# Report on quantitative assessment of climate policies

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# Abstract

In 2008, the European Council approved the climate and energy package, including the EU20-20-20 targets, setting the objective to reduce greenhouse gases by 20%, achieve a share of 20% renewable energy, and improve energy efficiency by 20%, all by the year 2020. A number of policy packages was implemented to aid in achieving the goals. This report presents a quantitative ex-post evaluation of EU climate policy over the period 2005-2020. A combination of top-down and bottom-up approaches is used. This consists of a decomposition analysis on greenhouse gas emissions based on the Kaya identity (top-down), and a literature review on the effectiveness of EU climate policies (bottom-up). Additionally, a monitoring framework is designed to track progress on indicators related to EU climate policy targets. Throughout the analysis, a link is made with the '4 I's': Innovation, Investment, Infrastructure and Integration. The evidence is however not strong enough to qualify as a causal or correlating relation. Based on qualitative evidence we see these cross-cutting core challenges as important enablers of EU climate policy. Without these enablers climate policies in the EU would not have reached its full effect potential, and they are strongly associated with monitoring indicators connected to different EU directives in scope of this WP. It is however important to notice that our conclusions stem from an ex-post evaluation framework. Ex-ante it can be expected that in the period until 2030 and further to 2050 when transformative policies are needed to spur the energy transition the link with the 4 I's will become stronger. Although no causal links are inferred in the bottom-up and top-down analyses, we find that considerable progress has been made on the EU climate goals, and these developments can at least be partly attributed to targets and policies implemented by the EU.

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# Abbreviations

| Abbreviation | Description |
|---|---|
| ACER | Agency for the Cooperation of Energy Regulators |
| AFID | Alternative Fuel Infrastructure Directive |
| CBAM | Carbon Border Adjustment Mechanism |

| Abbreviation | Description |
|---|---|
| CCUS | Carbon Capture, Utilisation and Storage |
| CCS | Carbon Capture and Storage |
| CNG | Compressed Natural Gas |
| $CO_2$ | Carbon dioxide |
| EC | European Commission |
| EEA | European Environmental Agency |
| EED | Energy Efficiency Directive |
| ENTSO | European Network of Transmission System Operators |
| EPBD | Energy Performance of Buildings Directive |
| ESD | Effort Sharing Decision |
| ETS | Emission Trading System |
| EU | European Union |
| FQD | Fuel Quality Directive |
| GDP | Gross Domestic Product |
| GHG | Greenhouse gas |
| LCV | Light commercial vehicle |
| LMDI | Logarithmic mean Divisia Index |
| MS | Member States |
| MTOE | Megaton of Oil-equivalents |
| Mton | Megaton |
| PCI | Project of Common Interest |
| PV | Photovoltaic |
| R&D | Research and Development |
| RED | Renewable Energy Directive |
| SMART | Specific, Measurable, Achievable, Relevant and Timebound |
| TEN-E | Trans-European Networks for Energy |
| TEN-T | Trans-European Networks for Transport |
| TWh | Terra Watt hour |

| Abbreviation | Description |
| --- | --- |
| UNFCCC | United Nations Framework Convention on Climate Change |

# Executive summary

This report contains an ex-post evaluation of the EU climate policy framework for the period 2005-2020, both for the EU27 and some selected Member States. The EU is making efforts to reduce greenhouse gas emissions and has put in place ambitious climate policies leading to a decoupling of emissions and economic growth. Therefore, the EU set three climate and energy targets for 2020 (the so-called 20-20-20 targets): reduce greenhouse gas emissions 20% compared to 1990 levels, increase the share of renewable energy use to 20%, and improve energy efficiency by 20%. In this report we identified the most relevant EU policies, assessed the progress towards these 2020 headline targets, and defined a list of policy indicators.

In order to assess the effectiveness of EU (climate) policy we used a combination of top-down and bottom-up analysis. This is illustrated in the Figure 1. In the top-down analysis, based on a decomposition analysis of greenhouse gas (GHG) emissions, we explored the different contributing factors to the historic emissions between 2008 and 2018. This way we tried to assess the potential impact of EU climate policies in relation to the reduction of GHG emissions. In the bottom-up analysis we carried out a literature review on the (individual) effectiveness and efficiency of EU policy instruments. This is complemented with a monitoring framework containing relevant policy and socioeconomic indicators.

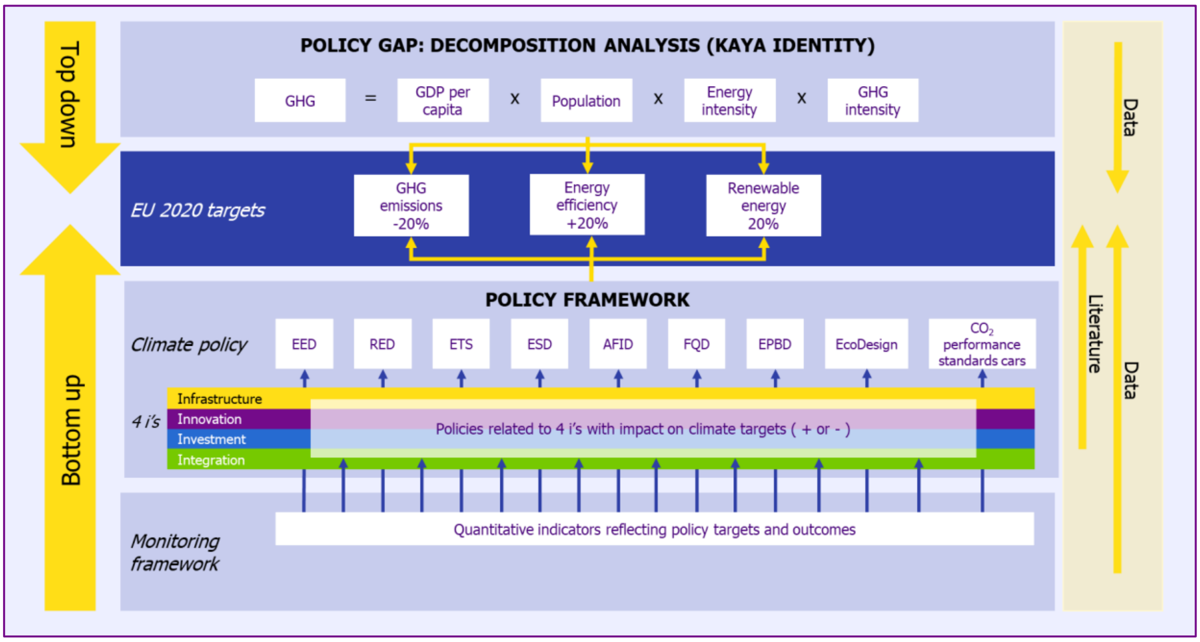


*Figure 1 – Illustration of top-down and bottom-up method used to assess EU climate policy*

### Progress on 20-20-20 targets

We found that EU27 greenhouse gas emissions were 35% lower in 2020 than in 1990. This constitutes a substantial overachievement of the 20% reduction target. The economic downturn as a result of COVID-19 helped considerably to reach the overall greenhouse target. The other targets for renewable energy and energy saving were met as well.

### Top-down: Decomposition analysis

With a decomposition method we analysed the changes in greenhouse gas emissions in the period 2009-2018. This method quantifies the effect of changes in GDP, population growth, sectoral composition between industry, services and transport (structural change), energy efficiency, the share of renewables in electricity generation, and other carbon savings on observed changes in greenhouse gas emissions. Together these effects add up to the total change in GHG emissions over the given period. Through the logarithmic mean Divisia index (LMDI) method, the effects of each of these elements are isolated. The resulting net impacts from energy efficiency, renewable electricity and other carbon savings can be considered as a result within the overall influence domain of national and EU climate policy. Figure 2 shows the results of the decomposition analysis on the EU level.

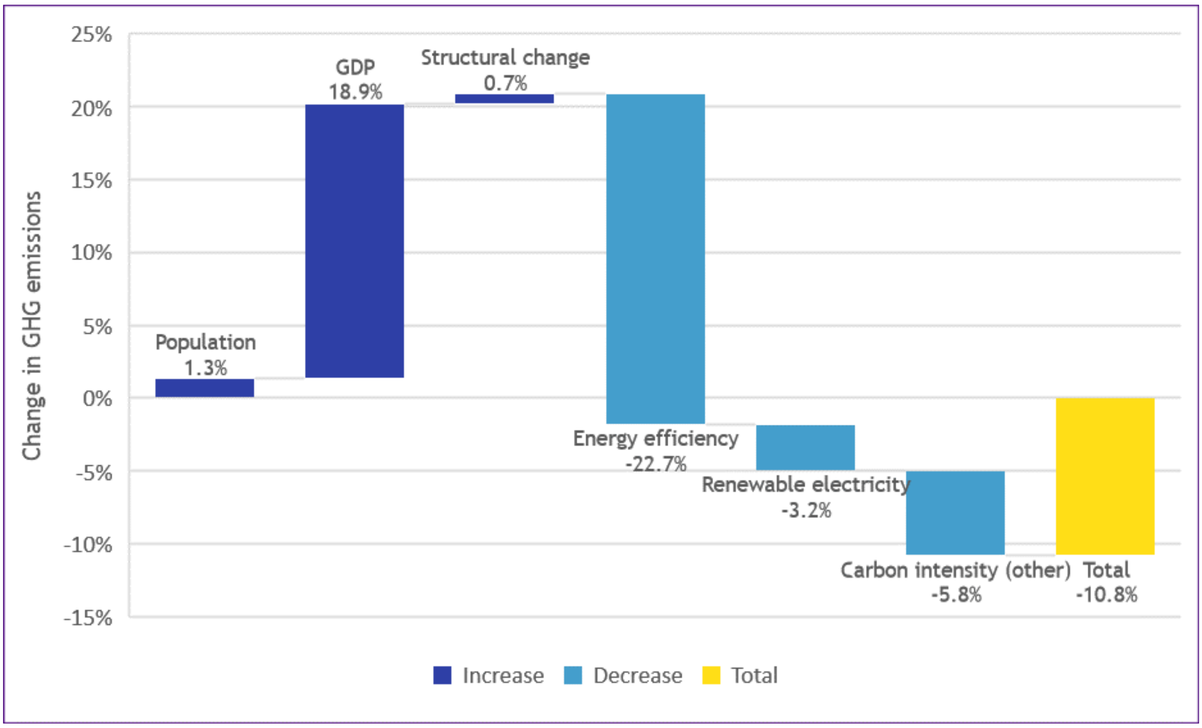


*Figure 2 – Decomposition analysis EU27 over 2009-2018: results*

The decomposition analysis on the 2009-2018 period reveals that emissions increased due to factors that generally fall outside the domain of climate policy, such as population growth, GDP growth, and structural changes in the economy. But other factors – energy efficiency, renewable electricity generation and carbon intensity reductions – are part of the climate policy domain: for instance, the EED affecting energy savings (energy use per unit of value added) and the RED and ETS directly reducing carbon intensities (carbon emissions per unit of energy). The results at the EU level suggest that energy savings were an important contributing factor to emission abatement. Even when incorporating an estimated effect of a 0.5-1% autonomous improvement in energy efficiency per year, the effect of policy-induced energy efficiency savings is noticeable. It is likely that energy market trends such as the favourable price margin of coal to gas price (the relative low $CO_2$ prices of ETS) have had opposite effects on the carbon intensity in some countries. However, overall the net effect due to the deployment of renewable resources is still positive. Moreover, other carbon savings suggest that there is a general shift in the EU away from carbon-intensive fuels such as coals to less polluting fuels.

## Bottom-up: literature review

In our literature review we looked at the most relevant policies and their impacts on the EU 2020 targets for GHG emissions, renewable energy, and energy efficiency. We studied both climate policies and relevant non-climate policies (policies that are not primarily aimed at climate goals, but do contribute to these goals). The literature assessment was based on evaluations, impact assessments, and other relevant studies.

### Limited amount of ex-post evaluations and quantitative assessments

We found that the amount of (recent) ex-post evaluations on these policies is limited – for only five out of the twelve policies an ex-post evaluation was performed after 2020. Moreover, we observed that a large part of the available studies lack quantitative assessment – for only three out of the twelve policies some form of quantitative assessment was carried out. The effectiveness and efficiency are often studied through interviews with stakeholders, case study analysis, or literature study and therefore have a qualitative character.

### EU policy impacts

In order to make the quantitative and qualitative outcomes of the different studies on EU policies more consistent, we have translated them into an 'expert score' that represents their relative effectiveness with regards to the headline targets. The directives directly related to the three headline targets (ETS, ESD, RED, and EED) score high on their relative effectiveness. Moreover, climate policies that are less directly related to the headline targets (such as the FQD, EPBD, $CO_2$ emission performance standards for cars, and Ecodesign Directive) make a fair contribution to the reduction of GHG emissions, increase of renewable energy, and the improvement of energy efficiency. Also non-climate policies are found to have contributed to the GHG target (TEN-T) and the renewables target (both TEN-E and TEN-T).

Some of the studies find an added value of implementing the policies at EU level, but for other policies it is less clear whether the same effect could have been realised with national policies alone. As a result, the empirical basis for drawing firm conclusions with regards to existence of causal impacts from EU climate policy instruments (both individual and packages) is restricted.

We found that the efficiency of most EU policies is assessed positively. Although in most studies some improvements were mentioned, none of the policies was assessed to be inefficient. For some policies there were no relevant assessments of the efficiency available in the literature.

### National policy impacts

For two Member States – Poland and The Netherlands – we studied national policies that are related to the selected EU policies. The literature review for The Netherlands provided a fair number of quantitative effects. Policies like the Stimulation of Sustainable Energy Production and Climate Transition (SDE+) and the Energy Investment Allowance (EIA) were found to have significant effects on the share of renewable energy and energy efficiency, respectively. The number of quantitative studies for Poland, however, was limited.

However, when interpreting the quantitative effects of the national policies, one has to keep in mind that not the whole effect that is found can be attributed to EU climate policy. This is illustrated by the example of The Netherlands. Some policies that contributed significantly to meeting the targets on renewable energy and energy efficiency were put in place (long) before the RED and the EED were established.

### Complexities to estimate policy effects at EU level

Empirical studies at EU level are complex due to the many factors – such as the many differences between Member States – that need to be taken into account and the difficulty to identify causal effects for a specific intervention against a counterfactual scenario. Theoretically, one could resemble and aggregate results from studies at Member State level in order to determine (bottom-up) the effect at EU level. Policies that are implemented on a national level directly affect measures reducing GHG emissions and are less complex to evaluate. The lower degree of complexity allowed us to study the isolated effects of national policies (see example the Netherlands). However, resembling and aggregating the results for all Member States would require that all these studies are actually carried out in the first place (see example Poland), and if so, that this is done in a consistent way taking into account other policy instruments and autonomous reductions.

A second reason for the complexity of EU policy evaluation stems from the *intervention logic* of EU policies. Some of the EU policies are aimed directly at GHG emission reductions within the EU (e.g. $CO_2$ emission standards or EU ETS directive). Others are targeted to accelerate national efforts to increase the share of renewable energy, or at increased energy efficiency, resulting in a reduced demand of fossil energy. All these mechanisms reduce GHG emissions and thereby contribute to the climate goals in an indirect and less explicit manner. These framework directives call for Member States to act on these policy domains.

### Bottom-up: Monitoring framework

The report describes a monitoring framework that is designed to measure progress towards (headline) climate policy targets. The framework – containing relevant indicators on the headline targets, climate policies, non-climate policies, and socioeconomic outcomes – is based on pre-2020 policies, but is meant to contribute to monitoring the 2030 and 2050 climate goals. We found that, depending on the nature of the policy and how targets and objectives are defined, a well-designed set of indicators is typically able to monitor the progress of the policies well.

### Connection with the 4 I's

In chapter 5, on the decomposition analysis, we linked – based on expert opinion – the different decomposition components to the '4 I's' (Infrastructure, Innovation, Investment, and Integration). We argued that energy savings and $CO_2$ savings – the components that can best be influenced by climate policy – have a strong relation with innovation and investment. The results of the decomposition analysis show that both components positively contributed to the reduction of $CO_2$ emissions, especially $CO_2$ savings. Therefore, these results suggest that innovation and investment are the most important enablers for (transformative) change and effective climate policy.

This conclusion is confirmed by the analysis that we performed in chapter 7, on the monitoring framework. We first linked – again, based on expert opinion – individual policy indicators to the 4 I's, and later the policies. This made clear that most policies are linked to innovation and investment – also the policies with the highest impact (as assessed by the literature review in chapter 7). Therefore, we concluded that – based on these results as well – innovation and investment can be considered the most important enablers for effective climate policy.

### Conclusion on EU policy attribution

Overall, the EU has made significant progress reducing greenhouse gas emissions reductions, promoting energy efficiency action, and renewable energy deployment. The economic downturn as a result of COVID-19 in 2020, however, has helped the EU to meet its 2020 targets. Energy efficiency, the increase of renewables, and fuel switching were essential drivers for economy wide reductions. It is likely that a relationship, as enabler, exists with at least investment and innovation.

Based on the top-down and the bottom-up analysis, we conclude that EU climate policy generally had a positive contribution to meeting the climate targets. The top-down analysis showed that a significant share of the decrease in $CO_2$ emissions can be attributed to energy efficiency, whereas renewable electricity and other carbon intensity effects contributed to a lesser extent to the decrease in $CO_2$ emissions. This complements the findings in the bottom-up analysis. The bottom-up analysis showed – through the literature review – that a positive contribution of EU climate policies to progress on the headline targets seems likely, but that it is difficult to quantitatively attribute climate policy to changes in GHG emissions, the share of renewable energy, and especially energy efficiency.

## Recommendations

*Develop a comprehensive evaluation programme for EU climate policy*

The track record of ex-post evaluations falls short to Europe's longstanding experience on ex-ante studies and impacts assessments. While evaluations are generally carried out in line with legal requirements, it is difficult to conclude on causal attributions in a quantitative manner of EU policy instruments. We identified shortcomings and omissions. To gain a better understanding of the costs and effects of climate policy in the EU, it is recommended to establish a comprehensive evaluation programme. This could consist of:

- establishing a clear methodology for determining costs and effects of EU climate policy in the coming years;
- conducting ex-post evaluations of the key climate instruments and policies in sectors, and an overarching review of costs and effects from EU policies.

*Embed the right conditions for a well-functioning monitoring framework in the design of EU climate policy*

Based on our design of the monitoring framework, we recommend to select relevant indicators and impose this type of monitoring framework in an early stage, ideally when transformative policies are designed. In this way, data collection can be targeted towards illustrating progress on the targets by means of the selected indicators. Secondly, we suggest to obligate – or strongly advise – Member States to monitor and collect (complementary to what is already obligated) data on these indicators. Thirdly, standards should be developed on how these data should be collected, stored, and presented. Finally, in case it is not possible to define targets or objectives that are SMART (Specific, Measurable, Achievable, Relevant, and Time-bound), we advise to define a set of indicators that – together – resembles key developments on targets and objectives, and is able to monitor in a reliable way.

# 1. Introduction

To achieve climate neutrality by 2050, EU policy will have to be re-oriented. The EU is contributing its share of efforts to reduce greenhouse gas emissions and has put in place ambitious climate policies leading to a decoupling of emissions and economic growth. It needs to work simultaneously towards climate neutrality across the economy – rapidly enough to achieve the Paris Agreement's goals – while delivering on a broad range of issues, from competitiveness and productivity to employment and health. The concept of the European Green Deal captures this overarching narrative. However, to mobilise the creative, financial, and political resources to achieve the required degree of technological, economic and behavioural change, the EU also needs a governance framework that facilitates cross-sectoral policy integration and allows citizens, public, and private stakeholders to participate in the process and to own the results.

Learning-by-doing is a key feature of EU climate policy making. In this context a relevant question is: how can EU policies directly or indirectly incentivise consumers and producers in every Member State to achieve climate neutrality in 2050? Evidence-based judgement of the extent to which an intervention has contributed to climate targets is an important input to this process of learning-by-doing.

## 1.1 Goal and scope of the report

In this report we aim to assess (ex-post) the overall effectiveness and efficiency of the EU climate policy framework – both at EU and Member State level – for the period 2005-2020. The Member States that we study are Belgium, Finland, France, Germany, Poland, Spain, and The Netherlands. Our evaluation centres around the EU's main climate and energy targets for 2020 (the so-called '20-20-20 targets', or – as we will frequently use in this report, shortly – 'headline targets'):

- greenhouse gas emissions reduction of 20%;
- renewable energy share of 20%;
- energy efficiency increase of 20%.

By conducting an ex-post assessment of EU climate policy during the 2005-2020 period, we aim to contribute to a better understanding of the challenges associated with the transformation towards climate neutrality. With a better understanding in impacts of current and future policies, new avenues are opened up for the development of more effective instruments that can target climate neutrality in a more transformational manner.

## 1.2 Methodology

The effectiveness of EU climate policy with regards to the 2020 headline targets is assessed by using a combination of a *top-down* and a *bottom-up* analysis. In the top-down analysis we will use a decomposition analysis to identify which factors play an important role in changing $CO_2$ emissions, and which proportion of these changes in emissions could potentially be attributed to (climate) policy. In the bottom-up analysis we look at the contribution of the specific policies to the headline targets. For this purpose, we perform a literature analysis on the effectiveness (and efficiency) of relevant policies. Additionally, we design a monitoring framework that can be used to track the progress of these policies towards the targets. This framework is based on policy indicators that are selected based on concept validity (i.e., whether they reflect policy targets in an adequate way) and data availability (i.e., whether they can be measured).

We will link the outcomes of our analyses to the '4 I's', that we view as important enablers for effective EU climate policy:

- infrastructure;
- innovation;
- investment;
- integration.

By linking the results of our ex-post evaluation with the 4 I's, we can provide more insight in the relevance of each of these components.

## 1.3 Reading guide

We will begin the next section by outlining our methodological approach to the analysis. Then, we will provide an overview of the main climate policies and headline targets, followed by a presentation of the progress made towards achieving the 20-20-20 targets during the period of 2000-2020. Next, we will present our bottom-up literature assessment of EU climate policies (and relevant non-climate policies), followed by a more quantitative top-down decomposition analysis. We will then report on how to set up a monitoring framework (including a selection of indicators to measure the headline targets and policies) that can be used for future ex-post evaluations, and the lessons learned from this monitoring framework. Finally, the last section will conclude on all the elements presented in the analysis.

# 2. Methodology

## 2.1 Introduction

An ex-post policy evaluation is an important step in the policy cycle; they are essential for making policies more effective and efficient. A full ex-post policy evaluation in principle boils down to answering the following two classic evaluation questions:

- Effectiveness: What was the contribution of the policy instruments in the realisation of policy targets?
- Efficiency: What was the cost effectiveness of the policy instruments and could targets have been reached with lower costs or using alternative policies?

In this context the effectiveness of a policy refers to what has been the contribution of policy instruments to achieving policy targets, for example on the reduction of $CO_2$ emissions. The difficulty in such an ex-post policy evaluation on effectiveness is to establish a correct counterfactual: how would $CO_2$ emissions have developed without the policy instruments? This is even more challenging at EU level, where the potential number of exogenous factors to correct for is larger than at a national level.

In the evaluation framework of this report our primary focus is on assessing the effectiveness of EU climate policy with respect to the 2020 headline targets, while also addressing the efficiency. We aim to analyse the effectiveness of EU policies along two different angles:

- top-down analysis (using a decomposition analysis);
- bottom-up analysis (using a literature review).

In the *top-down analysis* we will use a decomposition analysis to identify which factors play an important role in changing $CO_2$ emissions, and which proportion of changes in emissions are potentially attributable to (climate) policy (EEA, 2016) (EEA, 2017). In the *bottom-up analysis* we look at the contribution of the specific policies to the headline targets. For this purpose, we perform a literature analysis on the effectiveness (and efficiency) of relevant policies. Additionally, we design a monitoring framework that can be used to track the progress of these policies towards the targets.

The top-down and bottom-up analyses will be integrated to assess the effectiveness of climate policy instruments. This will help to attribute the reduction of greenhouse gas emissions to EU climate policy. Such a combination of top-down and bottom-up approaches has been proven to be successful in other studies (see e.g. CE Delft, (2005) AEA et al., (2009)).

Figure 3 shows a schematic overview of the main elements of the evaluation in this report. The EU 2020 headline targets are given in the middle, with the top-down and bottom-up approaches above and under it, respectively. More detail on the top down (Kaya identity) and bottom up (literature review and monitoring framework) will be given in the next sections.

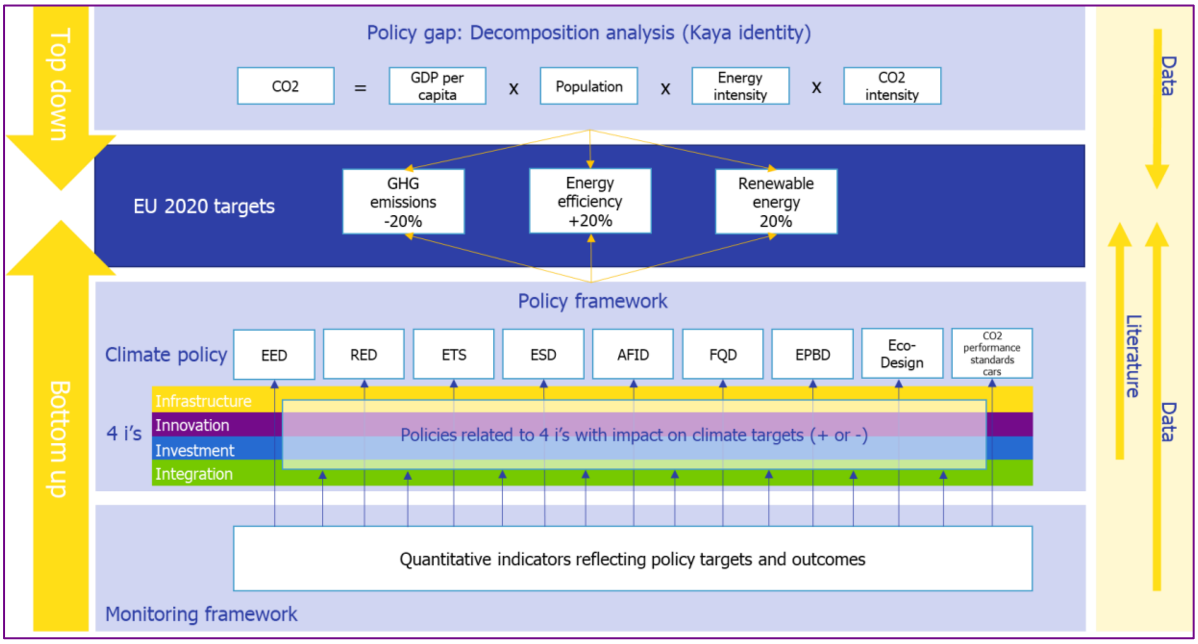


*Figure 3 – Methodology to assess EU 2020 climate policies*

As illustrated in Figure 3, this report relates the outcome of the evaluation to the 4 I's. An elaborate description of the 4 I's is given in the following text box.

This report structures around four cross-cutting core challenges, the '4 I's'[1].

- **Innovation** – The transformation to a climate-neutral economy requires technologies and processes that are not yet invented or available at scale. Innovation here includes technological, business model, and governance innovation. It considers how to facilitate 'technology push' and 'demand pull' policies and focuses on innovations at higher levels of technological readiness.

- **Investment and finance** – A climate neutral economy requires large-scale investments. For the investment and finance challenge, specific instruments are identified with a high transformative potential for mainstreaming climate issues in the financial sector by considering the role of financial supervisors and financial institutions. It also aims to develop proposals how the financial sector can contribute to the exnovation/phase-out of incumbent fossil technologies.

[1] This structure ties the evaluation in with results from other projects within the 4i-TRACTION programme, to be found on https://www.4i-traction.eu/.

- **Infrastructure** – Infrastructure is both an enabler to and a barrier for the transformation to climate neutrality – locking-in fossil technologies but also enabling clean ones. 4i-TRACTION seeks to understand what new infrastructure is needed for climate neutrality, which needs to be upgraded, which can be converted, and which becomes obsolete. It considers how to support the co-evolution of infrastructure and technologies, and how physical infrastructure and regulation interact.
- **Integration** – The transformation to climate neutrality requires the coordination of parallel processes. In the 4i-TRACTION project, 'integration' is understood both as sector integration – the economic/technical linking of different sectors through technological solutions – and as climate policy integration – the systematic integration of climate policy objectives across different sectors.

We view these 4 I's as enablers for effective climate policy. Although we restrict to an ex-post analysis of more traditional policies to only part of the 2005-2020 period (because of data availability), we aim to link our traditional approach to the 4Is-structure, which is more relevant for future systemic transformations.

## 2.2 EU 2020 targets, policies, and progress

We start the analysis by identifying the relevant EU climate policies and targets. The most important climate policies are already shown in Figure 3. More detail on these targets and policies is given in chapter 3.

In chapter 4, we study the progress in the EU on the three headline targets on GHG emissions, share of renewable energy, and energy efficiency. We do this for both the EU and the selected Member States for the period 2005-2020. The result of this exercise is an overview of the achievement of the 2020 headline targets. This gives a first indication as to whether EU policy has helped to reach the targets, although formally no conclusions can be drawn as to attribution of the achievement to the policy instruments. This in itself is thus not conclusive. To assess whether policy has contributed to this progress, it is essential to know how development on these three headline targets would have progressed without policy interventions. Of course, this is a hypothetical question as there is no EU thinkable without energy and climate policy. This notion is analysed through both the top-down and bottom-up framework, as discussed in the next sections.

## 2.3 Top-down analysis

In the top-down framework we will use a decomposition analysis to identify a 'counterfactual' and the policy gap in the development of total greenhouse gas emissions. This counterfactual could be considered as the emission development in the absence of policy interventions. The impact on $CO_2$ emissions is estimated by comparing this counterfactual to those observed in reality, given EU policy intervention. The decomposition analysis enables us to take into account important autonomous trends such as economic growth, population growth, and changes in sector efficiency.

We use the Kaya identity[2] to measure a counterfactual by means of decomposition analysis of how the emissions could have developed without policy (Kaya, 1990). The Kaya analysis is a common method applied across the climate mitigation literature, such as recently by EEA, (2017).

By comparing the current emissions with the counterfactual, we can determine the net impact of a whole package of policy instruments on emissions. The Kaya identity – that can be applied at EU and Member State level – reads as follows:

$$Emissions = Population \times GDP\ per\ capita \times Energy\ intensity \times Emissions\ efficiency$$

Here energy intensity is the weighted average of the sectoral energy intensities (weights are based on sector's share of value added to GDP). Similarly, emission efficiency is the weighted average of sector's emission efficiency weighted with the share of the sector's energy use in total energy use. This means that we take into account that different fuels – with different $CO_2$ intensities – are used.

The elements of the Kaya identity are used to identify the components in the decomposition analysis. We use these elements to estimate so-called counterfactual emissions. That means, we compare emissions at the beginning of the evaluation period and at the end of the evaluation period. For each element, we determine how emissions would have developed if that element was the only factor, while keeping other factors constant. This gives insight in the contribution of that single element to the total changes in greenhouse gas emissions over the evaluation period. Counterfactual emissions therefore mean the emissions that would have happened if one of the elements had developed differently over time. The method to estimate counterfactual emissions is the logarithmic mean Divisia method (LMDI). The method used for the decomposition analysis is further elaborated upon in chapter 5 and annex 5.

The latter two elements (energy intensity and emissions efficiency) of the Kaya identity typically are part of EU climate policy domain, whereas the first two elements (developments in population and GDP per capita) are beyond the domain of climate policy makers. By examining the latter two elements, this decomposition analysis therefore gives some quantitative insight into the contribution EU climate policy has had towards the reduction of greenhouse gas emissions in the

[2] A detailed description is provided in annex 5.

evaluation period. Finally, we will link the components to the 4 I's. Combining this with the effects that have been estimated for these components, will provide insight in the relevance of the 4 I's.

## 2.4 Bottom-up analysis

The bottom-up analysis consists of two parts: a literature review on the contribution of EU policy to the progress on the 2020 climate targets, and the design of a monitoring framework to track progress on targets within EU climate policy packages.

### 2.4.1 Literature review

The European Commission's 2015 Better Regulation package has placed ex-post evaluations at the centre of European governance. Even though the political process of ex-post evaluations is not yet fully streamlined (Listorti et al., 2020), many EU policy instruments have been formally evaluated (ex-post or ex-ante), which forms a source of literature estimating the effects of an individual policy instrument.

When estimating the effect of EU climate policy on $CO_2$ emissions one could use these quantified effects. One should notice, however, that when a quantified effect is available, adding all evaluations of individual policy instruments together most likely results in an overestimation of the policy effect because of the interaction of various policy instruments. This is the case when more policy interventions are targeted towards the same technical measures of behavioural changes, and evaluations do not correct for this overlap.

In order to gain more insight in the impact EU climate policy, however, we use evaluations, impact assessments, and other relevant studies so that we can identify quantified impacts of EU policy on the headline targets. Where available, we note the measured impact of the policy on the climate outcomes of greenhouse gas emission reduction, share of renewable energy, and energy efficiency. When such quantifications are not available, a qualitative assessment will be used.

### 2.4.2 Monitoring framework

In this part of the report a monitoring framework for the selected EU policies is presented. The framework is based on a list of policy indicators (who are able to track progress with respect to the policy targets) and so socio-economic indicators (who describe relevant developments with respect to the headline targets). By linking these indicators to the 4 I's, we can provide more insight in the relevance of these 4 I's.

The indicators are selected based on concept validity (do they reflect policy targets?) and data availability (can they be measured?). As it will turn out, some variables are appropriate for quantitative analysis, while others are not. The extent to which they are suitable for quantitative analysis in relation the (headline) targets is measured using the SMART method: an indicator is

SMART when it is Specific, Measurable, Achievable, Relevant, and Time-bound. With this in mind, we assess how SMART the indicators have been defined, looking at the policies' targets (or objectives), the availability of data, and the way the data is structured. The SMART-assessment of the indicators is performed by expert opinion and ranges from 1 (very useful) to 2 (somewhat useful) to 3 (not useful). Based on this we can assess how well the selected policies can be monitored by the indicators in our monitoring framework, and identify how policies that are less well covered by the monitoring framework are characterized.

Besides that, for each of the indicators, we assess how well these indicators can be used to estimate the policy's contribution to the headline targets (based on expert opinion). Finally, we discuss how the indicators and policies relate to the 4 I's (again, based on expert opinion). In this we limit ourselves to direct links between the indicators and the 4 I's.

We base indicators on existing data from Eurostat and other relevant sources. The indicator database is populated with inputs for the EU as a whole and for the selected set of Member States. This results in an extended list of variables relevant for policy making and their connection to the 4 I's. The database with indicators serves as the main building block for the monitoring framework for EU climate policy. This framework – that will be based on policies that had an effect on the 2020 headline targets – aims to show demonstratable progress to achieving climate objectives and is meant to contribute to monitoring the 2030 and 2050 goals.

# 3. Policies and targets

## 3.1 Introduction

This chapter describes the policies and targets relevant to the EU 2020 targets on greenhouse gas emissions, renewable energy, and energy efficiency. First of all, we discuss the headline targets in more detail. After that, we discuss the most relevant climate policies and non-climate policies.

## 3.2 Headline targets

The main policy targets for 2020 in the European Union are captured by the 20-20-20 targets set in 2009:

- 20% greenhouse gas emissions reduction (compared to 1990 levels);
- 20% of total EU energy from renewable sources (of the final energy consumption);
- 20% improvement in energy efficiency (compared to PRIMES 2007 projections).

- The responsible directives for meeting the GHG emission target are the EU emissions trading system (EU ETS) and the Effort Sharing Decision (ESD). The main directive for renewable energy is the Renewable Energy Directive (RED), which contains binding targets for individual Member States. Besides the overall 20% renewable energy target, 10% of energy in the transport sector should be from renewable sources by 2020. For the energy efficiency target the main instrument is the Energy Efficiency Directive (EED). The 20% improvement of energy efficiency by 2020 is defined as a 20% reduction in energy consumption compared to PRIMES 2007 projections[3]. Energy efficiency targets are expressed as a reduction target in terms of final energy consumption. For the ESD, RED, and EED individual, national targets are defined for each Member State. All Member State national targets are shown in annex 1.

## 3.3 Climate policies

Below we outline the most relevant EU climate policy packages that were implemented with the goal of reaching the 2020 climate targets. These constitute the main policies by the EU which set obligations and give direction for Member States to achieve EU and national climate and energy targets. The climate policies that we study in this report – which are discussed in more detail in annex 2 – are:

- EU Emission Trading System (ETS);
- Effort Sharing Decision (ESD);
- Renewable Energy Directive (RED);
- Energy Efficiency Directive (EED);
- Alternative Fuel Infrastructure Directive (AFID);
- Fuel Quality Directive (FQD);
- $CO_2$ emission performance standards for new passenger cars and new LCV;
- Energy Performance of Buildings Directive (EPBD);
- CCS Directive;
- Ecodesign Directive.

There is an important difference between for example the ETS directive on the one hand and the ESD, RED and EED on the other hand. Namely, the first directive regulates the EU emission of industry directly by setting an EU cap, whilst the latter call for extra policy efforts if Member States are to fall short compared to binding or indicative targets. Higher targets in these latter directives

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[3] Projections of the energy use based on the PRIMES Energy System Model. This model is designed to project the energy demand, supply, prices, trade and emissions for European countries and assess policy impacts.

increase the importance of effective implementation of the policy plans outlined in national plans. Here the question of what part can be attributed to the EU and what to the national policy (already in place before the directive was effectual) is inherently complex to answer.

Finally, European directives like the Ecodesign and performance standards for cars could require manufacturers directly to comply with more stringent minimum energy use or $CO_2$ emission requirements. This type of EU policy will result in more energy-efficient appliances and vehicles and will reduce energy use at the source. Figure 4 gives an overview of the classification of the EU climate policies and their impact.

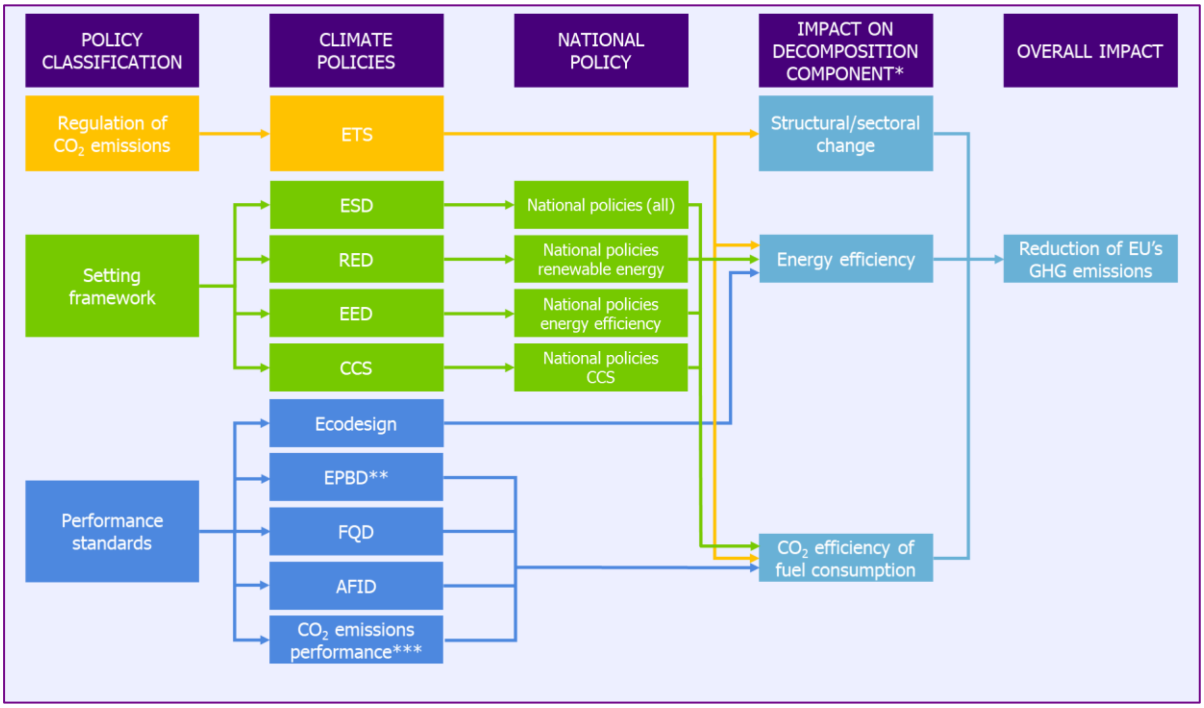


*Figure 4 – Classification of EU climate policies and their impact*

* Chapter 5 elaborates more on these principles.

** EPBD also calls for MS to implement national policies. For the sake of simplicity we focussed on the 'performance standards' part.

*** $CO_2$ emission performance standards for new passenger cars and new LCV.

## 3.4 Non-climate policies

There are also policies that have not been designed to contribute to the headline targets, but that do have an effect on GHG emissions, the share of renewables, or energy efficiency. For these policies we use the term 'non-climate policies'. The non-climate polices – of which a short description of is given in annex 3 – that we consider in this study are:

- Trans-European Networks for Energy (TEN-E);

- Trans-European Networks for Transport (TEN-T);
- Electricity connection target for 2020;
- Creation of ACER and cooperation structures for ENTSOs.

## 3.5 Funding programmes

Besides policies that contribute to meeting the climate and energy targets, EU wide this effort is supported by funding programmes. These programmes can be seen enablers for effective climate policy, as they support investments that contribute to these goals. The most relevant funding programme in relation to the EU 2020 headline targets is the NER 300 Programme. This programme was set up alongside the EU ETS and funded by auctioning revenue from 300 million emission allowances (€ 2.1 billion). It aims at innovative low-carbon technology, focusing on the demonstration of environmentally safe CCS and innovative renewable energy technologies on a commercial scale within the EU.

# 4. Progress on 20-20-20 targets

## 4.1 Introduction

In this chapter, we outline the progress on the headline targets for 2020. We discuss the progress for the EU as a whole, and zoom in on the seven selected Member States to gain a detailed picture on the status of climate goals in 2020.

## 4.2 EU level

In 2020, the EU as a whole reached its 20-20-20 targets. The progress is shown in Figure 5.

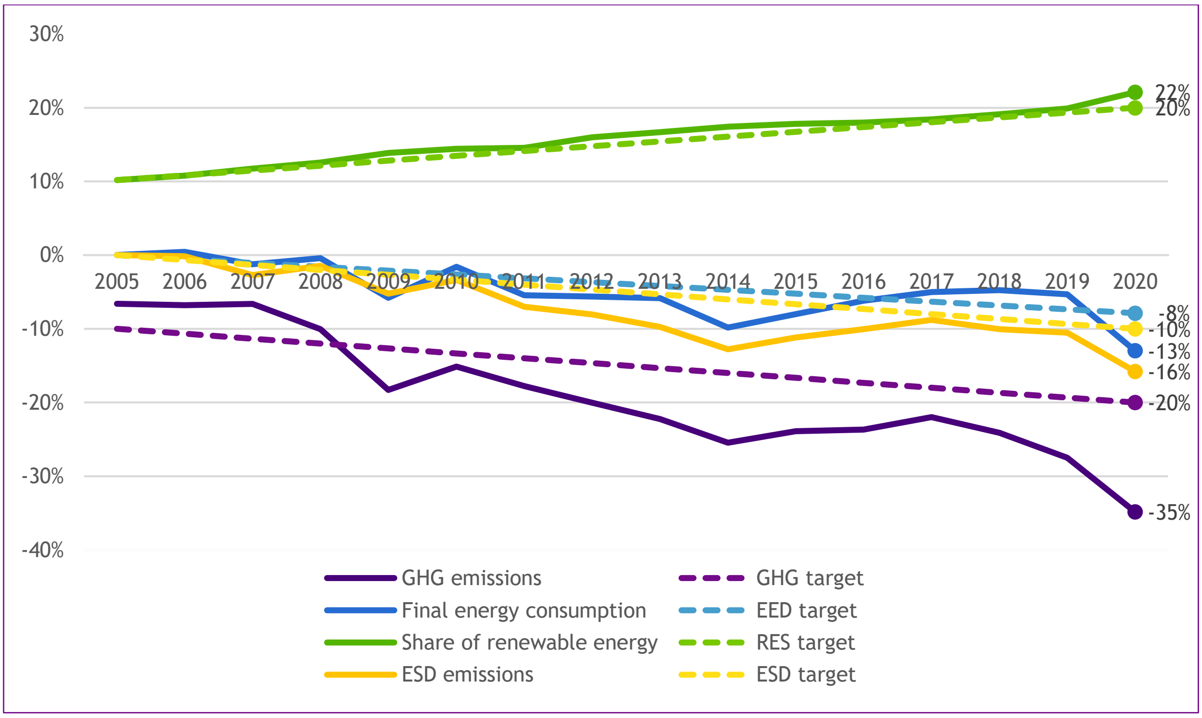


*Figure 5 - Progress on 20-20-20 targets EU27*

Greenhouse gas emissions, as reported to the UNFCCC have decreased by 35% compared to 1990, surpassing the target of 20% by 15 percentage points. The share of renewable energy has increased up to 22%, which is 2 percentage points higher than the target of 20%.

Progress on the energy efficiency target is measured in terms of final energy consumption. Here, the progress in terms of final energy consumption is given. Total final energy consumption was 1.041 Mtoe in 2005, with the target to be reduced to 959 Mtoe in 2020, a reduction of 8%. In 2020, total final energy consumption dropped to 906 Mtoe, a reduction of 13%, surpassing the 2020 target.

In this figure, the progress on the effort sharing decision (ESD) is also shown. The overall target for the ESD sectors is a 10% greenhouse gas reduction in 2020 compared to the levels in 2005. The EU27 emitted a total of 2,469 Mton of greenhouse gases in 2005, making the target in 2020 2,222 Mton (90% of 2,469). This goal is exceeded by 6 percentage points, with an overall established reduction of 16%.

Between 2019 and 2020, a relatively steep improvement can be observed. Around the beginning of 2020, the COVID-19 pandemic and measures taken to contain the virus caused a significant downturn in economic activity. People were limited in their ability to move around. A side effect of the pandemic was a subsequent drop in emissions and air pollution. This has impacted the extent to which the EU targets were achieved. Although the effects of climate policy and the COVID-19 are difficult to disentangle, there is a possibility that progress on the targets would have been somewhat smaller than without a pandemic (EC, 2011). Figure 5 shows that the GHG and RES target were well on track before 2020, which implies that these targets might have been met regardless of the COVID-19 pandemic. The EED target was met due to the steep improvement between 2019 and 2020, although progress was not far from the target before 2020. Therefore, we note the influence of the pandemic in 2020, but conclude that progress towards the 20-20-20 targets in 2020 was significant.

## 4.3 Member State level

For seven Member States, the progress on the three headline targets is tracked in annex 4. The following countries have been selected: Belgium, Germany, Finland, France, Poland, Spain, and the Netherlands. These countries were selected in line with the scope of the broader research programme under the 4i TRACTION framework. Progress on the targets for these Member States is given to put the results in the following chapters in perspective.

# 5. Top-down: Decomposition analysis

## 5.1 Introduction

In this chapter we will use a 'decomposition analysis' method to analyse and explain historical changes in greenhouse gas emissions. This method quantitatively attributes observed changes in carbon emissions to influencing factors. The decomposition analysis is based on the Kaya identity and performed using the LMDI method[4]. Below, we present the general methodology, the results for the EU27 and we relate the analysis to the 4 I's. Detailed information on the methodology and the Member State results can be found in annex 5.

## 5.2 Methodology

Decomposition analysis is a method to estimate the relative impacts of a predefined set of factors on an outcome variable, in this case greenhouse gas emissions (EEA, 2016). Examples of such factors are changes in population, economic development (i.e. gross domestic product (GDP)), the energy intensity of the economy, the proportion renewable fuels in primary energy consumption, and the emission content of fossil fuels that are deployed as fuel or as feedstock in industrial processes. A decomposition analysis allows us to calculate the contribution of each of these factors to the total change in greenhouse gas emissions over a given period of time.

As described in section 2.3, we use the Kaya identity to identify the relevant decomposition factors. The Kaya identity is a mathematical identity that separates total greenhouse gas

[4] Logarithmic Mean Divisia Index. Detail on the LMDI approach is given in annex 5.

emissions into a set of factors that determine total greenhouse gas emissions (Kaya, 1990). It reads as follows:

$$C = P \times \frac{Y}{P} \times \frac{E}{Y} \times \frac{C}{E}$$

where C denotes greenhouse gas emissions, P denotes population, Y denotes GDP, and E denotes energy consumption. The terms in the equation can be interpreted as follows:

- C: total greenhouse gas emissions;
- P: total population;
- Y/P: GDP per capita;
- E/Y: the energy intensity (volume of energy consumed per unit of value added);
- C/E: the carbon intensity (the carbon emissions per unit of energy consumed).

To add more detail, we distinguish the various sectors in the EU economy as well. Therefore, we introduce the element $\alpha_j$ to indicate the share of value added of sector '$j$', and distinguish for each sector the energy intensity per value added and carbon intensity of energy. All sectors add up to the total EU (or Member State) economy.

$$C = P \times \frac{Y}{P} \times \sum_j \alpha_j \left(\frac{E_j}{Y_j}\right)\left(\frac{C_j}{E_j}\right)$$

with $\sum_j \alpha_j = 1$

Hence, the added elements are:

- subscript j refers to the sector[5];
- $\alpha_j$ denotes the share of value added in sector j;
- $\left(\frac{E_j}{Y_j}\right)$ denotes emission intensity in sector j;
- $\left(\frac{C_j}{E_j}\right)$ denotes carbon intensity in sector j.

The addition of this sector specification allows us to evaluate the impact of structural change on total emission intensity. Because the share of sectors in terms of value added can change over time, it is likely that total greenhouse gas emissions change as a result. This is especially clear when considering a movement from economic activity in industrial sectors to service sectors (or vice versa). The energy intensity is much lower in service sectors, such that an increasing share

[5] Sectors generally follow NACE Rev 2. Definition. For more detail on data analysis and sector aggregation, see annex 5.

of service sectors (in terms of GDP) leads to a lower overall energy intensity in the EU economy, which leads to (relatively) fewer greenhouse gas emissions.

From these equations, we identify six separate factors that explain changes in greenhouse gas emissions over the evaluation period:

1. Changes in population.
2. Change in value added per capita (average income).
3. Structural changes in the economy, resulting in a change of the share of a sector.
4. Changes in energy intensity per sector.
5. Changes in emissions due to use of renewable energy (per sector).
6. Other changes in carbon intensity (per sector).

Note that we separate the effect of carbon intensity into an effect due to changes in the deployment of renewable energy, and other carbon savings on energy use. We use these six elements to estimate so-called counterfactual emissions. That means, we compare emissions at the beginning of the evaluation period and at the end of the evaluation period. For each of these six elements above, we determine how emissions would have developed if that element was the only factor, while keeping other factors constant. This gives insight in the contribution of that single element to the total changes in greenhouse gas emissions over the evaluation period. Counterfactual emissions therefore mean the emissions that would have happened if one of the elements had developed differently over time. The method used to determine these counterfactual emissions is the so-called LMDI approach (logarithmic mean Divisia index), which is explained in further detail in annex 5.

The latter three elements (energy intensity, renewable energy, and other carbon intensity effects) are typically part of EU climate policy domain, whereas the first three elements (changes in population, GDP, and sectoral structure) are generally beyond the domain of climate policy makers. For more details on the methods and data selection, we refer to annex 5. Figure 6 summarises the decomposition components and the general policy attribution on EU level.

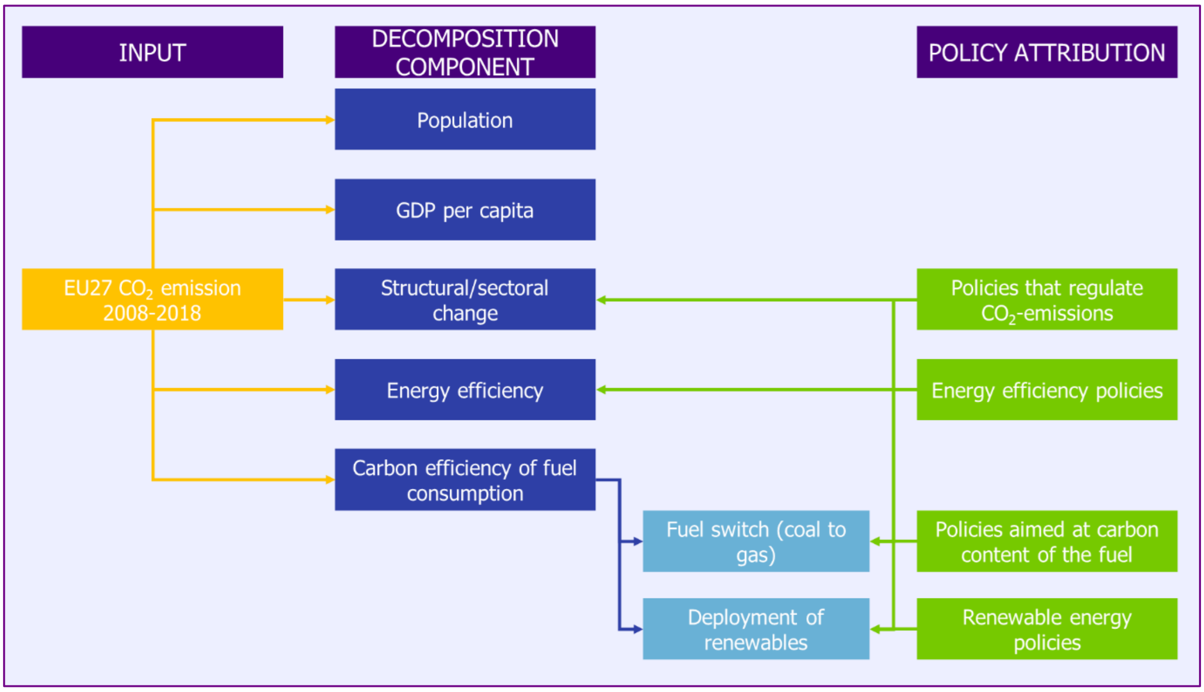


*Figure 6 – Decomposition analysis and policy attribution*

We identify the changes between two historical years with regards to these different elements. Note that we want to analyze structural changes, and avoid focusing on outlier years as much as possible. Therefore, we do not focus only on one year, but instead look at the developments of the average emissions over three years. The reason is that, for example, certain years might be significantly warmer (or colder) than average. Also, this way yearly fluctuations in the added value (of certain sectors) can be smoothed. So when we report on the year 2009, we actually estimate the average emissions of 2008, 2009, and 2010. Due to limited data availability[6], especially on energy consumption, the analysis is limited to the approximate period 2009-2018 (meaning we used data from 2007 to 2019). Henceforth, we refer to the averages of 2008, 2009, 2010 as the situation 'before', and to the years 2017, 2018, 2019 as the situation 'after'.

Within subscript *j*, we can identify three main sectors: industry, service, and transport. A lower level of aggregation has proven impossible due to data limitations. In general, we consider energy intensity to be an important determinant in distinguishing different sectors. Carbon intensity could in theory be similar across all sectors, to a certain extent. Therefore, we believe that a general distinction between industry, service, and transport provides a good first impression of the effects that the shift between economic activity has on total greenhouse gas emissions. Nonetheless, for structural change, it must be stressed that the only effect taken into consideration is a shift from activity between general industrial sectors, general service sectors, and the transport sector.

[6] Data is generally collected from public sources such as Eurostat and EEA. The main bottleneck in data availability is energy use per sector, and emissions per sector according to NACE Rev. 2 before the year 2008. These data limitations restrict the analysis to the given years and sectors.

As such, a caveat in this analysis is that composition shifts within industry that result in changes in average energy-intensity are not captured in this analysis.

## 5.3 Results decomposition analysis EU27

Below, we present the results of the decomposition analysis for the EU27. The EU27 is considered as a single area, without including composition effects at a national level. Results at a Member State level are given in annex 5. These national level results gives more insight on different trends in different Member States, and provide the opportunity to compare developments across various countries.

Figure 7 shows the results of the decomposition analysis for the EU27 for the period 2009-2018. In total, emissions are reduced by a net of 10.8% over the studied period between 'before' and 'after'.

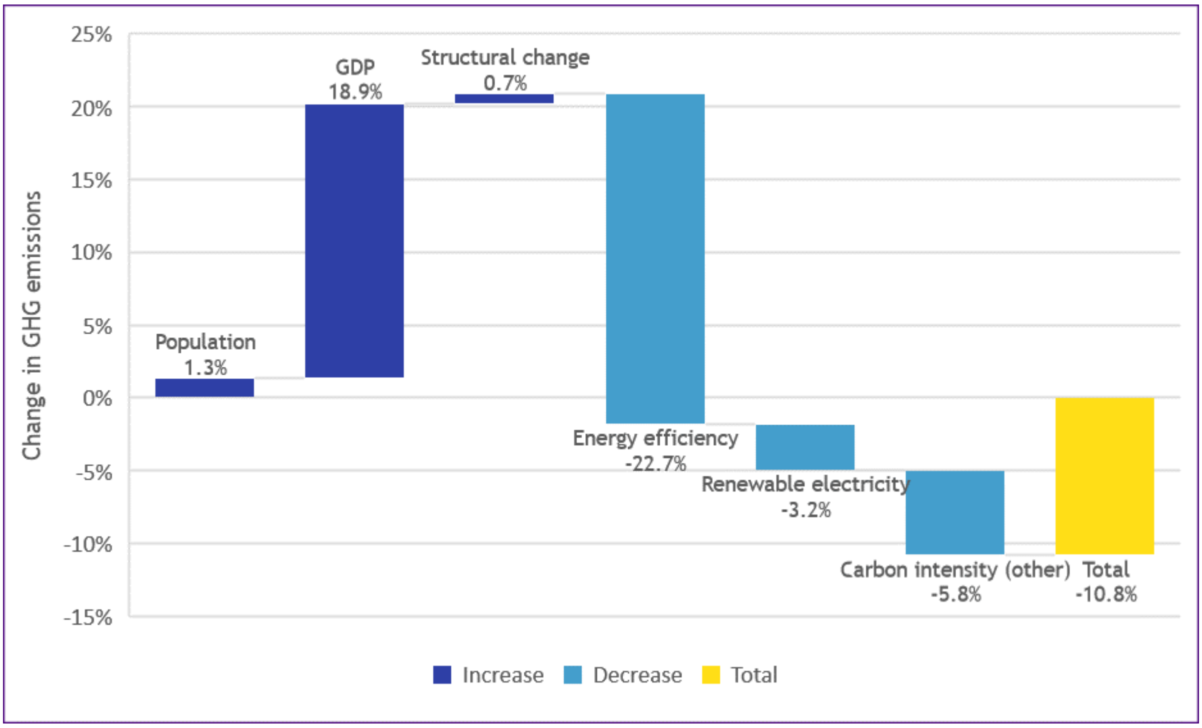


*Figure 7 – Decomposition analysis EU27 2009-2018: GHG emissions*

The analysis shows that due to population growth, GHG emissions rose by 1.3%. Moreover, economic growth (GDP) contributed to an increase in emissions by 18.9%. This can be explained by the start (2009) marking a period of financial crisis across the EU. Since then, the economy has recovered, leading to a significant increase in economic activity since the period around 2009.

According to this analysis, structural change turns out to have a small effect: the shift between industry, services, and transport has led to a slight increase in greenhouse gas emissions of 0.7%. This means that there has been a small shift from sectors with lower energy intensity (services) to sectors with higher energy intensity (industry and transport). Note that this is an overall EU average. The limited size of this effect is partly due to the limited number of sectors included in the analysis. If more sectors could be included, more detailed effects of structural change might be revealed. Nonetheless, in general, the share of industrial sectors in the total economy has not changed significantly over the studied period, which is reflected by the limited contribution of structural change in Figure 7.

The other contributing factors to changes in greenhouse gas emissions are what we consider to be part of the EU policy domain. The largest factor in reducing greenhouse gas emissions is the increase in energy efficiency across the economy. This implies that 22.7% of greenhouse gas emissions have been reduced through energy savings (i.e. a similar level of economic activity has been achieved by 22.7% less energy use). We can relate this figure to the policy domain regarding energy efficiency: one of the main goals of EU policy has been to improve energy efficiency. This analysis shows that there has indeed been a significant increase in energy efficiency over the given years. It must be noted that apart from policy-induced savings, autonomous energy savings are part of this component.

When we assume the current Autonomous Energy Efficiency Improvement (AEEI) in high-income region like the EU to be roughly equal to 0.5% per year[7], the additional effect reduces to approximately 17%. With an AEEI of 1%, the additional effect would reduce to approximately 12%. This is still a significant improvement in energy efficiency that can potentially be related to incentives from policy measures. Although this cannot be concluded from decomposition analysis alone, the results suggest that energy efficiency improvements have been stronger than the levels of savings that are mostly connected to business-as-usual.

The contribution of an increased deployment of renewable energy in electricity generation to reduction in GHG gases is estimated to be 3.2%. The developments on the deployment of renewable energy are important for progress on the EU target of a share of 20% renewable energy in 2020, which is in turn aimed at reducing greenhouse gas emissions. From this analysis, we conclude that there has been a positive contribution of the deployment of renewable energy to savings in greenhouse gas emissions. However, we cannot conclude that this is causally related to EU policy measures. Nonetheless, the results suggest a positive association between these developments.

Other carbon savings account for a 5.8% saving in greenhouse gas emissions. These savings consist of fuel switches in the production process, for instance a general move away from the use of coals, which has a higher emission factor per unit of energy than, e.g., natural gas. It can also include the use of biofuels in production processes. Such developments cannot be further distinguished based on the available data, but these developments are in line with EU policy goals of decreasing the carbon intensity of energy.

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[7] The literature is scarce on estimated values for AEEI. Generally, the AEEI lies in the range of 0.0–2.6% per year, and depends on income and time (Webster et al., 2008).

Overall, these results suggest that there is a positive association between the main areas of EU climate policy and the contributing factors to changes in greenhouse gas emissions. Although decomposition analysis is not able to find causal links, there is at least a strong indication that EU climate policy has been in favour of reducing GHG emissions in the common policy domains. These trends were noticeable despite strong economic growth and population growth, which typically cause an increase in emissions.

Note that we report here only the developments of the overall emissions by EU27 and refrain from a decomposition of the growth of emissions by countries, but all changes in emissions are subject to national composition effects. For the selected Member States, we present a similar analysis as well, as found in annex 5.

## 5.4 Conclusion

### 5.4.1 Reflection and comparison

When comparing the results at the EU27 level with and among results at the Member State level (see annex 5), a general pattern becomes apparent, with some noticeable deviations on Member State level.

Generally, population has naturally grown over the studied period, leading to an increase in emissions. Moreover, GDP has grown quite significantly over the given period following the recovery from the financial crisis, leading to a strong contributing factor of 18.9% increase in GHG emissions. In some Member States this effect is more significant, such as Poland, or less significant, such as in Spain. Had 2020 data been available and included in the analysis, the effect might have been smaller due to the drop in economic activity at the onset of the COVID-19 pandemic.

Moreover, general results point to a limited effect of structural change to changes in GHG emissions. The average effect in the EU27 is a dissaving effect of 0.4%. Two main factors may play a role in this regard. First, the analysis in this chapter limits to the study of only three main sectors: industry, services, and transport. Constrained by data availability, this limited breakdown of economic structure cannot capture potentially significant intra-sectoral shifts in the industrial, service, or transport areas. As such, only general trends between these three segments of the EU economy are included in the analysis, reducing the explanatory power of this element in the decomposition analysis. Second, the movement from a manufacturing-based economy to a service economy has been in process since far before the period studied in this analysis (Schettkat & Yocarini, 2003). Therefore, the trend may have been largely saturated by the starting year of our analysis, leaving little further discernible changes in the nine years analysed here.

Emission reductions due to improvements in energy efficiency are substantial across the EU. On average, 22.7% of greenhouse gas emissions are reduced due to increased energy efficiency. Of the selected Member States, the savings are smallest in Finland (11.4%), although still significant enough to exceed expected improvements due to autonomous developments. The most significant savings of the seven analysed Member States are found in Germany, with 33.5%. Overall, the results point to positive association between EU climate policy on energy efficiency and the resulting developments in the given period. We conclude that it is likely that these results are not only due to 'business as usual' savings (autonomous level of energy-efficiency in the economy), but can to considerable extent be attributed to policy efforts, both on EU and MS levels, in the domain of energy-efficiency.

Lastly, emission reduction due to improvements in carbon intensity are split into an effect due to the deployment of renewable sources in electricity generation, and other carbon savings. On average, 3.2% of GHG emissions are reduced due to more electricity generation from renewable sources. This effect is positive across all studied Member States, meaning that the share of renewables in electricity has increased (and substituted fossils) in each of the countries included in this study. Other carbon savings amount to an average of 5.8% emission reduction. Notable exceptions to the general picture in terms of carbon savings are Germany and the Netherlands. Although there is a net positive effect in terms of carbon savings, the estimated contribution of the deployment of renewable energy in electricity production is offset by a deterioration in carbon intensity from other fossil sources (e.g. more coal, or more import). Potential explanations point to specific developments in these countries such as the closing of nuclear power plants in Germany, the favourable economic conditions for substituting gas by coal because of the margin difference, and the extension of coal capacity in electricity mix.

In summary, developments within the sphere of influence of EU climate policy seem to generally be in line with policy objectives. This gives a tentative indication that EU policy has been at least somewhat effective. As shown in chapter 4, achievements on the three headline climate targets were in line with the objectives by the year 2020, notwithstanding economic and population growth. Combined with the findings in this chapter, this points to a generally positive picture in terms of results in the main pillars of the EU climate policy in 2005-2020.

### 5.4.2 4I-framework

As discussed in chapter 1 and 2 we view the 4 I's (infrastructure, innovation, investment, and integration) as enablers for effective climate policy. If not properly addressed, however, they can also be a barrier to climate neutrality. Therefore, it is relevant to combine these cross-cutting core challenges with the outcomes of the top-down analysis in this chapter. This way, we can acquire more insight in the relevance of the 4 I's in relation to EU climate policy.

Table 1 provides an overview of the decomposition components, their relation to the 4 I's (based on expert opinion), and their impact on the reduction of $CO_2$ emissions (as presented in paragraph 5.3). The table shows that energy efficiency, renewable electricity, and carbon intensity (other) –

that have a strong link with climate policy and have positive impact on the reduction of $CO_2$ emissions – especially show a relation with innovation and investment. Based on this analysis, this suggests that innovation and investment are the most important enablers in this context.

*Table 1 – Decomposition components: relation to the 4 I's and impact on the reduction of $CO_2$ emissions (at EU level)*

| Decomposition component | Infrastructure | Innovation | Investment | Integration | Impact* |
|---|---|---|---|---|---|
| Population | | | | | - |
| GDP | ✓ | ✓ | ✓ | | --- |
| Structural change | ✓ | ✓ | ✓ | ✓ | - |
| Energy efficiency | | ✓ | ✓ | | +++ |
| Renewable electricity | ✓ | ✓ | ✓ | | + |
| Carbon intensity (other) | | ✓ | ✓ | | + |

* Expressed as the positive (+) or negative impact (-) the component has on the reduction of $CO_2$ emissions.

# 6. Bottom-up: Literature review

In this chapter we perform a literature review on the contribution of EU policy to the 2020 headline targets on GHG emissions, renewable energy, and energy efficiency. The aim of this review is to document and illustrate climate effects that can be attributed to EU climate policies, relevant non-climate policies, and relevant funding programmes. By combining these effects, we try to assess to what extent EU policy has contributed to meeting the headline targets. This is a so-called bottom-up approach.

## 6.1 Methodology

For each of the policies described in chapter 3 we use (ex-post) evaluations, impact assessments, and other relevant studies to assess the effectiveness of these policies, focussing on the effectiveness in relation to the three headline targets. Ex-post evaluations were most valuable in our review, as they are better able to assess the actual (policy) effect that has taken place than impact assessments. For each policy we have limited ourselves to the most recent studies available, preferably published after 2020. With the literature review we try to assess the actual contribution of the policy to these targets – quantitatively, as much as possible.

Besides that, for each policy, we collect findings on the EU added value of the policy (i.e. the added value of implementing EU policy instead of only having national policies). The combination of these insights lead to an assessment of its contribution to the GHG target, the renewable energy target, and the energy efficiency target. The effect will be assessed using the methodology in Table 2.

*Table 2 – Assessment method for the contribution of policies to headline targets*

| Effect | Symbol |
|---|---|
| Strong positive effect | +++ |
| Significant positive effect | ++ |
| Positive, but limited effect | + |
| No effect | 0 |
| Negative effect[8] | - |
| Effect not studied | n/a |

The chapter starts with the literature review of EU policies. We focus on EC-commissioned policy evaluations and impact assessments. Moreover, we conduct a search for literature containing estimations of the effect of EU climate policy. For the EU, we limit ourselves to estimations on an EU level. Each document is analysed on the availability of quantified policy effects, and if not available, on a general assessment of the added value of the policy directive. Detailed assessments on a more qualitative level are not reported in this study. Because national policy cannot be ignored, we selected two countries for further assessment through a case study. The Netherlands and Poland are further elaborated upon. In these case studies we follow a similar procedure, now focussing on the effect of national policies. We conclude with the main findings of this chapter.

## 6.2 Climate policies

Below, a literature analysis of each policy directive related to climate is given. Quantified effects are focused on. A description of each of the policies is included in annex 2.

[8] Of the selected policies no significant negative effects with respect to the headline targets were found in the literature.

### 6.2.1 EU Emission Trading System (ETS)

The objective of the EU ETS is to reduce greenhouse gas emissions in the subjected sectors through a cap-and-trade system. The emissions ceiling declines each year, such that the goal is achieved by definition: total emissions cannot exceed the cap. Emissions allowance within the cap are allocated to installations and can be freely traded among emitters. This market mechanism ensures that emissions abatement will be conducted at lowest costs.

Over the full period of 2005-2020, the reduction in the cap on greenhouse gas emissions represents a total reduction 21% in emissions. This implies that greenhouse gas emissions have fallen by at least as much, given full compliance.

According to a review by Laing et al., (2013), assessing the added value of the EU ETS system to greenhouse gas emission reductions is complex, but it is estimated that the added contribution of EU ETS (above reductions that would been achieved without the ETS) is in the range of 40 to 80 Mton $CO_2$ per year until that point in time (2013). This is around 2-4% of the total capped emissions in those years. Although this seems limited, it is noted by the reviewers that this effect is much higher than the impact of many other individual instruments (Umweltbundesamt et al., 2015).

This last evaluation also states that the EU ETS Directive provides the incentives to reduce emissions efficiently (in terms of limited administrative efforts, and by incentivising emission reductions where they are most cost-efficient). Besides a general evaluation of the directive, the study also focusses on more detailed evaluation areas such as cap setting, auctioning, free allocation and carbon leakage, and support for indirect $CO_2$ costs. Although the directive is generally viewed as efficient, some issues – like the low carbon price – have been found that make the EU ETS less efficient.

It is found that the EU ETS Directive has a high EU-added value. It is unquestioned in reviews of the ETS that the EU-wide application is more efficient, effective and fairer than any national system could have been. Furthermore, the EU-wide system is a prerequisite for establishing a level playing field on the internal market for industry in the EU.

In terms of other headline targets, it is found that the EU ETS has also contributed to the overall EU targets to increase renewable energy generation and reduce primary energy use. Through pricing $CO_2$ emissions, an incentive is created for emitters to employ cleaner and more efficient technologies, contributing to increasing the employment of renewable energy and reducing primary energy use (Umweltbundesamt et al., 2015).

Overall, we conclude that the EU ETS made a large contribution to the achievement of $CO_2$ emission reduction (+++) due to its inherent effectiveness. Literature evidence shows a demonstrable contribution of 40 to 80 Mton per year. It also has a positive (++) impact on the other headline targets of increased renewable energy consumption and energy efficiency.

### 6.2.2 Effort Sharing Decision (ESD)

The Effort Sharing Decision was adopted in 2009 and sets limits for GHG emissions for each EU Member State for 2020. The objective is to reduce GHG emissions in 2020 by 10% compared to 2005 and covers emissions transport, buildings, agriculture, small industry and waste sectors. This puts reduction targets on sectors not covered by the EU ETS, hence 'effort sharing' among Member States and sectors. National targets were set for each Member State, according to economic capacity to implement measures to achieve the given target. Member States are expected to implement national policies and measures to fulfil their obligations. ESD calls for extra policy efforts if Member States fall short compared to their targets. The influence on policy making is resulting from an indirect pathway.

An evaluation of the ESD (Ricardo et al., 2016) found that the ESD was partially effective (++) in promoting the reduction of GHG emissions in the targeted sectors. The effects are not quantified due to insufficient evidence. There are mixed results on the added value of ESD for the implementation of national policies and the evidence can be considered as limited: only selected countries report national policies directly linked to the ESD. Nonetheless, national policies might have been taken later or not at all without the ESD as an (indirect) driver. Overall, Ricardo et al. conclude that ESD has added value through EU action, noting that the same level of actions by Member States would not have been taken in the absence of the ESD.

The evaluation also found that the ESD deliver the outcomes efficiently, although there may still be some opportunities for reducing administrative burdens. The main costs associated with the implementation of the ESD arise from the monitoring and reporting requirements, and from the costs associated with any resulting policies. Despite the fact the additional costs under the ESD respect to the monitoring and reporting activities are modest, it is found that burdens may be reduced further and streamlining with other instruments (e.g. reporting of energy data) could be improved.

ESD contributes to the other headline targets of increased renewable energy consumption and reduced primary energy consumption in an indirect manner. GHG emissions are reduced mainly through implementing measures aimed at employing cleaner energy or more efficient technologies. It therefore has an indirect positive effect on the other headlines (+).

### 6.2.3 Renewable Energy Directive (RED)

The Renewable Energy Directive was set into force in 2009. It sets out binding national targets for the employment of renewable energy. It is the main policy directive to fulfil the headline target of 20% increase in renewable energy use by 2020. Under the RED, Member States are obligated to report their plans and policy measures in National Renewable Action Plans (NREAPs). Like the ESD, the RED requires Member States to implement national policy to meet the mandatory targets.

The 2015 evaluation of the RED (CE Delft et al., 2015) does not contain a quantitative estimation of the contribution of the RED to the achievement of the renewable energy target. It is indicated that the mandatory targets are effective, especially for Member States with low renewable energy sources. This indicates that the RED mostly has had an impact on the growth of renewable energy for countries where renewable sources are not abundantly available by nature.

The study evaluated provisions of the directive individually. Some provisions are found to be both effective and efficient, but most still have potential for further improvement. Some of the provisions were not thoroughly assessed, for various reasons such as a lack of data, delays in MS implementation or limited use of the provisions up to that point. Overall, administrative costs related to the RED seem reasonable.

A report on the achievement of the RED targets in 2020 (Guidehouse, 2022) notes that all Member States have achieved their national target, with the exception of France. Overall, the EU has reached its target of 20% renewable energy.

### 6.2.4 Energy Efficiency Directive (EED)

The EED was adopted in 2012 to promote increased energy efficiency in the EU. The main goal is to achieve the headline target for energy efficiency in 2020 and 2030. The target for energy efficiency is set at a 20% increase in 2020 compared to 2005. Under the EED, Member States are incentivised to implement national measures and policies to achieve the goals.

An evaluation of the EED in 2021 (EC, 2021c) finds that especially the energy savings obligations from Article 7 have driven the effectiveness of the directive. Added value of the EED to the achievement of energy savings is not quantified. Nonetheless, it is noted that the EED has contributed to promoting energy efficiency across the EU, with varying degrees of success across Member States. Furthermore, it is concluded that the EED has a high EU added value given its binding nature. Without the targets and measures, energy efficiency might not have improved at the level observed. The EED is closely related to the GHG emissions and renewable energy targets. Energy efficiency is achieved through energy savings, leading to a decrease in greenhouse gas emissions.

The 2021 evaluation concludes that, overall, the EED had contributed to achieving energy savings in the EU in a cost-effective manner. In terms of efficiency, there are no indications for significant differences in the magnitude of costs amongst the Member States for most of the provisions of the EED, except for Article 7 (the costs depend on the design and scope of the policy measure).

There are no quantitative estimations of the contribution of EED to the EU headline targets. We conclude that the EED has positively contributed to the headline targets of energy efficiency (++), greenhouse gas emissions (+) and renewable energy (+/-).

### 6.2.5 Alternative Fuel Infrastructure Directive (AFID)

The general objectives of the AFID were 1) establishing a common framework of measures for the deployment of alternative fuels infrastructure in the EU, 2) minimizing the dependency on fossil fuel (ensuring the security of supply), and 3) mitigating the environmental impact of transport by reducing GHG emissions and air pollutant emissions.

In the evaluation of this directive (EC, 2021b) assesses the effectiveness of the AFID with respect to these objectives at EU level. Concerning the mitigation of environmental impacts – the objective that has the most direct link to the GHG headline target – there has been very limited change in terms of the level of Tank-to-Wheel (TTW) $CO_2$ emission up to 2019 compared to the baseline. The evaluation also shows that the AFID contributed to a limited extent to the reduction of $CO_2$ emissions in transport (net decrease of 0.2% in transport by 2019) and the share of energy from renewable sources in transport (net increase of 0.1% in transport by 2019).

Moreover, the evaluation concludes that the costs of the Directive have been rather proportional to the benefits of the implementation of the Directive. The evaluation did not find any indication that there would have been a largely more cost-efficient approach possible for delivering the same outcomes.

The evaluation also concludes that the directive has added value by implementing it on EU level. According to stakeholders that have been interviewed for the evaluation, markets for alternative fuels and infrastructure would have been less developed without the AFID. Individual action at Member State level would not have resulted in common market development and related adoption of technical specifications for infrastructure and vehicles.

Concluding, we assess that the AFID has made a positive but limited contribution to the 2020 targets on the reduction of $CO_2$ emissions (0) and the increase of use of renewable energy sources (0). Its contribution to the increase of energy efficiency is not studied (n/a). Overall, we conclude that the AFID has had a positive, but limited effect on the headline targets.

### 6.2.6 Fuel Quality Directive (FQD)

As discussed in section 3.3 the FQD set technical specifications for fuels and targets to reduce life cycle greenhouse gas emissions from transport fuels. A target of 10% reduction of life cycle greenhouse gas emissions per unit of energy from fuel and energy supplied (by the 31st of December 2020, compared with the comparator) was built up by an obligatory 6% reduction target and two indicative additional targets of 2%.

In the evaluation of FQD Art.7A the EC et al., (2021) confirm the effectiveness of the directive in creating the conditions for the development of markets for biofuels and other fuels with lower GHG intensity. However, according to consulted stakeholders, the FQD has not yet contributed to its expected environmental impacts. Moreover, the directive's effect on more efficient engines seems to be limited; a relatively low share of survey respondents consider that the FQD has had positive impacts on engine efficiency. The study states that there have been a couple of factors that limit the effectiveness of the directive: the inconsistency of the regulatory framework (due mostly to inconsistencies with RED), low foreseen return on investments for fuel supplies and producers for curbing GHG intensity, a lack of national (supporting) schemes, insufficient availability of sustainable feedstocks, and a lack of harmonisation of national transpositions and of blending mandates in the Member States that have opted to introduce them in national legislation.

With regards to the efficiency of the directive the evaluation provides strong evidence that stakeholders (fuel suppliers/producers and national competent authorities) cannot disentangle the administrative costs induced by both the FQD and the RED, demonstrating how intertwined both directives are. The stakeholders generally consider the costs as reasonable (amounting to 1-2 fte), but it is indicated that this is highly dependent on the way both directives are transposed in each Member State. Also, the stakeholders assess the method to calculate GHG emission intensity of supplied transport fuels as rather easy, even though it could be enhanced by making it provide better guidance as to how Upstream Emission Reductions (UERs) should be accounted for. The evaluation did not find evidence of major issues regarding the efficiency of the monitoring and reporting systems.

It is confirmed by the EC et al., (2021) that the FQD has had added value in decreasing GHG emission intensity from fuel consumption of transport. However, whether or not national initiatives alone would have achieved similar or higher GHG intensity reductions of transport fuels remains unclear.

Concluding, we assess that the FQD has made a small contribution to the use of renewable energy sources (+). However, the directive did not contribute significantly to the 2020 target on $CO_2$ emissions (0) and also the effect on the increase of energy efficiency in engines seems to be limited (0). Therefore, we conclude that overall the FQD has had a positive, but limited effect on the headline targets.

### 6.2.7 $CO_2$ emission performance standards for new passenger cars and new LCV

The regulation (2019/631) aimed on reducing $CO_2$ emissions from cars and vans. As discussed in section 3.3 the regulation set targets for the EU fleet-wide average emission performance ($CO_2$ emission per kilometre) of new passenger cars and new light commercial vehicles registered in the EU.

The impact assessments that have been carried out for this regulation in 2017 and 2021 have not estimated or assessed its contribution to either of the headline targets (EC, 2017) (EC, 2021e). Despite the fact that setting $CO_2$ targets for newly registered vehicles will have an impact on the EU's $CO_2$ emissions over time – and manufactures will have gradually adapted their vehicles' emission performance – we expect that the effect on the 2020 GHG target was limited. The full effect of setting new $CO_2$ targets for newly registered vehicles in the period 2021-2030 will only be realised over time as a larger share of the overall vehicle stock becomes subject to the new targets due to fleet renewal.

The 2017 and 2021 impact assessments on the $CO_2$ emission performance standards for new passenger cars and new LCV have not assessed the efficiency of this regulation.

With respect to the regulation's added value by implementing it on a EU level, it is recognized that despite the fact that initiatives can create synergies when implementing it at national, regional and local level, alone they will not be sufficient (EC, 2021e). Lack of EU coordination would lead to a risk of market fragmentation due to the diversity of national schemes, ambition levels and design parameters. On their own, individual Member States would also represent too small of a market to achieve the same level of results.

Concluding, we assess that the regulation for $CO_2$ emission performance standards for new passenger cars and new LCV has made a positive, but limited contribution to the reduction of $CO_2$ emissions in 2020 (+). However, the regulation's effect on the use of renewable energy sources has not been assessed (n/a), as has been the effect on energy efficiency (n/a).

### 6.2.8 Energy Performance of Buildings Directive (EPBD)

The first version of the EPBD was published in 2002, after which it was revised in 2010 and 2018. With regards to the 2020 the EPBD (2010/31/EU) required Member States to ensure a set of requirements for new buildings.

The last evaluation of the EPBD was done in 2016. It showed that the Directive was effective and that it was delivering on its general and specific objectives (EC, 2016). By performing a decomposition analysis the study provides evidence of around 48.9 Mtoe of additional final energy savings by 2014 in buildings compared to the 2007 baseline of the EPBD (hence, these are the cumulative savings between 2007 and 2014). These savings occur mainly within the scope of the EPBD – space heating, cooling and domestic hot water – and a significant part can be attributed to factors influenced by policy interventions. This figure of 48.9 Mtoe by 2014 is in line with the 2008 Impact Assessment supporting the EPBD, which estimated that the Directive would deliver 60 to 80 Mtoe of final energy savings by 2020. A similar analysis shows that between 2007 and 2013 direct GHG emissions were reduced by 63 Mton $CO_2$, for the residential sector only (i.e. 8% of the 1990 total emissions of household and service sector). In the same period, the share of renewable energy in final energy consumption increased steadily, with a significant contribution of small scale on-building installations. However, the contribution of the EPBD to this cannot be exactly determined.

The 2016 evaluation shows a good performance of the directive on efficiency. The choice of a cost-optimal methodology to steer existing national energy performance requirements towards cost-efficient levels has proved to be an efficient approach for both new and existing buildings.

Analysis of national reports shows that it is ensuring reasonably ambitious levels of requirements. A large cost effective energy saving potential remains in the building sector.

The evaluation states that intervention at EU level is crucial to address the challenge to transform the building stock. For this a proportionate level of harmonisation amongst Member States is justified and necessary. For example, when one or several Member States are not acting in the area of buildings, this would imply overall higher GHG abatement costs for the EU as a whole. Besides that, minimum energy efficiency requirements related to new and existing buildings play an important role to ensure that EU funding is focused on the effective delivery of 2020 targets. Also, the setting of a European ambition for nearly zero-energy buildings created a vision for the sector and helped mobilising stakeholders.

Assuming that 60 tot 80 Mtoe of energy savings are actually achieved, that a significant share of this can be contributed to policy interventions (of which the EPBD was one of the main responsible agents), and that the EPBD had added value by implementing it on EU level, we assess that the directive has made a significant contribution to the energy efficiency target (++). With regards to $CO_2$ emissions we assess that the directive has made a positive, but relatively smaller contribution to the headline targets (+). There has been an improvement of the amount of energy from renewables, but the contribution of the EPBD to this cannot be exactly determined (n/a).

### 6.2.9 CCS Directive

The Directive on the geological storage of $CO_2$ (CCS Directive) is in place since 2009. Since it is mainly aimed at the removal of $CO_2$ from the air, it has a most direct link with the GHG headline target.

According to IOGP, (2022) two CCUS projects were realized between 2009 and 2020. These projects – in France and The Netherlands – were both capture projects. The combined capacity of these two locations is 0.2 Mton $CO_2$ per year.

There is no relevant literature on the efficiency of the CCS Directive. Therefore, this cannot be assessed from literature. The added value of CCS Directive – by setting up a regulatory framework on EU level – is not clear. It is likely that the regulatory has contributed to effectiveness, but no relevant literature in which this effect is isolated is available.

Concluding, the CCS Directive has likely made only a minor contribution to the headline target for GHG by realizing two CCUS projects (0). There’s no direct, studied link with both the renewable energy target (n/a) and the energy efficiency target (n/a).

### 6.2.10 Ecodesign Directive

The Ecodesign Directive was implemented in 2009. In 2012, an official evaluation was done by CSES. The main objective of the Ecodesign Directive was to reduce energy consumption and relevant environmental impacts for energy-related products. The directive sets out minimum mandatory requirements for the energy efficiency of a range of products. Product-specific regulations are directly applicable to all EU Member States.

In the 2012 evaluation (CSES & Oxford Research, 2012), no direct statements are made as to the effectiveness of the Ecodesign Directive due to lack of data. Nonetheless, it is noted that the energy consumption from appliances is decreasing, and that the Ecodesign Directive seems to have an encouraging effect. Improvements are especially notable in electrical appliances.

An evaluation in 2020 (European Court of Auditors, 2020) further notes that EU policy although EU actions have contributed effectively to reaching the objectives of the Ecodesign directive, although effectiveness could have been higher if there had not been significant delays in the regulatory process. Therefore, we conclude that there is a moderately positive effect on energy efficiency.

In these evaluations no conclusive findings are reported on the efficiency of the Ecodesign Directive.

## 6.3 Non-climate policies

Below, an analysis is done based on literature on non-climate policies. The focus is on quantified effects of these policies on climate outcomes in the EU. A description of the policies is given in annex 3.

### 6.3.1 Trans-European Networks for Energy (TEN-E)

TEN-E is focused on linking the energy networks of the Member States of the EU. Although initially implemented to facilitate infrastructure for fossil fuels, it has also become a key instrument for the creation of a pan-European electricity network, crucial for large-scale application of renewable energy sources. Moreover, it can support the deployment of innovative energy sources such as hydrogen. These networks are facilitated under TEN-E through PCIs (Project of Common Interest).

Due to its relevance to energy infrastructure, measures to achieve the goals under TEN-E could have indirect effects on climate objectives. In the 2021 evaluation of TEN-E (Ecorys et al., 2021) it is noted that it is difficult to establish a direct link between TEN-E and climate achievements in terms of greenhouse gas emission reductions, as well as in terms of climate efficiency. Although not quantified, the 2018 evaluation of the TEN-E regulation finds that there is at least a positive link to climate targets rather than a negative one. That means that TEN-E potentially contributes to the achievement of climate targets. (Trinomics, 2018)

There is a clearer link with the renewable energy target. Several of the PCIs were developed with the explicit intention of facilitating imports and exports of electricity from renewable energy sources. It is less clear whether gas interconnectors contribute positively or negatively to climate objectives. If they facilitate a shift from coal or oil to gas, an improvement in terms of climate goals could be established, but if they compete with electricity PCIs, it might hinder the deployment of renewable energy (Trinomics, 2018).

In relation to the efficiency of the regulation, the 2021 evaluation by Ecorys concludes that – although a quantification of all the benefits and costs is not possible – based on an analysis of the cost drivers, benefits of the TEN-E Regulation outweigh the costs of the Regulation. Benefits include socio-economic net benefits and market efficiency. These socio-economic net benefits were realised through an increase in SOS, competition and integration of markets, and – to a lesser extent – sustainability. The main cost drivers are the PCI selection process and monitoring, the permitting process, stakeholder consultation and costs associated with decisions on CBCA and regulatory incentives. In general, stakeholders view the costs associated with the Regulation to be justified.

It is concluded in the evaluation by Trinomics that TEN-E has a clear added value in the EU. It is deemed appropriate to promote trans-European energy infrastructure at EU level, and it offers benefits beyond what Member States could achieve individually. It is also noted that this EU wide policy is more beneficial for some Member States than others, as is the case with many policy packages.

Overall, it seems there is an unquantified but positive effect of TEN-E policies on general climate objectives. Especially electricity PCIs act as enables for progressing on the renewable energy target (+).

### 6.3.2 Trans-European Networks for Transport (TEN-T)

TEN-T is focused on creating a transport infrastructure network throughout the EU. It is not primarily focused on climate targets, but can potentially contribute to climate targets by steering toward climate friendly modes of transport, such as railways.

There are no known quantitative studies on the contribution of TEN-T to EU climate targets in 2020. In an evaluation of TEN-T (EC, 2021d), it is however pointed out that TEN-T is coherent with EU climate policy. This means that there is no indication that TEN-T inherently opposes EU climate targets. A conclusion from the evaluation is that nonetheless, closer alignment with EU policies such as the RED and AFID are needed. Greenhouse gas reductions are noted as one of the beneficial effects of the TEN-T framework. This effect is not quantified.

The evaluation in 2021 notes that there is high agreement that the TEN-T directive is of added value at the EU level. Around 85% of consulted respondents in a survey disagreed or strongly disagreed that the same results would have been achieved at the regional or national level, without the TEN-T policy. This is not directly linked to the added value in terms of climate outcomes, but instead concerns the direct outcomes of the TEN-T policy. However, it does give an indication that whatever positive effects on climate outcomes there are, they might have been smaller or absent without the TEN-T policy.

With regards to the efficiency of the regulation, the 2021 evaluation points out that Governance across Member States and sectors has improved, which helps to make administrative gains through multilevel governance. The coordination between core network corridors (focusing on infrastructure development) and rail freight corridors (focusing on operational aspects) has also led to efficiency gains. In relation to the reporting and monitoring obligations set out in the TEN-T Regulation more generally, the evaluation suggests that there is some need for streamlining and strengthening these tools of TEN-T policy.

Overall, we conclude that TEN-T does not negatively contribute to EU climate targets. There might be positive effects on the GHG reduction target (+) and the renewable energy target (+). Energy efficiency is not adressed in the evaluation (n/a).

## 6.4 Funding programmes

### 6.4.1 NER 300 Programme

As discussed in section 3.5, this programme stimulates innovative low-carbon technology, focusing on the demonstration of environmentally safe CCS and innovative renewable energy technologies on a commercial scale within the EU.

Åhman et al., (2018) assessed the programme. The study points out that that many projects of the programme were delayed or withdrawn (especially CCS projects and to a lesser extent bioenergy projects), which can be explained by specific design features in the program that placed large-scale projects at a disadvantage, and by the wider context of EU climate and energy policies providing inadequate market-pull incentives for CCS and biofuels. According to the study, the identified design and policy challenges are more related to political feasibility than to lack of knowledge of what is needed to trigger innovation.

No official evaluation has been carried out on effectiveness, efficiency, and EU added value of the NER 300 programme after 2020. Therefore, these components – and the contribution of the programme to the headline targets – are not assessed.

## 6.5 Member State examples

This section describes the implementation of EU climate policy in two selected Member States: The Netherlands and Poland. We discuss the most relevant national instruments for these countries in relation to EU climate policy between 2005 and 2020, and their contribution to the targets on GHG emissions, renewable energy, and energy efficiency.

### 6.5.1 The Netherlands

#### 6.5.1.1 EU Emission Trading System (ETS)

The EU ETS has been implemented in the Netherlands through a provision in the Dutch Environment Management Act. Here, all elements pertaining to i.a. the issuing of permits, monitoring and inspection, and auctioning are registered. The Dutch Emission Authority (Nederlandse Emissie Autorieit, NEa) is responsible for the functioning of the ETS in the Netherlands. The Netherlands participate in the common auction platform for the emission permits in the period up to 2020. In 2020, 419 installations in the Netherlands were subject to the EU ETS. Together they are responsible for 74.1 Mton $CO_2$ emissions in 2020 (NEa, 2020).

Several policies have been implemented to facilitate the reduction of greenhouse gas emissions among ETS sectors in the Netherlands, as well as to address the targets under RED and EED. These policies are therefore mostly aimed at the deployment of renewable energy and the stimulation of energy efficiency. Examples of these policies are subsidies for renewable energy (SDE+) and long-term agreements in industrial sectors on energy savings. These policies are further discussed in the following sections.

#### 6.5.1.2 Renewable Energy Directive (RED)

Between 2010 and 2020 there have been a number of subsidies in the Netherlands that have contributed significantly to its RES target. The most important subsidy was the Stimulation of Sustainable Energy Production and Climate Transition (SDE+, established in 2011), that stimulated renewable energy production by compensating the 'unprofitable' part of investments ('onrendabele top') in energy projects. In the evaluation of the SDE+ it is shown that this subsidy had a major contribution to the Dutch renewable energy production: 20 TWh of renewable energy in 2020 was produced with support of the SDE+ (33% of the total renewable energy production) (Trinomics, 2021). About 11,8 TWh of SDE+ subsidized projects (11% of final energy consumption) was electricity production, mainly through solar PV and wind power on land. The evaluation shows that the vast majority of SDE+ projects was additional – meaning that they would not have been realized without the SDE+. Therefore, it can be concluded that the SDE+ contributed significantly to scaling up the Dutch renewable energy production towards 2020.

Other subsidies that made a contribution to the Dutch renewable energy production in 2020 were the SDE (established in 2008 and the predecessor of the SDE+), Environmental Quality Electricity Production subsidy (MEP, open between 2003 and 2006), Netting and Zip Code regulation[9] ('Salderings- en postcoderoosregeling', established in 1998), tenders Offshore Wind Power (tenders 'wind op zee'), and the admixture obligation ('bijmengverplichting', established in 2007). Together these were responsible for about one-thirds of the renewable energy production in 2020.

The Netting and Zip Code regulation contributed for about 10% to the share of renewables in 2020. As this regulation originates from 1998, this share cannot be contributed to the RED (that was established in 2009).

#### 6.5.1.3 Energy Efficiency Directive (EED)

Article 7 of EED requires Member States to achieve a certain amount of energy savings every year. The target for The Netherlands was set at 482 PJ for the period 2014-2020. This was pursued by a wide range of policy instruments. The most important instruments are listed in the progress report on the 2020 targets for renewable energy and energy efficiency that was submitted to the European Commission[10]. The report mentions The Energy Investment Allowance (EIA, originating from 1997), Long Term Agreement industry (MJA3, originating from 2008, and its oldest predecessor from 1992), Long Term Agreement big industry (MEE, established in 2009 as a response to the EU ETS), Long Term Agreement service sector, policies targeted to households, and policies targeted to the service sector. In total these instruments make up for 672 PJ (or 16 Mtoe) of energy savings.

As we can see, the EIA (responsible for about one-thirds of the savings) and MJA3 and MEE (together responsible for about 20% of the savings) are (much) older than the EED (that originates from 2012). This means that – although these regulations have been updated over time – it is likely that a significant share of these reported savings would have also been achieved without the EED.

#### 6.5.1.4 Alternative Fuel Infrastructure Directive (AFID)

As described in section 3.3, Member States were obliged to ensure that an appropriate number of publicly accessible recharging points were in place by the 31st of December 2020. The Netherlands have implemented the AFID by carrying out the Resolution Infrastructure Alternative Fuels in 2017. This resolution mentioned a target of 25,000 public recharging points by 2020. This was met by having more than 67,000 points in place by the end of 2020 (EAFO, 2023).

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9 This regulation enables households with solar panels to deliver abundant electricity back to the electricity net, for which they are compensated by the energy company.

10 Progress report renewable energy and energy savings in 2020

According to EC, (2021a) – which assesses the Dutch Implementation Report on the AFID – the Dutch Climate Act and Climate Agreement[11] (established in 2019) have been the main drivers for the national measures related to the AFID. The portfolio of measures contains legal measures, policy measures and deployment and manufacturing support measures. With regards to policy measures the Dutch Government has put in place a significant number of direct incentives to stimulate the deployment of alternative fuel vehicles and related infrastructure. Most of them are of financial nature, applicable at national level and complemented with public procurement initiatives at regional and local level. For example, the Autobrief II contains incentives to promote zero-emission vehicles by providing exemption from registration tax, reduced income tax liability for business users and exemption from annual vehicle tax. Besides that, a favourable tax rate for both CNG and electricity from public recharging points was put in place. Another instrument that was widely used was the Environmental Investment Deduction Allowance (MIA\VAMIL), that provided additional tax deduction on taxes on income and profits – applicable to investments in electric vehicles and charging infrastructure. Besides these measures on national level, various financial and non-financial measures were implemented at local level. The report assesses the overall impact of the (legal, policy, and deployment and manufacturing) measures for electricity as high and for CNG as low.

#### 6.5.1.5 Fuel Quality Directive (FQD)

The Netherlands have not met the 6% GHG intensity target in 2020. The average greenhouse gas intensity of road transport fuels ended at 5.4% excluding ILUC[12] (or 5.2% including ILUC) (EEA, 2022).

There have not been any recent evaluations on Dutch policy related to the FQD. However, CE Delft, (2020) points out that the Climate Agreement states that – with respect to feedstock use and sustainability and a lower GHG intensity of fuels – no growth of biofuels from food and feed crops will take place above the level of 2020. This is more strict than the provisions of the RED.

#### 6.5.1.6 $CO_2$ emission performance standards for new passenger cars and new LCV

In The Netherland there no specific policies have been implemented in relation the $CO_2$ emissions standards of new cars and LCV's. However, the EU standards have a significant effect on the

[11] The Climate Agreement is part of Dutch climate policy and is an agreement between organisations and companies in The Netherlands to reduce greenhouse gas emissions. The agreement involves five sectors: built environment, mobility, industry, agriculture and land use, and electricity. Reference: National Climate Agreement – The Netherlands.

[12] Indirect Land Use Change. When biofuels are produced on existing agricultural land, the demand for food and feed crops remains, and may lead to someone producing more food and feed somewhere else. This can imply land use change (by changing e.g. forest into agricultural land), which implies that a substantial amount of $CO_2$ emissions are released into the atmosphere.

energy efficiency target. It is estimated that 10 to 13 PJ of energy is saved due to the $CO_2$ standards (PBL, 2019). The effect on the reduction of $CO_2$ emissions is not quantified.

#### 6.5.1.7 Energy Performance of Buildings Directive (EPBD)

This directive stated that Member States should set requirements for new buildings and houses by 2020, making them nearly zero-energy. As a consequence of this directive The Netherlands have introduced a set of requirements for nearly zero-energy houses ('BENG'). Besides that, the government has abolished an obligation to connect newly constructed houses to the natural gas network. Both instruments facilitate that new houses after 2020 will be more sustainable, being heated with delivered heat or electrical heat pumps. Without the adjustment of the obligation to connect to natural gas, half the newly constructed houses would have still been partly or completely heated with natural gas (PBL, 2019). Another instrument that has been introduced in relation to the EPBD is the obligation to register new buildings with an energy label. This has to make sure that future buyers or renters of a house receive correct information about a building, and its potential energy saving measures (CE Delft, 2022).

### 6.5.2 Poland

As described by (Nachmany et al., 2015), Poland has no single separate policy document setting a comprehensive climate change strategy. The 'Climate Policy of Poland: Strategy to reduce greenhouse gas emissions in Poland until 2020' was developed by the Environment Ministry and adopted by the Council of Ministers in 2003, but became outdated and is no longer in force. Instead, Polish climate policy is established in a number of different laws and policies.

Important strategies are the 'Strategy for Economic Innovation and Effectiveness' (2012-2020, adopted in 2013), the 'Strategy for Energy Security and Environment' (ESE, adopted in 2014). The most relevant with respect to energy and environment is the ESE, which identifies key priorities for environmental policy by 2020. Other relevant instruments are the Energy Policy of Poland until 2030 (EPP 2030) – that is focused on improving energy security, efficiency and competitiveness – and the National Green Investment Scheme (GIS), that stimulates different programs (such as programs on energy management in public buildings; agricultural biogas plants; or biomass combined heat and power stations)

In the following paragraphs we describe the most relevant Polish instruments with regards to the EU climate policy between 2005 and 2020.

#### 6.5.2.1 Renewable Energy Directive (RED)

In relation to the RED, the EPP establishes that Poland's energy supply should consist of a mix between cogeneration, renewables, grid modernisation, and nuclear (Nachmany et al., 2015). In order to steer this the EPP set measurable targets for the share of renewable energy sources, the share of biofuels in the transportation fuels market, and building of at least one biogas agricultural plant in each commune by 2020. The EPP 2030 strategy document also addresses the need to gradually increase the share of bio-components fuel in transportation fuels. As a result, the government established differentiated fuel taxes in order to promote alternative fuels.

#### 6.5.2.2 Energy Efficiency Directive (EED)

In 2011 the Energy Efficiency Law was adopted in Poland (prior to the EED). This Act established the legal framework for stimulating investment in energy efficiency in Poland. The system is based on the obligation of the specified entities to use certificates of energy efficiency (so called 'white certificates') or the payment of a replacement fee. This obligation has been imposed on a wide range of energy users, such as energy companies selling electricity, heat and natural gas to end-users connected to the Polish network.

The most important documents defining the energy efficiency policy in Poland include the EPP and – in line with the EED – the National Action Plans (KPD) regarding energy efficiency (1, 2, 3, 4 KPD for the years 2007, 2012, 2014, 2017, respectively) (IOS-PIB, 2019). The Third Action Plan (3 KPD) on energy efficiency – adopted in 2014 – summarized the achieved energy efficiency improvement targets, presented the objectives for 2020, and updated the actions and measures taken, as well as planned in order to accomplish the goals.

Another relevant instrument in relation the energy efficiency is the Strategy for Energy Security and Environment (ESE). Besides ensuring the energy supply through measures such as better use of domestic energy resources and modernising the power industry (including development of nuclear power), this policy strives to improve energy efficiency (Nachmany et al., 2015).

#### 6.5.2.3 Alternative Fuel Infrastructure Directive (AFID)

Poland has carried carried out the AFID by implementing a set of legal and policy measures to support alternative fuels, mainly focussing on electricity and CNG. According to EC, (2021a) – in which the Polish Implementation Report on the AFID is assessed – the overall impact of these measures is estimated to have a low to medium impact. Most measures are covered by the *Act of 11 January 2018 on electromobility and alternative fuels* that addresses entirely or partly the topic of alternative fuels and by national legal acts transposing EU Directives. The Low-Emission Transport Fund, that was put in place in 2019, was designed to finance the implemation of the measures.

Moreover, as described by Nachmany et al., (2015), the EPP strives to increase the share of biofuel in transportation fuels. As a result, the government established differentiated fuel taxes to promote alternative fuels. In 2013 the fuel fees charged to producers or importers of motor fuel were differentiated.

#### 6.5.2.4 Fuel Quality Directive (FQD)

The Act on Biocomponents and Liquid Biofuels has been the most relevant policy in Poland in relation to the FQD. This Act obligates producers, importers, and suppliers of fuels to meet an annual quota of biofuels in the total amount of liquid fuels that are produced, supplied, and imported. The Act that was originally established in 2009 was updated in 2013. The Regulation established that the obliged companies have to ensure that biofuels make up the following quotas of the company's total annual sale or consumption of fuel: 7.1% between 2013 and 2016, 7.8% in 2017, and 8.5% in 2018 (Nachmany et al., 2015).

#### 6.5.2.5 Energy Performance of Buildings Directive (EPBD)

In relation to the EPBD, Poland has designed measures for the improvement of energy efficiency in the housing sector. The Thermomodernization and Renovation Fund – in place since 2009 – was used to support thermomodernization projects and tasks associated with the thermomodernization of renovation projects, implemented in old, multi-family residential buildings. The resources from the Thermomodernization and Renovation Fund were allocated to refinancing parts of the costs of thermomodernization and renovation projects aimed at improving the technical condition of existing housing stock, while simultaneously decreasing the heat demand. The estimated energy savings through the the fund add up to 79 TWh between 2009 and 2020 (IOS-PIB, 2019).

## 6.6 Conclusion

This chapter resembles a literature review of the most relevant policies with respect to the EU 2020 targets for GHG emissions, renewable energy, and energy efficiency. We have assessed the effectiveness of the policies with respect to these targets, the efficiency of the policies, and to what extent there was added value by implementing it at EU rather than at Member State level. We have based our literature review on evaluations, impact assessments, and other relevant studies.

Table 3 gives an overview of the findings of our literature review. The second column ('Ex-post evaluation after 2020') indicates whether an ex-post evaluation has been carried out after 2020. It shows that this was done for only five out of the twelve policies. For the remaining seven policies we either used older ex-post evaluations or impact assessments that were carried for the revision of the directives. The latter provided some ex-post insights, but these were often less useful and structured than those from ex-post evaluations carried after 2020.

### 6.6.1 EU policy impacts

We have found that only few studies quantify the effects of (EU) policies on either of the three headline targets. One conclusion that can be drawn from this, is that it is too complex to isolate the contribution of EU policies on these targets. The nature of their effect is often rather indirect. The majority of the EU policies provide guidelines along which Member States need to act. Policies that are implemented on a national level are often policies that have a more direct effect on GHG emissions, renewable energy, or energy efficiency. This is illustrated in section 6.5, which shows that a case study on Member State level provides more insight in the actual quantitative effect. The lower degree of complexity allows us to study the isolated effects of national policies more easily and accurately.

In order to make the outcomes of the different studies on EU policies more consistent, we have translated them in an expert score that represents their relative effectiveness with regards to the headline targets. An overview of these scores is shown in Table 3. Intuitively, the directives that are directly related to the three headline targets (ETS, ESD, RED, and RED) score high on their relative effectiveness. The table also shows that Energy efficiency is relatively poorly studied, possibly because it is harder to measure than GHG emissions or the share of the renewables. An explanation for the could be the complexity to estimate a counterfactual for energy efficiency, as energy efficiency policy have been in place in Member States for more than thirty years, which makes it almost impossible to estimate the autonomous development of energy efficiency. The effect on the renewable energy target is slightly better covered in the literature. Table 3 also shows that the climate policies that are less directly related to the headline targets make a fair contribution to the reduction of GHG emissions, increase of renewable energy, and the improvement of energy efficiency.

The efficiency of the EU policies for most policies are assessed positively in the different studies. Table 3 gives an overview of the findings. Here '+' indicates that the policy is found to be efficient, and 'n/a' that the efficiency is not assessed. Although for most policies the studies mention some improvements, none of the policies was assessed to be inefficient.

With respect to the policies' added value by implementing it at EU level we conclude that it generally had a positive contribution. The added value is often studied through interviews with stakeholders and therefore has a qualitative character. For most policies this effect is expected to be positive. For some policies it is less clear whether the same effect could have been reached with national policies alone.

### 6.6.2 National policy impacts

For two Member States – Poland and The Netherlands – we studied national policies that are related to the selected EU policies. The literature review for The Netherlands provided a fair amount of quantitative effects. Policies like the Stimulation of Sustainable Energy Production and Climate Transition (SDE+) and the Energy Investment Allowance (EIA) were found to have significant effects on the share of renewable energy and energy efficiency, respectively. The amount of quantitative studies for Poland, however, were limited.

However, when interpreting the quantitative effects of the national policies, one has to keep in mind that not the whole effect that is found can be attributed to EU climate policy. This is illustrated by the example of The Netherlands. We saw that the EIA (originating from 1997), the Long Term Agreement industry (MJA3, originating from 2008, and its oldest predecessor from 1992), and the Long Term Agreement big industry (MEE, established in 2009 as a response to the EU ETS) were major contributors to the reported energy savings in 2020 (about one-thirds, 10%, and 10%, respectively). The EED, however, was established in 2012, meaning that it is likely that a significant share of these reported savings would have also been achieved without the EED. To a lesser extent we also see this in relation RED: the Netting and Zip Code regulation – that enables households with solar panels to be compensated for the abundant electricity that they deliver back to the electricity net – contributed for about 10% to the total share of renewables in 2020. As this regulation originates from 1998, this share cannot be contributed to the RED (that was established in 2009).

### 6.6.3 Lessons learned

Empirical studies at EU level are complex due to the many factors – such as the many differences between Member States – that need to be taken into account and the difficulty to identify causal effects for a specific intervention against a counterfactual scenario. Theoretically, one could resemble and aggregate results from studies at Member State level in order to determine (bottom-up) the effect at EU level. Policies that are implemented on a national level directly affect measures reducing GHG emissions, and are less complex to evaluate. The lower degree of complexity allowed us to study the isolated effects of national policies (see example the Netherlands). However, resembling and aggregating the results for all Member States would require that all these studies are actually carried out in the first place (see example Poland), and if so, that this is done in a consistent way – taking into account other policy instruments and autonomous reductions. Therefore, in our eyes, a decomposition analysis – as carried out in chapter 5 - is more suitable for gaining insight in the actual (quantitative) effect of EU (climate) policy.

*Table 3 – Assessment of EU policies, based on literature review*

| Policy | Ex-post evaluation after 2020[13] | Quantitative assessment[14] | Effectiveness | | | Efficiency | EU added value |
|---|---|---|---|---|---|---|---|
| | | | GHG emissions | Renewables | Energy efficiency | | |
| EU Emission Trading System (ETS) | | ü | +++ | ++ | ++ | + | +++ |
| Effort Sharing Decision (ESD) | | | ++ | + | + | + | ++ |
| Renewable Energy Directive (RED) | | | + | +++ | 0 | + | n/a |
| Energy Efficiency Directive (EED) | ü | | + | 0 | ++ | + | ++ |
| Alternative Fuel Infrastructure Directive (AFID) | ü | ü | 0 | 0 | n/a | + | + |
| Fuel Quality Directive (FQD) | ü | | 0 | + | 0 | + | + |
| $CO_2$ emission performance standards for cars | | | + | n/a | n/a | n/a | ++ |
| Energy Performance of Buildings Directive (EPBD) | | ü | + | n/a | ++ | + | ++ |
| CCS Directive | | | 0 | n/a | n/a | n/a | n/a |
| Ecodesign Directive | | | + | n/a | + | n/a | + |
| Trans-European Networks for Energy | ü | | 0 | + | n/a | + | + |

[13] If an ex-post evaluation after 2020 is not available, we make use of evaluations in earlier years, impact assessments, or other relevant studies. This does not cover the full evaluation period, but provides insights into the effectiveness of the policy instrument, nonetheless.
[14] If a quantitative assessment is not available, a general conclusion on the qualitative assessment of the instrument is used to provide insight into the general added value of the instrument towards progress on the headline targets.

| Policy | Ex-post evaluation after 2020[13] | Quantitative assessment[14] | Effectiveness | | | Efficiency | EU added value |
|---|---|---|---|---|---|---|---|
| | | | GHG emissions | Renewables | Energy efficiency | | |
| (TEN-E) | | | | | | | |
| Trans-European Networks for Transport (TEN-T) | ü | | + | + | n/a | + | + |
| NER 300 Programme | | | n/a | n/a | n/a | n/a | n/a |

# 7. Bottom-up: Monitoring framework

## 7.1 Introduction

In order to be able to meet the climate goals for 2030 and 2050, it is important to learn from the past. As we have seen in chapter 6, being able to assess the effectiveness of (climate) policy highly depends on the availability of monitoring data. The ability to monitor the progress of climate policies towards its targets and objectives, increases the ability to adjust and improve policies in time so that they can be more effective. In this chapter a first draft of a monitoring framework on EU climate policies is presented, based on the policies that have been discussed in the previous chapters.

The selection of indicators is based on the targets and objectives as defined in each of the policy directives. This allows to track progress on the goals within the policy directive as close as possible. As we will see in this chapter, not all policies have a target or objective that is defined in a way that provides clear indicators to quantitatively monitor progress. The less clear a target or objective is defined, the more need there is for a set of indicators that approach a description of the effects of these policies. This chapter presents a set of indicators for the selected policies. The monitoring framework is based on this list of indicators.

The list of indicators that we have developed contains focuses on quantitative indicators, that are publicly available, and monitored systematically. This means that we do not, for example, include indicators that are based on survey results. Also, it needs to be stressed that the list of indicators is non-exhaustive and that it serves as a starting point for a monitoring framework that is to be developed. The list of indicators, and the data that has been collected on those indicators, are stored in a database has been developed during this project.

In order to create structure for the monitoring framework we use the SMART principle, as discussed in section 2.4.2. With this in mind, we assess how SMART the indicators have been defined, looking at the policies' targets or objectives, the availability of data, and the way the data is structured. The SMART-assessment of the indicators range from 1 (very useful) to 2 (somewhat useful) to 3 (not useful). Besides that, for each of the indicators, we assess how well these indicators can be used to estimate the policy's contribution to the headline targets. Finally, we discuss how the indicators and policies relate to the 4 I's. In this we try to limit ourselves to direct links.

## 7.2 Selection of indicators

### 7.2.1 Headline targets

The indicators for the headline targets are shown in Table 4. The column 'Level' indicates the level (EU or Member State) at which indicator data can be collected. The column 'SMART (1-3)' indicates the SMART-ness level of the indicator. The last four columns of the table indicate whether the indicator has a relevant link with any of the 4 I's.

For the GHG target, two indicators are defined: the change in GHG emissions and the change in consumption emissions. The former is sufficient to monitor and assess the progress towards the 20% reduction target. However, it only contains the emissions that are created within the EU. In line with the current developments around the upcoming CBAM regulation (Council of the European Union, 2022), we have added an indicator for emissions from consumption. Data for both indicators are available at EU and Member State level. Both indicators are assessed as SMART (1) since they are well reported, and relevant and specific with regards to the target (in case of consumption emissions more so for future targets that incorporate emissions from outside the EU).

With regards to the renewables target we have selected a set of indicators. The main indicator is the total share of energy from renewables (as share of gross final energy consumption), which reflects the progress towards the 2020 RES target. The other indicators are a breakdown and thus contain information about the share of energy from specific sources. Although these indicators are not necessary to monitor the progress with regards to the main target, it does give us additional information in relation to the GHG target. Biofuels, for example, classify as renewable energy source and has seen a big increase in its use (72% for the EU27 between 2005 and 2020), but its climate impact has been debated (Solarin et al., 2018). Data for the indicators are available on EU and Member State level. We assess all indicators as SMART (1) as they are well reported by Eurostat, and relevant and specific with regards to the target (in case of the specific renewable energy sources also in relation to the GHG target).

We have selected two indicators for the energy efficiency target: final energy consumption and primary energy consumption. These indicators are directly related to the target, as the 20% increase in energy efficiency is expressed in both the required decrease in final energy consumption as well as the primary energy consumption. The data is available at Eurostat (at EU and Member State level). Following the reasoning in the previous two paragraphs these indicators are assessed as SMART (1).

The scope of the headline targets is wide. This is illustrated by the relation between the indicators with the 4 I's, as shown in Table 4. Each of the indicators related to the three headline targets is – one way or another – dependent on infrastructure, innovation, investments, and integration. As we will see in the remainder of this chapter, both the SMART assessment and the relation will the 4 I's will start to vary amongst different indicators.

*Table 4 – Overview of indicators for headline targets*

| Target | Indicator | Level | SMART (1-3) | Infrastructure | Innovation | Investment | Integration |
|---|---|---|---|---|---|---|---|
| -20% GHG emissions | % change in GHG emissions since 1990 | EU, MS | 1 | ü | ü | ü | ü |
| | % change in consumption emissions | EU, MS | 1 | ü | ü | ü | ü |
| 20% renewables[15] | % energy from renewable sources (total) | EU, MS | 1 | ü | ü | ü | ü |
| | % energy from wind power | EU, MS | 1 | ü | ü | ü | ü |
| | % energy from solar PV | EU, MS | 1 | ü | ü | ü | ü |
| | % energy from solar thermal | EU, MS | 1 | ü | ü | ü | ü |
| | % energy from primary solid biofuels | EU, MS | 1 | ü | ü | ü | ü |
| | % energy from hydro power | EU, MS | 1 | ü | ü | ü | ü |
| | % energy from biogas | EU, MS | 1 | ü | ü | ü | ü |
| | % energy from other renewable sources | EU, MS | 1 | ü | ü | ü | ü |
| +20% energy efficiency | Final energy consumption (Mtoe) | EU, MS | 1 | ü | ü | ü | ü |
| | Primary energy consumption (Mtoe) | EU, MS | 1 | ü | ü | ü | ü |

We conclude that future targets on GHG emissions, renewable energy and energy efficiency can be properly monitored by the indicators that are shown in Table 4. We have assessed all indicators as SMART. The indicators express the progress with regards to the targets, and the data are well available (both on EU and Member State level). Besides that, we have added indicators – such as consumption emissions and the breakdown of share of renewable energy to sources – that are able to give more insight in the actual climate effects. This can contribute to a better understanding of the impact and effectiveness of EU climate policy.

15 Share of gross final energy consumption. Categories are based on Eurostat categorisation.

## 7.2.2 Climate policies

In this section the indicators related to the climate policies are discussed, similarly to the previous section. The directives often contain more than one target or objective. We have only included targets or objectives that are explicitly defined and relevant in relation to the headline targets.

### 7.2.2.1 EU ETS

For the EU ETS, we have included three indicators. The first is an indicator that reflects the cap on $CO_2$ emissions for all ETS sectors. This indicator tracks the theoretical path that $CO_2$ emissions should develop: permits are only distributed and auctioned to a maximum equal to the cap. The next indicator is the actual $CO_2$ emissions in ETS sectors. This indicator reflects the total reported $CO_2$ emissions in ETS sectors. This should not exceed the total cap. However, it is possible since exceedances are sanctioned with a fine. Lastly, we include the ETS price as an indicator. There is no direct objective in EU policy regarding the level of the EU ETS price, as it is established in the market. However, the ETS price can be compared with theoretical abatement or damage costs used in other fields, and as such give insight into the level of internalisation of damage costs within the ETS price. In general, the EU ETS has a strong link with the 'I' Integration. It integrates climate policy across all Member States in a single system and across multiple sectors. As a result, an efficient system has evolved in which the market decides in which sectors the most efficient reduction can take place, while the overall goal is still achieved. Moreover, indicators on the $CO_2$ emissions in each sector and the ETS price are related to all 4 I's. Especially innovation as a price on $CO_2$ emissions spurs the development of cleaner technologies. All indicators pertaining to the EU ETS are indicated as SMART. They are measurable, reflect the policy goals well, and there is systematic data available on this topic.

### 7.2.2.2 ESD

The main target of the ESD is to reduce greenhouse gas emissions in non-ETS sectors by 10% in 2020. Therefore, the most straightforward indicator on this topic is the total greenhouse gas emissions in non-ETS sectors, measured on EU level and on Member State level. Note that on Member State level, there are individual national targets, such that the actual emissions should be compared to the individual target for the relevant Member State. As with the EU ETS, there is a connection with each of the 4 I's, with a special relevance to integration and innovation. Although there are separate targets for the Member States, the ESD unites the greenhouse gas emission reduction in a single target of 10% overall. Moreover, it considers multiple sectors together in one policy, strongly integrating economic activities across Member States. As with the ETS, the ESD can encourage innovation, as national policies implemented to achieve the goals under ESD favour the development of cleaner technology and energy savings. This indicator is SMART, since it aptly measures the target of ESD, by definition.

#### 7.2.2.3 RED

Table 5 shows three targets (or objectives) for the Renewable Energy Directive (RED). The first target is derived from the headline target on renewables and focusses specifically on the share of renewables in transport. The corresponding indicator is SMART since it is simply defined as its target. The indicator for minimum GHG-savings from biofuels and bioliquids is assessed as 'somewhat useful' (2); although it relates well with the GHG target, its translation into the RES target is harder. Generally, the indicators for the RED have a clear link with the 4 I's. The indicator on GHG-savings on biofuels (which is part of the national renewable energy plan) does not have a clear link with integration, as it applies at Member State level.

#### 7.2.2.4 EED

As can be seen in Table 5, the definition of the objectives of the EED are less SMART than the other directives' objectives. This means that also the indicators are more difficult to define. This can be seen in the SMART-assessment of the indicators. The yearly renovation of 3% of central governmental buildings, for example, requires more than just one indicator to provide insight in the potential impact of the policy. The combination of these indicators creates added value and is able to give an good indication of the progress towards the objective. The same holds for the other objectives and indicators. Most of the EED's indicators have a strong link with the energy efficiency target – and more indirectly with the GHG target. However, they do not translate well into a quantitative contribution to these targets. Of the 4 I's, the indicators are strongest related to innovation and investment, and in a lesser extent to infrastructure (e.g. through heat networks or improved electricity networks).

#### 7.2.2.5 AFID

With regards to the AFID we have selected for both objectives – an appropriate number of public electrical recharging points and CNG refuel points for cars – a set of indicators. Although the target itself is not defined SMART by using the term 'appropriate', the combination of the indicators together give a good image of the progress towards the directive's targets. Therefore, and because the data are relatively well documented and available, the indicators for this directive are assessed as SMART (1). Looking at the headline targets, the indicators have a clear link with the share of renewables (in transport), but the effects on GHG emissions and energy efficiency are harder to determine. With regards to the 4 I's, the indicators have a strong link with infrastructure: recharging and refuel points are the infrastructure itself, and the demand for electric and CNG cars increases as there are more recharge and refuel points. As innovation proceeds, costs for alternative fuel infrastructure and cars will continue to drop, making this type of transport more attractive. Therefore, there is also a strong relation between these indicators and both innovation and investment.

### 7.2.2.6 FQD

The FQD is aimed at reducing the life cycle GHG emissions by fuel suppliers. This can be monitored by an indicator that captures the achieved reduction as a percentage (compared with the comparator). The indicator is assessed as SMART (1), since it translates well into the directive's target and the data is available. Also, the indicator is suitable for making estimates on its contribution to the GHG target. With regards to the 4 I's, the indicator has the strongest link to innovation and investment.

### 7.2.2.7 $CO_2$ emission performance standards

Table 5 shows the targets and the indicators related to the $CO_2$ emission performance standards for new passenger cars and LCV's. The legislation looks at the average emissions of the fleet (as proposed by car manufacturers). Monitoring these averages over the years could indicate trends in the actual emissions from cars and LCV's. However, average emissions of cars that are actually sold would give a better indication of the trends in $CO_2$ emissions. Therefore, we have proposed indicators that capture these emissions as well. That way, the effect of this policy on the GHG target is expressed in a better way. Overall, we assess the indicators for $CO_2$ emission performance standards for new passenger cars and LCV's as SMART (1). The indicators have clear link with innovation – needed to improve emission performance standards – which effects investments in new cars and LCV's.

### 7.2.2.8 EPBD

The objectives of the EPBD have been defined less SMART. For example, it is not specifically defined what the 'cost-optimal' level is, that is mentioned in the objective on ensuring a minimum energy performance of building. The indicator that we have defined should be able to provide insight in trends with regards the energy performance of buildings, but it is not conclusive with respect to the directive's objective, or its contribution to either of the headline targets. The other two objectives leave room open for interpretation, by referring to 'nearly' zero-energy buildings. Also, their quantitative effect on the headline targets is hard to estimate. With regards to the 4 I's the indicators have a link with infrastructure (such as heat networks), innovation (continuous improvements in the energy performance of buildings), and investment (as investments need to be done to realise the objectives).

#### 7.2.2.9 CCS Directive

As described in section 6.2, there were only a few CCS projects that were realised until 2020. The impact of the CCS Directive on the 2020 targets has thus been limited. Nevertheless, it is expected that CCS will play an important role in meeting the 2030 and 2050 climate goals. The indicators defined in Table 5 can help monitoring the progress of the realisation of CCS projects and its contribution to the climate goals. The indicators are SMART (1) and link mostly to infrastructure, innovation, and investments.

#### 7.2.2.10 Ecodesign Directive

The main target of the directive is to reduce energy consumption and relevant environmental impacts for energy-related products. Since this objective is not SMART defined with a clear target, we have selected a set of indicators that is able to describe general patterns in relation to the objective of this policy. Individually, we have assessed all the indicators as 'somewhat useful' (2) as they do not translate directly into energy savings or reduced environmental impacts. However, the set of indicators together provide good insight in the relevant developments. The directive and its indicators mostly relate to innovation, as it stimulates manufactures to improve the energy efficiency of their products. Through its objective the directive has a strong link with energy efficiency, and more indirectly with the GHG emission target.

*Table 5 – Overview of indicators for climate policies*

| Policy | Target/objective | Indicator | Level | SMART (1-3) | Link to headline targets (1-3) | Infrastructure | Innovation | Investment | Integration |
|---|---|---|---|---|---|---|---|---|---|
| EU ETS | 21% reduction in GHG emissions for ETS sectors by 2020 (compared to 1990) | Cap on $CO_2$ emissions in ETS sectors | EU, MS | 1 | 1 | | ✓ | ✓ | ✓ |
| | | $CO_2$ emissions in ETS sectors | EU, MS | 1 | 1 | | ✓ | ✓ | ✓ |
| | | ETS price | EU | 1 | 2 | | ✓ | ✓ | ✓ |
| ESD | 10% reduction in GHG emissions for non-ETS sectors by 2020 (compared to 1990) | $CO_2$ emissions in non-ETS sectors | EU, MS | 1 | 1 | | ✓ | ✓ | ✓ |
| RED | 10% renewables (of gross final energy consumption) for transport | % energy from renewable sources (transport) | EU, MS | 1 | 1 | ✓ | ✓ | ✓ | ✓ |
| | Minimum GHG-savings for biofuels and bioliquids | Achieved GHG-savings from the use of biofuels and bioliquids | MS | 2 | 1 | ✓ | ✓ | ✓ | |
| EED | Yearly renovation of 3% of central government owned and occupied buildings to meet minimum energy performance requirements | % government buildings meeting minimum energy performance requirements | MS | 2 | 1 | ✓ | ✓ | ✓ | |
| | | Total floor area of government buildings meeting minimum energy performance requirements | MS | 3 | 2 | ✓ | ✓ | ✓ | |
| | | Total government spending on improving governmental buildings | MS | 2 | 3 | | | ✓ | |
| | Improved consumption energy-efficient | % of spending on energy-efficient products | MS | 2 | 2 | | ✓ | ✓ | |

| Policy | Target/objective | Indicator | Level | SMART (1-3) | Link to headline targets (1-3) | Infrastructure | Innovation | Investment | Integration |
|---|---|---|---|---|---|---|---|---|---|
| | products by central government | Total government spending on energy-efficient products | MS | 2 | 2 | | ✓ | ✓ | |
| | Energy efficiency obligation schemes (at least 1,5% yearly new energy savings) | Obligation scheme implemented (dummy) | MS | 2 | 1 | | ✓ | ✓ | |
| | | Energy savings by energy distributors and retail energy sales companies | MS | 2 | 1 | ✓ | ✓ | ✓ | ✓ |
| | Promote energy savings among regulators, SMEs and households | Estimated energy savings through national policies | MS | 2 | 1 | ✓ | ✓ | ✓ | ✓ |
| AFID | Appropriate number of public electrical recharging points for cars | Number of public recharging points | MS | 1 | 2 | ✓ | ✓ | ✓ | |
| | | Number of electric passenger cars | MS | 1 | 2 | ✓ | ✓ | ✓ | |
| | | % market share of electric passenger cars | MS | 1 | 1 | ✓ | ✓ | ✓ | |
| | | Electrical recharging point density (per km2) | MS | 2 | 2 | ✓ | ✓ | ✓ | |
| | Appropriate number of public CNG refuel points for cars | Number of public CNG refuel points | MS | 1 | 2 | ✓ | ✓ | ✓ | |
| | | Number of CNG passenger cars | MS | 1 | 2 | ✓ | ✓ | ✓ | |
| | | % market share of CNG passenger cars | MS | 1 | 1 | ✓ | ✓ | ✓ | |
| | | CNG refuel point density (per km2) | MS | 2 | 2 | ✓ | ✓ | ✓ | |
| FQD | Up to 10% reduction of life cycle GHG emissions by fuel suppliers by end of 2020 | % reduction of life cycle GHG emissions by fuel suppliers | MS | 1 | 1 | | ✓ | ✓ | |

| Policy | Target/objective | Indicator | Level | SMART (1-3) | Link to headline targets (1-3) | Infrastructure | Innovation | Investment | Integration |
|---|---|---|---|---|---|---|---|---|---|
| $CO_2$ emission performance standards for cars | Average emission performance (new passenger cars): 95 g $CO_2$/km | Average emission performance of passenger car fleet (as proposed by car manufacturers) | EU | 1 | 1 | | ✓ | ✓ | |
| | | Average emission performance new passenger cars sold | EU, MS | 2 | 1 | | ✓ | ✓ | |
| | Average emission performance (new LCV's): 147 g $CO_2$/km | Average emission performance of LCV fleet (as proposed by car manufacturers) | EU | 1 | 1 | | ✓ | ✓ | |
| | | Average emission performance new LCV's sold | EU, MS | 2 | 1 | | ✓ | ✓ | |
| EPBD | Ensure a minimum energy performance of buildings on a cost-optimal level | Average energy label houses and buildings | MS | 3 | 2 | ✓ | ✓ | ✓ | |
| | New buildings 'nearly' zero-energy buildings (by end of 2020) | % of new buildings 'nearly' zero-energy | MS | 2 | 2 | ✓ | ✓ | ✓ | |
| | New buildings occupied and owned by public authorities 'nearly' zero-energy buildings | % of new buildings 'nearly' zero-energy (public authorities) | MS | 2 | 2 | ✓ | ✓ | ✓ | |
| CCS Directive | Reduce the emissions of $CO_2$ to the atmosphere for hard-to-abate industrial processes by enhanced use of CCS | Number of CCS projects | EU, MS | 1 | 1 | ✓ | ✓ | ✓ | |
| | | Storing capacity (in Mton) | EU, MS | 1 | 1 | ✓ | ✓ | ✓ | |
| | | $CO_2$ stored (in Mton) | EU, MS | 1 | 1 | ✓ | ✓ | ✓ | |
| Ecodesign | Reduce energy consumption and | Number of Eco-innovation related patents | EU, MS | 2 | 1 | | ✓ | ✓ | |

| Policy | Target/objective | Indicator | Level | SMART (1-3) | Link to headline targets (1-3) | Infrastructure | Innovation | Investment | Integration |
|---|---|---|---|---|---|---|---|---|---|
| Directive | relevant environmental impacts for energy-related products | Number of Eco-innovation related academic publications | EU, MS | 2 | 1 | | ✓ | | |
| | | Number of ISO 14001 registered organisations | EU, MS | 2 | 1 | | ✓ | | |
| | | Employment in eco-industries | EU, MS | 2 | 1 | | ✓ | | |
| | | R&D employment | EU, MS | 2 | 1 | | ✓ | | |
| | | Innovation expenditures (including design, software, marketing) | EU, MS | 2 | 1 | | ✓ | ✓ | |
| | | Eco-innovation index | EU, MS | 2 | 1 | | ✓ | | |

The findings in Table 5 provide an overview of the main targets and objectives EU climate policies, and which indicators can help monitoring these targets and objectives. Some of the policies have a design – and the availability of relevant data – that makes is easy to develop a monitoring framework. Other policies are less suitable for this. We see that policies with (SMART) targets are typically better suited for a monitoring framework than policies with objectives (that are typically less SMART). Table 6 gives an overview for the climate policies that we have discussed. The climate policies are most strongly linked to innovation and investment, and to a lesser extent to infrastructure. The link with integration is found to be relatively weak.

*Table 6 – Policies' suitability for a monitoring framework*

| Suitability | Policy |
|---|---|
| Good | ETS, ESD, CCS Directive |
| Ok | RED, AFID, FQD, Ecodesign, $CO_2$ emission performance standards for cars |
| Poor | EPBD, EED |

### 7.2.3 Non-climate policies

The most relevant non-climate policies that have a clear link with the headline targets are given in Table 7, along with their objectives and the selected indicators. Both the TEN-E and the TEN-T do not have SMART targets, but rather broad objectives instead. Whereas TEN-E is a policy that focuses on linking the energy infrastructure of EU countries, TEN-T is focused on developing a coherent, efficient, multimodal, and high-quality transport infrastructure across the EU. Hence, there is a wide range of aspects that can be monitored in order to measure the policies' effect. This can be seen by the indicators that have been selected. Since no single indicator captures the objectives of these polices, each indicator is classified as 'somewhat useful' (2). The combination of these indicators, however, can help assessing the effectiveness of these policies. When using these indicators in analyses in many cases it would be wise to correct them for autonomous factors such as (growth in) GDP or population.

Since these policies are not designed as climate policies, not all effects are positive with regards to the climate. TEN-E, for example, also supports infrastructure for natural gas, which could lead to more emissions. Similarly, for TEN-T, expanding the EU transport infrastructure by building new highways or airports could have negative climate effects.

The indicator for the electricity interconnection target – import capacity as % of installed capacity – is assessed as SMART. Increasing the electricity interconnection within the EU can be seen as an enabler for a reliable electricity infrastructure, which could have a positive effect on the demand for electricity. However, it is hard to translate this into a quantitative contribution to the share of renewables.

The non-climate policies, discussed in Chapter 6.3, are all more or less designed to improve EU's infrastructure. This can be seen in Table 7. Another pattern that we see is that the indicators related to these policies have a relation with innovation that is less strong; the policies are mostly aimed at existing technologies. Moreover, the policies have a strong relationship with investments and integration (as there is a strong focus on integrating the EU's energy and transport infrastructure).

For the policy on the creation of ACER and cooperation structures for ENTSOs, we have not found any suitable, publicly available indicators. As an expansion of the monitoring framework indicators could be added on, for example, the number of meetings in Brussels, the outcome of these meetings, or the number of cross-TSO staff exchanges. However, these do not fit into our current methodology of involving publicly accessible data in our framework.

*Table 7 – Overview of indicators for non-climate policies*

| Policy | Target/objective | Indicator | Level | SMART (1-3) | Link to headline targets (1-3) | Infrastructure | Innovation | Investment | Integration |
|---|---|---|---|---|---|---|---|---|---|
| TEN-E | Linking energy networks of Member States and supporting the development of the backbone of the European energy networks by defining priority corridors | Number of PCI’s (natural gas) | EU | 2 | 3 | ✓ | | ✓ | ✓ |
| | | Number of PCI’s (electricity) | EU | 2 | 2 | ✓ | | ✓ | ✓ |
| | | Investment in TEN-E infrastructure (natural gas) in € | EU | 2 | 3 | ✓ | | ✓ | ✓ |
| | | Investment in TEN-E infrastructure (electricity) in € | EU | 2 | 2 | ✓ | | ✓ | ✓ |
| | | Linking infrastructure (natural gas) in km | EU | 2 | 3 | ✓ | | ✓ | ✓ |
| | | Linking infrastructure (electricity) in km | EU | 2 | 2 | ✓ | | ✓ | ✓ |
| | | Smart grids (in km) | EU | 2 | 2 | ✓ | ✓ | ✓ | ✓ |
| | | Electric highways (in km) | EU | 2 | 2 | ✓ | | ✓ | ✓ |
| | | $CO_2$ networks (in km) | EU | 2 | 2 | ✓ | | ✓ | ✓ |
| TEN-T | Create a comprehensive EU network for a (climate friendly) transport infrastructure | Railways (in km) | EU | 2 | 2 | ✓ | | ✓ | ✓ |
| | | Investment in railways (in €) | EU | 2 | 2 | ✓ | | ✓ | ✓ |
| | | Passengers transported by train | EU | 2 | 2 | ✓ | | | ✓ |
| | | Cycling lanes or roads (in km) | EU | 2 | 2 | ✓ | | ✓ | |
| | | Investment in bike lanes or roads (in €) | EU | 2 | 2 | ✓ | | ✓ | |

| Policy | Target/objective | Indicator | Level | SMART (1-3) | Link to headline targets (1-3) | Infrastructure | Innovation | Investment | Integration |
|---|---|---|---|---|---|---|---|---|---|
| Electricity interconnection target | 10% electricity interconnection target (for 2020) | Import capacity as % of installed capacity | MS | 1 | 2 | ✓ | | ✓ | ✓ |
| Creation of ACER and cooperation structures for ENTSOs | Improving coordination of grid operation throughout the EU including cross-border infrastructures | n/a | n/a | n/a | n/a | | | | ✓ |

### 7.2.4 Socio-economic indicators

A last category to add to the monitoring framework is that of socio-economic outcomes. Socio-economic developments are both an important influence and an important consequence of policy related to climate. In chapter 5, it is shown that greenhouse gas emissions would rise by a large share due to economic growth and population growth alone, if there are no improvements in energy savings and energy efficiency. Especially GDP growth implies a large increase in greenhouse gas emissions. More economic activity means more use of resources and therefore more resulting emissions.

Moreover, other socio-economic developments can be induced from climate policy. Stimulating economic activity with lower carbon footprints also means a shift to different sectors, more employment in innovative industries, and a movement to more service-related industries. As such, climate policy and the intended transitions to a more sustainable economy can lead to important shifts in employment figures and GDP growth.

In terms of the '4 I's' framework, socio-economic outcomes induced by climate policy are even more diverse and important. The need for innovation creates economic activity and new types of employment. In particular, employment in R&D can be linked to required innovation for developing low-carbon technologies. Investments in infrastructure generate (temporary) employment and as such income. Implementation of policies require investments, in turn spurring economic growth.

The main indicators we selected to add to the monitoring framework are GDP per capita, and employment figures. These are important factors to sustain an economy. Therefore, they should be tracked alongside indicators focused on climate outcomes. Table 8 gives an overview of the socio-economic indicators considered in the monitoring framework.

*Table 8 – Overview of indicators socio-economic outcomes*

| **Indicator** | **Level** | **SMART (1-3)** | **Link to headline targets (1-3)** | **Infrastructure** | **Innovation** | **Investment** | **Integration** |
|---|---|---|---|---|---|---|---|
| Population | EU, MS | 1 | 2 | | | | |
| GDP | EU, MS | 1 | 1 | ü | ü | ü | |
| GDP per capita | EU, MS | 1 | 1 | ü | ü | ü | |
| Employment rate | EU, MS | 1 | 3 | ü | ü | ü | |
| Unemployment rate | EU, MS | 1 | 3 | ü | ü | ü | |

| Indicator | Level | SMART (1-3) | Link to headline targets (1-3) | Infrastructure | Innovation | Investment | Integration |
|---|---|---|---|---|---|---|---|
| R&D employment | EU, MS | 1 | 2 | | ü | ü | |

## 7.3 Conclusion

This chapter presents a monitoring framework that can be used to monitor the progress of EU policies and their contribution to climate goals on GHG emissions, renewable energy, and energy efficiency. The framework – containing indicators – is based on pre-2020 climate and non-climate policies, but is meant to contribute to monitoring the 2030 and 2050 climate and energy goals.

### 7.3.1 Selection of indicators

In section 7.2.1 we discussed relevant indicators for monitoring the headline targets directly. We found that future targets on GHG emissions, renewable energy, and energy efficiency can be properly monitored by these indicators. We assessed the indicators as SMART, both on EU and Member State level. Besides indicators that are sufficient to determine whether the 2020 targets were met, we have added indicators – such as consumption emissions and a breakdown of the share of renewable energy to different sources – that are able to give more insight in the actual climate effects. This can contribute to a better understanding of the impact and effectiveness of EU climate policy.

In section 7.2.2 we discussed relevant indicators for monitoring EU climate policies, especially in relation to the headline targets. We found that some of the policies have a design – and the availability of relevant data – that makes it easy to select suitable indicators and develop a monitoring framework. Other policies are less suitable for this. We see those policies with (SMART) targets are typically better suited for a monitoring framework than policies with objectives (that are typically less SMART).

In section 7.2.3 we discussed indicators that are suitable for monitoring non-climate policies that are relevant to EU climate goals. We found that these policies can be monitored sufficiently by the set of indicators that we selected. Moreover, we pointed out that these policies can also have negative climate effects since they are not designed as climate policies as such.

In section 7.2.4 we discussed relevant socio-economic indicators – such as population, GDP, and (un)employment rates – that are included in the monitoring framework. This is relevant because, on the one hand, socio-economic developments can influence outcomes that are being pursued by climate policies. This is demonstrated in the decomposition analyses in chapter 5, where we illustrated the impact of developments in economic and population growth on $CO_2$ emissions. On the other hand, socio-economic developments can be induced by climate policy. Stimulating economic activity with lower carbon footprints, for example, also means a shift to different sectors, more employment in innovative industries, and a movement to more service-related industries. As such, climate policy and the intended transitions to a more sustainable economy can lead to important shifts in employment figures and GDP growth.

### 7.3.2 Monitoring framework

Concludingly, we assess the monitoring potential for the headline targets as 'good', for climate policies as 'good to poor', and for selected non-climate policies as 'ok'. We see several opportunities to improve the value of the monitoring framework. First of all, we advise to select relevant indicators in an early stage, ideally when policies are designed. Secondly, we suggest to obligate – or strongly advise – Member States to monitor and collect (complementary to what is already obligated) data on these indicators. Thirdly, standards should be developed on how these data should be collected and stored. Finally, in case it is not possible to define targets or objectives SMART, we advise to define a set of indicators that is able to monitor in a reliable way. These indicators on their own might not all be SMART, but a combination of indicators is often able to provide good insight. Keeping these principles in mind when designing new policies would improve the quality of such a monitoring framework, and thereby the effectiveness of these policies.

### 7.3.3 4I-framework

In this chapter we linked the indicators for the headline targets, climate policies, non-climate policies, and socioeconomic outcomes to the 4 I's. In line with the wide scope of the headline targets, we found that the indicators for these targets link to all of the 4 I's. The climate policies are most strongly linked to innovation and investment, and to a lesser extent to infrastructure. The link with integration is found to be relatively weak. The studied non-climate policies are all more or less designed to improve EU's infrastructure and therefore have a strong link to this I. The relation of non-climate policies with innovation is less strong (as these policies are mostly aimed at existing technologies), but they have a strong relationship with investments and integration (as there is a strong focus on integrating the EU's energy and transport infrastructure). The socioeconomic indicators are most strongly linked to infrastructure, innovation, and investment. The need for innovation creates economic activity and new types of employment. In particular, employment in R&D can be linked to required innovation for developing low-carbon technologies. Investments in infrastructure generate (temporary) employment and as such income. Implementation of policies require investments, in turn spurring economic growth.

An overview of the policies, their relation to the 4 I's, and their impact in relation to 2020 headline targets (based on the literature review in chapter 6) is given in Table 9. The link with the 4 I's is based on the underlying indicators. In general, the table shows that most policies are linked to innovation and investment – also the policies with the highest impact. The overview in Table 9 suggests that innovation and investment are the most important enablers in this context.

*Table 9 – EU policies: relation to the 4 I's (based on underlying indicators) and impact in relation to the 2020 headline targets*

| Policy | Infrastructure | Innovation | Investment | Integration | Impact* |
|---|---|---|---|---|---|
| EU Emission Trading System (ETS) | | ✓ | ✓ | ✓ | +++ |
| Effort Sharing Decision (ESD) | | ✓ | ✓ | ✓ | ++ |
| Renewable Energy Directive (RED) | ✓ | ✓ | ✓ | | +++ |
| Energy Efficiency Directive (EED) | | ✓ | ✓ | | ++ |
| Alternative Fuel Infrastructure Directive (AFID) | ✓ | ✓ | ✓ | | 0 |
| Fuel Quality Directive (FQD) | | ✓ | ✓ | | + |
| $CO_2$ emission performance standards for cars | | ✓ | ✓ | | + |
| Energy Performance of Buildings Directive (EPBD) | ✓ | ✓ | ✓ | | ++ |
| CCS Directive | ✓ | ✓ | ✓ | | 0 |
| Ecodesign Directive | | ✓ | | | + |
| Trans-European Networks for Energy (TEN-E) | ✓ | | ✓ | ✓ | + |
| Trans-European Networks for Transport (TEN-T) | ✓ | | ✓ | ✓ | + |

* Relative effectiveness in relation to the 2020 headline targets; based on the literature review in chapter 6.

# 8. Conclusions

This report contains an ex-post evaluation of the EU climate policy framework over the period 2005-2020, both for the EU27 and some selected Member States. We quantitatively assessed the overall effectiveness and efficiency of EU climate policy, focussing on the 2020 headline targets for climate and energy (the so-called 20-20-20 targets): reduce greenhouse gas emissions 20% compared to 1990 levels, increase the share of renewable energy use to 20%, and improve energy efficiency by 20%.

We have defined a list of relevant EU policies and exposed the progress towards the 2020 headline targets for climate and energy. In order to assess the effectiveness of EU (climate) policy we used a combination of a top-down approach (using a decomposition analysis) and a bottom-up approach (performing a literature review and designing a monitoring framework).

## 8.1 Progress on 20-20-20 targets

We found that EU27 greenhouse gas emissions were 35% lower in 2020 than in 1990. This constitutes a substantial overachievement of the 20% reduction target. The economic downturn as a result of COVID-19 helped considerably to reach the overall greenhouse gas target. The targets on renewable energy and energy savings were met as well.

## 8.2 Top-down: decomposition analysis

The decomposition analysis on the 2009-2018 period reveals that emissions increased due to factors that generally fall outside the domain of climate policy, such as population growth, GDP growth, and structural changes in the economy. But other factors – energy efficiency, renewable electricity generation and carbon intensity reductions – are part of the climate policy domain: for instance, the EED affecting energy savings (energy use per unit of value added) and the RED and ETS directly reducing carbon intensities (carbon emissions per unit of energy). The results at the EU level suggest that energy savings were an important contributing factor to emission abatement. Even when incorporating an estimated effect of a 0.5-1% autonomous improvement in energy efficiency per year, the effect of policy-induced energy efficiency savings is noticeable. It is likely that energy market trends such as the favourable price margin of coal to gas price (the relative low $CO_2$ prices of ETS) have had opposite effects on the carbon intensity in some countries. However, overall the net effect due to the deployment of renewable resources is still positive. Moreover, other carbon savings suggest that there is a general shift in the EU away from carbon-intensive fuels such as coals to less polluting fuels.

## 8.3 Bottom-up: literature review

In our literature review we looked at the most relevant policies and their (quantitative, as much as possible) impacts on the EU 2020 targets for GHG emissions, renewable energy, and energy efficiency. We studied both climate policies and relevant non-climate policies (policies that are not primarily aimed at climate goals, but do contribute to these goals). The literature assessment was based on evaluations, impact assessments, and other relevant studies.

### 8.3.1 Limited amount of ex-post evaluations and quantitative assessments

We found that the amount of (recent) ex-post evaluations on these policies is limited – for only five out of the twelve policies an ex-post evaluation was performed after 2020. For the remaining seven policies we either used older ex-post evaluations or impact assessments that were carried for the revision of the directives. The latter provided some ex-post insights, but these were often less useful and structured than those from ex-post evaluations carried after 2020.

Moreover, we observed that a large part of the available studies lack quantitative assessment – for only three out of the twelve policies some form of quantitative assessment was carried out. The effectiveness and efficiency are often studied through interviews with stakeholders, case study analysis, or literature study and therefore have a qualitative character.

### 8.3.2 EU policy impacts

In order to make the quantitative and qualitative outcomes of the different studies on EU policies more consistent, we have translated them into a 'expert score' that represents their relative effectiveness with regards to the headline targets (see Table 3). The directives directly related to the three headline targets (ETS, ESD, RED, and EED) score high on their relative effectiveness. Moreover, climate policies that are less directly related to the headline targets (such as the FQD, EPBD, $CO_2$ emission performance standards for cars, and Ecodesign Directive) make a fair contribution to the reduction of GHG emissions, increase of renewable energy, and the improvement of energy efficiency. Also non-climate policies are found to have contributed to the GHG target (TEN-T) and the renewables target (both TEN-E and TEN-T).

Based on the literature review, we found that the efficiency of most EU policies are assessed positively. Although in most studies some improvements were mentioned, none of the policies was assessed to be inefficient. For some policies there were no relevant assessments of the efficiency available in the literature.

With respect to the policies' added value by implementing it at EU level we conclude that it generally had a positive contribution. The added value is often studied through interviews with stakeholders and therefore has a qualitative character. For most policies this effect is expected to be positive. For some policies it is less clear whether the same effect could have been reached with national policies alone.

### 8.3.3 National policy impacts

For two Member States – Poland and the Netherlands – we studied national policies that are related to the selected EU policies. The literature review for The Netherlands provided a fair amount of quantitative effects. This illustrates our claim that quantitative effects are easier to determine at national level than at EU level. Policies like the Stimulation of Sustainable Energy Production and Climate Transition (SDE+) and the Energy Investment Allowance (EIA) were found to have significant effects on the share of renewable energy and energy efficiency, respectively. The amount of quantitative studies for Poland, however, were limited.

However, when interpreting the quantitative effects of the national policies, one has to keep in mind that not the whole effect that is found can be attributed to EU climate policy. This is illustrated by the example of The Netherlands. We saw that the EIA (originating from 1997), the Long Term Agreement industry (MJA3, originating from 2008, and its oldest predecessor from 1992), and the Long Term Agreement big industry (MEE, established in 2009 as a response to the EU ETS) were major contributors to the reported energy savings in 2020 (about one-thirds, 10%, and 10%, respectively). The EED, however, was established in 2012, meaning that it is likely that a significant share of these reported savings would have also been achieved without the EED. To a lesser extent we also see this in relation RED: the Netting and Zip Code regulation – that enables households with solar panels to be compensated for the abundant electricity that they deliver back to the electricity net – contributed for about 10% to the total share of renewables in 2020. As this regulation originates from 1998, this share cannot be contributed to the RED (that was established in 2009).

### 8.3.4 Complexities to estimate policy effects at EU level

Empirical studies at EU level are complex due to the many factors – such as the many differences between Member States – that need to be taken into account and the difficulty to identify causal effects for a specific intervention against a counterfactual scenario. Theoretically, one could resemble and aggregate results from studies at Member State level in order to determine (bottom-up) the effect at EU level. Policies that are implemented on a national level directly affect measures reducing GHG emissions, and are less complex to evaluate. The lower degree of complexity allowed us to study the isolated effects of national policies (see example The Netherlands). However, resembling and aggregating the results for all Member States would require that all these studies are actually carried out in the first place (see example Poland), and if so, that this is done in a consistent way taking into account other policy instruments and autonomous reductions.

A second reason for the complexity of EU policy evaluation stems from the *intervention logic* of EU policies. Some of the EU policies are aimed directly at GHG emission reductions within the EU (e.g. $CO_2$ emission standards or EU ETS directive). Others are targeted to accelerate national efforts to increase the share of renewable energy, or at increased energy efficiency, resulting in a reduced demand of fossil energy. All these mechanisms reduce GHG emissions and thereby contribute to the climate goals in an indirect and less explicit manner. These framework directives call for Member States to act on these policy domains.

## 8.4 Bottom-up: Monitoring framework

In this report we describe a monitoring framework that is designed to measure progress towards (headline) climate policy targets. The framework – containing relevant indicators on the headline targets, climate policies, and non-climate policies – is based on pre-2020 policies, but is meant to contribute to monitoring the 2030 and 2050 climate goals. We found that, depending on the nature of the policy and how targets and objectives are defined, a well-designed set of indicators is typically able to monitor the progress of the policies well. We found that for targets or objectives that are defined SMART (Specific, Measurable, Achievable, Relevant, and Time-bound) it is easier to find suitable indicators. When this is not the case, a combination of indicators is sometimes able to reflect the impact of the policy well. Overall, we assess the monitoring potential for the headline targets as 'good', for climate policies as 'good to poor', and for selected non-climate policies as 'ok'.

Besides policy indicators, we also discussed relevant socioeconomic indicators – such as population, GDP, and (un)employment rates – that are included in the monitoring framework. This is relevant because, on the one hand, socioeconomic developments can influence outcomes that are being pursued by climate policies (as was demonstrated in the decomposition analysis, where the impact of developments in economic and population growth on $CO_2$ emissions was shown). On the other hand, socioeconomic developments can be induced by climate policy. Stimulating economic activity with lower carbon footprints, for example, also means a shift to different sectors, more employment in innovative industries, and a movement to more service-related industries. As such, climate policy and the intended transitions to a more sustainable economy can lead to important shifts in employment figures and GDP growth.

## 8.5 Connection with the 4 I's

In chapter 5, on the decomposition analysis, we linked – based on expert opinion – the different decomposition components to the 4 I's (Infrastructure, Innovation, Investment, and Integration). We argued that energy savings and $CO_2$ savings – the components that can best be influenced by climate policy – have a strong relation with innovation and investment. The results of the decomposition analysis show that both components positively contributed to the reduction of $CO_2$

emissions, especially $CO_2$ savings. Therefore, these results suggest that innovation and investment are the most important enablers for effective climate policy.

This image is confirmed by the analysis that we performed in chapter 7, on the monitoring framework. We first linked – again, based on expert opinion – individual policy indicators to the 4 I's, and later the policies. This made clear that most policies are linked to innovation and investment – also the policies with the highest impact (as assessed by the literature review in chapter 6). Therefore, we concluded that – based on these results as well – innovation and investment are the most important enablers for effective climate policy.

## 8.6 Policy attribution

Overall, the EU has made significant progress reducing greenhouse gas emissions reductions, promoting energy efficiency action, and renewable energy deployment. The economic downturn as a result of COVID-19 in 2020 has helped the EU to meet its 2020 targets. Energy efficiency, the increase of renewables and fuel switching were essential drivers for economy wide reductions.

Based on the top-down and the bottom-up analysis, we conclude that EU climate policy generally had a positive contribution to meeting the climate targets. The top-down analysis showed that a significant share of the decrease in $CO_2$ emissions can be attributed to energy efficiency, whereas renewable electricity and other carbon intensity effects contributed to a lesser extent to the decrease in $CO_2$ emissions. This complements the findings in the bottom-up analysis. The bottom-up analysis showed – through the literature review – that a positive contribution of EU climate policies to progress on the headline targets seems likely, but that it is difficult to quantitatively attribute climate policy to changes in GHG emissions, the share of renewable energy, and especially energy efficiency.

## 8.7 Recommendations

*Develop a comprehensive evaluation programme for EU climate policy*

The track record of ex-post evaluations falls short to Europe's longstanding experience on ex-ante studies and impacts assessments. While evaluations are generally carried out in line with legal requirements, it is difficult to conclude on causal attributions in a quantitative manner of EU policy instruments. We identified shortcomings and omissions. To gain a better understanding of the costs and effects of climate policy in the EU, it is recommended to establish a comprehensive evaluation programme. This could consist of:

- establishing a clear methodology for determining costs and effects of EU climate policy in the coming years;

- conducting ex-post evaluations of the key climate instruments and policies in sectors, and an overarching review of costs and effects from EU policies.

*Embed the right conditions for a well-functioning monitoring framework in the design of EU climate policy*

Based on our design of a monitoring framework, we recommend selecting relevant indicators and impose this type of monitoring framework in an early stage, ideally when transformative policies are designed. In this way, data collection can be targeted towards illustrating progress on the targets by means of the selected indicators. Secondly, we suggest obligating – or strongly advise – Member States to monitor and collect (complementary to what is already obligated) data on these indicators. Thirdly, standards should be developed on how these data should be collected, stored, and presented. Finally, in case it is not possible to define targets or objectives that are SMART, we advise to define a set of indicators that – together – resembles key developments on targets and objectives and is able to monitor in a reliable way.

# References

**AEA, Ecofys, Fraunhofer & ICCS,** 2009.*Quantification of the effects on greenhouse gas emissions of policies and measures: Final Report*, Brussels: European Commission

**Åhman, M., Skjærseth, J. B. & Eikeland, P. O.,** 2018.*Demonstrating climate mitigation technologies: An early assessment of the NER 300 programme*: Energy Policy

**Ang, B. W.,** 2005. The LMDI approach to decomposition analysis: A practical guide. *Energy Policy,* 33**,** 867-871.

**Bundesamt für die Sicherheit der nuklearen Entsorgung**. 2023. *Der Atomausstieg in Deutschland* [Online] https://www.base.bund.de/DE/themen/kt/ausstieg-atomkraft/ausstieg_node.html. May 2023

**CBS**. 2020. *De economische rol van aardgas na de productiebeperkingen* [Online] https://www.cbs.nl/nl-nl/longread/de-nederlandse-economie/2020/de-economische-rol-van-aardgas-na-de-productiebeperkingen/5-aardgasverbruik-door-elektriciteitscentrales-in-nederland. May 2023

**CE Delft,** 2005.*Evaluatie doelmatigheid binnenlands klimaatbeleid : Kosten en Effecten, 1999-2004*, Delft: CE Delft

**CE Delft,** 2020.*Effects of an EU 55% GHG reduction target - Assessment of potential impacts on Dutch climate policies*, Delft: CE Delft,

**CE Delft,** 2022.*Beleid voor Energietransitie Gebouwde Omgeving - Beleidsdoorlichting art. 4.1 BZK 2015-2020*, Delft: CE Delft

**CE Delft, Ecologic Institute, Ricardo, REKK & E-Bridge,** 2015.*Mid-term evaluation of the Renewable Energy Directive: A study in the context of the REFIT programme*, Delft: European Commission DG ENER

**Council of the European Union**. 2022 *EU climate action: provisional agreement reached on Carbon Border Adjustment Mechanism (CBAM)* [Online] https://www.consilium.europa.eu/en/press/press-releases/2022/12/13/eu-climate-action-provisional-agreement-reached-on-carbon-border-adjustment-mechanism-cbam/.

**CSES & Oxford Research,** 2012.*Evaluation of the Ecodesign Directive (2009/125/EC)*, Sevenoaks (UK): Centre for Strategy & Evaluation Services

**EAFO**. 2023 *Alternative fuels in Europe - Road* [Online] https://alternative-fuels-observatory.ec.europa.eu/transport-mode/road.

**EC,** 2003. Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC (Text with EEA relevance). *Official Journal of the European Union,* L275**,** 32-46.

**EC,** 2009. Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC (Text with EEA relevance). *Official Journal of the European Union,* L140**,** 16-62.

**EC**. 2011. *Consolidated text: Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control) (Recast) Text with EEA relevance* [Online] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02010L0075-20110106.

**EC,** 2012. Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC Text with EEA relevance. *Official Journal of the European Union,* L 315**,** 1-56.

**EC,** 2015a.*Energy Union Package Communication from the Commission to the European Parliament and the Council - Achieving the 10% electricity interconnection target - Making Europe's electricity grid fit for 2020*: European Commission

**EC**. 2015b. *Graph of the week: Poland's success story* [Online] https://ec.europa.eu/economy_finance/graphs/2014-10-06_poland_success_story_en.htm. May 2023

**EC,** 2016.*Commission staff working document evaluation of Directive 2010/31/EU on the energy performance of buildings Accompanying the document Proposal for a Directive of the European Parliament and of the Council amending Directive 2010/31/EU on the energy performance of buildings SWD/2016/0408 final - 2016/0381 (COD)*, Brussels: European Commission (EC)

**EC,** 2017.*Commission Staff Working Document Impact Assessment Accompanying the document Proposal for a Regulation of the European Parliament and of the Council setting emission performance standards for new passenger cars and for new light commercial vehicles as part of the Union's integrated approach to reduce $CO_2$ emissions from lightduty vehicles and amending Regulation (EC) No 715/2007 (recast)*, Brussels: European Commission (EC)

**EC,** 2021a.*Commission Staf Working Document. Detailed Assessment of the Member States Implementation Reports on the National Policy Frameworks for the development of the market as regards alternative fuels in the transport sector and the deployment of the relevant infrastructure. Implementation of Art 10 (3) of Directive 2014/94/EU. Accompanying the document Report from the Commission to the European Parliament and the Council on the application of Directive 2014/94/EU on the deployment of alternative fuels infrastructure*, Brussels: European Commission (EC)

**EC,** 2021b.*Commission staff working document evaluation of Directive 2014/94/EU of the European Parliament and of the Council on the deployment of alternative fuels infrastructure: accompanying the Proposal for a Regulation of the European Parliament and of the Council on the deployment of alternative fuels infrastructure, and repealing Directive 2014/94/EU of the European Parliament and of the Council SWD/2021/637 final*, Brussels: European Commission (EC)

**EC,** 2021c.*Evaluation of directive 2012/27/EU on Energy Efficiency*, Brussels: European Commission

**EC,** 2021d.*Evaluation of the Regulation (EU) No 1315/2013 on Union Guidelines for the development of trans-European transport network*, Brussels: European Commission

**EC**. 2021e. *Proposal for a Regulation of the European Parliament and of the Council amending Regulation (EU) 2019/631 as regards strengthening the $CO_2$ emission performance standards for new passenger cars and new light commercial vehicles in line with the Union's increased climate ambition, COM /2021/556 final* [Online] https://ec.europa.eu/info/sites/default/files/amendment-regulation-co2-emission-standards-cars-vans-with-annexes_en.pdf.

**EC**. 2023. *Development of EU ETS (2005-2020)* [Online] https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets/development-eu-ets-2005-2020_en. May 2023

**EC, Directorate-General for Climate Action, Goumas, T., Markianidou, P., Skolina, J., Kveiborg, O., Lo Piparo, L., Chicot, J., Wahler, L., Le Gallou, M., et al.,** 2021. *Support study on the evaluation of Article 7A of the Fuel Quality Directive and assessment of approaches to reduce greenhouse gas emissions from transport fuels : final report,* Brussels, Publications Office.

**Ecorys, Ramboll, REKK & Shepherd Wedderburn,** 2021.*Support to the evaluation of Regulation (EU) No 347/2013 on guidelines for trans-European energy infrastructure*, Brussels: European Commission - DG ENER

**EEA,** 2016.*Analysis of key trends and drivers in greenhouse gas emissions in the EU between 1990 and 2014*: European Environment Agency

**EEA,** 2017.*Analysis of key trends and drivers in greenhouse gas emissions in the EU between 1990 and 2015*: European Environment Agency

**EEA**. 2022. *Greenhouse gas emission intensity of fuels and biofuels for road transport in Europe* [Online] https://www.eea.europa.eu/ims/greenhouse-gas-emission-intensity-of.

**EIA**. 2023. *Nuclear power plants generated 68% of France's electricity in 2021* [Online] https://www.eia.gov/todayinenergy/detail.php?id=55259#. May 2023

**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*: Official Journal of the European Union

**EU,** 2009b. Directive 2009/30/EC of the European Parliament and of the Council of 23 April 2009 amending Directive 98/70/EC as regards the specification of petrol, diesel and gas-oil and introducing a mechanism to monitor and reduce greenhouse gas emissions and amending Council Directive 1999/32/EC as regards the specification of fuel used by inland waterway vessels and repealing Directive 93/12/EEC (Text with EEA relevance). *Official Journal of the European Union,* L149**,** 88-113.

**EU,** 2009c. Directive 2009/31/EC of the European Parliament and of the Council of 23 April 2009 on the geological storage of carbon dioxide and amending Council Directive 85/337/EEC, European Parliament and Council Directives 2000/60/EC, 2001/80/EC, 2004/35/EC, 2006/12/EC, 2008/1/EC and Regulation (EC) No 1013/2006.

**EU,** 2009d.*Regulation (EC) No 713/2009 of the European Parliament and of the Council of 13 July 2009 establishing an Agency for the Cooperation of Energy Regulators*: Official Journal of the European Union

**EU,** 2013a. Regulation (EU) No 347/2013 of the European Parliament and of the Council of 17 April 2013 on guidelines for trans-European energy infrastructure and repealing Decision No 1364/2006/EC and amending Regulations (EC) No 713/2009, (EC) No 714/2009 and (EC) No 715/2009.

**EU,** 2013b. Regulation (EU) No 1315/2013 of the European Parliament and of the Council of 11 December 2013 on Union guidelines for the development of the trans-European transport network and repealing Decision No 661/2010/EU.

**EU,** 2014. Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure Text with EEA relevance. *Official Journal of the European Union,* L307**,** 1-20.

**EU,** 2017.*Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation*: Official Journal of the European Union

**EU,** 2019. Regulation (EU) 2019/631 of the European Parliament and of the Council of 17-4-2019 setting $CO_2$ emission performance standards for new passenger cars and for new light commercial vehicles, and repealing Regulations (EC) N. 443/2009 and (EU) N. 510/2011. *Official Journal of the European Union,* L 111**,** 13-53.

**European Court of Auditors,** 2020.*EU action on Ecodesign and Energy Labelling: important contribution to greater energy efficiency reduced by signficant delays and non-compliance*, Luxembourg: European Court of Auditors

**European Parliament & Council of the European Union,** 2009. Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products (Text with EEA relevance). *Official Journal of the European Union,* L285**,** 10-35.

**European Parliament & The Council of the European Union,** 2010. Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings. *Official Journal of the European Union,* L153**,** 13-35.

**Eurostat,** 2008.*NACE Rev. 2 : Statistical classification of economic activites in the European Community*, Luxembourg: Office for Official Publications of the European Communities

**Guidehouse,** 2022.*Assessment of Member States' reports for the year 2020*, Berlin: European Commission - DG ENER

**IOGP**. 2022. *CCUS projects in Europe* [Online] https://iogpeurope.org/resource/map-of-eu-ccus-projects/.

**IOS-PIB,** 2019.*Climate for Poland - Poland for Climate*: Institute of Environmental Protection - National Research Institute

**Kaya, Y.,** 1990.*Impact of Carbon Dioxide Emission Control on GNP Growth: Interpretation of Proposed Scenarios*: IPCC Energy and Industry Subgroup, Response Strategies Working Group

**Laing, T., Sato, M., Grubb, C. & Comberti,** 2013.*Assessing the effectiveness of the EU Emissions Trading System*: Center for Climate Change Economics and Policy Working paper No. 126 / Grantham Research Institute on Climate Change and the Environment Working Paper No. 106

**Listorti, G., Basyte-Ferrari, E., Acs, S. & Smits, P.,** 2020. Towards an Evidence-Based and Integrated Policy Cycle in the EU: A Review of the Debate on the Better Regulation Agenda. *Journal of Common Market Studies,* 58**,** 1558-1577.

**Nachmany, M., Fankhause, S., Davidová, J., Kingsmill, N., Landesman, T., Roppongi, H., Schleifer, P., Setzer, J., Sharman, A., Singleton, C. S., et al.,** 2015.*Climate change legislation in Poland - An Excerpt from the 2015 Global Climate Legislation Study A Review of Climate Change Legislation in 99 Countries*, London: The Grantham Research Institute, London School of Economics

**NEa**. 2020. *Factsheet: $CO_2$-uitstoot van ETS bedrijven in 2020* [Online] https://www.emissieautoriteit.nl/binaries/nederlandse-emissieautoriteit/documenten/publicatie/2021/05/31/factsheet-ets-uitstoot-2020/72399+-+NEA+-+Factsheet+CO2-uitstoot_2020_TG.pdf.

**ODYSSEE-MURE**. 2023. *Netherlands Profile* [Online] https://www.odyssee-mure.eu/publications/efficiency-trends-policies-profiles/netherlands.html. May 2023

**PBL,** 2019.*Klimaat- en energieverkenning (KEV) 2019*, Den Haag: Planbureau voor de Leefomgeving (PBL)

**Ricardo, Trinomics & VITO,** 2016.*Supporting study for the Evaluation of Decision No 406/2009/EC (Effort Sharing Decision)*, Brussels: European Commission

**RVO**. 2012. *Feiten en cijfers SDE(+)(+)* [Online] https://www.rvo.nl/subsidies-financiering/sde/aanvragen/feiten-en-cijfers. May 2023

**Schettkat, R. & Yocarini, L.,** 2003.*The shift to services: A review of the literature*, Bonn: IZA

**Solarin, S. A., Al-Mulali, U., Gan, G. G. G. & Shahbaz, M.,** 2018. The impact of biomass energy consumption on pollution: evidence from 80 developed and developing countries. *Environmental Science and Pollution Research,* 25**,** 22641-22657.

**Trinomics,** 2018.*Evaluation of the TEN-E Regulation and assessing the impacts of alternative policy scnearios - ENER/B1/2015-570*, Rotterdam: European Commission

**Trinomics,** 2021.*Evaluatie van de SDE+*: Trinomics

**Umweltbundesamt, Ecologic & Consult, S.,** 2015.*Evaluation of the EU ETS Directive - Support for the review of teh EU Emissions Trading System*, Vienna: Umweltbundesamt

**Webster, M., Paltsev, S. & Reilly, J.,** 2008. Autonomous efficiency improvement or income elasticity of energy demand: Does it matter? *Energy Economics,* 30**,** 2785-2798.

# Annex 1: Member State targets 2020

| Member State (EU27) | Total GHG emission reduction targets | Effort Sharing targets (non-ETS) | Share of energy from renewable sources: target in 2020 | | Energy efficiency target (final energy consumption) |
|---|---|---|---|---|---|
| | Reduction target 2005-2020 | Reduction target 2005-2020 | Share of RE in 2005 | Target share of RE in 2020 | Reduction target 2005-2020 |
| Austria | -16% | -16% | 23.3% | 34% | -10% |
| Belgium | -15% | -15% | 2.2% | 13% | -12% |
| Bulgaria | 20% | 20% | 9.4% | 16% | -15% |
| Croatia | | | | | -4% |
| Cyprus | -5% | -5% | 2.9% | 13% | 4% |
| Czech Republic | 9% | 9% | 6.1% | 13% | -3% |
| Denmark | -20% | -20% | 17.0% | 30% | -2% |
| Estonia | 11% | 11% | 18.0% | 25% | -2% |
| Finland | -16% | -16% | 28.5% | 38% | 6% |
| France | -14% | -14% | 10.3% | 23% | -14% |
| Germany | -14% | -14% | 5.8% | 18% | -12% |
| Greece | -4% | -4% | 6.9% | 18% | -12% |
| Hungary | 10% | 10% | 4.3% | 13% | -3% |
| Ireland | -20% | -20% | 3.1% | 16% | -7% |
| Italy | -13% | -13% | 5.2% | 17% | -10% |
| Latvia | 17% | 17% | 32.6% | 40% | 11% |
| Lithuania | 15% | 15% | 15.0% | 23% | -8% |
| Luxembourg | -20% | -20% | 0.9% | 11% | -5% |
| Malta | 5% | 5% | 0.0% | 10% | 37% |
| Netherlands | -16% | -16% | 2.4% | 14% | -3% |
| Poland | 14% | 14% | 7.2% | 15% | 22% |
| Portugal | 1% | 1% | 20.5% | 31% | -8% |
| Romania | 19% | 19% | 17.8% | 24% | 23% |
| Slovenia | 4% | 4% | 16.0% | 25% | 0% |
| Slovakia | 13% | 13% | 6.7% | 14% | -10% |
| Spain | -10% | -10% | 8.7% | 20% | -11% |

| Member State (EU27) | Total GHG emission reduction targets | Effort Sharing targets (non-ETS) | Share of energy from renewable sources: target in 2020 | | Energy efficiency target (final energy consumption) |
|---|---|---|---|---|---|
| | Reduction target 2005-2020 | Reduction target 2005-2020 | Share of RE in 2005 | Target share of RE in 2020 | Reduction target 2005-2020 |
| Sweden | -17% | -17% | 39.8% | 49% | -9% |

# Annex 2: Climate policies

This annex describes the most relevant climate policies and the targets and objectives that are relevant with respect to the headline targets. While some policies included targets for after 2020, we only discuss targets for 2020.

## EU Emission Trading System (ETS)

- The EU ETS is a 'cap and trade' system, setting an absolute cap on greenhouse gas emissions within the subjected sectors in the EU (EC, 2003). Emission permits are needed by the installations under the EU ETS, and exceedances are penalised. The cap decreases over time, setting a trajectory for emission reduction over time. Gases covered by the EU ETS are carbon dioxide ($CO_2$), nitrous oxide ($N_2O$), and perfluorocarbons (PFCs). The EU ETS initially covered the power and industry sectors. In 2012 the aviation sector was added. Together, the EU ETS sectors cover approximately 40% of total EU emissions in 2019. The target for 2020 is a 21% reduction in greenhouse gas emissions compared to the 2005 emission level.
- The EU ETS sets a cap, which is the total amount of greenhouse gases the operators in the system are allowed to emit. This cap is reduced over time. Operators in the system can buy emission allowances, and can trade these with other operators. The price of the allowance is a signal that serves as an incentive to invest in innovative low-carbon technologies. The trading mechanism ensures that emissions are reduced where it is least costly to do so.
- There has been an introduction phase, where 'free' allowances are distributed up to a certain amount. The number of these free allowances is reduced over time, preparing operators for having to cover all emissions with a paid-for allowance. At the end of each year, allowances have to be surrendered. If they do not cover all emissions, heavy fines are imposed.
- Phase 1 lasted from 2005-2007. In this period, only emissions from power generators and energy-intensive industries were covered, and almost all allowances were given for free. Phase 2 ran from 2008-2012, where more sectors and countries were added to the system. The cap was decreased and fewer free allowances were allocated. The carbon prices was not very high during this period, due to the economic crisis of 2008 leading to a decrease in emissions caused by the reduction in economic activity rather than the cap on emissions. Phase 3 lasted from 2013-2020. In this phase, an EU-wide cap was established rather than national caps on emissions. Free allocation was mostly phased out, and more sectors and gases were included in the system (EC, 2023).

## Effort Sharing Decision (ESD)

- The Effort Sharing Decision states national emission targets for Member States between 2013 and 2020 for non-ETS sectors, such as transport, buildings, agriculture, and waste (EU, 2009a). The ESD does not apply to emissions covered by the EU ETS, and to emissions and removals from land use, emission and removals from land use change and forestry (LULUCF).
- The EU target for 2020 is a 10% emission greenhouse gas emission reduction compared to 2005 levels in ESD sectors. These targets vary between Member States according to wealth. Together with a 21% emission reduction in the EU ETS sectors by 2020, this comprises the climate targets for 2020. The ESD was made into a regulation for 2030, the Effort Sharing Regulation (ESR). Member State targets are displayed in annex 1.
- Where the EU ETS is regulated at the EU level, responsibility for the implementation of policies to achieve the targets under ESD lies with the Member States. Member States must set out policies to reduce or limit emissions from the sectors covered by the ESD. Examples of such policies concern the promotion of public transport, shifting away from fossil fuels, climate-friendly farming practices, renewable energy for heating and cooling, and more.
- The EU has also taken measures to aid in achieving national targets under the ESD. Examples of these are the $CO_2$ emission standards for cars, the Energy Performance of Buildings Directive, or the Eco-design Directive. These policies are discussed separately.

## Renewable Energy Directive (RED)

The RED (2009/28/EC) has set mandatory national targets for the overall share of energy from renewable sources in gross final consumption of energy and for the share of energy from renewable sources in transport (EC, 2009). The gross final consumption of energy from renewable sources in each Member State is calculated as the sum of:

- gross final consumption of electricity from renewable energy sources;
- gross final consumption of energy from renewable sources for heating and cooling; and
- final consumption of energy from renewable sources in transport.

National Member State targets can be found in annex 1. The targets on the share of renewable energy vary according to Member States' starting points and ability to increase the share of renewable energy (from 10% in Malta to 49% in Sweden).

In addition to the general RES target, the RED also contained a specific transport target for every Member State of at least 10% of final energy consumption in transport. Next to the national targets, each Member State was required to adopt a national renewable energy plan and notify the Commission on this plan by 30 June 2010. The RED also laid down sustainability criteria for biofuel and bioliquids – such as minimum GHG emission reduction requirements that become stricter over the years.

## Energy Efficiency Directive (EED)

Based on the 2012 EED (Directive 2012/27/EU), Member States were required to use energy more efficiently at all stages of the energy chain, including generation, transmission, distribution and consumption (EC, 2012). In order to reach the 20% efficiency target of 2020, overall EU energy consumption would have needed to decrease to 1,086 Mtoe of final energy. There are separate, indicative targets for each Member State. These can be found in annex 1.

Art. 5 of the EED prescribed that each Member State should have ensured that, as from 1 January 2014, 3% of the total floor area (over 500 $m^2$ from 2014 and over 250 $m^2$ from 9 July 2015) of heated and/or cooled buildings owned and occupied by its central government would be renovated each year to meet at least the minimum energy performance requirements that it has set in application of Article 4 of Directive 2010/31/EU.

Member States should also have ensured that central governments purchase only products, services and buildings with high energy-efficiency performance, insofar as that is consistent with cost-effectiveness, economic feasibility, wider sustainability, technical suitability, as well as sufficient competition, with criteria further specified in Annex III of the Directive. The provision was only applicable to public purchase contracts above the threshold as specified in Article 7 of Directive 2004/18/EC.

Article 7 obliged Member States to set up energy efficiency obligation schemes or implement equivalent measures, that ensure that energy distributors and/or retail energy sales companies achieve a cumulative end-use energy savings target by December 31st, 2020. That target shall be at least equivalent to achieving new savings each year from the 1st of January 2014 to the 31st of December 2020. These savings should be at least 1.5% of the annual energy sales to final customers of all energy distributors or all retail energy sales companies by volume (averaged over the most recent three-year period prior to the 1st of January 2013). The sales of energy, by volume, used in transport may be partially or fully excluded from this calculation.

The EED also contains several articles based on which Member States are encouraged to take measures to promote energy savings among regulators, SMEs and households. This includes providing meters that reflect the actual energy consumption.

## Alternative Fuel Infrastructure Directive (AFID)

The AFID (2014/94/EU) established a common framework of measures for the deployment of alternative fuels infrastructure in the EU. This includes electric recharging points and LNG, CNG and hydrogen fuel points (EU, 2014). Member States were obliged to ensure that an appropriate number (based on an estimate of electric vehicles in 2020) of publicly accessible recharging points were in place by the 31st of December 2020. This had to ensure that electric vehicles can circulate at least in (sub)urban agglomerations and other densely populated areas. The provision was also applicable for 2020 for CNG vehicles. Other alternative fuels within the directive had targets further ahead in time (e.g. 2025 or 2027).

## Fuel Quality Directive (FQD)

The FQD (2009/30/EC) set technical specifications for fuels and a target for the reduction of life cycle GHG-emissions (EU, 2009b). Member States were required to oblige fuel suppliers to reduce life cycle greenhouse gas emissions per unit of energy from fuel and energy supplied by up to 10% compared with the comparator. This reduction should have consisted of:

- 6% by the 31st of December 2020. Member States may require suppliers, for this reduction, to comply with the following intermediate targets: 2% by the 31st of December 2014 and 4% by the 31st of December 2017;
- an indicative additional target of 2% by the 31st of December 2020, subject to Article 9(1)(h), to be achieved through one or both of the following methods:
    - the supply of energy for transport supplied for use in any type of road vehicle, non-road mobile machinery (including inland waterway vessels), agricultural or forestry tractor or recreational craft;
    - (ii) the use of any technology (including carbon capture and storage) capable of reducing life cycle greenhouse gas emissions per unit of energy from fuel or energy supplied;
- an indicative additional target of 2% by the 31st of December 2020, subject to Article 9(1)(i), to be achieved through the use of credits purchased through the Clean Development Mechanism of the Kyoto Protocol, under the conditions set out in Directive 2003/87/EC of the European Parliament and of the Council of the 13th of October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community (17), for reductions in the fuel supply sector.

## $CO_2$ emission performance standards for new passenger cars and new LCV

The objectives of this regulation (2019/631) were to contribute to the achievement of the EU's commitments under the Paris Agreement and to strengthen the competitiveness of EU automotive industry (EU, 2019). With regards to our study, especially the former objective is of interest. More specifically, it aims on reducing $CO_2$ emissions from cars and vans.

The regulation sets targets for the EU fleet-wide average emission performance ($CO_2$ emission per kilometre) of new passenger cars and new light commercial vehicles registered in the EU. 2020 NEDC-based targets are defined for cars (95 g $CO_2$/km) and vans (147 g $CO_2$/km), in line with the previous Regulation of 2010. In 2020 95% of manufacturers registered cars were taken into account. Cars with less then 50 g $CO_2$/km were to be counted as two passenger cars.

## Energy Performance of Buildings Directive (EPBD)

In the EPBD (2010/31/EU) Member States were required to ensure a minimum energy performance of buildings on a cost-optimal level (European Parliament & The Council of the European Union, 2010). Member States were also obliged to make sure that by December 2020 all new buildings were nearly zero-energy buildings and that after the 31st December 2018 new buildings occupied and owned by public authorities were nearly zero-energy buildings.

## CCS Directive

The Directive on the geological storage of $CO_2$ (CCS Directive) is in place since 2009 (EU, 2009c). It establishes a legal framework for the safe storage of $CO_2$ and contains provisions on the capture and transport of $CO_2$. CC(U)S provides an option to reduce the emissions of $CO_2$ to the atmosphere for hard-to-abate industrial processes. Also, the technique can be applied in carbon removal processes such as BECCS (Bio-Energy Carbon Capture and Storage) and DACCS (Direct Air Carbon Capture and Storage).

## Ecodesign Directive

The main objective of the Ecodesign Directive (2009/125/EC) is to reduce energy consumption and relevant environmental impacts for energy-related products (European Parliament & Council of the European Union, 2009). In order to achieve this the directive provides a consistent set of EU-wide rules that are aimed to improve the environmental performance of products like households appliances, information and communication technologies, or industrial products. The guidelines mainly apply to products that are sold often and that have an effect on the environment. The directive sets out minimum mandatory requirements for the energy efficiency of these products. The Ecodesign Directive is implemented through product-specific regulations, directly applicable in all EU Member States. The directive also helps to ensure the functioning of the internal market by requiring products to reach an adequate level of environmental performance.

# Annex 3: Non-climate policies

## Trans-European Networks for Energy (TEN-E)

TEN-E can be considered as the main EU policy framework for energy infrastructure. It is focused on linking the energy networks of the Member States and supporting the development of the backbone of the European energy networks by defining priority corridors (EU, 2013a). To strengthen the European networks and the priority corridors in particular, Projects of Common Interest (PCIs) are identified and funded through the Connecting Europe Facility for energy (CEF-E).

TEN-E was originally aimed at ending fragmentation in the single market for energy and does facilitate fossil fuel networks (oil and gas). However, it has become a key instrument for EU climate policy as it supports the creation of a robust pan-European electricity network. This is crucial for large-scale application of renewable energy sources (RES). Also a well-developed gas network is needed, both for natural gas as a transition fuel and for future deployment of sustainable gases such as green hydrogen.

Next to the priority corridors, three thematic areas were defined within TEN-E that are closely related to the energy transition: electricity highways, smart grids and cross-border $CO_2$ networks.

## Trans-European Networks for Transport (TEN-T)

The TEN-T policy framework aims to create a comprehensive network throughout the EU, focussed on transport infrastructure (EU, 2013b). Since its inception in the 1990s it has made use of Priority Projects (PPs) to strengthen the most essential connections.

Although TEN-T covers all modes of transport, it has placed emphasis on climate friendly ones, mostly railways. Since their 2013 revision, the TEN-T guidelines also provide a coordination structure on the implementation of the European Railway Transport Management System (ERTMS). This implementation is necessary to extend (high-speed) cross-border railway connections in the EU.

## Electricity connection target for 2020

In 2014 the European Council endorsed a 10% electricity connection target for Member States for 2020 (EC, 2015a). This is defined as import capacity over installed generation capacity in a Member State. This target has contributed to the development of cross-border electricity connections, which in turn have facilitated large scale use of RES.

## Creation of ACER and cooperation structures for ENTSOs

In 2009, the setup of an EU Agency for the Cooperation of Energy Regulators (ACER) was legislated (EU, 2009d). In 2019 its coordination role was strengthened. Besides that, cooperation structures for European Network Transmission Systems Operators (ENTSOs) for gas and electricity were created (EU, 2017). Both ACER and the ENTSOs are aimed at coordinating grid operation throughout the EU including cross-border infrastructures.

# Annex 4: Progress on 20-20-20 targets in MS

Below, the progress on the 20-20-20 targets for the seven selected Member States (Belgium, Finland, France, Germany, the Netherlands, Poland and Spain) is presented.

## Belgium

Progress on the 2020 targets for Belgium is shown in Figure 8. According to the UNFCC, Belgium's GHG target was met by the end of 2020. The target was set at a 15% reduction compared to 2005 and was reached by achieving a 27% decrease. The COVID-19 pandemic can be expected to have caused a drop in the last year, but even without that Belgium was well on track of reaching their target.

The RES target for Belgium was reached by the end of 2020. It was set at 13%, the lowest target of the Member States that are being studied, and met by achieving a 13% share of renewables. While in 2019 this share was still at 10%, Belgium managed to increase their share of renewables in the last year by 3 percentage points.

Belgium had a target of 12% reduction in final energy consumption under the Energy Efficiency Directive. This target was not met, as final energy consumption has reached a 10 percentage point reduction by 2020 compared to 2005.

However, overall Belgium has reached its ESD target for 2020. The goal was set at a 15% decrease of ESD emissions, while they achieved a decrease of 16 percentage points. Between 2015 and 2019 they were not on track for reaching this target, but a drop of 6 percentage points in 2020 changed this. This may be caused by the impact of COVID-19.

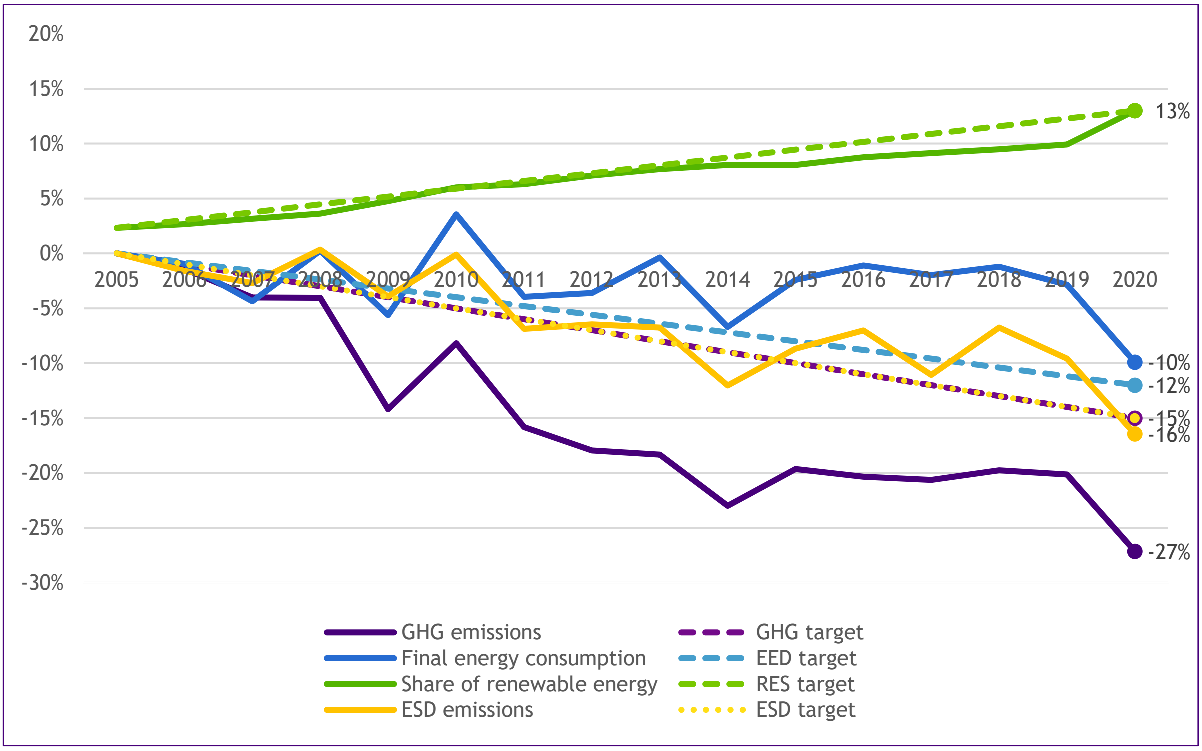


*Figure 8 – Progress on 2020 targets Belgium*

## Finland

Finland's GHG emission reduction target was set at a 16% reduction compared to 2005 and it exceeded this target by achieving an impressive 47% decrease in GHG emissions. However, Figure 9 shows that Finland's trend with regards to their emission reductions is characterised by a spikey pattern, which makes it harder to interpret the value of this 2020 achievement. The fluctuations can be explained by fluctuations in emissions in the energy sector.

By the end 2020 Finland reached its RES target and even exceeded it by about 6 percentage points. The target that was set was the highest amongst the selected Member States (38%) while a 44% share of renewables was achieved. Figure 9 shows a steady, upward-sloping trend and indicates that the share of renewables Finland experienced a relatively faster growth between 2011 and 2014.

The energy efficiency target for Finland was a limited growth in final energy consumption of 6%. However, Finland has managed a reduction of 7% compared to 2005, exceeding their goal by 13 percentage points.

According to the emissions reported by Eurostat Finland has reached its ESD targets for 2020. The target was set at 16%, which was met by achieving emission reduction just over 16%. In contrast to the overall GHG emissions the ESD related emissions show a more stable trend.

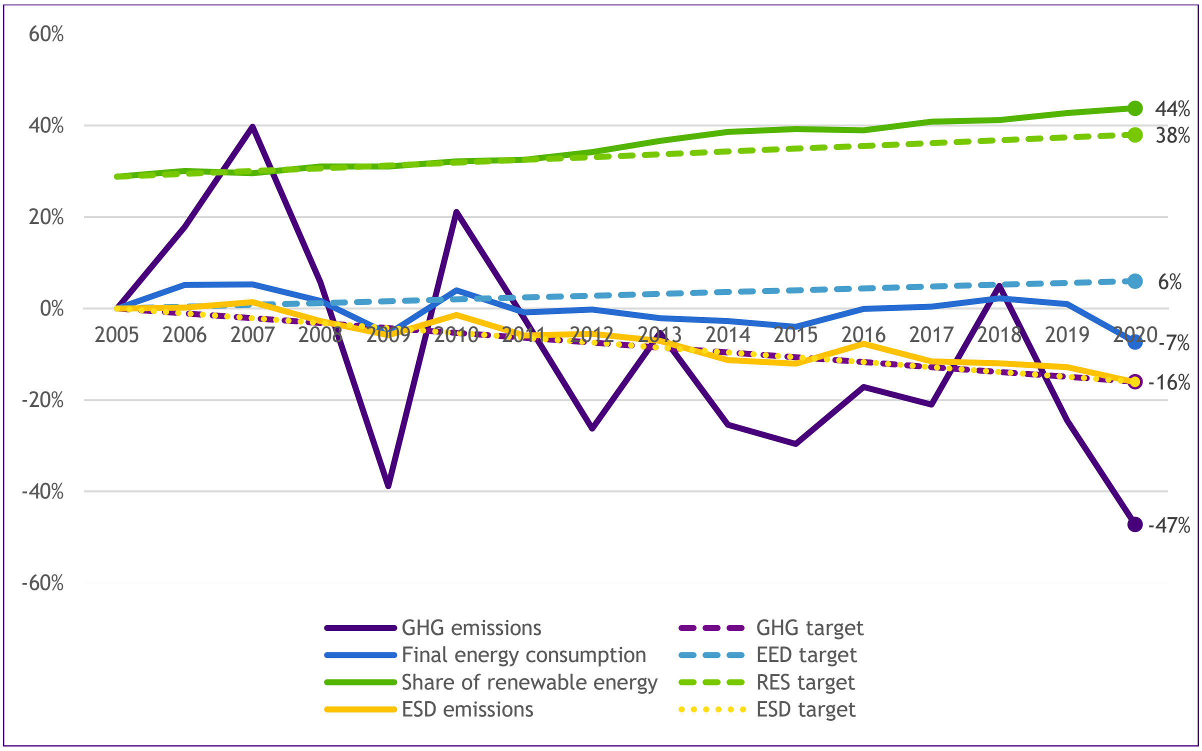


*Figure 9 – Progress on 2020 targets Finland*

## France

The UNFCCC's data show, as given in Figure 10, that France has reached its GHG reduction target for 2020. It was set at 14% and met by achieving a 28% reduction compared to 2005. The trend shows that France was well on track in the years before 2020, suggesting that even without a drop due to the COVID-19 pandemic the target would have been met.

The RES target for France was set at 23%, but was not met by the end of 2020: they ended with a 19% share of renewables. Among the selected Member States, the 23% target was the most ambitious target after Finland's.

Within the energy efficiency targets, France was set a goal of a 14% reduction in final energy consumption. Only in 2020 was this goal surpassed with a reduction of 2019. However, recent data shows that in 2021, the net reduction has lowered again to 10%, suggesting that 2020 was an outlier year, potentially due to COVID-19.

By the end of 2020 France has exceeded its ESD target by about 8 percentage points. Whereas the target was set at 14%, France managed to reduce their GHG emissions by 22% compared to 2005. The trend towards this target shows a steady trend ending with a 7 percentage point drop, potentially due to the COVID-19 pandemic.

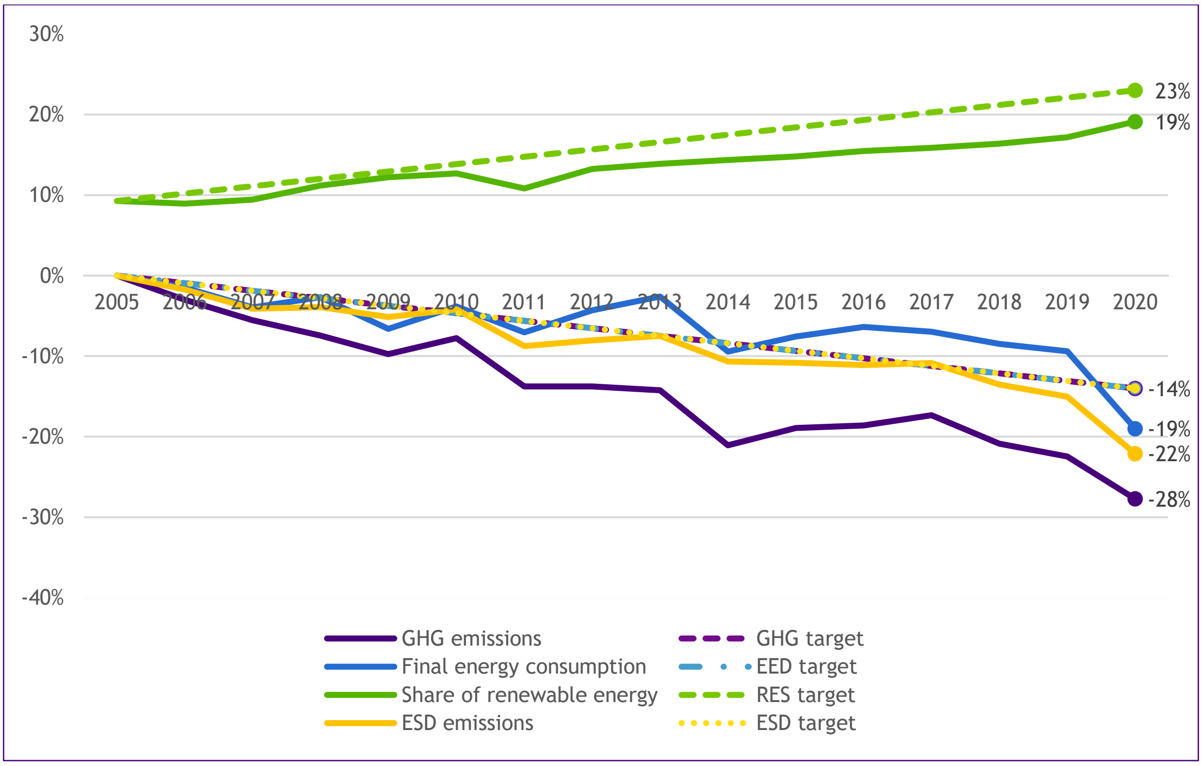


*Figure 10 – Progress on 2020 targets France*

## Germany

Progress on the 2020 targets for Germany is given in Figure 11. Germany's GHG emissions target and final emission reductions are closely identical to France's: the target was set at 14% and it reached by achieving a 28% reduction compared to 2005. However, the trend towards to achievement shows a rather different pattern than France. While Germany's trend was steady and downward-sloping, it was only until 2018 that Germany's emissions reductions really started to accelerate. This contributed to a 13 percentage point reduction between 2018 and 2020. Inspecting Figure 11, it can be expected that the target would have been met without the COVID-19 drop.

Eurostat data show that Germany reached their RES target by the end of 2020. The target was set at 18% while they achieved a 19% share of renewables. The figure shows that Germany's trend towards this achievement was steady with a small spike in 2020.

The goals concerning energy efficiency in terms of final energy consumption were not met in Germany. The reduction of 8% was not enough to meet the target set at a 12% reduction in 2020.

The ESD target that was set for Germany was not reached by the end of 2020. The goal was to reduce GHG emissions by 14% compared to 2005, but despite a significant drop of 5% in the last year only a 12% reduction was reached.

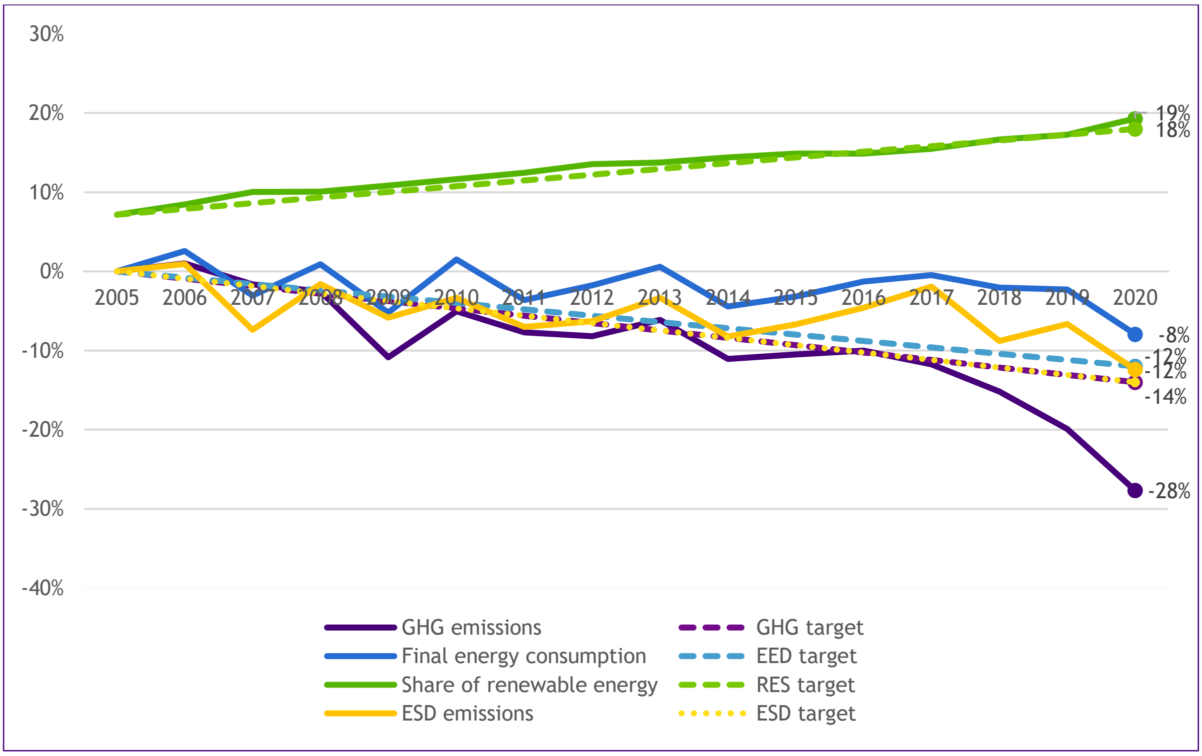


*Figure 11 – Progress on 2020 targets Germany*

## Netherlands

By the end of 2020 the Netherlands managed to reach their GHG target, as shown in Figure 12. Among the seven Member States that are analysed they had the highest target of 16% reduction, which was exceeded by achieving a 22% emission reduction compared to 2005. However, the COVID-19 pandemic seems to have contributed significantly to this: in 2020 only the emission reduction dropped by an additional 9 percentage points. This shows a sharp contrast with the period 2012-2017, when only an extra 1 percentage point reduction was achieved.

By the end of 2020 The Netherlands reached their RES target (14%) by achieving a 14% share of renewables. Figure 12 shows that in the years before 2019 the share was relatively low and not much growth was seen. Between 2008 and 2018 the share of renewables grow only with 3%, whereas the growth between 2019 and 2020 was about 7%. It has to be noted that the share of renewables that was actually produced in The Netherlands ended at 11% in 2020. Therefore, the Netherlands agreed with Denmark to use a share of their renewable energy production, so that the Dutch target would be met.

The Netherlands was set a limited goal in terms of energy consumption of only 3%. Realised reduction in final energy consumption has been as high as 17%, far exceeding the goal that was set.

After Spain, The Netherlands have exceeded their ESD target most significantly. It was set at 16%, but a 27% reduction was achieved. This is the largest reduction among the selected countries.

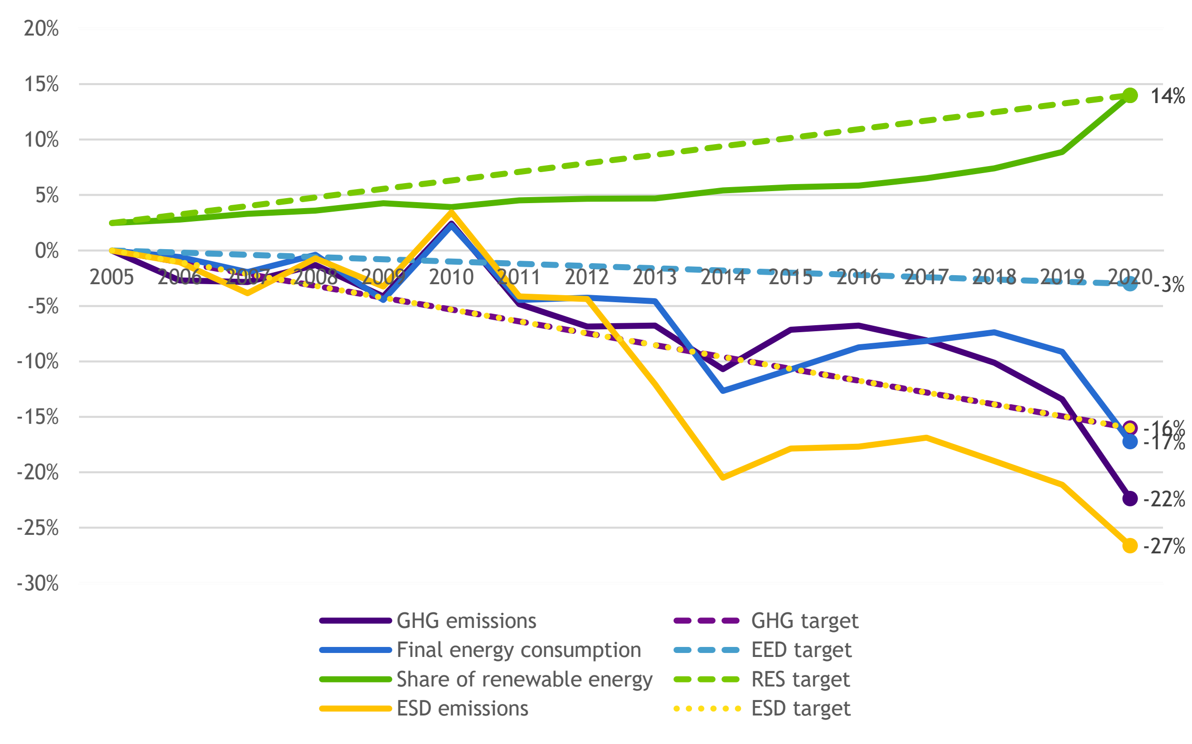


*Figure 12 – Progress on 2020 targets Netherlands*

## Poland

As the only country among Member States that are analysed in this study with a target that allowed an increase in GHG emissions (14%), Poland did manage meet this target by minimizing their increase of GHG emissions to only 3%. The COVID-19 pandemic seems to have contributed to this, observing the 8 percentage point drop in 2020.

The RES target for Poland was reached by the end of 2020. It was set at 15% and met by achieving a 16% share of renewables. Between 2012 and 2017, Poland's share of renewables stabilized around 11%, followed by a sharp increase in 2018 that contributed to meeting the target in 2020.

The target for final energy consumption was a growth limited to 22%. This goal was only just met in 2020, after a rapid growth in final energy consumption between 2014 and 2018 was followed by a rapid decrease in 2020, precisely meeting the target.

In contrast to the other selected Member States Poland was allowed a 14% increase of GHG emissions under the ESD. This was achieved by minimizing their increase of emissions to 10%. Poland's trend shows a cyclical pattern.

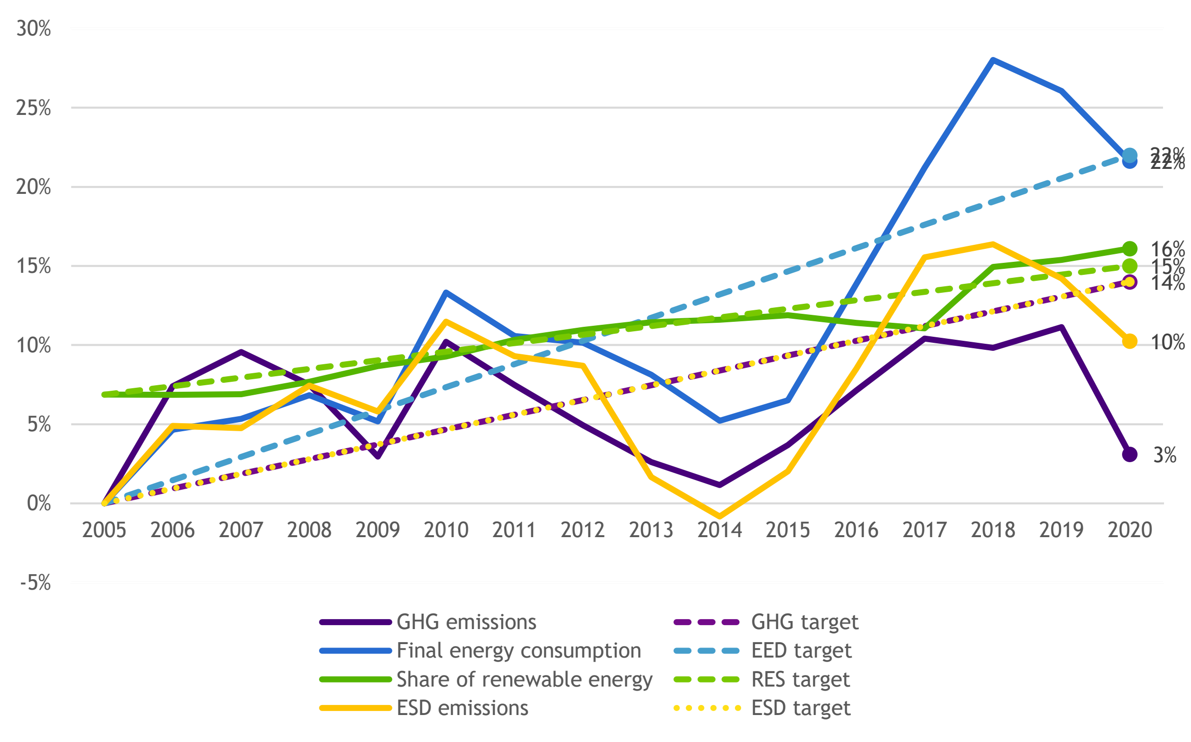


*Figure 13 – Progress on 2020 targets Poland*

## Spain

After Finland Spain has achieved the highest relative reduction in GHG emissions among the selected Member States, as given in Figure 14. Although their target was set at a 10% reduction, they managed to reduce their emissions by about 46% compared to 2005. In contrast to for example Finland, Spain's trend shows to be a lot more stable over the years.

Spain's RES target was set at 20% and was met by the end of 2020. In this last year they managed to increase their share of renewables from 18 to 21%. The development of the share of renewables shows a stable trend very much on track to the target in 2020.

Final energy consumption was to be reduced by 11% in 2020. Spain has exceeded this target quite early, ending at a 25% reduction in 2020.

Among the selected Member States Spain has managed to exceed their ESD target most significantly. Their target was set at 10%, but by the end of 2020 their emissions had dropped by about 25% compared to 2005. After an upward trend between 2005 and 2007 the line in Figure

14 shows a steady downward slope, finishing with a drop of about 9 percentage points in the last year.

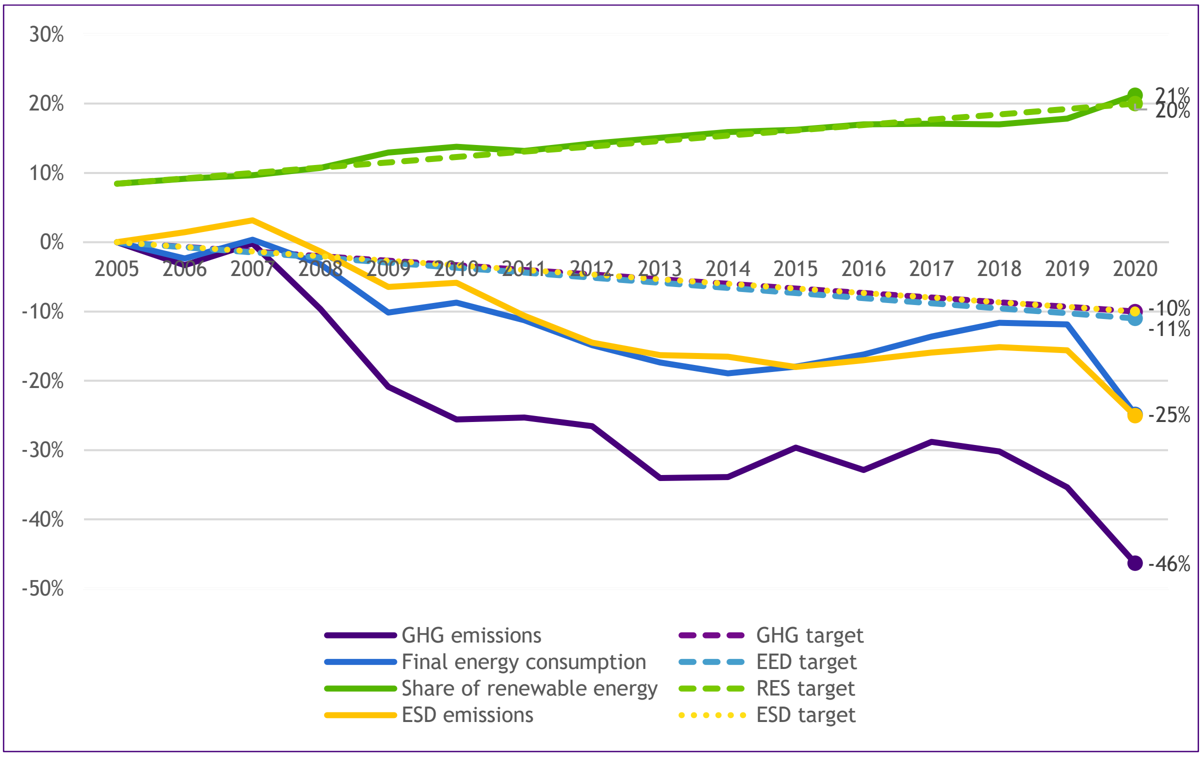


*Figure 14 – Progress on 2020 targets Spain*

# Annex 5: Decomposition analysis

In chapter 5, the method of decomposition analysis is used to estimate the contribution of various factors to the total reduction in greenhouse gases in the EU27 and the seven selected Member States. This annex further elaborates on the method, data and assumptions involved in this analysis.

## Kaya identity

The decomposition chapter 5 is linked to the various elements of the Kaya identity, which is a mathematical expression to define total GHG emissions as a result of a set of determinants. These determinants consist of total population, GDP per capita, energy intensity of GDP (or value added, in production terms), and carbon intensity of energy. Multiplying these factors results in the total $CO_2$ emissions (of the EU or Member State). Moreover, this identity is expanded by introducing the sectoral structure, specifying energy intensity of GDP and carbon intensity of energy further into different sectors of the economy. This allows us to examine the effect of structural change of the economy on total greenhouse gas emissions.

The total expression for all components therefore reads as follows:

$$C_i = P_i \times \frac{Y_i}{P_i} \times \left( \sum_j \alpha_{ij} \left( \frac{E_{ij}}{Y_{ij}} \right) \left( \frac{C_{ij}}{E_{ij}} \right) \right)$$

Which denotes the following:

- Ci = total GHG emissions in $CO_2$ equivalents in year I;
- Pi = total population in year I;
- Yi = total GDP (or value added, in production terms) in year I;
- $\left(\frac{E_{ij}}{Y_{ij}}\right)$ = energy intensity (EI) of value added in year i in sector j;
- $\left(\frac{C_{ij}}{E_{ij}}\right)$ = carbon intensity of energy (CI) in year i in sector j;
- $\alpha_{ij}$ = share of value added of sector j in total economy in year i. Where the condition is $\sum_j \alpha_{ij} = 1$ to account for the total economy.

Moving forward, we will consider this expression in each of two points in time: 'before' (denote by 'B') and 'after' (denoted by ('A'). 'Before' is the average situation in the years 2008-2010. We use simple averages of these three years in each underlying data source, in order to partly eliminate yearly anomalies (such as a cold winter or economic crises). 'After' is the average situation in the years 2017-2019. This gives us an evaluation period of approximately 9 years.

Due to data limitations, it was not possible to extend the evaluation period to before 2008 or after 2019.

We use the expression to estimate so-called counterfactual emissions. The counterfactual emissions are the emissions that would have happened, if one or more of the elements in the expression had not changed over time. To elaborate, total GHG emissions can change over time due to changes in any of the expressions in the above equation: changes in total population, changes in GDP per capita, changes in the share of sector $j$, changes in the energy intensity of value added, and changes in the carbon intensity of energy. Each of these factors have changed over the evaluation period between 'before' and 'after'. In order to isolate the effect of any one of these factors, we have to create a hypothetical situation where the other factors did not change over time. This allows us to reveal the isolated effect of the factors under investigation. Below, we show the method used and steps taken to arrive at the isolated effects of each of these factors.

## LMDI method

In accordance with previous literature, the Logarithmic Mean Divisia Index (LMDI) approach is used to perform the decomposition analysis and estimate counterfactual situations. This method has been determined in literature as the preferred method for decomposition analysis (Ang, 2005). This method uses all the elements to be decomposed in a formula which allows to gauge the relative contribution of each element to the total change in the outcome variable (greenhouse gas emissions, in this case). The general formula writes as follows:

$$\Delta C_x = \sum_j \left( \frac{C_j^A - C_j^B}{lnC_j^A - lnC_j^B} \ln\left(\frac{x_j^A}{x_j^B}\right) \right)$$

Where $\Delta \mathrm{C}$ denotes the change in greenhouse gas emissions between 'before' and 'after', and $x$ denotes each of the elements included in the Kaya identity (population, GDP per capita, share of value added of sector $j$ in the economy, energy intensity of value added, and carbon intensity of energy). The sectors are denoted by subscript $j$. Notations 'B' and 'A' are used to denote the situation 'before' and 'after' in the evaluation period.

Applying this formula to each of the five elements in the Kaya identity gives us the following set of formulas, which are used to estimate the contribution of each of these elements to the total change in greenhouse gas emissions:

$$\Delta \mathrm{C}_{\mathrm{population}} = \Delta C_P = \frac{C^A - C^B}{lnC^A - lnC^B} \ln\left(\frac{P^A}{P^B}\right)$$

$$\Delta \mathrm{C}_{\mathrm{GDP}} = \Delta \mathrm{C}_{\mathrm{Y}} = \frac{C^A - C^B}{lnC^A - lnC^B} \ln\left(\frac{Y^A}{Y^B}\right)$$

$$\Delta C_{\text{structure}} = \Delta C_{\alpha} = \sum_{j}\left(\frac{C_j^A - C_j^B}{lnC_j^A - lnC_j^B}\ln\left(\frac{\alpha_j^A}{\alpha_j^B}\right)\right)$$

$$\Delta C_{\text{energy intensity}} = \Delta C_{EI} = \sum_{j}\left(\frac{C_j^A - C_j^B}{lnC_j^A - lnC_j^B}\ln\left(\frac{EI_j^A}{EI_j^B}\right)\right)$$

$$\Delta C_{\text{carbon intensity}} = \Delta C_{CI} = \sum_{j}\left(\frac{C_j^A - C_j^B}{lnC_j^A - lnC_j^B}\ln\left(\frac{CI_j^A}{CI_j^B}\right)\right)$$

Where P denotes population, Y denotes value added per capita, $\alpha_j$ denotes the share of value added in sector *j* in total value added, $EI_j$ denotes energy intensity of sector *j*, and $CI_j$ denotes carbon intensity of energy in sector *j*. Further, note that for $\Delta C_{\text{population}}$ and $\Delta C_{GDP}$, sectoral structure is irrelevant and subscript *j* is therefore omitted from the equation.

Adding the results of each of these equations together gives the total change in greenhouse gas emissions over the period between 'before' and 'after':

$$\Delta C = \Delta C_P + \Delta C_Y + \Delta C_\alpha + \Delta C_{EI} + \Delta C_{CI}$$

Next, we express the changes in greenhouse gas emissions due to each element as a percentage of the total greenhouse gas emissions in the situation 'before', by dividing the change in emissions due to each element by total greenhouse gas emissions before:

$$Change\ in\ emissions\ due\ to\ x = \frac{\Delta C_x}{C^B}$$

All relative changes due to each element added together results in the net percentage change in greenhouse gas emissions over the studied period.

$$\frac{\Delta C}{C^B} = \frac{\Delta C_P}{C^B} + \frac{\Delta C_Y}{C^B} + \frac{\Delta C_\alpha}{C^B} + \frac{\Delta C_{EI}}{\mathrm{C}^B} + \frac{\Delta C_{CI}}{C^B}$$

## Explained: contribution of value added

The share of value added of each sector in the total value added influences the total GHG emissions, due to its link with both energy intensity of value added, and the carbon intensity of energy used. Some sectors are considerably more energy intensive than others. In general, industrial sectors have a high energy intensity, whereas service sectors have a low energy intensity. When the relative share of different types of sectors changes, it influences the relative use of energy to produce total GDP. Therefore, total GHG emissions are influenced if certain sectors grow or shrink relative to other sectors. Note that here we only consider the *relative* changes in economic structure: effects of changes in absolute GDP (value added) are captured in the previous step.

## Explained: contribution of carbon intensity

Carbon intensity influences total greenhouse gas emissions through the underlying energy structure. Within the term $E_{ij}$ of the Kaya identity, all types of energy are comprised. Different types of energy have a different GHG emission factor/intensity . Generally, the use of renewable energy has an emission factor of zero or close to zero, whereas the use of fossil fuels produces a high amount of GHG emissions. Both by replacing fossil-based fuels by renewable sources, as well as by crowding out the fuels with the highest carbon intensity, savings in carbon intensity can be achieved. In the next section, the contribution of these two general avenues is estimated.

# Contribution of electricity from renewable sources

One of the main staples of EU climate policy is the stimulation of renewable energy use. For 2020, the goal was to have at least 20% of energy come from renewable sources. Therefore, we further decompose the effect of carbon intensity to a contribution of changes in use of electricity from renewable sources, and other carbon intensity effects. Due to data limitations on energy statistics on a sectoral level, we limit our estimations to the production of electricity from renewable sources. Therefore, 'other carbon intensity effects' refers to a combination of fuel switches in the production process, as well as fuel switches between non-renewable sources in electricity production. These elements cannot be further distinguished.

To estimate the contribution of an increased electricity production from renewable sources, we use a combination of data on total electricity production, the share of renewables in electricity production, and carbon intensity of electricity.

The calculation of GHG emissions from electricity production can be simplified as follows:

$$C_{electricity} = \beta \times E \times CI_R + (1-\beta) \times E \times CI_F$$

Where $C_{electricity}$ denotes the greenhouse gas emissions from electricity production, $\beta$ the share of renewable sources in electricity production, E the total energy production, CI the carbon intensity of electricity production, and subscripts R and F indicate renewable and fossil sources respectively. $(1-\beta)$ is the share of non-renewable (fossil, for short) sources in electricity production.

Data on total electricity production is taken from Eurostat, which contains data on electricity generation by type of fuel. From this, the average share of renewable sources is also calculated in both the 'before' and 'after' period. Carbon intensity indicators are taken from EEA. This provides an estimation of greenhouse gas intensity of electricity generation. In order to distinguish a carbon intensity for fossil and renewable sources, we assume that emissions from renewable electricity production is (close to) zero. Of course, this is not entirely true, but making this assumption allows us to estimate the effect of a switch to renewable energy. This assumption enables a calculation of carbon intensity of non-renewable electricity production: we simply divide the average carbon intensity by the share of non-renewable sources in the relevant year. We further use this calculation to estimate GHG emissions from non-renewable electricity production. This simplifies the calculation above further to the following equation:

$$C_{electricity} = (1-\beta) \times E_F \times CI_F$$

Now, another decomposition analysis is performed. This is also done using the LMDI method. We are in this instance mainly interested in the contribution of the factor $\beta$ in the above equation. Specifically, we use the factor $(1-\beta)$, i.e. the share of non-renewable resources in electricity generation to determine the effect of a shift between renewable and non-renewable sources. The following formula from the LMDI is used:

$$\Delta \mathrm{C}_{\text{renewable electricity}} = \Delta C_{RES} = \frac{C^A_{electricity} - C^B_{electricity}}{lnC^A_{electricity} - lnC^B_{electricity}} \ln\left(\frac{(1-\beta)^A}{(1-\beta)^B}\right)$$

Where $\Delta C_{RES}$ denotes the change in emissions from electricity generation due to a change in the share of renewable sources in electricity generation.

The final step is to divide the total change in emissions due to a change in the share of renewable sources in electricity generation by the total emissions in the 'before' period.

$$Change\ in\ emissions\ due\ to\ share\ of\ renewables\ in\ electricity = \frac{\Delta C_{RES}}{C^B}$$

The resulting effect is subtracted from the previously found effect from carbon intensity in the main decomposition analysis. Here, we define the remaining effect as changes in greenhouse gas emissions from fuel switches in the production process, as well as changes in fuel switches between fossil resources in electricity generation. The complete decomposition analysis becomes:

$$\frac{\Delta C}{C^B} = \frac{\Delta C_P}{C^B} + \frac{\Delta C_Y}{C^B} + \frac{\Delta C_\alpha}{C^B} + \frac{\Delta C_{EI}}{\mathrm{C}^B} + \frac{\Delta C_{RES}}{C^B} + \left(\frac{\Delta C_{CI}}{C^B} - \frac{\Delta C_{RES}}{C^B}\right)$$

Where the last term $\left(\frac{\Delta C_{CI}}{C^B} - \frac{\Delta C_{RES}}{C^B}\right)$ denotes the carbon savings other than those due to the change in the share of renewable sources in electricity generation.

# Data collection

Data for the decomposition analysis is collected from public sources. The main source of data is Eurostat. The availability of public data sources is the main reason for the selection of time periods and sectors: a match must be made between each time period and sector, in every dataset, to complete the elements needed in the LMDI approach. In terms of time periods, data availability limits the analysis to the period 2008-2019, where 'before' is an average of the years 2008-2010, and 'after' an average of 2017-2019, effectively producing an evaluation period of 9 years. Although this does not cover the full analysis period of 2005-2020, it does give some valuable insights into the developments over the studied period.

Four general variables are used in the main decomposition analysis: population, value added, energy use and greenhouse gas emissions. A note must be made that the analysis here limits to scope 1 and 2 emissions. Imported emissions (scope 3) are not considered. Moreover, some additional variables are used for the estimation of the contribution of electricity from renewable sources: electricity production by renewable and non-renewable source, and $CO_2$ intensity of electricity production. An overview of data sources for the variables used is given in Table 10.

*Table 10 – Data sources for decomposition analysis*

| Variable | Data source |
|---|---|
| Population | Eurostat: Population on 1 January by age and sex (DEMO_PJAN) |
| Value added | Eurostat: National accounts aggregates by industry (NAMA_10_A64) |
| Energy use | Eurostat: Energy flow – Sankey diagram data (NRG_BAL_SD) |
| Greenhouse gas emissions | Eurostat: Air emissions accounts by NACE Rev. 2 activity (ENV_AC_AINAH_R2) |
| Electricity production incl. share of renewable sources | Eurostat: Gross and net production of electricity and derived heat by type of plant and operator (NRG_IND_PEH) |
| $CO_2$ intensity of electricity production | EEA: Greenhouse gas emission intensity of electricity generation in Europe (2022) |

Ideally, one would include all sectors on a granular level for the variables constructed out of value added, energy use and GHG emissions. On a European scale, a common sector specification is NACE Rev 2 (Eurostat, 2008). This coded system groups together economic data on different levels of granularity. The highest level divides the economy into broad sectors such as 'agriculture, forestry and fishing', 'manufacture', 'transportation and storage', while lower levels of aggregation include very specific industries.

To estimate the decomposition effects on a sectoral level as defined in the Kaya identity, data on sector level must be complete for each of the elements. Unfortunately, public data is not consistently available on the desired level of granularity. Therefore, the effects on a sector level are estimated using a small set of generalised sectors. This means we limit our set of industries captured in '$j$' to a selected number, which together make up the total economy. We make a distinction between industries with a high level of energy intensity ('industry'), and a low level of energy intensity ('services'), in order to capture the main developments in terms of structural change. The most significant effects on GHG emissions due to structural change are generally caused by a move from production and manufacturing to more service-related economic activity. Due to the lower energy intensity in service industries, energy use will decrease relative to a situation with a higher share of manufacturing industries. A third group of sectors which can be identified across all data sources, is transport. Therefore this sector is also considered separately.

Generally, intra-sectoral changes that lead to changes in energy-intensity are not captured in this way. Structural changes analysed here result in energy-intensity changes in the economy as a whole.

Table 11 gives an overview of sectors considered in the classification systems for on the one hand the NACE Rev. 2 system, and on the other hand the segmentation implemented for energy use.

*Table 11 – Sector definition for decomposition analysis*

| Grouped sector | Included sectors from NACE Rev. 2 | Included sectors from energy use data |
|---|---|---|
| Industry | A-C | Industry sector; Agriculture and forestry; Fishing |
| Service | D-G and I-U | Commercial and public services; Not elsewhere specified |
| Transport | H | Transport sector |

## Results Member State level

Below, the results of the decomposition analysis for the seven selected Member States (Belgium, Finland, France, Germany, the Netherlands, Poland and Spain) are presented.

### Belgium

Total greenhouse gas emission reduction amounts to 11.1% in Belgium, as shown in Figure 15. Population growth and GDP growth show a countereffect to savings of 5.5 and 19.4% respectively. The effect of structural change between service, industry and transport is a reduction of 4.7%, which is larger than average in the EU. This implies that in Belgium, in the period 2009-2018 there has been a shift from carbon intensive sectors to less carbon intensive sectors.

Remaining factors all also have a reducing effect on GHG emissions. Savings due to energy efficiency amount to 20.6%, also enough to overshoot estimations of autonomous improvements in energy efficiency by some 10 to 15%. The contribution to savings due to the deployment of renewable sources in electricity generation is smaller than EU average, but positive nonetheless, by 2.1%. other carbon intensity savings represent a significant contribution of 8.7% to savings in greenhouse gas emissions. All in all, it can be stated that developments related to the reduction in greenhouse gas emissions have behaved as expected given climate policy targets. This results in an overall reduction in greenhouse gas emissions slightly over the EU27 average.

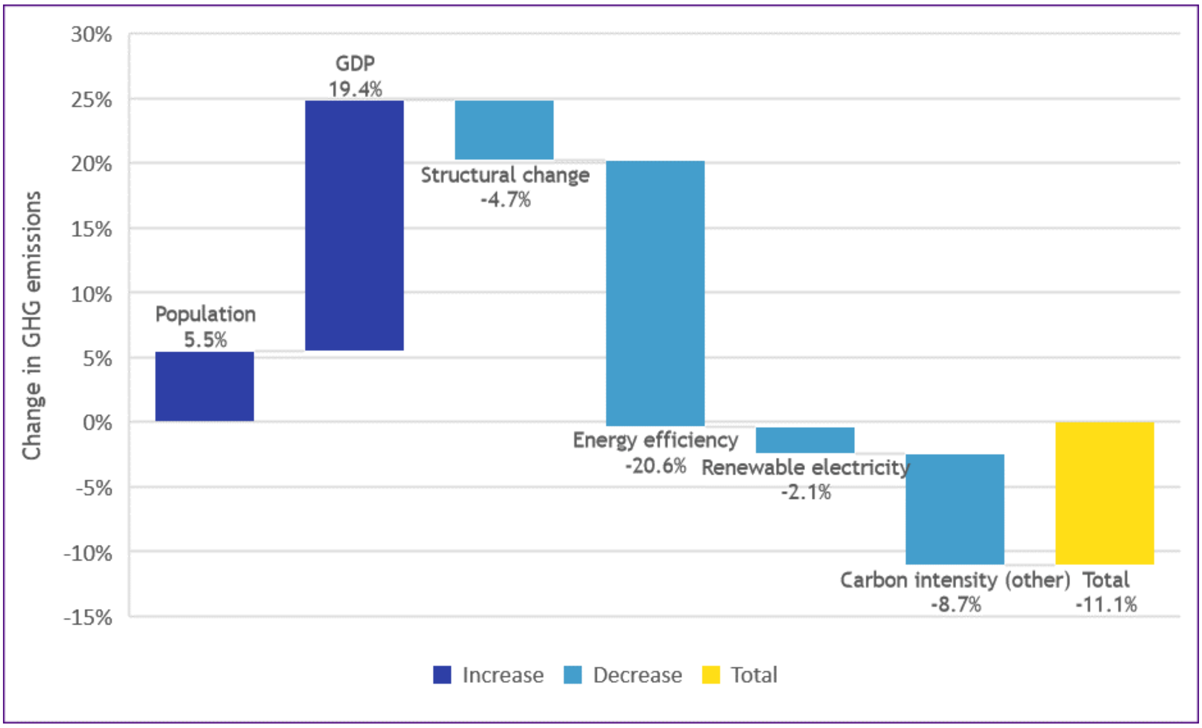


*Figure 15 – Decomposition analysis Belgium 2009-2018: GHG emissions*

## Finland

GHG emissions in Finland are above average with a net reduction of 22.8%. Population and GDP growth serve as countereffect with a 3 and 14.6% contribution to dissavings in GHG emissions. Similar to Belgium, a discernible shift has occurred from carbon intensive sectors to less carbon intensive sectors, illustrated by the 4.8% reduction in greenhouse gas emissions due to structural change.

Energy efficiency savings in Finland are lower than average, with a total of 11.4%. Given an autonomous improvement of 0.5% to 1% per year, this only slightly presents an additional effect. On the contrary, carbon intensity savings are significant, and higher than average in the EU. Only a limited share is due to the deployment of renewable sources in electricity generation. This can partly be explained by the fact that Finland had a relatively high share of renewable energy to begin with, of over 30% in 2009. Overall, the factors within climate policy domain show a net saving effect, allowing a positive connotation with effective climate policy, although this is not causally inferred from the current analysis.

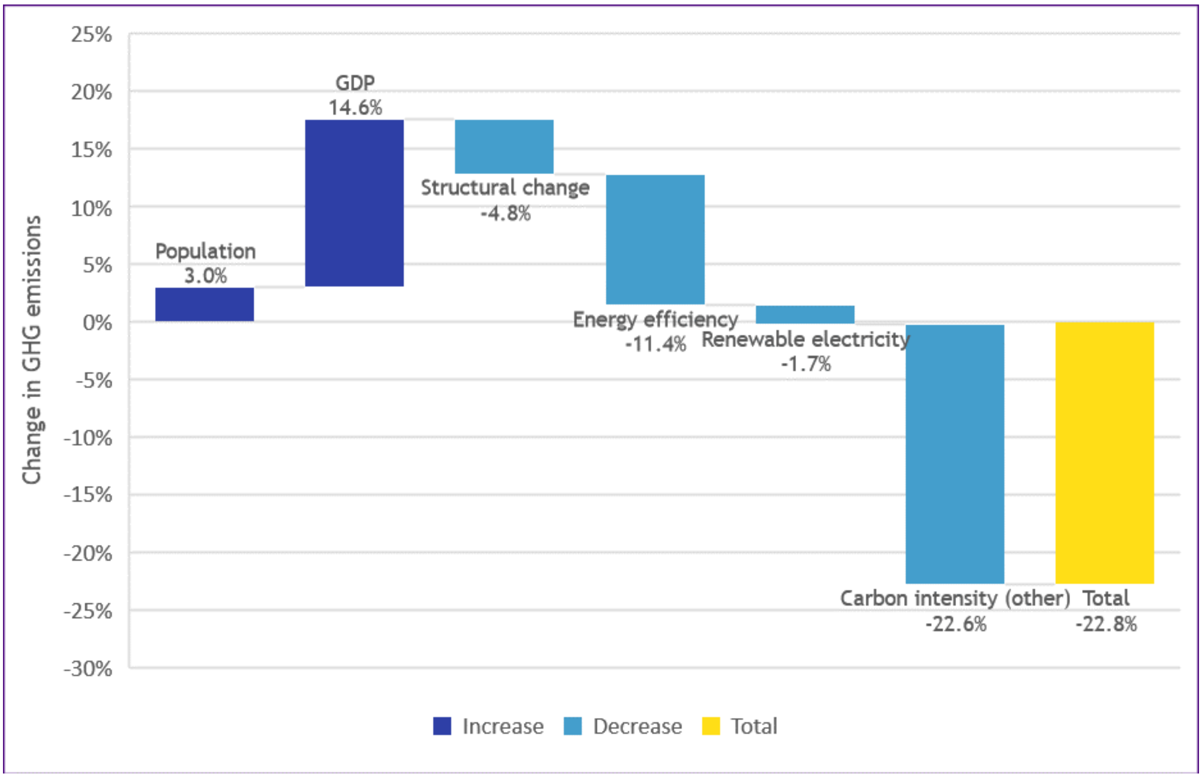


*Figure 16 – Decomposition analysis Finland 2009-2018: GHG emissions*

## France

The result of the decomposition analysis on the national level for France are given in Figure 17. A general reduction in GHG emissions of 13% was achieved over the given period. Dissaving of emissions amount to 3.8 and 11.9% due to population and GDP growth respectively. About 1.7% in GHG savings were brought about by the shift from carbon-intensive industries to less carbon-intensive sectors. The limited size of this effect is in line with previous observations that in western Europe, the major trend toward a service economy was observed long before the period studied in this analysis. Moreover, intra-sectoral structural developments are not captured in this result.

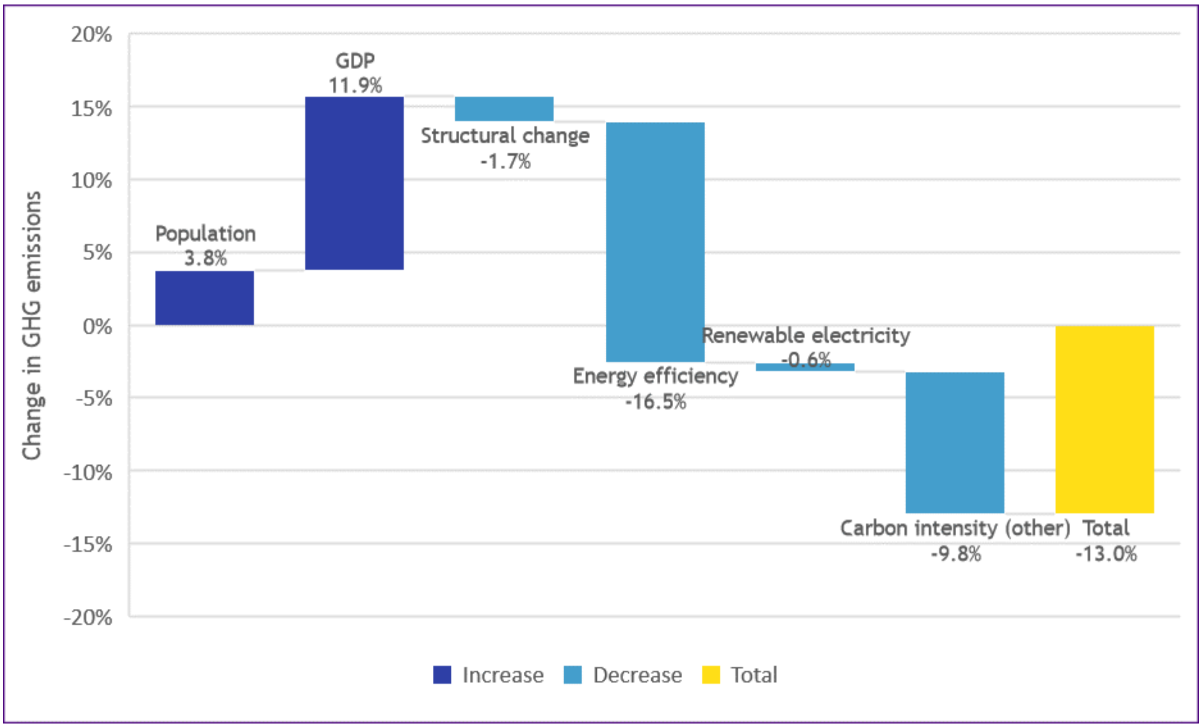


*Figure 17 – Decomposition analysis France 2009-2018: GHG emissions*

Improvements in energy efficiency have contributed to GHG emission reduction by 16.5%. Subtracting a yearly autonomous improvement of 0.5% to 1%, leaves a still positive policy-induced effect of approximately 7.5 to 12%. The contribution of the deployment of renewable energy is limited, but still positive with a contribution to reduction of about 0.6%. A potential explanation is the large capacity for nuclear energy in France: France is among the countries with the highest percentage of electricity being generated by nuclear power plants (EIA, 2023). As nuclear energy does not produce GHG emissions in the use phase, a switch to renewables does not establish a large impact on greenhouse gas emission reductions. Remaining carbon savings account for about 9.8% in GHG emission reduction. This implies that the developments within the climate policy domain contribute positively to GHG emission reductions, meaning that a positive association to climate policy could be inferred.

Compared the EU average, France shows a larger impact due to population growth, and a positive impact on emissions due to structural change rather than a growth in emissions, but on average has established fewer energy efficiency savings. Savings in terms of carbon intensity improvements other than the deployment of renewable energy is larger than the EU average.

## Germany

The results of the decomposition analysis for Germany is given in Figure 18. Over the studied period, total greenhouse gas emissions have decreased by 10% overall. Population growth has played only a minor role in the development of greenhouse gas emissions. GDP growth has contributed about 27% to dissaving of greenhouse gas emissions. Structural changes in the economy have not had a significant effect on the development of GHG emissions. The effect is very small, but positive, implying that there has been a slight shift in sectoral shares to more carbon-intensive sectors. This does not capture potential intra-sectoral shifts. The lack of significant changes due to sectoral shifts may be in part explained by the developments that already took place before the studied period (starting in 2009). At the turn of the century, major shifts in the economy towards a more service-based economy had already taken place (Schettkat & Yocarini, 2003). As such, developments have slowed down in more recent years.

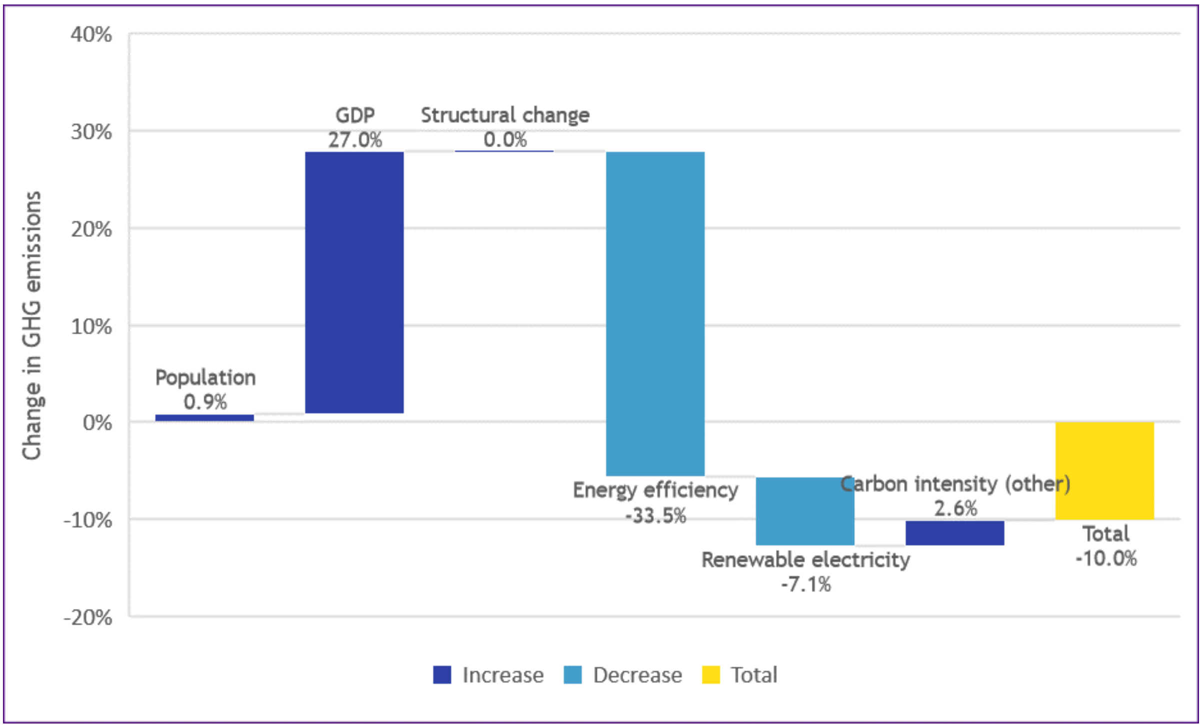


*Figure 18 – Decomposition analysis Germany 2009-2018: GHG emissions*

Developments within the climate policy domain show a net savings due to improvements in energy efficiency and the deployment of renewable energy. These developments are partly offset by a small dissaving due to carbon intensity outside the realm of renewable electricity production.

Although surprising, this effect may be explained by phasing out of nuclear power. Over the period between 2002, starting with the Amendment of the Atomic Energy Act, to 2023, with the shutdown of the last three nuclear power plants, the share of nuclear power in German energy consumption has steadily decreased (Bundesamt für die Sicherheit der nuklearen Entsorgung, 2023). Although scrutinised for i.a. the dangers involved in nuclear power generation, nuclear power has a high energy density and produces zero emissions in the use phase (GHG emissions for nuclear energy are scope 3). As such, the phasing out of nuclear power leads to a replacement by alternative fuels with potentially higher emission factors. German energy policy is marked by a transition from nuclear power to renewable electricity production. Nonetheless, the share of fuels in energy consumption such as natural gas has increased slightly, as given by Eurostat statistics.

Overall, the contribution of energy efficiency and carbon savings to total GHG savings is substantial, leading to a general decrease in GHG emissions over the studied period. We can conclude that the developments within the climate policy domain are in line with policy objectives. Especially the move to renewable sources for electricity production is remarkable in the case of Germany, together with the overall improvements in energy efficiency.

## Netherlands

The results of the decomposition analysis on the Netherlands is shown in Figure 19. Overall, emissions have decreased by a net 6.8% over the studied period. Both population growth and GDP growth offset GHG savings by 4 and 14.7% respectively.

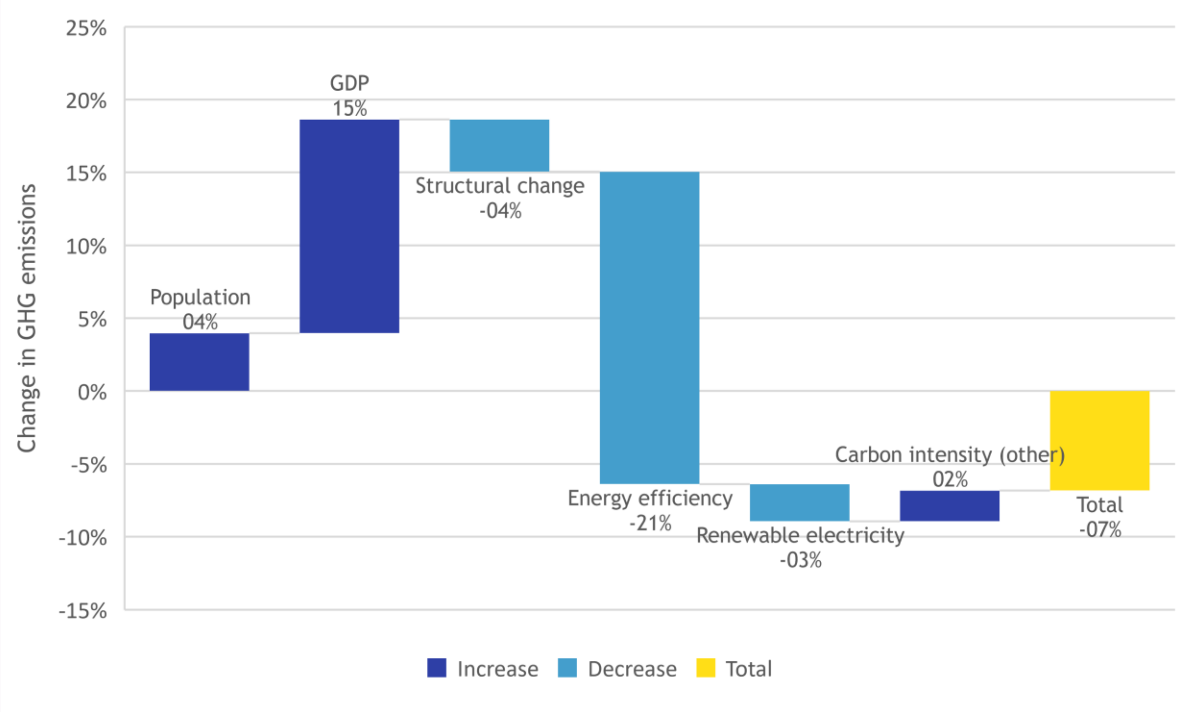


*Figure 19 – Decomposition analysis Netherlands 2009-2018: GHG emissions*

Changes in the share of economic activity have led to a decrease in emissions of 3.6%. This implies that there has been a movement from activity with higher energy intensity to activity with a lower energy intensity. Over this period, the share of the service sectors in total GDP has increased, leading to the observed GHG savings in the decomposition analysis. As emphasised before, the high level of sector aggregation only gives a limited view of structural changes and their interaction with ultimate greenhouse gas emissions. Intra-sectoral shifts that have occurred are not captured by this analysis.

The largest chunk of GHG emission savings has been established by improvements in energy efficiency. This factor accounts for a reduction of 21.4% in greenhouse gas emissions. Similar to the results in the EU27 overall, a significant reduction is established when also taking into account autonomous energy savings. Relatively much attention has been paid to energy savings policies in the Netherlands, with an Energy Saving Obligation (an obligation to invest in measures for which the investment is returned in 5 years or less), energy taxes, and subsidies for energy saving investments. (ODYSSEE-MURE, 2023)

Carbon intensity improvements only account for less than net 1% in GHG emission savings. A savings of -2.5% in GHG emissions has been established due to the deployment of more renewable energy. In the Netherlands, a substantial amount of government funds have been spent on subsidies towards upscaling the use of renewable energy, up to € 6 billion per year (RVO, 2012). This effect is offset by an increase in emissions due to an increase in carbon intensity in other areas of energy use. A potential explanation is the expansion of electricity produced from coal. Since 2007, it has been cheaper to produce electricity from coal than from gas. Capacity for coal-based energy was increased. This may have slowed the improvements in carbon intensity for fossil fuels (CBS, 2020). Overall, carbon intensity in the service sector has improved quite a bit (about 5%), but carbon intensity of energy use in the industrial sectors have remained practically the same.

## Poland

Figure 20 shows the results of the decomposition analysis for Poland over the period 2009-2018. Poland shows a small increase in GHG emissions of 1.2% over the studied period. Contrary to other Member States included in this report, population has slightly shrunk in Poland, leading to a net reducing effect of population on GHG emissions. Nonetheless, the Polish economy has grown much faster than average in the EU over this same period, given an increase of 36.3% in emissions due to GDP growth. This is almost twice as high as the EU average. This effect is due to the accelerated growth of the Polish economy over the past two decades (EC, 2015b). In terms of structural change, the effect of shifting sector composition is negligible with a slight contribution of 0.2% to GHG emissions.

In terms of climate policy-related factors, Poland shows a large increase in energy efficiency, resulting in a 30.7% reduction in GHG emissions due to energy savings. This is higher than the EU average. Carbon intensity savings are smaller, but also contribute positively to GHG emission savings. Due to an increased deployment of renewable resources in electricity production, emissions decreased by an estimated 2.9%. Moreover, a general move away from fossil resources can be inferred from the savings in other carbon intensity of 1.4%. A possible explanation is the reduction in the use of coal for electricity generation. The share of coal in total energy use has declined over the studied period, being replaced by fuels with lower carbon intensity.

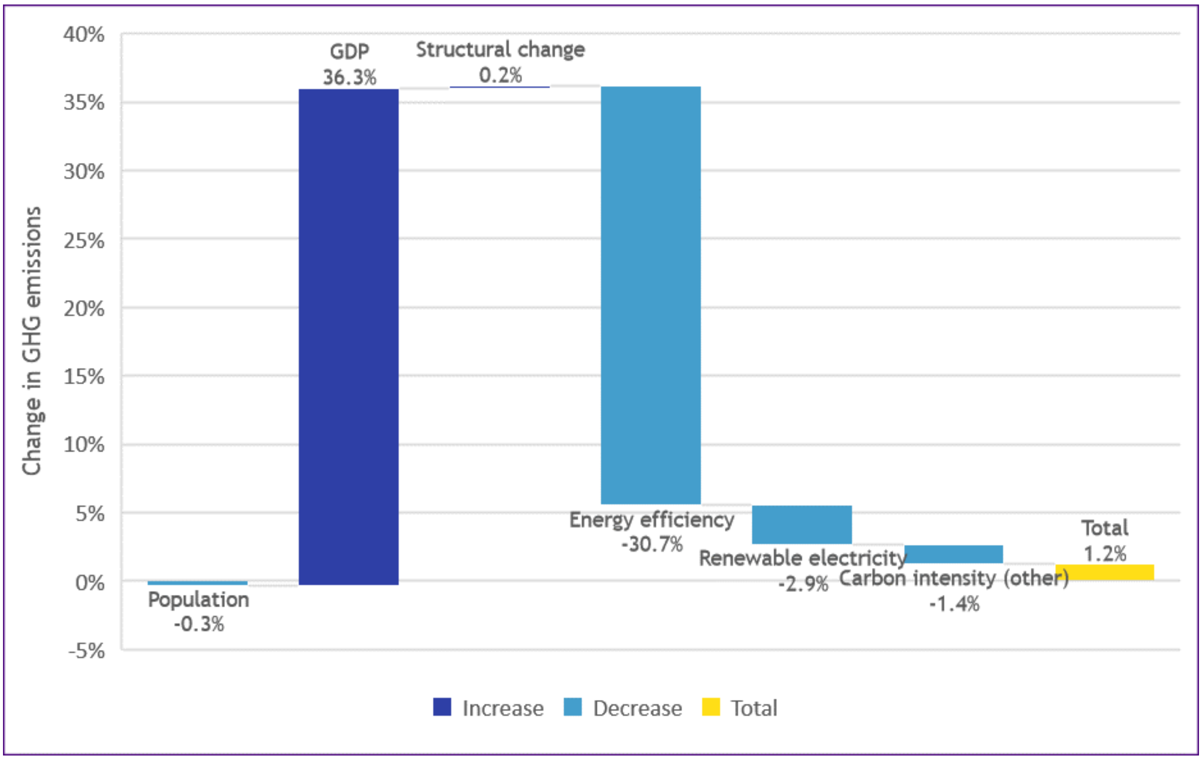


*Figure 20 – Decomposition analysis Poland 2009-2018: GHG emissions*

## Spain

Decomposition results for Spain are given in Figure 21. Total greenhouse gas emissions have reduced by 13.3% over the given period. Overall, the factors leading to an increase in GHG emissions represent a lower share than the EU average. Population growth, GDP growth and structural change lead to a 1.2%, 6.6% and 0.4% increase in emissions respectively. The pattern is similar to that of the average in the EU, although emissions due to GDP growth are smaller than average.

Energy efficiency improvements have led to a 12.3% reduction in GHG emissions. This is lower than the EU average, but still exceeds estimated autonomous improvements of 0.5% to 1% per year over the nine year period. Moreover, there is a positive contribution of the increase in the use of renewables in electricity production to emission reduction of 3.2%. Other savings due to improvements in carbon intensity amount to another 6% in emission reduction. These developments are very close the EU average. Overall, the results indicate developments in line with the objectives of EU climate policy.

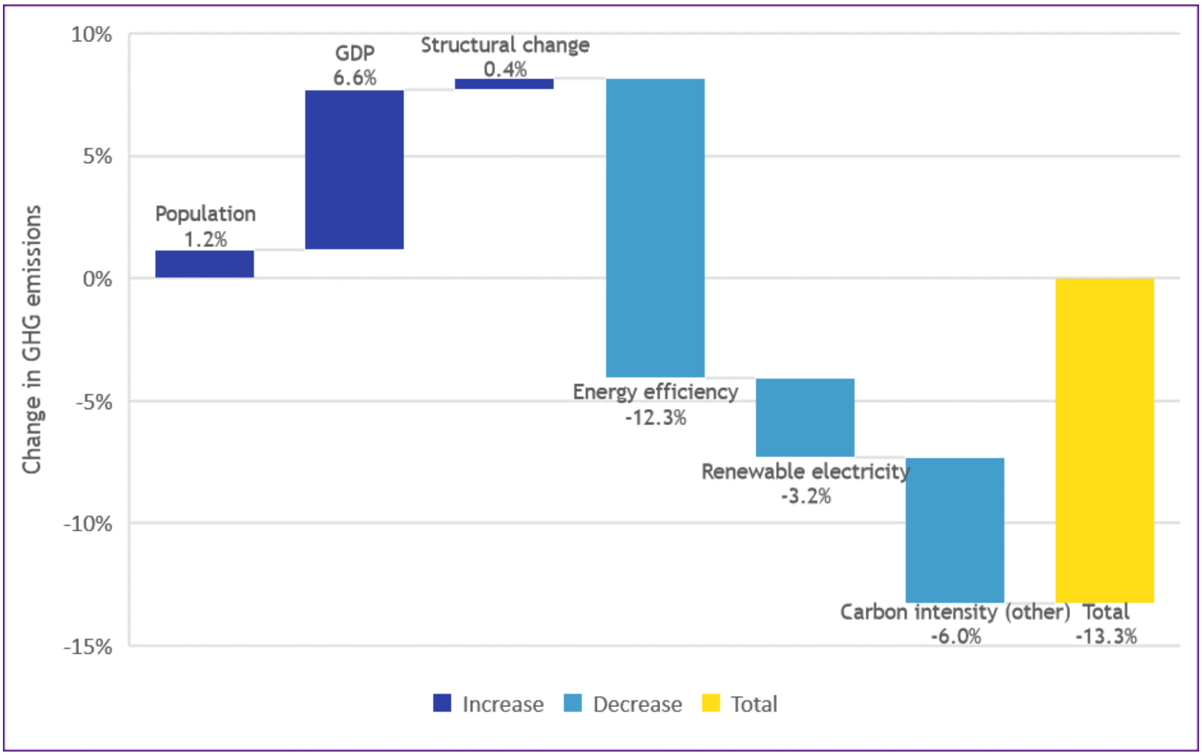


*Figure 21 – Decomposition analysis Spain 2009-2018: GHG emissions*

# Annex 6: Data sources monitoring framework

| Cat.* | Indicator | Data source | Level | Complete? ** |
|---|---|---|---|---|
| GHG | GHG gas emissions | Eurostat (ENV_AC_AINAH_R2) | EU/MS | Yes |
| GHG | % Change in consumption based emissions | Our World in Data (Global Carbon Project) | EU/MS | Yes |
| ESD | $CO_2$ emissions in non-ETS sectors (in relation to ESD) | Eurostat (ENV_AIR_ESD) | EU/MS | Yes |
| ETS | Cap on $CO_2$ emissions in ETS sectors | EC (ETS Directive) | EU | Yes |
| ETS | $CO_2$ emissions in ETS sectors | EEA (EU ETS data) | EU/MS | Yes |
| ETS | ETS price | EEA (Emissions, allowances, surplus and prices in the EU ETS, 2005-2020) | EU | Yes |
| RED | % energy from renewable sources (total) | Eurostat (SDG_07_40) | EU/MS | Yes |
| RED | % energy from wind power, solar PV, solar thermal, primary solid biofuels, hydro power, biogas and other renewable sources | Eurostat(NRG_IND_URED) | EU/MS | Yes |
| RED | % share of renewable energy in gross final consumption in transport | *No data* | | |
| RED | National renewable energy plan | *No data* | | |
| RED | GHG savings for biofuels | *No data* | | |
| EED | Final energy consumption (in Mtoe) | Eurostat (NRG_IND_EFF) | EU/MS | Yes |
| EED | Primary energy consumption (in Mtoe) | Eurostat (NRG_IND_EFF) | EU/MS | Yes |
| EED | % government owned and occupied buildings meeting minimum energy performance requirements | *No data* | | |
| EED | Total floor area of government buildings (owned and/or occupied) meeting minimum energy performance requirements | *No data* | | |
| EED | Total government spending on improving (central) governmental buildings | *No data* | | |

| Cat.* | Indicator | Data source | Level | Complete? ** |
|---|---|---|---|---|
| EED | % of spending on energy-efficient products | *No data* | | |
| EED | Total government spending on energy-efficient products | *No data* | | |
| EED | Obligation scheme implemented | *No data* | | |
| EED | Energy savings by energy distributors and retail energy sales companies | *No data* | | |
| EED | Estimated energy savings through national policies | *No data* | | |
| AFID | # of public recharging points | EC (EAFO – Transport mode road) | EU/MS | No |
| AFID | # of electric passenger cars | Eurostat (road_eqs_carpda) | EU/MS | No |
| AFID | % Market Share of Electric Passenger Cars | Eurostat (road_eqs_carpda) | EU/MS | Not complete on MS level |
| AFID | Electrical recharging point density (per $km^2$) | IEA (Global EV Outlook) | EU/MS | Not complete on MS level |
| AFID | # of public CNG refuel points | EC (EAFO – Transport mode road) | EU/MS | Yes |
| AFID | CNG refuel point density (per km2) | EC (EAFO – Transport mode road) | EU/MS | Yes |
| AFID | # of CNG passenger cars | EC (EAFO – Transport mode road) | EU/MS | Yes |
| AFID | % market share of CNG passenger cars | EC (EAFO – Transport mode road) | EU/MS | Yes |
| FQD | % reduction of life cycle GHG emissions by fuel suppliers | *No data* | | |
| EPBD | Average energy label houses and buildings | EC (EU Building Stock Observatory) | EU/MS | No (both EU, MS and over time) |
| EPBD | % of new buildings ‘nearly’ zero-energy | *No data* | | |
| EPBD | % of new buildings 'nearly' zero-energy (public authorities) | *No data* | | |
| EPBD | Energy consumption by households | Eurostat (TEN0012) | EU/MS | Yes |
| CCSD | Number of CCS projects | *No data* | | |
| CCSD | Storing capacity (in Mton) | *No data* | | |

| Cat.* | Indicator | Data source | Level | Complete? ** |
|---|---|---|---|---|
| CCSD | $CO_2$ stored (in Mton) | *No data* | | |
| EDD | Number of Eco-innovation related patents | EC (Environment – Green Business – Eco-Innovation) | EU/MS | No |
| EDD | Number of Eco-innovation related academic publications | EC (Environment – Green Business – Eco-Innovation) | EU/MS | No |
| EDD | Number of ISO 14001 registered organisations | ISO (ISO Survey 2021) | EU/MS | No |
| EDD | Employment in eco-industries | Eurostat (env_ac_egss1) | EU/MS | No |
| EDD | R&D employment | Eurostat (rd_p_perslf) | EU/MS | No |
| EDD | Innovation expenditures (including design, software, marketing) | Eurostat (tsc00001) | EU/MS | No |
| EDD | Eco-innovation index | Data.Europa.EU (Eco-innovation inde) | EU/MS | No |
| TEN-E | # of PCI's (natural gas) | EC (Infrastructure – Projects of Common Interest) | EU | Yes |
| TEN-E | # of PCI's (electricity) | EC (Infrastructure – Projects of Common Interest) | EU | Yes |
| TEN-E | Investment in TEN-E infrastructure (/funding by CEF-E) | EC (Infrastructure – Projects of Common Interest) | EU | Yes |
| TEN-E | # km extra linking infrastructure (gas) | *No data* | | |
| TEN-E | # km extra linking infrastructure (electricity) | *No data* | | |
| TEN-E | # km smart grids | *No data* | | |
| TEN-E | # km electric highways | *No data* | | |
| TEN-E | # km cross-border $CO_2$ networks | *No data* | | |
| TEN-E | % linked energy networks | *No data* | | |
| TEN-T | # km additional railways | Eurostat (rail_if_tracks) | EU/MS | No |
| TEN-T | Amount invested in railways | OECD (Transport infrastructure investment and maintenance) | EU/MS | No, not complete on MS level |
| TEN-T | Passengers transported by train in million passengers kilometres. | Eurostat (RAIL_PA_TOTAL) | EU/MS | No, not complete on MS level |

| Cat.* | Indicator | Data source | Level | Complete? ** |
|---|---|---|---|---|
| TEN-T | Cycling lanes or roads (in km) | Eurostat (URB_LTRAN__custom_6076400) | EU/MS | No, not complete (most data on city level) |
| TEN-T | Investment in bike lanes and foot pathways (in €) | EC (In profile: EU support to footpaths and cyclepaths) | EU/MS | Yes |
| ECT | Electricity import capacity as % of installed capacity | Eurostat (nrg_bal_peh; nrg_ti_eh) | EU/MS | Yes |

* Category (Cat.) refer to policy directive. GHG: Greenhouse gas emissions target; EDD: Ecodesign Directive; CCSD: CCS Directive; ECT: Electricity Connection Target.

** This column gives an indication of the completeness of the given dataset. 'No' means that there are either some years or MS for which no data is available.

## About the project

4i-TRACTION – innovation, investment, infrastructure and sector integration:
TRAnsformative policies for a ClimaTe-neutral European UnION

To achieve climate neutrality by 2050, EU policy will have to be reoriented – from incremental towards structural change. As expressed in the European Green Deal, the challenge is to initiate the necessary transformation to climate neutrality in the coming years, while enhancing competitiveness, productivity, employment.

To mobilise the creative, financial and political resources, the EU also needs a governance framework that facilitates cross-sectoral policy integration and that allows citizens, public and private stakeholders to participate in the process and to own the results. The 4i-TRACTION project analyses how this can be done.

## Project partners

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