Master's Thesis - master Energy Science

DECOMPOSITION ANALYSIS OF DUTCH AND EUROPEAN ENERGY SCENARIOS

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Abstract

Information about potential implications and uncertainties in the future is necessary to develop successful long-term energy policy. Energy scenarios are a tool to gather this information. Because of rapidly changing drivers, e.g. economic growth, demographic changes and new policies, these energy scenarios are updated on a regularly basis. The impact of these drivers remains mostly unexplained. This research aims at unravelling the impact of these drivers on the outcome of energy scenarios. This report focusses on the specific case of the impact of drivers on the expected CO_2 emission in the Netherlands. Since energy scenarios are developed on different scales, the Dutch Energy Outlook (NEV) of 2014, 2016, and the EU Reference Scenarios of 2013 and 2016 are compared. Getting a better understanding of the impact of these drivers could help harmonise policies between the EU and the Netherlands.

First a trend analysis was carried out in order to identify major differences between the scenarios. Based on this trend analysis, hypotheses about the impact of the drivers were drawn. By conducting a decomposition analysis these hypotheses were checked and the impact of the drivers was quantified. In order to get a more detailed conclusion, the scenarios were not only decomposed on a national level but also on sectoral level.

From this research it can be concluded that economic growth and changes in energy consumption due to new policies, had the largest influence on the expected CO_2 emissions in 2030. Comparing the scenarios between themselves shows that the major differences are within the NEV 2014 scenario, since it was still based on an outdated calculation model. From the comparison of the NEV 2016 scenario with the EU 2016 scenario it can be concluded, that however the total difference in CO_2 emissions is relatively small, the impact of the drivers, especially the expected GDP growth and development of energy efficiency, show larger differences.

When comparing the scenarios on a sectoral level, similar conclusions could be made. The total differences in CO_2 emissions are relatively small, which made it harder to track it down to a single driver. Most difference are explained by small differences in economic growth and new policies. Demographic changes turned out to have a minimal impact on the difference between the scenarios.

Keywords: energy scenarios, drivers, decomposition analysis, trend analysis

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1. Introduction

In 2015 more then 150 countries signed the Paris Agreement in which they agreed on several climate targets (United Nations, 2015). Energy policies play an important role in reaching these climate targets. Difficulties with implementing energy or climate policies are the long-term uncertainties. Therefore, successful long-term energy policy requires information about potential implications and uncertainties in the future (Ghanadan & Koomey, 2005). A potential way to gather this information is using energy scenarios.

Energy scenarios are updated on a regular basis. These updates are necessary because of rapidly changing drivers, e.g. economic growth, demographic changes and new policies, which lead to a change in the outcome of the scenarios (Sadorsky, 2009). These drivers differ between energy scenarios. However, what the impact of these different drivers is on the scenario remains mostly unexplained. The understanding of the impact of these drivers on the scenarios could help policymakers in better understanding the impact of policies and the outcomes of the scenarios (Smit, Hu, & Harmsen, 2014).

Unravelling the most important drivers of certain change is mostly done on a historical basis (Jeong & Kim, 2013; Xu, Fleiter, Eichhammer, & Fan, 2012). In some researches the most important drivers are identified in future energy scenarios. Agnolucci et al. (2010) analysed two radically different energy scenarios of UK's energy use towards 2050. Goal of this research was to analyse to most effective way, and thus most effective drivers, to reach a 60% greenhouse gas (GHG) emissions reduction (Agnolucci et al., 2007). Capros et al. (2014) used seven large energy models to find out the necessary drivers and costs to transform the energy system in order to meet emission targets.

Whereas those two researches compared drivers between different scenarios, Smit et al. (2014) compared the same energy scenario developed in different years. Their research aimed at explaining the difference between the EU 2013 and 2016 Reference Scenarios. Their study showed that the difference between the two scenarios could largely be explained by a combined impact of economic recession and new policies (Smit et al., 2014). However, there were also other effects causing the difference, but these effects remained mostly unexplained in the scenarios (Smit et al., 2014).

In this report a similar research is conducted, focussing on the specific case of the development of the CO_2 emissions in the Netherlands towards 2030. As one of the few EU member states The Netherlands has developed their own model, with their own drivers, to assess their climate policy. Every year this model leads to the Dutch Energy Outlook (Nederlandse Energieverkenning, NEV), which is published by the Dutch Government (PBL, 2014). The Netherlands is also modelled in the European PRIMES model (E3MLab, 2014). The PRIMES energy model is developed by the European Union (EU) in order to find out if the single member states are on track to meet the climate targets and to assess the European climate policy (European Commission, n.d.). The EU publishes the results of the PRIMES energy model in an EU Reference Scenario every three years (latest in 2016) (European Commission, 2016b).

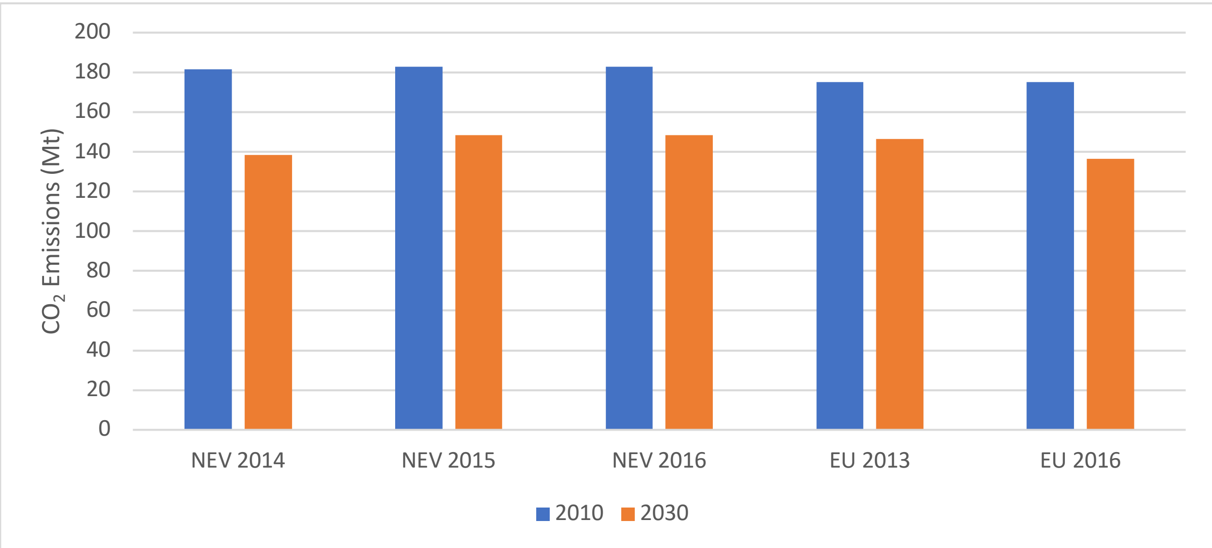

Figure 1. Development of the CO_2 emissions for all scenarios

As shown in Figure 1 these scenarios report a different amount of CO_2 emissions in 2010 and these difference between the scenarios is even bigger when comparing the expected CO_2 emissions in 2030. By comparing these five scenarios, this research aimed at unravelling the impact of the different drivers on the outcomes of the scenarios and thereby explaining the observed difference in outcome between the scenarios. This is done by answering the following research question:

How do different drivers contribute to the projected CO_2 emission in 2030 in several scenarios for the Netherlands and how can difference between the scenarios be explained?

In the next part of this research some background information about the NEVs and EU Reference Scenarios is given. Followed by a detailed method section in which is described how the research question will be answered. Next the results of the analysis are shown and interpreted. Next, potential consequences of the results are discussed and finally, the research question is answered.

2. Background Information

2.1 Dutch Energy Outlook (NEV)

From 2014 onward the Dutch Government (Ministry of Economic Affairs) commissions Energieonderzoek Centrum Nederland (ECN), Planbureau voor de Leefomgeving (PBL), Centraal Bureau voor de Statistiek (CBS) and the Rijksdienst voor Ondernemend Nederland (RVO) to write an energy outlook (PBL, 2014). The Dutch Energy Outlook (NEV) was published every year from then. The NEV sketches the current state of affairs regarding the Dutch energy system in an international context. Besides that, the NEV also provides an energy outlook based on two policy scenarios. The first one only including policies and measures that are already in force, the so called 'established policy' scenario. The 'intended policy' scenario however also includes policies and measures that are likely to be in force in the future. Since this research focusses on the NEV of 2014, 2015 and 2016, a short summary of the three is given in order to identify the major differences (ECN, PBL, CBS, & RVO, 2014, 2015, 2016).

2.1.1 NEV 2014

Since 2004 the total energy usage of the Netherlands decreases (ECN et al., 2014). In NEV 2014 it is expected that this decline will continue. Besides that, it is expected that the share of renewable energy will increase rapidly, due to the introduction of subsidies (PBL, 2014). This increase is however uncertain and very dependent on willingness to invest, public acceptance and cost. In the NEV 2014 is it also observed that GHG, and thus CO_2, emissions are decreasing. It is expected that this decrease will continue and therefore it is expected that the Netherlands will comfortably meet the European goal for GHG emissions. Looking at the economic perspective of the NEV 2014, a GDP growth of 30% is expected from 2010 towards 2030.

2.1.2 NEV 2015

In the NEV 2015 a few major observations are done (ECN et al., 2015). Firstly, the share of renewable energy will be increasing at an accelerated pace. The second observation is that although the energy usage and CO_2 emissions have decreased in 2013 and in NEV 2014 it was expected this decrease would continue, NEV 2015 is not certain this decrease will continue (PBL, 2015). From a policy perspective it is concluded that energy and climate policy should be considered on a long-term perspective, since the current short-term perspective makes it to precarious for the necessary innovations.

When comparing to the NEV 2014, four major reasons for differences in the outcomes are identified (ECN et al., 2015). One of them is the drastic decrease of the oil-price in 2015. Besides that, insights about the expected economic growth are adjusted, resulting in an expected GDP growth of 32% compared to 30% for NEV 2014. From a policy perspective two major developments took place in 2015. One of them is the concretion of the goals set in the Dutch Energy Agreement ('Energieakkoord' in Dutch). Secondly, it was decided to decrease the gas extraction in the north of the Netherlands, which has an influence on the energy mix.

2.1.3 NEV 2016

Five major observations are done in the NEV 2016 (ECN et al., 2016). The first observation is regarding the low electricity prices. Primary energy carriers as coal, gas and oil as well as electricity prices are expected to decrease even further then was expected in the NEV 2015. Where it was still the question if energy usage will decrease constantly in the NEV 2015, in NEV 2016 it is observed that this is likely to be the case, although this decrease will take place slower because of the expected increase in economic growth. Thirdly, NEV 2016 observes big differences in the impact of several measures. The development of sustainable energy production is one of the fastest, while the development of alternative heat supply has little impact yet. The two last observations are policy related. First it is observed that the proposed energy and climate policy will not have the desired impact, since it turns out to be hard to change the energy system. Besides that, it is observed that there is also a lot of uncertainty in the energy and climate policy of the other European countries. From an economic point of view the NEV 2016 is the most optimistic with an expected GDP growth of 34% from 2010 towards 2030.

2.2 European Energy Scenarios

European energy and climate policies are substantiated by thorough assessments and analyses (European Commission, 2018). For these assessments and analyses, the European Commission uses mathematical models and tools. One of these analysis tools is the EU Reference Scenario. This scenario is used by policy-makers, in the areas of energy, transport and climate action, in order to assess the effectiveness and evaluate the potential consequences of their policies. The EU Reference Scenario is based on the PRIMES model and published every three years (European Commission, 2013, 2016b). Figure 2 shows that the PRIMES model makes use of five different input sources in order to model the reference scenario. Three of them are projections or assumptions, while the other two, GDP and added value and energy import prices, are based on other models (Collins, Deane, & Ó Gallachóir, 2017). Since this research focusses on the EU Reference Scenarios of 2013 and 2016, a short summary of both scenarios is given in order to identify the major differences.

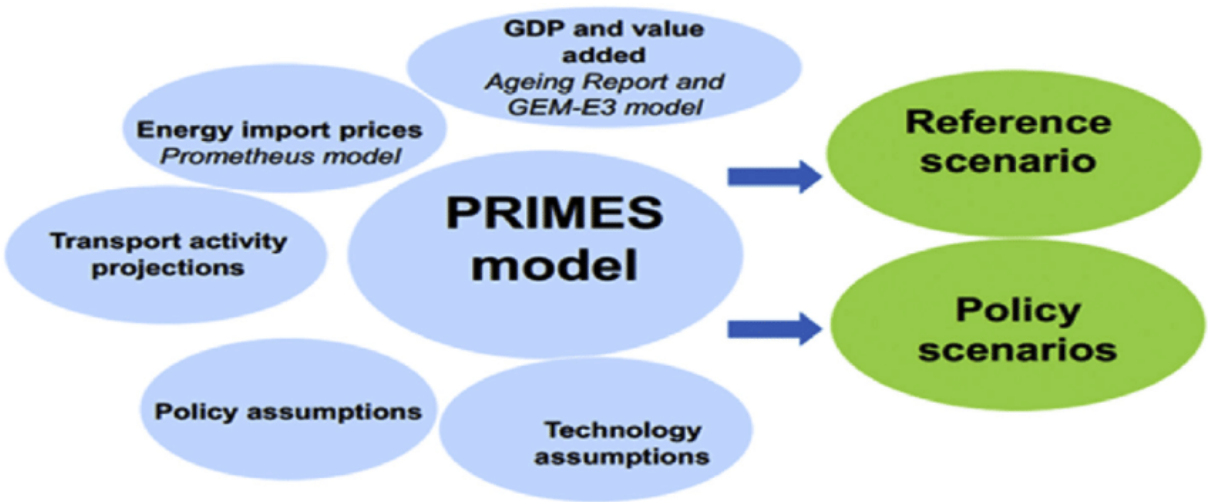

Figure 2. PRIMES model structure (Collins et al., 2017)

2.2.1 EU Reference Scenario 2013

In the EU Reference Scenario 2013 it is expected that the overall primary energy consumption will decrease, mostly caused by energy efficiency improvements (European Commission, 2013). Besides that, it is expected that the share of renewable energy will increase rapidly. By issuing less allowances, the European Commission also tries to decrease the GHG emissions (European Commission, 2013). The EU 2013 scenarios expected the GDP to increase with 30% from 2010 towards 2030.

2.2.2 EU Reference Scenario 2016

In the EU Reference Scenario 2016 it is expected that fossil fuel production will decrease (European Commission, 2016a). Due to a decrease in the net imports of fossil fuels as well, this will lead to a slightly increase in the EU's import dependency. Besides this, it is expected that the EU energy mix will change in the direction of renewables. So, the share of renewables is likely to increase thanks to an expected increase in the willingness to investment. Together with the expected improvements in energy efficiency this will lead to a decrease in CO_2 emissions. This decrease is however not expected to be large enough in order to meet long-term climate goals (European Commission, 2016b). The EU 2016 scenarios expected a similar GDP growth (30%) as the EU 2013 scenario.

3. Methods

The methods section consists of two steps. In the first step the scenarios are compared on a country-wide level. This is done by first conducting a trend analysis. The observed trends are then quantified by a decomposition analysis. In the second step also a decomposition analysis is used in order to compare the scenarios on a sectoral level.

3.1 Step 1: Country-wide comparison

3.1.1 Trend Analysis

First part of this step was to identify the influence of the drivers on the different scenarios. In order to do so a trend analysis was carried out. So, by conducting a trend analysis, potential effects, are plotted over time (from 2010 until 2030). 2010 was selected as a base year, since all scenarios use given numbers and no projections for this year. The trends of the CO_2 emissions were already plotted in Figure 1. Next, these observed trends in CO_2 emissions were explained by analysing the trends of the to four effects that are used in the decomposition analysis (Paragraph 3.1.2). The trends of the effects led to hypotheses about the impact of the effects on the outcomes.

3.1.2 Decomposition Analysis

In order to quantify the impact of the different drivers on the outcome of the EU Reference Scenarios and the NEVs and verify the hypotheses from the trend analysis, a decomposition analysis was conducted. Decomposition Analysis is a widely accepted mathematical tool for the analysis of environmental and energy related issues (Ang, 2004). Aggregated factors, in this research CO_2 emissions, are decomposed into their driving forces by applying decomposition analysis (Smit et al., 2014). Decomposition analysis is thus eminently suitable to not only identify the differences in drivers but also to quantify the impact of the different drivers on the outcomes.

In this research, Additive Log Mean Divisia Index (LMDI) decomposition is used. This specific decomposition method is preferred because it has no residual factor (Ang, Liu, & Chew, 2003). Besides that, additive decomposition is easier to interpret, since it provides an actual number as the difference. The CO_2 emissions of the scenarios are decomposed according to equation 1.

$$CO_2 = GDP * \frac{Final\ Energy}{GDP} * \frac{Primary\ Energy}{Final\ Energy} * \frac{CO_2}{Primary\ Energy} \quad [1]$$

From this equation, four effects are identified. The activity effect (1) refers to an increase in GDP. The intensity effect (2) refers to a change in the energy intensity. This effect is measured as a proportion between the final energy and GDP. Next, the efficiency effect (3) refers to the effect of energy efficiency improvements, which is seen as a proportion between the primary energy and the final energy. The last effect that was identified, is the emission-factor effect (4). This effect is measured as a proportion between the CO_2 emissions and the primary energy.

For the calculations of these effects, general equation 2 was used. The equations for the calculation of the single effects are shown in Appendix I.

$$\Delta\, CO_{2_x} = w\, ln\, (\frac{x^T}{x^0}) \text{ (Additive)} \quad [2]$$

Where $w = \frac{C^T - C^0}{\ln C^T - \ln C^0}$

In this equation, C refers to the CO_2 emissions and x refers to one of the four effects. Superscript 0 and T refer to the base and end year of the decomposition period, respectively 2010 and 2030.

When the single effects were calculated, the total change in CO_2 emissions ($\Delta CO_{2_{tot}}$), was calculated according equation 3.

$$\Delta CO_{2_{tot}} = CO_2{}^T - CO_2{}^0 = \Delta CO_{2_{act}} + \Delta CO_{2_{ins}} + \Delta CO_{2_{eff}} + \Delta CO_{2_{emf}} \quad [3]$$

Final step is the comparison of the scenarios. An overview of all the different energy scenarios that are compared is shown in Table 1. In this research only the 'established policy' NEV scenarios are used, in order to make a fair comparison with the EU Reference Scenario. The EU Reference Scenario namely also only uses policies that are agreed on before the scenario is modelled (European Commission, 2013).

Table 1

Overview of energy scenario comparison possibilities

Comparison	Scenario 1	Scenario 2
1	NEV 2014	NEV 2015
2	NEV 2015	NEV 2016
3	EU Reference Scenario 2013	EU Reference Scenario 2016
4	EU Reference Scenario 2016	NEV 2016

In order to compare the scenarios, the single effects (ΔCO_{2_x}) of the scenarios were subtracted. Doing this provided insights in how much the development of the CO_2 emissions in both scenarios were in line with each other. In other words, when two scenarios have an equal difference in CO_2 emissions in 2010 and 2030, the development of CO_2 emissions is in line with each other. By subtracting the single effects of the two scenarios, it is however determined if this development is caused by the same drivers and how big the contribution of these drivers is. This way conclusions were drawn about the differences in impact of the drivers.

3.1.3 Data availability

A decomposition analysis is only possible when indicators used to calculate the effects are reported in the same unit. In other words, the efficiency effect of the Netherlands cannot be decomposed if the NEV reports primary and final energy use in PJ and the EU Reference Scenario reports in kilo tonnes of oil equivalent (ktoe). Table 2 provides an overview of the indicators and their reported unit. These indicators are already linked to one of the four effects.

Table 2

Data availability for LMDI Decomposition Analysis of the NEVs

Effect	Potential Indicator	Unit NEV	Unit EU Ref Scenario
Activity Effect	GDP	Index (base year: 2013, 2014 and 2016)	Index (base year: 1990)
Intensity Effect	Final Energy Use	PJ	ktoe
Efficiency Effect	Primary Energy Use	PJ	ktoe
Emission-factor effect	CO_2 Emissions	Mt of CO_2	Mt of CO_2

From Table 2 it becomes clear that both the NEV and EU Reference Scenario use index numbers to report the GDP. For the EU scenarios it is however known that the EU 2013 scenarios uses '10€ and the EU 2016 scenario uses '13€. In order to check if the base year values were comparable, a GDP deflator was used (The World Bank, 2019). The '10€ from EU 2013 were converted into '13€ from EU 2016 scenario. It turned out that the values show a marginal difference after deflating, so the index numbers were assumed to be comparable. This check could not be carried out for the NEV comparison, since no absolute GDP value was reported.

The scenarios however, all use another base year for the index numbers. These numbers are therefore converted to the same base year. This was done according to equation 4.

$$New\ Index\ Number = \frac{Old\ Index\ Number}{New\ Base\ Year\ Number} * 100 \qquad [4]$$

Next to that the NEV and EU Reference scenario do not use the same unit to report the final and primary energy use. Equation 5 is used to convert kilo tonnes of oil equivalent (ktoe) into peta joules (PJ).

$$Energy\ Consumption\ (PJ) = 0.041868 * Energy\ Consumption\ (ktoe) \qquad [5]$$

3.2 Step 2: Sectoral Comparison

3.2.1 Data Availability

In order to gain deeper insights in the impact of the drivers on the outcomes of the scenarios, also a sectoral decomposition analysis was conducted. The six sectors that are decomposed are the following: Agriculture, Services, Residential, Transport, Industry and Power Generation. As stated, before a decomposition analysis is only possible when indicators used to calculate the effects are reported in the same unit. Table 3 provides an overview of the available data and their unit.

Table 3
Data availability sectoral comparison

Effect	Agriculture Sector			Services Sector		
	Indicator	*Unit NEV*	*Unit EU*	*Indicator*	*Unit NEV*	*Unit EU*
Activity	Sectoral Added Value	% of GDP	% of GDP	Sectoral Added Value	% of GDP	% of GDP
Intensity	Final Energy	PJ	ktoe	Final Energy	PJ	ktoe
Emission-factor	CO_2	Mt	Mt	CO_2	Mt	Mt
Effect	**Residential Sector**			**Transport**		
	Indicator	*Unit NEV*	*Unit EU*	*Indicator*	*Unit NEV*	*Unit EU*
Activity	Households	Million	Million	Final Energy/ Passenger Distance (PD)	PJ	Gpkm
Structure	n/a			PD per transport way	n/a	Gpkm
Intensity	Final Energy	PJ	ktoe	Final Energy	n/a	ktoe
Emission-factor	CO_2	Mt	Mt	CO_2	Mt	Mt
Effect	**Industry Sector**			**Power Generation Sector**		
	Indicator	*Unit NEV*	*Unit EU*	*Indicator*	*Unit NEV*	*Unit EU*
Activity	Sectoral Added Value	% of GDP	% of GDP	Power Generation	n/a	PJ
Structure	Sub-sectoral Added Value	n/a	% of GDP	n/a		
Intensity	Final Energy	ktoe	PJ	n/a		
Efficiency	n/a			Fuel Input	n/a	ktoe
Emission-factor	CO_2	Mt	Mt	CO_2	Mt	Mt

When necessary the units were converted using equation 4 and 5. Besides this, to make the decomposition analysis as elaborated as possible, it is preferable to use indicators with the same unit on the highest detail level as possible.

3.2.2 Decomposition Analysis

From Table 3 it turned out that the NEV scenarios and EU Reference Scenarios do not report on the same level of detail. In general, it can be concluded that the EU Reference Scenario is more detailed. This made that the decomposition equations for the EU Reference Scenario could be more detailed for the transport and industry sector. For the comparison of the NEV 2016 with the EU 2016 the EU 2016 is also decomposed according to the more simplistic equations of the NEV scenarios.

For the decomposition of the agriculture and services sector equation 6 was used for both the NEV as EU scenarios. From the decomposition equation an activity, intensity and emission-factor effect could be identified.

$$CO_2 = Sectoral\ Added\ Value * \frac{Final\ Energy}{Sectoral\ Added\ Value} * \frac{CO_2}{Final\ Energy} \qquad [6]$$

For the decomposition of the residential sector a similar equation is used (Equation 7). Difference is in the fact that sectoral added value has no direct link to the residential sector and the number of households is used as an activity indicator. The identified effects are similar to the agriculture and service sector.

$$CO_2 = Households * \frac{Final\ Energy}{Households} * \frac{CO_2}{Final\ Energy} \qquad [7]$$

The decomposition of the transport sector in the NEV scenarios had an even more simplistic formula (Equation 8), since only the final energy consumption and corresponding CO_2 emissions were reported. Therefore, only an activity and emission-factor effect have been identified.

$$CO_2 = Final\ Energy * \frac{CO_2}{Final\ Energy} \qquad [8]$$

The EU Reference Scenario has reported the transport data with more detail, which made that the decomposition could be more detailed. In addition to the data that was also provided by the NEV scenarios, the EU scenarios also provide data about the passenger kilometres. Besides that, the data is split up in four transport options. Namely, road transport, aviation, rail transport and inland navigation. All together this led to the decomposition equation 9, in which *i* refers to the different transport options. The observed effects are similar to the effects observed at the other sectors.

$$CO_2 = \sum_i CO_2 = Passenger\ kilometres_i * \frac{Final\ Energy_i}{Passenger\ kilometres_i} * \frac{CO_{2_i}}{Final\ Energy_i} \quad [9]$$

For the NEV scenarios the industry sector was decomposed according to equation 6. In the EU scenarios the reported data about the industry sector was more detailed. Because of this the decomposition could be done over nine subsectors within the industry sector. This led to decomposition equation 10, in which *i* refers to the different subsectors. Again, the observed effects are the activity, intensity and emission-factor effect.

$$CO_2 = \sum_i CO_2 = Added\ value_i * \frac{Final\ Energy_i}{Added\ value_i} * \frac{CO_{2_i}}{Final\ Energy_i} \quad [10]$$

Finally, the power generation sector is decomposed. This is only done for the EU scenarios, since the NEV scenarios did not provide the necessary data. The Power Generation sector is decomposed according to equation 11. The observed effects are the activity, efficiency and emission-factor effect.

$$CO_2 = Power\ Generation * \frac{Fuel\ Input}{Power\ Generation} * \frac{CO_2}{Fuel\ Input} \quad [11]$$

Next part was decomposing the CO_2 emissions of the sectors into the single effects (ΔC_x) using additive decomposition (Equation 2). When the single effects were calculated, the total change in CO_2 emissions ($\Delta CO_{2_{tot}}$), was calculated according equation 3.

Final step is the comparison of the scenarios, which is done similar to the comparison of the scenario's on country-wide level. So, the single effects (ΔCO_{2_x}) of the scenarios were subtracted in order to draw conclusions about the impact of the drivers on the difference in outcome.

4. Analysis Results

4.1. Country-wide Decomposition

4.1.1 Trendline Analysis

In Figure 1 the projected CO_2 emissions for all scenarios were plotted, Table 4 provides a summary of Figure 1. In general, it can be concluded all scenarios follow a decreasing trend over the years. Besides that, a few more things were noticed. Comparing the EU scenarios with the NEV scenarios, the EU scenarios have a lower starting point caused by different calculation methods. The NEV 2014 and EU 2016 showed the largest decrease over the years.

Looking even more in detail, it is also noticeable that not all NEV scenarios start at the same amount of CO_2 emissions. To be precise, the NEV 2014 estimated the CO_2 emissions in 2010 lower that the other two NEV scenarios. This difference could be explained by the difference in guidelines for calculating emissions. The NEV 2014 uses the IPCC Guidelines of 1996 whereas from NEV 2015 onwards they were updated to the IPCC Guidelines of 2006 (ECN et al., 2014, 2015).

Table 4
CO_2 Development of all scenarios

	NEV 2014	NEV 2015	NEV 2016	EU 2013	EU 2016
2010	181.5	182.7	182.8	175.2	175.0
2030	138.4	148.5	148.5	146.6	136.5
Decrease	-43.1	-34.2	-34.3	-28.6	-38.5
% Decrease	-23.7%	-18.7%	-18.8%	-16.3%	-22.0%

The downwards trend in CO_2 emissions in all scenarios has to be explained by one or more of the four effects. In Figure 3 it can be noticed that the GDP, and therefore the activity effect, show an increasing trend and therefore counteracts the decreasing trend in CO_2 emissions. From Figure 3 it becomes clear the two European scenarios expect almost the same economic growth over the years. The NEV scenarios on the other hand, all follow roughly the same trend, but show small difference in outcomes.

Looking more in detail to the trends of the NEV scenarios it can be seen the GDP growth projects become more optimistic over the years. Explanation for this is found in the economic crisis which came about in 2008 and ended around 2013 (ECN et al., 2014). This made the expectations about economic growth modest in NEV 2014 and becoming more optimistic every year.

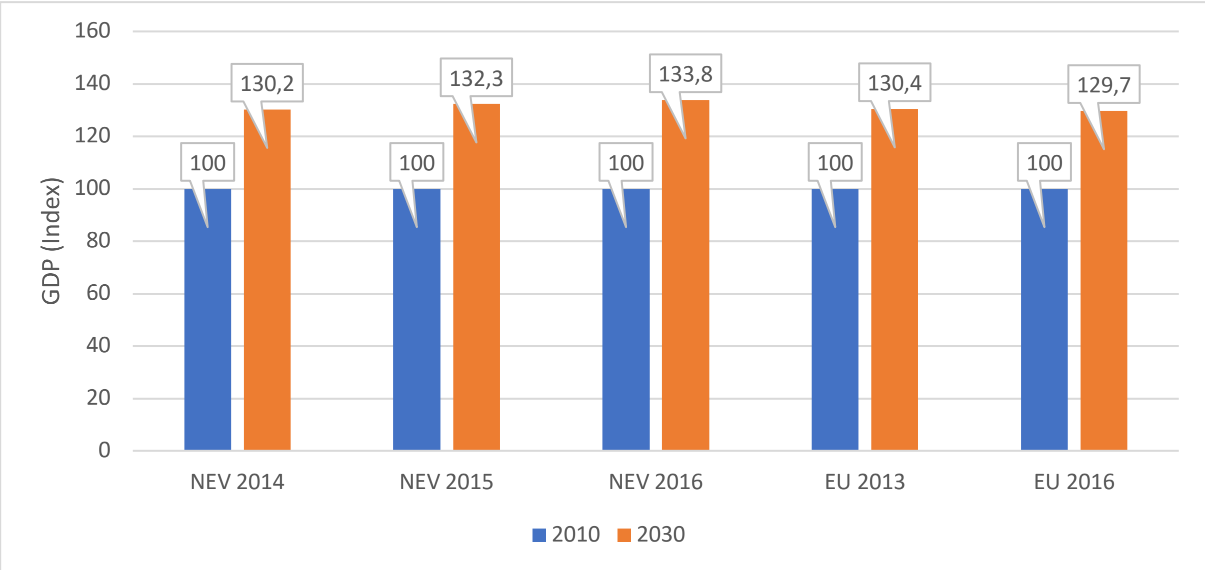

Figure 3. Expected GDP growth for all scenarios

Looking at the energy intensity (Final Energy Consumption over GDP), plotted in Figure 4, a clear decreasing trend is observed. It is observed that the NEV 2014 scenario has the highest energy intensity in 2030. This trend is partly explained by the modest GDP growth expectations. Looking to the data in more detail, it also turns out the NEV 2014 scenario expects the smallest decrease in final energy consumption, as is shown in Figure 5. This decrease becomes larger every next scenario. According to the NEV 2015 and 2016 this is the result of new established energy policy (ECN et al., 2015, 2016).

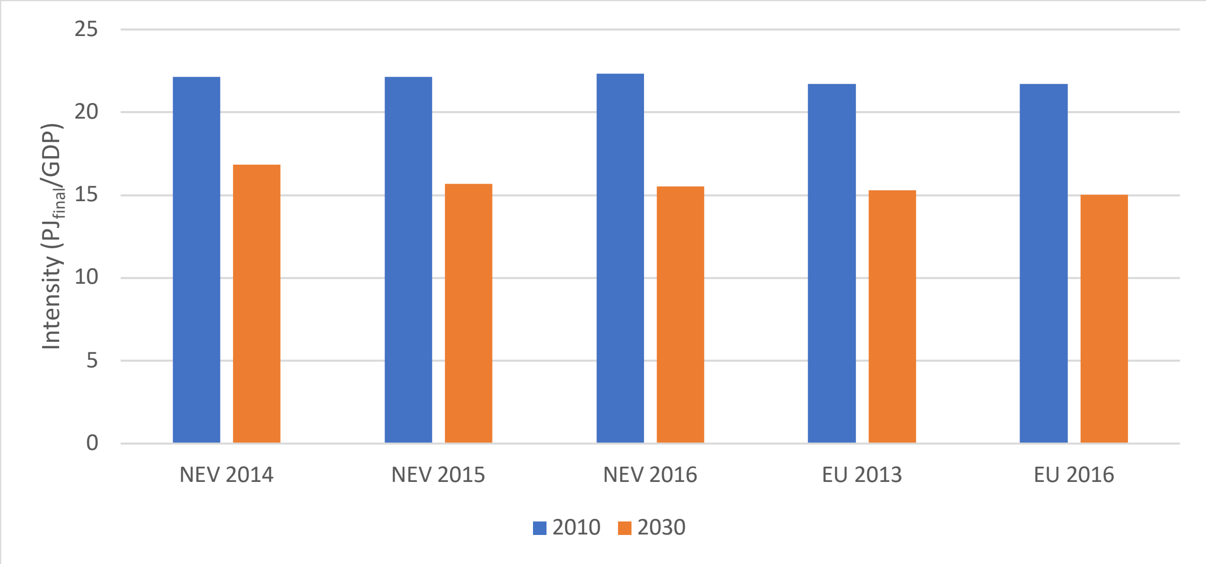

Figure 4. Energy Intensity over the year in all scenarios

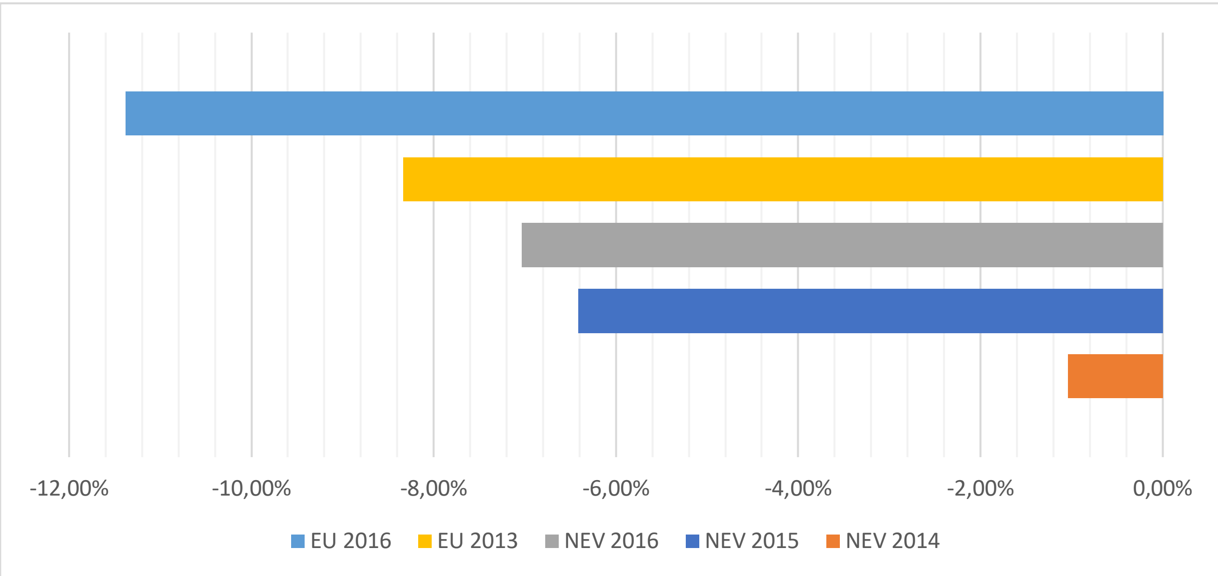

Figure 5. Expected percentage change in final energy from 2010 towards 2030

The energy efficiency (ratio between final and primary energy), plotted in Figure 6, shows more diverse trends. First thing to notice is the lower efficiency for the EU scenarios compared to the NEV scenarios. On first sight, an explanation for this would be expected in the power generation sector. Looking more in to detail however shows us the power generation sector in the EU scenarios is even slightly more efficient than in the NEV scenarios. Explanation for the lower efficiency on a national level therefore has to be in the other sectors, e.g. raw fuel use in the industry sector or gas consumption for heating in the residential sector.

Looking closer to the NEV scenarios, it is noticed that all three scenarios show an increase in efficiency. This increase is explained by two factors. First, the expected shift in the energy mix. Over the years a shift towards renewables is expected, so the share of renewables in the energy mix increases. Since renewables do not require any fuel input, the model uses an efficiency of 100% for renewables and therefore the total efficiency increases. Besides that, technological developments are expected to cause an increase in energy efficiency.

Looking more in detail to the EU scenarios, it stands out that the efficiency of European scenarios decreases in contradiction to the NEV scenarios. Explanation for this is found in the increasing share of the power generation sector on a national level. Although the efficiency of the power sector is expected to increase due to an expected shift in the energy mix and technological developments, the efficiency of the power generation sector is still below the whole country efficiency.

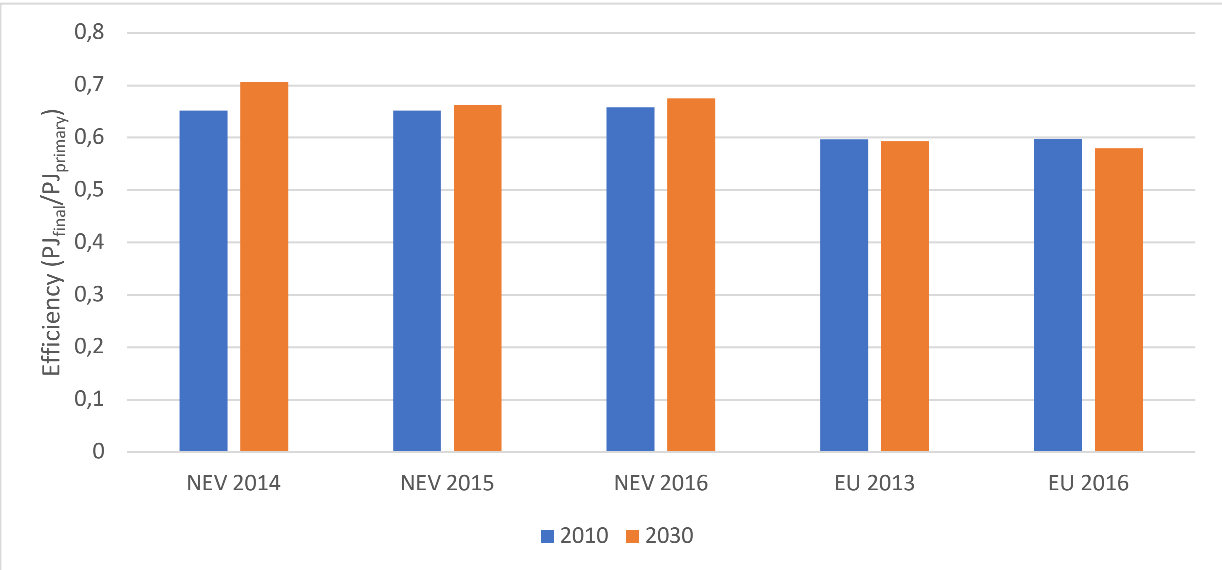

Figure 6. Expected efficiency (final energy over primary energy) development

Lastly, the emission-factor is plotted in Figure 7. In general, it is noticed that the emission-factor effect shows a downwards trend. It stands out that the EU scenarios have lower emissions factors in 2010 compared to the NEV scenarios. This is explained by the fact that the EU scenarios reported lower CO_2 emissions and higher primary energy use than the NEV scenarios. This difference in emission-factor is still there in 2030.

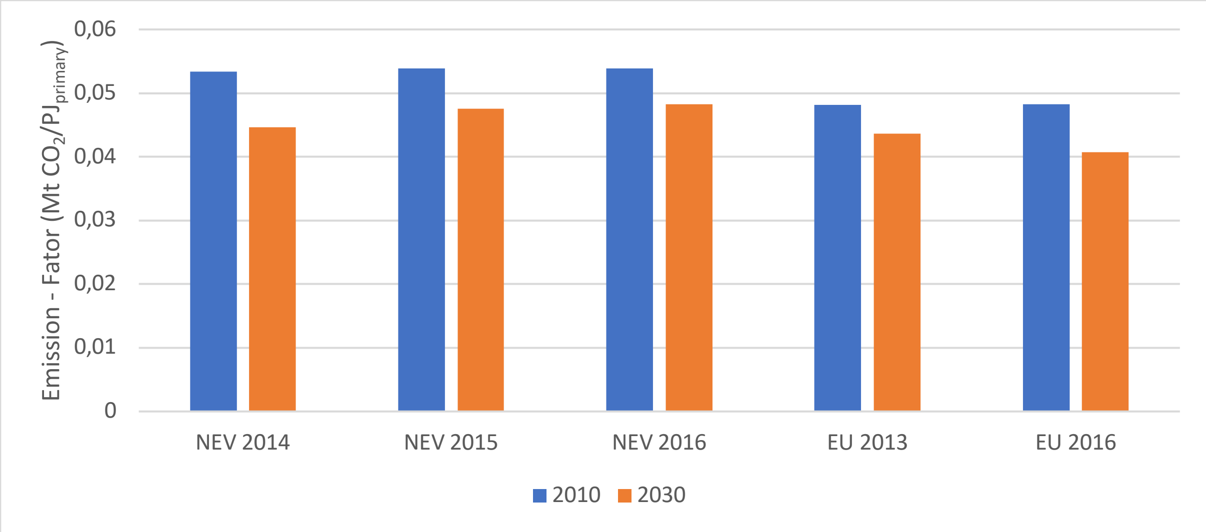

Figure 7. Emission-Factor over the years for all scenarios

As is shown in Figure 8 the difference in 2030 is largely explained by a difference in the energy mix. The NEV 2016 scenario, with the highest emission-factor, has a larger share in high carbon energy carriers (solids and oil) compared to the lowest emission-factor scenario, EU 2016, which has a larger share in natural gas and renewables. A similar difference in energy mix is shown in 2010, which explains how higher primary energy use for the EU scenarios led to lower CO_2 emissions, as was observed in Figure 7.

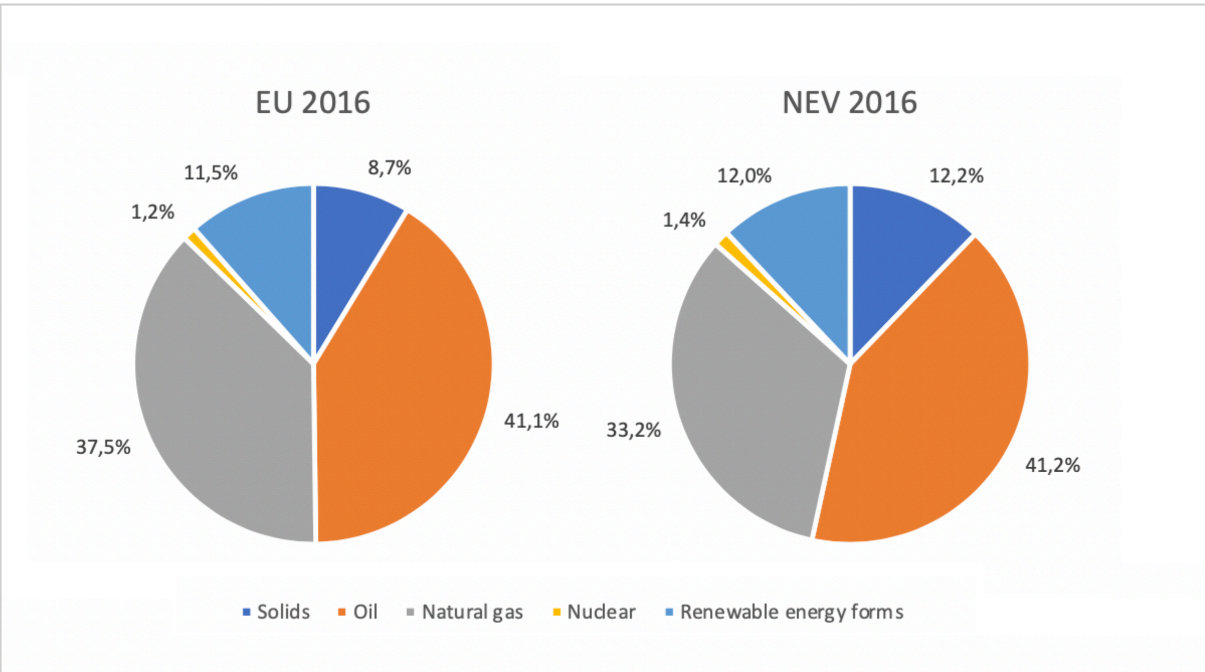

Figure 8. Primary energy-mix in 2030

Comparing the EU scenarios, it stands out that the 2016 scenario decreases more than the 2013 scenario. This is a reason for the difference in CO_2 emissions shown in Figure 1. Explanation for this difference is the change in energy mix. The EU 2016 scenario expects a larger shift towards renewables (European Commission, 2016b).

When comparing the NEV scenarios it is noticed that the 2014 scenario decreases more, resulting in a lower emission-factor in 2030 for the NEV 2014 scenarios compared to the NEV 2015 and 2016 scenarios. This difference is explained by the difference in guidelines for calculating emissions.

Combining all the observed trends, hypotheses about the potential influence of the effects on the CO_2 emission could be drawn. Table 3 explains the expected impact of every effect on the outcome.

Table 3

Expected impact on the development of CO_2 emissions

	NEV 2014	NEV 2015	NEV 2016	EU 2013	EU 2016
GDP Growth	+	+	+	+	+
Energy Intensity	-	-	-	-	-
Energy Efficiency	-	-	-	+	+
Emission-factor	-	-	-	-	-

Note: '+' = expects increasing CO_2 emissions and '-' = expects decreasing CO_2 emissions

4.1.2 Decomposition Results

NEV Scenarios

Results of the decomposition of the NEV scenarios are shown in Table 4. As was shown in Figure 1, all three scenarios show a decrease in CO_2 emissions. Besides that, the other effects are also in line with the observed trends in Table 3. The activity effect increases over the years, due to more optimistic expectations about GDP growth. From this it is concluded the driver economic growth has a positive impact on the expected CO_2 emissions. The intensity effect shows a decrease, due to an increase in final energy savings. Since energy savings mainly the results of policies it is concluded the driver policy has a negative impact on the outcome. The same could be said about the emission-factor effects, which is mainly the result of policy as well. All three scenarios show a negative effect. The relatively big effect for the NEV 2014 scenarios is explained by the difference in guidelines for the calculations of the emission-factor.

The efficiency effect also shows, as expected from trend analysis, negative values. Negative values are expected because of a shift in energy production towards renewables, caused by policies. Besides that, technological developments are a driver as well, resulting in more efficient energy conversions. Noticeable is also the relatively big efficiency effect for the 2014 scenario. Although the 2014 scenario expected the primary energy to decrease, the final energy is hardly decreasing compared to the other scenarios (Figure 5). Resulting in a higher efficiency. This minimal decrease of the NEV 2014 scenarios can be explained by the fact that only heat is expected to decrease, whereas the NEV 2015 and 2016 scenario also expect a decrease in electricity transport fuels.

Table 4
Decomposition Results NEV

	Activity	Intensity	Efficiency	Emission-factor	Total
Scenario					
2014	42.0	-43.6	-12.8	-28.6	-43.1
2015	46.1	-57.1	-2.6	-20.6	-34.2
2016	48.1	-60.1	-4.1	-18.2	-34.3
Comparison					
2014 - 2015	4.2	-13.4	10.2	8.0	8.9
2015 - 2016	1.9	-3.0	-1.4	2.4	-0.1

In Table 4 the results of the comparison of the NEV scenarios are also shown. As expected from the trend analysis, the difference between the 2014 and 2015 scenario is larger than the difference between the 2015 and 2016 scenarios. Explanation is again found in the difference in guidelines, which makes the comparison of 2014 and 2015 unfair according to ECN et al. (2015).

However, a few things are concluded from the comparison of the scenarios. The activity effect, and therefore the GDP growth, is the lowest in all comparisons and therefore has the smallest effect on the differences between the scenarios. On the other hand, the intensity factor, and therefore the growth in final energy use, is the largest in all comparisons and has the biggest impact. The intensity effect is also the only effect that always has a negative number, and therefore leads to less CO_2 emissions over the years.

EU Reference Scenarios

Results of the decomposition of the two EU scenarios are shown in Table 5. This table shows that, as was already noticed in the trend analysis, the 2016 scenario expected a larger decrease in CO_2 emissions than the 2013 scenario.

Table 5

Decomposition Results EU Reference Scenarios

	Activity	Intensity	Efficiency	Emission-factor	Total
Scenario					
2013	42.6	-56.6	1.2	-15.8	-28.6
2016	40.3	-57.2	4.8	-26.5	-38.5
Comparison					
2013 - 2016	-2.3	-0.6	3.6	-10.6	-9.9

This decrease has largely to do with a lower emission-factor, resulting in a large negative emission-factor effect. Besides that, the activity and intensity effect are negative as well and therefore contributing to a larger decrease. In other words, the bigger expected GDP growth and the larger expected decrease in energy consumption causes a negative effect. Both are explained by the modest expected GDP growth in the 2016 scenario compared to the 2013 scenario. Besides that, the 2016 scenario expects a larger decrease in final energy (Figure 5) due to energy policies (European Commission, 2016b). The efficiency effect however counteracts this. As was already expected from the trend analysis the EU 2013 scenarios showed a smaller increase in efficiency than the EU 2016 scenario.

NEV 2016 – EU 2016 Comparison

Finally, the decomposition results of the comparison of the EU 2016 and NEV 2016 scenarios are shown in Table 6. The relatively low difference in total effect show that although the NEV 2016 and EU 2016 scenarios have different starting and ending point, they follow roughly the same trend.

Table 6
Decomposition Results NEV 2016 – EU 2016 Comparison

	Activity	Intensity	Efficiency	Emission-factor	Total
Scenario					
NEV 2016	48.1	-60.1	-4.1	-18.2	-34.3
EU 2016	40.3	-59.0	5.1	-25.0	-38.5
Comparison					
NEV - EU	-7.8	1.2	9.2	-6.8	-4.2

In contradiction to the total effect, the single effects are relatively large from which can be concluded that the development of CO_2 emissions is influenced by different factor. As became clear from the trend analysis, the expected GDP growth from the EU 2016 scenario was modest in comparison to the other scenarios, since it reflects the legacies of the economic crisis longer (European Commission, 2016b). As shown in Table 6 this leads to a negative activity effect. In contradiction the efficiency effect shows large positive numbers, caused by the decrease in efficiency for the EU 2016 scenario, whereas the NEV 2016 expected the efficiency to increase due to technological developments and energy policies. Both scenarios expected a similar decrease in intensity and therefore final energy, resulting in a relatively small intensity effect. The emission-factor effects show a negative value for both scenarios. The emission-factor is however expected to decrease more in the EU scenarios and therefore contributing to lower CO_2 emissions in the EU 2016 scenario compared to NEV 2016. This is explained by the difference in energy mix (Figure 8).

4.2 Sectoral Analysis

In this part of the results the decomposition of the sectors of the scenarios is discussed. Decomposition was carried out according to the formulas described in Method section 3.2.2. Results are presented in tables and figures.

4.2.1 Agriculture Sector

In Table 7 the results of the decomposition of the agriculture sector are shown. Looking at the scenario decompositions it is noticed that the activity, so added GDP, of the agriculture sector is expected to decrease. Together with a decrease in emission-factor, this results in lower CO_2 emissions. It can be noticed that all scenarios, except the NEV 2016, expect an increase in intensity. Looking closer to the data it is however the case that all scenarios expect a decrease in energy use. So, the NEV 2016 is the only scenario were the energy consumption is expected to decrease more than the added GDP of the sector.

When focussing on the comparison of the scenarios, the biggest difference is between the EU 2016 and NEV 2016 scenario. NEV 2016 expects the CO_2 emissions to decrease with 51%, whereas the EU 2016 scenario only expects a decrease of 16%. Decomposition showed that both scenarios however showed a similar decrease in added GDP. The difference is therefore within the intensity and emission-factor. Difference in these two effects are caused by an increasing amount of biomass CHP installations in NEV 2016, stimulated by policy (ECN et al., 2016) resulting in an higher efficiency, so lower energy use and less CO_2 emissions.

Table 7
Decomposition Results Agriculture Sector

	Activity	Intensity	Emission-Factor	Total
Scenario				
NEV 2014	-1.1	1.4	-2.6	-2.3
NEV 2015	-1.2	0.6	-2.1	-2.7
NEV 2016	-0.7	-0.8	-3.1	-4.6
EU 2013	-1.0	0.2	-1.0	-1.8
EU 2016	-0.8	0.5	-0.6	-1.0
Comparison				
NEV 2014 - 2015	-0.1	-0.8	0.5	-0.4
NEV 2015 - 2016	0.5	-1.4	-1.0	-1.9
EU 2013 - 2016	0.1	0.2	0.4	0.8
NEV 2016 - EU 2016	-0.1	1.3	2.5	3.6

4.2.2 Services Sector

The results of the decomposition of the services sector are shown in Table 8. In contradiction to the agriculture sector, all scenarios expect the added GDP for the services sector to increase, resulting in positive activity effects. Besides that, all scenarios expect a decrease in energy consumption and an even larger decrease in emissions, resulting in both a negative intensity and emission-factor effect. It is noticed that the EU scenarios have larger total effects and therefore expect a larger decrease in CO_2 emissions. Explanations for these differences are the difference in what is included in the service sector. Besides that, the EU 2016 scenario expect more effective policy stimulating the energy efficiency in the sector (European Commission, 2016b).

Table 8

Decomposition Results Services Sector

	Activity	Intensity	Emission-Factor	Total
Scenario				
NEV 2014	0.4	-1.9	-0.6	-2.1
NEV 2015	0.7	-1.8	-0.6	-1.7
NEV 2016	0.6	-1.9	-1.9	-3.3
EU 2013	0.2	-2.8	-4.5	-7.0
EU 2016	0.1	-2.8	-3.9	-6.5
Comparison				
NEV 2014 - 2015	0.3	0.1	0.0	0.4
NEV 2015 - 2016	-0.1	-0.1	-1.3	-1.6
EU 2013 - 2016	-0.1	0.0	0.7	0.5
NEV 2016 - EU 2016	-0.4	-0.9	-2.0	-3.2

4.2.3 Residential Sector

Table 9 provides the results of the decomposition of the residential sector. It is concluded that all scenarios expect an almost equal increase in households. The driver demographic changes therefore has a limited impact on the differences between the scenarios. The intensity and thus energy consumption is expected to decrease. Together with the decrease in emission-factor, this results in lower expected CO_2 emissions in 2030. When comparing the scenarios, the biggest difference is again within the NEV 2016 and EU 2016 scenario. As can be noticed from Table 9, this difference is mainly caused by a difference in intensity effect. Since both scenarios expect equal increase in activity the difference is in the expected energy consumption. Looking closer to the data, indeed shows that whereas the NEV 2016 expects the energy consumption to drop with 18%, the EU 2016 scenario only expects a drop of 10%.

Table 9

Decomposition Results Services Sector

	Activity	Intensity	Emission-Factor	Total
Scenario				
NEV 2014	2.2	-5.0	-2.7	-5.5
NEV 2015	2.1	-5.0	-2.1	-5.0
NEV 2016	2.1	-5.5	-2.2	-5.6
EU 2013	2.3	-4.2	-3.4	-5.2
EU 2016	2.1	-3.9	-2.4	-4.2
Comparison				
NEV 2014 - 2015	-0.1	0.0	0.6	0.5
NEV 2015 - 2016	0.0	-0.5	-0.1	-0.6
EU 2013 - 2016	-0.2	0.2	1.0	1.0
NEV 2016 - EU 2016	0.0	1.5	-0.2	1.4

4.2.4 Transport Sector

As explained in Method section 3.2.2, the decomposition of the transport sector was carried out in two parts. Table 10 provides the results of the first part, the decomposition of the NEV scenarios and the EU 2016 scenario to compare with the NEV 2016. From Table 11 it can be concluded that all scenarios expect a decrease in energy consumption and an even larger decrease in CO_2 emissions, resulting in negative activity and emission-factor effects. While the NEV 2016 and the EU 2016 scenario expect the same decrease in activity, the NEV 2016 expects a larger decrease in CO_2 emissions. An explanation for this difference is within the expected improvements of the fuel efficiency and stimulation of more efficient transport means, especially in passenger transport, driven by policies. NEV 2016 expects the policies to be more successful leading to less CO_2 emissions.

Table 10
Decomposition Results NEV and EU 2016 Transport Sector

	Activity	Emission-Factor	Total
Scenario			
NEV 2014	-1.8	-2.9	-4.7
NEV 2015	-3.2	-3.1	-6.3
NEV 2016	-4.7	-2.6	-7.3
EU 2016	-4.7	-1.6	-6.4
Comparison			
NEV 2014 - 2015	-1.4	-0.2	-1.6
NEV 2015 - 2016	-1.5	0.5	-1.0
NEV 2016 - EU 2016	-0.1	1.0	0.9

Table 11 provides the results of the decomposition of the EU scenarios. It is noticed that both scenarios expect a relatively large increase in activity. In other words, both scenarios expect the passenger kilometres to increase. Looking closer to the data, it is noticed this increase is mainly expected in the road and aviation transport. The energy consumption, is however expected to decrease even more, resulting in a negative intensity effect. Interesting to see is that this decrease in only caused by a decrease in energy consumption in the road transport sector. As Figure 9 shows, the energy consumption of all other ways of transport are expected to increase. The difference in total CO2 emissions is caused by the fact that the EU 2016 scenarios expects more successful policies leading to more efficient transport means (European Commission, 2016b).

Table 11
Decomposition Results EU Transport Sector

	Activity	Structure	Intensity	Emission-factor	Total
Scenario					
EU 2013	6.2	2.3	-10.7	-2.4	-4.6
EU 2016	6.9	1.4	-13.1	-1.6	-6.4
Comparison					
EU 2013 - EU 2016	0.6	-0.8	-2.4	0.9	-1.7

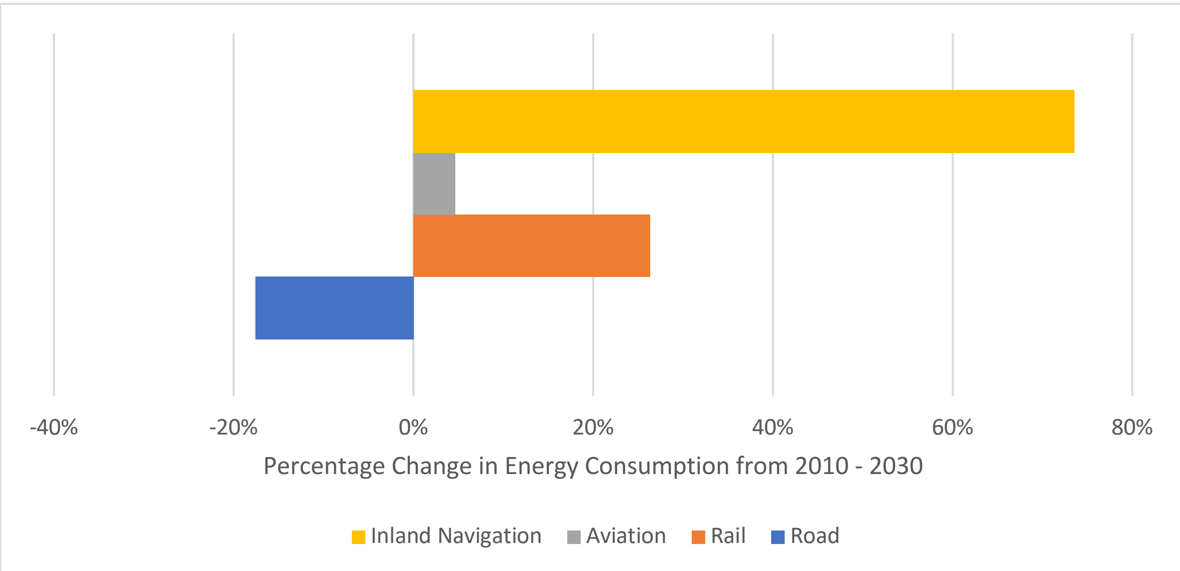

Figure 9. Change in Energy Consumption EU Transport Sector

4.2.5 Industry Sector

Again, the decomposition of the industry sector is split into two parts. Table 12 provides the results of the first part. The decomposition of the NEV scenarios and the EU 2016 scenario for comparison with NEV 2016. From the decomposition it is concluded that all scenarios expect a decrease in the share of GDP for the industry sector. Besides that, all scenarios except NEV 2014, expect a decrease in energy consumption. NEV 2014 expected a small increase in energy consumption as a response on the shrinking of the industry sector during the economic crisis (ECN et al., 2014). The decrease of energy consumption was in all scenarios lower than the expected decrease in the share of GDP, resulting in positive intensity effect. In all scenarios the emission-factor is also expected to decrease, resulting in a negative total effect for all scenarios. In other words, all scenarios expect a decrease in CO_2 emissions. When comparing the scenarios, it is noticed that the NEV 2014 shows the biggest differences. This is explained by the fact that this scenario is the only one with an expected increase in energy consumption.

Table 12
Decomposition Results NEV and EU 2016 Industry Sector

	Activity	Intensity	Emission-Factor	Total
Scenario				
NEV 2014	-0.2	1.5	-1.6	-0.4
NEV 2015	-1.5	1.1	-3.8	-4.2
NEV 2016	-1.2	0.9	-4.1	-4.4
EU 2016	-0.9	0.4	-2.6	-3.2
Comparison				
NEV 2014 - 2015	-1.3	-0.3	-2.2	-3.8
NEV 2015 - 2016	0.3	-0.2	-0.3	-0.2
NEV 2016 - EU 2016	0.3	-0.5	1.4	1.2

The results of the decomposition of the EU scenarios are shown in Table 13. As could be concluded from the positive activity effect, both scenarios expect an increase in value added. Most increase is expected in the chemicals, engineering and other industries. All other three effects are negative, which in total result in a decrease in CO_2 emissions. From comparing the data in more detail, it is noticed that this decrease does not happen in every industry. The chemical and other industries sector both expect an increase in CO_2 emissions, due to their large activity increase and energy consumption increase. The difference in emission-factor has mainly to do with the chemicals and food, drink and tobacco sector. In both sectors the 2013 scenario expected more CO_2 emissions, due to larger expected increase in activity.

Table 13
Decomposition Results EU Industry Sector

	Activity	Structure	Intensity	Emission-factor	Total
Scenario					
EU 2013	5.2	-2.7	-2.5	-1.3	-1.4
EU 2016	4.7	-1.0	-3.5	-3.3	-3.2
Comparison					
EU 2013 - 2016	-0.5	1.7	-1.0	-2.0	-1.8

4.2.6 Power Generation Sector

For the EU scenarios the results of the decomposition of the power generation sector are shown in Table 14. Both scenarios, expected an increase in power production, resulting in a positive activity effect. An explanation for the higher effect for the 2013 scenario is the higher expected GDP growth. The efficiency of both scenarios is expected to increase, due to energy policy and technological development. Besides that, the electricity production is expected to shift towards renewables. This not only ensures a higher efficiency but also decreases the CO_2 emissions. The difference in emission-factor can therefore also be explained by the fact that the EU 2016 scenario has a larger share in renewables and nuclear than the EU 2013 scenario.

Table 14
Decomposition Results EU Power Generation Sector

	Activity	Efficiency	Emission-Factor	Total
Scenario				
EU 2013	7.5	-13.0	-2.4	-7.8
EU 2016	7.1	-11.3	-10.9	-15.1
Comparison				
EU 2013 - EU 2016	-0.4	1.7	-8.6	-7.3

5. Discussion

5.1 Research Limitations

For this analysis, almost only data provided in the scenarios was used. Using this free to access data offers the reader the opportunity to check the calculations and numbers and therefore maximizes the transparency of this research. Using this data however also had a downside, especially for the comparison of the NEV 2016 with the EU 2016 scenario. Interpretation of the decomposition results was hard, because they did not make use of the same sectors or energy carriers. By splitting up and combining them, a decomposition analysis was still carried out successfully.

Next to that, the data provided by the scenarios was not always comprehensive, especially for the sector. As a result, the sector decomposition of the NEV could not always be based on the same equation as the EU scenario, which made it harder to compare.

5.2 Theoretical Implications

To the knowledge of the author, this was the first time a decomposition analysis was not only used to decompose difference between scenario based on the same model, but also compare scenario based on different models. Decomposition analysis has proven itself as a suitable tool to not only confirm the expected hypotheses from the trendline analysis, but also to quantify the impact of the different drivers on the outcome. A precondition for easy interpretations of the decomposition turned out to be using the same sectors and energy carriers.

In following research, it would be interesting to compare the underlying calculations models. A better insight in the underlying calculations could possible already provide explanations for the, in this research, observed differences. Besides that, this research has shown that the difference between the scenarios could not always be explained by the main drivers. Especially the efficiency effect showed some unexpected value, which were difficult to explain. For future research it would therefore be interesting to focus on the differences in efficiency between the scenarios and search for the underlying drivers.

5.3 Policy Implications

If one thing became clear from this research, it is the fact that scenarios change rapidly. Even the NEV model, which are updated every year, showed significant differences over the years. The same applies to the EU scenarios which are only updated every three years. Most of these differences can be explained by either policy (e.g. the change in heat production from gas towards electricity), economic drivers (e.g. GDP growth) or a change in the underlying calculations methods (e.g. change from IPCC guidelines in NEV 2015 compared to NEV 2014).

These scenarios however have a large influence on the intended policy. Since it takes some years to formulate and carry out policy it is very well possible that policies are based on scenarios that are already outdated and provided outdated information. For the formulation of policy, it is therefore of great importance that policymakers are aware of this. A better understanding of the drivers behind these scenarios could help policymakers place the older scenarios in a current-time perspective.

From the comparison between the Dutch and European scenarios it became clear both models have much in common but also differ on some essential points, of which the difference in efficiency development is the most striking. Where the Dutch policies seem to support energy savings and thereby cause a decrease in CO_2 emissions, the European policy has an opposite effect on the energy efficiency. These are the differences that could lead to friction between the policies proposed by the EU and the policies proposed by the Dutch government. A better understanding of the impact of the drivers on both scenarios could therefore lead to more harmonised policy between the EU and the Netherlands.

6. Conclusion

The objective of this research was to get a better understanding of the impact of different drivers, e.g. economic growth, demographic changes and new policies, on the outcomes of the EU Reference Scenarios of 2013 and 2016 and the NEV scenarios of 2014, 2015 and 2016. Differences between the scenarios were tried to be explained. In order to do so a trend and decomposition analysis was carried out.

It may be expected that especially the drivers of the NEVs of 2014, 2015 and 2016 and of the EU 2013 and 2016 scenario would not differ that much since they are based on the same model. However, analysing the NEV scenarios and the EU scenarios showed something else. From the trend analysis is became clear that these models develop every year and therefore show different trends in time sensitive effect such as GDP growth and energy consumption. Decomposition analysis confirmed that on a national level these two effects had the largest influence on the expected GHG emissions in 2030. From this it is concluded that the driver economic growth and new policies have the largest impact on the outcome of the scenarios. The impact of demographic changes is minimal, since no clear difference in demographic factors was identified between the scenarios.

Comparing the NEV scenarios between themselves it is concluded the NEV 2015 and 2016 scenario largely follow the same trend for every driver. The NEV 2014 however shows much more differences, especially on energy consumption, energy efficiency and emission-factor the difference are relatively large. According to the developers of the NEV this can be explained by a change in the underlying calculation models and guidelines (ECN et al., 2015). Differences between the NEV scenarios are mostly explained by changes in the expected economic growth and the implementation of new policies.

Comparing the EU scenarios, the difference in CO_2 emissions cannot be linked to one single driver but seems to be caused by small differences in all drivers. Biggest difference between the two scenarios is the much larger expected decrease in final energy use and therefore CO_2 emissions for the 2016 scenario, as a result of new energy policy.

Comparing the EU 2016 and NEV 2016 scenarios on a national level shows that however the total difference in CO_2 emissions is relatively small, the impact of the drivers on the outcomes seem to differ more. Especially the expected GDP growth and development of the energy efficiency show relatively large differences. The difference in expected GDP growth can be explained by the fact that the EU scenarios takes the implications of the financial crisis into account for a longer time period. The NEV 2016 already became more optimistic about the economic growth.

Looking into the sectors of the scenarios, provides similar insight about the single scenarios. However, the differences in outcomes are relatively small and therefore harder to be linked to single effects. They are mostly a result of small changes in both the economic drivers and new implemented policies.

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Appendix I: Country – wide Decomposition Formulas

Additive Decomposition

$$\Delta\, C_{act} = \; w \ln\left(\frac{GDP^{T}}{GDP^{0}}\right)$$

$$\Delta\, C_{int} = \; w \ln\left(\frac{Intensity^{T}}{Intensity^{0}}\right)$$

$$\Delta\, C_{eff} = \; w \ln\left(\frac{Efficiency^{T}}{Efficiency^{0}}\right)$$

$$\Delta\, C_{emf} = \; w \ln\left(\frac{Emission - factor^{T}}{Emission - factor^{0}}\right)$$

$$w = \frac{{CO_2}^{T} - {CO_2}^{0}}{\ln {CO_2}^{T} - \ln {CO_2}^{0}}$$