables, both combustible (biomass) and non-combustible (wind and solar) was a common factor in most EU countries (see Figure 9). The exceptions were Finland (partly due to a bad hydro year and lower woody biomass consumption), Romania (lower hydro production) and Malta (zero growth because of the absence of a renewable energy sector there).

([9]) The residuals are independent, homocedastic, have zero mean and are normally distributed. The residual vs. fit plot suggests the residuals have zero mean and constant variance. The Breusch-Pagan/Cook Weirberg test confirms the residuals are homocedastic. The errors are also independent. There is no misspecification of the model and there is no autocorrelation bias because of omitted variables. The kernel-density plot and the quantile and normal probability plots look normal. The Shapiro-Wilk W test, Jarque-Bera and the skewness/kurtosis tests do not reject the null hypothesis of normal residuals. Finally, the inter-quantile test suggests there are no outliers in the final regression model.

[10] Model 4 using weighted least squares suggests GDP was more important than renewables to explain the reduction in greenhouse gas emissions in 2009.

Figure 9 Growth in primary energy consumption of renewable energy, 2008–2009



Source: Eurostat energy balances

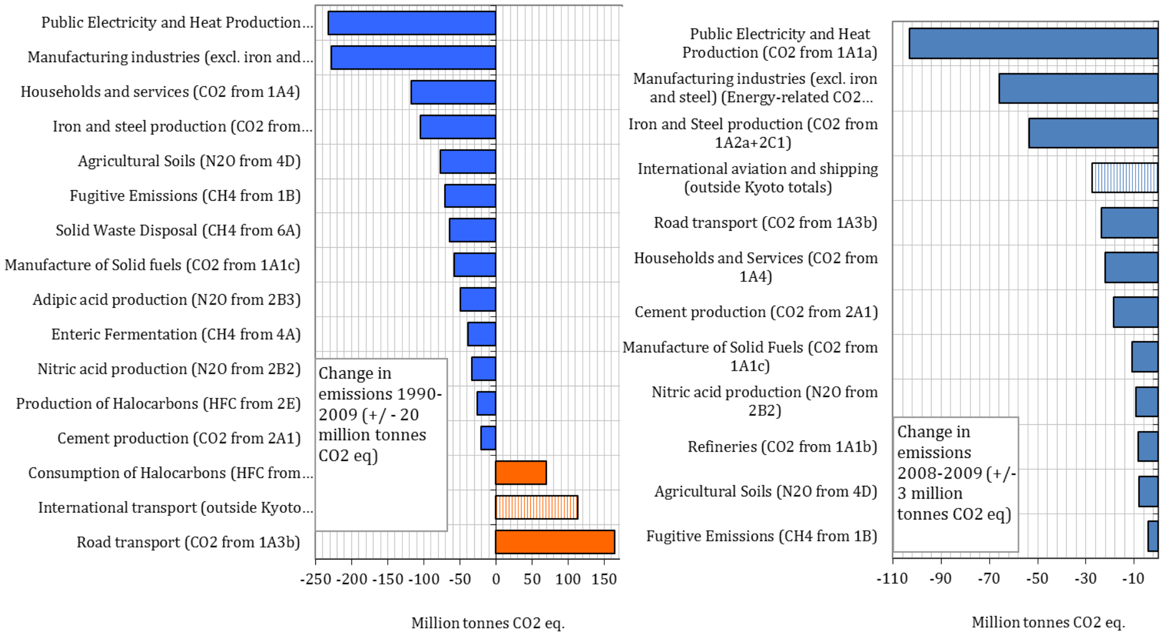
International transport emissions

Emissions from international aviation and maritime transport are not relevant for Kyoto compliance. They are reported in the greenhouse gas inventory as Memorandum items. They are shown in Figure 10because of their significant contribution to greenhouse gas emissions in the EU.

In 2009, emissions from international aviation and maritime transport fell for the second consecutive year. The decline in emissions from international shipping was stronger, reflecting the severity of the economic recession and lower freight transport. Since 1990, however, international transport emissions have grown very rapidly and have reached 6.3 % of total greenhouse gas emissions in the EU.

The final charts show the most influential key emission source categories in the EU in the periods 1990–2009 and 2008–2009.

Figure 10Overview of the EU-27 source categories showing the largest increases and decreases in the periods 1990–2009 and 2008–2009



Source: EEA

Verified EU ETS emissions for 2010

Verified data from the EU ETS for 2010 show greenhouse gas emissions increased by about 3 % compared to 2009. This increase in emissions partly reflects the economic recovery after the 2009 economic recession, with GDP up by 1.8 % in 2010.

The EEA will publish early EU-27 greenhouse gas estimates for 2010 in autumn 2011, a few months ahead of the official EU greenhouse gas inventory submitted to the UNFCCC.

For more information

Annual EU greenhouse gas inventory 1990–2009 and inventory report 2011

http://www.eea.europa.eu/publications/european-union-greenhouse-gas-inventory-2011/

EEA GHG data viewer

http://dataservice.eea.europa.eu/PivotApp/pivot.aspx?pivotid=475

EEA EU-ETS data viewer

http://dataservice.eea.europa.eu/PivotApp/pivot.aspx?pivotid=473