Master of Sustainable Development – Energy and Materials

Utrecht University

Unravelling and quantifying the Greenhouse gases reduction in the EU non-ETS sectors in the period 2005-2020.

An in-depth analysis focused on the impacts of recession and policy implementation on three EU Member states.

Master's Thesis - GEO4-2321

Student name: Giorgio Ponte

Student number: 5919223

Student email: g.ponte@students.uu.nl

Supervisor: Dr. Robert Harmsen

Table of Contents

1 Summary of thesis

The Climate and Energy package from the European Union (EU) contains a series of measures aiming at reaching a low carbon society with the goal of fighting climate change. One of the main measures included in the package is the Effort Sharing Decision (ESD). The ESD aims at reducing Greenhouse Gas (GHG) emissions in five different sectors: transport, residential, services, agriculture and a portion of industry which does not fall into the Emission Trading Scheme (ETS). The Decision targets the reduction of both CO_2 GHG as well as non- CO_2 GHGs. The ESD was implemented in 2009 and targeted an average 10% reduction of the emissions in 2020 compared to 2005 levels. The Decision has been then extended through the Effort Sharing Regulation (ESR) for the years 2021-2030 and set a target 30% reduction in 2030 compared to 2005. The research analyses the development of emissions in all ESD sectors in three different European member states: Italy, Germany and the Netherlands. The aim of the research is to unravel and quantify the different effects related to the changes in the emission trends to display the different changes which occurred in the CO_2 historical emissions and its projections in the period 2005-2020. By using data provided by the PRIMES (Price Induced Market Equilibrium System) 2016 scenario by Capros et al. (2016), the researcher identifies and quantifies the effects which caused a variation in the emission trends throughout the period 2005-2020. More in depth, the research follows a three-step-pathway. Firstly, an analysis of the ESD CO_2 emissions is provided and the potential effects affecting the trends are identified. Secondly, through decomposition analysis, the potential effects are quantified. Lastly, through policy analysis, the research analyses and correlates policies which might have had an influence in the CO_2 variations in the ESD sectors.

	2005-2020		
	Italy	**Germany**	**Netherlands**
Volume effect ($Mt\ CO_2$)	8	31	7
Structure effect ($Mt\ CO_2$)	-0.2	-3	-2
Intensity effect ($Mt\ CO_2$)	-25	-52	-8
Fuel mix effect ($Mt\ CO_2$)	-22	-26	-3

Table 1, summary of results from decomposition analysis of all the ESD sectors.

The results show that, depending on the sector, there are different effects correlated with the variations in emissions. The effects can be summarized in volume (indirect effect), structural effects, efficiency effects and CO_2 intensity effects. With the decomposition analysis of emissions in each different subsector, the researcher identified the magnitude of the different direct and indirect effects that have been affecting the sectors throughout the study period. More in depth, results from decomposition analysis show that the effects differed in magnitude in each MS (Table 1) and that certain effects were more dominant than other depending on the sector. Results from the policy analysis show, that the majority of policies implemented in the ESD sectors target the efficiency of the subsectors and its linked CO_2 intensity, suggesting that a diversification of policy types might be beneficial in further CO_2 reduction.

This thesis provides a clear view of the different factors involved in the emissions variations and can be used as a guideline for future policy design. Furthermore, the research covers the knowledge gap found in literature, since it can be considered one of the first in-depth study on the ESD measure and the progress that MS have made towards the achievement of this target regarding its CO_2 emissions. However, the scope of the research is limited since it analyses CO_2 emissions only, therefore further research on non-CO_2 GHG emission in the ESD and on policies implemented is encouraged.

To conclude, this study provides a valuable overview of the current development of the CO_2 emissions in the sector and can be used as a guideline for the development of policies in the ESD sectors to achieve the 2030 target set by the ESR.

2 Introduction

2.1 Context

Fighting climate change and reducing human impact on the environment is one of the biggest challenges faced nowadays. The effects of increasing CO_2 concentration in the atmosphere are becoming increasingly visible in the recent years, with several consequences ranging from the decreasing artic ice cap cover to the rise in sea level and temperatures. Tackling climate change includes fundamental steps such as reducing GHG emissions and constructing a sustainable energy system. The EU has taken a worldwide leadership in this carbon neutral and sustainable energy transition (EC, 2011).

In 2009, The European Commission (EC) adopted the Climate and Energy package which included a series of mid-term binding targets for 2020 in order to achieve the 2050 end vision. The regulation assessed in this thesis, the ESD (Decision 406/2009/EC) falls under this package. The ESD became official in 2009. The Decree targets a reduction on the EU GHG which do not fall under the Emission Trading Scheme (ETS) sector. The targeted reduction has been quantified as 10% less in 2020 than the 2005 levels (EC, 2008) and as 30% less in 2030 compared to 2005 level. At a national level, the ESD targets range from a GHG reduction of 20% in the countries with the higher GDP/capita to a maximum allowed increase of 20% of the least developed European countries (EC,2008). The ESD also sets annual sub targets for the period 2013-2020 to monitor the progress of the countries towards their target. To provide adequate information and transparency, each Member State (MS) should provide data on their yearly emissions which should not exceed the 'Annual Emission Allocation'.

The non-ETS sector is responsible for more than 60% of the total GHG emissions, however it can be argued that the Decision has not been subject of research for academics compared to ETS. As a comparative index, when searching for the words 'Europe Effort Sharing Decision', 'EU ESD' 'Effort Sharing' and 'Europe Emission Trading Scheme', 'Emission Trading', 'EU ETS' on Scopus, the search engine gives 36 results for ESD and 434 for ETS unravelling the gap in research between the two EU regulations.

The Decision covers all six GHG included in the Kyoto protocol: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs). The sectors included in the ESD are the majority of the sectors which do not fall under the EU ETS such as: Transport (excluding aviation and international maritime shipping, buildings, Agriculture, small industrial installations, Waste (Capros et al., 2011). According to the EC (2009), the GDP/capita approach expresses two main advantages. It ensures that the efforts are fairly distributed among countries according to their wealth and, at the same time, it allows less developed countries to have less constraints from the emission reduction target and to have further room for development.

Lastly, differently from the ETS scheme, which follows EU-wide regulations, it is the responsibility of each of the member states to design policies which will lead to the reduction of non-ETS emissions. The EC calls for responsibility of each member state to implement policies which will limit the CO_2 emissions from the sector covered in the ESD (EC, 2009).

2.2 Problem definition & knowledge gap

Analysis by Harmsen et al. (2011) criticized the method applied in the ESD as it showed that it resulted in some imbalances. More in depth, their research showed a flaw in the GDP/Capita method since it showed to favour countries with higher shares of non-CO_2 GHG as Harmsen et al. (2011) demonstrated that non-CO_2 GHG are not directly linked with the magnitude of GDP per capita. In other words, the study argued that the increase in non-CO_2 emissions is not coupled with GDP growth. Harmsen et al. (2011) argued that this flaw in the ESD could cause an imbalance in the effort needed to achieve the target. The then projected emissions from the GAINS and PRIMES scenarios showed that some MS would have easily reached the target, while other countries would have had more difficulties and required extra policy implementations to reach the target (Fig 1). Other researchers, such as Longo (2013) and Anagnostopoulos (2013) investigated the distance of MS to the ESD target and referred to the flaw first identified by Harmsen et al. (2011).

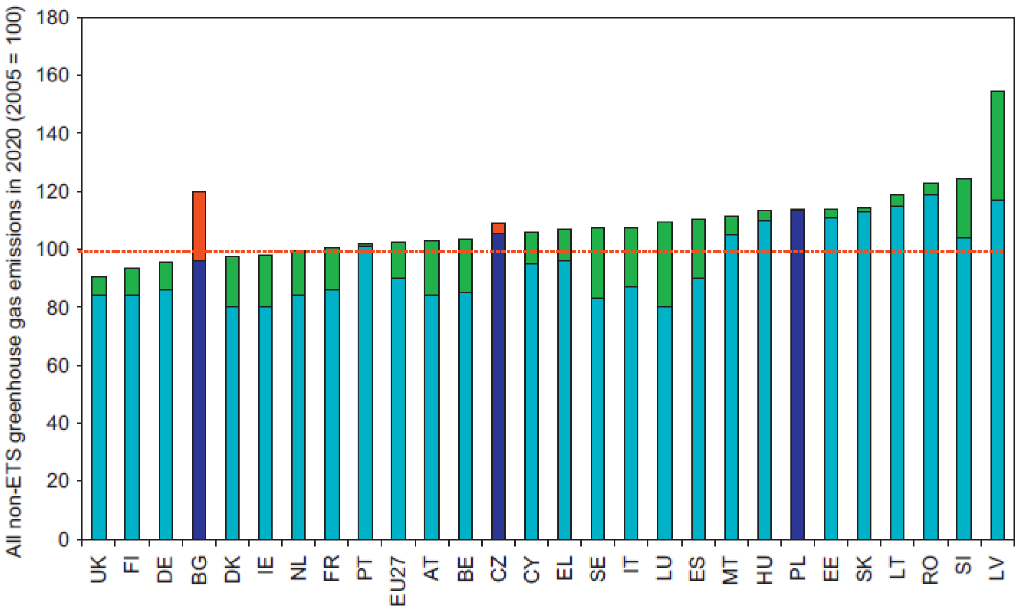

Figure 1, effort needed for each MS to reach their national ESD target. The light blue bar shows the national target, while the green bar shows the distance to the target. The dark blue and red bars show the national target for BG, PL and CZ. The red bar represents the overshoot in the target for CZ and BG, meaning that the countries will achieve the target already in the baseline projections. (Source Harmsen et al. 2011).

However, in 2016 all but three MS (Ireland, Malta and Germany) exhibited emissions that were below their 2016 target (Fig. 2). The overall scenario seems completely different from the established targets in 2005. Based on the projections by Harmsen et al (2011), the expected status of different MS changed from the 2011 projections. For example, the Netherlands is projected to overachieve its target while compared to the analysis done by Harmsen et al (2011) (Figure 1), The Netherlands was projected to have difficulties in achieving the ESD target. As shown in Figure 2 below, there are countries which are already far below their cap target set for the target year and only a few countries which will eventually require extra measures to achieve their midterm 2020 target.

The difference between the past projections and the current emission data, leads to different questions regarding whether the EU MS have been implementing effective measures tackling emissions in the ESD, or whether other indirect factors (e.g. the 2008-2012 economic recession) have influenced the ESD sectors to a point that the projected emissions have drastically changed.

Figure 2, ESD emissions and emission cap for the year 2015 and 2016 (Source EC 2016). It can be noticed that most of the MS, present emissions which are far lower the limit established for 2016.

The identified problem for this research lies in the difference between the projected emissions from 2007, 2009 and the current scenario. According to the 2016 evaluation of the ESD, the EU is on track with its target and is expected to overachieve the 2020 target. The EC underlines that the ESD has incentivized MS to become more active in reducing the emissions in their sectors. Furthermore, the Commission recognizes the effect that the economic recession has had on the emission reduction but argues that many of the sectors within the ESD emit non-CO_2 GHG and therefore their reduction cannot be directly linked with the recession (EC, 2016). Estimates on GHG emissions development, especially in the long term always contain a high degree of uncertainty since there are many direct and indirect factors which can affect volume and influence emissions (Hast et al., 2013).

However, seeing that most of the countries are overachieving their targets, the question that arises is why the settled target for 2020 is being achieved with ease by most of the EU MS, while previous projections indicated that the countries would encounter difficulties in achieving it.

The interest of this thesis is on the effectiveness of ESD and on the impact policies implemented that direct (e.g. policies implemented) and indirect factors (e.g. economic recession) have had on it. It is still unclear to what extent factors such as recession, policies and other possible elements explain and contributed to the progress of MS in meeting their effort sharing target.

2.3 Research objective & research questions

In line with the problem definition, this research aims at analysing the effectiveness of the ESD, seeing the unpredicted outcome of the recent years. The proposed research question aims to develop useful insights on the factors which mostly influenced the unexpected overachievement in the non-ETS emissions reductions.

The aim of the research is to use quantitative analysis of ESD CO_2 emission data and qualitative analysis of policies targeting ESD to unravel the disbalances in the ESD which have brought to this scenario change. The research question, which will be answered in this thesis, will then be:

To what extent can the ESD be considered a successful policy framework which contributed to a reduction of the non-ETS CO_2 emissions? What are the main explanatory factors for EU member states regarding the progress they make in meeting their effort sharing target?

Although the ESD covers six GHG, the scope of the research is limited to analysing CO_2 variations only. By taking an analytical approach based on qualitative policy analysis and a quantitative approach on the effect of recession and policy implementation in all the ESD sectors of three different MS. The proposed countries for this analysis are the following: Italy, Netherlands and Germany.

The reason behind the choice of these countries lies behind the different background that each MS has. On the one hand, Italy has been highly influenced by the recession and it is one of the countries which is mostly overachieving the target (Fig.2), however according to Figure 1 from

Harmsen et al (2011), Italy was projected to face a larger distance to the target. The Netherlands, according to the GAINS and PRIMES 2007 scenarios (Harmsen et al., 2011, Fig. 1 & 3) seemed like one of the countries which would have had a hard time achieving the ESD target, however, according to the data from 2015 and 2016 it seems like they are also perfectly in line with the target requirements. On the other hand, Germany was, in 2011, projected as one of the few countries that would have achieved the 2020 ESD target. However, according to the recent emission data (Fig. 2), it seems that it might be one of the countries which may not achieve the target.

The research question will be addressed through a quantitative analysis measuring the different effects influencing the emissions variations and a qualitative part which will connect the recent implemented measures (both on a MS and EU level) with the effects found through the quantitative analysis.

Finally, the researcher will provide insights and recommendations for the 2030 target. An analysis of the dominant effects in the decomposition analysis, as well as of the most impactful policies could be considered as helpful material when designing the policy framework for 2030.

3 Concepts and definitions

The purpose of this chapter is giving a brief explanation of the legislative background behind the ESD and the mechanism used to monitor its progress. Furthermore, the second part of the chapter provides a more exhaustive overview of the analytical methods used to quantify the emission changes which occurred during the analysed period.

3.1 Legislative background

Regarding the legislative background, there are two main legislations which are highly interconnected: The ESD and the Monitoring Mechanism Decision. The ESD can be considered as the core policy for this research as it sets the targets for the member states that will be assessed. The monitoring mechanism has been adopted as a tool to measure the yearly progress of the MS.

3.1.1 The Effort Sharing Decision*:*

The EC Directive N. 406/2009 is the agreement which includes the largest share of emissions within the EC climate and Energy package. This legislation is complementary to the European Emission Trading Scheme and it regulates all the emissions outside the ETS sector. These sectors, known as non-ETS, are non-ETS industry, agriculture, transport (excluding aviation and maritime transport). The Directive is binding and sets an intermediate target of a 10% reduction by 2020 compared to 2005. In 2016, the EC proposed a new target aiming at a 30% reduction in 2030 (compared to 2005) through the implementation of the ESR. As previously mentioned, the obligatory reductions range from a decrease of 20% to an increase of 20% depending on the GDP per capita of each country. One of the binding points of the Directive states that countries cannot exceed the annual emission allocation within the period 2013-2020, which will be monitored through the Monitoring Mechanism Decision.

By emission allocations it is meant the maximum amount of emissions which are allowed every year within the 2013-2020 period. Every member state can design and implement customized policies on a national level to remain within the emission boundaries. Furthermore, some flexibility has been introduced in the Directive. More in depth, countries can contribute to the target by supporting emission reduction projects in developing countries. Other flexibility mechanisms include the possibility for the MS to allocate some of the previous year's emissions, in case the emissions have been lower than the target for that year, to the year after. MS can allocate a maximum of 5% of the exceeding or residual emissions.

3.1.2 The Monitoring Mechanism Decision (EC 280/2004):

The Monitoring Mechanism Decision (MMD), can be considered as a complementary policy to measure the progress by each of the countries. The Decision regulates and monitors the yearly GHG emissions of every MS. Countries are obligated to provide a yearly report which includes emissions from each sector (article 3 of 280/2004/EC). Furthermore, the MS need to provide a set of information every two years.

The information needed in the biennial report are legislation provisions addressing emission reduction. The member states should provide the EC with legal provisions addressing the GHG emissions. Projections on the emissions by sources and removals including the measures implemented to tackle the reduction. These projections must be provided every five years until 2020 with special attention towards the policies and measures applied in the scenario development.

3.2 Historical trends & projections

For the development of the historical trends and projections the research used the EU energy Models known as PRIMES. PRIMES is one of the main models adopted by the EU. This model provides accurate values of the entire energy system for each European country. The values include projections for different parameters ranging from the general energy demand and emission to a breakdown of the values of these parameters per sector (Capros et al., 2009). The model designs long term energy projections up to the year 2050, focusing on the energy and emission prices, using demand and supply simultaneously to keep a balance in the market. PRIMES 2016 model used in the research. contains detailed information regarding historical data and projections up to 2050 in the ESD subsectors. The model is based on Eurostat data and it presents both projections and historical data in five years steps.

3.3 Decomposition analysis:

The method for the quantitative analysis was based on decomposition analysis. Decomposition analysis is a fundamental tool in energy and emission analysis and, since its creation, it has been widely used in energy related studies (Ang et al., 2004). It can be generally defined as the disaggregation of a value representing, in this case, the total emissions of a sector. Decomposition analysis allows the researcher to quantitatively allocate different emission to its correspondent sources. It mainly focuses on the decomposition of the total amount of energy used or on emissions (such as in this research) and assigns a specific weight to the pre-defined factors.

The method can provide clear insights on the history and on the projections of emissions. The researchers can obtain a disaggregation of the emission value per year and can therefore monitor how the different sources of emissions have changed through the period of study. Ang et al (2004), presents different methods for decomposition analysis. The reason why decomposition analysis was chosen is it allows for precise quantification of the magnitude of the effects observed during the trend analysis. Furthermore, by using decomposition analysis the researcher can allocate emissions to different effects and obtain more insights on the influence of a specific effect in the ESD sectors.

The most indicated method for a multi-factor decomposition, is the Logarithmic mean Divisia method (LMD). The LMD method allows a perfect decomposition where no residues are created (Ang, 2004). Ang (2004) and Ang (2005) argue that it should be the preferred method because of its adaptability, for its user friendliness and the for its easy interpretation of the results. The general LMD allows the disaggregation of the CO_2 emissions, in this case, into different effects (Ang, 2005). The general identity used in the decomposition analysis formula for the different effects can be represented as follows:

$$\Delta CO_2 = V\ x \frac{A}{V}\ x \frac{E}{A}\ x \frac{CO_2}{E}$$

Equation 1, General identity used in decomposition analysis.

Where V represents the volume effect, A/V is the structure effect, i.e. sectorial volume over total volume, E/A the intensity effect and CO_2 /E represents the variation in the energy mix through the years, also known as CO_2 intensity effect. The different effects are calculated with the following formulas, using the raw data obtained from statistics or models, in this case PRIMES 2016.

$$Volume\ effect\ =\ LM\ x\ ln(V_t/V_0)$$

Equation 2, Formula used for Volume effect calculation.

Where LM represents the Logarithmic Mean of CO_{2t} and CO_{20} expressed by the formula:

$$LM = (CO_{2t} - CO_{20})/(ln(CO_{2t}\ /CO_{20})\ )$$

Equation 3, General logarithmic Mean formula for CO_2.

while V_t and V_0 indicated the volume in the target and base year. The structure effect was calculated using the following formula:

$$Structure\ effect =\ \ LM\ x \ln\ (\frac{A_t}{V_t})/(\frac{A_0}{V_0})$$

Equation 4, structure effect formula.

Where A_t and A_0 indicate the sectorial volume in the base and the target year. The intensity effect was calculated as follows:

$$Intensity\ effect\ =\ \ LM\ x\ \ln\ (\frac{E_t}{A_t})/(\frac{E_0}{A_0})$$

Equation 5, intensity effect formula.

Where E_t and E_0 indicate the energy intensity in the base and target year. Finally, the fuel mix effect was calculated as follows:

$$\text{Fuel mix effect}\ = \text{LM x}\ ln\ (\frac{\text{CO}_{2t}}{\text{E}_t} / \frac{\text{CO}_{20}}{\text{E}_0})$$

Equation 6, Fuel mix effect formula.

4 Methods

The methods for this research followed an approach based on a qualitative and a quantitative analysis. The research followed two distinct pathways for the decomposition analysis and for its correlation with the policy implemented in the analysed MS during the period of study. The historical data and the projections of the different indicators (including CO_2 emissions) were gathered from the EU PRIMES 2016 scenario. The year 2005 (base year for the research) of the 2016 PRIMES scenario was compared to the year 2020 (target year).

4.1 Quantitative analysis: Quantifying the effect of the recession and policies on the non-ETS sectors.

The quantitative analysis can help the researcher to have a better overview of the direct (i.e. effect of policies implementation) and the indirect (i.e. recession effect) effects on the sectors falling into the ESD. The analysis aims at providing insights in the development of the ETS emissions during the period 2005-2020. The method for the quantitative part of the research followed the following steps:

4.1.1 Trend analysis

Before performing the decomposition analysis of the different sectors for each MS, the historical trends and the projections up to 2020 for the ESD sectors in the MS subject of this research were displayed. The methods for this section was performed in the following way:

Firstly, the emissions from the ESD sectors (Passenger Transport, Freight Transport, Agriculture, Residential, Services, non-ETS industry) for the periods 2005-2010, 2010-2015 and 2015-2020 were gathered from the PRIMES 2016 scenario. Once all the information was available, the historical and projected emissions, together with the respective volume indicators, e.g. Passenger Kilometer (PKM) or Sector Value Added (SVA), were graphed for each one of the sectors in the three MS. From the visual representation of these emission trends, and the division of the entire period of study into three subperiods, the researcher could identify how the emissions have varied through the years. In order to develop the CO_2 emission variation trends in the different sectors, it was necessary to gather different indicators which served for the preliminary country analysis and the data trend analysis.

Sector	Volume indicator
Passenger Transport ***Public road transport*** ***Private cars and motorcycles*** ***Rail*** ***Inland navigation***	pkm
Freight Transport ***Trucks*** ***Rail*** ***Inland navigation***	tkm
Agriculture	SVA (€)
Services	SVA (€)
Non ETS Industry ***Food, drink and tobacco*** ***Engineering*** ***Textiles*** ***Other***	SVA (€)
Residential	Population

Table 2, Data gathered from PRIMES 2016 for the MS analysis.

Table 2 above shows the different indicators which have been used in the country analysis. The development of the different indicators (SVA, pkm etc), together with the CO_2 trends for the period 2005-2020, allowed the researcher to get an insightful overview of the MS development throughout the study period.

4.1.2 Data analysis through decomposition analysis

Initially, the graphs for the preliminary country emissions analysis were used to identify large variations in the emissions within five years subperiods (i.e. emissions in the Italian Passenger transport sector for 2010-2015). Next, it was decided to complete a decomposition analysis, using the LMD method, for all the ESD sectors for the whole period of study (2005-2020) as well as for the three subperiods (2005-2010, 2010-2015, 2015-2020). All the data for the decomposition analysis was gathered from PRIMES 2016, using 2005 as a base year and 2020 for the target year.

The formula for the decomposition analysis was kept the same for all the sectors studied, however, what changes is the different indicators used for volume/ structure and intensity. The research identified four different effects for the decomposition analysis: A volume effect, a structure effect, an intensity effect and a fuel mix effect. The four factors general formula used for the decomposition analysis was equal to equation 1 in section 3.1. When it was not possible to perform a four-factor decomposition analysis a three factorial decomposition formula was used. That was the case for the agricultural, services and residential sectors.

$$\Delta CO_2 = V\ x \frac{E}{V}\ x \frac{CO_2}{E}$$

Equation 7, three factor decomposition identity used in agriculture, services and residential.

Table 3 below explains in more detail how the sector indicators were identified and selected.

Sector	Formula used
Passenger Transport ***Public road transport*** ***Private cars and motorcycles*** ***Rail*** ***Inland navigation***	$CO_2 = Gpkm\ x \sum_i^n \frac{Gpkm_i}{Gpkm}\ x \frac{Ei}{Gpkm_i} x \frac{CO_{2i}}{Ei}$
Freight Transport ***Trucks*** ***Rail*** ***Inland navigation***	$CO_2 = Gtkm\ x \sum_i^n \frac{Gtkm_i}{Gtkm}\ x \frac{Ei}{Gtkm_i} x \frac{CO_{2i}}{Ei}$
Agriculture	$CO_2 = SVA\ \ x \frac{EI}{SVA}\ x \frac{CO_2}{EI}$
Services	$CO_2 = SVA\ \ x \frac{EI}{SVA}\ x \frac{CO_2}{EI}$
Residential	$CO_2 = Pop\ \ x \frac{EI}{Pop}\ x \frac{CO_2}{EI}$
Non ETS Industry ***Food, drink and tobacco*** ***Engineering*** ***Textiles*** ***Other***	$CO_2 = SVA\ x \sum_i^n \frac{SVA_i}{SVA}\ x \frac{Ei}{SVA_i} x \frac{CO_{2i}}{Ei}$

Table 3, Formulas used for decomposition analysis in each of the ESD subsectors analysed.

In the transport sector, the fuel mix effect was set to zero, since the majority of vehicles run on oil-based fuels which have similar emission factors and the number of electric vehicles can be considered negligible when compared to the total vehicles fleet. Therefore, for this research, a common factor of 73g CO_2/GJ was used for the transport sector, thus not considering a fuel mix effect. The average common factor for the CO_2 intensity in transport was calculated by averaging the different emission factors of fuel used in transport retrieved from NEA (2018). In the case of agriculture, residential and services sectors, the formula for the decomposition analysis does not include a structure effect since the subsectors were not considered. Once all the decomposition identities were set, the magnitude of the different effects was calculated using the LMD formula shown in section 3.3. Once the results from the decomposition analysis were provided, they were showed in a bar chart, merging all the results of each sector in every country.

4.2 Policies identification

4.2.1 Qualitative analysis of policies

The second, and main, method used for the policy analysis assessed the impact of the policies which have been implemented by the studied MS. The methods for this policy identification was done as follows:

Firstly, an archive of the major policies targeting the ESD sectors was constructed. The policies were gathered from different sources such as: Governmental reports, intergovernmental reports and policies and measure database such as Odyssee-MURE (Mesures d'Utilisation Rationnelle de l'Energie). From these sources, it was possible to obtain a detailed description of the policies, of the measure of intervention included in the policy framework and, in some cases, an estimation of the emission reductions as a result of the policy implementation. The archive constructed categorises the policy with the following information: name of the policy, target sector, and estimated reduction impact retrieved from the sources.

The policies identified where then selected using the estimated reduction provided by the third biennial report from the studied MS to the United Nations Framework Convention on Climate Change (UNFCCC) and the impact quantification provided by the Odysee-MURE policy assessment tool (Odysee, 2018). By using these criteria, the author selected the main policies implemented in each ESD sector.

Through the analysis of the policies and the proposed interventions suggested, the author categorized the policies in different categories i.e. policies aiming at volume reduction or energy efficiency policies. After looking at the quantitative results from the decompositions analysis in the different subperiods, the researcher identified the dominant effect responsible for the variation of emissions in one or more MS (for example, a dominant fuel mix effect in the period 2010-2015 in the Italian passenger transport sector). When the dominant effects were identified, the researcher developed a policy archive of the policies which were categorized as 'high impact policies' from different governmental sources. Using the policy archive and the results from the decomposition analysis, the researcher matched the different effects with relevant policies implemented in each MS and identified a correlation between the two elements.

4.2.2 Quantitative analysis of policies

When possible, the impact of a certain policy effect was quantitatively assessed in the thesis. This was the case when analysing the regulation EC 443/2009 regarding car fleet emissions from the EU. In this case, the researcher estimated the impact that the policy could have had on the intensity effect of the MS subject to this study. The calculation was done as follows:

Firstly, the historical data for the new car's registration in Europe for the period 2000-2016 It, DE and NL were retrieved from the EEA Report No 19/2017 (EEA, 2017). The data could then be considered as a good proxy for new car sales. Afterwards, a projection for the new car registration was developed. This step was accomplished by determining an average using the last years from the car registration data (2012-2015). The researcher also estimated the average amount of Km driven per car in 2020 using data from the Odyssee Mure database (Odyssee, 2016) as a base for the projection. Lastly, using the average emission factors for new cars (EEA, 2017), it was possible to estimate an average emission factor for the entire car fleet in 2005 and 2020. Once all the data was gathered, it was possible to estimate the change in emissions in the target year by using the following formula:

$$\Delta CO_2 = (Carfleet_{2020}\ x\ ef_{2005}\ x\ km_{2005}) - (Carfleet_{2020}\ x\ e.f._{2020}\ x\ km_{2020})$$

Equation 8, formula used for EC 443/2009 quantitative analysis.

Where $carfleet_{2020}$ indicates the total car fleet in the target year, $e.f_{2005}$ and $e.f_{2020}$ indicate the emission factors in the base and the target year while Km_{2020} indicates the average number of kilometers driven in the target year.

5 Results

The first step of the research consists of a preliminary analysis of the ESD sectors of the examined countries. More in depth, the historical data and the projected data for the period 2005-2020 are presented and interpreted. In this section of the thesis, the different emissions and variations of the volume indicator in the ESD sectors are displayed. The analysis of the non-ETS branch at an aggregate level can provide different insights regarding the country profile and its different developments. Countries could present variations in the sub periods in which the whole period of study has been divided (2005-2020).

The goal of this section is to identify how the emissions and the volume indicator of the analysed sectors have been fluctuating before reaching their final value in 2020. The risk with only providing a decomposition analysis from the period 2020-2005 is to show a result which only represents an averaged value of the period. With the country profile analysis, it is possible to visualize how the trend developed year per year and then it can be possible to decompose another period if the results are particularly interesting. This section provides more depth of results as it allows the researcher to use and compare the data from the decomposition analysis of the three sub periods (2005-2010, 2010-2015 and 2015-2020) to the whole period of study (2005-2020).

The data from PRIMES 2016 regarding volume indicators (passenger per kilometre, ton per kilometre or Sector Value Added (SVA)) and emissions were graphed. The goal of this section is to observe how the indicators have changed, suggesting that in each of the sectors, different effects could have occurred.

5.1 Passenger transport

5.1.1 Trend results passenger transport

Firstly, the data for the historical emissions and passenger transport (Gpkm) are presented for the three studied countries.

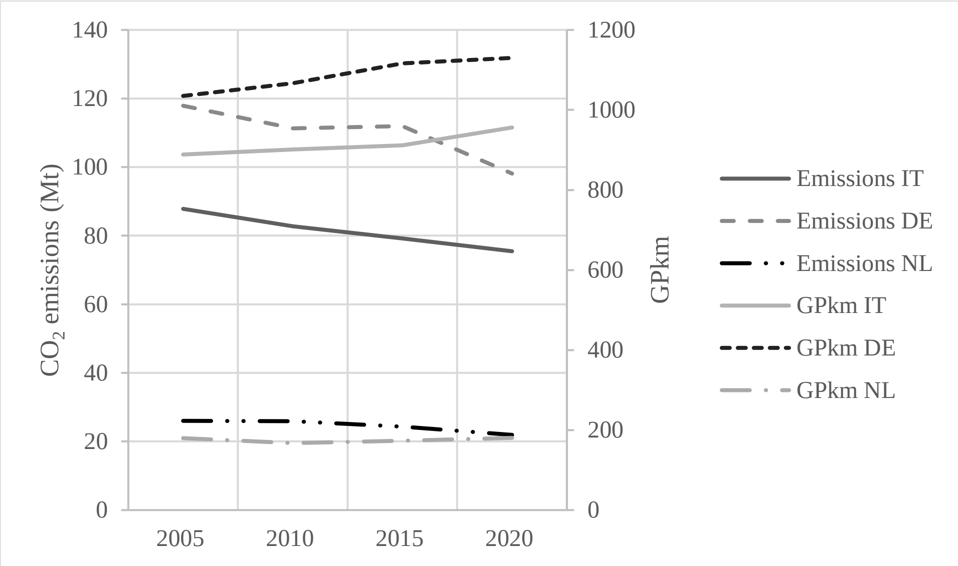

Figure 3, Variation of CO2 Emissions and passenger transport (GPKM) passenger transport sector in IT, DE and NL during the period 2005-2020 (Source: PRIMES, 2016).

Figure 3 shows that the emissions in all three MS are projected to decrease by 2020, while the amount of pkm is projected to increase in IT and DE. However, the trends in the countries present some differences. In Italy, it can be noticed that the emissions gradually decrease from 2005 while the passenger transport shows to increase from 2015. German emissions show a decrease during the period 2005-2010, followed by a plateau phase during 2010-2015 and a sharp decline projected for the following five years (2015-2020), whereas the German passenger transport shows a stable increasing trend during 2005-2015 and is projected to further increase between 2015-2020. Another interesting observation regards the change which could have occurred in Germany in the transport sector, where the share of private cars Gpkm increased by 2% while the total transport sector Gpkm decreased (Fig.4).

Figure 4, variation of Gpkm in of private cars and motorcycles over the total Gpkm in passenger transport when comparing 2010 (left) to 2005 (right)

This variation in the pkm sector could have an effect on the emission variations in the subperiod leading to a potential structure effect.

The Netherlands shows a different trend, both in the historical data and in the projected values. On the one hand, historical emissions have remained stable until the early 2010's and have been decreasing only after that, with projections showing a further reduction during 2015-2020. On the other hand, the number of pkm, did not show any significant variations during the whole analysed period. The preliminary analysis of the passenger transport sector could then suggest the presence of a dominating intensity effect, since emissions have been decreasing, and are projected to decrease, while the total volume has been increasing and is projected to further increase.

5.1.2 Decomposition analysis passenger transport

When carrying out a decomposition analysis of the passenger transport sector, it was possible to quantify the different effects observed in the preliminary trend analysis.

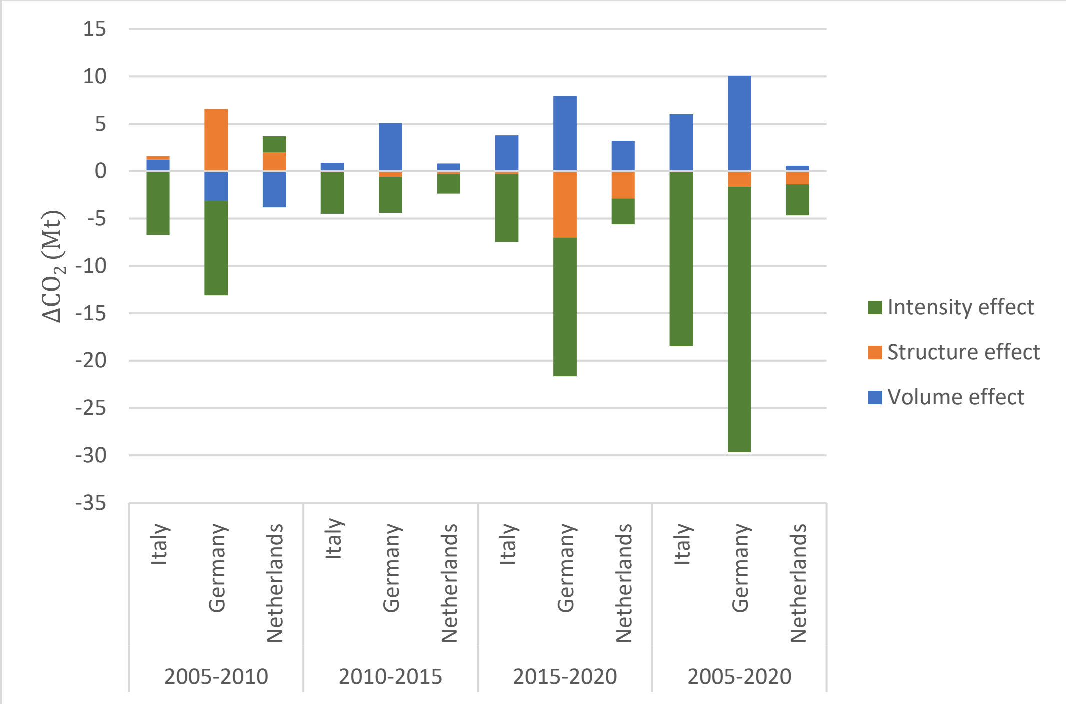

Figure 5, Decomposition analysis for passenger transport sector in the periods 2005-2010, 2010-2015, 2015-2020 and for the whole 2005-2020 period. For Italy, Germany and The Netherlands (Source: PRIMES 2016).

The results from the decomposition analysis of the passenger transport sector present different trends among the analysed countries. In the overall period, the dominating effect in the sector is the intensity effect, with a reduction of ≈18 Mt in IT, ≈28 Mt in DE and ≈3Mt in NL, suggesting that most of the emission reductions has been achieved or will be achieved due to reductions in the energy intensity (GJ) over the pkm in the subsectors (Fig.5). Most of the emissions in the transport sector are dominated by the private cars subsectors. From a further analysis of the emissions, it can be noticed (Fig.5) that in the overall period 2005-2020, the sector shows a net decrease in emissions largely due to a decrease in intensity. When analysing the decomposition results for the five-year period, some interesting results can be noticed. For example, during the 2005-2010 period, Germany experienced an increase in emissions due to a structure effect which was due to an overall decrease in the pkm combined with an increase in the pkm in the private vehicles subsector. On the other hand, in 2015-2020, the opposite effect has been calculated (based on projections) where the overall pkm has increased but a decrease in the pkm in the private vehicles subsector is being projected for DE and NL.

5.1.3 Policy analysis passenger & freight transport

From the policy analysis results, nine main policies targeting the transport sector where found. Some of the policies were found to target both the passenger transport as well as the freight transport, whereas others were specific to one subsector only. In the following table, the policies, with their estimated CO_2 reduction effect from the UNFCCC reports, are linked with the effects calculated in the decomposition analysis.

	Name of Policy	Targeted subsector (P/F)	Year of implementation	CO_2 reduction in 2020 (Mt)	Target effect
Italy	National strategic framework	(P/F)	2007	1.28	Intensity
	EC 443/2009	(P)	2009	10.20	Intensity
	Decree 128/05 from Directive EC2009/28 (Biofuels)	(P/F)	2008	1.58	Intensity
	Infrastructural measures	(P/F)	2008	5.70	Intensity / Volume
	Total Reduction It			18.76	
Germany	EC 443/2009	(P)	2009	n.a	Intensity
	Decree 128/05 from Directive EC2009/28	(P/F)	2008	n.a.	Intensity
	Total Reduction DE	(P/F)		1.40	
Netherlands	EC 443/2009	(P)	2009	2.70	Intensity
	Decree 128/05 from Directive EC2009/28	(P/F)	2008	3.00	Intensity
	Eco Driving campaign	(P)	2013	0.50	Structure/ Intensity
	Total Reduction NL			6.20	

Table 4, list of main measure implemented in the transport sector (passenger and freight) and their potential areas of influence (Source UNFCCC 2017, a,b,c).

According to UNFCCC third biennial report of 2017, the sum of the main policies in the transport sector of IT, DE and NL leads to a reduction of ≈28 Mt of CO_2 (Table 4). From Table 4, it can be noticed that the clear majority of the measures analysed are considered to influence the intensity effects (UNFCCC 2017 a,b,c). This result could be correlated with the large intensity effect present in the sector throughout the period of study. Furthermore, the absence of policies targeting volume reduction could be correlated with the increase in volume in the sector. The CO_2 reduction estimated in the UNFCCC papers does not match with the amounts quantified in the decomposition analysis, however they do suggest that these policies could have contributed to the reduction in the CO_2 intensity of the sector.

The policies with a major impact on the transport sector at a European level are the following, and they can be correlated with the overall reduction of emissions in the sector:

Biofuel Target EC/28/2009

Directive EC/28/2009 establishes that the transport sector of all MS of the EU should have a minimum share of Biofuel in the total energy consumption in transport. This share amounts up to 10% of all energy consumption. According to the Eurostat (2018), the share of Biofuel in 2015 in the analysed MS was 6.40% in IT, 6.80% in DE and 5.30% in NL. The effects of this policy could be correlated with the intensity effect since a higher share of Biofuels would contribute to lowering the CO_2 intensity of the carbon sector.

Regulation EC no.443/2009

In 2009, the EU set a regulation, agreed among the European car manufacturers, to establish a target of 130g CO_2 per Km for the fleet average in 2015. The target was then improved in 2014 by regulation 333/2014, where the emission standards were lowered to an average 95g CO2 per Km in 2021. A similar regulation was applied to light commercial vehicles (which emissions are included in the passenger transport decomposition analysis), where regulation EC 510/2011 set a target of 175g CO_2/Km for 2017 which was consequently improved to 147 g CO_2/Km for 2020 by regulation EC 253/2014. The impact of these regulations in the passenger transport sector can be correlated to the dominating intensity effect present through the whole period of study. Following the methods described in 4.2.2 it was possible to estimate the emission reduction and compare it to the reduction estimated in the UNFCCC reports (2017a,b,c).

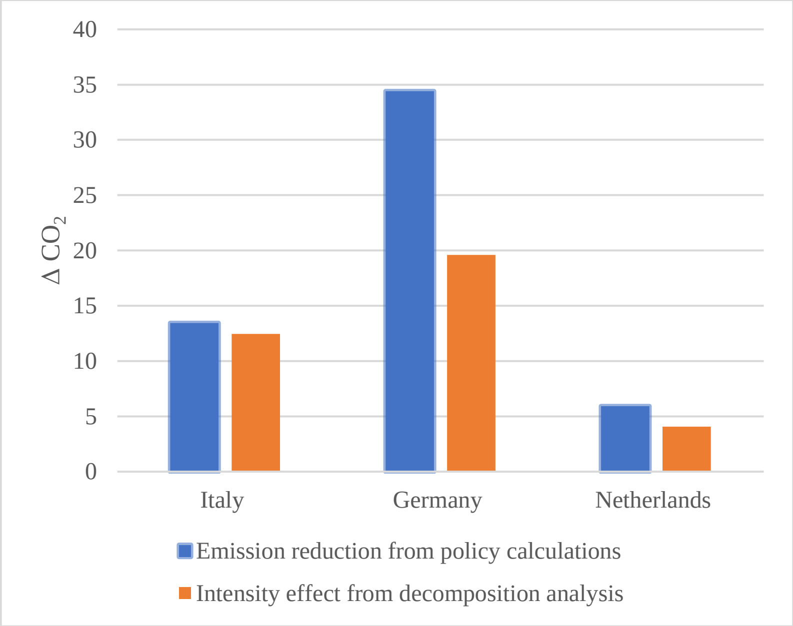

Figure 6, comparison of the effect of measure EC no. 443/2009 with the magnitude of the intensity effect calculated in the decomposition analysis.

The comparison between the intensity effect and the reduction from the policy effect calculation shows some discrepancies in the results (Fig.6). The emission reduction from the policy calculations show a higher reduction than the one calculated from the quantitative analysis, suggesting that different factors could have had an influence in the system, reducing the effect of the policy.

5.2 Freight transport

5.2.1 Trend analysis freight transport

The data for the historical emissions in freight transport (tkm) are presented for the three studied countries.

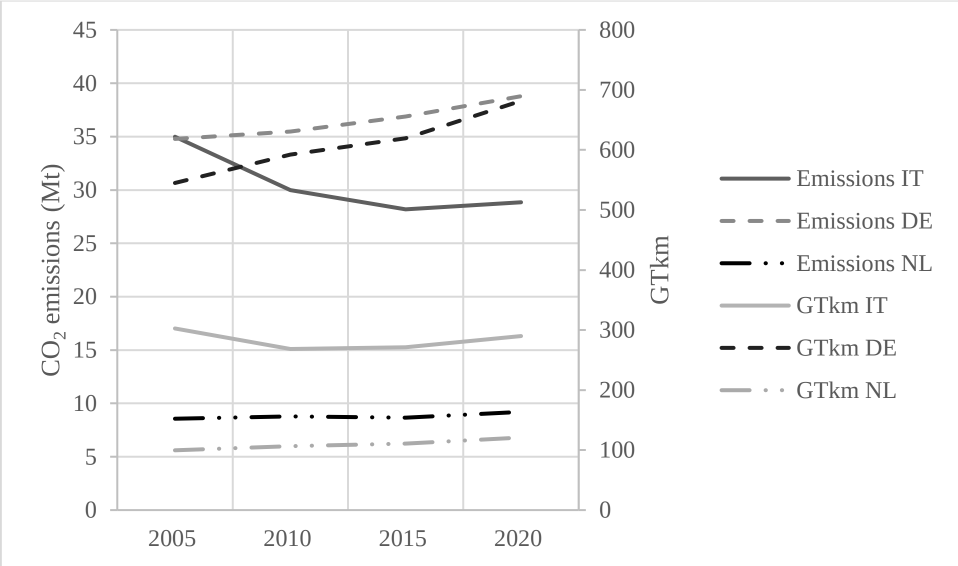

Figure 7, Variation of Emissions and freight transport (Gtkm) in IT, DE and NL during the period 2005-2020 (Source: from PRIMES, 2016).

The historical data and the projections from the freight transport show a different development when compared to the passenger transport sector. Germany and the Netherlands show a similar trend, with a projected increase in Gtkm and emissions. Italy shows a decline in both volume and emissions (Fig. 7). More in depth, during the period 2005-2010, emissions have decreased or slowly increased, followed by a rapid growth (DE and NL) and a rapid decline (IT). The Italian indicators for the freight transport show that an increase in emissions and Gtkm is projected to occur during the period 2015-2020 (Fig.7)

The preliminary analysis of this sector suggests that the dominant effect characterizing the change in emissions might be the volume effect, since the trend already suggests a correlation between tkm and CO_2 emissions (Fig.7).

5.2.2 Decomposition analysis freight transport

Through the decomposition analysis, it was possible to quantify the effects present in the different subperiods.

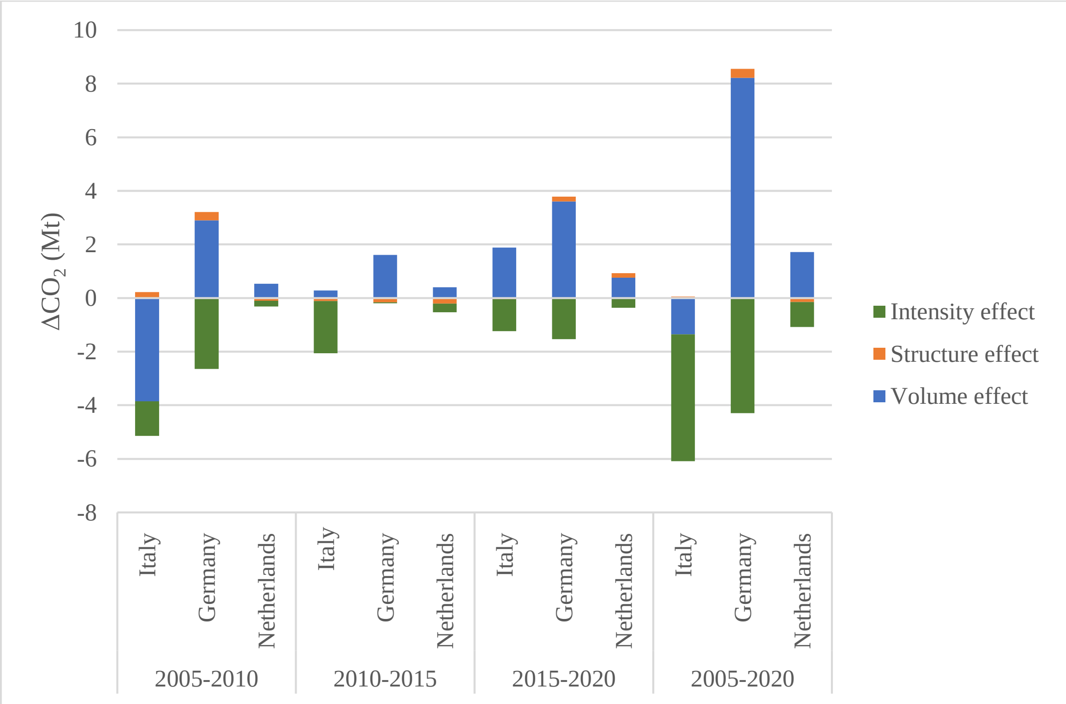

Figure 8, Decomposition analysis results for the Italian emissions in freight transport sector between the period 2005-2020 (Source: PRIMES 2016).

The aggregate result for the freight transport sector shows different results for Italy, Germany and the Netherlands. On the one hand, In Italy, the decomposition analysis for the historical period and for the projections shows a decrease in the emissions. A large decrease in emissions in the Italian freight transport especially occurred during the years 2005-2010. Most of it is due to a decrease in volume which could be attributed to an indirect effect. When comparing the total period of study, the effects can be quantified in a decrease of ≈ 6 Mt for Italy whereas Germany and the Netherlands would show a total increase of ≈ 4. and ≈0.7 Mt CO_2respectively (Fig.8). In this case, the indirect effect correlated to the decrease in volume could be identified in the economic crisis of 2008.

On the other hand, in Germany and the Netherlands, emissions are expected to largely increase. In this case, the dominating effect is volume (i.e. higher number of tkm in 2020 than in 2005). However, it can be noticed that all three countries have a dominant intensity effect (GJ/tkm) which, in the case of DE and NL mitigates the increase in emissions due to volume growth. These results suggest that the efficiency of freight transport has increased, indicating that MS might have implemented certain regulations to reduce the amount of energy needed in freight transport.

5.3 Agriculture:

5.3.1 Trend analysis agriculture

The historical and projected value for the CO_2 emissions and the SVA of the agricultural sector show different trends among MS and are subject of large fluctuations among the subperiods (Fig.9).

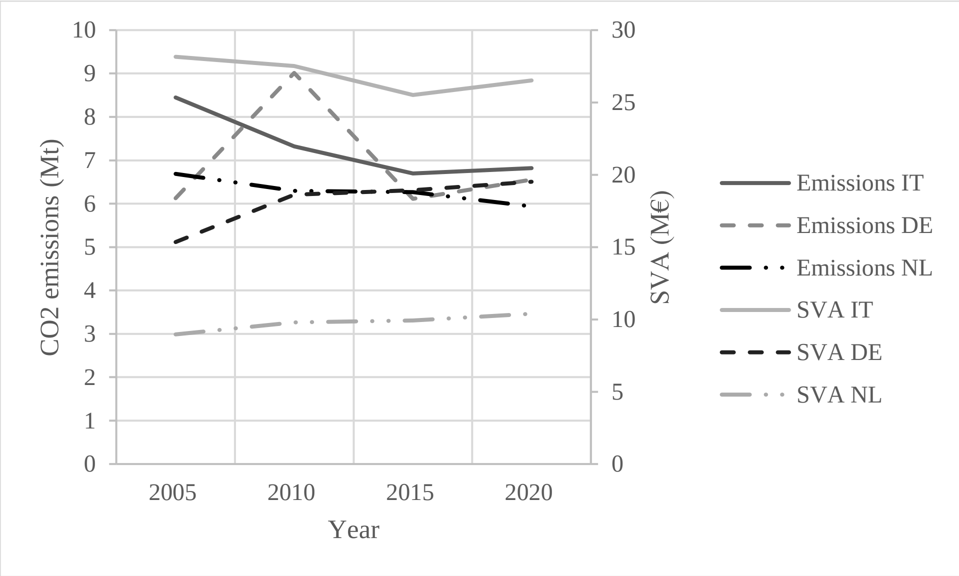

Figure 9 Variation of Emissions and SVA in the agricultural sector for IT, DE and NL during the period 2005-2020 (Source: PRIMES, 2016).

It can be noticed that during the recession time, the SVA of the agricultural sector experienced a sharp decrease in its value in two of the MS (IT and DE). The CO_2 emissions diminished as well. However, it can be noticed that the emissions do not follow the same trend as the SVA.

Among the three MS, DE shows to have the largest variation in emissions, suggesting that different effects could have been alternating throughout the entire period of study. From the preliminary data it can be assumed that there could be different effects that can be correlated with the emission variations. In the case of IT, one could hypothesize that most of the emission reduction can be linked with a decrease in volume (decreasing SVA) whereas in DE and NL the emissions could have been influenced by a dominant fuel mix or intensity effect.

Another point of interest can be represented by the sharp decline in emissions in Germany between 2010-2015. When looking at the statistics for the final energy demand, the following result can be observed:

Year	Sectoral Value Added (SVA)	Final Energy Demand (PJ)
2010	18.62	156.92
2015	18.93	109.32

Table 5, SVA and final energy demand of the German Agricultural sector during period 2010-2015 (Source: PRIMES).

From table 5 above, it can be noticed that the intensity of the agricultural sector drastically decreased during 2010-2015 due to the decrease of the energy demand together with the increase of the SVA correlated with the post-recession period.

5.3.2 Decomposition analysis agriculture

When quantifying the hypothesized effects responsible for the variation of the emissions, it can be noticed that different magnitudes influenced the MS emissions throughout the entire period of study (Figure 10).

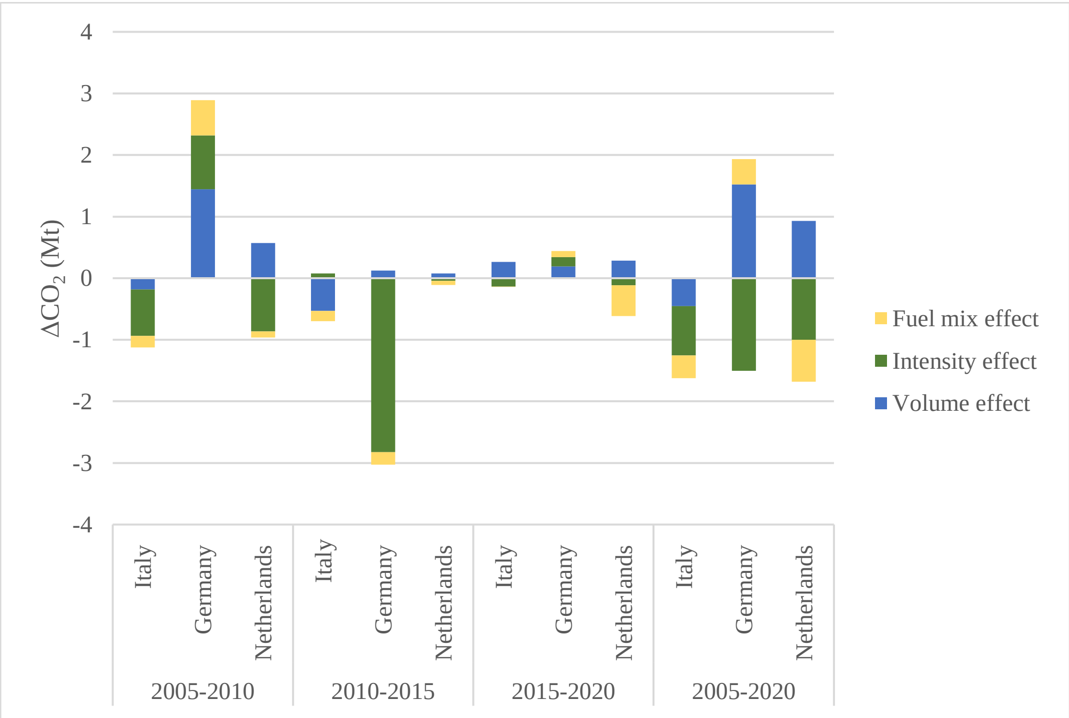

Figure 10, Decomposition analysis for the agricultural sector in the periods 2005-2010, 2010-2015, 2015-2020 and for the whole 2005-2020 period. For Italy, Germany and The Netherlands (Source: PRIMES).

Results in the agricultural sector show remarkably different trends in the emissions among the studied MS. As previously mentioned in the country profile section, the emissions in the agricultural sector present tangible differences also when considering the five-year analysis period.

Results for Germany show an increase in emissions during the 2005-2010 period, due to a volume effect, but also an increase in intensity and fuel mix. Whereas Italy and Netherlands show a decline in emissions related to intensity effect. During period 2010-2015, Germany presents a large decline in emissions (≈3 Mt) mostly due to a large intensity effect, whereas when looking at the period 2015-2020 (historical data and projections), emissions reduction is lower than in the previous lustrum (Fig. 10). When considering the decomposition analysis results for the entire period of study, emissions decreased in Italy (≈2 Mt) and in the Netherlands (0.5 Mt) but slightly increased in Germany (0.4 Mt). The increase in emissions could be correlated to a volume effect, which could be explained by an increase in SVA of the agricultural sector. One of the explanations for a higher reduction of emissions in the Italian sector, could be correlated to the higher impact that recession had on the country. From the historical data provided by PRIMES 2016, it can be noticed that the Italian SVA for the agricultural sector decreased from 28 m€ to 26 m€, whereas in the two other member states it shows an increase in the SVA.

5.3.3 Policy analysis agriculture

From the policies analysis results, only one relevant policy specifically targeting CO_2 reduction was found for the agricultural sector.

Netherlands	Name of Policy	Year of implementation	CO_2 reduction in 2020 (Mt)	Target effect
	Agrocovenant Directive	2008	0.70	Fuel mix
	Total NL		0.70	

Table 6, Policies assessed in the Agricultural sector (Source UFCCC 2017c).

When analysing the policies targeting CO_2 emission reduction in the agricultural sector, the only relevant policy encountered was found in the Netherlands, where one policy (Agrocovenant Directive) was found to have a correlation with the fuel mix effect. The other policies implemented in the agricultural sector mostly target the reduction of other GHG gases such as methane (CH_4) and nitrous oxides (NO_x) and therefore are not subject of this research.

The Agrocovenant Directive is a measure implemented by the Dutch government to reduce the energy intensity of the agricultural sector by adopting a series of interventions ranging from energy saving to more efficient infrastructures (e.g. more efficient greenhouses). Through this measure, the Dutch government aims at a reduction of 0.70 MT of CO_2 in 2020 (Verdonk & Hof, 2013). The measure was identified to be correlated with the fuel mix effect as it reduces the CO_2 intensity of the sector.

5.4 Services

5.4.1 Trend analysis services

The historical and projected value for the CO_2 emissions and the SVA of the services sector are presented in this section:

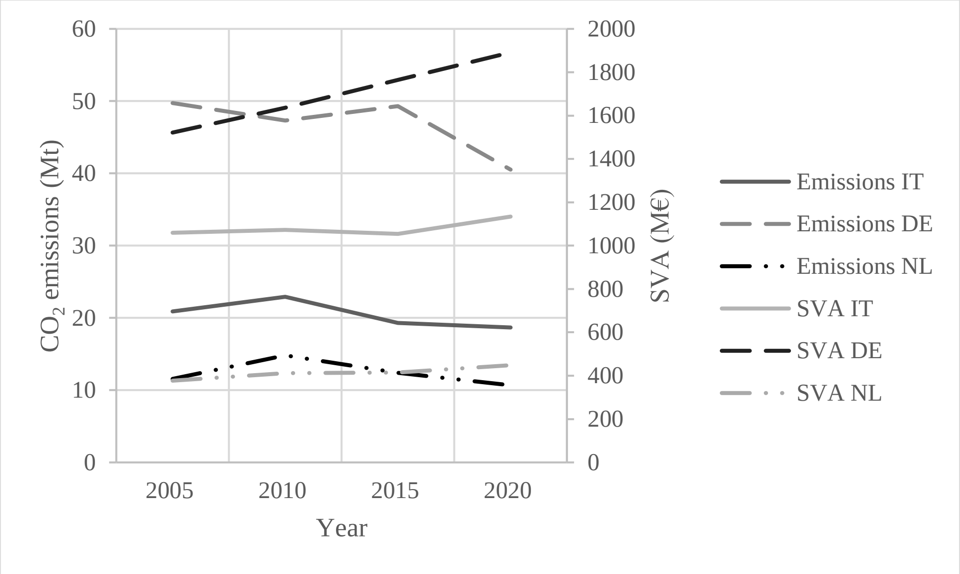

Figure 11, Variation of Emissions and SVA in the services sector for IT, DE and NL during the period 2005-2020 (Source: PRIMES, 2016).

The historical and projected data for the services sector shows contrasting trends among the different countries (Fig. 11). During the period 2005-2010, all the countries recorded an increase in the SVA and in emissions. During 2010-2015, the trends started to differentiate among countries, Italian and Dutch emissions declined whereas German emissions increased. The SVA of the MS rapidly increased in DE while it stabilized or recorded a slower growth in IT and NL. The projections for 2015-2020 show a sharp decrease in the CO_2 emissions in each of the MS followed by a growth in the SVA. According to the trends shown, it can be assumed that different effects could have influenced the emission trends (Fig.11). The sharp decline in emissions projected for 2015-2020 and the increase in SVA could be correlated with a dominating intensity effect or to a change in the fuel mix.

5.4.2 Decomposition analysis services

When performing the decomposition analysis of the sector, it was possible to quantify the different effects that distinguished the evolution of the emissions in the services sector of the different MS through the period of study.

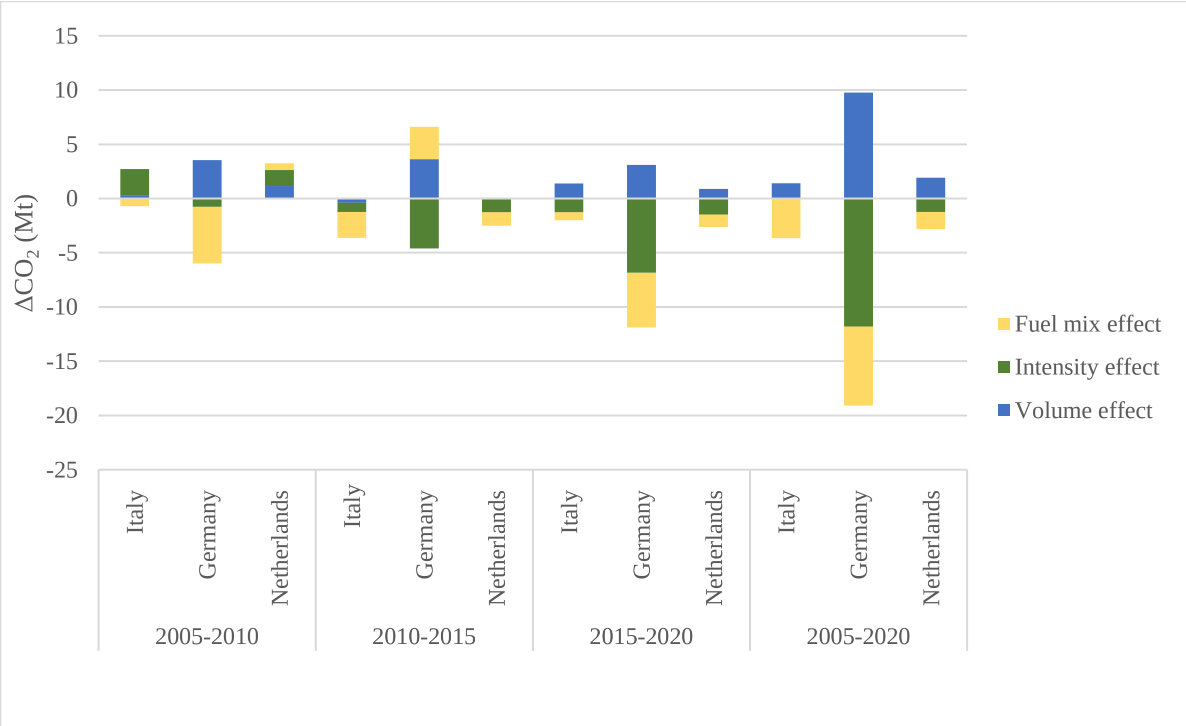

Figure 12, Decomposition analysis for the services sector in the periods 2005-2010, 2010-2015, 2015-2020 and for the whole 2005-2020 period. For Italy, Germany and The Netherlands (Source: PRIMES).

The decomposition results of the services sector show that a reduction in the emissions will occur in all the MS when comparing the base year with the target year (Fig. 12). Throughout the entire period of study, including the subperiods, it can be noticed that the dominant effects in the sector vary depending on the MS. In Italy, most of the reduction, ≈ 4 Mt CO_2, is due to a dominating fuel mix effect, whereas Germany's and the Netherlands' reductions are due to a large influence of both an intensity effect (≈12 Mt for DE and ≈1 Mt for NL) and a fuel mix effect (≈7 Mt for DE and ≈2 for NL). Furthermore, it can be noticed that both Germany and the Netherlands present a large volume effect (≈10 Mt and ≈2 Mt respectively) which partially compensates for the emission reduction (Fig. 12). The reason for an increase in emissions due to a volume effect in DE and NL can be correlated with the rapid growth of the SVA in the last decade and on its projected growth.

5.4.3 Policy analysis services

Regarding the policies implemented in the services sector, no mayor policies have been analysed since most of the policies can be considered similar to the ones designed for the residential sector which, have been assessed in section 5.5.3 of the research.

5.5 Residential

5.5.1 Trend analysis residential

The historical and projected value for the CO_2 emissions and the population of the residential sector are presented in this section:

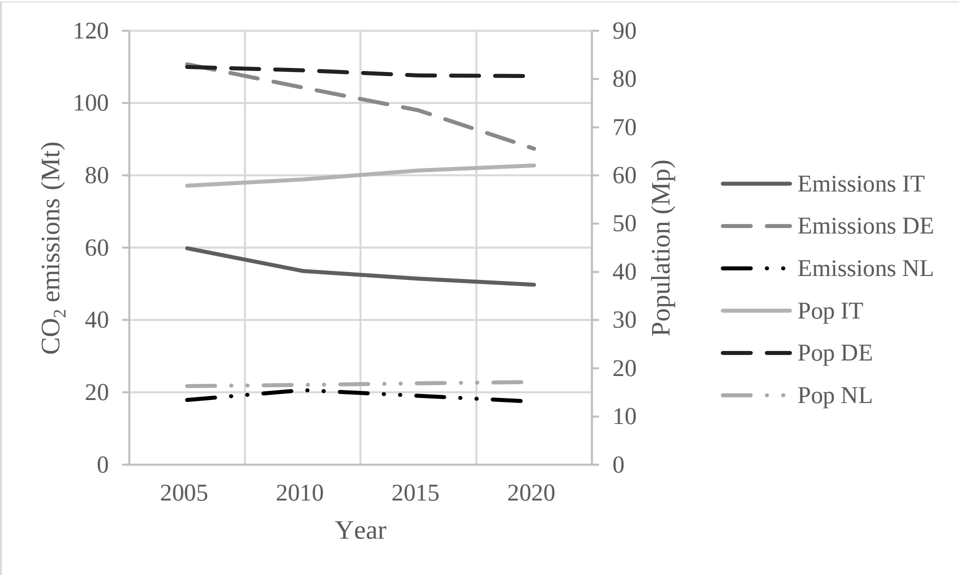

Figure 13, Variation of Emissions and Population in the residential sector for IT, DE and NL during the period 2005-2020 (Source: PRIMES, 2016).

Historical and projected emissions and population growth show some differences among the three studied MS. On the one hand, Italy and the Netherlands are projected to experience a population growth, whereas Germany's population is slightly declining and is projected to continue on the same trend even in 2020 (Fig. 13). Emission trends from the historical period show a rapid decline which will continue in the projections until 2020. The only exception is represented by the Netherlands, which recorded an increase in emissions during the period 2005-2010. The decline in emissions in the last years and the projected decline for the 2015-2020 period suggest that there could have been interventions targeting the efficiency of the sector. This assumption is further confirmed by the inverting trends in the CO_2 emissions and population growth. Therefore, from the preliminary data it can be hypothesized that the dominant effect in the residential sector will concern either the fuel mix effect or the intensity effect.

The residential sector can be considered as one of the sectors where the highest amount of emission reduction occurred (Fig.13). In all the countries, the combination of the effects leads to a reduction in the emissions. When comparing 2005 to 2020, it can be noticed that most of the CO2 reduction occurred due to a dominant fuel mix effect (g CO_2/GJ), which contributed to a reduction of ≈16 Mt CO_2 in Italy, ≈16 in Germany and ≈ 1 in the Netherlands (Fig. 13).

Most of the reduction in the CO_2 emissions can be then correlated to an increasing fuel mix effect, where the CO_2 intensity of the fuel mix decreased through the period of study. The difference in the volume effect present when comparing Italy and the Netherlands (increase in volume) with Germany (decrease in Volume) could be related to the decrease of population projected for DE in 2020, which could positively affect the emissions in the residential sector.

In this sector, it can be noticed that a dominant fuel mix effect is present. The reduction in emissions due to the fuel mix effect can be represented by the decrease in g CO_2 emitted per GJ.

5.5.2 Decomposition analysis residential

From the decomposition analysis of the residential sector, the different effects that occurred throughout the period of study were quantified and interpreted.

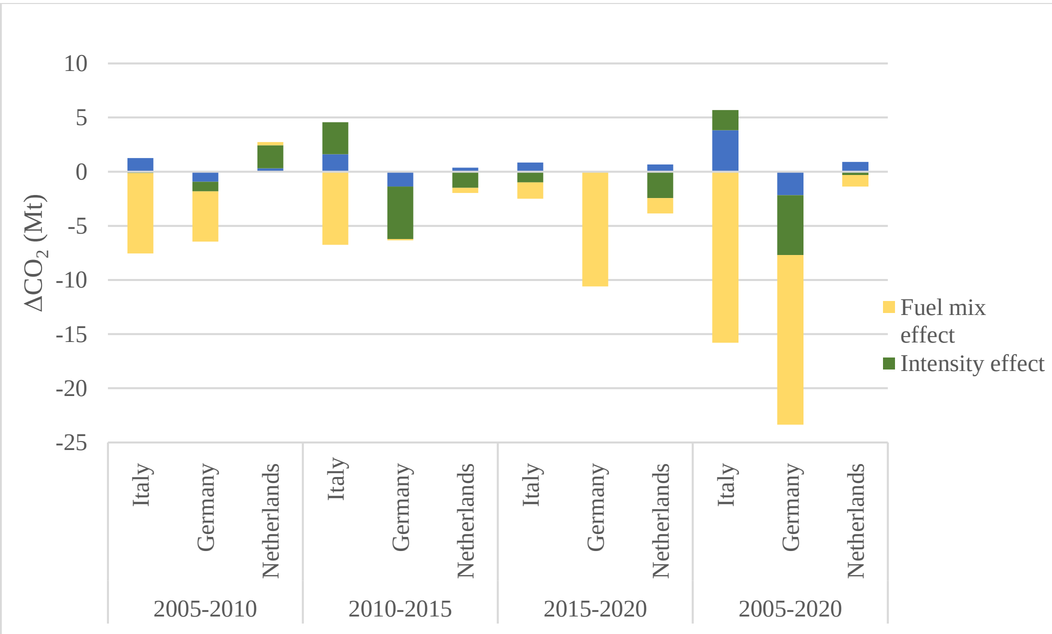

Figure 14, Decomposition analysis results for the analysed MS emissions in the Residential and buildings sector between the period 2005-2020 (Source: PRIMES 2016).

Residential sector can be considered as one of the sectors where the highest amount of emission reduction occurred (Fig.13 & 14). In all the countries, the combination of the effects leads to a reduction in the emissions. When comparing 2005 to 2020, it can be noticed that most of the CO_2 reduction occurred due to a dominant fuel mix effect (g CO_2/GJ), which contributed to a reduction of ≈ 16 Mt CO_2 in Italy, ≈16 in Germany and ≈1 in the Netherlands (Fig. 14). Most of the reduction in the CO2 emissions can be then correlated to an increasing fuel mix effect, where the CO_2 intensity of the fuel mix decreased through the period of study.

In this sector, it can be noticed that a dominant fuel mix effect is present. The reduction in emissions due to the fuel mix effect can be represented by the decrease in g CO_2.

5.5.3 Policy analysis residential and services sectors.

The policy analysis results show that the residential and services sectors have been targeted with several measures to mitigate the CO2 emissions of those sectors (table 7).

	Name of Policy	**Targeted subsector (R/S)**	**Year of implementation**	**CO_2 reduction in 2020 (Mt)**	**Target effect**
Italy	Building Regulation 192/05 (From Directive 2002/91/EC)	(R)	2006	3.61	Fuel mix
	Tax deduction for energy saving in buildings	(R)	2008	10.50	Fuel mix
	White certificates Decree 2007	(R)	2008	3.12	Fuel mix
	Ecodesign Directive (2005/32/EC)	(R/S)	2005	2.60	Fuel mix
	Energy performance of Buildings Directive (EPBD)	(R)	2008	n.a.	Fuel mix
	Total It			19.83	
Germany	2002/91/EC	(R)	2006	n.a.	Fuel mix
	EPBD	(R)	2008	n.a.	Fuel mix
	Ecodesign Directive (2005/32/EC)	(R/S)	2005	n.a.	Fuel mix
	Total DE			8.60	
Netherlands	EPDB	(R)		n.a.	Fuel mix
	Ecodesign Directive	(R/S)		n.a.	Fuel mix
	Existing buildings Directives	(R)		n.a.	Structure/Fuel Mix
	Total NL			3.20	

Table 7, list of main measure implemented in the Residential sector and their potential areas of influence (Source UNFCCC, 2017 a,b,c)

In total, 11 relevant policies have been found. Most of these policies are European Directives, however national implementations have been found to have an important effect as well. The effects of the policies can be correlated with the fuel mix effect (CO_2/GJ) found in the decomposition analysis, since most of the policies target an increase in energy efficiency, thus a reduction of the CO_2 intensity in the entire system. In this case, it can be noticed that all the policies analysed are found to primarily target the efficiency of the sector. At a European level, the main policies implemented in the Residential and services sectors are the following:

Ecodesign

Directive 2005/32/EC known as the Ecodesign Directive provides a series of rules for product specific regulations in order to improve the energetic performance of energy-related household and industrial products (e.g. Boilers). The implementation of the Ecodesign Directive establishes minimum energy requirements for products and thus can influence the overall energy efficiency of households/industry. This policy can be then correlated with the fuel mix effect since it reduces the overall CO_2 intensity of the sector.

EPBD Directive

The European Energy Performance of Buildings Directive (EPBD) sets ambitious energy targets for new buildings such as improvement of energy performance in old building and energy neutrality of new building by 2020. The Directive can be correlated with the fuel mix effect as it could directly reduce energy demand in the subsectors and therefore producing a net negative fuel mix effect.

5.6 Non-ETS industry

5.6.1 Trend analysis non-ETS industry

The historical and projected value for the CO_2 emissions and the SVA of the non-ETS industry sector are presented in this section.

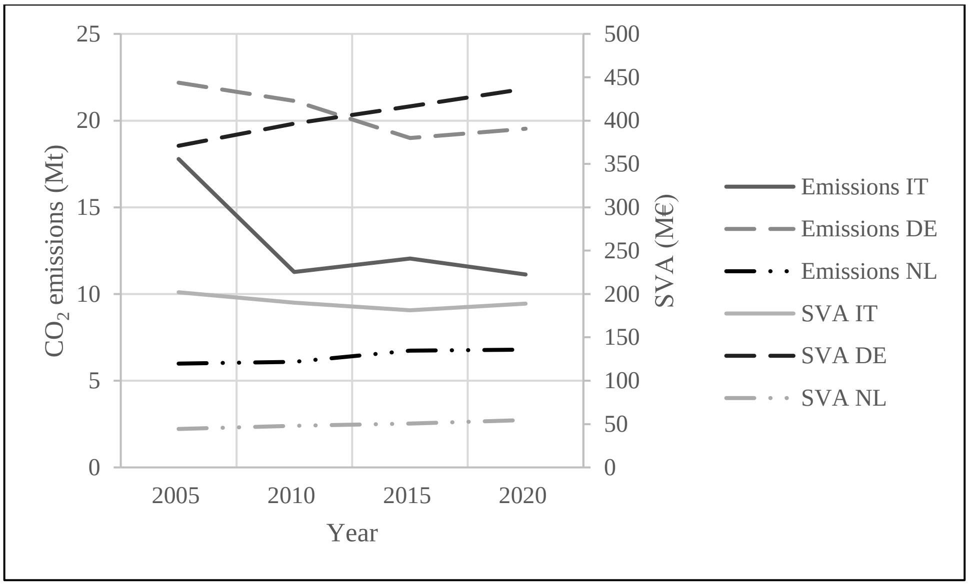

Figure 15, Variation of Emissions and SVA in the non-ETS industry sector for IT, DE and NL during the period 2005-2020 (Source: PRIMES, 2016).

The non-ETS industrial sector historical and projected emissions and SVA values show to have profound differences among the analysed MS. Italy presents a sharp reduction in the emissions during 2005-2010, followed by a small increase in 2010-2015 and a decrease for 2015-2020. At the same time, the SVA presents a decline during the period 2005-2015 and it is projected to increase only after 2015 (Fig.15).

German emissions also show a sharp reduction between 2005 and 2015 and are projected to increase in the last five years of the analysed period (2015-2020), while its SVA has been increasing during the whole historical period and it is expected to continue in 2015-2020 as well. In the Netherlands, both the CO_2 emissions and the SVA have been increasing for the entire period and are projected to continue the same trend until 2020. From the historical period and the projected trends, it can be noticed that the non-ETS sector presents several discrepancies among countries. The difference in the data could be correlated to different factors such as the economic situation in the countries or the different policies implemented. Due to the different situations in the MS, it can be hypothesized that the Italian emission reduction could have been influenced by a reduction in volume (as a consequence of the recession) in combination with an intensity effect. Whereas in Germany and the Netherlands, the reduction in emission could be correlated to a dominant intensity or fuel mix effect.

Figure 16, relative growth of the Food drink and tobacco SVA over the total SVA in 2020 (right) compared to 2015 (left).

5.6.2 Decomposition analysis non-ETS industry

The decomposition analysis of the non-ETS sector, enabled to quantify the different effects that influenced the emissions of the analysed MS.

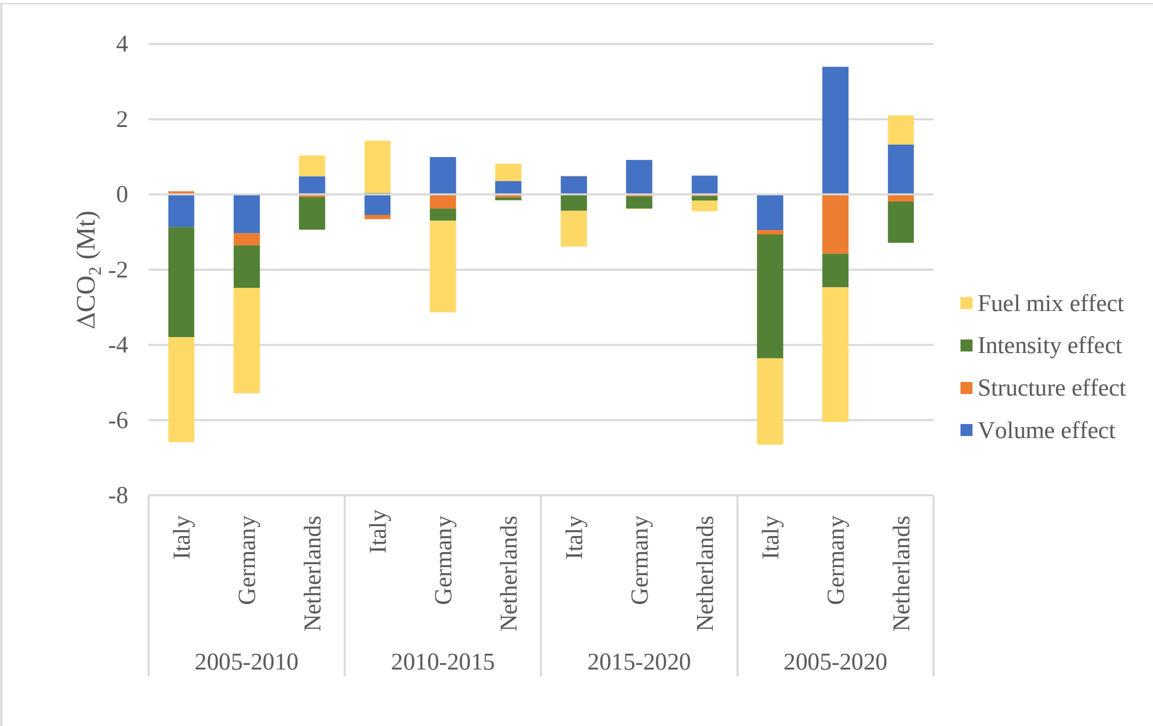

Figure 17, Decomposition analysis results for the analysed MS emissions in the non-ETS industrial sector between the period 2005-2020 (source: PRIMES).

The decomposition analysis for the historical and projected emissions of the non ETS industry sector shows various differences among the MS. When comparing 2005 with 2020, it can be noticed that Italy presents the highest reduction in emissions (≈6 Mt). When looking at the subperiod 2005-2010 for Italy, a large intensity effect can be noticed, the effect can be explained by a reduction of the energy demand in every subsector (food drink and tobacco, textile, engineering and others) (Fig.17). As previously explained in the methods, the intensity effect is represented by the energy demand over the sector value added of a specific subsector. For example, according to PRIMES 2016, the energy demand of the Italian textile subsector went from 99 million GJ to 56 million GJ, while its SVA went from ≈38 billion € to ≈19 billion € thus reducing the intensity of the sector. When looking at the decomposition results for Germany and the Netherlands, there is a dominant volume effect (≈3 Mt in DE and ≈1 in NL) leading to an increase in emissions in NL and a minor emission reduction in DE. According to PRIMES 2016, the total volume of non-ETS industry in DE was 371 billion € in 2005 and is projected to rise to 437 billion € in 2020, whereas for NL it was 44 billion € in 2005 and is projected to become 55 billion € in 2020. Differently from the other MS, Italy presents a reduction of emissions due to volume. This reduction could be correlated with the decrease in the SVA due to the economic recession (MiSE, 2017). According to PRIMES 2016, the Italian SVA was 190 billion € in 2005, it decreased up to 181 billion€ in 2015 and is projected to increase only after 2015.

Germany's rise in emissions is mostly counter balanced by a large fuel mix effect (≈4 Mt) and a structure effect (≈2 Mt). The structure effect presents in the German non ETS industry can be correlated with a stabilization of the SVA of the "food drink and tobacco" subsector compared to a growth of the SVA of the total non-ETS industry (Figure 16).

5.6.3 Non-ETS industry policy analysis

The policies implemented in the non ETS-industry sector ranged from policies targeting energy efficiency as well as programs for CO_2 reduction of products. In total, 7 policies have been identified as the most impactful policies in the subsector.

	Name of Policy	Year of implementation	CO_2 reduction in 2020 (Mt)	Target effect
Italy	Ecodesign in industry (2005/32/EC)	2006	1.92	Fuel mix
	White certificates Decree 2007 for industry	2008	n.a.	Fuel mix
	White certificates Decree 2007	2008	2.02	Fuel mix
	Total It		n.a.	
Germany	Ecodesign in industry (2005/32/EC)	2006	n.a.	Fuel mix
	Kfw energy efficiency program in industry	2003 (updated in 2015)	n.a	Fuel mix
	Total DE		4.90	
Netherlands	Ecodesign in industry (2005/32/EC)	2006	n.a.	Fuel mix
	Long term agreement' efficiency policies	2008	0.40	Fuel mix
	Total NL		0.40	

Table 8, major policies implemented in the non ETS industry sector and their main target effect Source UNFCCC, 2017 a,b,c)

.

Table 8 shows the main policies implemented by the studied MS in the non-ETS industry sector. As it can be noticed from the table, all the policies have been found to have a correlation with the fuel mix effect, suggesting that they could have contributed to the large fuel mix effect quantified in the decomposition analysis. In the case of Italy, it can be noticed that the fuel mix effect contributed to an increase in the emissions during 2010-2015. It can be thus hypothesized, that the policies could still have had an effect in reducing the emissions, but the overall intensity of the system increased. Similarly, to the other ESD sectors, all the policies assessed can be considered as policies targeting efficiency, further strengthening the evidence that there might be a lack of policies targeting the other effects.

6 Discussion

The objective of this thesis was to discuss and identify the different causes responsible for the recent improvements in the ESD Decision and its changes in the scenario and prediction compared to previous years. This chapter analyses the limitations of the research and the potential implications that the research might have in policy implementations and in its possible use as guideline for the designing of policies in the ESD 2030 target.

6.1 Limitation of the research

The research has been limited to only three EU MS, which have been selected because they have developed different projections compared to the initial predictions hypothesized when the ESD was initially implemented. However, this limitation in the sample size (three EU MS over a total of 28 MS) excludes insights on other MS measures to reduce non-ETS emissions since many policies are country specific. However, the model developed for the decomposition analysis can be fitted to other MS data as well, thus providing a base for further research on the development of ESD emissions in other MS.

Another interesting point of discussion and a potential limitation is given by the choice of population as volume indicator in the residential sector. When choosing this indicator, rather than number of households, the research does not include a potential structure effect which could have been calculated when choosing an indicator which could have provided more understanding on the structure of the residential sector such as number of people per household (Pop/HH). This indicator would have allowed to unravel a potential structure effect due to a changing number of people per household as suggested in previous research done by Liddle (2004).

Furthermore, the research does not provide an in-depth analysis of the policy effects. In most of the policies analysed. Additional data regarding the policy implementations and further analysis could contribute to a more insightful policy analysis. More in depth, the policy analysis is limited to qualitative analysis and on quantification based on other studies, more 'back of the envelope' data calculation, such as the one used for regulation EC 443/2009, could have been used to further strengthen the correlation between policy and the effects found. A more quantitative approach in the policy analysis could provide further understanding on the real effects of the policies and thus, could provide help in understanding the development of each ESD subsector with additional accuracy.

This research is also limited in the data used for the decomposition analysis. PRIMES can be considered as a valid model for comparison of ESD sectors among EU MS, however it lacks detail within the subsectors. Applying the decomposition analysis on national CO_2 emissions scenarios could have provided different results and perhaps more details regarding country specific subsectors development.

Furthermore, the scope of the research presents some limitations. The research does not include the trends for non-CO_2 GHG, which are part of the ESD, but its historical emissions and projections are not present in PRIMES (Capros 2016). The research does not then consider a large part of the emissions which are caused by non-CO_2 GHG and the policies implemented to reduce them.

6.2 Contribution to research

The research contributed to filling in a knowledge gap, as this could be considered as the first in depth analysis of the evolution of the CO_2 emissions in the different subsectors of the ESD. Furthermore, the thesis can be considered as the first research which unravels and quantifies with details the different factors contributing to the development of the ESD CO_2 emissions. The thesis can contribute in understanding the trends and which effects have the major impact on the overall emission variations. By having more knowledge on the magnitude of the different effects, the policymakers could obtain more insights when formulating the new measures which could contribute to the reduction of the target. Furthermore, the quantification of the reduction in the emissions and the knowledge on the major effects influencing them can be used a guideline when designing policies for the future target.

6.3 Recommendations for further research

Although the research provides an overview of the developments of the ESD CO2 emissions in the period 2005-2020, there is still room for further research in the field. Future research could look into the development of non-CO_2 greenhouse gases emissions in the ESD sectors. These emissions are particularly abundant in the agricultural sector (CH_4) as well as in transport (N_2O) and therefore having a deeper understanding of their trends and projections might be crucial when designing policies for these specific sectors.

Furthermore, further research could use different indicators in the decomposition analysis of the ESD sectors. For example, in the case of the residential sector, researchers use number of households as a volume indicator. This would enable the researchers to get insights on a possible structure effect due to a variation in the number of people per households. This is just an example of other possible indicators which could be used in decomposition analysis for explaining potential structure effects. Another interesting insight could be gained by looking into the development of the energy mix in the ESD subsectors. When data is available, researchers could potentially find an effect correlated with a change in the emissions due to a change in the type of fuel used in the sector.

7 Conclusion & Policy implications

7.1 Conclusion

The research question posed at the beginning of the thesis states: *To what extent can the ESD be considered a successful policy framework which contributed to a reduction of the non-ETS CO_2 emissions? What are the main explanatory factors for EU member states regarding the progress they make in meeting their effort sharing target?*

It can be stated that the analysed MS are in line with the target established in 2009. The reason for this achievement can be correlated with different factors depending on the MS. In certain sectors, the main reason for a reduction in the emissions can be correlated to an overall reduction of the CO_2 intensity of the subsector (decarbonization). It cannot be stated with certainty which factors is responsible for this decarbonization, however it can be hypothesized that the different energy efficiency policies, together with recent technological development, could have contributed to this event. It can be also hypothesized that the projections from the previous PRIMES scenarios, on which Harmsen et al (2011) based its results presented a more pessimistic scenario. The results are thus encouraging for the achievement of the 2030 target, however the increase in volume in many subsectors might be a problem in case energy efficiency could not be further improved, thus it might be important to further diversify the future policies to also target a reduction in volumes.

7.2 Policy implications

The research can be of valuable use when designing the next policies for the 2030 target. The identity for the decomposition analysis can be further used with new data when assessing the development of the ESD target in 2030. The model developed can also be of further use in quantifying the distance from the 2030 target. The method used in this thesis, combining quantitative and qualitative analysis can be a valuable tool when assessing the future impact of policies designed for the next target. Additional policies targeting volume reduction, although being extremely unpopular in certain cases, would stimulate additional reduction in CO_2 emissions and would target an effect which has shown to be growing the past years. Finally, expecting an eventual plateau in the efficiency of a sector, it is necessary to diversify the type of measures that need to be implemented to tackle CO_2 emissions in the ESD sectors.

Acknowledgements

I would like to thank dr. Robert Harmsen for being a patient and consistent supervisor. Thank you for supporting me in this long and difficult stage of my academic carrier. A special mention goes to my colleagues from the Green Office, Anjelle, Roy, Emily, Madeleine, Tamar, Libby, Marenthe, George, Fay, Annemijn, Elsa, Tessa, Sake, Sandra, Josep, Michiel. To my housemates Gregorio, Julen, Pascal, Giovanni and all the others who supported me in this period and helped me in my personal development throughout this journey. In the infinite list of people, I am grateful to know, I would especially like to thank my girlfriend for all the support in these months. Thanks to my always present and imperfect family and thanks to all my friends spread around Europe (Utrecht, Genova, Amsterdam, London, Berlin, Brussels, Maastricht etc..) I am simply grateful to have you.

8 References

Anagnostopoulos, F. (2013). *Estimation and decomposition of Member States' distance to the Effort-Sharing Decision Targets in 2020* (Master's thesis).

Ang, B.W. (2004). Decomposition analysis for policymaking in energy: which is the preferred method? *Energy Policy*, 32: 1131–1139.

Ang, B. W. (2005). The LMDI approach to decomposition analysis: a practical guide. *Energy policy*, *33*(7), 867-871.

Capros, P., Mantzos, L., Parousos, L., Tasios, N., Klaassen, G., & Van Ierland, T. (2011). Analysis of the EU policy package on climate change and renewables. *Energy policy*, *39*(3), 1476-1485.

Capros, P., Mantzos, L., Papandreou, V., & Tasios, N. (2008). European energy and transport. *Trends.*

Capros, P., De Vita, A., Tasios, N., Siskos, P., Kannavou, M., Petropoulos, A., ... & Paroussos, L. (2016). EU Reference Scenario PRIMES 2016-Energy, transport and GHG emissions Trends to 2050.

European Commission (EC). (2011). A roadmap for moving towards a competitive low carbon economy in 2050. *COM*, 112.

European Environment Agency (2017). *Monitoring CO2 emissions from passenger cars and vans in 2015* (Publication No. 19/2017). doi:10.2800/9879

European Environment Agency. (2017). Approximated greenhouse gas emissions in 2016. Retrieved May 25, 2018, from https://www.eea.europa.eu/publications/approximated-eu-greenhouse-gas-inventory-2016

European Parliament and European Council, 2009. 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 GHG Emissions to Meet the Community's GHG Emission Reduction Commitments up to 2020.

European Parliament and European Council, 2009. Decision No 443/2009EC of the European Parliament and of the council on setting emission performances standards for new passenger cars as part of the Community's integrated approach to reduce CO2 emissions from light-duty vehicles.

European Parliament and European Council 2999. 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

European Parliament and European Council 2018. Regulation (EU) 2018/842 of the European Parliament and of the Council of 30 May 2018 on binding annual greenhouse gas emission reductions by Member States from 2021 to 2030 contributing to climate action to meet commitments under the Paris Agreement and amending Regulation (EU) No 525/2013

European Parliament and European Council 2005. Directive 2005/32/EC of the European Parliament and of the Council of 6 July 2005 establishing a framework for the setting of ecodesign requirements for energy-using products and amending Council Directive 92/42/EEC and Directives 96/57/EC and 2000/55/EC of the European Parliament and of the Council

European Parliament and European Council 2010. Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings

European Union, European Commission (EC). (2016). *Report from the Commission to the European Parliament and the council on evaluating the implementation of Decision No. 406/2009/EC pursuant to its Article 14* (pp. 1-9). Brussels, BE.

Eurostat (2018). Primary production of energy by type. Retrieved October 5, 2018 from https://ec.europa.eu/eurostat/web/main/home

Hast, A., Ekholm, T., & Savolainen, I. (2013). Meeting emission targets under uncertainty—the case of Finnish non-emission-trading sector. *Mitigation and adaptation strategies for global change*, *18*(5), 637-658.

Harmsen, R., Eichhammer, W., & Wesselink, B. (2011). Imbalance in Europe's Effort Sharing Decision: Scope for strengthening incentives for energy savings in the non-ETS sectors. *Energy policy*, *39*(10), 6636-6649.

Liddle, B. (2004). Demographic dynamics and per capita environmental impact: Using panel regressions and household decompositions to examine population and transport. *Population and Environment*, *26*(1), 23-39.

Longo, M. (2013). *The Italian effort under the EU Effort Sharing Decision: impact assessment of economic crisis and policy framework in the current and expected progress* (Bachelor's thesis, Università Ca'Foscari Venezia).

Ministero dello Sviluppo Economico (MiSE) (2017). National Energy Strategy [Dataset]. Retrieved September 12, 2018, from :https://www.sviluppoeconomico.gov.it/index.php/en/202-news-english/2037432-national-energy-strategy

Netherlands Enterprise Agency (NEA) (2018). The Netherlands: list of fuels and standard CO_2 emission factors version of January 2018.

Odysee- MURE database publications. Sectoral Profile - Transport. (2018). Retrieved from http://www.odyssee-mure.eu/publications/efficiency-by-sector/transport/distance-travelled-by-car.html

UNFCCC (2017a) Germany, The Federal Minister for the Environment, Nature Conservation, and Nuclear Safety. (2017). Germany 's Third Biennial Report under the United Nations Framework Convention on Climate Change 2017. Retrieved October 29, 2018, from

unfccc.int/files/national_reports/biennial_reports_and_iar/submitted_biennial_reports/application/pdf/65021783_germany-br3-1-171220_3__biennial_report_to_unfccc.pdf

UNFCCC (2017b), Italy, Ministry for the Environment and protection of land and sea. (2017). Italy's Third Biennial Report under the United Nations Framework Convention on Climate Change. Retrieved on 29 October 2018, from : http://unfccc.int/files/national_reports/biennial_reports_and_iar/submitted_biennial_reports/application/pdf/132867045_italy-br3-1-br3_2017_italy.pdf

UNFCCC (2017c) The Netherlands, Ministry of Economic Affairs and Climate Policy. (2017). The Netherlands Third Biennial Report under the United Nations Framework Convention on Climate Change. Retrieved on 29 October 2018, from http://unfccc.int/files/national_reports/biennial_reports_and_iar/submitted_biennial_reports/application/pdf/625803941_netherlands-br3-1-the_netherlands_third_biennial_report_under_the_unfccc.pdf

Verdonk and Hof (2013), Non-ETS emission targets for 2030. PBL publication number 1192, PBL Netherlands Environmental Assessment Agency, The Hague.