Analysis of drivers of historic and future ESD emission trends

ETC/ACM Technical Paper 2017/13
March 2018

Rosie Brook, Justin Goodwin, Tom Dauwe, Sabine Gores, Hannah Förster, Carmen Schmid, Henrik Neier, Giorgos Mellios

European Topic Centre on Air Pollution and Climate Change Mitigation

The European Topic Centre on Air Pollution and Climate Change Mitigation (ETC/ACM)
is a consortium of European institutes under contract of the European Environment Agency
RIVM Aether CHMI CSIC EMISIA INERIS NILU ÖKO-Institut ÖKO-Recherche PBL UAB UBA-V VITO 4Sfera

Front page picture:
Sunset. Free for commercial use, no attribution required.

Author affiliation:
Rosie Brook, Justin Goodwin: Aether, UK
Tom Dauwe: Vito, BE
Sabine Gores, Hannah Förster: Öko, DE
Carmen Schmid, Henrik Neier: UBA-V, AT
Giorgos Mellios: Emisia, GR

DISCLAIMER

ETC/ACM Technical Paper 2017/13
European Topic Centre on Air Pollution and Climate Change Mitigation
PO Box 1
3720 BA Bilthoven
The Netherlands
Phone +31 30 2748562
Fax +31 30 2744433
Email etcacm@rivm.nl
Website http://acm.eionet.europa.eu/

Contents

Abbreviations

AEAs	Annual Emission Allocations
CAP	Common Agricultural Policy
CDM	Clean Development Mechanism
GHG	Greenhouse gas
GDP	Gross domestic product
EC	European Commission
EEA	European Environment Agency
EPBD	Energy Performance of Buildings Directive
ESD	Effort Sharing Decision
ETC	European Topic Centre
ETS	Emissions Trading Scheme
EU	European Union
F-gases	Fluorinated gases
LCP	Large Combustion Plant
LNG	Liquified Natural Gas
LULUCF	Land Use, Land Use Change and Forestry
MMR	Monitoring Mechanism Regulation
Mt CO_2eq	Million tonnes carbon dioxide equivalent
MSW	Municipal solid waste
N	Nitrogen
PaMs	Policies and Measures
PCF	Perfluorocarbon
QA/QC	Quality assurance/quality control
RES	Renewable energy sources
SWD	Solid waste disposal
WAM	With additional measures
WEM	With existing measures

Executive Summary

Key messages:

- Emissions covered by the Effort Sharing Decision (ESD, Decision No 406/2009) contributed to over half of the EU-28 GHG emissions in 2015
- The EU is on track to meet the 2020 targets for ESD emission reductions
- The key drivers for ESD emission reductions are improved energy efficiency in buildings and switching to less carbon intensive fuels, including renewables. These drivers are linked to the greatest reduction in ESD emissions between 1990 and 2035 seen in the residential and commercial sector.
- Large reductions in the waste sector have already been realised due to the improvement of waste management.
- Much faster rates of GHG emission decreases are necessary to achieve an 80%, or even a 95%, decrease by 2050, even if the 2030 target is met.

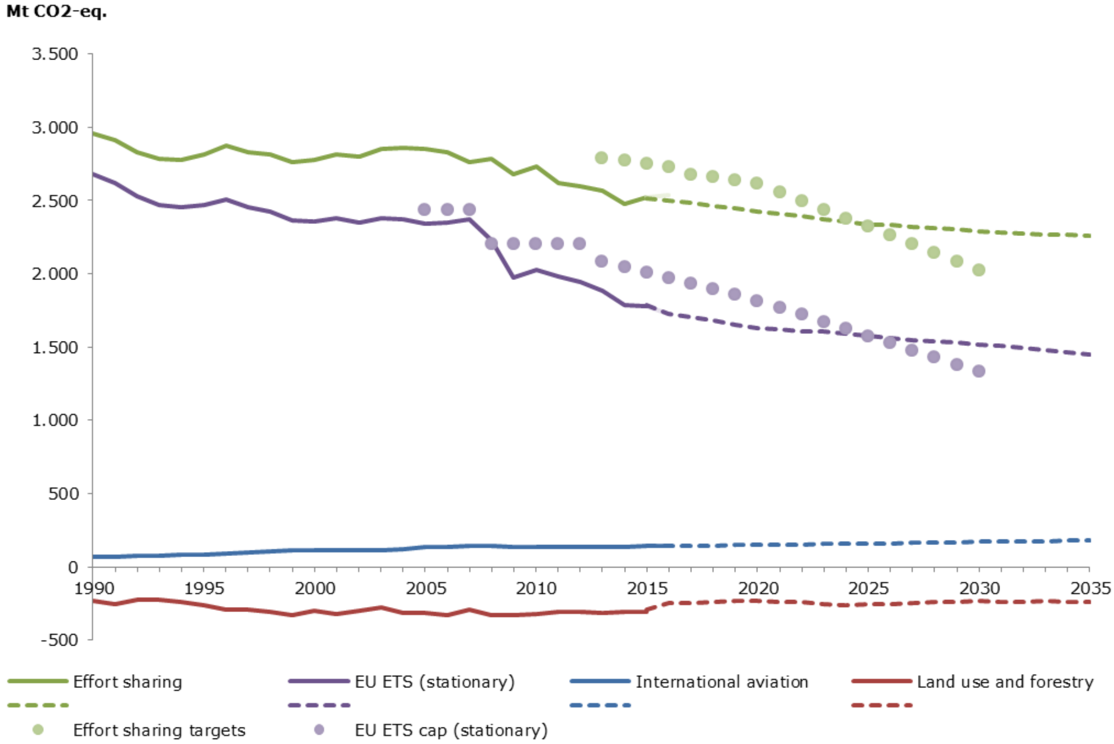
The Effort Sharing Decision (ESD, Decision No 406/2009) establishes national burden sharing targets for EU Member States. It focusses on those categories that are not covered by the Emissions Trading Scheme (ETS) and those that do not relate to Land Use Land Use Change and Forestry (LULUCF). The objective of this report is to present a trend analysis of historic and future anthropogenic GHG emissions for the most significant sectors covered by the ESD (Decision No 406/2009). This report considers the emissions from sources under the ETS (excluded from the ESD) and sources and sinks from LULUCF in order to put the ESD emissions into context. The report looks at the possible alignment of emission reductions with the implementation of Policies and Measures (PaMs) designed to reduce emissions as well as other potential climatic or economic driving forces, in particular, considering whether this will lead to the success or failure of Member States reaching their national ESD 2020 targets.

Emissions covered under the **ESD contributed to 58% of emissions** and removals from greenhouse gases (GHGs) from the EU-28 in 2015. The key categories from sectors covered under the ESD are:

- transport (1A3, excluding domestic aviation);
- residential and commercial energy (1A4 & 1A5);
- agriculture (3);
- waste (5);
- industry (1A2, 2A-E).

Figure ES1 shows the trends in emissions for ESD, ETS, LULUCF and aviation emission trends and projections (Mt CO_2eq) for 1990–2035.

Figure ES1 Trends in emissions for ESD, ETS, LULUCF and international aviation emission trends and projections (Mt CO_2eq), 1990–2035. ESD and ETS emission targets are highlighted.



Note: mobile ETS emissions (e.g. domestic aviation) are not included

Source: Trends and Projections Report (EEA, 2017a)

In 2016, total net GHG emissions ESD + ETS + LULUCF were estimated to be 27% lower than 1990 levels. The latest national projections (EEA, 2017a) indicate that EU GHG emissions will **remain on track to meet the 20% reduction in ESD and ETS emissions** (compared to 1990 levels) by 2020 target set out in the 2020 climate and energy package[1]. In 2015, GHG emissions were already 22% less than 1990 levels. Emissions have been **steadily declining** since 1990 the EU has seen a 12% emissions reduction between 2005 (the base year for the ESD) and 2015. GHG emissions covered by the ETS have also decreased significantly since 1990 and at a faster rate than sectors covered under the ESD. ETS emissions in 2015 were 24% less than in 2005 and, according to preliminary estimates ('proxy'), were 27% less in 2016. The trend in LULUCF emissions and removals remains relatively stable between 1990 and 2035, overall resulting in an annual removal of emissions.

The pace of GHG emission reductions is projected to slow after 2020. Whilst population and GDP are projected to increase at the EU-28 level. The rate of reduction (2015–2035) is projected to be half that of the change in emissions experienced for 2005–2015. At the current rate the EU's efforts will not be sufficient to achieve the EU's target of a 40% reduction by 2030 (compared with 1990 levels). Much faster rates of GHG emission decreases are necessary to achieve an 80%, or even a 95%, decrease by 2050, even if the 2030 target is met.

[1] https://ec.europa.eu/clima/policies/strategies/2020_en

Not all Member States project that their annual emissions will reduce by 2035 compared to 2005, however, the number of Member States projecting a reduction in annual emissions accounts for 87% of the EU-28 total ESD emissions. The largest emitters, Germany, France, United Kingdom and Italy, will contribute to over half of the EU-28 ESD emissions between 2005 and 2035.

The largest absolute annual emission reductions in ESD emissions between 2005 and 2030 are expected to occur in the **residential and commercial sector** (-237 Mt CO_2eq). These emission reductions can be linked to increasing energy efficiency of buildings, the switch to renewable energy sources (RES) for heating and cooling and switches to less carbon intensive fuels. The PaMs expected to have the greatest impact are those linked to reduced energy consumption. Because most emissions are for heating, climatic conditions are an important factor resulting in short-term annual fluctuations in emissions and a long-term downward trend because of increasing average temperatures across Europe. Additionally, the Renewable Energy Directive has an impact via the promotion of RES for heating and cooling.

The **transport sector** has the greatest contribution ESD emissions across the time series (1990–2035). Annual emissions from transport are expected to reduce by 83 Mt CO_2eq (9%) by 2035 compared to 2005. Road transport is expected to be the main contributor to the projected reductions. The most significant PaMs target efficiency improvements in vehicles and the introduction of low carbon fuels. In particular, the electrification of transport, and specifically for road transport, the deployment of intelligent transport systems, are expected to lead to emission reductions.

For the **agriculture** sector, the 2013 Common Agricultural Policy (CAP) reform, put even greater emphasis on climate change mitigation. Most agriculture PaMs that have an impact on GHG emissions aim to reduce the use of fertilizers, improve cropland management and improve animal waste management. However, only a slight decrease (-2%) in emissions is projected in 2030 compared to 2005 levels.

In the EU, the largest decrease in relative emissions occurred in the **waste sector** (~100 Mt CO_2eq reduction in 2015 compared to 1990). By 2030, annual waste emissions are projected to decline by a further 51% compared to 2005 levels. The main drivers for the reduction in waste emissions are improved waste demand management/reduction, landfill management/reduction, treatment technologies and enhanced recycling.

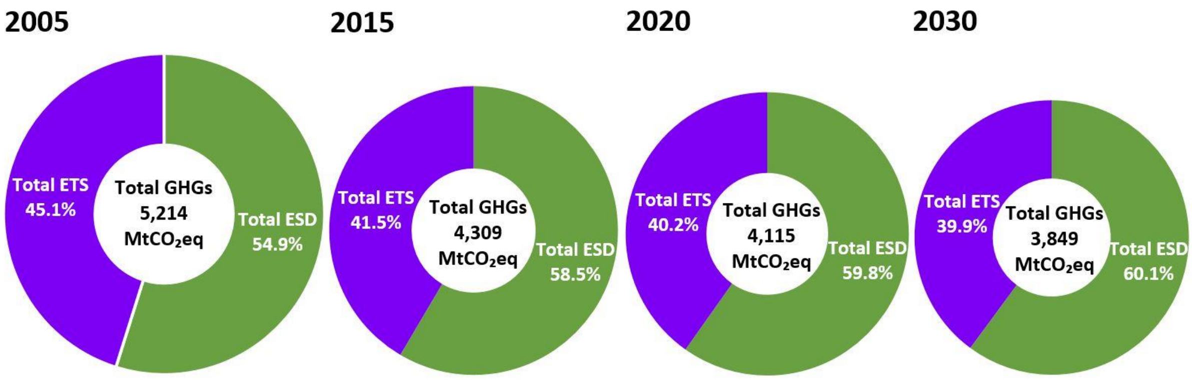
Reductions in CO_2 emissions from the **industrial sector** resulted primarily from improvements in energy efficiency and structural changes in the economy resulting predominantly from the closure of energy-intensive industries in the 1990s. Additionally, a shift in fuel type from coal to gas helped to deliver emission reductions with emissions from solid fuels more than halving between 1990 and 2015.

1 Introduction

The Effort Sharing Decision (ESD) establishes binding annual greenhouse gas (GHG) emission targets for European Union (EU) Member States for the period 2013–2020 under Decision No 406/2009 of the European Parliament and of the Council (EU, 2009a). Accounting for 58% of total EU GHG emissions in 2015 (**Figure 1.1**), emissions covered by the ESD account for the majority of sources not covered by the EU Emissions Trading System (EU ETS, hereafter referred to as ETS) (EU, 2009b). The ETS established a scheme for GHG emission allowance trading between Member States to promote reductions in an economically efficient manner (2009b). This has effectively placed a 'cap and trade' principle on installations covered by this system in order to restrict the total amount of GHG emitted. The main sectors included under the ETS are energy industries, manufacturing and construction and industrial processes. The ESD therefore covers a diverse range of sectors and activities; road transport, energy consumption in buildings, agriculture and waste management (European Environment Agency (EEA) 2017a). They do not include international maritime emissions, emissions from aviation, NF_3 emissions or emissions and removals from LULUCF.

Changes in GHG emissions under the ESD result from a number of different drivers, including population, economic factors, political priorities, climatic conditions and policies directly targeting emissions reduction. Analysis of GHG emissions trends from the most significant sectors under the ESD is important to determine the future success of ESD reductions in accordance with EU emissions objectives. The objective of this report is to present a trend analysis of historic and future anthropogenic GHG emissions comprised from the most significant sectors covered by the ESD.

Figure 1.1 Percentage contributions to EU GHG emissions and removals in 2005, 2015, 2020 and 2030.



Note: 2015 data is based on the 2017 projections data rather than the 2017 inventory data. ETS numbers refer to stationary installations only. The circles are sized based on total GHG emissions (excluding LULUCF) which are shown in the centre of the circles.

Source: Annual European Union GHG inventory 1990–2015 and inventory report 2017; Member States submissions under Art 14 of the EU MMR (2017)

1.1 Targets

Emissions covered under the ETS, and those under the ESD, collectively contribute to the 20% reduction in total GHG emissions by 2020 compared to the 1990 objective outlined in the EU Climate and Energy package (European Commission (EC), 2017a). Reduction objectives for ESD emissions alone are 9% between 2005 and 2020 at EU level. The 2020 target is an aggregation of individual Member State targets, which range from 20% reductions to 20% increases. These national targets are binding emission budgets, reported as Annual Emission Allocations (AEAs), based on the relative wealth of the Member States (measured as GDP per capita). This accounts for projected increased emissions resulting from increased economic growth, however, relative to 'business as usual' scenarios these still represent a limit on emissions, meaning that a reduction effort is required of all Member States. Additionally, the ESD sets obligations for annual progress monitoring for the 2013–2020 period, to allow for corrective action and to ensure the EU's 2020 targets are met. This monitoring is established under the Monitoring Mechanism Regulation (MMR) No 525/2013 of the European Parliament and of the Council (EU, 2013).

Beyond 2020, ESD emissions are incorporated under the 30% reduction that non-ETS sectors should achieve by 2030 as part of the EU target for 40% domestic reduction in GHG emissions compared to 1990. On 20 July 2016, the European Commission presented a legislative proposal to integrate GHG emissions and removals from LULUCF into the 2030 climate and energy framework. This will include accounting of the amount of biomass use for energy production.

1.2 Flexibilities

The ESD includes a flexibility mechanism to support Member States to achieve their emissions targets, expressed as quantities of AEAs. This mechanism allows for the transfer of annual emissions allocations between years, between Member States and the use of external credits through the Clean Development Mechanism (CDM). Within the Member State itself, flexibilities allow for any overachievement of up to 5% allocation in a preceding year to be carried over to subsequent years until 2020 (Article 3.2 of decision). In addition, AEAs may be transferred or sold between Member States to account for a surplus or deficit of credits (Article 3.4 and 3.5). Finally, international credit mechanisms can be used under certain conditions (Article 5) to earn credits which count towards reduction targets. For example, both the CDM and the Joint Implementation scheme involve the investment in and implementation of emission-reduction or emission removal projects.

1.3 Methodology

The focus for analysis is 2005–2030 which are the years covered by ESD, plus 2035 to have a view on the trajectory. This report uses EU level data GHG emission trends for the years 1990–2035 based on the national GHG inventories and projections reported in 2017 under the MMR No 525/2013. Member States are required to submit GHG emission projections on a biennial basis under Article 14 MMR. Member States must split reported total GHG emissions into ESD and ETS emissions per sector. When new information becomes available, or projection methodologies change, projected ESD emissions may differ between the current and previous submissions. This analysis focuses on the most recent projected data, submitted in 2017. However, analysis to compare the current and previous submission has been completed and is presented in **Annex I**. For the 2017 projection data, some projected emissions were gap-filled at the Member State level by the European Topic Centre on Air Pollution and Climate Change Mitigation (ETC/ACM) (see EEA, 2017d).

Only the key categories within the most significant ESD sectors will be considered, this is discussed in **Section 2.1**.

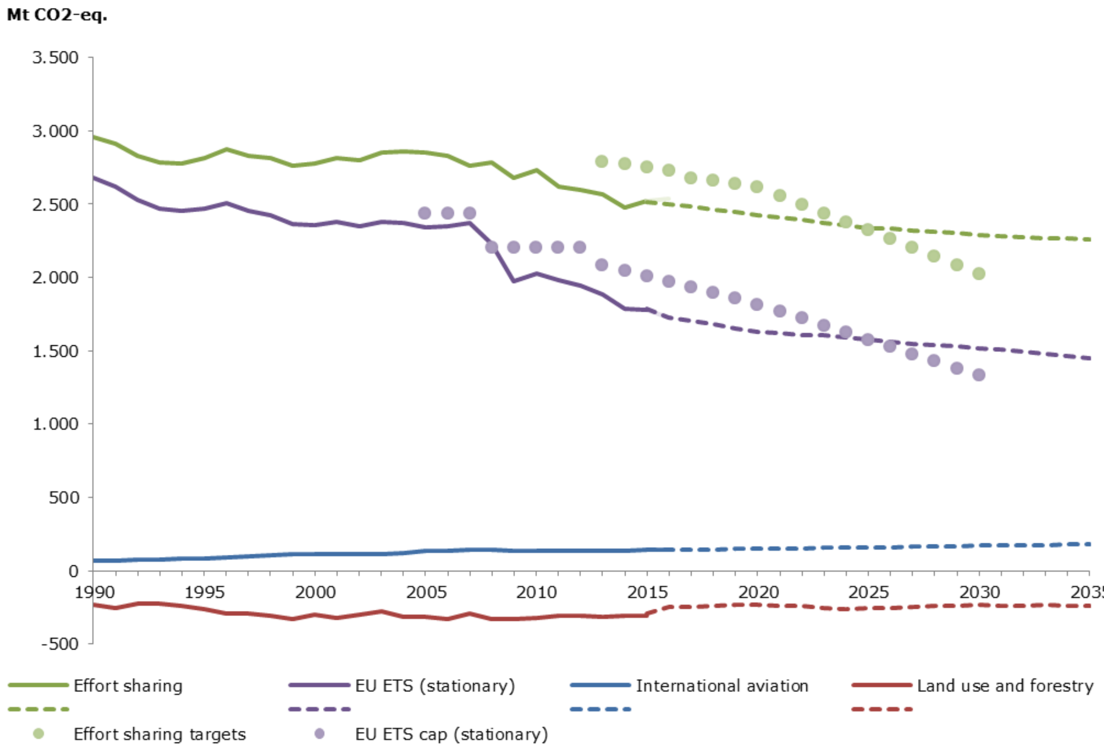
In addition to reporting GHG Projections, Member States are also required to submit information on their PaMs under the MMR (No 525/2013). Member States are required to report their climate PaMs to the EC every two years. This information is quality checked and aggregated by the EEA into a database. Although the reporting template is fixed, there are differences among Member States in how information is reported, and at what level of detail or disaggregation. To ensure more consistent results in this section, information from the PaM database was aggregated so it corresponds better with the transport, residential & commercial, agriculture, waste and industry sectors. Additionally, PaMs were weighted to account for differences in potential impact. The methodology for weighting PaMs is described in more detail in **Annex II**. The result of the weighting is that for each sector, the sum of weighted PaMs is 100. This weighting is based on a qualitative assessment, so results need to be interpreted carefully. An overview of the PaMs considered in this report is provided in **Section 2.2**.

2 Overall Trends and ESD Share

2.1 Overview of GHG emission trends

Emissions from sectors covered by the ESD have been decreasing since 1990 (**Figure 1.2**). Total historical ESD emissions for the EU-28 show a reduction of 12% between 2005 and 2015, which, in absolute numbers is a decrease of 330 Mt CO_2eq. The EU's Climate and Energy package dictates that the GHGs attributed to the ESD contribute, in addition to GHG emissions accounted for under the ETS, to its GHG emissions target of 20% decrease compared with 1990 levels by 2020. In 2016, total GHG emissions (excluding LULUCF and international aviation) were already > 30% less than 1990 levels and the latest national projections indicate that EU GHG emissions will remain well below the 2020 target (**Figure 2.1**). Based on the GHG projections reported by Member States in 2017, ESD emissions are projected to decrease by 10% between 2015 and 2035 in the 'with existing measures' (WEM) scenario. Therefore, the rate of emission reductions is projected to half between 2015 and 2035, as the same reduction in emissions achieved between 2005 and 2015 is projected to take another 20 years to be realised again. Emission reductions at this projected rate will be insufficient to meet the 30% reduction objective by 2030 (compared to 2005 levels) for non-ETS sectors. Member States have projected that with both WEM and 'with additional measures' (WAM) a 20% and 22% reduction on 2005 levels will be achieved, respectively (EEA, 2017a).

Figure 2.1 ESD, ETS, LULUCF and aviation emission trends and projections (Mt CO_2eq), 1990–2035. ESD and ETS emission targets are highlighted.



Source: Trends and Projections Report (EEA, 2017a)

GHG emissions covered by the ETS have decreased significantly since 1990 (**Figure 1.2**) and at a faster rate than sectors covered under the ESD. Total historical ETS emissions have been reduced by 570 Mt CO_2eq between the years 2005 and 2015, a reduction of 24% compared to ETS emissions in 2005. This decrease was largely driven by savings in emissions related to power generation and the shift in fuels used to produce heat and electricity away from coal towards renewables. In the WEM scenario for EU-28, ETS emissions are projected to further decrease by 19% between 2015 and 2035. While the reduction rates are considerably higher than those for ESD emissions, the reduction rate is also projected to half. The trend in LULUCF emissions and removals remains relatively stable between 1990 and 2035, overall resulting in an annual removal of emissions.

Factors influencing trends:

There are various reasons for these diverging trends in ETS and ESD emissions. Trends in ESD emissions are discussed in detail in the sectoral chapters below. However, general changes to the main drivers of different trend in ETS and ESD sector include:

- **Price sensitivity: EU ETS**: Operators of installations covered under the EU ETS are very sensitive to price of energy and to their allocations of GHG emissions and the price set for these emission units. Operators have strong incentives to ensure that their operations remain economically viable and will invest in order to achieve this. They are able to plan and to react relatively quickly to ensure targets and budgets are met. For the **ESD**, influencing emission reductions is more complex. Price and cost penalties to encourage reduced consumption are more difficult to apply. Conflicts exist in increasing the costs of energy because governments also want to ensure people have access to essential transport, food and heating/cooling.
- **Behavioural and lifestyle trends: ESD sector** emissions are also dependant on **behavioural and lifestyle trends** (e.g. driving rather than using public transport and the extensive use of energy for comfort and pleasure activities and electronics in the home). These are often observed not to always follow economic drivers as closely. This is especially the case where energy costs are not a large proportion of an individual’s living costs.
- **Energy switching and energy efficiency: Fuel switching and increased use of renewables** is an outcome of some influencing factors on availability and price of fuels. The effects of fuel switch, improved **energy efficiencies** as well as economic recessions are reducing emissions at a higher level in energy and industry installations, covered under the EU ETS. Fuel switching from solid and liquid fuels to gas, biofuels and renewables (which has had an impact on reduced emissions) has been quicker in the **ETS sector**. These large ETS consumers are more likely to be able to afford the investment needed to respond to price differences and potential risks to security of supply. In addition, the opening of the natural gas market has offered substantial opportunities for the energy generation sector which has also benefited emission reductions. In comparison, **ESD sectors** have been traditionally less able to switch. They rely on slower and costlier technological, and infrastructural changes often outside of individuals control. Switching requires collective and rather substantial investment (e.g. development of gas networks, electric vehicles, cheap reliable solar technology or biofuel supply). The use of renewables in the residential and commercial heating and cooling and transport sectors, which are mainly covered under the ESD, increased at a slower rate compared to the electricity sector: 11–19% for heating and cooling purposes and 2–7% in the transport sector (Eurostat Shares 2017). There is an increasing trend towards electrification in the **ESD sectors** in the home for heating and cooling and in transport. This is driven by a number of factors including the drive for cleaner air in cities. This will shift the burden of “generation” further into the **ETS domain** unless the ESD sectors generate their own electricity using renewables such as wind and solar or small district heating plant using fossil fuels or biomass that are not big enough to qualify for EU ETS. Therefore, a straight switch to using grid electricity will reduce the apparent emissions from ESD sectors and put more demand on the EU ETS sectors to produce clean electricity.

- **Climatic conditions** influence some sectors more than others. Where energy is used for heating and cooling there is a strong correlation between energy production (and associated emissions) and temperature. This will have an impact in the residential sector (ESD) and to some extent in the electricity generation (ETS) sector.

Decomposition analysis was beyond the scope of this report. Previous work, such as the retrospective trend analysis of GHG emissions in Europe, 1990–2008 (EEA, 2011) and the analysis of key trends and drivers in GHG emissions in the EU 1990–2015 (EEA, 2017) has been considered and summarised in this report. **Figure 2.2** presents results from the analysis and summarises the key drivers of the 24% overall reduction in GHG emissions across the EU over the years 1990–2015.

The period 1990–2015, has seen an increase in GDP of around 50%. Over this same time period, emissions decreased by 24% (EEA, 2017c). Some "decoupling" has been achieved through an increased share in renewable energy supply, increased use of lower carbon content fossil fuels (e.g. natural gas instead of coal) and improvements in energy efficiency. This has allowed GDP growth to occur while decreasing emissions. As energy demand remains intrinsically connected to economic growth (measured by GDP), complete decoupling is unfeasible under a fossil fuel economy. It is also difficult to determine how much reductions in emissions have resulted due to the EU's exportation of heavy manufacturing and high emissions intensity production in exchange for finance and service industries which have seen growth.

Growth in GDP, alongside population growth presents a challenge to emission reductions (**Figure 1.3**). Sustained economic development in southern European countries resulted in periods of increased emissions due to rising incomes, higher living standards and, consequently, a higher energy demand. Conversely, during periods of economic recession emissions decrease with GDP as indicated with the financial crisis in Europe in 2008–2010. The collapse of the Soviet Union led to widespread economic restructuring and economic downturn and consequent reduction in GHG levels across the energy, industry and agriculture sectors as heavily polluting industries were shut down (EEA 2011).

The negative impact of GDP growth on emissions reductions seems to be decreasing over time as renewable and energy efficient systems are implemented. It is projected that decoupling will continue (assuming favourable decarbonisation scenarios) until it reaches a point where GHG emissions are independent from economic growth and energy demand between 2030 and 2040 (EEA, 2017c). Despite its average effect, emissions still decreased with increasing GDP over all periods.

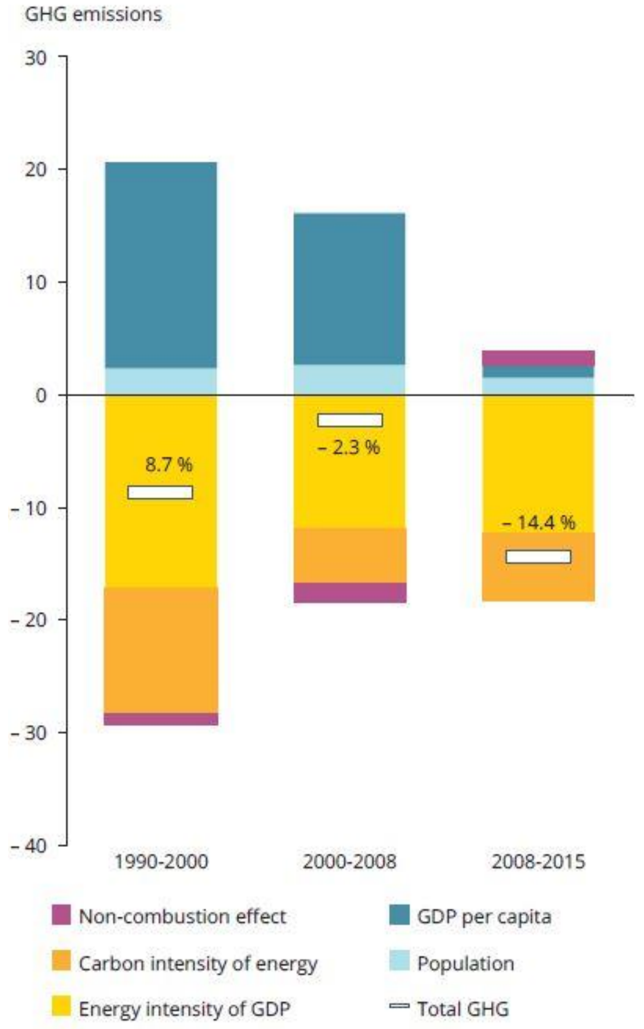
The decomposition analysis identified three factors driving reduced emissions; energy intensity of GDP, carbon intensity of GDP and the non-combustion effect. According to the EEA's Analysis of key trends and drivers in GHG emissions in the EU between 1990 and 2015', 'The reduction in GHG emissions over the 25 year period was due to a variety of factors, including the growing share in the use of renewables, the use of less carbon intensive fuels and improvements in energy efficiency, as well as to structural changes in the economy and the economic recession. Demand for energy to heat households has also been lower, as Europe on average has experienced milder winters since 1990, which has also helped reduce emissions.

Energy intensity of GDP → It is observable over the entire period that the energy intensity of GDP is a significant driver of decreasing emissions. Energy intensity of GDP refers to the amount of energy needed per unit of GDP. This 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 (cleaner and less energy intensive) services sector compared to the more energy intensive industrial sector.

Carbon intensity of GDP → The effect of this driver at reducing emissions is reflective of a move towards reduced dependence on carbon intensive fuels. This was most significant in the early period 1990–2000.

Non-combustion effect → These are from non-combustion sectors e.g. agriculture, industry and waste. In the final period 2008–2015 non-combustion effects actually worked in the opposite direction and offset emission decreases.

Figure 2.2 Decomposition of the cumulative changes in total GHG emissions in the EU-28 across three different periods; the 1990s, 2000s prior to the recession and post 2008.



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

Source: EEA, 2017c

It is also important to note the effect of policy on the reduction of emissions and their effect on the drivers. Although EU level policy implementation did not begin until 2000, the implementation of other national strategies in the 1990s began the shaping of GHG emission trends by policy. These early policies largely were not primarily designed to reduce GHG emissions. For example, the Large Combustion Plant (LCP) Directive (88/609/EEC) was initially targeted at reducing acidifying substances, but through providing incentive to shift fuel sources, indirectly reduced GHG emissions. The 1991 Nitrates Directive (91/676/EEC), had a similar effect at indirectly reducing nitrous oxide (N_2O) emissions.

Beyond 2000, the introduction of the first European Climate Change Programme saw emissions trends more directly targeted by climate policies. The main instrument at this level is the Kyoto Protocol and the Europe 2020 strategy. These are difficult to quantify and separate from the effect of national level policy, however it is recognised that increases in energy demand over this period largely outweighs savings made from EU policy in energy efficiency or renewable energy (i.e. the RES-E Directive 2001/77/EC).

ESD emission trends by sector

Table 2.1 shows total GHG emission reductions between 2015 and 2035 split into emission reduction in ETS and ESD, based on GHG projections for the EU-28[2].

[2] https://www.eea.europa.eu/data-and-maps/data/greenhouse-gas-emission-projections-for-3

Table 2.1 Total GHG, ETS and ESD emissions and reductions between 2015 and 2035 in the WEM scenario

	Total GHGs				**ETS emissions**				**ESD emissions**			
	2015	2035	Reduction 2015–2035		2015	2035	Reduction 2015–2035		2015	2035	Reduction 2015–2035	
	Mt CO_2eq			% of 2015	Mt CO_2eq			% of 2015	Mt CO_2eq			% of 2015
Total	4315	3730	-585	-14%	1786	1450	-336	-19%	2515	2262	-253	-10%
"Industry"	2187	1780	-407	-19%	1778	1443	-335	-19%	409	337	-72	-18%
Energy industries – 1A1, 1B, 1C	1343	988	-355	-26%	1209	856	-353	-29%	134	132	-2	-2%
Manufacturing and construction - 1A2	469	456	-13	-3%	346	345	-1	0%	123	111	-12	-10%
Industrial Processes - 2	375	336	-39	-10%	224	242	18	8%	152	94	-58	-38%
Transport - 1A3	902	889	-13	-1%	4	3	0	-7%	883	867	-17	-2%
Res. and com. sector - 1A4, 1A5	647	540	-107	-16%	4	3	0	-7%	644	537	-106	-17%
Agriculture - 3	437	430	-8	-2%	0	0	0		437	430	-8	-2%
Waste - 5	142	91	-50	-35%	0	0	0	0%	141	91	-50	-35%

Table 2.2 Total GHG, ETS and ESD emissions and reductions between 2015 and 2035 in the WAM scenario

	Total GHGs					**ETS emissions**					**ESD emissions**			
	2015	2035	Reduction 2015–2035			2015	2035	Reduction 2015–2035			2015	2035	Reduction 2015–2035	
	Mt CO_2eq			% of 2015		Mt CO_2eq			% of 2015		Mt CO_2eq			% of 2015
Total	4314	3570	-744	-17%		1788	1360	-427	-24%		2511	2191	-320	-13%
"Industry"	2185	1679	-506	-23%		1780	1354	-427	-24%		405	326	-80	-20%
Energy industries – 1A1, 1B, 1C	1342	900	-443	-33%		1211	775	-436	-36%		131	125	-6	-5%
Manufacturing and construction - 1A2	468	445	-23	-5%		346	338	-8	-2%		122	107	-15	-12%
Industrial Processes - 2	375	334	-41	-11%		224	241	17	8%		152	93	-59	-39%
Transport - 1A3	902	849	-53	-6%		4	3	0	-6%		883	827	-56	-6%
Res. and com. sector - 1A4, 1A5	647	530	-117	-18%		4	3	0	-9%		644	527	-117	-18%
Agriculture - 3	437	424	-13	-3%		0	0	0			437	424	-13	-3%
Waste - 5	142	88	-54	-38%		0	0	0			141	87	-54	-38%

For the WEM scenario, at the total level, ETS emissions are decreasing at a rate which is approximately twice as high as for emissions covered under the ESD. In contrast, for the sector “industry”, the rate of ETS and ESD reductions is comparable (19 and 18%, respectively). For the WAM scenario, additional reductions in ETS emissions are again higher than those of ESD emissions (see **Table 2.2**).

The most important sources from sectors covered under the ESD are; transport (1A3, excluding domestic aviation), residential and commercial energy (1A4 & 1A5), industry (1A2, 2A-E), agriculture (3) and waste (5). The relative contribution of each sector to total historical ESD emissions and projected trends until 2035 are shown in **Figure 2.3**. In addition, the change in ESD emissions between 2005 and 2015, and the projected changes between 2015 and 2030 are present in **Figure 2.4**. Compared to 2005 levels, the annual emissions from all sectors are projected to decrease by 2030. ESD emissions from energy industries is the only sector in which annual emissions have increased in 2015 compared to 2005 levels. The trends in the most important sources from sectors covered under the ESD are discussed below, together with the results from the EEA (2011 & 2017) decomposition analysis (blue boxes).

- **Transport:** The transport sector has been the largest contributor to ESD sectors since 1997 when it overtook the residential and commercial sector as the largest emitter. In 2015, it accounted for 35%, or 833 Mt CO_2eq, of emissions covered under the ESD. Between 2005 and 2030, annual emissions are projected to decrease by 83 Mt CO_2eq.

The **transport sector** experienced the largest increase in EU-27 emissions between 1990 and 2008 with a recorded 24% increase (excluding international aviation and navigation). This is attributable to increased mobility of persons and products within the context of globalised trade. In particular, sustained increases in demand for passenger and freight road transport, which accounted for 94% of transport emissions, resulted from economic growth and rising income levels. However, it is important to note that energy efficiency improvements, the uptake of diesel and decline of gasoline use, and the increased use of less carbon intensive fuels and biofuels, have restricted emission increases. Growth in transport emissions were only reduced in 2008 due to increased oil prices during the economic recession.

- **Residential and Commercial:** This sector has the least consistent trend, with a gradual decline marked by fluctuations (often due to temperature fluctuations; AEA, 2012) prior to 2015. Current projections show significant reductions in the ESD emission share of this sector, with the greatest annual reductions between 2005 and 2035 (237 Mt CO_2eq). This suggests that measures in the residential and commercial sector will be important for progress towards targets.

Emissions in the **residential sector** decreased by 126 Mt CO_2 eq between 1990–2015 (EEA, 2017c). This was driven largely by improvements in energy efficiency from developments in building insulation standards which decreased the demand for space heating. Fluctuations in emissions from the residential sector are due to weather conditions and resultant heating demand and an overall warming of autumn/winters in Europe has contributed to the lower emissions.

- **Agriculture:** Emissions from the agriculture sector remain relatively stable between 2005 and 2035. This sector is the third highest contributor to ESD emissions but has the lowest expected change in annual emissions with projected 2030 emissions just 2% below 2005 levels. GHG emissions from this sector are dominated by livestock numbers and fertiliser consumption.

Emissions from **agriculture** decreased between 1990 and 2009 by 20%. This is mainly attributable to macroeconomic factors which intensified practices and reduced emissions, however the CAP and the Nitrates Directive had a significant impact on the reduction of methane and N_2O emissions.

- **Waste:** Emissions from waste, although stable prior to 2005, followed a trend of substantial decrease after 2005. Projections suggest this decline will continue, albeit at a slower rate than the one observed over the past 10 years. Emission reductions in this sector have been strongly influenced by the effect of the Landfill Directive. The waste sector is projected to see the greatest percentage reduction in annual emissions in 2030 compared to 2005, with EU-28 emissions reducing from 203 Mt CO_2eq in 2005 to 99 Mt CO_2eq in 2030.

EU-27 GHG emissions from **waste** decreased by 30% between 1990–2008, the largest decrease in relative terms among the main GHG-emitters. The Landfill Directive (1999/31/EC) has exerted an important influence on this reduction, as the recovery of methane from landfills mandated by the directive was the most important factor in reducing emissions from waste.

- **Industry**: Non ETS industrial emissions accounted for 6% of ESD total in 2015. Continued reductions in emissions from this sector can be observed across the whole period, with the exception of increases in 2010 following a sudden reduction in 2009.

Decreases in CO_2 emissions from the **industrial sector** resulted primarily from improvements in energy efficiency and structural changes in the economy resulting predominantly from the closure of energy-intensive industries in the 1990s. Additionally a shift in fuel type from coal to gas helped to deliver emission reductions with emissions from solid fuels more than halving over 1990–2015.

As illustrated in **Table 1.1**, for the three sub-sectors within industry, very different developments can be observed:

- For the **energy industries** sector, the reduction in ETS emissions (-29% compared to ETS emissions in 2015) is much higher than in ESD emissions (-2% compared to ESD emissions in 2015). With ETS splits above 90%, the development in total GHG emissions is strongly dominated by the trend in ETS emissions (-26% compared to total emissions in 2015).
- For the **manufacturing and construction** sector, ETS emissions are about constant between 2015 and 2035, whereas ESD emissions are projected to decrease by 10%. Total GHG emissions show a decrease of 3%. Up to 2035, the ETS split slightly increases, due to higher reductions in ESD sectors.
- For the **industrial processes** sector, an increase of ETS emissions of 8% is projected, whereas ESD emissions are projected to decrease by 38%. In total, this results in a decrease of 10% between the years 2015 and 2035, driven by decreases in ESD emissions.

It is clear from **Table 1.2** that there are no strong additional measures targeting ETS emissions in Industrial processes, whereas emission reductions show a considerable additional reduction in ETS emissions of Energy industries due to additional measures.

Figure 2.3 ESD GHG emissions trend (Mt CO_2eq) by key category sectors between 2005 and 2035

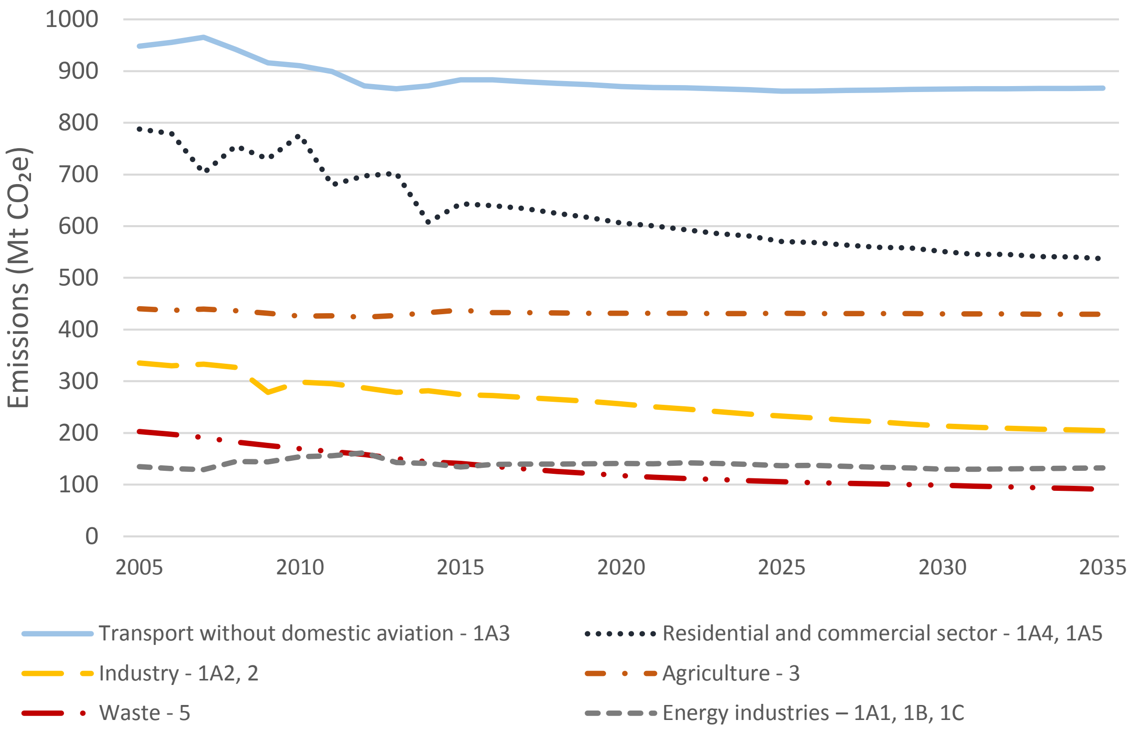
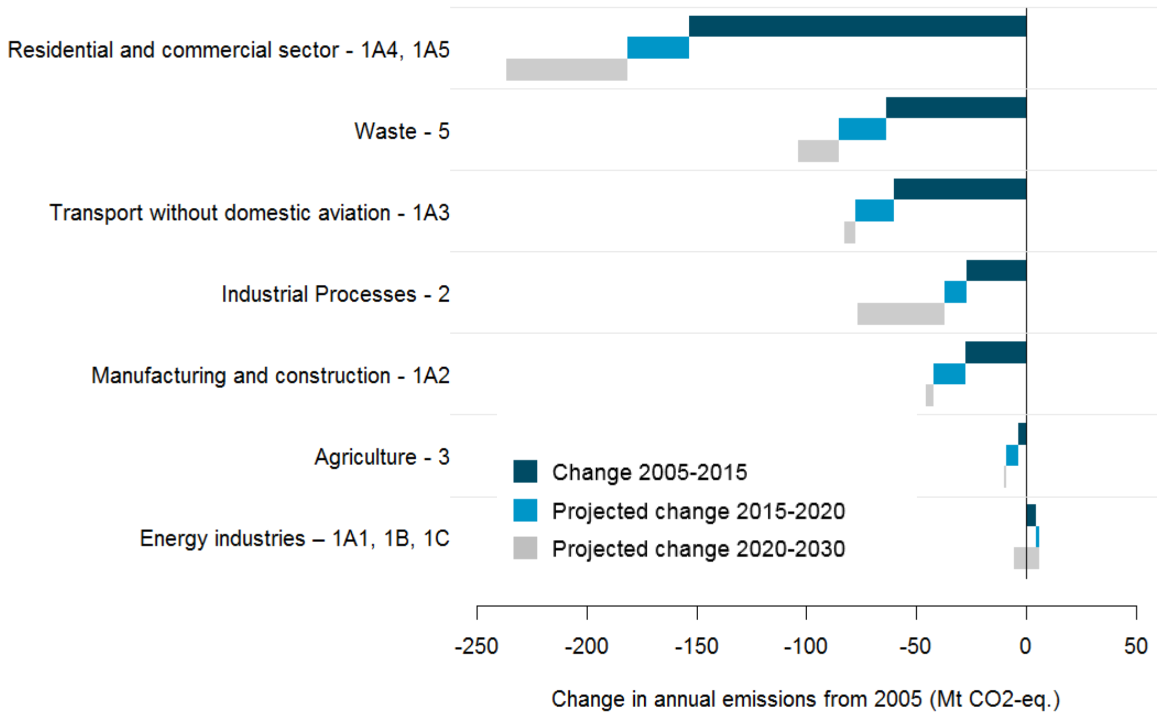


Figure 2.4 Change in ESD GHG emission (Mt CO_2eq) by key category sectors between 2005–2015, and projected change between 2015–2020 and 2020–2030



Member State contribution to ESD emissions

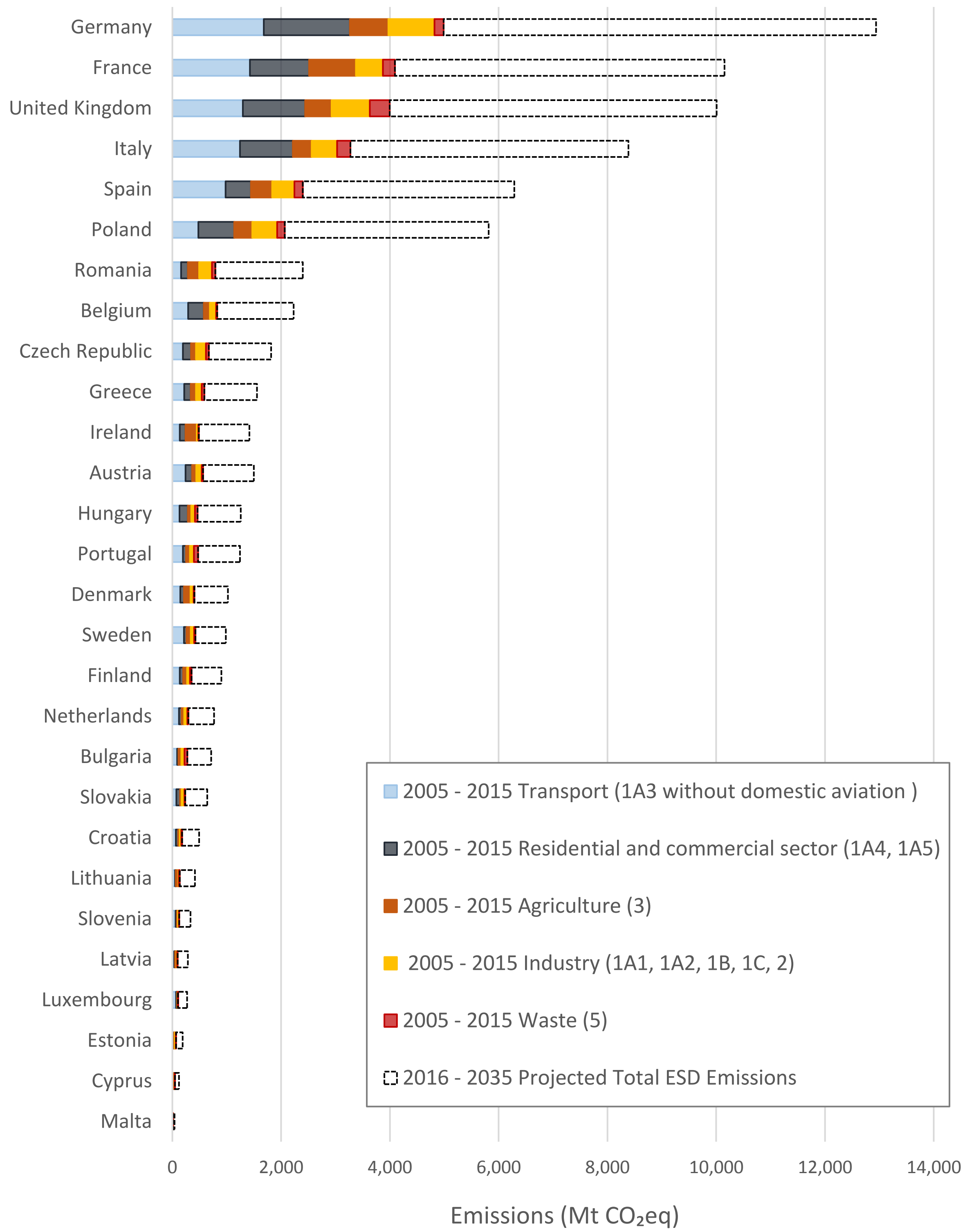
To ensure progress towards the EU's 2020 emissions targets for ESD, Member States are additionally obliged under the ESD to reach binding annual targets for each year of the 2013–2020 period. In 2015 all Member States, aside from Malta, met their annual ESD target (EEA 2017a). Ten Member States exceeded their targets by more than 10% (Croatia, Cyprus, Greece, Hungary, the Netherlands, Portugal, Slovakia, Slovenia, Spain and Sweden).

The latest projections (see **Figure 2.6**) indicate that this trend of decreasing emissions will remain consistent for the period 2016–2020 with 21 states projecting that they will meet their 2020 ESD emissions targets following the WEM scenario. However, under this same WEM scenario seven Member States (Austria, Belgium, Finland, Germany, Ireland, Luxemburg and Malta) will not meet their target. Of these states is it expected that five (Austria, Belgium, Finland, Germany, Ireland, Luxembourg) could still meet their targets using ESD flexibilities – transferring surplus AEAs from preceding years. The two remaining Member States would need to use additional flexibilities, such as the trade of AEAs from other states, in order to meet their targets.

Figure 2.5 presents the cumulative ESD emissions between 2005 and 2035 by Member State. The top four largest emitters (Germany, France, United Kingdom and Italy) will contribute to over half of the EU-28 ESD emissions between 2005 and 2035. Whilst Germany has the largest cumulative emissions between 2005 and 2015 in the transport (1A3), residential and commercial (1A4, 1A5) and industry (1A1, 1A2, 1B, 1C and 2) sectors, France and United Kingdom have the largest cumulative emissions in the agriculture (3) and waste (5) sectors, respectively.

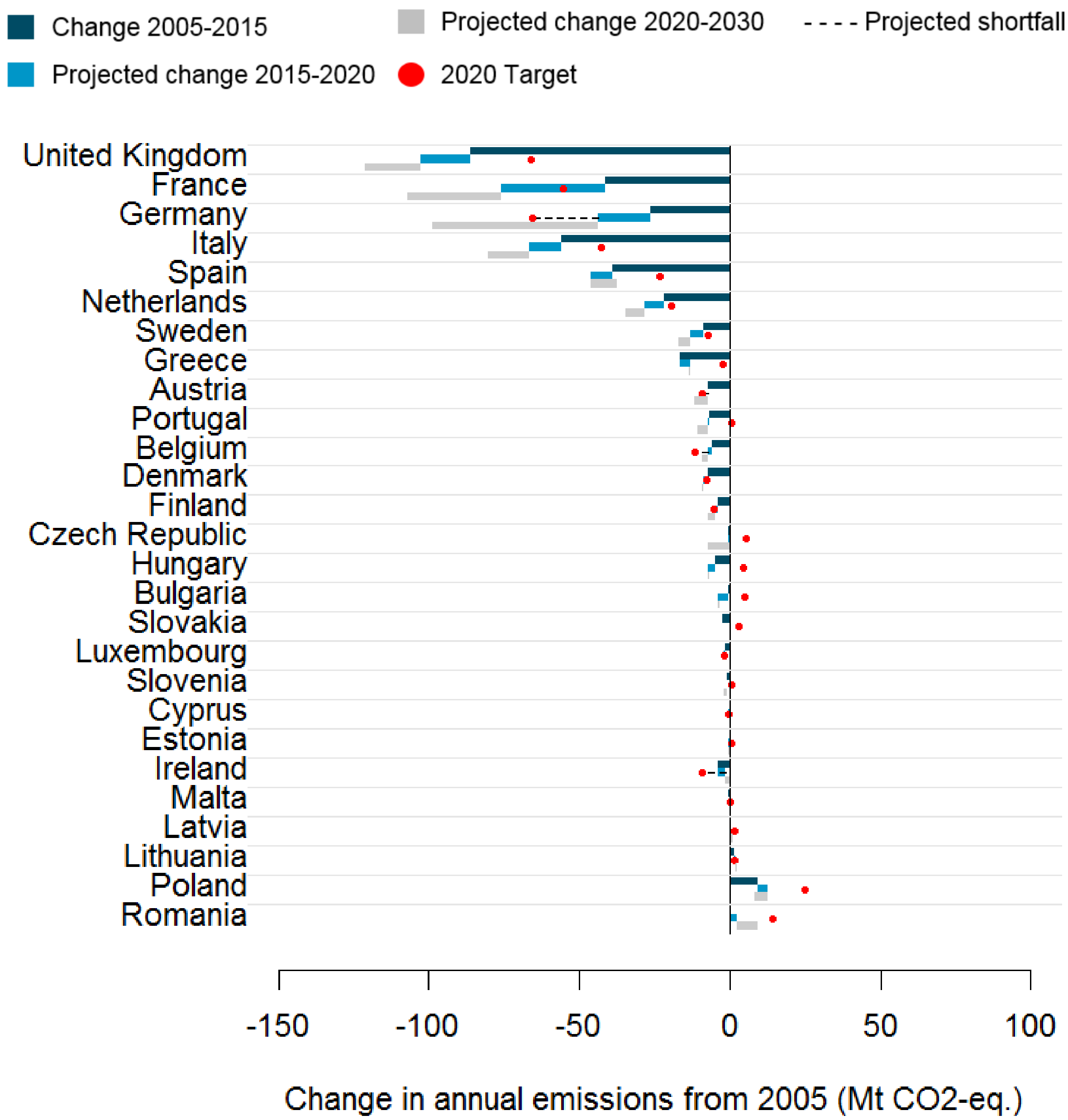
The EEA (2017c) decomposition analysis also considered the relative contributions of Member States to observed emission reductions. It was found that 48% of the EU net decrease in total GHG emissions were accounted for by Germany and the United Kingdom. For Germany, success can be accounted for by significant increases in efficiency in power following the economic restructuring and creation of five new Lander after the reunification of Germany. In the UK, decreases were primarily a result of a fuel switch in electricity production from oil and coal to gas, decreasing iron and steel production and the implementation of methane recovery systems at landfill sites.

Figure 2.5 Cumulative ESD GHG emissions (Mt CO_2eq) by sector between 2005 and 2015, and cumulative projected EDS GHG emissions between 2016 and 2035



Note: This graph presents the total cumulative emissions by Member State between 2005 and 2035. Historic emissions (pre–2015) are split by sector, and projected emissions are represented by a dotted line.

Figure 2.6 **Waterfall plot showing change in ESD emissions from 1990 to 2015, and projected change in ESD emissions from 2015 to 2020 and 2020 to 2030 by Member State. The Member State 2020 targets are highlighted together with the shortfall in reductions where applicable.**



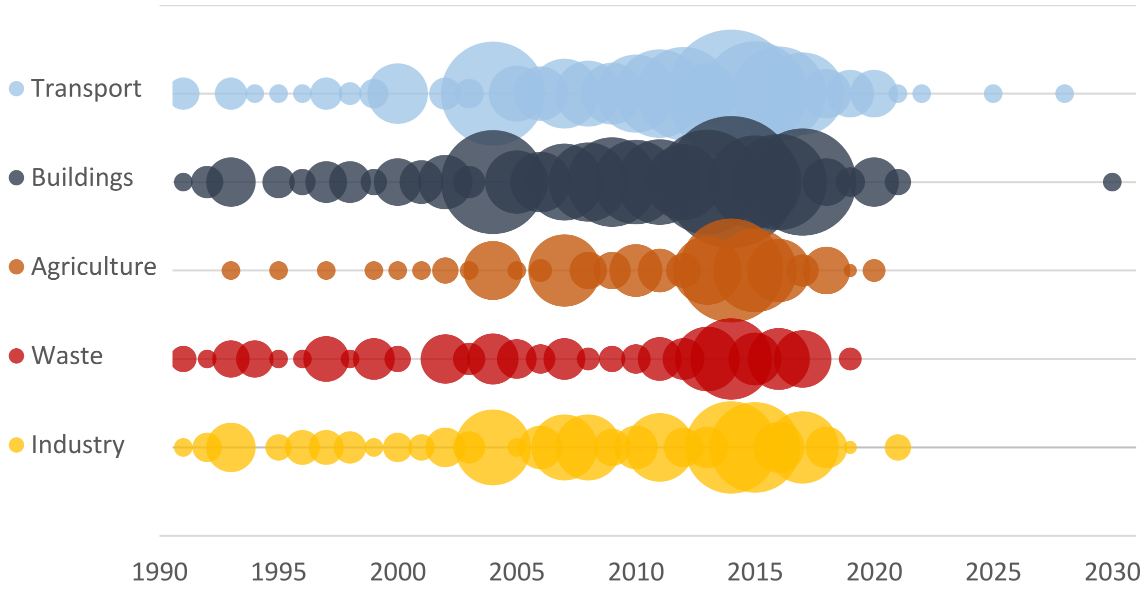
2.2 Policies and Measures (PaMs)

Overview of Policies and Measures (PaMs)

PaMs are the instruments targeting the reduction of GHG emissions. EU Member States report their PaMs every two years[3]. This includes qualitative descriptive information and some quantitative information on savings. The quantitative data is still not complete enough for analysis of ex-post or ex-ante savings and therefore has not been used in this report. The following sections present analysis of the qualitative impacts of reported PaMs for the ESD sectors. PaMs were weighted to account for their number and potential impact, depending on the related sectoral share of historical emissions of reporting Member State and the type of measure. The methodology is described in more detail in **Annex II**. An overview of the weighted numbers in their year of implementation of PaMs by ESD sector are presented in **Figure 2.7 and 2.8**.

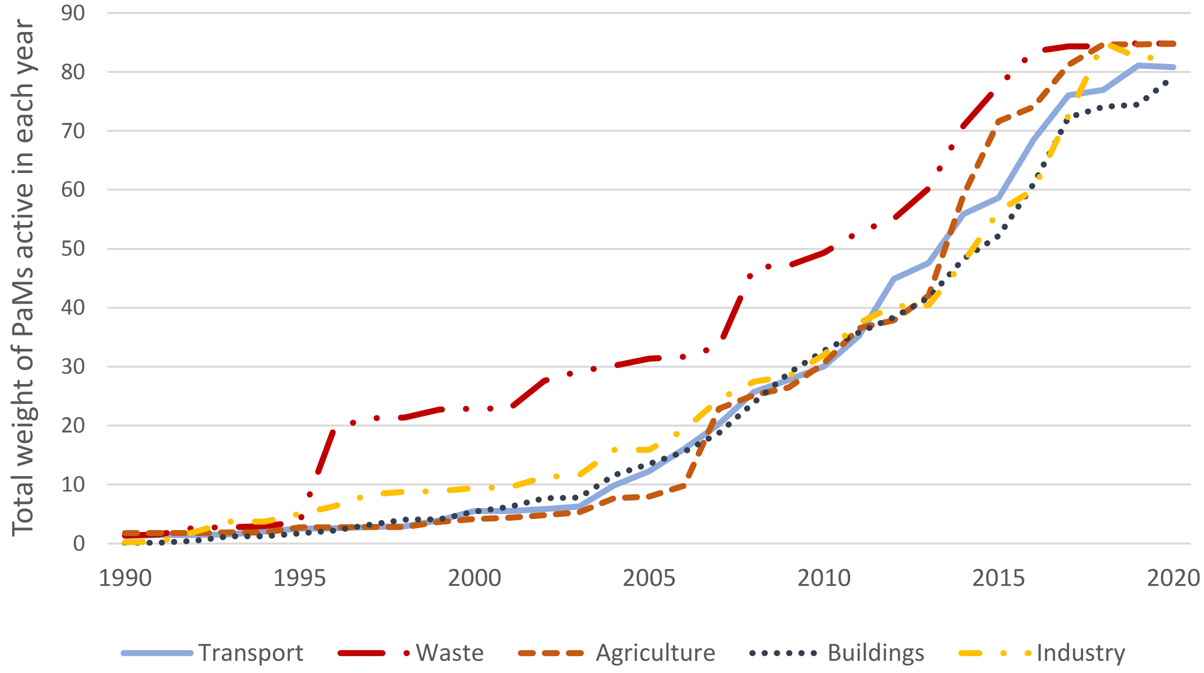
For all ESD sectors excluding waste, the weight of PaMs has shown a dramatic increase, from 2003 to 2020. Few policies were initiated prior to 2000. From 2004, implementation increased dramatically.

Figure 2.7 PaMs by year of implementation, shown by sector for the period 1990 to 2030. The bubbles are sized according the PaM weighting (see Annex II for methodology).



[3] The EEA PaMs database can be downloaded from: http://pam.apps.eea.europa.eu/

Figure 2.8 Weight of active PaMs, shown by sector for the period 1990 to 2020.



Transport

In the transport sector, the weight of PaMs steadily increases, from 2003 to 2020 (**Figure 2.8**). Few transport policies were initiated prior to 2000. From 2004, implementation increased and the transport sector is now one of the sectors with the single most PaMs reported. Most transport policies aim to promote low-carbon fuels, electric vehicles and more efficient vehicles. Policies promoting biofuels started in the 2000's with the implementation of the Biofuels Directive (2003/30/EC) as EU policy framework. Relatively few PaMs are scheduled to end before 2020. Apart from the biofuels directive, other relevant EU policies are imposed emission standards (e.g. the EURO 5 and 6 Regulation (2007/715/EC) and the CO_2 emission performance of cars and vans regulation (2009/443/EC)), the Fuel Quality Directive (2009/30/EC) and the Directive on the Promotion of Clean and Energy Efficient Road Transport Vehicles (2009/33/EC).

Residential and Commercial

The weight of PaMs affecting emissions in the residential and commercial sector are increasing over time, with the rate of annual increase getting more significant (**Figure 2.8**). This suggests that in recent years, new (or updated) PaMs have been increasingly implemented. The trend does not show any sudden increases. These PaMs aim to improve energy efficiency of buildings by increased insulation or more efficient heating and cooling and increase the share of renewables for heating. Most Member States have implemented several PaMs that target the residential and commercial sectors, which explains why the trend is smoother than for sectors where there are fewer individual single PaMs. The building sector is the only sector for which planned PaMs are already reported and expected to start in 2020, with a significant weight. The most important Union policies that have an impact on these emissions are the Recast of the Energy Performance of Buildings Directive (2010/31/EU) and the Energy Services Directive (2006/32/EC) and Energy Efficiency Directive (2012/27/EU), with the latter two having more horizontal measures promoting energy efficiency across different sectors. Additionally, the Renewable Energy Directive has an impact via the promotion of RES for heating and cooling.

Agriculture

For the agriculture sector, the weight of PaMs slowly increases between 1990 and 2005, after which the pace of implementing PaMs increases relatively steadily until 2015 (**Figure 2.8**). A significant part (75%) of agriculture PaMs are implemented in response to EU legislation, most importantly the CAP. This could partly be explained by the fact that the CAP reform in 2003 increasingly focused on environmental management, including GHG mitigation. The 2013 CAP reform, which followed the 2003 reform, put even greater emphasis on climate change mitigation. Most agriculture PaMs that have an impact on GHG emissions aim to reduce the use of fertilizers, improve cropland management and improve animal waste management.

Waste

For the waste sector, the weight of PaMs increased markedly between 1996 and 2008 (**Figure 2.8**). This corresponds partially with the start year of important EU policies on waste, more specifically the Landfill Directive (1999/31/EC) and the Waste Management Framework Directive (2008/98/EC). EU regulations are an important incentive to implement national waste policies; almost 75% of PaMs are linked to EU policy. The national PaMs primarily aim to reduce landfilling, increase recycling and reduce production of waste. A number of Member States reported few waste PaMs, which subsequently had a higher weight and impact on the outcome. The reporting also showed that few PaMs are planned to start after 2015.

Industry

For the industry sector (excluding PaMs which only affect ETS emissions), PaMs reported by Member State appear to have been implemented earlier compared to most other sectors. Starting shortly after 1990, the weight of the PaMs begins to increase (**Figure 2.8**). As a result, a significant part of the PaMs have already been implemented before 2010. PaMs in this sector are very diverse and cover for instance policies to reduce emissions from fluorinated GHGs. These national policies are mainly driven by the EU F-gas regulations (2006/842/EC and 517/2014) and the Mobile Air Conditioning Directive (2006/40/EC). Additionally, it also includes national PaMs to improve energy efficiency in industrial installations (not covered by the ETS). A part of the PaMs that are covered here have been implemented in response to Union policies aimed at reducing emissions of air pollutants, but that have an indirect impact on GHG emissions. This includes the Industrial Emissions Directive (2010/75/EU), the Large Combustion Plant Directive (200/80/EC) and the National Emission Ceilings Directive for certain pollutants (2001/81/EC).

3 Energy: Transport (1A3)

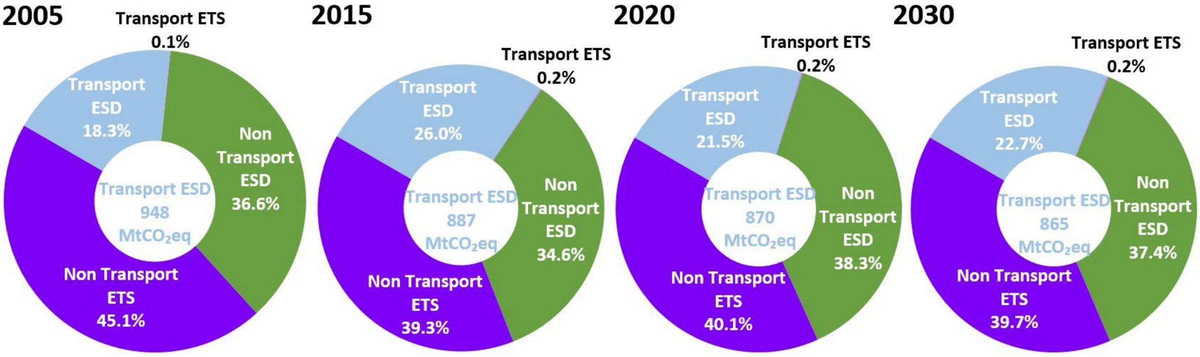
Key messages:

- Transport GHG emissions are projected to continue the decreasing trend that started in 2007 after a continuous increase compared to 1990 levels. The projected decrease however is rather small (for the WEM scenario) in view of the ambitious 2030 GHG targets set for the transport sector.
- Road transport is expected to be the main contributor to the projected reductions. This is mainly a result of European Regulations to limit CO_2 emissions from new cars and vans sold in Europe. The reductions however are somewhat counterbalanced by the gap between officially reported and real-world CO_2 emissions from cars and vans.
- The electrification of transport, and in particular road transport, and the deployment of intelligent transport systems, are expected to bring additional benefits.

3.1 Overview of transport ESD emissions

Transport is responsible for about 26% of total 2015 EU-28 GHG emissions without LULUCF, or 30.6% of total EU GHG emissions with LULUCF (**Figure 3.1**). The contribution is projected to decrease slightly to about 22% in 2020 and 2030. When considering ESD emissions only, the contribution of transport is on the order of 35–38% over the 2015–2030 period without the LULUCF, or 48–51% over the same period when emissions and removals from the LULUCF sector are included.

Figure 3.1 Percentage contributions of transport ESD and ETS emissions to total EU GHG emissions (without LULUCF). The circles for 2005, 2015, 2020 and 2030 are sized to total ESD transport GHG emissions.

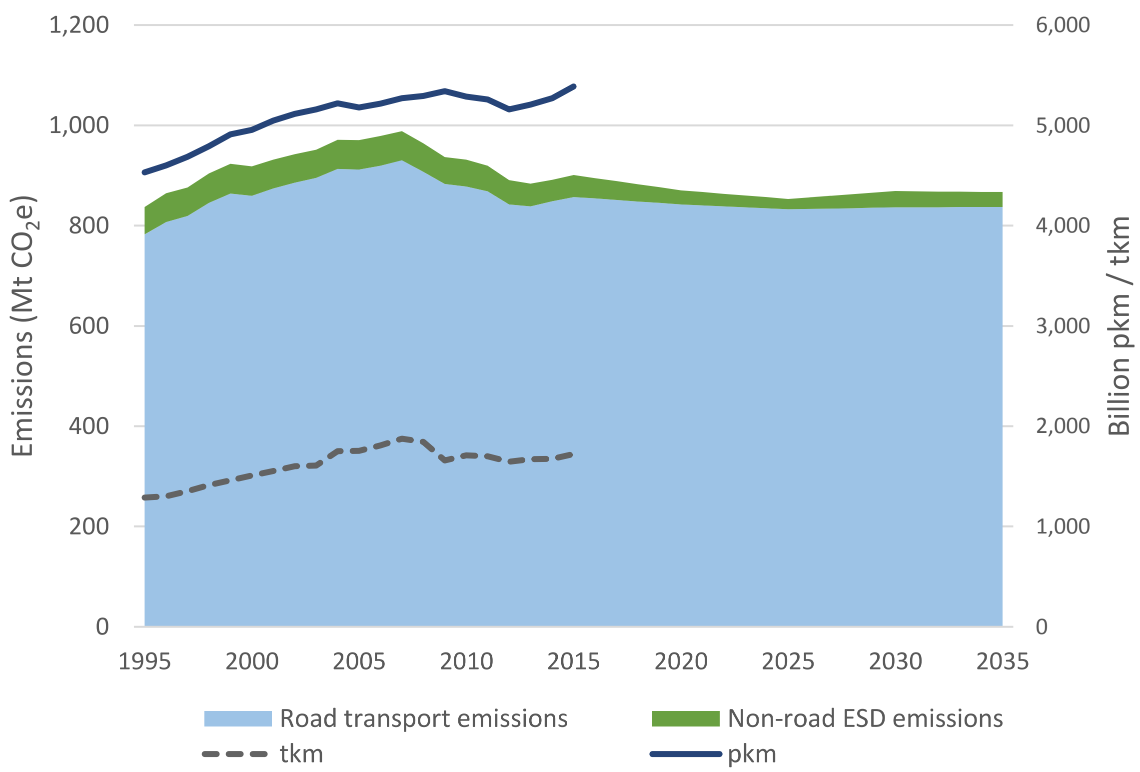


Transport ESD emissions are dominated by road transport. Emissions from the road transport sector have been increasing steadily from 1990 to 2007. This is mainly due to the increase in road transport demand, expressed in passenger-kilometres and tonne-kilometres for passenger and freight transport respectively. Since 2007, emissions dropped until 2013 because of the decrease in road transport activity following the economic downturn in Europe, as well as a shift to smaller and more fuel-efficient vehicles in the EU. Since 2013 emissions are increasing again as a result of an increase in demand and energy consumption from the road transport sector. This is despite the efforts to decrease CO_2 emissions from new cars and vans sold in the EU by 2021 and 2020 respectively. In that respect, the effectiveness of the relevant EU Regulations has been lower than expected, as officially reported CO_2 emissions used for monitoring are known to under-represent reality.

As a result, while officially reported CO_2 emissions from new cars and vans decrease drastically, real-world fuel consumption – and hence CO_2 emissions – decrease at a much lower rate or even increase. This gap between officially reported and real-world fuel consumption and CO_2 emissions is expected to close with the introduction of stricter legislation for the type approval of new vehicles from 2017. The effect is only visible in the projected GHG emissions until 2022–2023 which are projected to decrease slightly in the WEM scenario and then remain almost constant until 2035. The observed stabilisation in emissions from 2023 onwards, is despite the fact that the respective road transport demand will continue to increase. Projected activity is only available for a few EU Member States and hence is not shown in the graph below.

Other measures such as the increased use of biofuels, the penetration of different types of electric vehicles (such as battery electric, plug-in hybrids, range-extenders, fuel cell vehicles), as well as the deployment of intelligent transport systems also contribute to this stabilisation of emissions. With regard to electric vehicles, it should be noted however that any GHG emissions benefits from the lower vehicle emissions are to some extent counterbalanced by an increase in the respective emissions from electricity generation. This benefit is projected to increase in the future with the use of a cleaner fuel mix in the power sector.

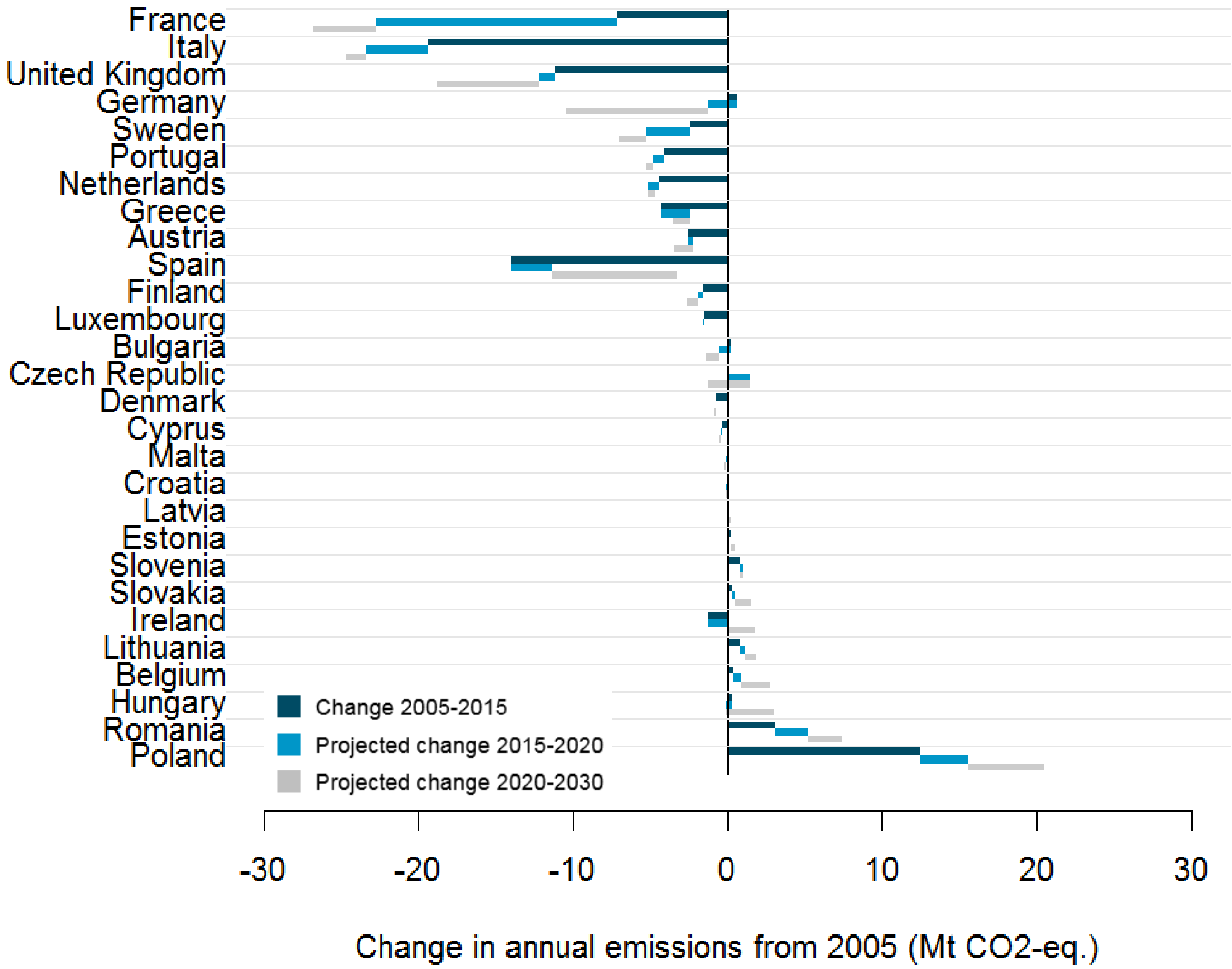
Figure 3.2 ESD road and non-road transport emissions between 1995 and 2035 compared to EU-28 passenger and freight activity (in pkm and tkm).



At the Member State level, France, Germany, the United Kingdom, Italy, and Sweden (despite its relatively small size) are the biggest contributors to projected emissions reductions from the road transport sector in the period 2015 to 2030 in the EU-28 (**Figure 3.3**). The reductions are due to several national policies to promote more energy efficient vehicles and fuels (such as liquified natural gas (LNG) for heavy trucks), electric mobility and advanced biofuels.

On the other hand, there are several Member States that are projected to further increase their emissions until 2030 with Spain, Poland and Romania having the highest contributions.

Figure 3.3 Waterfall plot showing change in ESD transport emissions 2005 to 2015, and projected change in ESD emission from 2015 to 2020 and 2020 to 2030 by Member State.



3.2 PaMs targeting ESD emissions in the transport sector

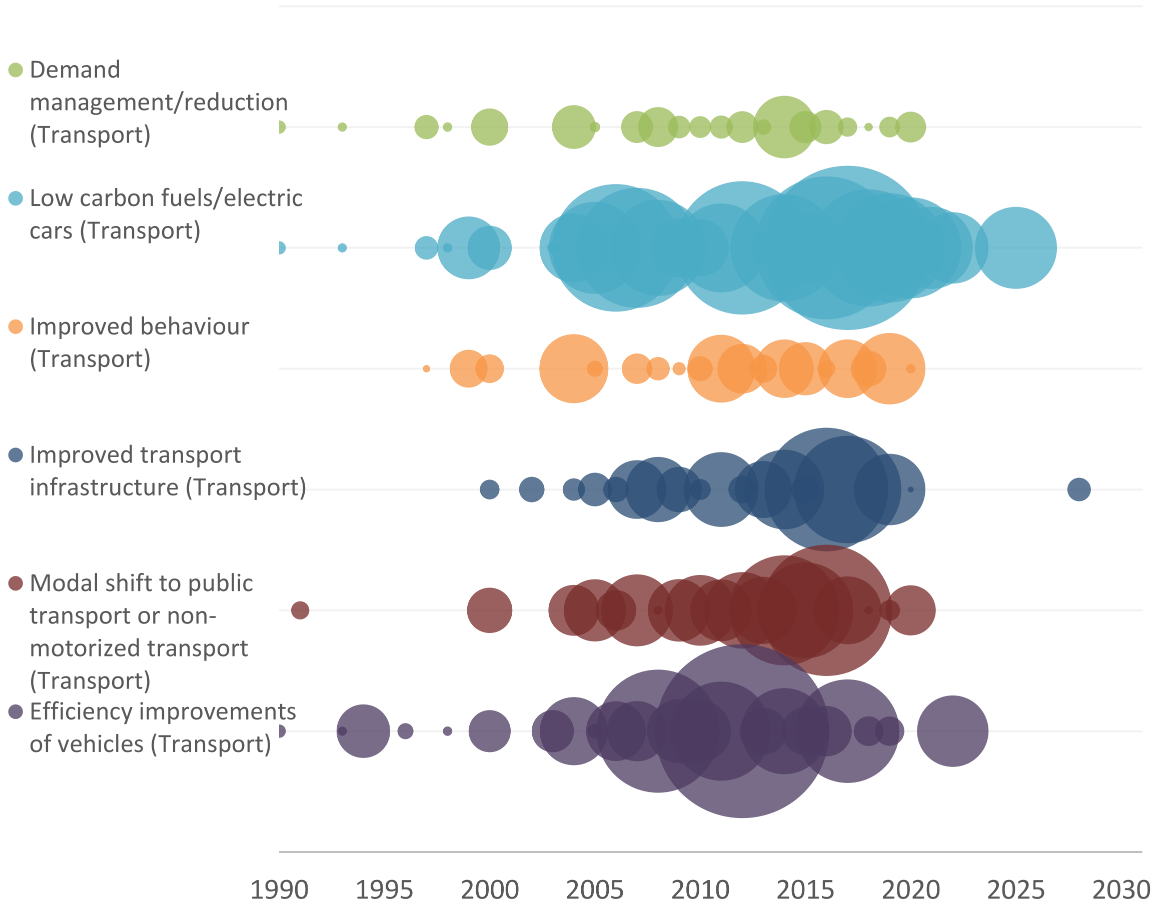
A large number of PaMs have been implemented by Member States in an attempt to reduce emissions from the transport sector.

The electrification of road transport is heavily promoted in several Member States, mainly by means of financial incentives. Such incentives include reductions or exemptions from registration and annual circulation taxes, and subsidies for vehicle purchase. Though the focus is primarily on pure electric vehicles (i.e. battery electric), other electrified vehicles such as plug-in hybrids, range extenders and fuel cell vehicles are also benefited. The expansion of the vehicle charging infrastructure is also an important element in facilitating the uptake of more electric vehicles.

Similarly, relevant tax incentives are offered for improving the vehicle efficiency in line with the EU Regulations for new cars and vans. This is achieved by e.g. downsizing of passenger vehicles and the use of lower carbon intensity fuels such as CNG and LPG. Further improvements to overall efficiency are expected by the deployment of different ITS (Intelligent Transport Systems) measures. The promotion of eco-driving is the most widespread measure for in-vehicle systems, whereas urban traffic control (e.g. by optical traffic light management) is the most common infrastructure-based system deployed. Specific targets for modal shift to less energy intensive transport modes, such as rail, are also set in several Member States.

The increasing use of biofuels continues to be heavily promoted in the EU with the use of a variety of PaMs. Fiscal incentives, such as lower excise duties, are now offered in almost all Member States for the promotion of mainly biodiesel and bioethanol but also other biofuels. Several Member States have set their own national targets for the uptake of biofuels and other renewables in the transport sector. An overview of national PaMs as reported by EU Member States for the transport sector is shown in **Figure 3.4**.

Figure 3.4 PaMs in the transport sector by year of implementation, shown by type for the period 1990 to 2030. The bubbles are sized according the PaM weighting (see Annex II for methodology).



4 Energy: Residential & Commercial (1A4 & 1A5)

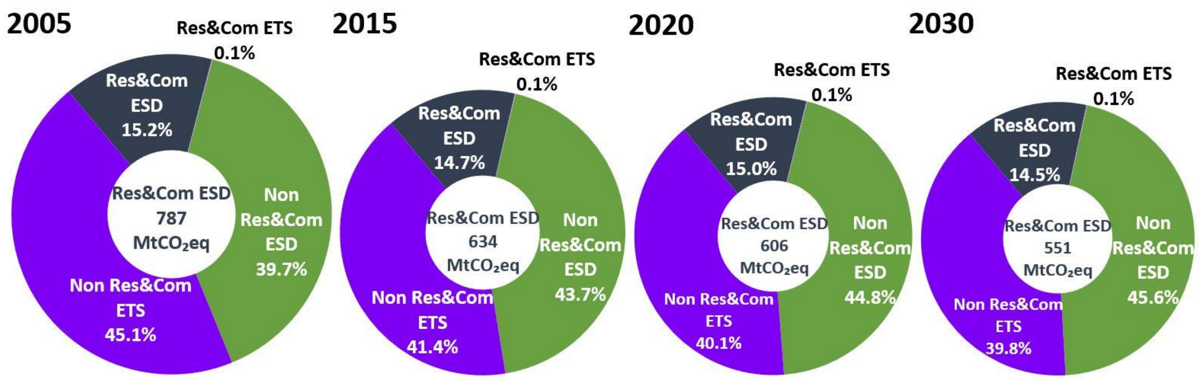
Key messages:

- Emissions in the residential and commercial sector are expected to decrease in future years, as they have been doing since 1990. The rate at which GHG emissions reduce between now and 2030 however is expected to be lower than in the past.
- The residential subsector contributes most to GHG emissions in this sector. GHG emissions go against the trend of increasing population size, both in the past and in the future.
- These emission reductions were and will be achieved by increasing energy efficiency of buildings, switch to RES for heating and cooling and switches to less carbon intensive fuels. Because most emissions are for heating, climatic conditions are an important factor resulting in short-term annual fluctuations in emissions and a long-term downward trend because of increasing average temperatures across Europe.

4.1 Overview of Residential and Commercial ESD emissions

The ‘residential and commercial’ sector aggregates emissions from the 1A4 and 1A5 sectors. In these sectors emissions are almost exclusively covered by the ESD (**Figure 4.1**). The share of ETS emissions in this sector is estimated to be only 0.6% of residential and commercial emissions in the EU-28.

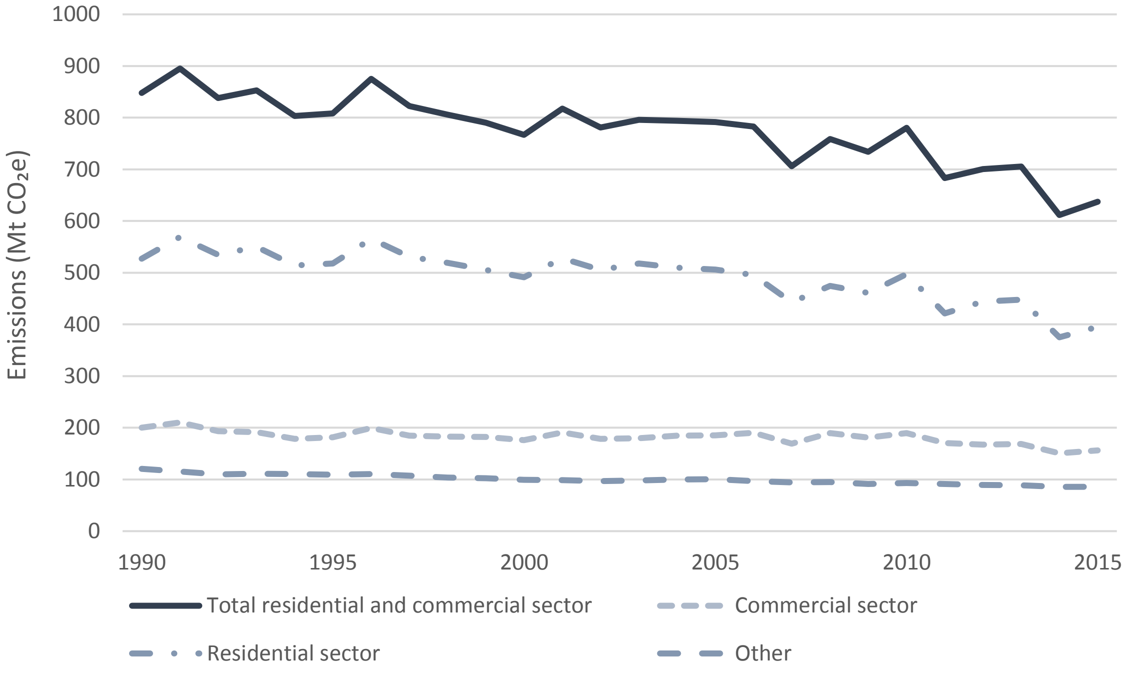
Figure 4.1 Percentage contributions of residential and commercial (res&com) ESD and ETS emissions to total EU GHG emissions (without LULUCF). The circles for 2005, 2015, 2020 and 2030 are sized to total GHG emissions.



The contribution (share) of emissions from the residential and commercial sector to total ESD emissions have steadily decreased from 27.7% in 2005 to 25.2% in 2015. ESD emissions in the residential and commercial sector have decreased at a faster rate compared to total ESD emissions between 2005 and 2015, a reduction rate of 22.4% and 13.3% was achieved respectively (see **Figure 1.4**). This trend is projected to continue in future years, and the contribution of ESD emissions from the residential and commercial sector is expected to decrease to 23.8% in 2035.

Historic emissions in the residential and commercial sector have shown a clear decline in total GHG emissions from 848 Mt CO_2eq in 1990, 792 Mt CO_2eq in 2005 to 637 Mt CO_2eq in 2015 (**Figure 4.2**). Emissions can be further split between the sectors commercial/institutional (1A4a), residential (1A4b) and other (which includes agriculture/forestry/fishing 1A4c and other stationary or mobile emissions from fuel combustion 1A5). The latter category is smaller and emissions have remained relatively stable over time. The emissions in the residential sector are clearly the most important, with a share of 62% in 2015. The residential subsector not only has the highest share of emissions in this sector, it contributes the most to the emission reductions. Emissions in the residential sector have decreased by 22%. or 111 Mt CO_2eq, in the EU in 2015 since 2005. In the commercial sector, emissions have only reduced by 16% or 29 Mt CO_2eq.

Figure 4.2 Total GHG emissions in 1990–2015 in the EU-28 in the residential and commercial sector



Emissions in the residential and commercial sector have been declining and are projected to do so until 2035. However, the rate at which emissions are decreasing is expected to slow in years to come (**Figures 4.3** and **4.4**).

In the EU-28, Member States have achieved an average annual emission reduction in the residential and commercial sector of 2% per year (over the period 2005–2015). Most Member States have been able to reduce emissions in this sector, with the exception of Estonia, Lithuania and Malta. For these three countries emissions have been stable in the period 2005–2015. Despite this overall historic achievement of a 2% annual reduction in emissions, Member States are less optimistic in their projections (**Figure 4.4**). In the WEM scenario, emissions are expected to decrease on average by only 0.8% per year until 2035. Moreover, in the WEM scenario more Member States expect that the declining emissions in the residential and the commercial sector cannot be maintained (such as the United Kingdom, Ireland, Spain and Greece). In the WAM scenario, the average annual emission reduction rate increases to 1% per year for the EU-28.

Figure 4.3 Waterfall plot showing change in ESD residential and commercial emissions 2005 to 2015, and projected change in ESD emission from 2015 to 2020 and 2020 to 2030 by Member State.

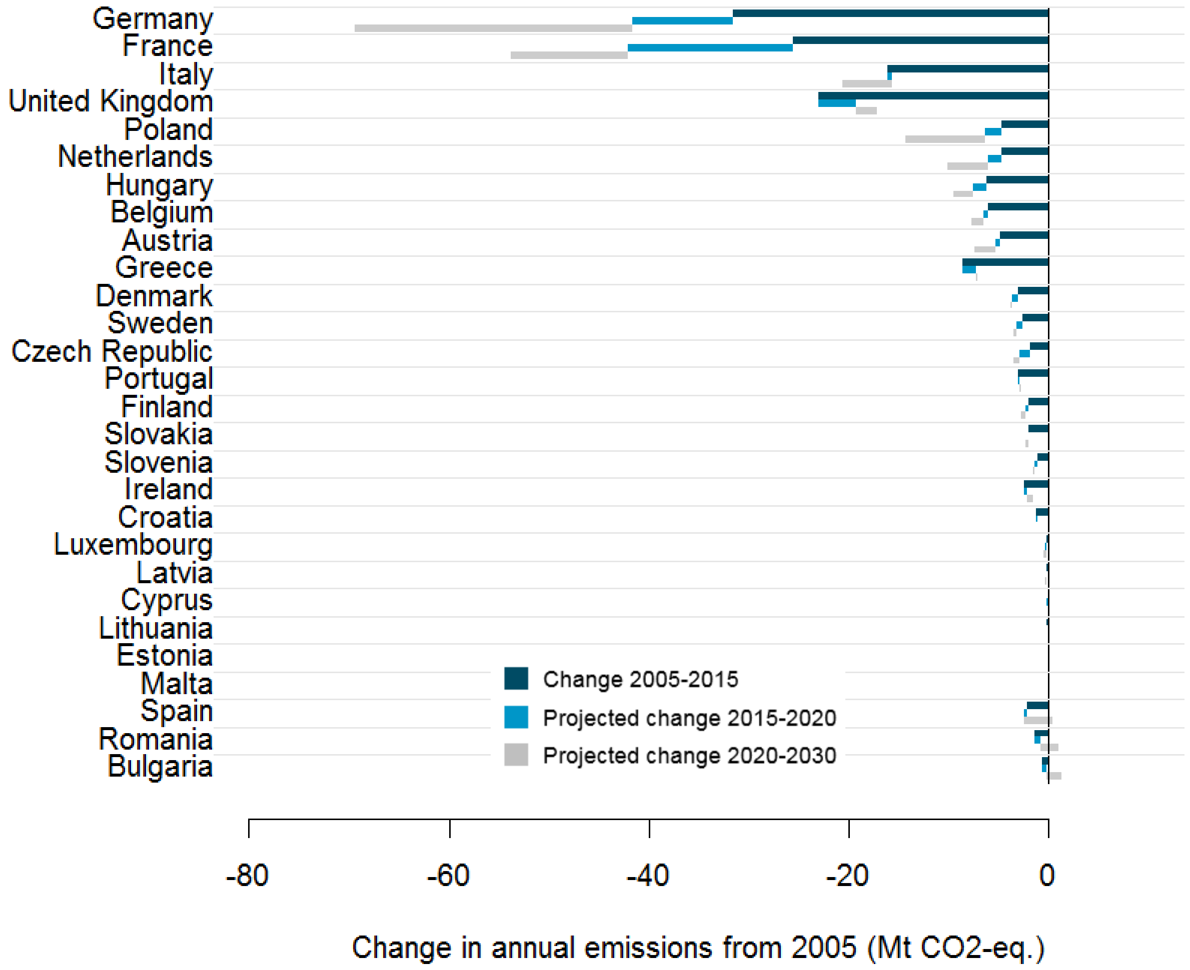
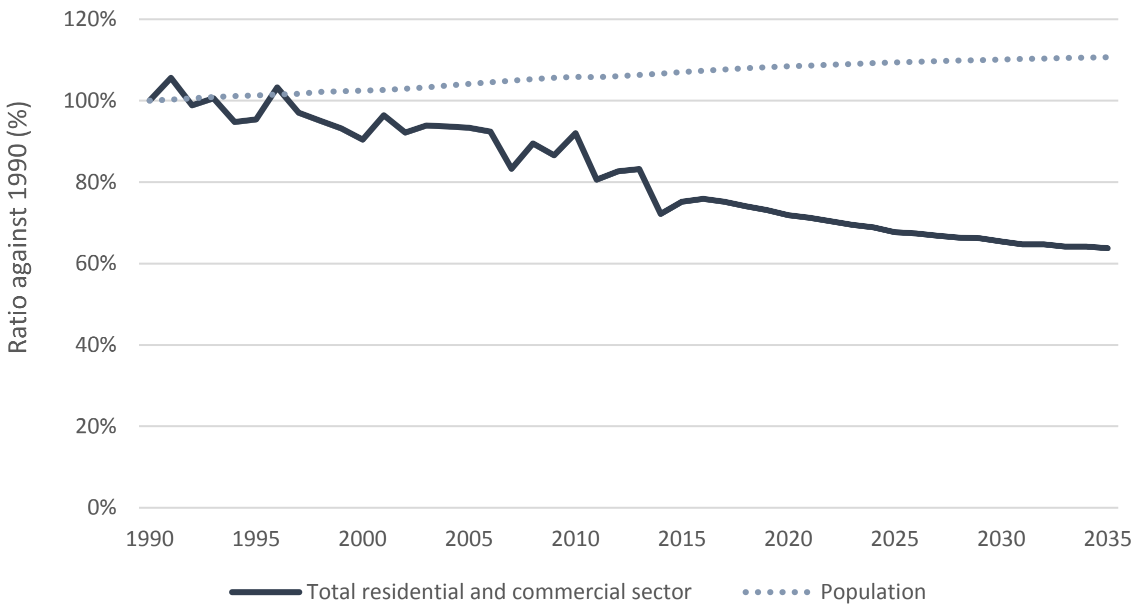


Figure 4.4 **Historic and projected (WEM) total GHG emissions and population size in the EU-28 (as % compared to 1990).**



4.2 PaMs targeting ESD emissions in the residential and commercial sector

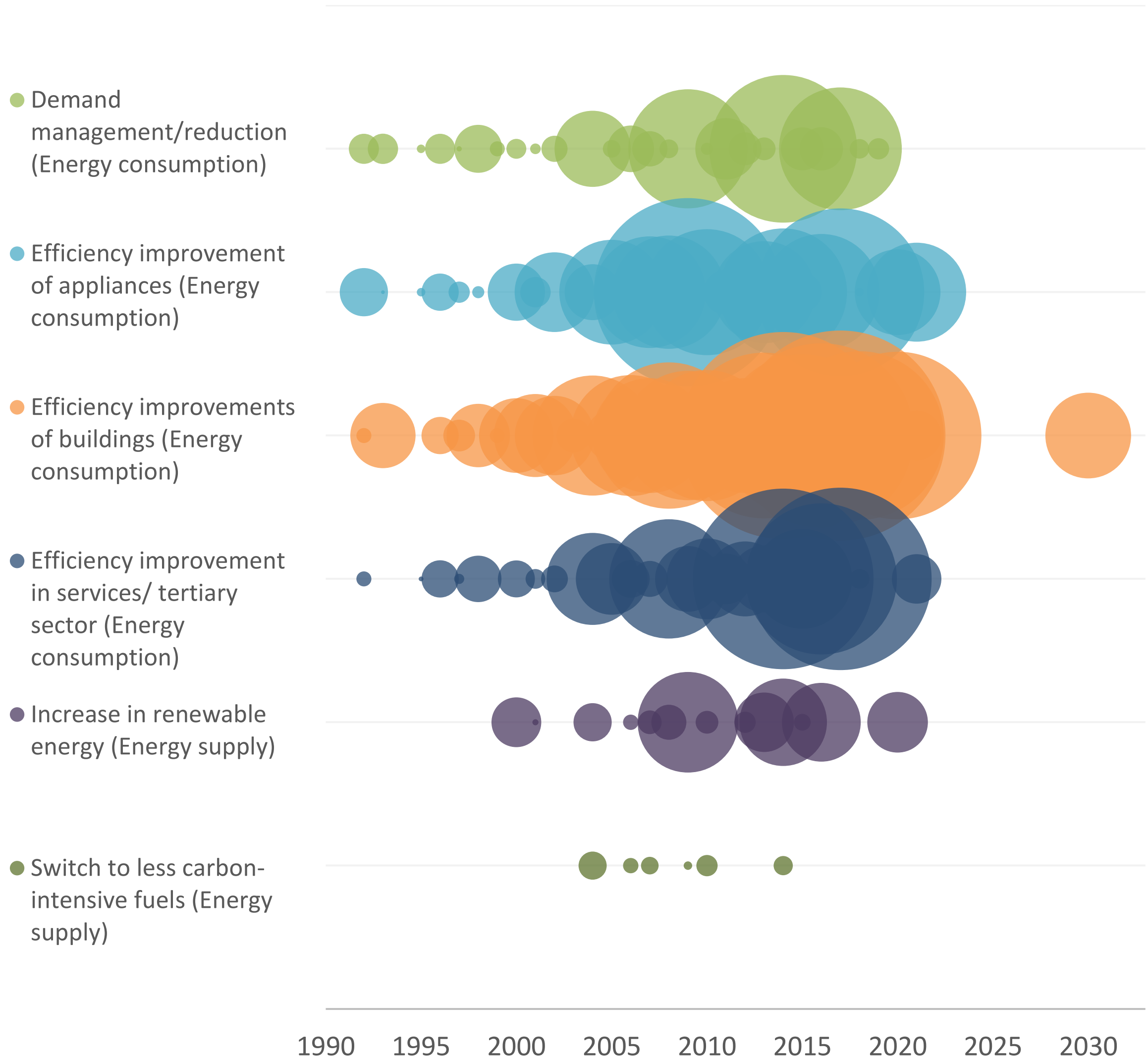
The analysis of the PaMs in this sector shows that especially in recent years, new PaMs have been implemented by Member States. This trend does not appear to be reflected in either historic or projected GHG emissions as these have been relatively consistently decreasing since the 1990s.

Mitigating GHG emissions in the residential and commercial sector is achieved via increased energy efficiency and renewable energy for heating and cooling. Of all PaMs reported by Member States in the context of the MMR, PaMs targeting the residential and commercial sector are the most numerous group of instruments. Apart from national action, promotion of energy efficiency in the residential sector is also achieved via an EU policy framework, including the Energy Services Directive, the Energy Efficiency Directive and the Recast of the Energy Performance of Buildings Directive (EPBD), which has had an important role. This EU legislation has been an incentive for many Member States to implement additional national PaMs to increase energy efficiency. Some national PaMs in Member States, such as building regulation codes pre-dates the start of EU action. In several Member States energy efficiency building codes have been in place well before 1990. This could explain why emissions have been steadily declining.

Additionally, PaMs promoting RES for heating and cooling are an important driver for emission reductions. The emission reductions achieved by RES in heating and cooling are smaller than in the electricity sector, but nevertheless are significant. It is estimated that ESD emissions were reduced by 52 Mt CO_2 in 2015 (and 15 in the ETS), which are the only additional emission savings since 2005 (EEA, 2017b).

Another effect, albeit much smaller than energy efficiency and renewable energy, is that GHG emissions might have been displaced from this sector to another. Installation of heat pumps resulting in increased electricity consumption reduces fossil fuel emissions in the residential sector, but increases emissions in the electricity generation sector. District heating networks could also mean a shift from emissions currently covered by the ESD to emissions that are covered by the ETS. An overview of national PaMs as reported by EU Member States for the residential and commercial sector is shown in **Figure 4.5**.

Figure 4.5 **PaMs in the residential and commercial sector by year of implementation, shown by type for the period 1990 to 2030. The bubbles are sized according the PaM weighting (see Annex II for methodology).**



5 Agriculture (3)

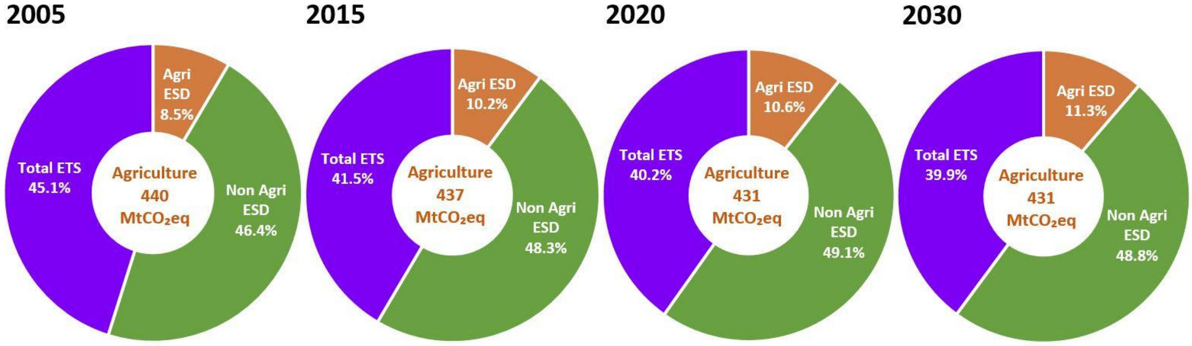
Key messages:

- The total projected emissions from the agriculture sector slightly decrease by 9.3 Mt CO_2eq (-2%) in 2030 compared to the ESD base year 2005. The largest decrease was recorded between 1990 and 2005 where the emissions decreased from 550 Mt to 440 Mt CO_2eq. Within the ESD it is the third largest sector, contributing to 8-11% of the total ESD emissions.
- The three key categories are Enteric fermentation, Manure management and Agricultural soils which are responsible for 97% of the sector's emissions. For this reason, emissions are strongly related with the size of the livestock and nitrogen inputs to soils. The overall animal population has decreased in the past whereas the nitrogen fertilizers increased.
- The agriculture sector was subject to deep structural changes in the past which were strongly linked to the key policy in the agriculture sector, namely the CAP. The CAP includes many measures that have direct or indirect influence on the emissions in this sector and triggered a transformation. The second most relevant policy is the Nitrate Directive which affects the nitrogen input to soils.

5.1 Overview of agriculture emissions

The agriculture sector is the third largest sector in the ESD and emissions amount to 437 Mt CO_2eq in 2015. The sector is contributing 17% to the ESD sector and approximately 10% to total EU emissions in 2015 (**Figure 5.1**).

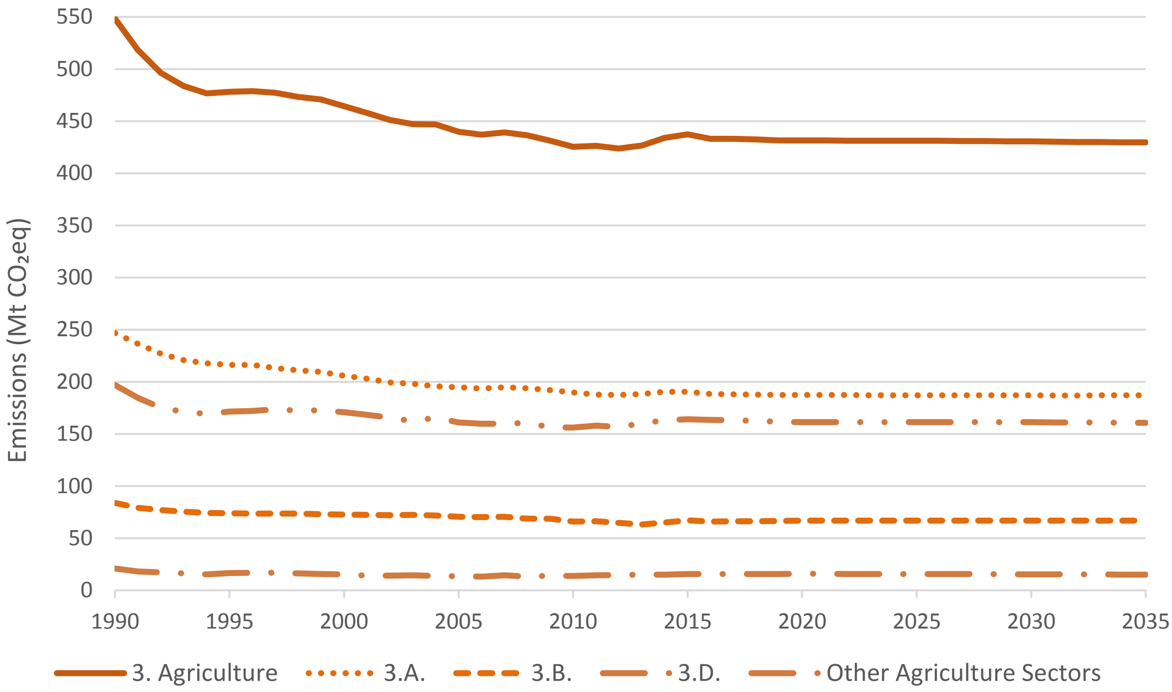
Figure 5.1 Percentage contributions of agriculture to EU GHG emissions 2005, 2015, 2020 and 2030. The circles are sized based on total agriculture GHG emissions which are shown in the centre of the circles.



Enteric fermentation (3A), Manure management (3B) and Agricultural soils (3D) are key categories in the EU GHG inventory. These three sub-sectors cover 97% of the total agricultural emissions in the EU. 3A is largest sub-sector causing 44% of the agriculture emissions, followed by 3B with 37% and 3D with 16%.

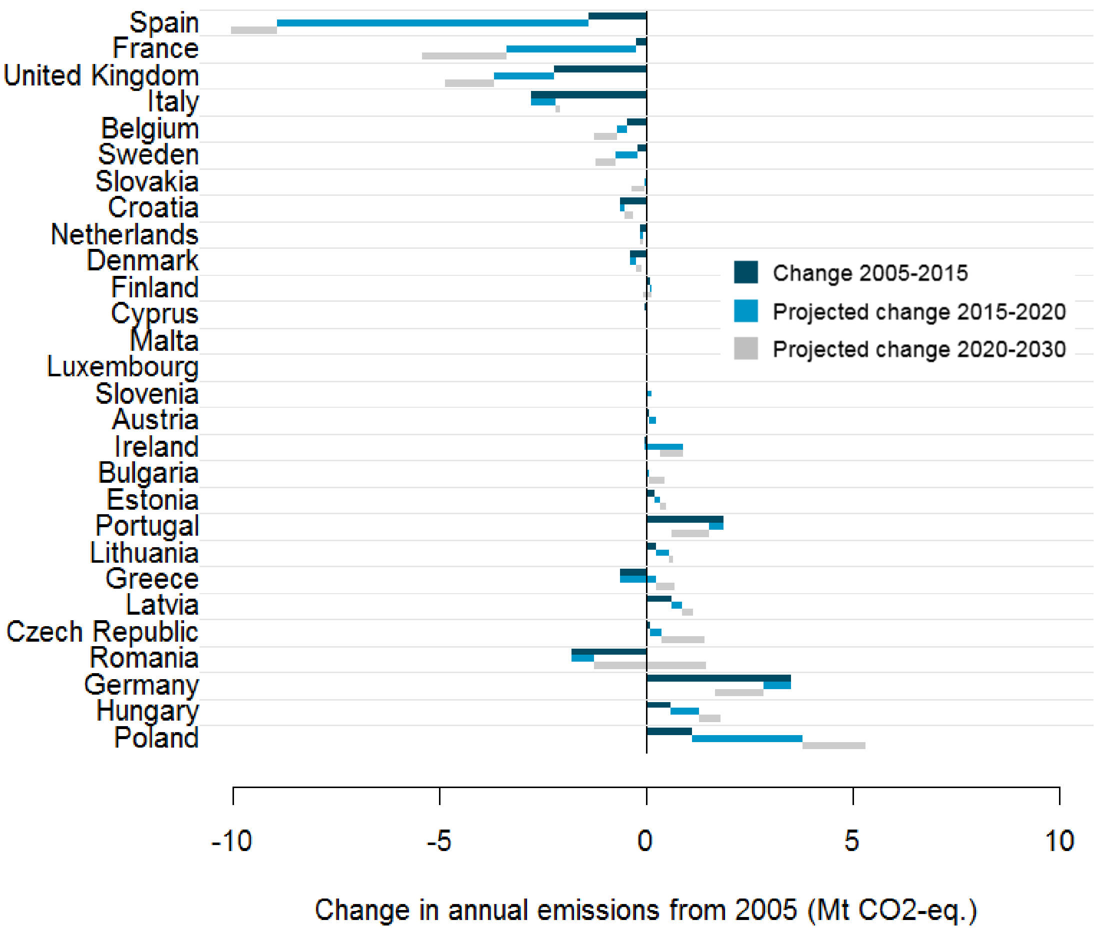
The emission trend in the agriculture sector is presented in **Figure 5.2**. Total emissions from agriculture show a slight decrease (by 2%) in 2030 compared to the ESD base year (2005). The two largest sub-sectors, 3A and 3B, also decline by 4% and 5% respectively, whereas the trend for sector 3D remains relatively constant. The other sub-sectors have a small contribution to the overall emissions of the sector, and are projected to increase by 14% by 2030.

Figure 5.2 **Emission development of the agriculture sector and the main sub-sectors (EU key categories) from 1990–2035 (projections from 2015–2035 WEM scenario)**



The largest emitting countries in terms of total emissions are France, Germany and the UK (18%, 15% and 10% of the EU's agriculture emissions in 2015, respectively). Regarding the emission trends, it can be seen in **Figure 5.3** that Spain reports the largest emissions reductions by 2030 compared to 2005 (-27%/-10 Mt CO_2eq), followed by France (-7%/-5 Mt CO_2eq) and the UK (-11%/-5 Mt CO_2eq). On the other hand, emission increases by 2030 are reported by Poland (+18%/+5 Mt CO_2eq), Hungary (+30%/+1.8 Mt CO_2eq) and Germany (+3%/+1.7 Mt CO_2eq).

Figure 5.3 Waterfall plot showing change in agriculture emissions 2005 to 2015, and projected change in ESD emission from 2015 to 2020 and 2020 to 2030 by Member State.



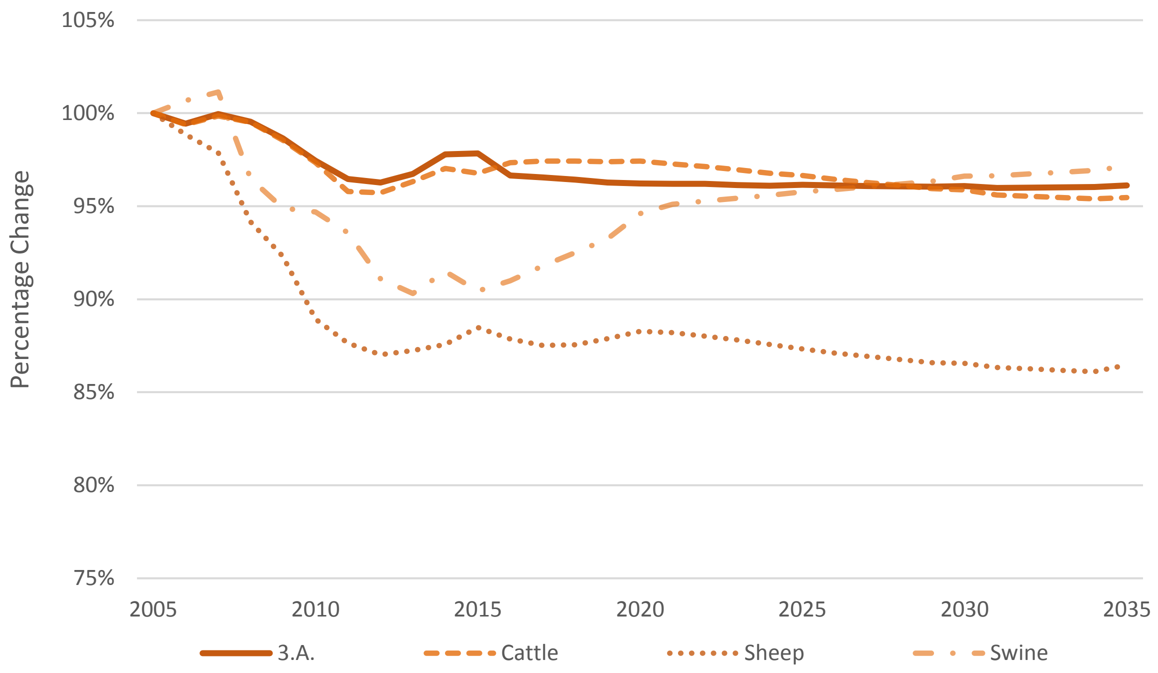
5.2 3A Enteric fermentation

Methane emissions from cattle and sheep are the main contributors to the emissions of this sector (84% and 11% of sector 3A in 2015 respectively). Emissions from enteric fermentation are strongly related with the animal stock and the feeding system, therefore the population number of livestock is the most relevant parameter to be analysed. This can also be seen in **Figure 5.4** where the emission trend is following a very similar pathway as the trend of the cattle population.

The main decrease was reported for the historical period 2005–2015 and continues to slowly level out by 2030 in the projections. For the whole period, the cattle population declines by 4% and the sheep population decreases by 13%. The population of swine also decreased in the historical time series, but the trend increases in the projections. However, in absolute numbers the contribution of emissions of swine to the sector is rather low (2% of sector 3A in 2015) and therefore changes in the population do not have a substantial influence on the sectoral emissions.

Although the cattle numbers decrease in the projections, the emissions remain rather constant, which can be explained by the intensification of milk production: there are fewer dairy cows but they produce more milk and therefore more emissions. For further analysis, it would be necessary to split the cattle into dairy and non-dairy cattle and to consider the milk yields, which was not possible due to a lack of data.

Figure 5.4 **Relative changes of the main parameters (cattle, sheep and swine population) and development of the emissions of sector 3A Enteric fermentation**

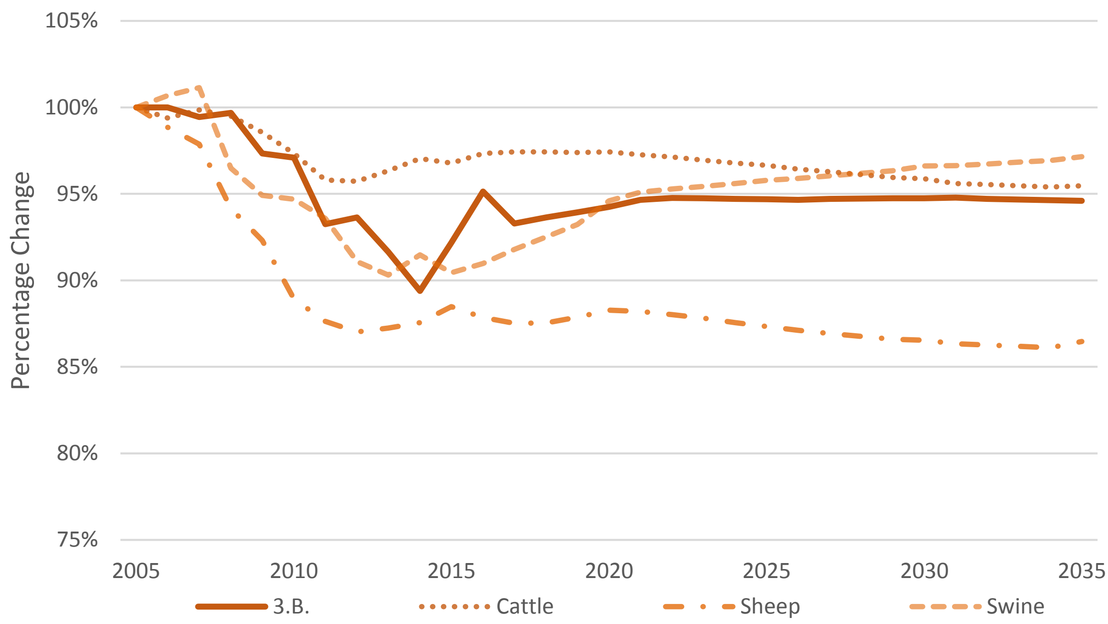


5.3 3B Manure management

The emissions from the second largest sub-sector 3B, is largely influenced by CH_4 emissions from the manure of cattle (47%) and swine (46% of the total CH_4 emissions in 3B in 2015), but also by N_2O emissions which occur during the storage of manure (anaerobic decomposition of manure). As for the sector 3A, the livestock numbers were taken into account for the analysis as this is the only agricultural parameter reported in projections by most Member States under the MMR.

The overall emissions trend shows a decrease of 5% in 2030 compared to 2005. As can be seen from **Figure 5.5**, the emissions trend follows the trend of the swine population which contribute almost half of the emissions in the sector. Between 2005 and 2030 the cattle and swine population is decreasing (by 4% and 3%, respectively). However, as can be seen from **Figure 5.2,** emissions were decreasing in the past, showing a change in the trend in recent years and slowly increasing until 2020, then remaining on a constant level below the levels of 2005. This follows a similar pattern to the development of the livestock. To make further conclusions it would be necessary to analyse the manure storage systems because these are very crucial for the emissions in this sector, but no information on this is available for the projections.

Figure 5.5 Relative changes of the main parameters (cattle, sheep and swine population) and development of the emissions (in kt CO_2) of sector 3B Manure management

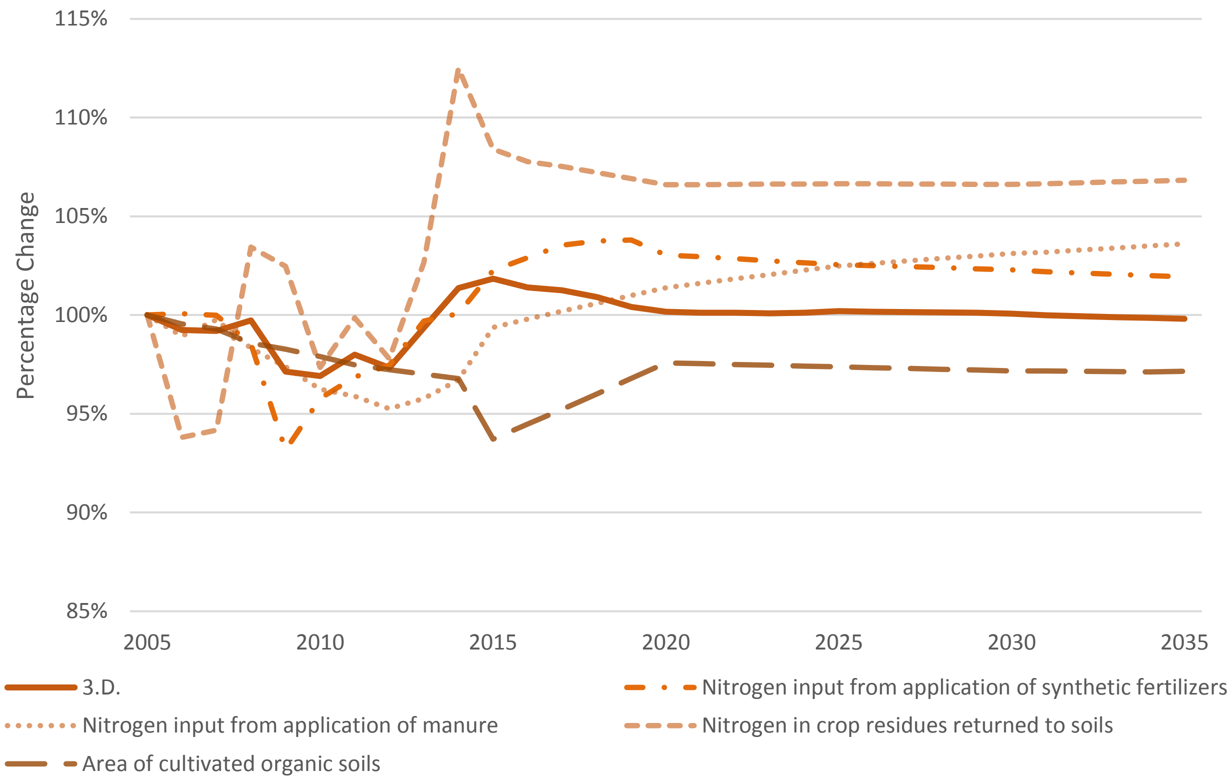


5.4 3D Agricultural soils

N_2O emissions from agricultural soils consist of direct emissions from the application of fertilisers and other soil input and of indirect emissions through atmospheric deposition, leaching and run-off. The largest contribution to direct N_2O emissions is from mineral fertilisers (39% of the emissions in 2015) and from organic fertilisers (18%). For indirect N_2O emissions, most emissions are due to nitrogen (N) from fertilisers and other agricultural inputs that are lost through leaching and run-off. **Figure 5.6** shows the development of the emissions and parameters available for the projections by most Member States.

Figure 5.6 shows that the amount of N input to soils from fertilisers, manure and crop residues slightly increases by 2030 compared to 2005, and that emissions remain constant. However, the trend is not stable in the historical data. Synthetic fertilisers, which are the largest N input to soils, first decreased and then increased from 2009 to 2020 followed by a slight decrease until 2030, which can be explained by an increased efficiency in the fertiliser use and measures that aim at reducing mineral fertilisers e.g. the Nitrates Directive (91/676/EEC). Manure application on the other hand is showing a similar trend until 2020, but is then projected to increase until 2030 which is in line with the increase of swine population. In addition, intensification measures can lead to higher N contents in the manure. N input from crop residues returned to soil has increased since 2005 and is projected to remain on the 2015 level by 2030. This parameter fluctuates annually depending on the harvest and weather conditions.

Figure 5.6 Relative changes of the main parameters (Nitrogen inputs from synthetic fertilisers, manure, crop residues and area of cultivated organic soils) and development of the emissions of sector 3D Agricultural soils



5.5 PaMs targeting emissions in the agriculture sector

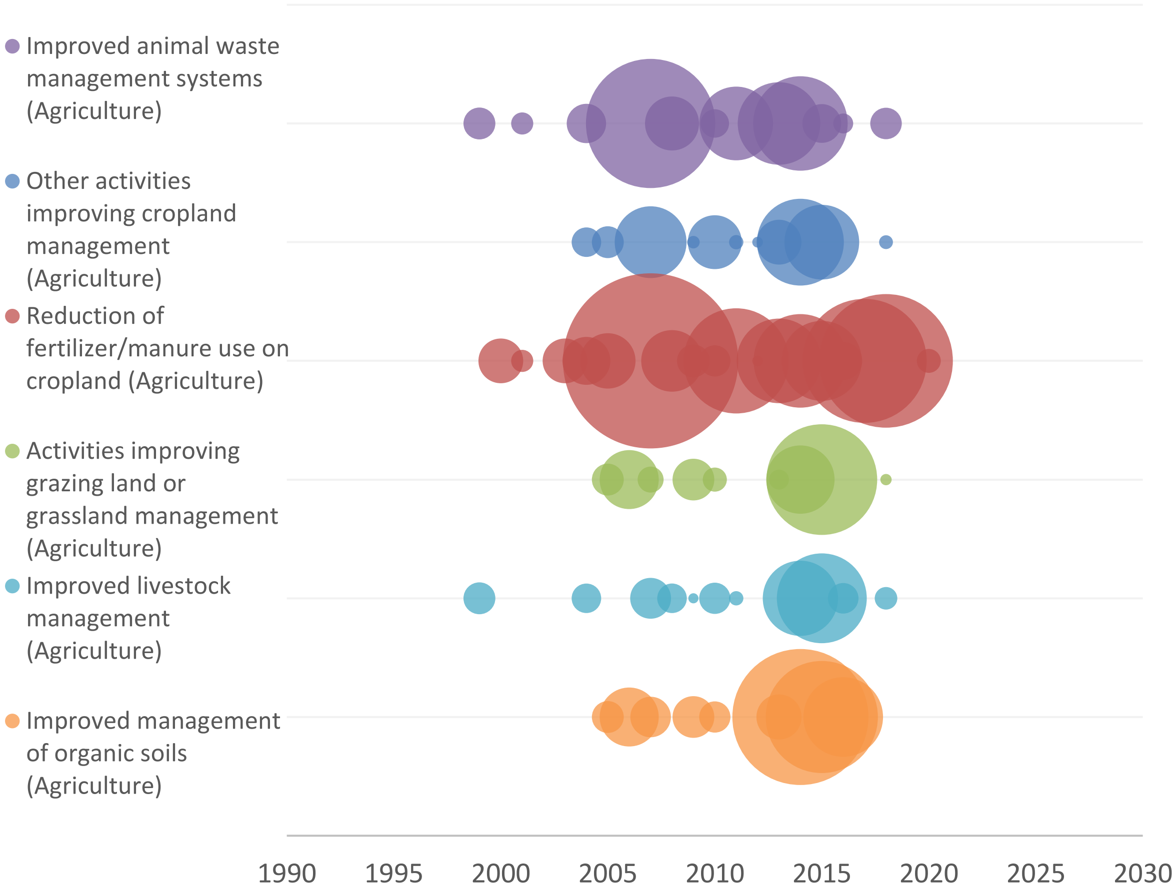
The CAP, the main policy in the agriculture sector, consists of several different sets of support measures targeting climate friendly agriculture. The CAP has been reformed several times, shifting to more market oriented measures and environmental protection introducing the "cross-compliance" which was implemented in the 2003 CAP-reform. Since then, direct payments are more strongly linked with the maintenance of agricultural land in good agricultural and environmental conditions. In 2013, the CAP was reformed again for the period 2014–2020, placing greater emphasis on the environment and climate friendly agriculture ("CAP greening"). Another important measure in the CAP is the abolition of the milk quota which ended in 2015 and is expected to have an impact on GHG emissions in this sector. In countries with high production capacities, it is expected that this will lead to a further increase in milk production and a likely increase in emissions, whereas, it will lead to decreases in other countries which have less capacity.

Regarding the emission trends as presented in previous sectors, it can be concluded that emission reductions due to reduced livestock numbers were partly compensated through intensification measures (e.g. of milk production). As can be seen from the WEM scenario projections, the overall EU trends in the agriculture sector are relatively stable. Therefore, direct effects of the CAP policy cannot be identified at this level and a deeper analysis would be necessary to provide further insight.

Another very important policy in the agriculture sector is the Nitrate Directive, which sets limits on nitrate concentrations in groundwater and therefore impacts on the application of manure and fertilisers to agricultural soils. This measure leads to a reduction of NH_3 and N_2O. However, as shown in **Figure 5.4**, emissions in this sector have remained stable.

In terms of national PaMs as reported by EU Member States it can be seen in **Figure 5.7** that the most relevant weighted objectives of agriculture PaMs focus at fertilizer use, animal waste, and organic soils. These objectives are strongly linked to the objectives of the PaMs previously described. A brief screening regarding the linkage of national PaMs to EU PaMs shows that the most referenced EU policy is the CAP to which 74 national PaMs refer, followed by the Nitrate Directive which is linked to 17 national PaMs. Some national agriculture PaMs were aligned with the ESD, the RES Directive and the Water Framework.

Figure 5.7 PaMs in the agriculture sector by year of implementation, shown by type for the period 1990 to 2030. The bubbles are sized according to the PaM weighting (see Annex II for methodology).



In general, the agriculture sector has been subject to deep structural changes, such as intensification, modernisation and restructuring seeing a transition from price and market support measures to direct support to farmers and more market oriented measures. Due to these complex and interlinked developments, it is challenging to align emission trends to certain measures. To achieve this, a more detailed analysis of the parameters and other underlying factors would be necessary.

6 Waste (5)

Key messages:

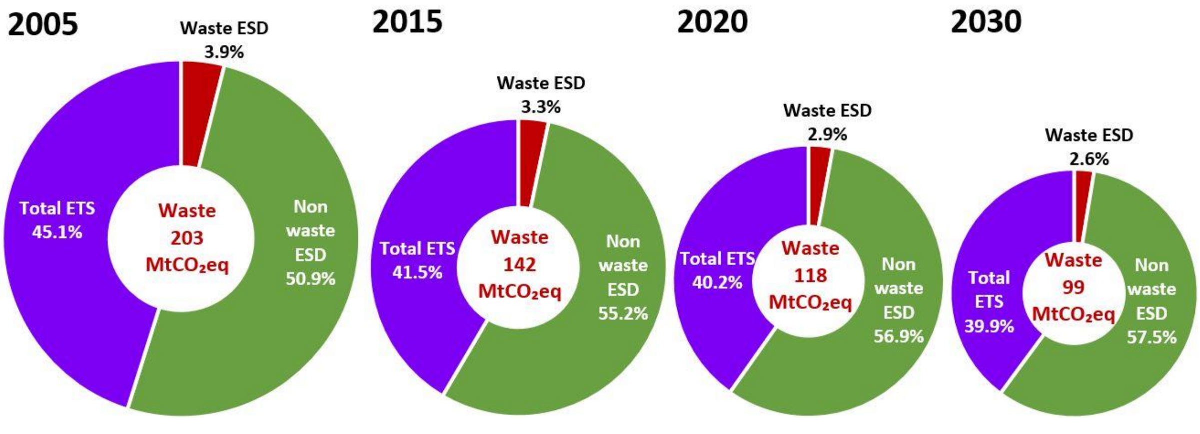
- In the EU, the largest decrease in emissions in relative terms occurred in the waste sector (over 40%, ~100 Mt CO_2eq reduction in 2015 compared to 1990). Within the current ESD time frame (2005–2030) annual emissions from the waste sector is projected to decline by 51% (104 Mt CO_2eq).
- The waste sector has been subject to significant changes over the past decades. For example, the overall amount of waste sent to landfilled declined strongly, other influential parameters such as GDP increased continuously, the population rose, but the ratio of waste generated per capita declined and is projected to further decline.
- Several PaMs were adopted in the last decades at EU level, which influence GHG emissions from the waste sector both directly and indirectly. A key policy in the waste sector is, amongst others, the Landfill Directive, which had substantial influence on the reduction of emissions in the sector.

6.1 Overview waste emissions

The waste sector can fully be attributed to the ESD sector. It consists of 5 sub-sectors: solid waste disposal (5A), wastewater treatment and discharge (5D), biological treatment of solid waste (5B), incineration and open burning of waste (5C) and other (5E).

The waste sector contributed 5.6% to the total EU–28 ESD emissions and 3.3% to the total EU–28 GHG emissions in year 2015. The share of the waste sector is projected to contribute 4.3% and 2.6% to ESD and total EU emissions in 2030, which would mean a decrease compared to 2015 by 1.3% and 0.7% respectively (**Figure 6.1**).

Figure 6.1 Percentage contributions of waste to EU GHG emissions 2005, 2015, 2020 and 2030. The circles are sized based on total waste GHG emissions which are shown in the centre of the circles.



Methane is the most important GHG in the waste sector contributing to approximately 90% of waste emissions in 2015, followed by N_2O (8%) and CO_2 (2%).

The largest decrease in EU emissions in relative terms occurred in the waste sector (over 40%, ~100 Mt CO_2eq reduction in 2015 compared to 1990), as shown in **Figures 6.1** and **6.2**. Within the current ESD time frame (2005–2030), the annual emissions from waste sector are projected to decline by 51% (104 Mt CO_2eq). Over the whole time series (1990–2035), this would amount to a decline of 150 Mt CO_2eq in the waste sector.

Figure 6.2 Emission development of the waste sector and its sub-sectors from 1990–2035 (inventory 1990–2014; projections from 2015–2035, WEM scenario)

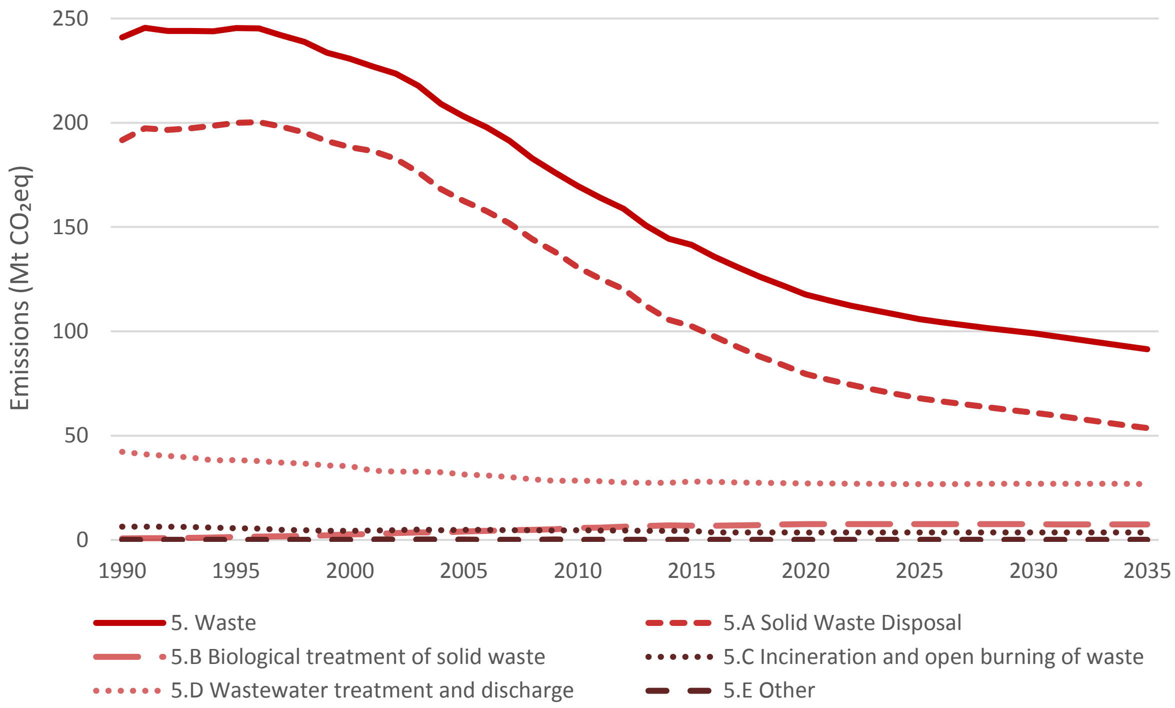


Figure 6.2 illustrates that solid waste disposal (5A) and wastewater treatment and discharge (5D) are the most important sub-sectors. They both are also key source categories in the EU GHG inventory[4]. The two sub-sectors cover 92.2% of the total waste emissions in the EU in 2015, of those 5A is the largest sub-sector causing 72.4% of the waste emissions followed by 5D with 19.8%. The other three sub-sectors, biological treatment of solid waste (5B), Incineration and open burning of waste (5C) and Other (5E), are combined responsible for 8% of the emissions in the waste sector in 2015. The share of solid waste disposal (5A) is projected to decline until 2030 and then amount to 61.6% of the total waste emissions. Conversely the share of wastewater treatment and discharge (5D) is projected to increase to 27.2%. Together they are projected to account for 88.8% of the emissions of the waste sector in 2030, which would be a decline of 3.4% compared to 2015 and 6.8% compared to the ESD base year in 2005. In the ESD time frame all sub-sectors are projected to decline apart from 5.B Biological treatment of solid waste, which is projected to increase.

[4] On the basis of data availability, sector 5D will not be described in detail in this report.

Figure 6.3 **Waterfall plot showing change in waste emissions 2005 to 2015, and projected change in ESD emission from 2015 to 2020 and 2020 to 2030 by Member State.**

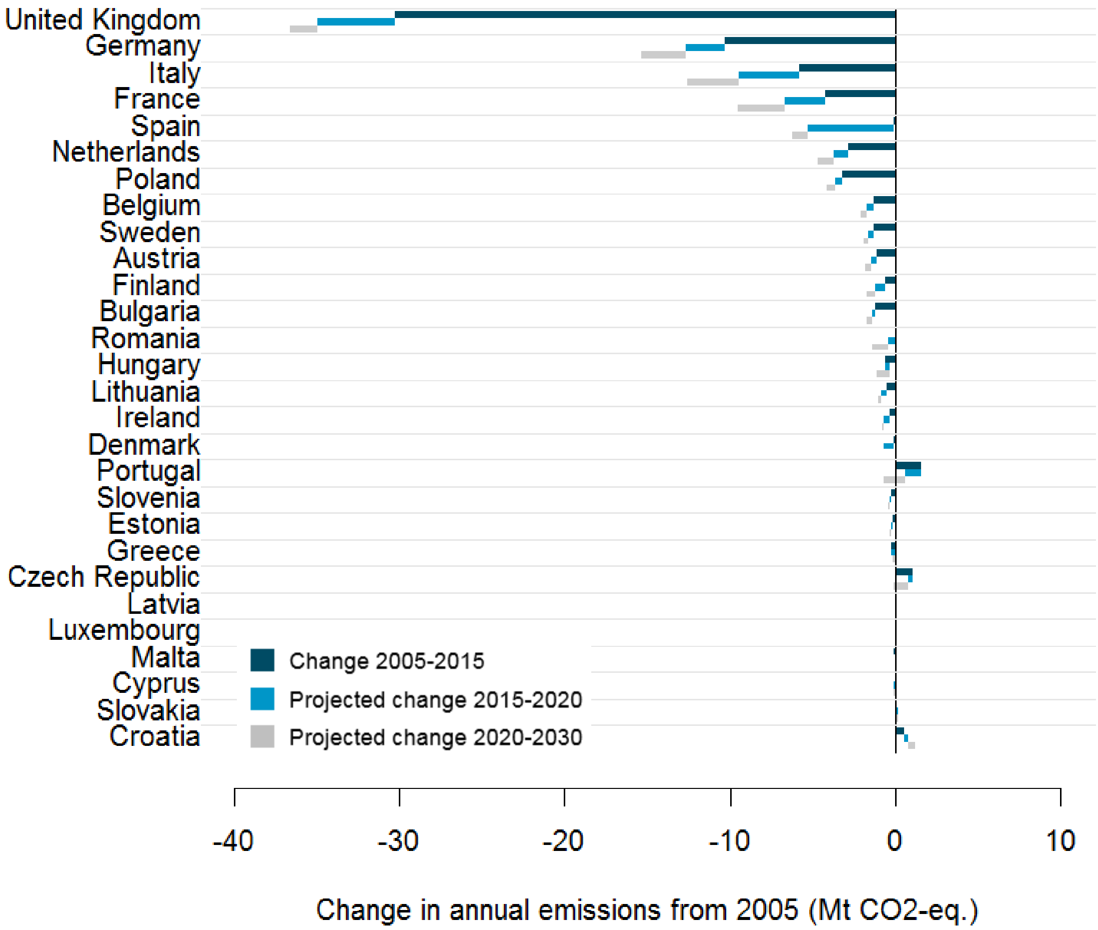


Figure 6.3 above illustrates which Member States are important for the overall EU trend. The largest emitting countries in 2015 are the United Kingdom, Italy and France (13.4%, 13.3% and 12.3% of the EU–28 Waste emissions in 2015, respectively). These countries are also the most influential Member States over the complete times series. The United Kingdom has the highest absolute decline between 1990 and 2030. It is projected to contribute 35% of the whole EU decrease within the ESD time frame (2005–2030). Germany had a share of 15.8% of the EU emissions in 1990, declined to 7.7% in 2015 and is projected to further decrease to 5.9% in 2030. 17 Member States show a declining trend between 1990 and 2015. In the ESD time frame 25 Member States are projected to have a declining trend. Only Croatia, Cyprus and Slovakia are projected to have an increasing trend between 2005 and 2030.

Solid Waste Disposal (5A)

Figure 6.4 shows the relative emission development of the sub-sector 5A solid waste disposal (SWD; solid line) in the EU–28 between 1990 and 2035 as well as the relative change of waste at SWD sites in the EU in kilo tonnes for the same time frame. The emission trend in SWD and the parameter trend follow very similar pathways. Emissions can be seen as interlinked with the actual amount of waste that is generated and landfilled at SWD sites. Therefore, this constitutes the most relevant parameter to be analysed. PaMs targeting the annual waste are also directly targeting SWD, and therefore the whole waste sector.

Figure 6.4 Relative emission development of the sub-sector 5A solid waste disposal in the EU Member States 1990–2035 and relative change of parameters: (1) waste at solid waste disposal sites (inventory activity data 'Annual waste at the SWDS' for 1990–2014; projections parameter 'Municipal solid waste (MSW) going to landfills' for 2015–2035; (2) Population and (3) GDP in billion Euro at 2010 prices)

Figure 6.4 illustrates the importance of the SWD sector (solid line) for the waste sector, by having almost the exact trend as the whole sector. As for total waste emissions, the United Kingdom, Italy and France have the highest share of emissions from SWD in the EU–28.

Other interlinked parameters which are influential with regard to waste emissions are the developments of the population, the GDP, and the ratio of waste generated per capita. These parameters are also shown in **Figure 6.4**. In absolute values, waste generation decreases from over 500 kg/capita in 1990, to 337 kg/capita in 2005, and is projected to further decline to 141 kg/capita in 2030. In contrast to this declining trend the population is increasing by 13% over the period 1990 until 2030 (5% within the ESD time frame). GDP is projected to continuously increase over the next decades. Within the ESD time frame (2005–2030) GDP is projected to increase by 40%. The GDP development shows a contrasting trend compared to the already achieved and projected emission decline.

6.2 PaMs in the Waste sector

In Europe waste management has a long history, with the first piece of legislation providing a framework published in 1975. Since then, several PaMs were adopted at the EU level, which influence GHG emissions from the waste sector both directly and indirectly.

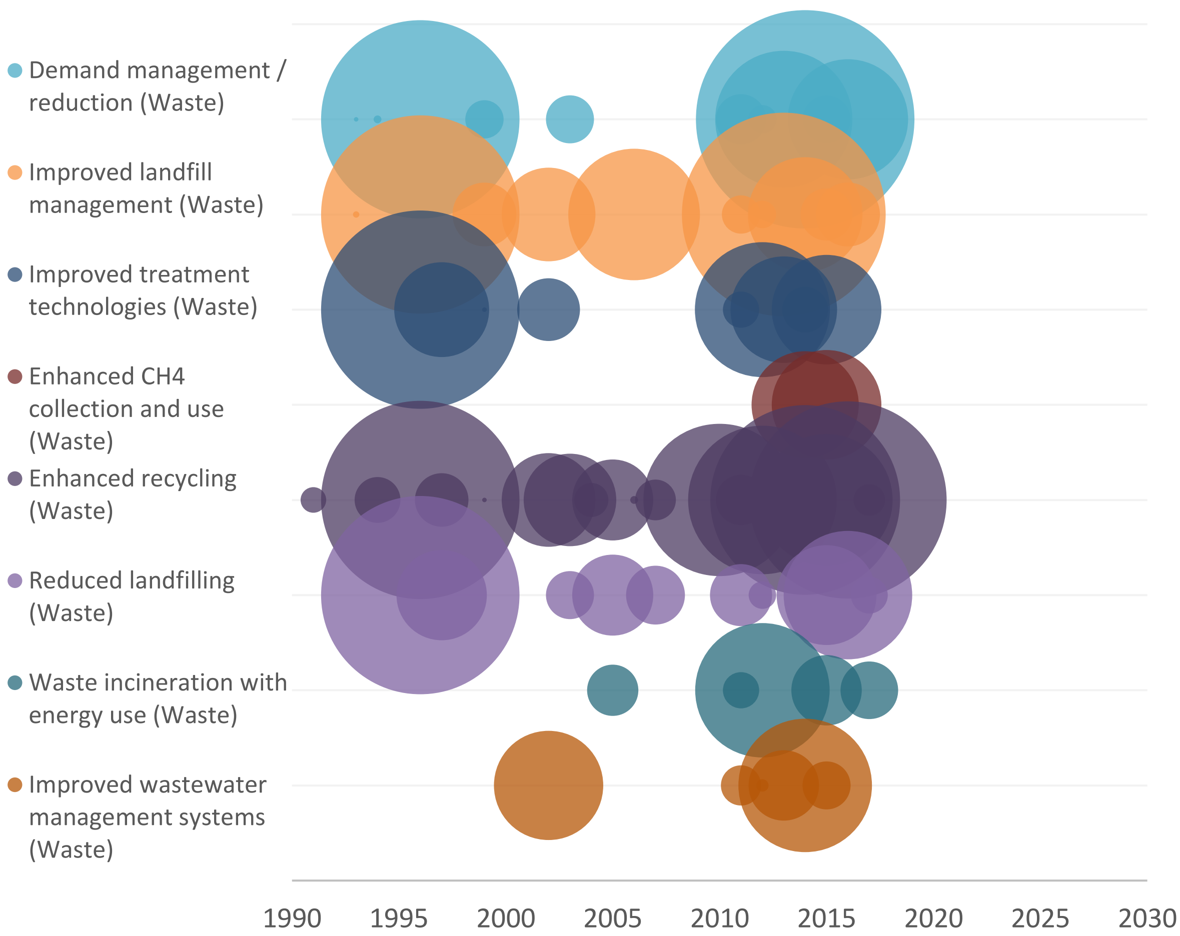
The main EU legislation potentially linked to GHG emissions from the waste sector are inter alia the Packaging and Packaging Waste Directive (1994), Landfill Directive (1999), Waste Incineration

Directive (2000), Eco-design Framework Directive (2005), Waste Directive (2006), Waste Framework Directive (2008), and the Directive on Waste of Electrical and Electronic Equipment (2012).

These PaMs affect GHG emissions by placing technical requirements on how waste is managed and treated; limiting landfilling waste by placing restrictions on the waste that can be managed at these landfill sites; assuring better waste management of packaging waste by way of recycling, treatment and incineration; regulating the collection, treatment and discharge of urban waste water as well as waste water from certain industrial sectors; targeting different waste streams and management of biodegradable waste as well as promoting eco-designed products.

In 2015, the EC presented a circular economy package which tries to go beyond traditional waste management by addressing the whole life cycle of resources and products, in order to close the loop.

Figure 6.5 PaMs in the waste sector by type for the period 1990 to 2030. The bubbles are sized according the PaM weighting (see Annex II for methodology).



In terms of national PaMs as reported by EU Member States it can be seen in **Figure 6.5** that the most relevant weighted objectives of waste PaMs focus on reduced landfilling, recycling, improved landfill management, methane collection and improved treatment technologies.

In summary, the waste sector was subject to significant changes over the past decades, such as the overall amount of waste that is landfilled declined strongly, even though other influential parameters like the GDP increased continuously, the population rose. This is reflected in the ratio of waste generated per capita which has declined substantially and is projected to decline further at the same rate. Amongst other factors this led to the largest decrease in emissions in relative terms in the EU between 1990 and 2015. These developments could be considered as an indicator that the PaMs are having effects as well as that economic growth and waste emissions are decoupling. But due to the aforementioned, as well as other unmentioned, complex societal developments, it is challenging to assert emission trends to certain PaMs, as all is interlinked and a more detailed analysis of the parameters and other underlying factors would be necessary.

7 Industry (Sectors mainly covered by ETS)

Key messages:

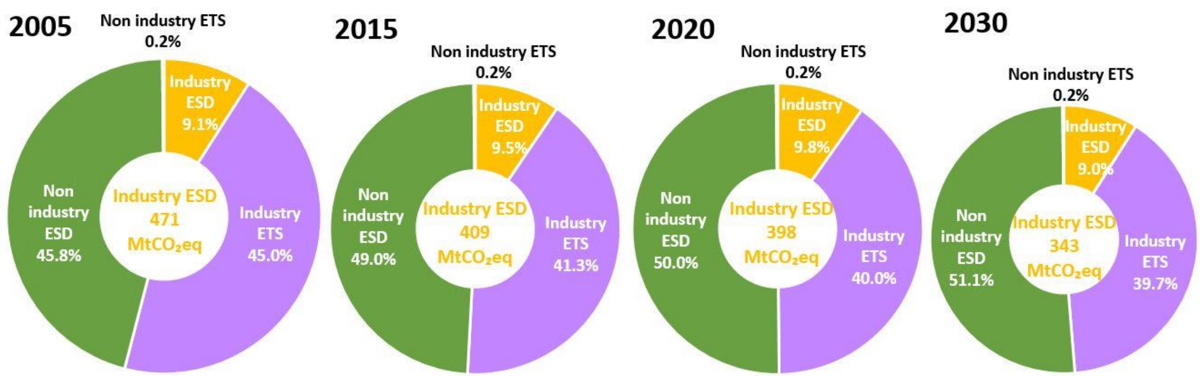
- The sector "industry" aggregates sectors which although mainly covered by the EU ETS contain emissions from smaller activities. These sectors are Energy Industries (1A1, 1B and 1C), Manufacturing and Construction (1A2) and Industrial processes (2).
- At the level of total EU emissions, ETS emissions are decreasing at a rate which is approximately twice as high as for emissions covered under the ESD. For the group of sectors covered under "Industry", the future rate of ETS and ESD reductions is heterogeneous.
- In the sectors of Manufacturing and Construction and Industrial Processes, ESD emissions are projected to decrease at a faster rate than under the ETS.
- Especially in the sector of industrial processes, ETS emissions are projected to increase, whereas ESD emissions are projected to decrease considerably. This is due to a high amount of PaMs targeting emissions of F-gases, which are mainly located under the ESD sector.

7.1 *Overview industry ESD emissions*

The sector "industry" in ESD sectors aggregates ESD emissions from the sector "Energy Industries", covering CRF sub-categories 1A1, 1B and 1C, "Manufacturing and construction", CRF category 1A2, and "Industrial Processes", CRF category 2.

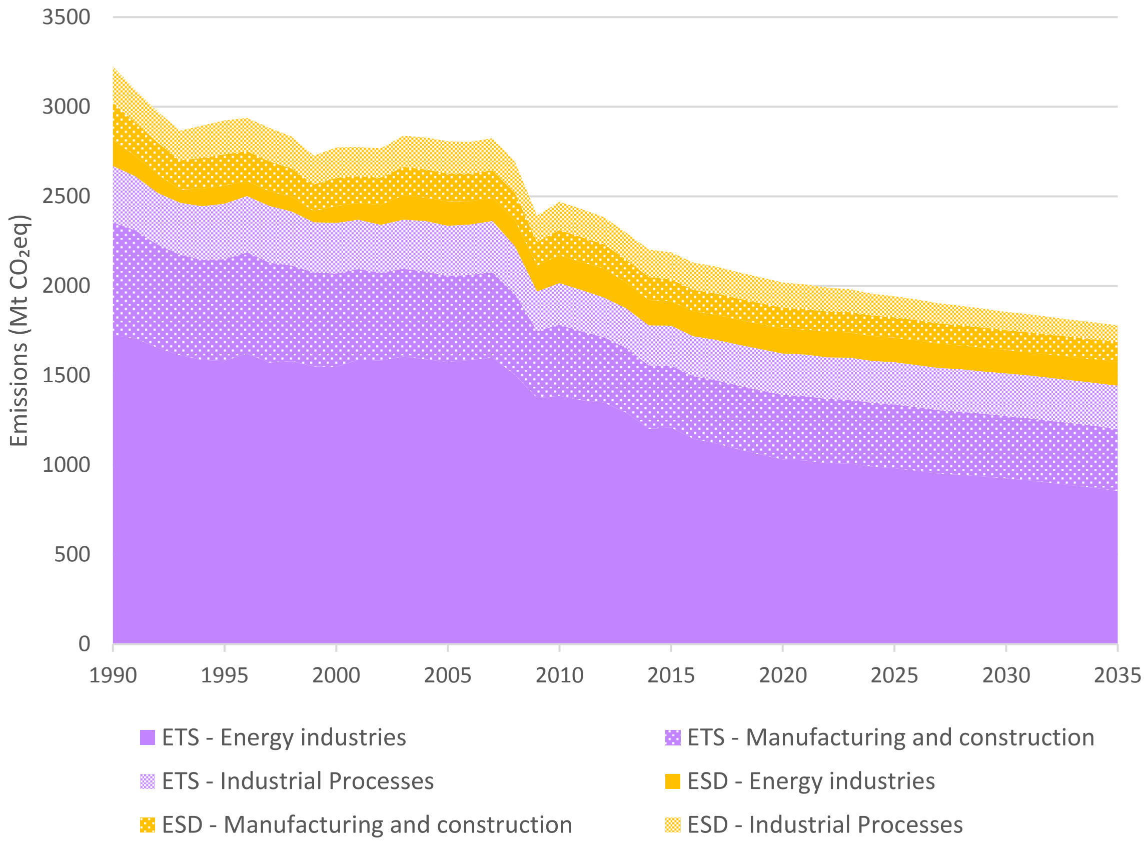
Emissions for this group of categories are mainly covered under the ETS. This is shown in **Figure 7.1**, where the small share of emissions covered under the ESD is highlighted. The share of this sector in ESD emissions remains about constant until 2030.

Figure 7.1 Percentage contributions of industry to EU GHG emissions 2015, 2020 and 2030 split by ESD and ETS. The circles are sized based on total industry GHG emissions which are shown in the centre of the circles.



In the Energy Industries sector, more than 90% of emissions are covered by the EU ETS, approximately 75% in the manufacturing and construction sector and 60–72% in the Industrial Processes sector. These ETS shares are relatively constant for energy sectors, whereas the ETS share for Industrial Process emissions shows a strong increase in GHG projections of Member States from 2020. This results from decreasing ESD emissions in this sector (**Figure 7.2**).

Figure 7.2 ETS splits in CRF-categories covered under "industry" (WEM scenario)



Overall, a clear trend of decreasing emissions can be observed in the sector "industry" from 2005 to 2035. The decrease is mainly driven by emission reductions under the EU ETS in the Energy Industries Sector, but ESD emissions of this group of sectors are also decreasing (see **Figure 1.4**).

Comparison of developments under the EU ETS and ESD

To understand the development of ESD emissions in the sector of "industry", developments under the ETS must also be considered. **Table 1.1** shows total GHG emission reductions between 2015 and 2035 split into emission reduction in ETS and ESD, based on GHG projections for the EU–28.

At the total level, ETS emissions are decreasing at a rate which is approximately twice as high as for emissions covered under the ESD. In contrast, for the sector "industry", the rate of ETS and ESD reductions is comparable (19 and 18%, respectively). For the three sub-sectors, very different developments can be observed:

- For the **energy industries** sector, the reduction in ETS emissions (-29% compared to ETS emissions in 2015) is much higher than in ESD emissions (-2% compared to ESD emissions in 2015). With ETS splits above 90%, the development in total GHG emissions is strongly dominated by the trend in ETS emissions (-26% compared to total emissions in 2015).
- For the **manufacturing and construction** sector, ETS emissions are about constant between 2015 and 2035, whereas ESD emissions are projected to decrease by 10%. Total GHG emissions

show a decrease of 3%. Up to 2035, the ETS split slightly increases, due to higher reductions in ESD sectors.

- For the **industrial processes** sector, an increase of ETS emissions of 8% is projected, whereas ESD emissions are projected to decrease by 38%. In total, this results in a decrease of 10% between the years 2015 and 2035, driven by decreases in ESD emissions.

For the WAM scenario, additional reductions in ETS emissions are again higher than those of ESD emissions (see **Table 7.1**). It is clear that there are no strong additional measures targeting ETS emissions in Industrial processes, whereas emission reductions show a considerable additional reduction in ETS emissions of Energy industries due to additional measures.

Developments in Member States

Figure 7.3 presents development of ESD emissions in the industry sectors by Member State. The highest absolute reductions until 2030 are seen for the United Kingdom, Spain, Italy and France. All four countries also show highest historical emission reductions between 2005 and 2015.

Figure 7.3 Waterfall plot showing change in ESD industry emissions 2005 to 2015, and projected change in ESD emission from 2015 to 2020 and 2020 to 2030 by Member State.

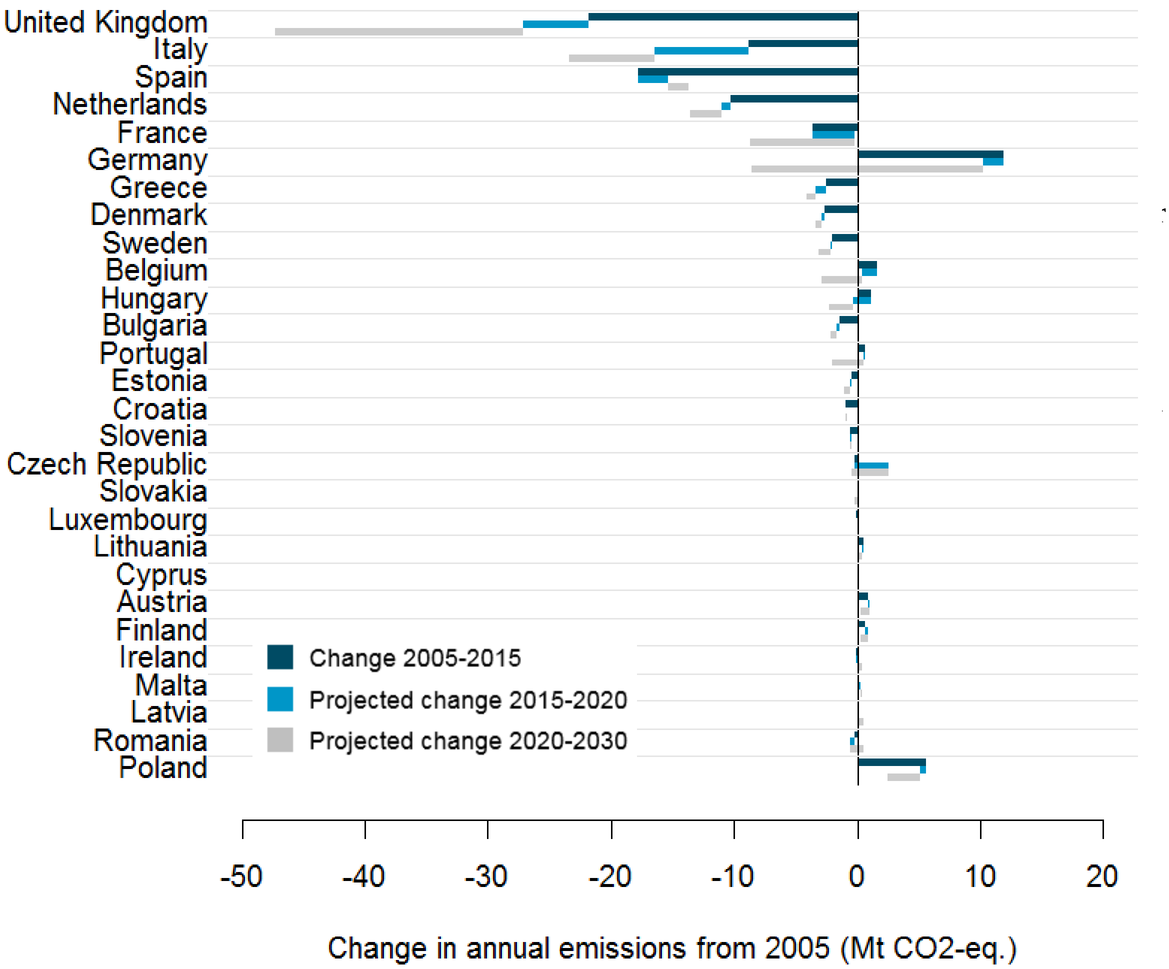
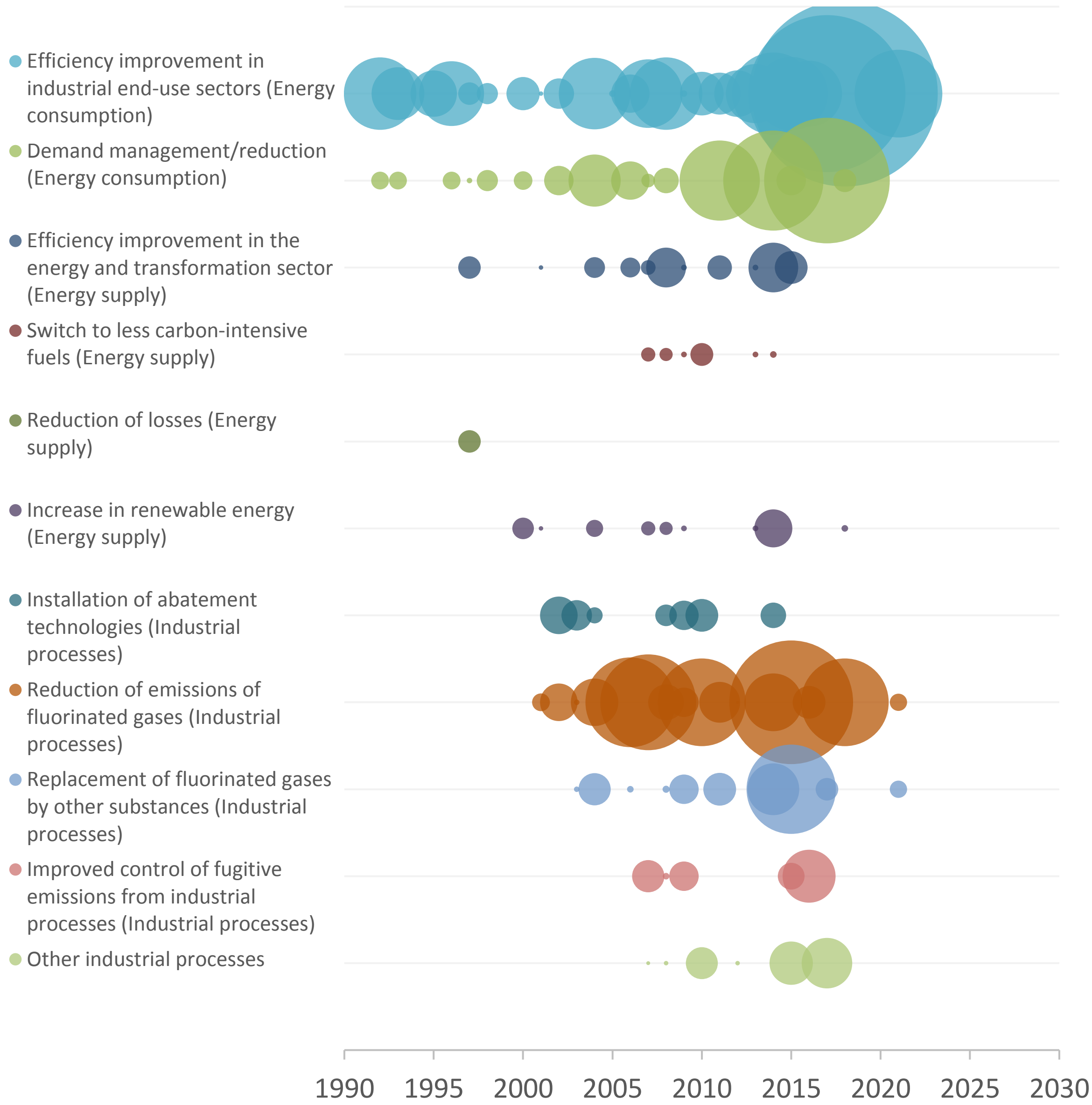


Figure 7.4 PaMs in the industry sectors (covered by ETS and ESD) by year of implementation, shown by type for the period 1990 to 2030. The bubbles are sized according the PaM weighting (see Annex II for methodology).



In general, it is very difficult to differentiate effects of PaMs into reductions of ETS or ESD emissions if only the highest sectoral level of these industrial sectors are considered. In addition, there is no clear separation of ETS and ESD emissions for historical years in these sectors. PaMs shown above are reducing emissions covered under the ETS, the ESD or emissions of both schemes. These complexities both on the reporting side from Member States and the process of analysis, must be considered here. To better understand the effects of PaMs on this group of industrial sectors, ESD emissions are assessed at the sub-sectoral level:

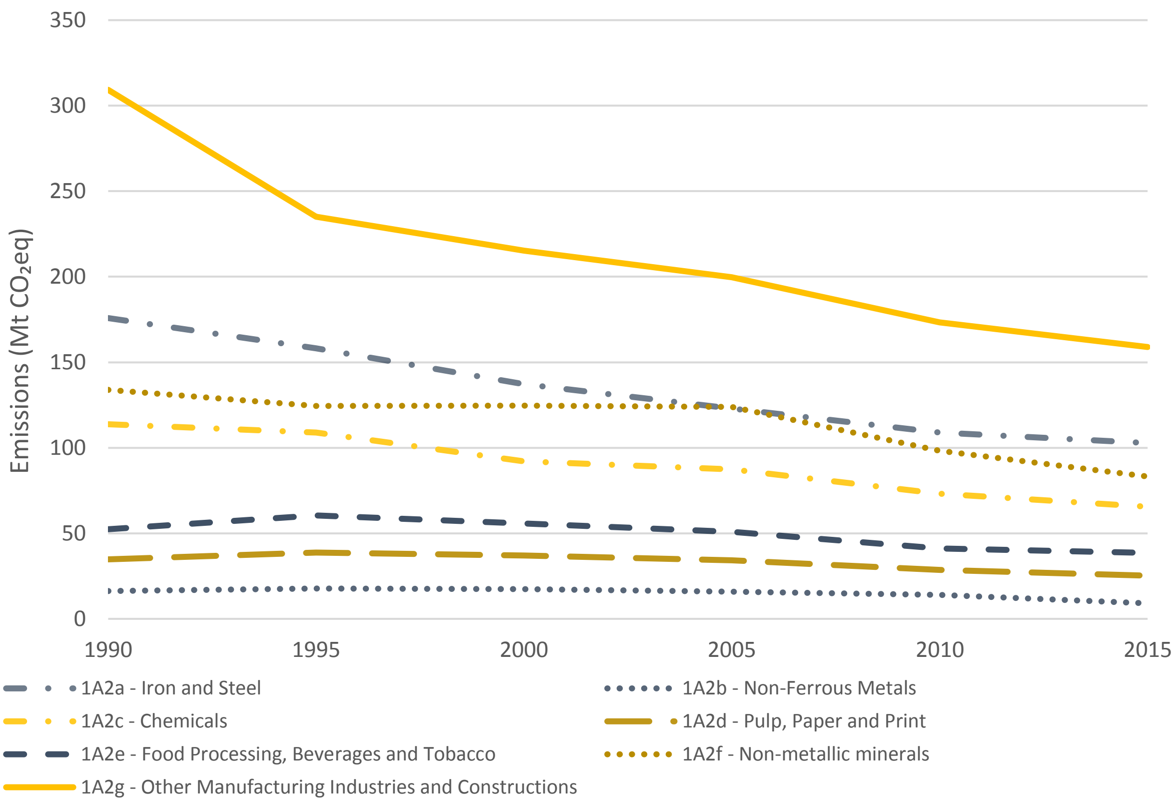
Energy Industries

In the energy industry sectors, the increased use of renewables for electricity generation and future fuel switches are particularly relevant for the projected reduction of emissions. In addition, measures to increase energy efficiency are lowering the electricity demand. As explained above, this sector is mainly covered under the ETS. Due to this, PaMs directly targeting ESD emissions in this sector are rare, which is reflected in the lower reduction rate for ESD emissions.

Manufacturing and Construction

To better understand this sector, a first overview is given on sub-sectors covered and their historical emission trends. These are shown in **Figure 7.5**. In all sub-sectors, decreasing trends are observed since 1995.

Figure 7.5 Historical GHG emissions in Sector 1A2 – Manufacturing and Construction by sub-categories



The allocation of ETS emissions to this sector is very demanding, since the categorisation of ETS information follows different rules for sectoral allocation than those for GHG inventories. This is one reason why the information collected from Member States reporting to Annex V under the Implementing Regulation (No 749/2014) is not always reliable. ETS splits vary widely for this sector and its sub-sectors.

Member State projections are not consistently reported down to the level of sub-categories and gap filling from the ETC is only conducted for main source categories. Therefore, sub-sectoral trends are not considered here at the EU-level and no clear trend can be identified.

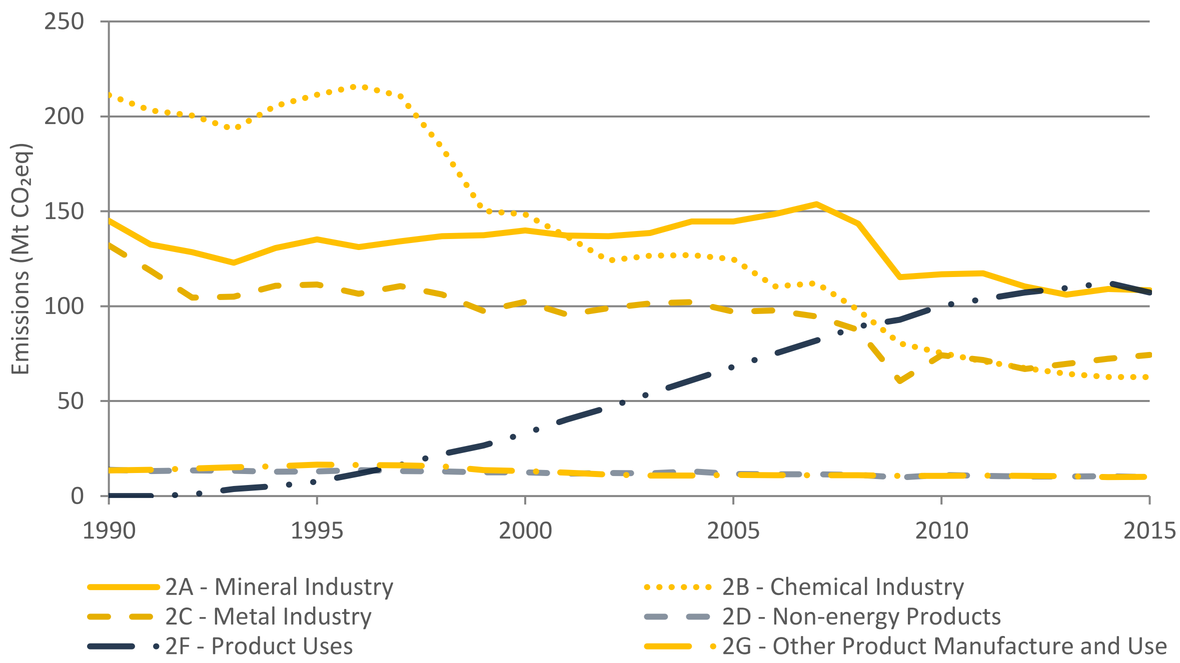
Most the sub-sectors are considerably affected by economic assumptions. Industrial parameters have only been reported by some Member States and were not quality checked. With increasing GDP values in every Member State projection, a general increase of emissions in this sector can be assumed. This would be the explanation of the small decrease of ETS emissions in this sector – in parallel to the increase of ETS emissions in the sector of Industrial Processes.

Following this analysis, the decrease of ESD emissions in this sector cannot be directly linked to reporting of PaMs by Member States. It can be assumed that this decrease is mainly driven by cross-sectoral measures and those aiming to reduce energy consumption.

Industrial Processes

An overview of sub-sectors covered under this sector and their historical emission trends is presented in **Figure 7.6**. Sub-sectors 2E (Electronic industry) and 2H (Other) are not relevant at the EU level because annual emissions are below 1 Mt CO_2 eq. In addition, sub-sectors 2D and 2G are also less relevant, as their emissions are consistently below 15 Mt CO_2 eq. A considerable increasing trend can be seen for sub-sector 2F (Product Use), in which emissions of F-gases are located. A linear decreasing trend can be seen for sub-sector 2B (Chemical Industry). In addition, decreasing trends are visible for sub-sectors 2A (Mineral Industry) and 2C (Metal industry).

Figure 7.6 Historical GHG emissions in Sector 2 – Industrial Processes by sub-category



ETS emissions only occur in sectors 2A, 2B and 2C. Under the ETS, mainly CO_2 emissions are covered. In addition, N_2O emissions are covered in sector 2B (Nitric Acid, Adipic Acid and Caprolactam, glyoxal and glyoxylic acid production) and PFC emissions from 2C (Aluminium production). **Table 7.1** clearly shows that the amount of non-CO_2 gases is not relevant at the EU-level.

Following the reporting from Member States in Annex V under the Implementing Regulation (No 749/2014), 73%, 56% and 86% of emissions from sector 2A, 2B and 2C are located under the ETS, respectively (**Table 7.1**).

Table 7.1 ETS emissions in the sector of Industrial Processes in the year 2015

Sector		ETS emissions from Annex V	Total GHG from inventory	ETS split
		kt CO_2eq		%
2A	Mineral Industry	79,507	108,442	73
2B	Chemical Industry	35,139	62,681	56
	CO_2	30,429		
	N_2O	4,710		
2C	Metal Industry	64,219	74,298	86
	CO_2	63,994		
	PFC	225		

Member State projections are not consistently reported down to the level of sub-categories and gap filling from ETC is only conducted for main source categories. This means that sub-sectoral trends cannot be considered at an EU-level.

Process emissions are often related to the production process with a relatively fixed rate between products and emissions due to stoichiometric relations, which cannot be improved. Only for some processes, fuel switches or changes in process types are reduction possibilities. With this, the sub-sectors 2A, 2B and 2C, with high shares of ETS emissions, are considerably affected by economic assumptions, similar to emissions in manufacturing and construction (1A2). Industrial parameters have only been reported by some Member States and weren't quality checked. With increasing GDP values in every Member State projection, a general increase of industrial production in these sectors can be assumed. This would explain the observed increase of ETS emissions in the sector of Industrial Processes.

Looking at reported PaMs from Member States for the sector of Industrial Processes, it is clear that these are mainly targeting F-gases which are located in subsector 2F located under the ESD. Of 38 PaMs reported for this sector, 35 are aimed at the reduction of F-gases in WEM scenarios, and 9 PaMs of 12 in WAM scenarios. This explains the high decrease of ESD emissions in this sector, which drives emissions down with regard to total GHG emissions and aims to halt the increasing emission trend of this subsector observed in **Figure 7.6**.

8 Recommendations for future work

Future work on the analysis of ESD trends should focus on:

1) Gathering of more detailed data and analysis on the impacts of PaMs on the trends vs other factors (GDP, population, temperature etc). Analysis should also look into the structural changes in industry and agriculture in Europe and whether this has had an impact on trends.
2) More detailed analysis of the types and classifications of PaMs is needed. A system to categorise PaMs for alignment with analysis of sectoral trends would be useful.
3) Improved quantification of the ex-post and ex-ante savings by Member States would help to provide more quantitative analysis of PaMs impacts. This would provide a better and more reliable analysis of the importance of PaMs, replacing the qualitative PaMs weighting undertaken for this report.
4) Improved linking of climate PaMs to PaMs for sectoral development (transport, agriculture, residential, energy would improve the ability to link ESD analysis to other strategic actions being implemented in Europe.

9 Summary

The ESD establishes binding annual GHG emission targets for EU Member States for the period 2013–2020. It covers a diverse range of sectors and activities; road transport, energy consumption in buildings, industry, agriculture and waste management. This report presents a trend analysis of historic and future anthropogenic GHG emissions comprised from the most significant sectors covered by the ESD. Sector specific PaMs have been considered to attempt to explain the historic and projected emission trends.

9.1 Main findings:

In 2016, total net GHG emissions ESD + ETS + LULUCF were estimated to be 27% lower than 1990 levels. The latest national projections (EEA, 2017a) indicate that EU GHG emissions will **remain on track to meet the 20% reduction** (compared to 1990 levels) by 2020 target set out in the 2020 climate and energy package[5]. Emissions covered under the **ESD contributed to approximately 50% of emissions** and removals from GHGs from the EU-28 in 2015.

The pace of GHG emission reductions is projected to slow after 2020. Whilst population and GDP are projected to increase at the EU-28 level. The rate of reduction (2015–2035) is projected to be half that of the change in emissions experienced for 2005–2015. At the current rate the EU's efforts will not be sufficient to achieve the EU's target of a 40% reduction by 2030 (compared with 1990 levels). Much faster rates of GHG emission decreases are necessary to achieve an 80%, or even a 95%, decrease by 2050, even if the 2030 target is met.

Factors influencing trends include those driving production and consumption such as the growth in GDP and population increase which will put pressure on any emissions reduction efforts. **Energy prices** have an impact on driving down emissions under the correct market environment. Prices can encourage the switch to less carbon intensive fuels and renewables. The large industry (ETS) sectors react more quickly to these influences as they have strong incentives to ensure that their operations remain economically viable and secure. For **the ESD sectors** conflicts exist that hamper market-based mechanisms. These include the need to ensure people have access to essential transport, food and heating/cooling and behavioural and lifestyle trends (e.g. driving rather than using public transport and the extensive use of energy for comfort and pleasure activities and electronics in the home). **Fuel switching to lower carbon fuels and renewables has increased.** Many large ETS consumers have invested in the switch to lower carbon fuels (e.g. natural gas) and renewables. This has been as a result of price differences and potential risks to security of supply. In comparison, for **ESD sectors** fuel switching has taken more time. Switching requires collective and rather substantial investment (e.g. development of gas networks, electric vehicles, cheap reliable solar technology or biofuel supply). There is an increasing trend towards **electrification** in the **ESD sectors**. This will shift the burden of energy "generation" further into the **ETS domain** unless the ESD sectors generate their own electricity using renewables such as wind and solar or small district heating plant using fossil fuels or biomass that are not big enough to qualify for EU ETS. A straight switch to using grid electricity will reduce the apparent emissions from ESD sectors and put more demand on the EU ETS sectors to produce clean electricity. Where energy is used for heating and cooling there is a strong correlation between energy production (and associated emissions) and **temperature**. This will have an impact in the residential sector (ESD) and to some extent in the electricity generation (ETS) sector.

[5] https://ec.europa.eu/clima/policies/strategies/2020_en

9.2 Transport (1A3)

The transport sector is projected to contribute to approximately 35% of ESD emissions between 2015–2030. Emissions steadily increased up to 2007 due to increased road transport demand. However, between 2015 and 2035 emissions are projected to remain relatively constant, despite efforts to increase fuel efficiency. Road transport is expected to be the main contributor to the projected reductions in ESD emissions. This is primarily due to the European Regulations to limit CO_2 emissions from new cars and vans sold in Europe. The reductions however are somewhat counterbalanced by the gap between officially reported and real-world CO_2 emissions from cars and vans. In the future, stricter legislation is expected to reduce the gap between reported and real-world emissions. The main PaMs for reducing emissions are national policies to promote energy efficient vehicles and fuels.

9.3 Residential and Commercial (1A4 & 1A5)

Emissions from the residential and commercial sector are reducing at a faster rate than total ESD emissions, and therefore the contribution of ESD residential and commercial emissions to total ESD emissions is expected to decrease. The current rate of emissions reduction, approximately 2% per year, is expected to half by 2035. The residential subsector has the greatest contribution to GHG emissions in this sector. Emissions from the residential sector are decreasing despite the trend of increasing population size at the EU-28 level, both in the past and in the future. This reduction in emissions is achieved through increasing the energy efficiency of buildings, switch to RES for heating and cooling and switches to less carbon intensive fuels. The main driver for emissions is heat demand, resulting in annual fluctuations in emissions. Therefore, the long-term downward trend in emissions is also linked to increasing average temperatures across Europe. The introduction of PaMs does not appear to have influenced the rate of emission reductions from this sector.

9.4 Agriculture (3)

Total emissions from agriculture show a slight decrease (-2%) in 2030 compared to 2005 levels, the smallest reduction of all sectors. The two largest sub-sectors, enteric fermentation and manure management, are projected to decline by 4% and 5% respectively, whereas the trend for sector agricultural soils remains relatively constant. Emissions from enteric fermentation, manure management and agriculture soils are dominated by animal stock and fertiliser application. In the past, the agriculture sector was subject to deep structural changes which were strongly linked to the key policy in the agriculture sector, namely the CAP. The CAP includes many measures that have direct or indirect influence on the emissions in this sector and triggered a transformation of the sector. The second most relevant policy is the Nitrate Directive which affects the nitrogen input to soils. Structural changes in the agriculture sector, such as intensification, modernisation and restructuring, a transition from price and market support measures to direct support to farmers and more market oriented measures, makes it difficult to assess the impact of individual PaMs. Overall, animal stocks are predicted to decrease; however, emissions are projected to remain relatively stable. This is assumed to be due to reduced livestock numbers being compensated through intensification measures.

9.5 Waste (5)

In the EU, the largest decrease in emissions in relative terms occurred in the waste sector (over 40%, ~100 Mt CO_2eq reduction in 2015 compared to 1990). Within the current ESD time frame (2005–2030), annual emissions from the waste sector are projected to decline by 51%. Despite increase in GDP and population, the ratio of waste generated per capita declined sufficiently to result in a reduction in emissions, and is expected to further decline in the future. Other significant changes include a reduction in the amount of waste that is sent to landfill. Several PaMs were adopted in the last decades at EU level, which influence GHG emissions from the waste sector both directly and indirectly. A key policy in the waste sector is, amongst others, the Landfill Directive, which had substantial influence on the reduction of emissions in the sector. Between 1990 and 2020, Member States have reported many PaMs linked to waste demand management/reduction, improved landfill management, improved treatment technologies, enhanced recycling and reduced landfilling.

9.6 Industry (1A1, 1B, 1C, 1A2, 2A – 2E)

The sector "industry" aggregates sectors which are mainly covered by the EU ETS. These sectors are Energy Industries (1A1, 1B and 1C), Manufacturing and Construction (1A2) and Industrial processes (2). However, industry still results in a significant proportion of the total ESD emissions (9% in 2015). In order to assess the trends in industry ESD emissions, the ETS component must also be considered. At the total level, ETS emissions are decreasing at a rate which is approximately twice as high as for emissions covered under the ESD. However, in the Manufacturing and Construction and Industrial Processes sectors, ESD emissions are projected to decrease at a faster rate than under the ETS. This is due to a high amount of PaMs targeting emissions of F-gases, which are mainly located under the ESD sector. In contrast, in the Energy Industries, fewer emissions are covered by the ESD compared to the ETS, and therefore PaMs seldom target ESD emissions.

References

AEA, 2012, Next phase of the European Climate Change Programme: Analysis of Member States actions to implement the Effort Sharing Decision and options for further communitywide measures. Appendix 1: Greenhouse gas emissions projections, emissions limits and abatement potential in ESD sectors. Available from: https://ec.europa.eu/clima/sites/clima/files/effort/docs/esd_emissions_projections_en.pdf Accessed 02/10/2017

EC, 2017a, *2020 climate & energy package – Climate Action – European Commission*. [online] Available at: https://ec.europa.eu/clima/policies/strategies/2020_en#tab-0-0 Accessed 26/09/17

EC, 2017b, Report from the Commission to the European Parliament and the Council. 2016 assessment of the progress made by Member States in 2014 towards the national energy efficiency targets for 2020 and towards the implementation of the Energy Efficiency Directive 2012/27/EU as required by Article 24 (3) of the Energy Efficiency Directive 2012/27/EU. Available from: https://ec.europa.eu/commission/sites/beta-political/files/report-energy-efficiency-progress_en.pdf Accessed 02/01/2017

EEA, 2011, Greenhouse gas emissions in Europe: a retrospective trend analysis for the period 1990–2008, *EEA Report No 6/2011.* Available from: https://www.eea.europa.eu/publications/ghg-retrospective-trend-analysis-1990-2008 Accessed 25/08/2017

EEA, 2017a publication pending, Trends and projections in Europe 2017 – Tracking progress towards Europe's climate and energy targets *EEA Report No 17/2017*. Available from: https://www.eea.europa.eu/publications/trends-and-projections-in-europe-2017 Accessed 02/02/2018

EEA,2017b, Renewable energy in Europe 2017: recent growth and knock-on effects *EEA Report No 3/2017*. Available from: https://www.eea.europa.eu/themes/climate/trends-and-projections-in-europe Accessed 02/10/2017

EEA, 2017c, Analysis of key trends and drivers in greenhouse gas emissions in the EU between 1990 and 2015. EEA report no 8/2017. Available at: https://www.eea.europa.eu/publications/analysis-of-key-trends-and Accessed 10 Oct. 2017

EEA, 2017d, Assessment of Member States' 2017 GHG projections

ETC/ACM Technical Paper 2017/8. Available at: http://acm.eionet.europa.eu/reports/ETCACM_TP_2017_8_assess_EU_GHGproj Accessed 02/02/2018

EU, 2009a, Decision No 406/2009/EC of the European Parliament and of the Council of 23 April 2009 on the effort of Member States to reduce their greenhouse gas emissions to meet the Community's greenhouse gas emission reduction commitments up to 2020 (OJ L 140,

05.06.2009, p. 136) (http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0136:0148:EN:PDF) Accessed 26/09/2017.

EU, 2009b, Directive 2009/29/EC of the European Parliament and of the Council of 23 April 2009 amending Directive 2003/87/EC so as to improve and extend the greenhouse gas emission allowance trading scheme of the Community (OJ L 140, 05.06.2009, p. 63) (http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0063:0087:en:PDF) Accessed 07/09/17

EU, 2013, Regulation (EU) No 525/2013 of the European Parliament and of the Council of 21 May 2013 on a mechanism for monitoring and reporting greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change and repealing Decision No 280/2004/EC (2013/162/EU) (OJ L 165, 18.06.2013, p.13). Available from: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013R0525&from=EN Accessed 25/09/2017

Annex I ESD Projection Comparison

A1.1 Introduction

This section compares ESD emissions projected by Member States in 2017 with ESD emissions projected by Member States in 2015 or 2016[6] (referred to as *2015_16* below) to provide insights into where most significant changes took place and how this impacts the EU-28 aggregate.

The analysis of the changes takes the following approach to determine differences in ESD emissions between the two submissions:

$$\text{Difference (\%)} = \frac{(\text{ESD emission projected in 2017} - \text{ESD emissions projected in 2015\_16})}{\text{ESD emission projected in 2017}}$$

Thus, positive values indicate that ESD emissions from the 2017 submission are larger than those projected in the *2015_16* submission. The results of the analysis are documented in a series of "heat-maps" below.

The sectoral coverage is:

- Total ESD emissions
- Buildings ESD emissions (1A4 & 1A5)
- Transport ESD emissions
- Agriculture ESD emissions

The sector analysis is accomplished to highlight how changes in total ESD emissions come about. The analysis considers the results of the WEM scenario and the projected values for the period 2015–2035 at 5-year intervals, i.e. covering mandatory reporting years.

A1.2 Results

Total ESD Emissions

Table A1.1 shows the development of the difference in total projected ESD emissions between Member States' 2017 submission and their *2015_16* submission in percent. The most significant differences are highlighted for the years 2020 and 2030 in Figures A1.1 and A1.2, and summarised as follows:

- The largest differences in terms of having projected greater total ESD emissions in 2017 are found for the Czech Republic, Estonia, Malta and Portugal.
- The largest differences in terms of having projected fewer total ESD emissions in 2017 are found for Croatia, France, Slovakia and Spain.
- Overall the most significant changes can be observed for Malta (between 30% and 34% compared to *2015_16* submission) and Croatia (between -11% and -21% compared to *2015_16* submission).
- No changes to projected total ESD emissions are observed for Cyprus, as Cyprus seems to have provided the same projection as in its previous submission.

[6] In 2016, eight Member States (Austria, Cyprus, Denmark, France, Ireland, Greece, Hungary and Luxembourg) provided updated projections.

- At the EU level, the reported differences add up to fewer total ESD emissions compared to the *2015_16* submissions and are in the range of -2% to -5%.

The reasons for such changes in projected emissions can be manifold and difficult to disentangle:

- Projection methodologies may have improved (including on how to model the impact of PaMs)
- Assumptions may have changed (e.g. energy prices, HDD, population, GDP, etc.)
- New PaMs may have been introduced between the preparation of 2017 projections and the previous submission, adding elements to the modelling and thus having impacted the results
- Existing PaMs may have started to show their effects which can be depicted in a more recent projection.

It is beyond the scope of this overview to assess the potential reasons for changes in detail, however some possible reasons are listed at the end of this section for Member States which show most prominent differences.

If changes can be observed on total ESD emissions, they may be due to changes in specific ESD sectors. Therefore, the analysis also extends into finding the most significant changes in the most important ESD sectors: buildings, transport and agriculture and can then serve as background information for the remainder of this paper, where an assessment of individual sectors takes place in subsequent chapters.

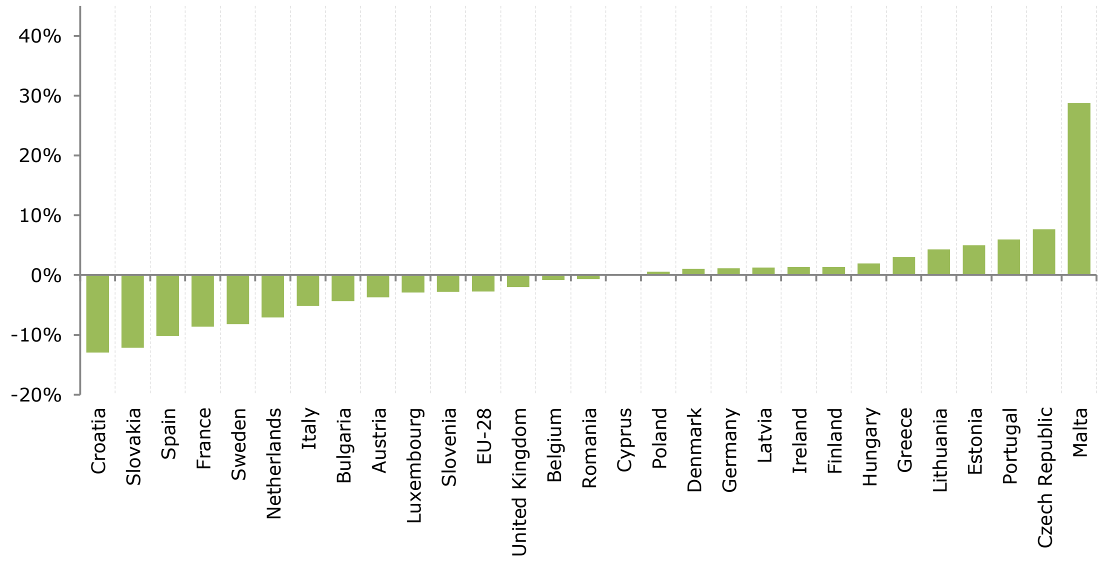
Table A1.1 Difference in total projected ESD emissions between the 2017 submission and 2015_16 submission. *Note:* positive values indicate that ESD emissions reported in the 2017 submission were larger than reported in the 2015_16 submission.

Member State	MS	2015	2020	2025	2030	2035
EU-28	**EU-28**	**-2%**	**-3%**	**-4%**	**-5%**	**-5%**
Austria	AT	-5%	-4%	-5%	-8%	-10%
Belgium	BE	1%	-1%	-1%	-1%	-1%
Bulgaria	BG	-3%	-4%	-4%	-5%	-5%
Croatia	HR	-11%	-13%	-16%	-18%	-21%
Cyprus	CY	0%	0%	0%	0%	0%
Czech Republic	CZ	-6%	8%	13%	8%	-1%
Denmark	DK	-1%	1%	2%	1%	-1%
Estonia	EE	8%	5%	9%	11%	12%
Finland	FI	-2%	1%	1%	2%	2%
France	FR	-2%	-9%	-13%	-15%	-17%
Germany	DE	1%	1%	1%	1%	1%
Greece	GR	-4%	3%	4%	6%	6%
Hungary	HU	7%	2%	4%	4%	4%
Ireland	IE	0%	1%	4%	3%	2%
Italy	IT	1%	-5%	-6%	-7%	-4%
Latvia	LV	5%	1%	0%	-2%	-4%
Lithuania	LT	5%	4%	3%	3%	3%
Luxembourg	LU	-1%	-3%	-4%	-6%	-9%
Malta	MT	30%	29%	29%	31%	34%
Netherlands	NL	-8%	-7%	-6%	-5%	-3%
Poland	PL	0%	1%	1%	1%	1%
Portugal	PT	6%	6%	6%	6%	4%
Romania	RO	5%	-1%	-6%	-13%	-19%
Slovakia	SK	-12%	-12%	-16%	-17%	-18%
Slovenia	SI	-5%	-3%	-4%	-7%	-12%
Spain	ES	-1%	-10%	-13%	-14%	-15%
Sweden	SE	-1%	-8%	-9%	-12%	-14%
United Kingdon	UK	-8%	-2%	-1%	-1%	-2%

Source: own calculations based on the projections database[7]. Positive values indicate that ESD emissions reported in the 2017 submission were larger than reported in the 2015_16 submission.

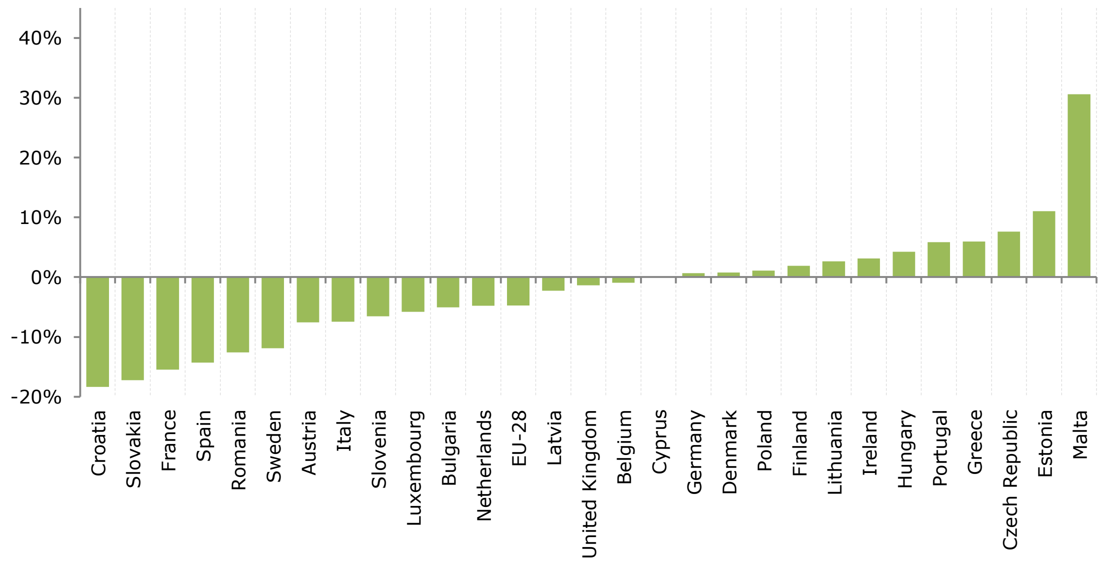
[7] https://www.eea.europa.eu/data-and-maps/data/greenhouse-gas-emission-projections-for-3

Figure A1.1 Difference in total projected ESD emissions in 2020 by Member State



Source: own calculations based on the projections database[7]. Positive values indicate that ESD emissions reported in the 2017 submission were larger than reported in the 2015_16 submission.

Figure A1.2 Difference in total projected ESD emissions in 2030 by Member State



Source: own calculations based on the projections database[7]. Positive values indicate that ESD emissions reported in the 2017 submission were larger than reported in the 2015_16 submission.

Buildings ESD Emissions

Table A1.1 shows the percentage difference in projected ESD emissions in the buildings sector between Member States' 2017 submission and their 2015_16 submission.

The greatest differences are highlighted for the years 2020 and 2030 in **Figures A1.1** and **A1.2**, and summarised as follows where **bold highlighted** Member States are also found among the same set for the most significant differences in total ESD emissions.

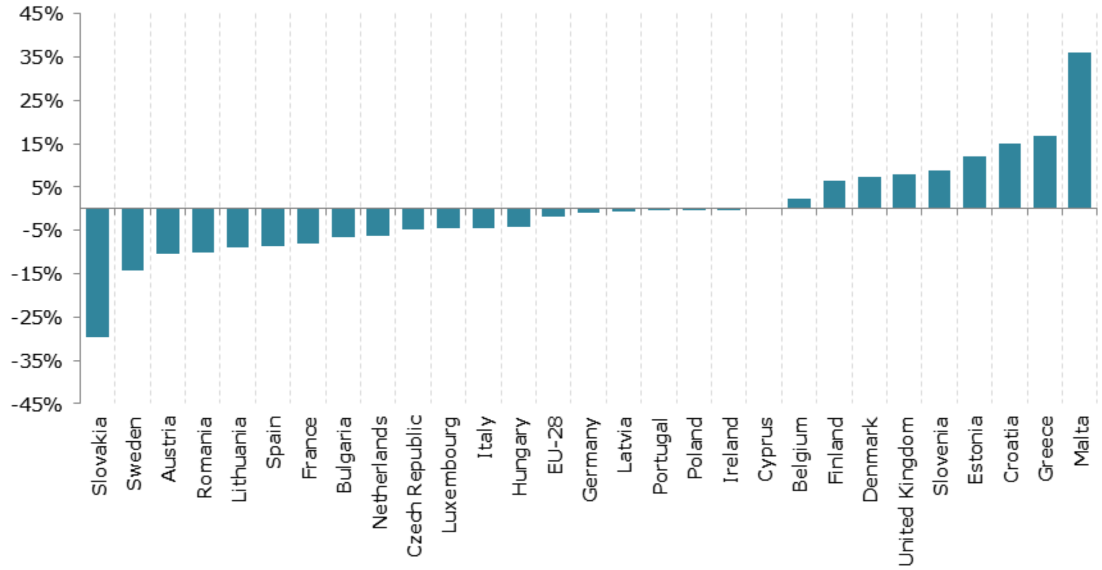
- The largest differences in terms of having projected greater total ESD emissions in 2017 are found for the Croatia, Greece, **Malta**, and Latvia.
- The largest differences in terms of having projected fewer total ESD emissions in 2017 are found for**, France,** Hungary, **Slovakia**, **Spain** and Sweden.
- No changes to projected buildings ESD emissions are observed for Cyprus, as Cyprus seems to have provided the same projection as in its previous submission.
- Poland and Portugal only exhibit very slight differences compared to their previous submission, (-0.1% for Poland and -0.2% - 0.4% for Portugal).
- Overall the most significant changes can be observed for Malta (between 31% and 58% compared to *2015_16* submission) and Slovakia (between -28% and -49% compared to *2015_16* submission). For both, the differences increase over the projection period.
- At the EU level, the reported differences add up to fewer buildings ESD emissions compared to the *2015_16* submissions and are in the range of 0% to -2%, where the differences decrease over the projection period.

Table A1.2 Difference in ESD emissions in the buildings sector

Member State	MS	2015	2020	2025	2030	2035
EU-28	**EU-28**	**-2%**	**-2%**	**-1%**	**-1%**	**0%**
Austria	AT	-16%	-10%	-9%	-11%	-16%
Belgium	BE	2%	2%	3%	5%	5%
Bulgaria	BG	-3%	-7%	-11%	-15%	-16%
Croatia	HR	13%	15%	11%	7%	3%
Cyprus	CY	0%	0%	0%	0%	0%
Czech Republic	CZ	-14%	-5%	6%	4%	7%
Denmark	DK	9%	7%	10%	8%	7%
Estonia	EE	17%	12%	12%	12%	12%
Finland	FI	-4%	6%	11%	14%	16%
France	FR	3%	-8%	-13%	-14%	-16%
Germany	DE	0%	-1%	-3%	-4%	-3%
Greece	GR	3%	17%	23%	23%	19%
Hungary	HU	5%	-4%	-13%	-22%	-32%
Ireland	IE	-6%	0%	7%	10%	14%
Italy	IT	-3%	-5%	3%	9%	13%
Latvia	LV	-10%	-1%	10%	18%	27%
Lithuania	LT	-8%	-9%	-10%	-11%	-12%
Luxembourg	LU	-5%	-5%	-4%	-5%	-6%
Malta	MT	31%	36%	43%	51%	58%
Netherlands	NL	-6%	-6%	-9%	-7%	-8%
Poland	PL	0%	0%	0%	0%	0%
Portugal	PT	0%	0%	0%	0%	0%
Romania	RO	-12%	-10%	-7%	-6%	-4%
Slovakia	SK	-28%	-30%	-37%	-43%	-49%
Slovenia	SI	6%	9%	9%	9%	9%
Spain	ES	-5%	-9%	-13%	-17%	-18%
Sweden	SE	3%	-14%	-8%	-10%	-9%
United Kingdom	UK	-4%	8%	10%	10%	10%

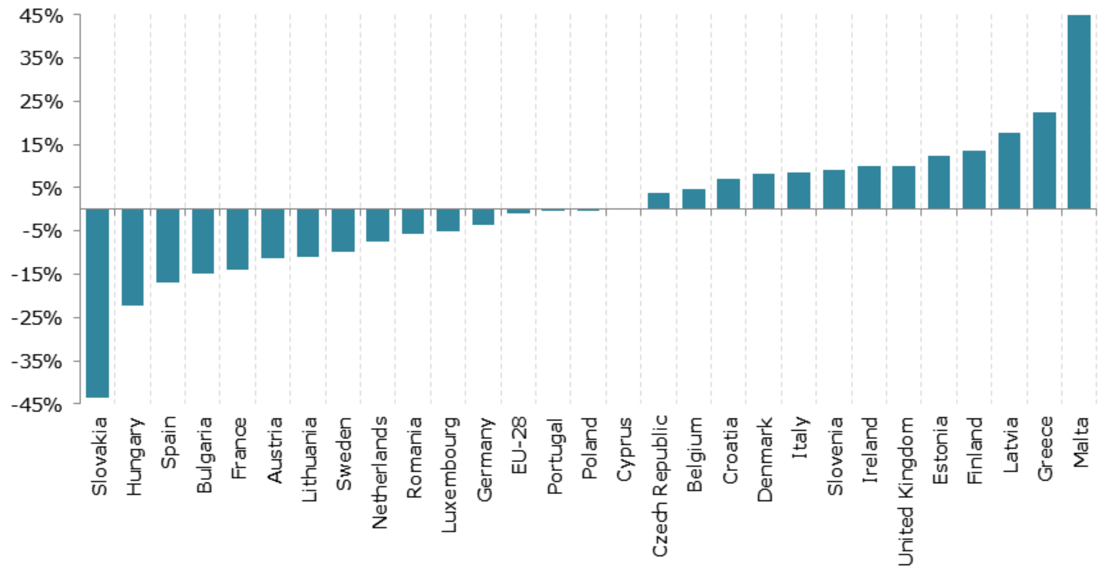
Source: own calculations based on the projections database[7]. Positive values indicate that ESD emissions reported in the 2017 submission were larger than reported in the 2015_16 submission.

Figure A1.3 Difference in projected ESD emissions of the buildings sector in 2020



Source: own calculations based on the projections database[7]. Positive values indicate that ESD emissions reported in the 2017 submission were larger than reported in the 2015_16 submission.

Figure A1.4 Difference in projected ESD emissions of the buildings sector in 2030



Source: own calculations based on the projections database[7]. Positive values indicate that ESD emissions reported in the 2017 submission were larger than reported in the 2015_16 submission.

Transport ESD Emissions

Table A1.3 shows the development of the difference in projected ESD emissions in the transport sector between Member States' 2017 submission and their *2015_16* submission in percent.

The differences are highlighted for the years 2020 and 2030 in Figures A1.3 and A1.4, and summarised as follows where **bold highlighted** Member States are also found among the same set for the most significant differences in total ESD emissions.

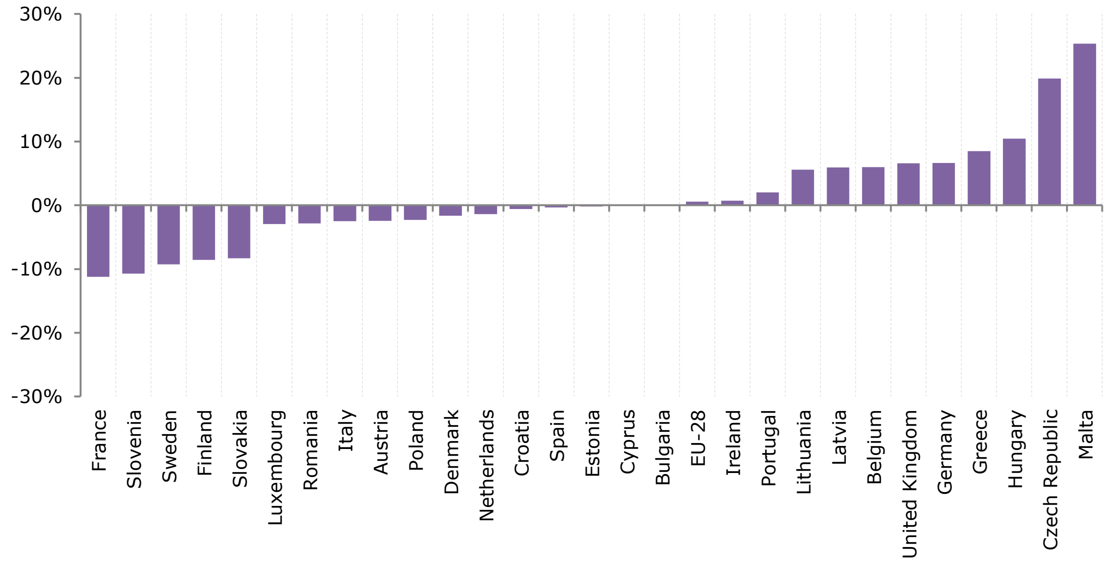
- The largest differences in terms of having projected greater total ESD emissions in 2017 are found for the **Czech Republic**, Germany, Hungary, **Malta**.
- The largest differences in terms of having projected fewer total ESD emissions in 2017 are found for **Croatia, France,** Slovenia, Sweden.
- No changes to projected transport ESD emissions are observed for Cyprus, as Cyprus seems to have provided the same projection as in its previous submission.
- Overall the most significant changes can be observed for Malta (between -3% and 43% compared to 2015_16 submission) and Slovenia (between -12% and -25% compared to 2015_16 submission). While the difference for Slovenia increases over the projection period, Malta's differences reduce.
- At the EU level, the reported differences add up to slightly more transport ESD emissions compared to the *2015_16* submissions and are in the range of 0% to 1%, with differences getting smaller the later the projection time.

Table A1.3 Difference in ESD emissions in the transport sector

Member State	MS	2015	2020	2025	2030	2035
EU-28	**EU-28**	**1%**	**1%**	**0%**	**0%**	**0%**
Austria	AT	-3%	-2%	-3%	-7%	-12%
Belgium	BE	7%	6%	7%	7%	8%
Bulgaria	BG	0%	0%	0%	0%	0%
Croatia	HR	4%	-1%	-7%	-14%	-23%
Cyprus	CY	0%	0%	0%	0%	0%
Czech Republic	CZ	3%	20%	24%	13%	-9%
Denmark	DK	-2%	-2%	-2%	-3%	-8%
Estonia	EE	2%	0%	5%	10%	10%
Finland	FI	-11%	-9%	-8%	-3%	2%
France	FR	1%	-11%	-15%	-15%	-14%
Germany	DE	3%	7%	8%	11%	15%
Greece	GR	1%	8%	9%	11%	13%
Hungary	HU	17%	10%	21%	25%	25%
Ireland	IE	0%	1%	6%	0%	-7%
Italy	IT	1%	-2%	-6%	-13%	-12%
Latvia	LV	11%	6%	8%	8%	10%
Lithuania	LT	7%	6%	5%	5%	5%
Luxembourg	LU	-2%	-3%	-5%	-8%	-12%
Malta	MT	43%	25%	16%	5%	-3%
Netherlands	NL	-2%	-1%	1%	2%	4%
Poland	PL	-2%	-2%	-2%	-2%	-2%
Portugal	PT	2%	2%	2%	2%	2%
Romania	RO	-2%	-3%	-1%	0%	0%
Slovakia	SK	-8%	-8%	-9%	-9%	-9%
Slovenia	SI	-12%	-11%	-12%	-15%	-25%
Spain	ES	2%	0%	-3%	-2%	-3%
Sweden	SE	1%	-9%	-10%	-13%	-14%
United Kingdom	UK	-1%	7%	8%	8%	5%

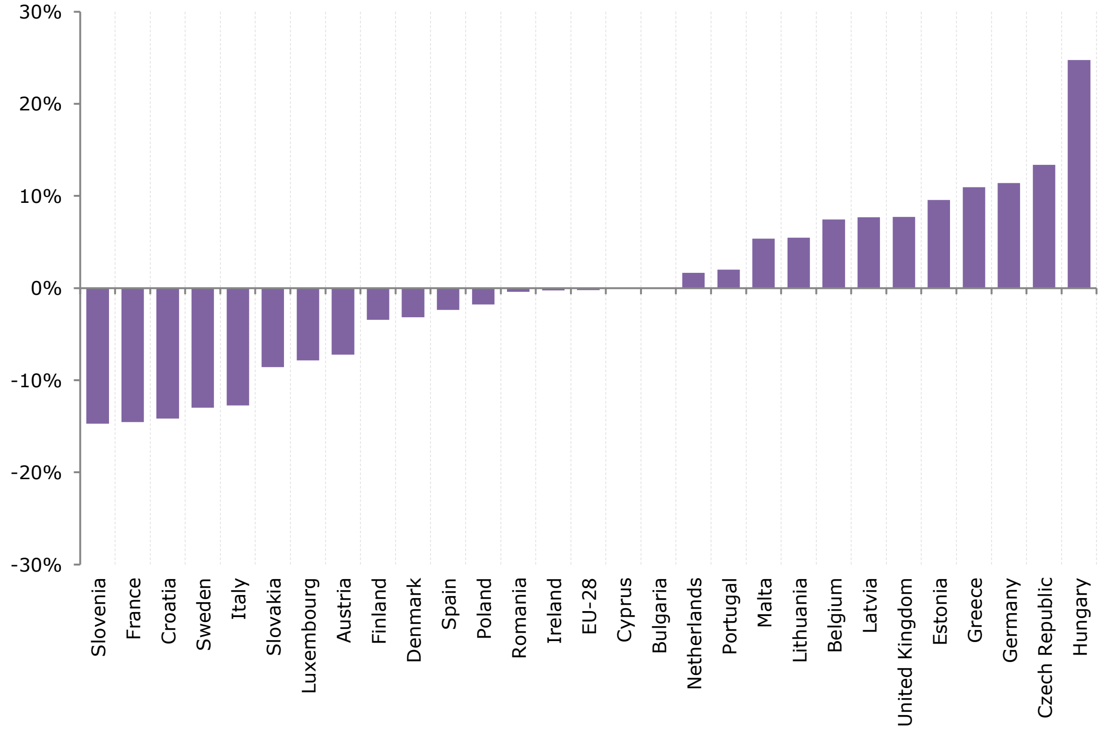
Source: own calculations based on the projections database[7]. Positive values indicate that ESD emissions reported in the 2017 submission were larger than reported in the 2015_16 submission.

Figure A1.5 Difference in projected ESD emissions of the transport sector in 2020



Source: own calculations based on the projections database[7]. Positive values indicate that ESD emissions reported in the 2017 submission were larger than reported in the 2015_16 submission.

Figure A1.6 Difference in projected ESD emissions of the transport sector in 2030



Source: own calculations based on the projections database[7]. Positive values indicate that ESD emissions reported in the 2017 submission were larger than reported in the 2015_16 submission.

Agriculture ESD Emissions

Table A1.4 shows the development of the difference in projected ESD emissions in the agriculture sector between Member States' 2017 submission and their *2015_16* submission in percent.

The differences are highlighted for the years 2020 and 2030 in Figures A1.5 and A1.6, and summarised as follows where **bold highlighted** Member States are also found among the same set for the most significant differences in total ESD emissions.

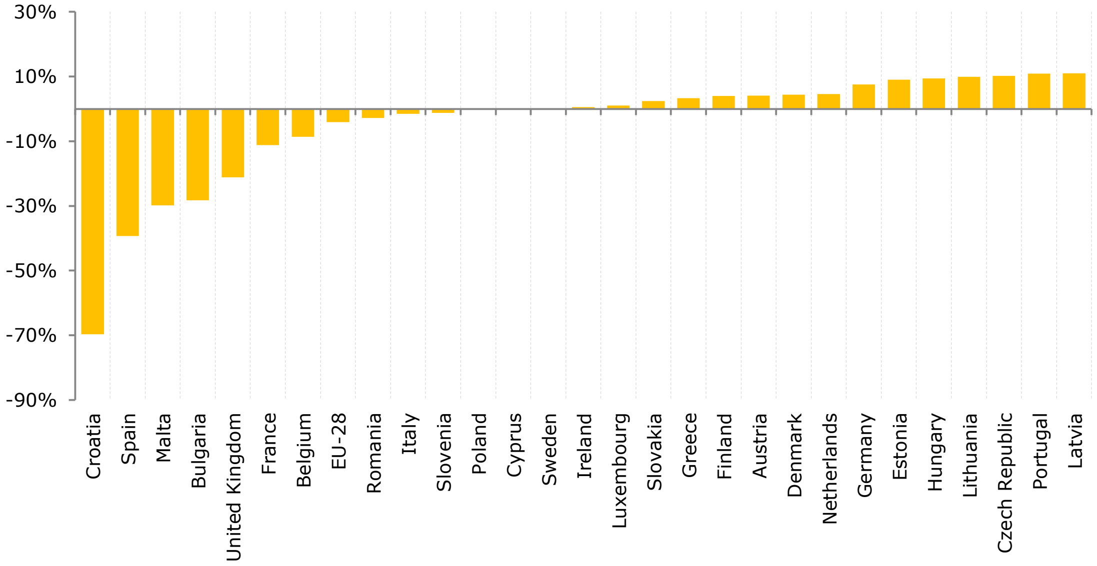
- The largest differences in terms of having projected greater total ESD emissions in 2017 are found for the Czech Republic, Estonia, Hungary, Latvia, Portugal.
- The largest differences in terms of having projected fewer total ESD emissions in 2017 are found for Bulgaria, **Croatia**, Malta, Spain.
- No changes to projected agriculture ESD emissions are observed for Cyprus, as Cyprus seems to have provided the same projection as in its previous submission.
- Overall the most significant changes can be observed for Hungary (between 5% and 20% compared to 2015_16 submission) and Croatia (between -61% and -74% compared to 2015_16 submission). While the difference increases over the projection period for both of them.
- At the EU level, the reported differences add up to slightly less agriculture ESD emissions compared to the 2015_16 submissions and are in the range of -2% to -7%, with changes becoming larger the further in the future.

Table A1.4 Difference in ESD emissions in the agriculture sector

Member State	MS	2015	2020	2025	2030	2035
EU-28	**EU-28**	**-2%**	**-4%**	**-5%**	**-6%**	**-7%**
Austria	AT	4%	4%	4%	4%	5%
Belgium	BE	-7%	-9%	-14%	-15%	-15%
Bulgaria	BG	-20%	-28%	-28%	-29%	-28%
Croatia	HR	-61%	-70%	-73%	-74%	-74%
Cyprus	CY	0%	0%	0%	0%	0%
Czech Republic	CZ	9%	10%	13%	16%	18%
Denmark	DK	3%	4%	4%	5%	5%
Estonia	EE	5%	9%	14%	16%	18%
Finland	FI	6%	4%	1%	0%	-1%
France	FR	0%	-4%	-6%	-7%	-9%
Germany	DE	10%	8%	7%	5%	3%
Greece	GR	-9%	3%	4%	4%	6%
Hungary	HU	5%	9%	14%	17%	20%
Ireland	IE	3%	1%	1%	1%	1%
Italy	IT	-3%	-2%	-2%	-2%	-2%
Latvia	LV	16%	11%	9%	3%	-4%
Lithuania	LT	7%	10%	10%	9%	9%
Luxembourg	LU	2%	1%	12%	14%	15%
Malta	MT	-22%	-30%	-27%	-24%	-23%
Netherlands	NL	0%	5%	6%	7%	9%
Poland	PL	0%	0%	0%	0%	0%
Portugal	PT	11%	11%	11%	11%	15%
Romania	RO	4%	-3%	-11%	-25%	-35%
Slovakia	SK	-1%	2%	-3%	-2%	-2%
Slovenia	SI	-1%	-1%	-1%	-1%	-1%
Spain	ES	-10%	-39%	-42%	-43%	-43%
Sweden	SE	5%	0%	0%	0%	-5%
United Kingdom	UK	-26%	-21%	-22%	-22%	-22%

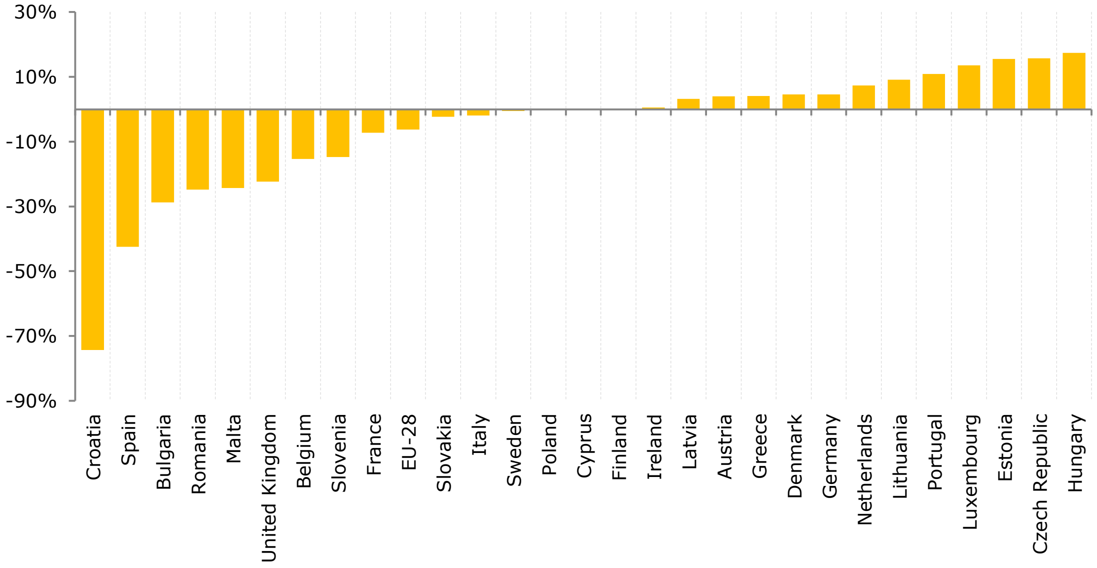
Source: own calculations based on the projections database[7]. Positive values indicate that ESD emissions reported in the 2017 submission were larger than reported in the 2015_16 submission.

Figure A1.7 Difference in projected ESD emissions of the agriculture sector in 2020



Source: own calculations based on the projections database[7]. Positive values indicate that ESD emissions reported in the 2017 submission were larger than reported in the 2015_16 submission.

Figure A1.8 Difference in projected ESD emissions of the agriculture sector in 2030



Source: own calculations based on the projections database[7]. Positive values indicate that ESD emissions reported in the 2017 submission were larger than reported in the 2015_16 submission.

Summary of most significant differences

Having compiled the detailed overview above it is challenging to summarise the most significant differences. Below, the most significant differences are summarised only for the years 2020 and 2030 and only for those Member States whose differences were **among the top three in total ESD emissions** either in 2020 or 2030.

The development of the differences over the whole projection period can be viewed in the series of heatmaps (**Tables A1.1 – A1.4**) above.

	Difference in 2020 and 2030 ESD emissions (cf. 2017 submission)							
Member State	**Total ESD**		**Buildings**		**Transport**		**Agriculture**	
	2020	**2030**	**2020**	**2030**	**2020**	**2030**	**2020**	**2030**
Fewer total ESD **emissions projected than in *2015_16***								
Croatia	-13%	-18%	15%	7%	-1%	-14%	-70%	-74%
Slovakia	-12%	-17%	-30%	-43%	-8%	-9%	-2%	-2%
Spain	-10%	-14%	-9%	-17%	0%	-2%	-39%	-43%
France	-9%	-15%	-8%	-14%	-11%	-15%	-11%	-7%
Greater total ESD **emissions projected than in *2015_16***								
Malta	29%	31%	36%	51%	25%	5%	-30%	-24%
Czech Republic	8%	8%	-5%	4%	20%	13%	10%	16%
Estonia	5%	11%	12%	12%	0%	10%	9%	16%
Portugal	6%	6%	0%	0%	2%	2%	11%	11%

Source: own calculations based on the projections database[7]. Positive values indicate that ESD emissions reported in the 2017 submission were larger than reported in the 2015_16 submission.

Possible reasons for differences between the 2017 and *2015_16* submissions:

Malta

- Has improved its projection methodology, most likely based on Commission Assistance project as their presentation states that Malta requested assistance to develop or review models for energy, agriculture, waste, IPPU and LULUCF sectors, and that an in-country visit helped to identify issues with the previous road transportation model. *(Source: ICF, IIASA, Aether 2017: EC Common Problems and Solutions workshop. 14 July 2017).*
- Observing also the large changes in projected emissions of the building sector it can be assumed that projection methodologies have changed for that sector, too.

Croatia

- Croatia also improved its projection methodology according to the presentation help at the common solutions workshop in July 2017 (Source: *ICF, IIASA, Aether 2017: EC Common Problems and Solutions workshop. 14 July 2017).*
- It now applies additional modelling software on top of their established modelling approach with LEAP and has indicated that modelling of transport sectors has been improved. However, from the presentation no detailed insights can be gained how the modelling approaches for the other ESD sectors have been improved.

- Comparing the projection reports from 2015 and 2017 provides no further possibility of comparing the methodologies applied in detail. However, it needs to be noted that the documentation of the methodological approach and the underlying data in the 2017 report is much more elaborated that in the 2015 version hinting towards an improved projection.
- Croatia also reported more detailed manner on measures included in the depiction of their sectors. In the transport sector for example the 2017 projection included measures listed in the National Action Plan for Energy Efficiency for the period 2017–2019, while the previous submission included the measures listed in the previous National Action plan which covered the period 2014–2016.
- For the agriculture sector Croatia assumed in the 2015 submission a recovery of agricultural production and an increase in the number of animals. In the 2017 submission projections were carried out by extrapolating historical input data, utilising expert assessment and strategic documents.

Annex II Grouping and aggregation of PaMs

This Annex provides the methodology used to group and aggregate PaMs into the five sectors considered in this analysis.

Step 1 – grouping PaMs per sector

The first step is to group the PaMs per sector. Although Member States are required to report the sector that is affected by the PaM[8], this information does not fully match with the sectoral division used for the ESD trend report. Therefore, some regrouping is needed based on the reported sector and objectives of the PaM:

- **Residential and Commercial (1A4 and 1A5):** PaMs with following the characteristics will be grouped automatically to this sector:
    - Sector 'energy consumption' & objective 'efficiency improvements of buildings'
    - Sector 'energy consumption' & objective 'efficiency improvements in services/ tertiary sector'
    - Sector energy consumption & objective 'efficiency improvement of appliances'[9]
- **Industry (1A2, 2A – E):** PaMs with the following characteristics will be grouped automatically to this sector:
    - Sector 'energy consumption' & objective 'efficiency improvements in industrial end-use sectors'
    - Sector 'industrial processes' & exclude PaMs affecting F-gases only.
- **Transport (1A3):** PaMs with following the characteristics will be grouped automatically to this sector:
    - Sector 'transport' & all objectives
- **Waste:** PaMs with the following characteristics will be grouped automatically to this sector:
    - Sector 'waste' & all objectives
- **Agriculture:** PaMs with the following characteristics will be grouped automatically to this sector:
    - Sector 'agriculture' & all objectives

Automatically allocating PaMs to sectors is not 'possible for all sectors, so manual checks are needed, especially for:

- Sector 'Energy consumption' & objective 'other'
- Sector 'Energy consumption' & objective 'demand management and reduction'
- Sector 'Cross-cutting'
- Sector 'Other'

[8] The PaM reporting distinguishes the following sectors: Energy supply, Energy consumption (this also includes electricity), Transport, Industrial Processes, Agriculture, LULUCF, Waste, Cross-cutting.

[9] This could also include electrical appliances. Manual check is needed.

As this report focuses on ESD emissions, PaMs affecting only the LULUCF or Energy Industries sectors will not be checked. It is possible that PaMs affect more than one sector. For example, a PaM affects both the sectors residential and industry. In this case the PaM will be allocated to both sectors.

Step 2 – Weighting of PaMs

For the PaM report the emphasis is on the information as it is reported by the Member States and therefore data is presented as the number of PaMs per sub-category. Weighting of PaMs is however appropriate for this analysis as we want to link the data on PaMs to EU GHG emission trends and the number of PaMs might not be the best indicator for that. There are several factors that need to be considered, and we link this to how we can address this in the table below. It is not possible to take into account all possible factors that could affect the effectiveness of the PaM in reducing EU-wide GHG emissions, so we opted to weight the PaMs based on simple criteria.

Factor	**Approach**
Not all instrument types are equally effective	Regulation, economic and fiscal measures generally are more effective than soft measures such as voluntary/negotiated agreements, planning, information, education, research and other. It is difficult to quantify how much more effective a regulation will be than an information campaign. We propose to give ‘hard’ measures a factor of 1 and ‘soft’ measures a factor of 0.5. In case there are multiple instrument types, the highest weighting factor is used. Leaving out the weighting would mean that an information campaign would count as much as an economic incentive.
The scope of the PaMs differs	Some PaMs are very specific, while others are more generic and have a larger impact. To some extent this is related to the reporting by the individual Member States, where some countries report many single PaMs (e.g. France and Belgium with over 100 PaMs) whereas other countries might report much less PaMs (e.g. Austria with less than 20). By giving PaMs a weight based on the number of PaMs the country reported, we can take this factor partially into account into our results. Note that in the case of multi-sectoral policies, weighting is already done as one PaM can be allocated to more than one sector.
In general, PaMs in small countries will usually have a smaller impact compared to PaMs in large countries.	PaMs from large Member States will on average have a bigger impact than PaMs from small Member States. To account for these differences weighting of PaMs is done based on the share of GHG emissions.

Step 2.1 Weighting based on instrument type

PaMs that are regulation, economic or fiscal are given a factor of 1, while PaMs that are not are given a factor of 0.5.

PaM	Instrument type	Sector	Weight instrument type	PaMs Buildings	PaMs Transport	PaMs Agriculture
1	Regulation	Agriculture	1			1
2	Information	Buildings	0.5	0.5		
3	Economic, information	Transport, Buildings	1	1	1	

Step 2.2 Weighting based on the number of PaMs in the Member State

To account for the fact that some Member States have only 20 single PaMs reported and others 100, for each MS the total score is calculated, in the example this is 3.5. The weighting that will be used is 1/3.5 or 0.286. The result is that if you add up all the scores for the PaMs the sum is 1 for all countries.

PaM	Instrument type	Sector	Weight number of PaMs	PaMs Buildings	PaMs Transport	PaMs Agriculture
1	Regulation	Agriculture	0.286			0.286
2	Information	Buildings	0.286	0.143		
3	Economic, information	Transport, Buildings	0.286	0.286	0.286	

The impact of the weighting means that for this country, PaM 3 is twice as important as PaM 1, and four times as important as PaM 2.

Step 2.3 Weighting based on the share of emissions

The final step is to weight the PaMs based on the share of GHG emissions. This will be done on a sectoral level (based on the emissions in the period 2010–2015).

PaM	Instrument type	Sector	Share emissions	PaMs Buildings	PaMs Transport	PaMs Agriculture
1	Regulation	Agriculture	2%			0.572
2	Information	Buildings	2.5%	0.358		
3	Economic, information	Transport, Buildings	3.5% 2.5%	0.715	1.001	

Step 3 – Combining data

In the PaM report, the number of PaMs per start year is presented but for this analysis this might not be so useful. An alternative approach is to do this cumulatively and take also the end year[10] of the PaM into account. This way the scoring reflects the number of PaMs that are effective in that year, and not the number of PaMs starting. For example, for the buildings PaMs:

PaM	Instrument type	Sector	Start – end year	PaMs Buildings
2	Information	Buildings	2009–2013	0.358
3	Economic, information	Transport, Buildings	2011–2020	0.715

Year	PaM 2	PaM 3	Total
2008			0
2009	0.358		0.358
2010	0.358		0.358
2011	0.358	0.715	1.073
2012	0.358	0.715	1.073
2013	0.358	0.715	1.073
2014		0.715	0.715
2015		0.715	0.715
2016		0.715	0.715

[10] In several cases the end year is not reported for PaMs because this is not known. For these policies, it is assumed that the PaM will continue to be implemented in future years. This is obviously not accurate but does often correspond with the assumptions used in GHG projections.