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# Model Low-Carbon Europe 2050

## Synthesis and decomposition analysis of long-term projections for die European Union and selected Member States

## ANNEX

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Synthesis and decomposition analysis of long-term projections for die European Union and selected Member States

**ANNEX**

by

Benjamin Greiner, Felix Chr. Matthes
Institute for Applied Ecology, Berlin

Vicki Duscha, Jakob Wachsmuth
Fraunhofer Institute for Systems and Innovation Research, Karlsruhe

On behalf of the German Environment Agency

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Umweltbundesamt
Wörlitzer Platz 1
06844 Dessau-Roßlau
Tel: +49 340-2103-0
Fax: +49 340-2103-2285
info@umweltbundesamt.de
Internet: www.umweltbundesamt.de

/umweltbundesamt.de
/umweltbundesamt

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Fraunhofer Institute for Systems and Innovation Research ISI
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# A Annex

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## A.1 Methodological approach

A comparative analysis of emission trajectories that result from different modelling exercises or approaches needs to reflect two different dimensions of the underlying modelling:

- It should identify the emission limitation or reduction contributions of different sectors or levers to the aggregate emission trajectory.

- An appropriate assessment of these contributions needs to consider the underlying driving forces that might be significantly different even for the case that the aggregate results show no significant differences.

Against this background the methodological approach of a decomposition analysis is used to identify driving forces and emission reduction levers of a broad range of scenarios analysis.

The starting point for the decomposition analysis is the methodology developed by Kaya (Kaya/Yokobori 1997), on the basis of which the total energy-related $CO_2$ emissions can be described as follows:

$$E = P \cdot \frac{V}{P} \cdot \frac{S}{V} \cdot \frac{E}{S} = P \cdot v \cdot s \cdot e$$

*with*

| | |
|---|---|
| *E* | *emissions* |
| *P* | *population* |
| *V* | *value added (gross domestic product)* |
| *S* | *primary energy use* |
| *v* | *specific value added per capita* |
| *s* | *economy-wide energy productivity* |
| *e* | *emission intensity of energy use* |

This basic analytical approach is extended in two directions for the aggregate as well as the sectoral decomposition analysis.

- Firstly, the approach is specified not only for the aggregate level of primary energy use[1] and total emissions but also for individual sectors or sub-sectors; and

- Secondly, the number of explanatory variables is increased (more complex set of energy carriers, carbon capture and storage) so that more of the key levers for emission reductions can be identified and classified.

Such a description of emission levels at the aggregate, a sector or sub-sector level can be formulated in a decomposition analysis using a more complex set of explanatory factors, as follows (if applied for economy-wide aggregate emissions, the primary energy supply should be used in terms of energy supply, otherwise the energy supply should be based on final energy supplies):

[1] It should be noted that the primary energy consumption in some analyses includes also the non-energy use of primary energy (as feed-stock for chemical processes etc.) and no sufficient information is provided that would allow for a consistent separation of this part of the total primary energy consumption. This might lead in some modelling exercises to a situation that a certain level of primary energy consumption from fossils fuels remains even for the case that $CO_2$ emissions are fully avoided and no use of CCS is considered. These inconsistencies lead, however, not to significant distortions of the results of the decomposition analysis for the regional aggregates that were included in the analysis presented in this study. A consistent separation of non-energy uses of primary energy is however an important point for future analyses.

$$E_i^s = A^s \cdot \frac{A_i^s}{A^s} \cdot \frac{ES_i^{tot}}{A_i^s} \cdot \frac{ES_i^{fos}}{ES_i^{tot}} \cdot \frac{E_i^{fos}}{ES_i^{fos}} - E_i^{cpt} = A^s \cdot a_i^s \cdot ep_i^{tot} \cdot es_i^{fos} \cdot e_i^{fos} - E_i^{cpt}$$

*with*

| | |
|---|---|
| $E_i^s$ | *emissions from sub-sector i in sector s* |
| $A^s$ | *driving force parameter (activity) for sector s* |
| $A_i^s$ | *driving force parameter (activity) for sub-sectors i in sector s* |
| $ES_i^{tot}$ | *total energy supply to sub-sector i* |
| $ES_i^{fos}$ | *total fossil fuel supply to sub-sector i* |
| $E_i^{fos}$ | *total emissions from fossil fuel use in sub-sector i* |
| $a_i^s$ | *share of sub-sector i in total activity of sector s* |
| $ep_i^{tot}$ | *energy productivity of sub-sector i* |
| $es_i^{fos}$ | *fossil fuel share in total energy supply to sub-sector i* |
| $e_i^{fos}$ | *emissions intensity of fossil fuel use in sub-sector i* |
| $E_i^{cpt}$ | *captured emissions from fossil fuel used in sub-sector i* |

In this way, both intersectoral shifts in activity (e.g. the modal shift in the transportation sector) and the different components which have intrasectoral effects can be described. However, the following derivations only refer to intrasectoral contributions to emission reduction.

Furthermore, the contribution to emission reduction of the fossil fuel share within the total energy use of a specific sector or sub-sector can also be indirectly specified via the shares of non-fossil energy carriers (including the secondary energy carriers of electricity, district/local heat and electricity-based fuels). For the decomposition analysis of economy-wide emission levels and primary energy supplies the terms for electricity, district/local heat and electricity-based fuels need to be applied for the net imports of these energy carriers.

$$es_i^{fos} = \frac{E_i^{tot} \cdot \left(1 - \frac{ES_i^{res}}{ES_i^{tot}} - \frac{ES_i^{nuc}}{ES_i^{tot}} - \frac{ES_i^{el}}{ES_i^{tot}} - \frac{ES_i^{dh}}{ES_i^{tot}} - \frac{ES_i^{ptx}}{ES_i^{tot}}\right)}{E_i^{tot}}$$

$$= 1 - es_i^{ren} - es_i^{nuc} - es_i^{el} - es_i^{dh} - es_i^{ptx}$$

*with*

| | |
|---|---|
| $E_i^{tot}$ | *total emissions from fossil fuel use in sub-sector i* |
| $ES_i^{res}$ | *use of renewable energies in sub-sector i* |
| $ES_i^{nuc}$ | *use of nuclear energy in sub-sector i* |
| $ES_i^{el}$ | *use of electricity in sub-sector i* |
| $ES_i^{dh}$ | *use of district heat in sub-sector i* |
| $ES_i^{ptx}$ | *use of electricity-based fuels in sub-sector i* |
| $es_i^{ren}$ | *share of renewable energies in energy use in sub-sector i* |
| $es_i^{nuc}$ | *share of nuclear energy in energy use in sub-sector i* |
| $es_i^{el}$ | *share of electricity in energy use in sub-sector i* |
| $es_i^{dh}$ | *share of district heat in energy use in sub-sector i* |
| $es_i^{ptx}$ | *share of electricity-based fuels in energy use in sub-sector i* |

According to these specifications the decomposition analysis can be based on the following identity:

$$E_i^s = A^s \cdot a_i^s \cdot ep_i^{tot} \cdot \left(1 - es_i^{res} - es_i^{nuc} - es_i^{el} - es_i^{dh} - es_i^{ptx}\right) \cdot e_i^{fos} - E_i^{cap}$$

*with*

| | |
|---|---|
| $E_i^s$ | *emissions from sub-sector i in sector s* |
| $A^s$ | *driving force parameter (activity) for sector s* |
| $a_i^s$ | *share of sub-sector i in total activity of sector s* |
| $ep_i^{tot}$ | *energy productivity of sub-sector i* |
| $es_i^{res}$ | *share of renewable energies in energy use in sub-sector i* |
| $es_i^{nuc}$ | *share of nuclear energy in energy use in sub-sector i* |
| $es_i^{el}$ | *share of electricity in energy use in sub-sector i* |
| $es_i^{dh}$ | *share of district heat in energy use in sub-sector i* |
| $es_i^{ptx}$ | *share of electricity-based fuels in energy use in sub-sector i* |
| $e_i^{fos}$ | *emissions intensity of fossil fuel use in sub-sector i* |
| $E_i^{cpt}$ | *captured emissions from fossil fuel used in sub-sector i* |

Based on this identity the decomposition analysis for the emission levers ($A^s$, $a_i^s$, $ep_i^{tot}$, $es_i^{res}$ etc.) is based on a hybrid approach using different methodologies for decomposition.

In a first round of analysis the contributions from all levers that are linked with multiplication ($A^s$, $a_i^s$, $ep_i^{tot}$, $es_i^{fos}$, $e_i^{fos}$) are analyzed with the Logarithmic Mean Divisia Index (LMDI) method.

$$\Delta E_m^s = \frac{E_{i_t}^s - E_{i_{t0}}^s}{\ln\left(E_t^s\right) - \ln\left(E_{t0}^s\right)} \cdot \frac{\ln\left(el_t^m\right)}{\ln\left(el_{t0}^m\right)}$$

*with*

| | |
|---|---|
| $\Delta E_m^s$ | |
| $E_{i_{t/t0}}^s$ | *total emissions from (sub-)sector s at time point t or $t_0$* |
| $el_{t/t0}^m$ | *emission lever m at at time point t or $t_0$* |

The LMDI approach is most suitable for multiplicative links and significant parameter differences (e.g. longer time horizons).

In order to analyze the additional additive links ($es_i^{res}$, $es_i^{nuc}$, $es_i^{el}$, $es_i^{dh}$, $es_i^{ptx}$) a combination of *Laspeyres* and *Paasche* decomposition is used.

The *Laspeyres* method is based on the two step approach showed below. The calculation of the residual contribution is necessary due to the fact that the *Laspeyres* approach usually leads an mixed effects residual.

$$\Delta E'^{s}_{m} = e\left(l^{1}_{t0},\ldots,l^{m-1}_{t0},l^{m}_{t},l^{m+1}_{t0},\ldots,l^{n}_{t0}\right) - E^{s}_{t0}$$

*with*

$\Delta E'^{s}_{m}$ *preliminary emissions contribution from lever m in (sub-)sector s from time point $t_0$ to t*

$E^{s}_{t0}$ *total emissions from (sub-)sector s in base period $t_0$*

$e$ *emission identity*

$el^{1\ldots m\ldots n}_{t/t0}$ *emission lever 1...m...n at time point t or $t_0$*

$$E^{s}_{r} = \sum_{i=1}^{n} \Delta E'^{s}_{i} - \left(E^{s}_{t} - E^{s}_{t0}\right)$$

*with*

$E^{s}_{r}$ *residual emission contribution for (sub-)sector s from time point $t_0$ to t*

$\Delta E'^{s}_{m}$ *preliminary emissions contribution from lever m in (sub-)sector s from time point $t_0$ to t*

$E^{s}_{t/t0}$ *total emissions from (sub-)sector s at time point t or $t_0$*

The *Paasche* method is based on the same two step approach but identifies the contributions starting from the future levels instead of the base period levels as in the *Laspeyres* method.

$$\Delta E'^{s}_{m} = E^{s}_{t} - e\left(l^{1}_{t},\ldots,l^{m-1}_{t},l^{m}_{t0},l^{m+1}_{t},\ldots,l^{n}_{t}\right)$$

*with*

$\Delta E'^{s}_{m}$ *preliminary emissions contribution from lever m in (sub-)sector s from time point $t_0$ to t*

$E^{s}_{t}$ *total emissions from (sub-)sector s at time point t*

$e$ *emission identity*

$el^{1\ldots m\ldots n}_{t/t0}$ *emission lever 1...m...n at time point t or $t_0$*

$$E^{s}_{r} = \sum_{i=1}^{n} \Delta E'^{s}_{i} - \left(E^{s}_{t} - E^{s}_{t0}\right)$$

*with*

$E^{s}_{r}$ *residual emission contribution for (sub-)sector s from time point $t_0$ to t*

$\Delta E'^{s}_{m}$ *preliminary emissions contribution from lever m in (sub-)sector s from time point $t_0$ to t*

$E^{s}_{t/t0}$ *total emissions from (sub-)sector s at time point t or $t_0$*

For significant parameter differences (e.g. longer time periods) the residual component for both, the *Laspeyres* and the *Paasche* method tends to reach significant levels. If however the single contributions (including the residual) are averaged, the residuals tend to very low levels or even zero. The remaining (small) residual from the combination of *Laspeyres* and *Paasche* is proportionally distributed among the single emission contributions:

$$\Delta E^{s}_{m} = \frac{\Delta E'^{s}_{m_L} + \Delta E'^{s}_{m_P}}{2} \cdot \left(1 + E^{s}_{r} \cdot \frac{1}{\sum_{i=1}^{n} \frac{\Delta E'^{s}_{i_L} + \Delta E'^{s}_{i_P}}{2}}\right)$$

*with*

$\Delta E^{s}_{m}$ *emissions contribution from lever m in (sub-)sector s from time point $t_0$ to t*

$\Delta E'^{s}_{m/i_{L/P}}$ *preliminary emissions contribution from lever m or i in (sub-)sector s from time point $t_0$ to t based on Laspeyres or Paasche approach*

$E^{s}_{r}$ *residual emission contribution for (sub-)sector s from time point $t_0$ to t*

All analysis described above does not reflect $CO_2$ that is produced but not released to the atmosphere. The contribution of $CO_2$ capture and storage is reflected in the decomposition analysis with the absolute quantities of $CO_2$ that are captured and stored between the base period and the relevant scenario point.

Practical experiences from comparisons between the different approaches for the decomposition analysis of scenarios for $CO_2$ emissions from fuel combustion show that the decomposition analysis using the LMDI approach tends to increase the levers with high or dominating contributions to the particular emission trends compared to the *Laspeyres/Paasche* approach. Small contributions to increasing emission trends or rather small emission abatement levers are rated higher with the *Laspeyres/Paasche* than with the LMDI approach in many cases.

For the analysis of economy-wide emission trends as well the sectoral decomposition for the electricity sector a pre-processing of data was carried out to avoid distortions that might result from statistical provisions on the accounting of electricity production from hydro, wind, solar energy and nuclear energy as well as electricity imports.

According to the statistical guidelines issued by the International Energy Agency and Eurostat, electricity production from hydro, wind and solar energy as well as (net) electricity imports is transferred into energy input respectively primary energy terms using an efficiency of 100%. For electricity production from nuclear energy in this context a standardized efficiency of 33% is used. Especially for high-renewables scenarios this might to statistical artefacts that significantly overestimate the role of energy productivity.

In order to avoid such distortions for the economy-wide and the electricity sector analysis the input data for the decomposition analysis were adjusted in a pre-processing step.

$$
\begin{aligned}
ES_i^{tot} = {} & ES_i'^{tot} - ES_{EG}'^{hyd} - ES_{EG}'^{sol} - ES_{EG}'^{wnd} - ES_{EG}'^{tid} - ES_{EG}'^{nuc} - ES_{imp}'^{el} \\
& + \left(EG^{hyd} + EG^{sol} + EG^{wnd} + EG^{tid} + EG^{nuc} + EI\right) \cdot \frac{ES_{EG}^{oth}}{EG^{oth}}
\end{aligned}
$$

*with*

| | |
|---|---|
| $ES_i^{tot}$ | *adjusted total energy supply to sector i* |
| $ES_i'^{tot}$ | *original total fuel supply to sector i* |
| $ES_{EG}'^{hyd}$ | *original fuel supply for electricity generation from hydro energy (excluding pumped hydro)* |
| $ES_{EG}'^{sol}$ | *original fuel supply for electricity generation from solar energy* |
| $ES_{EG}'^{wnd}$ | *original fuel supply for electricity generation from wind energy* |
| $ES_{EG}'^{tid}$ | *original fuel supply for electricity generation from tidal energy* |
| $ES_{EG}'^{nuc}$ | *original fuel supply for electricity generation from nuclear energy* |
| $ES_{imp}'^{el}$ | *original fuel supply for net electricity imports* |
| $ES_{EG}'^{oth}$ | *original fuel supply for electricity generation from other sources* |
| $EG_{EG}^{hyd}$ | *electricity generation from hydro energy (excluding pumped hydro)* |
| $EG_{EG}^{sol}$ | *electricity generation from solar energy* |
| $EG_{EG}^{wnd}$ | *electricity generation from wind energy* |
| $EG_{EG}^{tid}$ | *electricity generation from tidal energy* |
| $EG_{EG}^{nuc}$ | *electricity generation from nuclear energy* |
| $EI$ | *net electricity imports* |
| $EG_{EG}^{oth}$ | *electricity generation from other sources* |

For the inter-scenario comparison of emission reduction levers, a normalization is carried out in order to make the total emission reduction efforts consistent to the contribution of driving forces in a way that allows for robust comparisons that reflect comparable emission effects from driving forces at comparable activity levels.

In a first step of the normalization process, the effects from the driving forces on the total emission changes are made comparable.

$$\Delta E'_{tot_m} = E_{t_0} + \sum_{i=1}^{n} \left( \Delta E^{df}_{i_0} \cdot \frac{\Delta A^{df}_{i_n}}{\Delta A^{df}_{i_0}} \right) - E_t$$

*with*

$\Delta E'_{tot_m}$ *total adjusted emission reduction after effect from driving forces for scenario m*

$E_{t_0}$ *emission level for the start year* $t_0$

$\Delta E^{df}_{i_0}$ *emission contribution from driving force i for the period* $t_0$ *to t in the base scenario of the inter-scenario comparison*

$\Delta A^{df}_{i_n}$ *activity change for driving force i in scenario m for the period* $t_0$ *to t*

$\Delta A^{df}_{i_0}$ *activity change for driving force i for the period* $t_0$ *to t in the base scenario for the for the inter-scenario comparison*

$E_t$ *emission level for the end year t*

In a second step of the normalization process, the remaining emission levers are specified according to their contributions to the original total emission reduction.

$$\Delta E'_{n_m} = \Delta E'_{tot_m} \cdot \frac{\Delta E^{rl}_{n_m}}{\sum_{i=1}^{p} \Delta E^{rl}_{p_m}}$$

*with*

$\Delta E'_{i_m}$ *normalized emission reduction contribution for reduction lever i in scenario m*

$\Delta E'_{tot_m}$ *total adjusted emission reduction after effect from driving forces for scenario m*

$\Delta E^{rl}_{i_m}$ *original emission reduction contribution for reduction lever i in scenario m (excluding contributions which are attributed to driving forces)*

As a result of the normalization process, a set of emission contributions for the driving forces is available that mirrors exactly the activity changes of the driving forces in an inter-scenario comparison and a set of emission reduction levers that reflects the original patterns of these emission reduction levers in the different scenarios.

For both approaches, the primary decomposition analysis and the comparison of normalized levers that determine emission trends the following caveats need to be considered:

- The primary decomposition analysis allows for a consistent comparison of driving forces on the one hand and emission abatement levers on the other hand. The results of this analysis have only limited value with regard to inter-scenario comparisons.

- The normalization process leads to results that allow for consistent comparisons between the driving forces in different scenarios on the one hand and emission abatement levers in different scenarios on the other hand. The ratio between the contributions of driving forces and of the different emission abatement levers might, however, be distorted. Accordingly, this normalization is only applied in the inter-scenario comparison.

- Both approaches lead to exactly the same results with regard to total changes of emissions at the aggregate or sectoral levels.

### A.2 Results of the decomposition analysis for EU scenarios

In this section, we present the results of the decomposition analysis for the evaluated EU scenarios for the periods 2010–2030 and 2010–2050. For each scenario, we start with the results for the total energy-related $CO_2$ emissions. Afterwards, we provide the sectoral results for all sectors that are covered in a sufficient level of detail in the corresponding study. In particular, sector-specific data on the emissions and the energy mix as well as on the chosen sectoral driving force is required. The individual driving forces are:

- Aggregate: gross domestic product (GDP) in constant monetary values;
- Electricity sector: electricity generation in terms of energy;
- Industry and tertiary sector: value added in constant monetary values;
- Residential sector: number of households;
- Freight and passenger transport: total freight distance in ton-kilometers and total passenger distance in person-kilometers

In some cases, the sectoral driving forces were estimated based on the available data (see the individual footnotes). In some other cases, the level of detail of the available data was not sufficient for an estimation and the sector had to be left out completely.

For each of the abatement levers, the figures show their contribution to the total emission reduction relative to 2010, according to the LMDI approach to the index decomposition (see Section A 1 for details of the methodology). The individual levers are:

- Driving force and demand reduction: change of the chosen driving force in a baseline scenario and in the evaluated scenario relative to the baseline;
- Energy efficiency: change of the energy used per activity level of the driving force;
- Electricity/heat/renewables/PtG/PtL/nuclear: change of the energy carrier's share in the energy mix;
- $CO_2$ intensity and CCS: change of the carbon emitted per fossil energy due to fuel switch and application of CCS respectively.

Note here that the LMDI approach takes into account the activity level, the carbon and the energy intensities both in the starting and in the target year. Therefore, it is possible that e.g. a higher growth of the activity level corresponds to a lower increase of emissions, if a lower carbon intensity is reached in the target year. This effect has been removed by a normalization in the inter-scenario comparison presented in Section 3, but it is not removed here for reasons explained in Annex A1.

### A.2.1 Energy Roadmap 2050–Current Policies Scenario

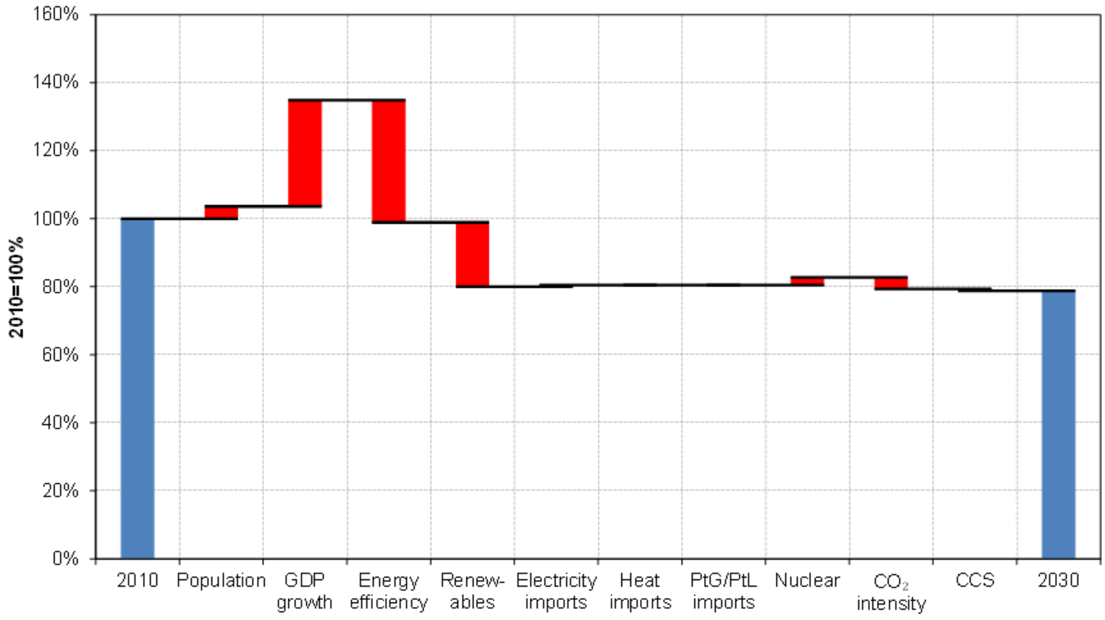
#### A 2.1.1 Aggregate trends

The Current Policies scenario attains a 21% reduction in total $CO_2$ emissions from energy until 2030 (Figure A 1) and 36% until 2050 (Figure A 2).

In 2030, GDP growth is approximately offset by improvements in energy efficiency. The emissions increase due to the nuclear phase-out (+2%) is offset by improvements in $CO_2$ intensity of fossil fuels (-3%). The main driver of emissions is therefore the expansion of renewable energies, contributing 19% to the total 21% decrease.

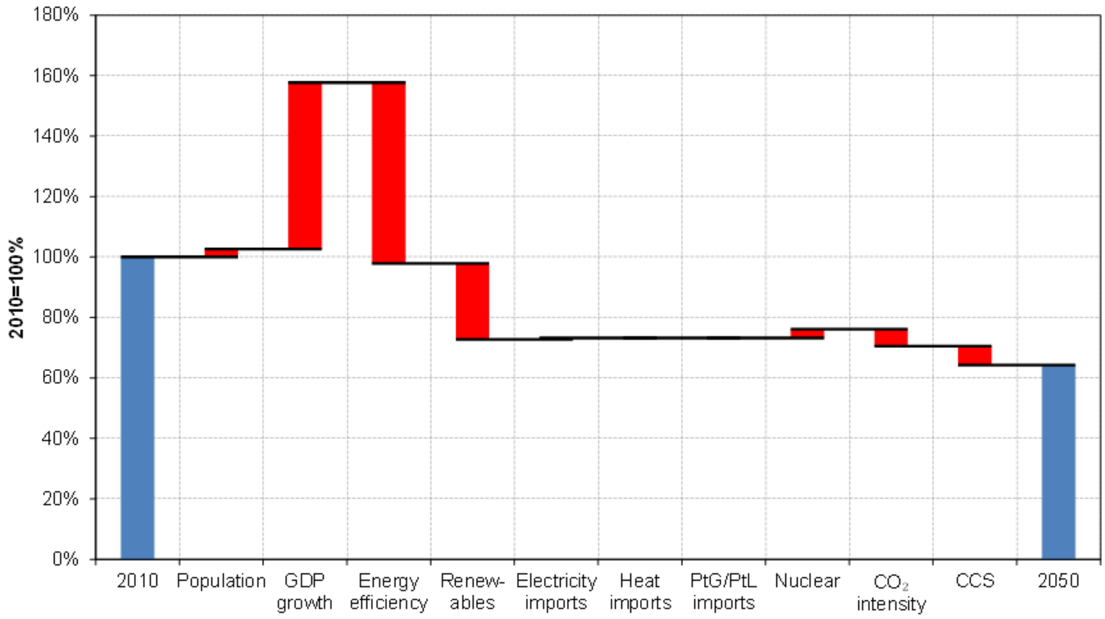
In 2050, the pattern is similar: Efficiency offsets GDP growth, but the growth of renewables slows down after 2030, reaching 25% reduction in 2050. However, additional reductions are attained by a less $CO_2$-intensive fossil fuel mix than in 2030 (-6%). A significant contribution comes from CCS (-6%).

**Figure A 1: Energy Roadmap 2050, Current Policies Scenario: Decomposition analysis for aggregate trends, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut

**Figure A 2: Energy Roadmap 2050, Current Policies Scenario: Decomposition analysis for aggregate trends, 2010–2050**




Source: European Commission 2011, calculations by Öko-Institut

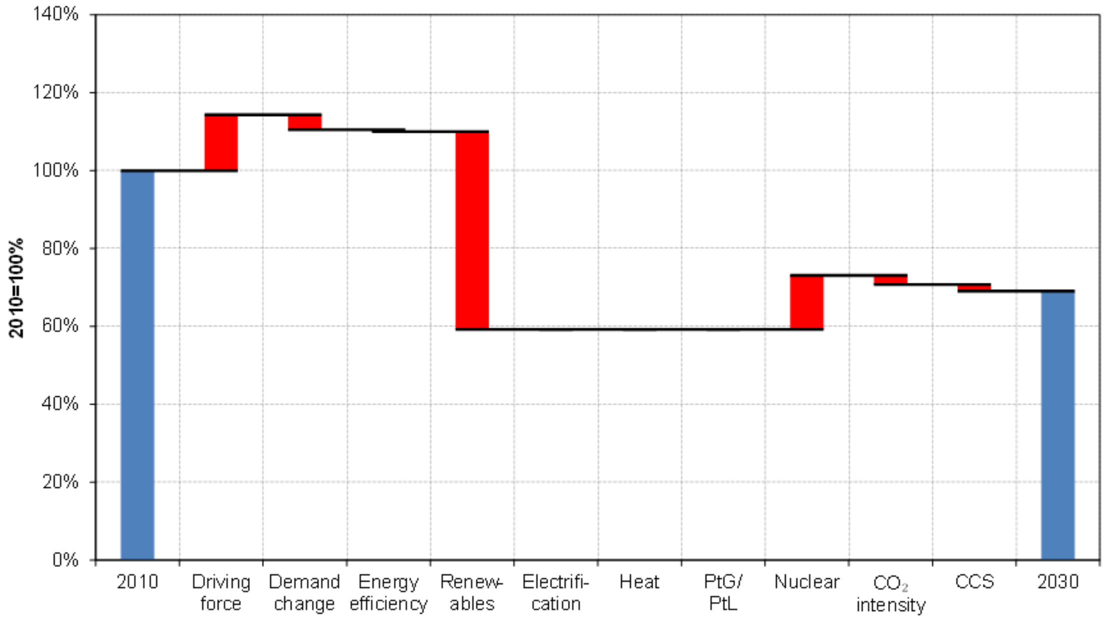
### A 2.1.2 Sectoral trends

#### A 2.1.2.1 Electricity sector

In the electricity sector, emissions are 31% lower in 2030 (Figure A 3). This is mainly due to expansion of renewables which displace 51% of the 2010 emissions. However, the strong shift is partially offset by an 11% increase in electricity production (which is still 4% below the reference seen in the leftmost red column) and the nuclear phase-out which increases emissions by 14%. Minor contributions are made by lower $CO_2$ intensity of fossil fuels and some CCS.

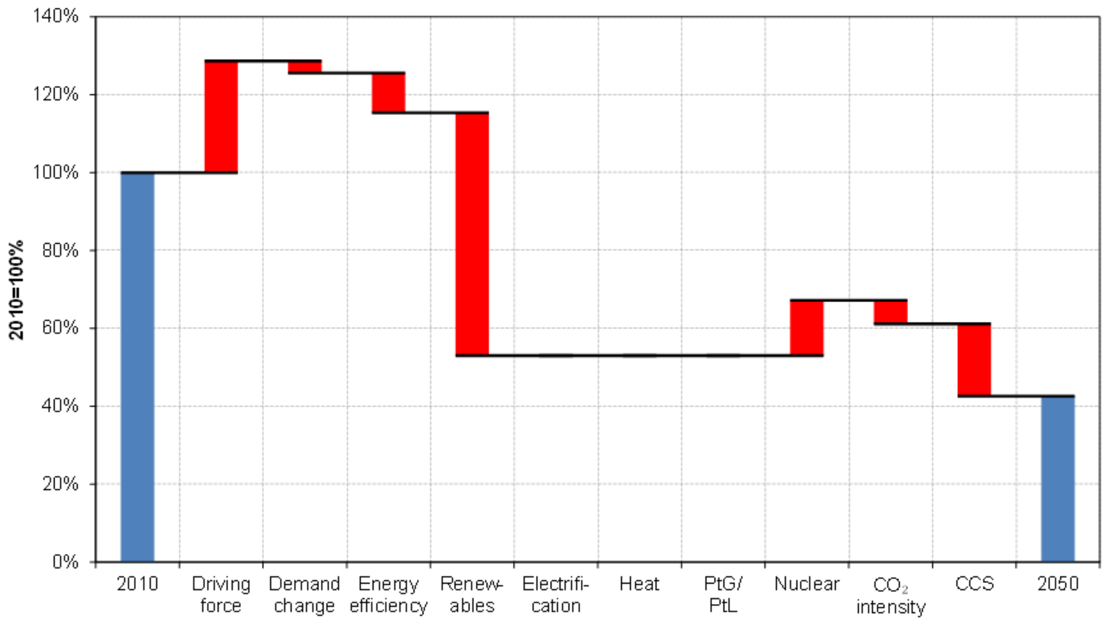
In 2050, emissions are reduced to 57% below the 2010 baseline (Figure A 4). In comparison to 2030, electricity demand continues to grow to 26% over baseline (3% under reference scenario). There is also a higher contribution from renewables, but with a less drastic change than between 2010 and 2030, reaching 62% potential reduction of emissions. The largest additional reduction over 2030 comes from CCS (19% reduction), but there are also small contributions from energy efficiency (-10%) and reduced $CO_2$ intensity of the remaning fossil fuels (-6%).

**Figure A 3: Energy Roadmap 2050, Current Policies Scenario: Decomposition analysis for the electricity sector, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut.

**Figure A 4: Energy Roadmap 2050, Current Policies Scenario: Decomposition analysis for the electricity sector, 2010–2050**



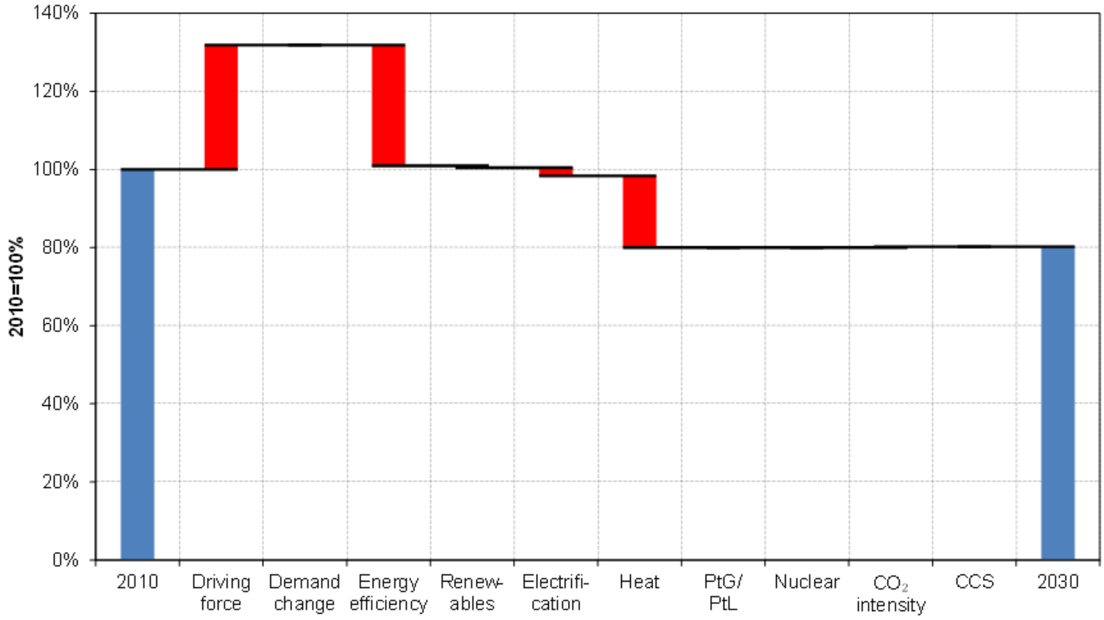

Source: European Commission 2011, calculations by Öko-Institut

#### A 2.1.2.2 Industry sector

In the industry sector, the pattern for 2030 is very clear (Figure A 5): Efficiency gains completely offset the growth of industrial production (32% growth vs. 31% higher efficiency), while a net reduction of 20% of emissions is attained by switching to heat (-18%) and electricity (-2%).

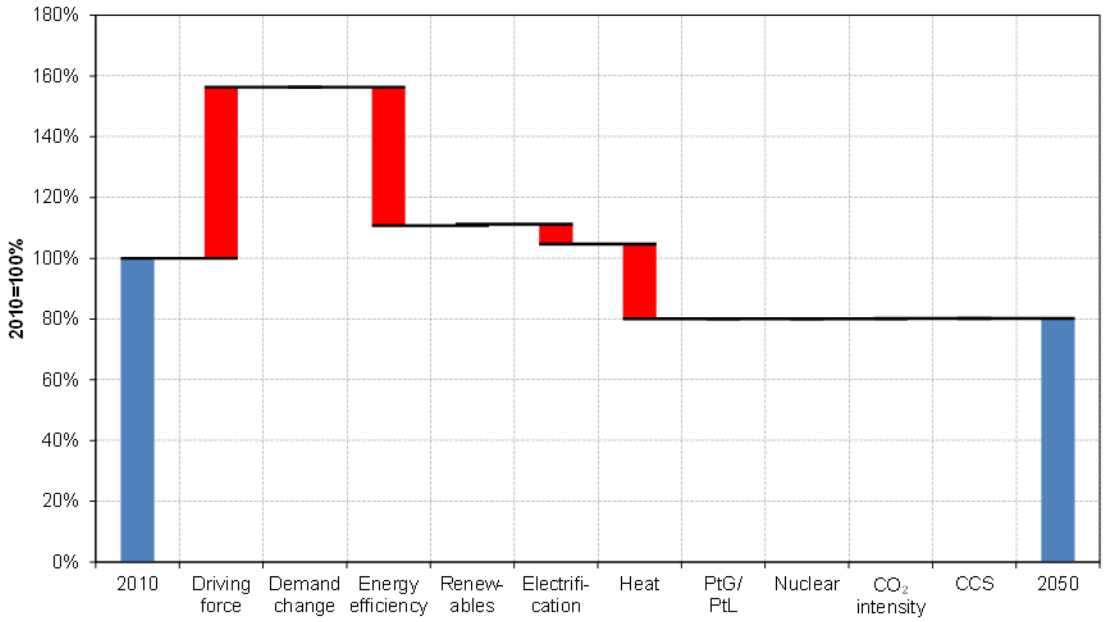
In 2050 (Figure A 6), there is less remaining potential for efficiency gains, such that the industrial growth cannot be completely offset anymore (56% growth vs. 46% efficiency gains), a net increase of 10% of emissions. The same holds true for using distributed heat in industrial processes, contributing reduction (25%) only seven percentage points higher than in 2030. However, electricity in 2050 contributes a 7% reduction, such that the total net emissions reduction remains the same (20% of baseline emissions) despite the higher energy demand.

**Figure A 5: Energy Roadmap 2050, Current Policies Scenario: Decomposition analysis for the industry sector, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut.

**Figure A 6: Energy Roadmap 2050, Current Policies Scenario: Decomposition analysis for the industry sector, 2010–2050**



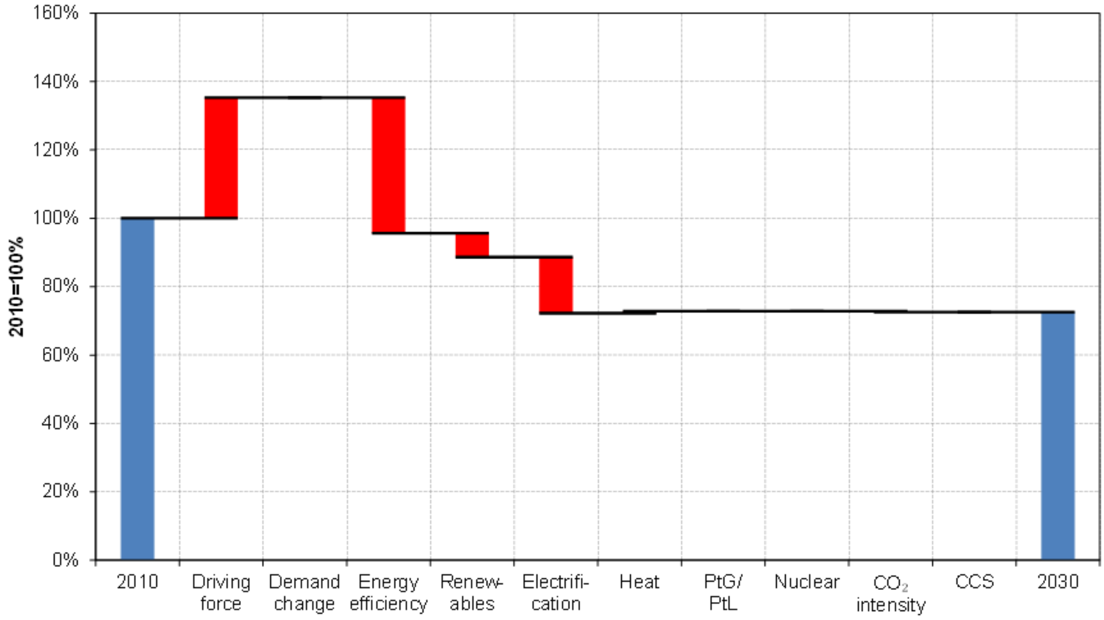

Source: European Commission 2011, calculations by Öko-Institut

#### A 2.1.2.3 Tertiary sector

The tertiary sector improves efficiency more strongly than demand growth, leading to a 4% net reduction in 2030 (Figure A 7). Additionally, there is significant emissions abatement from switching to renewables (-7%) and electricity (-16%), leading to a total emissions reduction of 27% in 2030.

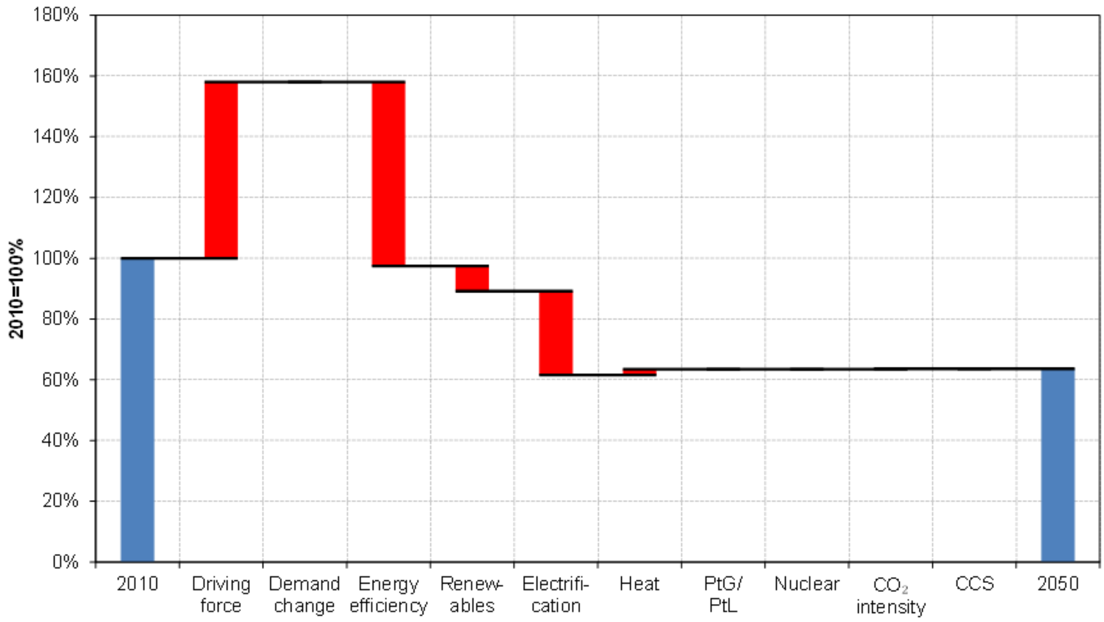
In 2050 (Figure A 8), the picture remains identical, but total reduction stands at -36% due to continued growth of renewables (-8%) and electricity (-28%).

**Figure A 7: Energy Roadmap 2050, Current Policies Scenario: Decomposition analysis for the tertiary sector, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut

**Figure A 8: Energy Roadmap 2050, Current Policies Scenario: Decomposition analysis for the tertiary sector, 2010–2050**



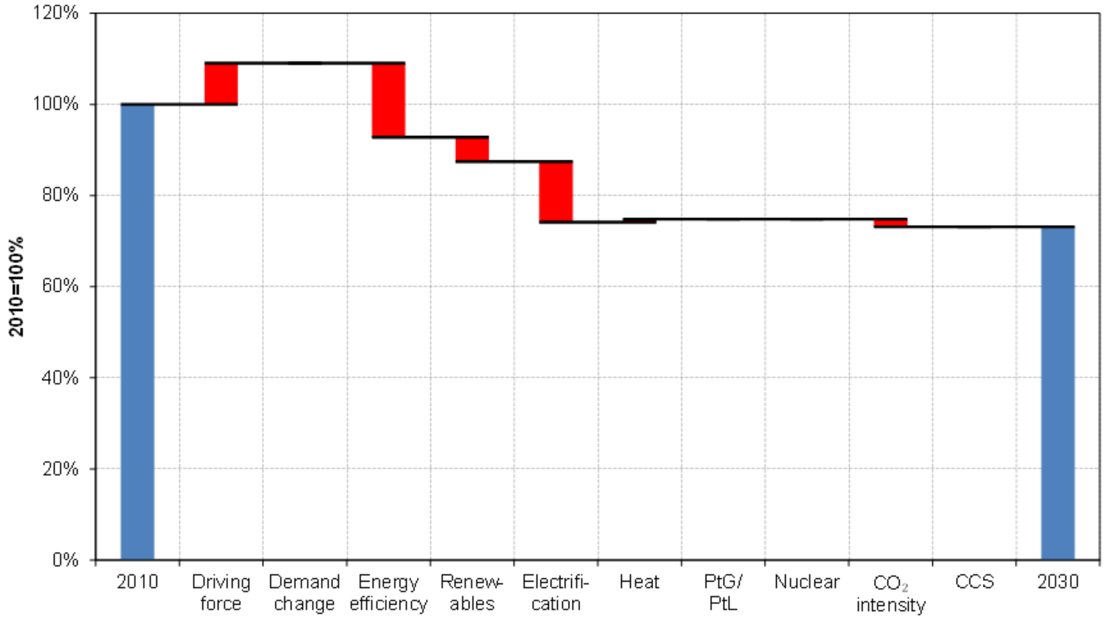

Source: European Commission 2011, calculations by Öko-Institut

#### A 2.1.2.4 Residential sector

In the residential sector, efficiency gains attain a 7% net reduction of energy demand despite a growing number of households. In addition to this, a switch to renewables and electricity contributes 5% and 13%, respectively, of emissions reduction each in comparison to 2010. There is a slight decrease in the $CO_2$ intensity of fuels (-2%), leading to a 27% total reduction of emissions in 2030 (Figure A 9).

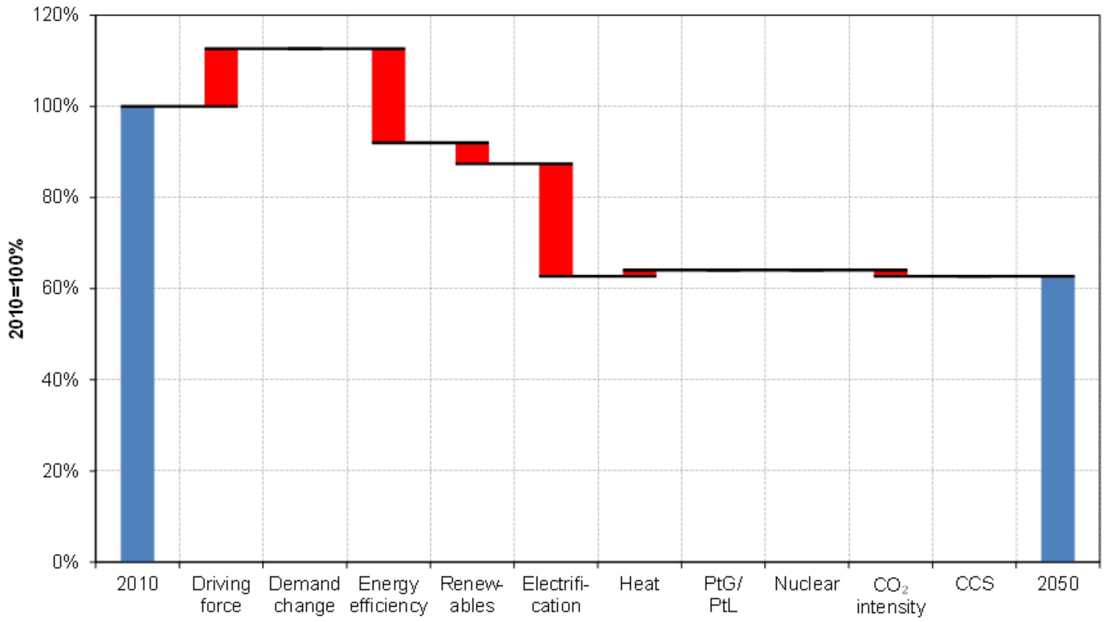
In 2050, the picture is largely identical (Figure A 10), but most drivers have continued growing steadily. Despite a number of households 13% above the baseline, efficiency gains lead to an 8% net decrease, while electrification grows fast after 2030 and abates 25% of baseline emissions in 2050. Notably, the contribution of renewables still stands at 5% in 2050. This leads to a 37% total reduction of emissions.

**Figure A 9: Energy Roadmap 2050, Current Policies Scenario: Decomposition analysis for the residential sector, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut

**Figure A 10: Energy Roadmap 2050, Current Policies Scenario: Decomposition analysis for the residential sector, 2010–2050**



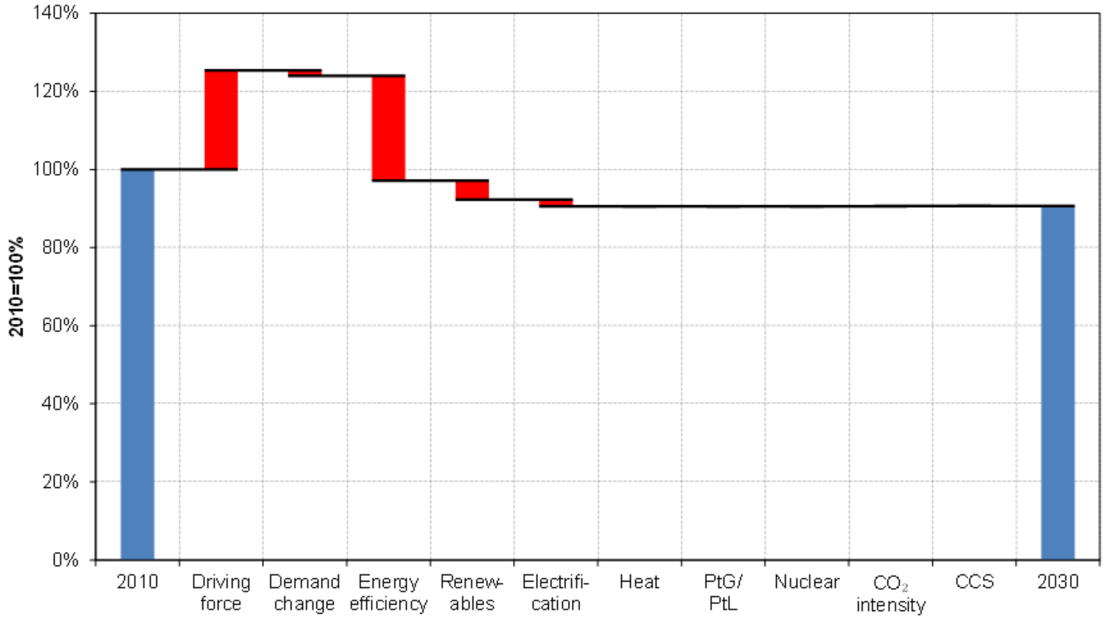

Source: European Commission 2011, calculations by Öko-Institut

#### A 2.1.2.5 Passenger transport

In passenger transport (Figure A 11), demand is 25% higher in 2030 than in 2010, but this is offset by efficiency (-27%). A small contribution is made by renewables (-5%) and electrification (-2%) leading to a net decrease of 9% compared to baseline.

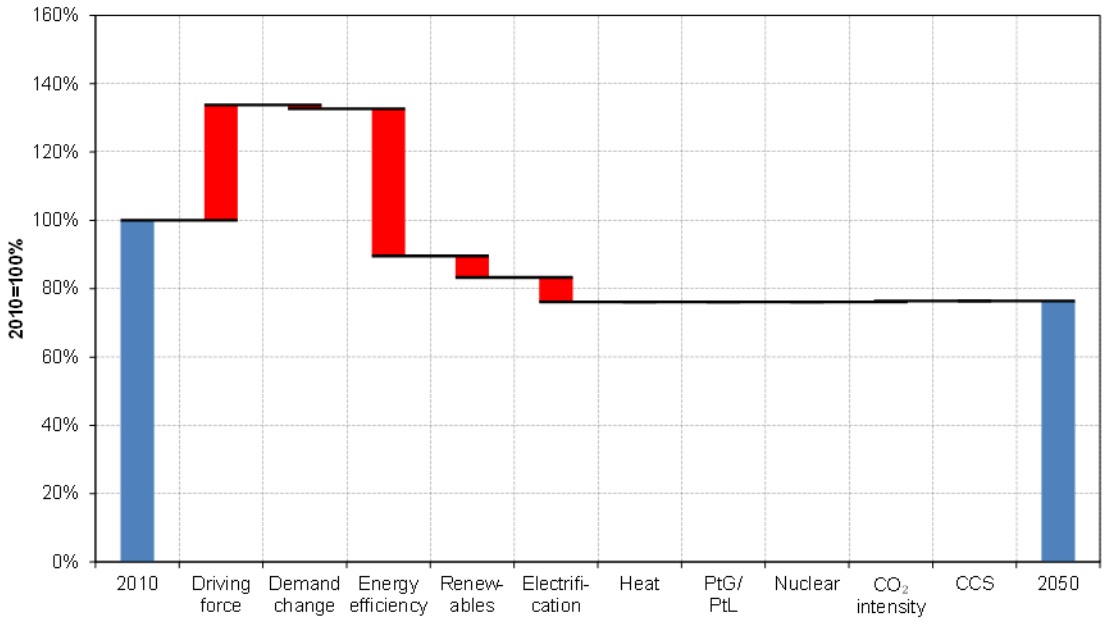
In 2050 (Figure A 12), the development of renewables is stagnant and remains at -6%, but efficiency improves markedly and more than offsets the growing demand by 10%. In this scenario, a small (1%) decrease is also due to lower transport demand than in the reference scenario. However, the main addition is from electrification (7% reduction). All drivers together lead to a 24% net reduction of emissions.

**Figure A 11: Energy Roadmap 2050, Current Policies Scenario: Decomposition analysis for passenger transport, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut

**Figure A 12: Energy Roadmap 2050, Current Policies Scenario: Decomposition analysis for passenger transport, 2010–2050**



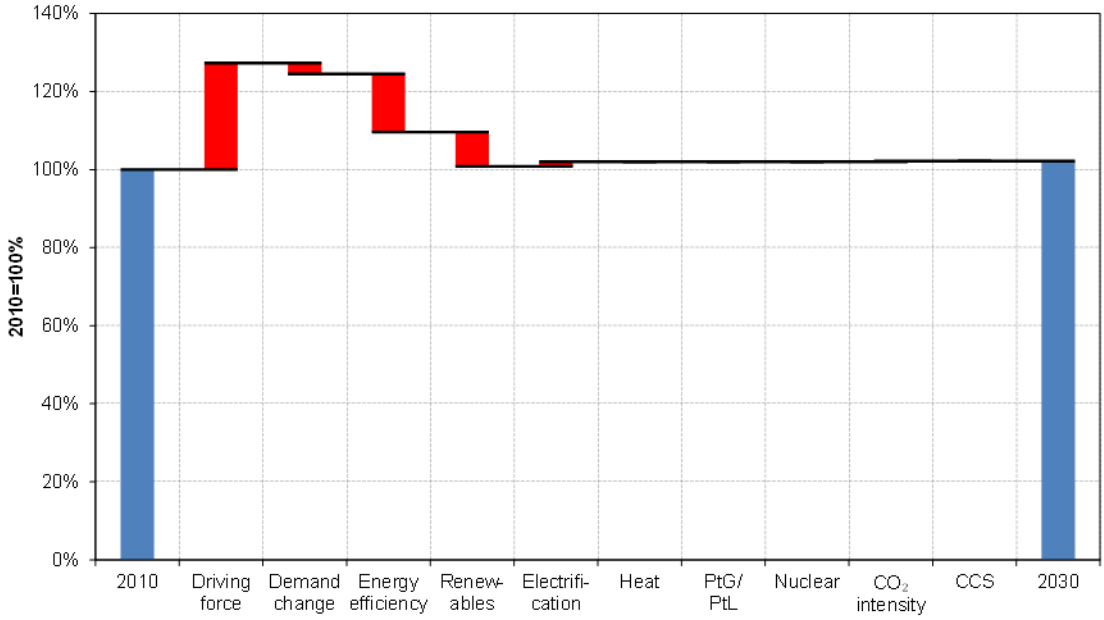

Source: European Commission 2011, calculations by Öko-Institut

#### A 2.1.2.6 Freight transport

In contrast to passenger transport, freight transport emissions increase slightly until 2030 (+2% compared to 2010, Figure A 13). This is mostly due to an increase in demand (+25%; 3% below reference) that is almost, but not quite offset by either efficiency gains (-15%) or renewables (-9%). The share of electricity actually decreases, adding a further 1% to emissions.

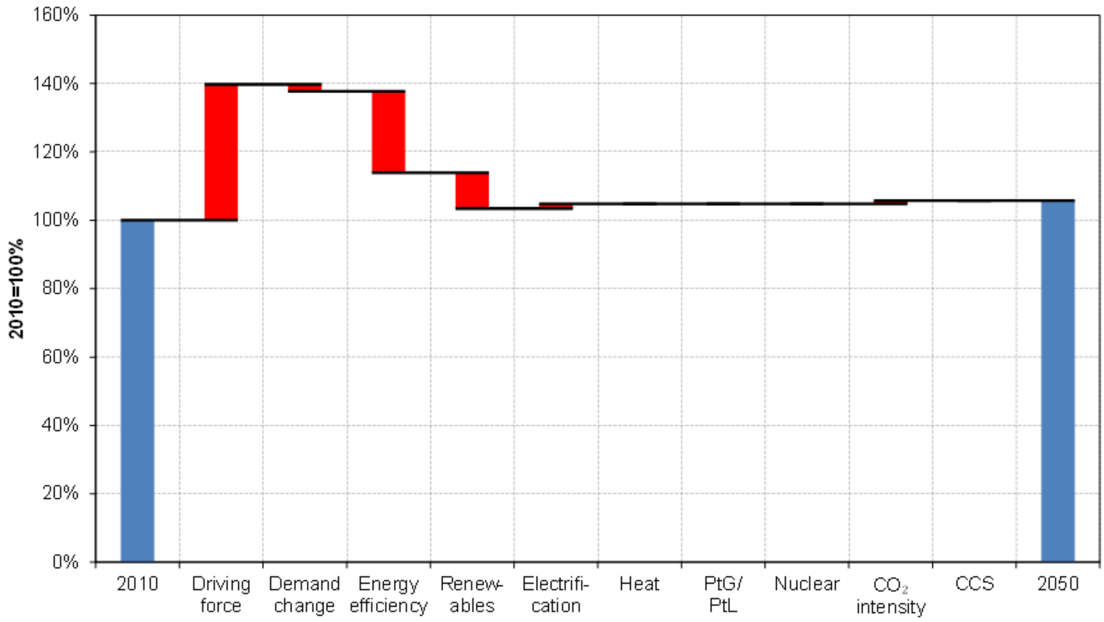
The picture is almost exactly identical in 2050 (Figure A 14). Demand has risen further to +38% (2% below reference), while efficiency gains only offset 24 percentage points. Renewables stagnate at 11% reduction, leading to even higher emissions (6% above 2010 baseline) than in 2030.

**Figure A 13: Energy Roadmap 2050, Current Policies Scenario: Decomposition analysis for freight transport, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut

**Figure A 14: Energy Roadmap 2050, Current Policies Scenario: Decomposition analysis for the freight transport sector, 2010–2050**




Source: European Commission 2011, calculations by Öko-Institut

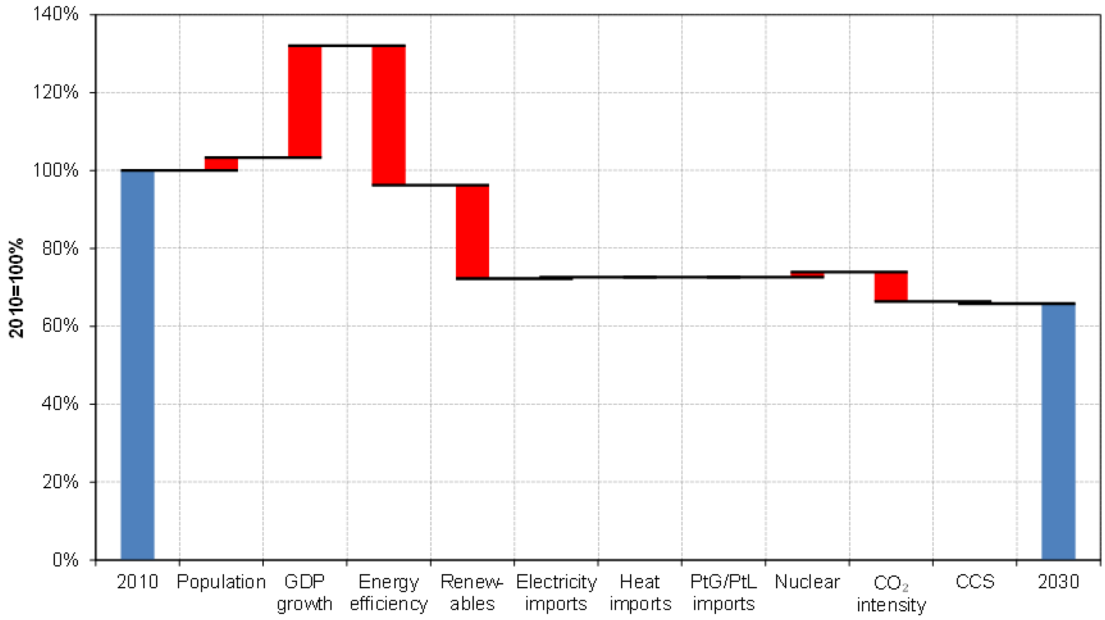
### A.2.2 Energy Roadmap 2050 – Delayed CCS Scenario

#### A 2.2.1 Aggregate trends

Until 2030, there is a 3% population and 29% GDP growth, which is more than offset by energy efficiency improvements that reduce 36% of the baseline emissions. Renewable energy contributes 24 percentage points of reduction, while the $CO_2$ intensity of fossil fuels reduces a further 8%. Only a small amount of the decrease (1%) is lost to the phase-out of nuclear energy, leading to net reductions of 34% compared to 2020 (Figure A 15).

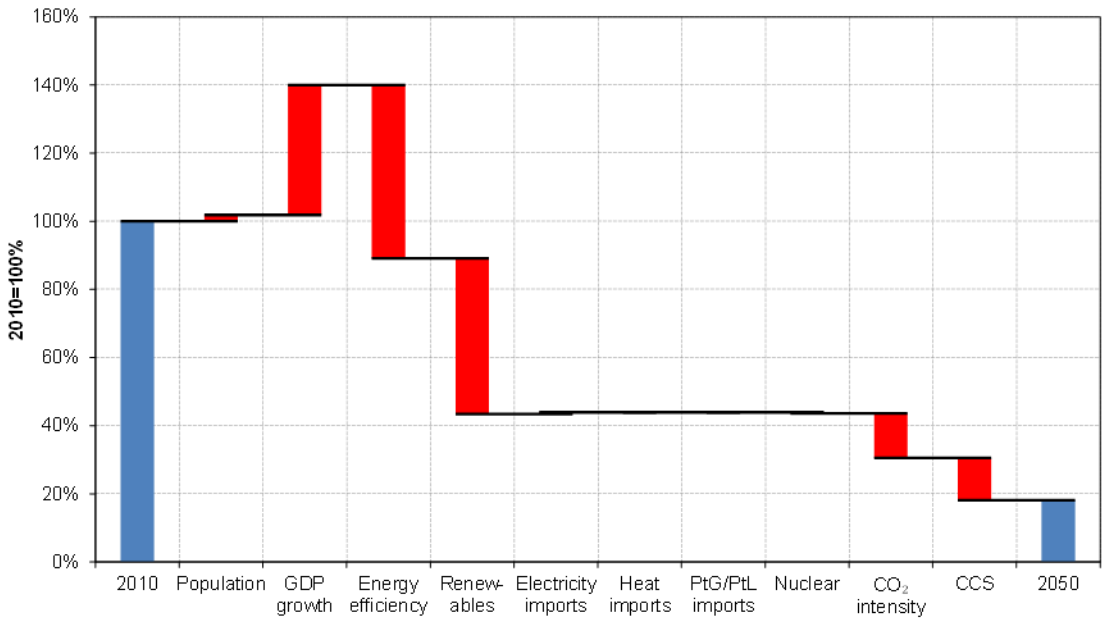
Until 2050 (Figure A 16), there are further improvements in energy efficiency (11% reduction compared to 2020, after accounting for population and GDP growth, and significant expansion of renewables (46% reduction). The $CO_2$ intensity of fossil fuels is slightly lower than in 2030 (13% reduction compared to 8%). In 2050, CCS contributes significant emissions reductions at 12% of the baseline.

**Figure A 15: Energy Roadmap 2050, Delayed CCS Scenario: Decomposition analysis for aggregate trends, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut

**Figure A 16: Energy Roadmap 2050, Delayed CCS Scenario: Decomposition analysis for aggregate trends, 2010–2050**




Source: European Commission 2011, calculations by Öko-Institut

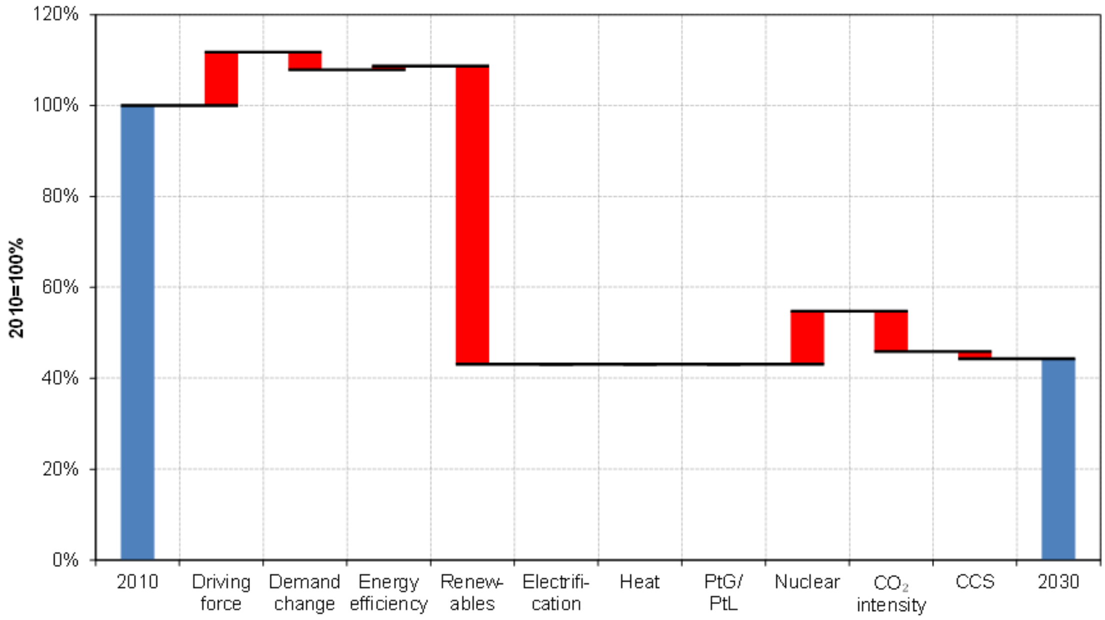
### A 2.2.2 Sectoral trend

#### A 2.2.2.1 Electricity sector

The electricity sector (Figure A 17) reduces net emissions by 56% until 2030, although demand and the nuclear phase-out increase emissions by 12% each. However, the increase is entirely offset by renewables expansion (-66%), a shift to less $CO_2$-intensive fossil fuels (-9%), and CCS (-2%).

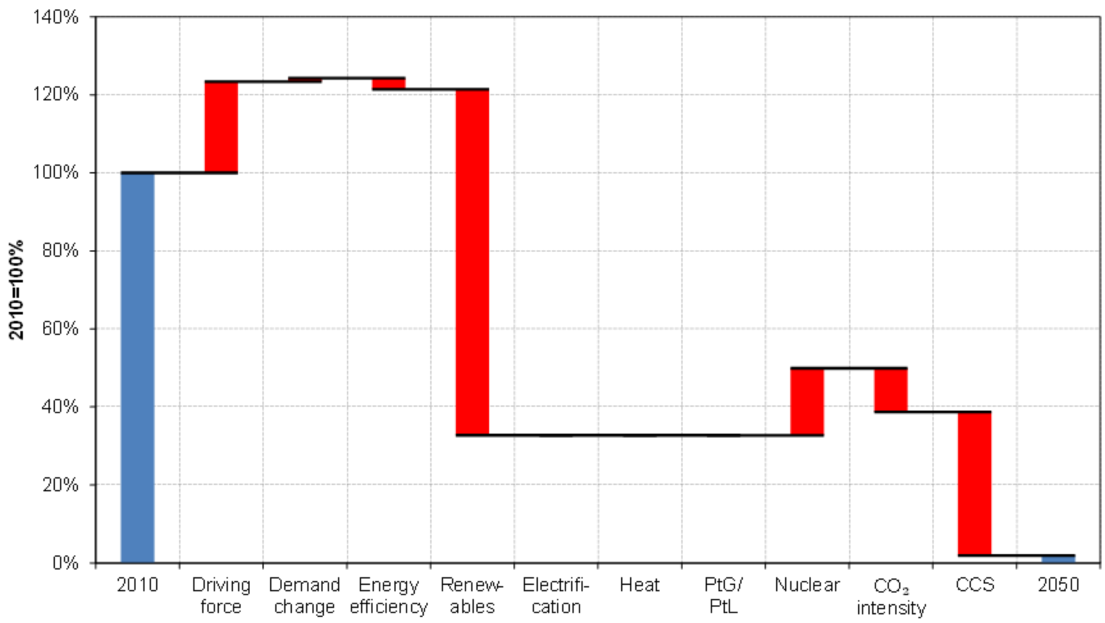
Until 2050 (Figure A 18), the sector is almost entirely decarbonized (98% reduction). After 2030, there is strong growth of CCS which attains a 37% reduction in 2050. $CO_2$ intensity also further decreases and contributes 11% reduction compared to 2010. The growth of renewables slows after 2030, but still contributes the largest part of the reduction at -89% compared to 2010. This is balanced out by a 24% increase of demand compared to 2010, and a 17% increase of emissions due to the nuclear phase-out.

**Figure A 17: Energy Roadmap 2050, Delayed CCS Scenario: Decomposition analysis for the electricity sector, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut

**Figure A 18: Energy Roadmap 2050, Delayed CCS Scenario: Decomposition analysis for the electricity sector, 2010–2050**



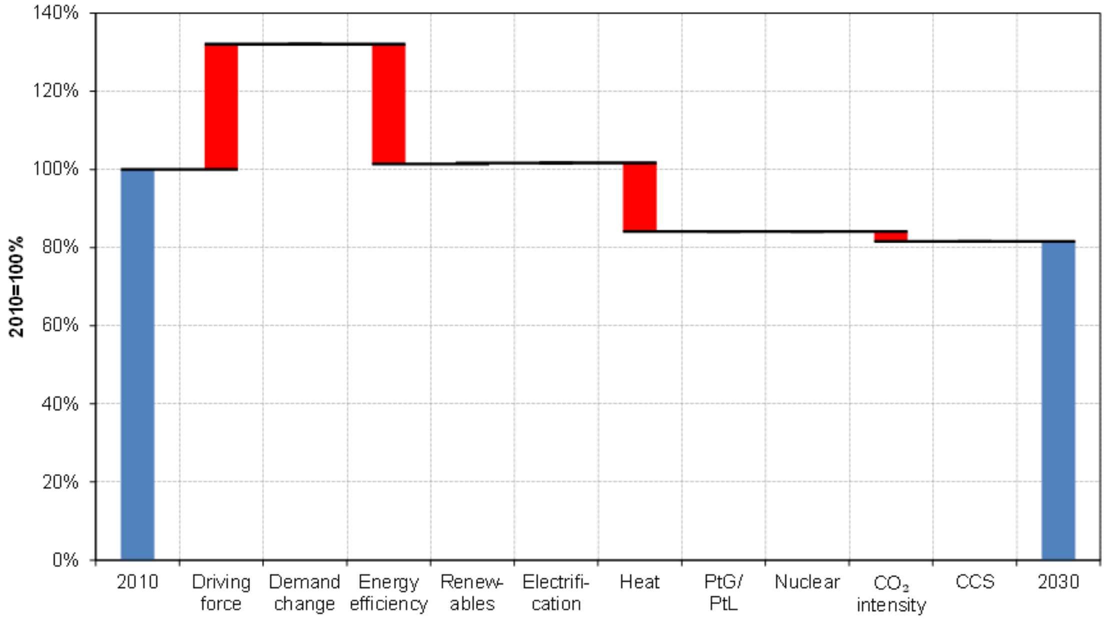

Source: European Commission 2011, calculations by Öko-Institut

#### A 2.2.2.2 Industry sector

The industry sector reduces emissions by 18% in 2030 (Figure A 19). The main drivers behind this is higher use of distributed heat (-17%) and lower $CO_2$ intensity of fuels (-3%). The difference is caused by a higher production (32%) which is not fully offset by efficiency gains (-31%) and small changes in other drivers.

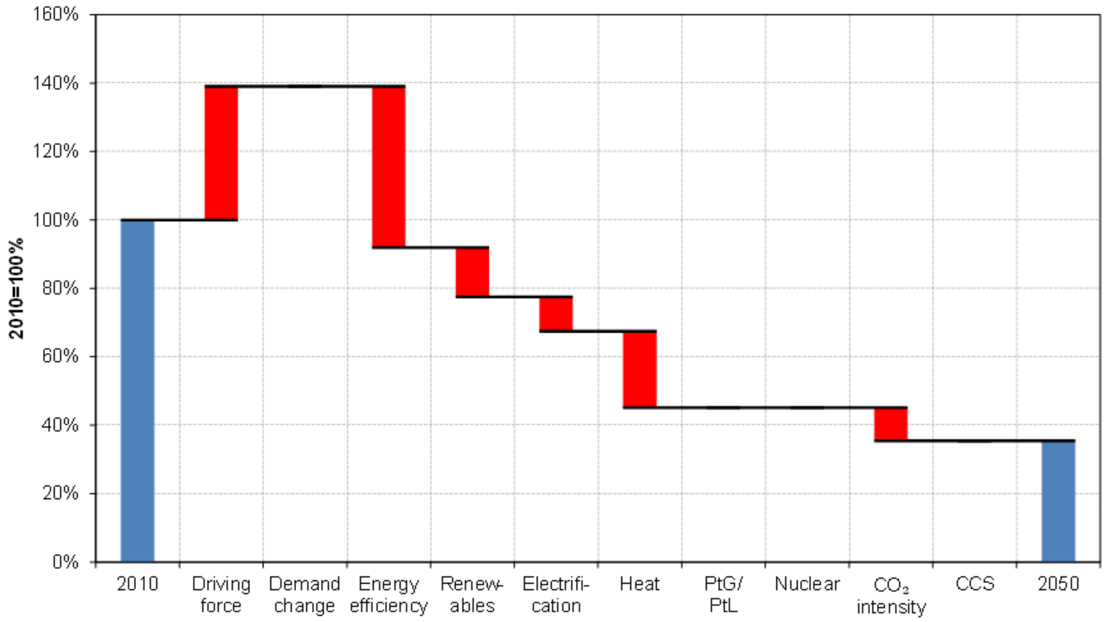
In 2050 (Figure A 20), total reductions attain 65%, caused mainly by strong gains in energy efficiency (-47%, more than offsetting a 39% growth in production), a shift to renewable energy (-14%) and electricity (-10%), and further reductions in $CO_2$ intensity (-10%). The use of heat (-22% in 2050) does not increase much further compared to 2030.

**Figure A 19: Energy Roadmap 2050, Delayed CCS Scenario: Decomposition analysis for the industry sector, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut

**Figure A 20: Energy Roadmap 2050, Delayed CCS Scenario: Decomposition analysis for the industry sector, 2010–2050**



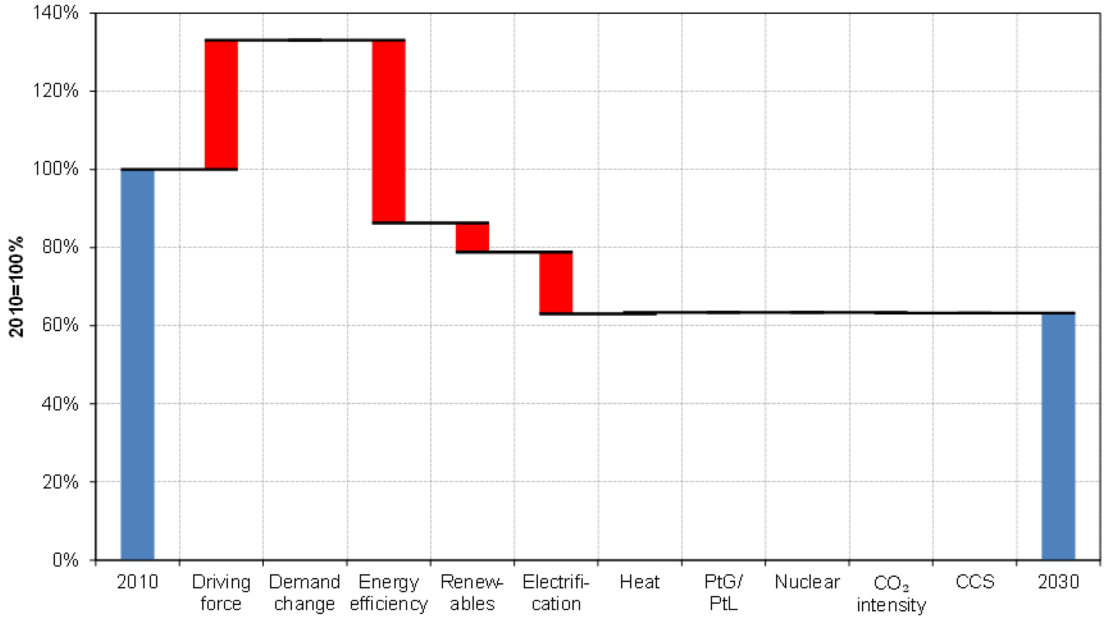

Source: European Commission 2011, calculations by Öko-Institut

#### A 2.2.2.3 Tertiary sector

The tertiary sector reaches a significant reduction of 37% in 2030 (Figure A 21), mainly from increases in energy efficiency (-47% vs. a 33% increase in emissions due to higher production), renewable energy (-8%), and electrification (-16%).

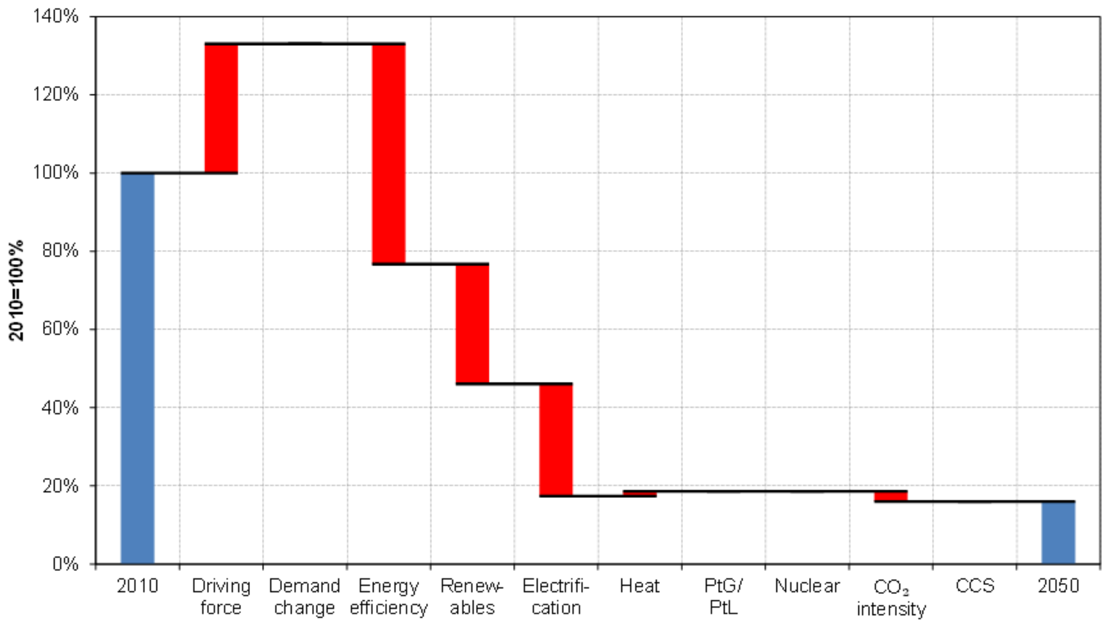
For the period from 2010 to 2050 (Figure A 22), improving energy efficiency with 56% is the biggest lever for reducing $CO_2$ emissions, compared to an emissions growth of 33% due to economic growth. The use of renewables represents an emission reduction contribution of 31% compared to the base year emission level. The contribution of electrification in the tertiary sectors amounts to 29%. The contributions of all other levers to the reduction of $CO_2$ emissions in the tertiary sectors (Heat, PtG/PtL, CCS, $CO_2$ intensity of fossil fuels) are negligible.

**Figure A 21: Energy Roadmap 2050, Delayed CCS Scenario: Decomposition analysis for the tertiary sector, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut

**Figure A 22: Energy Roadmap 2050, Delayed CCS Scenario: Decomposition analysis for the tertiary sector, 2010–2050**



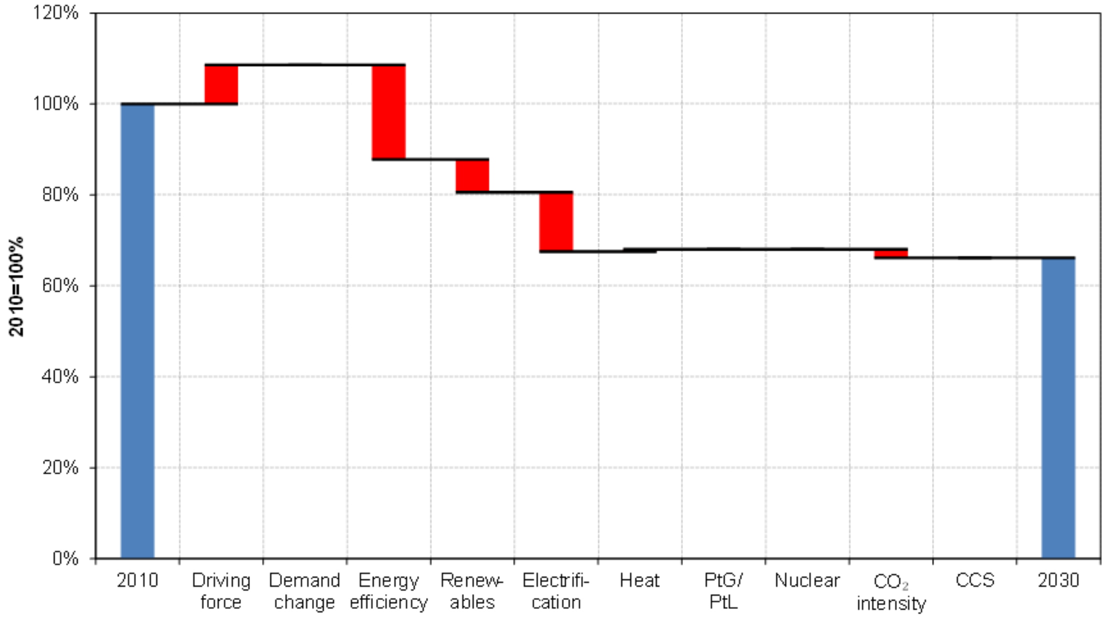

Source: European Commission 2011, calculations by Öko-Institut

### A 2.2.2.4 Residential sector

The residential sector abates 34% of emissions until 2030 (Figure A 23). There is only little increase in the number of households (+9%), but energy efficiency balances this out and decreases emissions by close to 21%. Additionally, there is a significant shift to renewable energy (-7%) and electricity (-13%). $CO_2$ intensity decreases only slightly and contributes 2% of reductions.

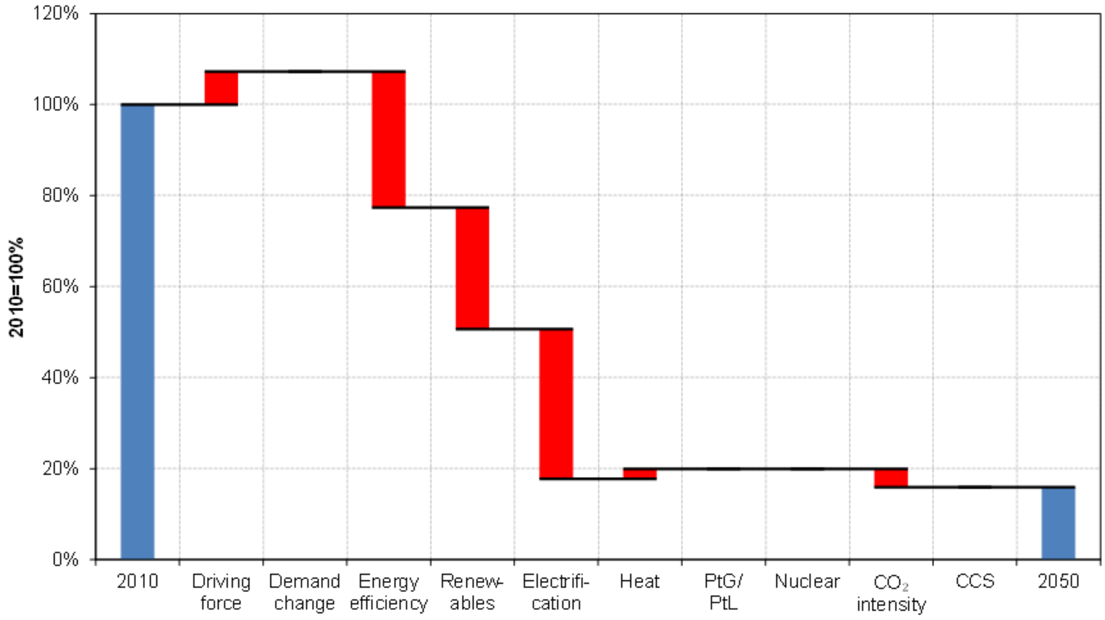
In 2050 (Figure A 24), total reductions increase very strongly to -84% due to large improvements in energy efficiency (-30%), renewables (-27%), and electrification (-33%; all numbers relative to 2010). $CO_2$ intensity decreases further, but with a small contribution (-4%). Additionally, the relative contribution of the number of households to the emissions balance is actually smaller than in 2030 (+7% compared to 2010).

**Figure A 23: Energy Roadmap 2050, Delayed CCS Scenario: Decomposition analysis for the residential sector, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut

**Figure A 24: Energy Roadmap 2050, Delayed CCS Scenario: Decomposition analysis for the residential sector, 2010–2050**



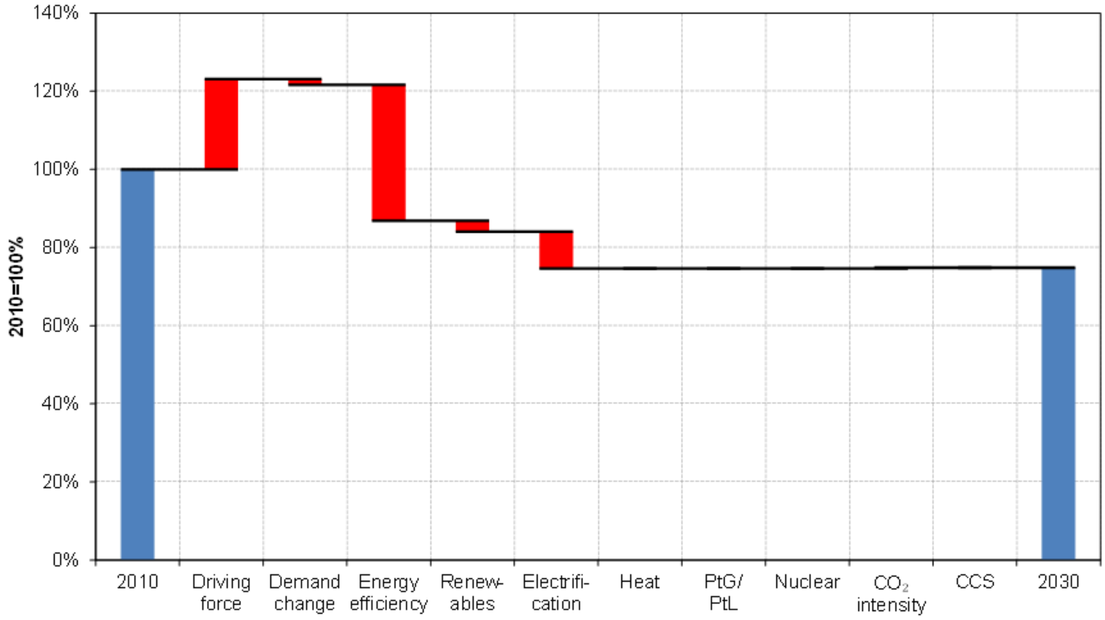

Source: European Commission 2011, calculations by Öko-Institut

#### A 2.2.2.5 Passenger transport

In passenger transport, there is significant increasing pressure on emissions (+22%) until 2030 (Figure A 25) even after accounting for a slightly lower demand than in the reference scenario. This is offset by energy efficiency improvements, leading to a 13% net reduction in emissions. Additionally, emissions are abated by increased renewables use (-3%) and electrification (-9%), leading to a total reduction of 25% of emissions compared to 2010.

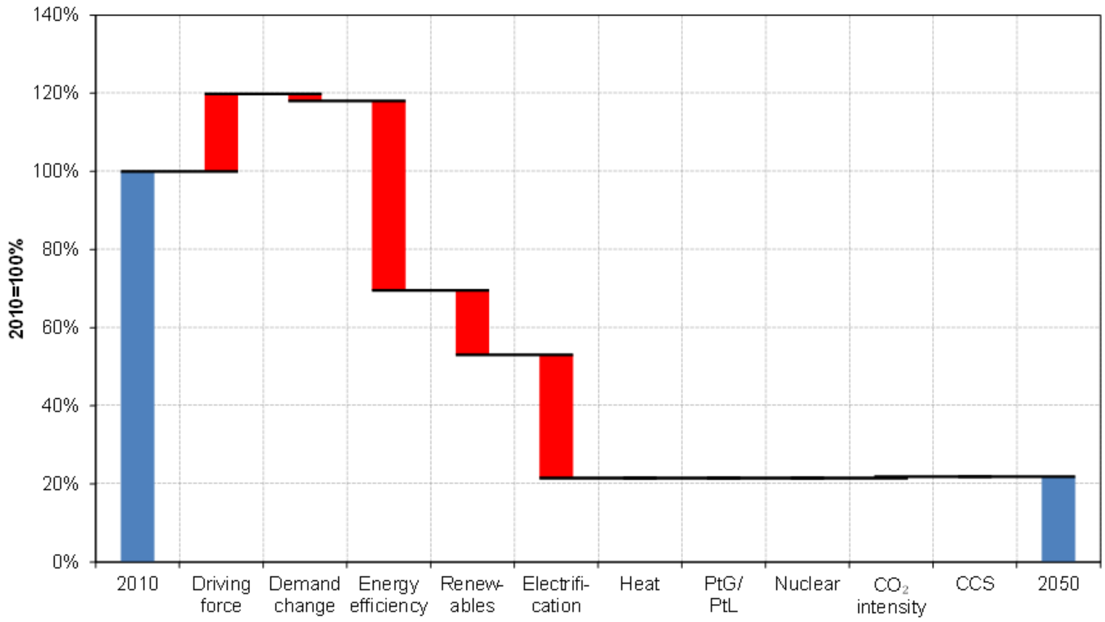
In 2050 (Figure A 26), the contribution by renewables and electrification increases markedly (-17% and -32%, respectively). There is a smaller relative contribution by increased demand (18%) in 2050 than in 2030 even though demand keeps rising in absolute terms. Additionally, efficiency gains increase to deliver a 49% contribution to emissions reductions. The total reduction in passenger transport in 2050 is -78%.

**Figure A 25: Energy Roadmap 2050, Delayed CCS Scenario: Decomposition analysis for passenger transport, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut

**Figure A 26: Energy Roadmap 2050, Delayed CCS Scenario: Decomposition analysis for passenger transport, 2010–2050**



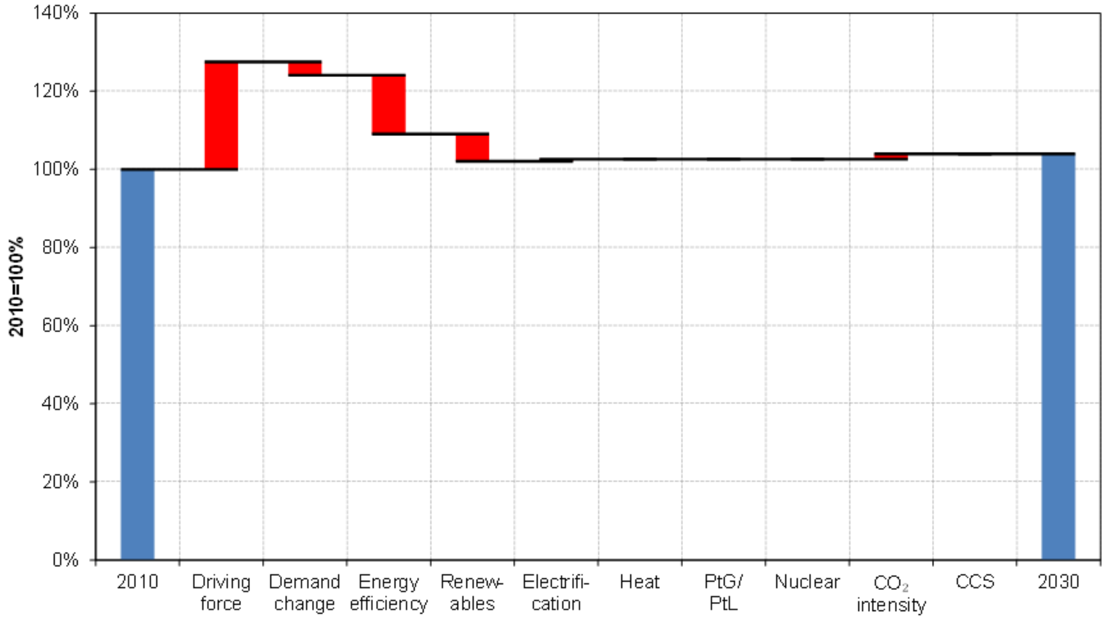

Source: European Commission 2011, calculations by Öko-Institut

#### A 2.2.2.6 Freight transport

In contrast to passenger transport, freight transport emissions increase slightly until 2030 (+4% compared to 2010) (Figure A 27). This is mostly due to an increase in demand (+24% relative contribution to emissions compared to 2010, 3% below reference) that is not fully offset by the reducing drivers efficiency (-15%) and renewables (-7%).

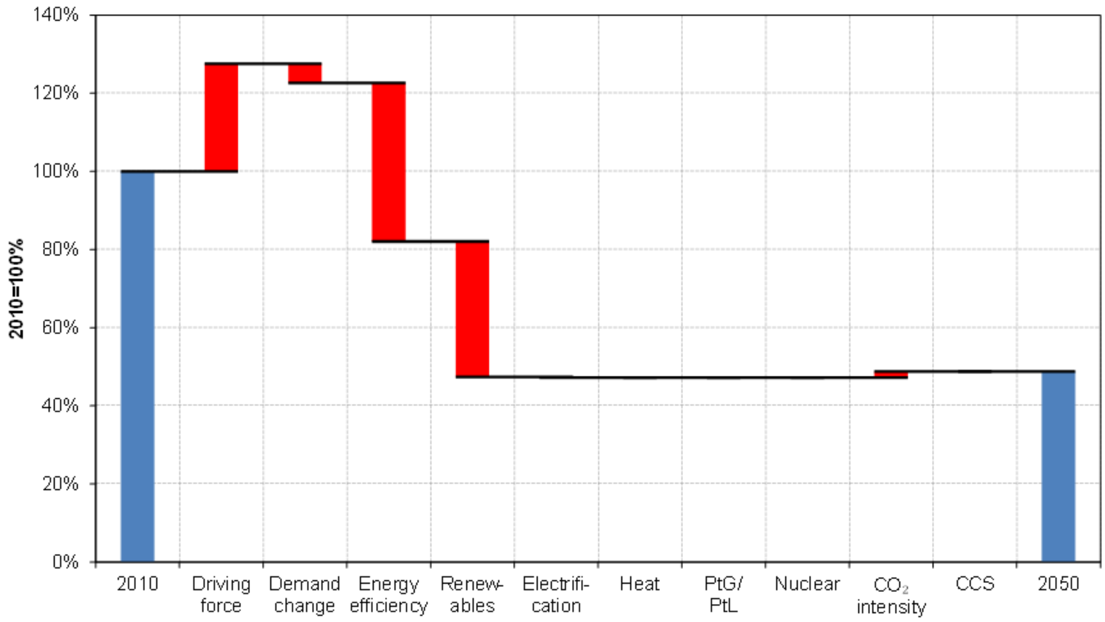
In 2050 (Figure A 28) however, there is strong reduction (-51%) due to the increasing use of renewables with a relative contribution of 35 percentage points, and strongly improved efficiency compared to 2010 and 2030 that reduces baseline emissions by 41%. The increasing pressure by demand change is roughly equal to 2030. The large net reduction is slightly weakened by increased $CO_2$ intensity of the fuels used (+2%), but not significantly altered.

**Figure A 27: Energy Roadmap 2050, Delayed CCS Scenario: Decomposition analysis for freight transport, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut

**Figure A 28: Energy Roadmap 2050, Delayed CCS Scenario: Decomposition analysis for the freight transport sector, 2010–2050**




Source: European Commission 2011, calculations by Öko-Institut

## A.2.3 Energy Roadmap 2050 – High Renewables Scenario

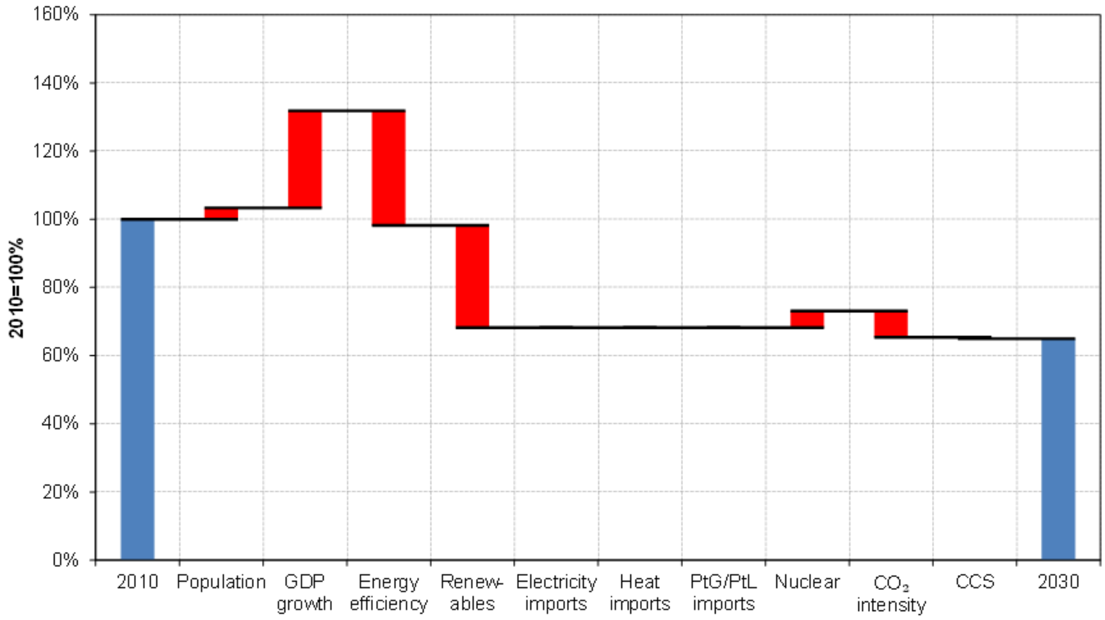
### A 2.3.1 Aggregate trends

The High Renewables scenario attains a 35% reduction reduction in total $CO_2$ emissions from energy until 2030 (Figure A 29) and 82% until 2050 (Figure A 30), compared to 2010. The main drivers, which the figures show in the following order, are:

- Productivity gains: While GDP grows by 34% until 2050, this is more than offset by higher productivity (40% less $CO_2$ per unit of GDP). The combination of both developments results in a 6% net decrease of emissions in 2050. Notably, this development is largely finished already by 2030 (29% of GDP growth, 34% productivity gains).
- Renewables: Two-thirds of fossil fuel consumption is displaced by renewables, which grow to 387 Mtoe in 2030 and 676 Mtoe in 2050. $CO_2$ emissions are reduced by 30% until 2030, with an accelerating development afterwards, to 67% in 2050, making renewables the strongest driver of this scenario.
- Shift to natural gas: Over the whole period, consumption is reduced more quickly than other fossil fuels, resulting in a slightly lower $CO_2$ intensity. However, after 2030, there is a strong shift to natural gas, which dominates the fuel mix (51%) by 2050 and reduces emissions by 16% compared to 2010 (much more strongly apparent Figure A 30).

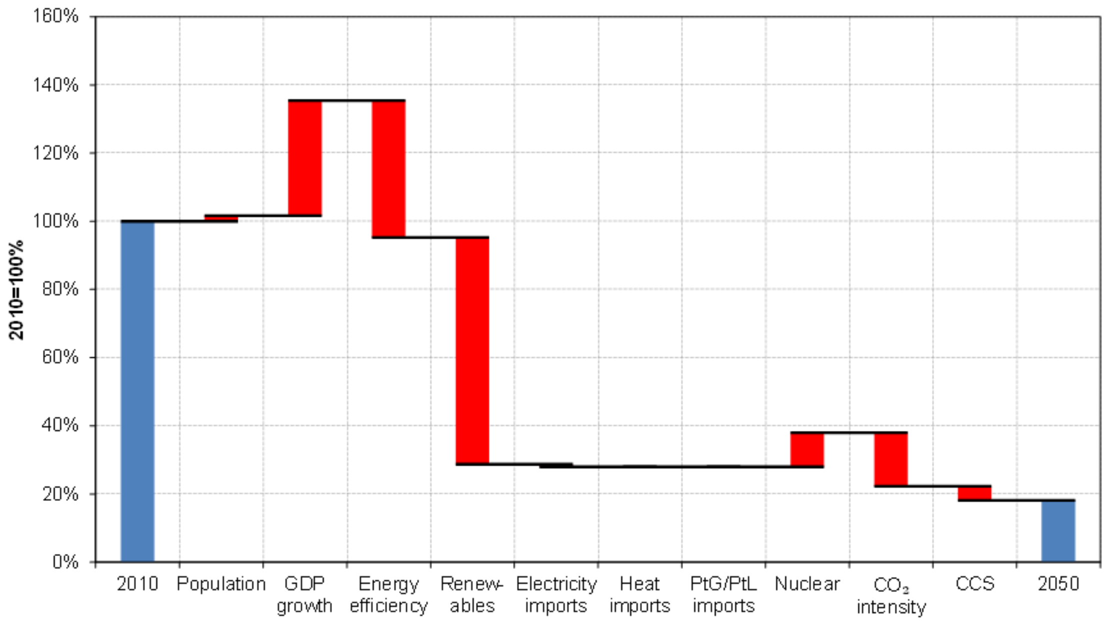
Compared to the above drivers, there are few changes in the scenario that have an increasing effect on emissions. Population does not change significantly over the period, and the share of imported electricity, heat, and synthetic fuels (electricity-based fuels like synthetic motor fuels, synthetic methane or hydrogen) remains constant. However, a steady phase-out of most nuclear electricity increases emissions by 10% in 2050 compared to 2010, leading to the aforementioned net decrease of 82% of $CO_2$ emissions.

**Figure A 29: Energy Roadmap 2050, High Renewables Scenario: Decomposition analysis for aggregate trends, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut

**Figure A 30: Energy Roadmap 2050, High Renewables Scenario: Decomposition analysis for aggregate trends, 2010–2050**




Source: European Commission 2011, calculations by Öko-Institut

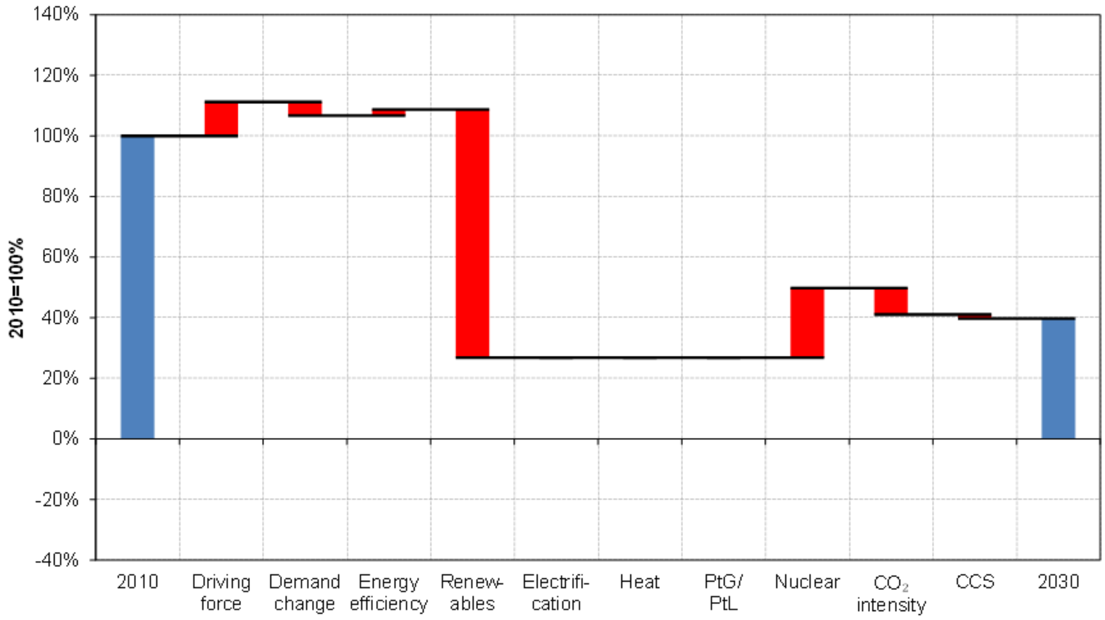
### A 2.3.2 Sectoral trends

#### A 2.3.2.1 Electricity sector

The strong contribution of renewables is clearly seen in the electricity sector. It is dominated by two drivers: The nuclear phase-out causes an increase of emissions (+23%) which is more than offset by the expansion of renewables (–82%) until 2030 (Figure A 31). The remaining fossil generation becomes slightly cleaner (-9%) than in 2010, but this is a minor driver.

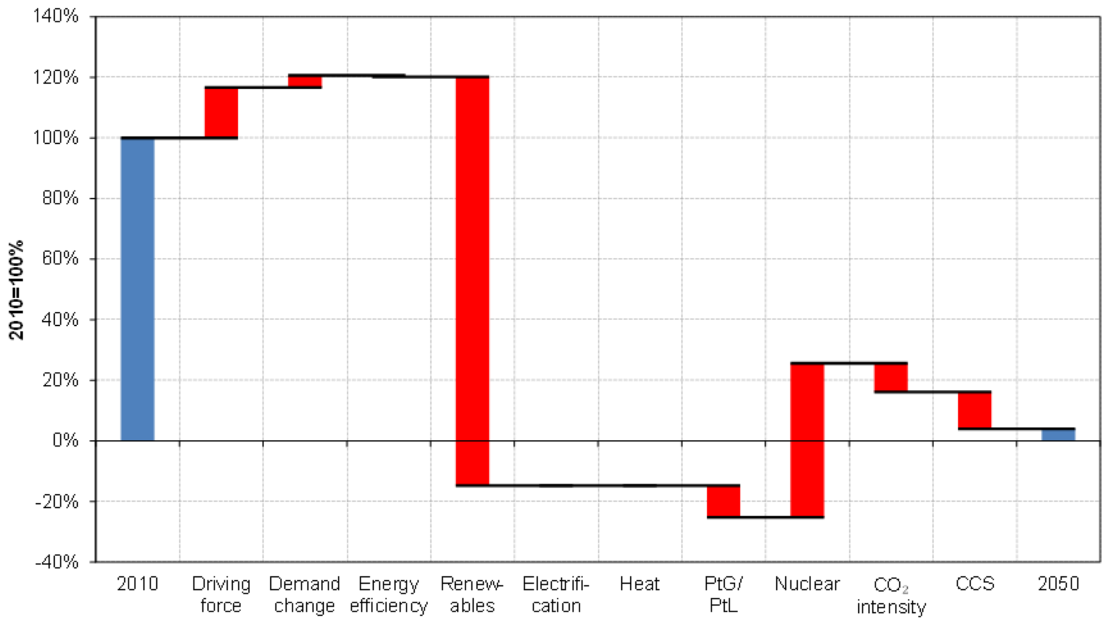
This pattern is even more pronounced in 2050 (Figure A 32) where renewables expansion is far greater than fossil electricity generation in 2010 (with the potential to abate 135% of baseline emissions), thus offsetting all of the nuclear phase-out (+51%) as well as increased demand (+17%). Further contributions by CCS, switch to renewable PtX fuels and natural gas (about 10% of 2010 emissions each) together in effect reduce $CO_2$ emissions to a minimum (96% decrease in 2050).

**Figure A 31: Energy Roadmap 2050, High Renewables Scenario: Decomposition analysis for the electricity sector, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut

**Figure A 32: Energy Roadmap 2050, High Renewables Scenario: Decomposition analysis for the electricity sector, 2010–2050**



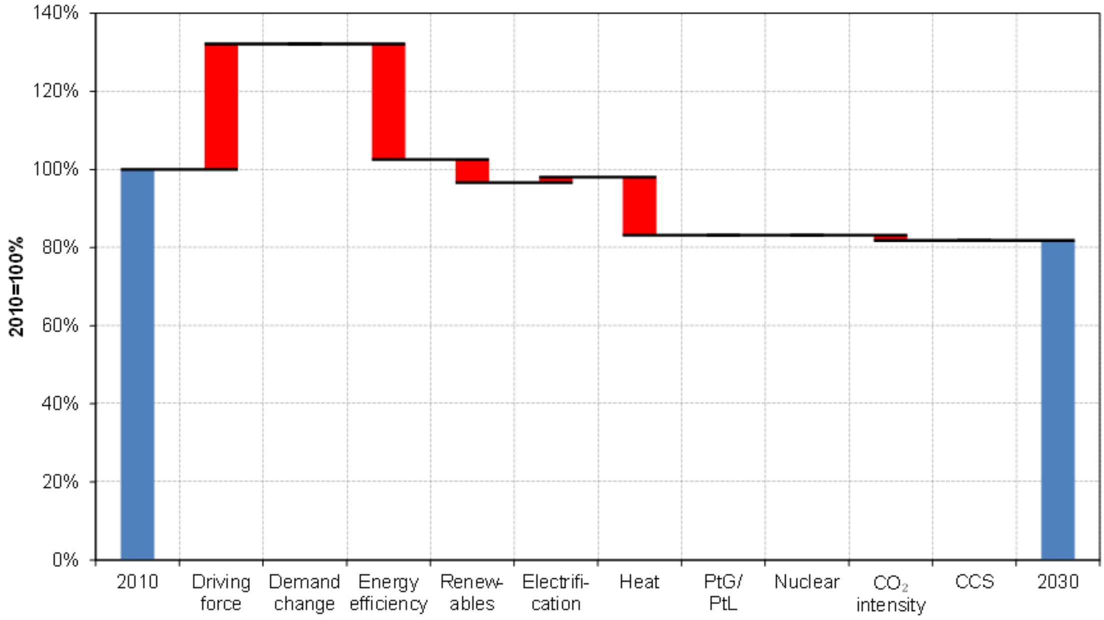

Source: European Commission 2011, calculations by Öko-Institut

#### A 2.3.2.2 Industry sector

The picture is very different for the industry sector. Until 2030, total reduction of emissions is only 18%. Efficiency gains (-30%) do not fully manage to offset a 32% increase in production over 2010. However, increased use of renewables (-6%) and distributed heat (-15%) ensure a net reduction of emissions in 2030 (Figure A 33).

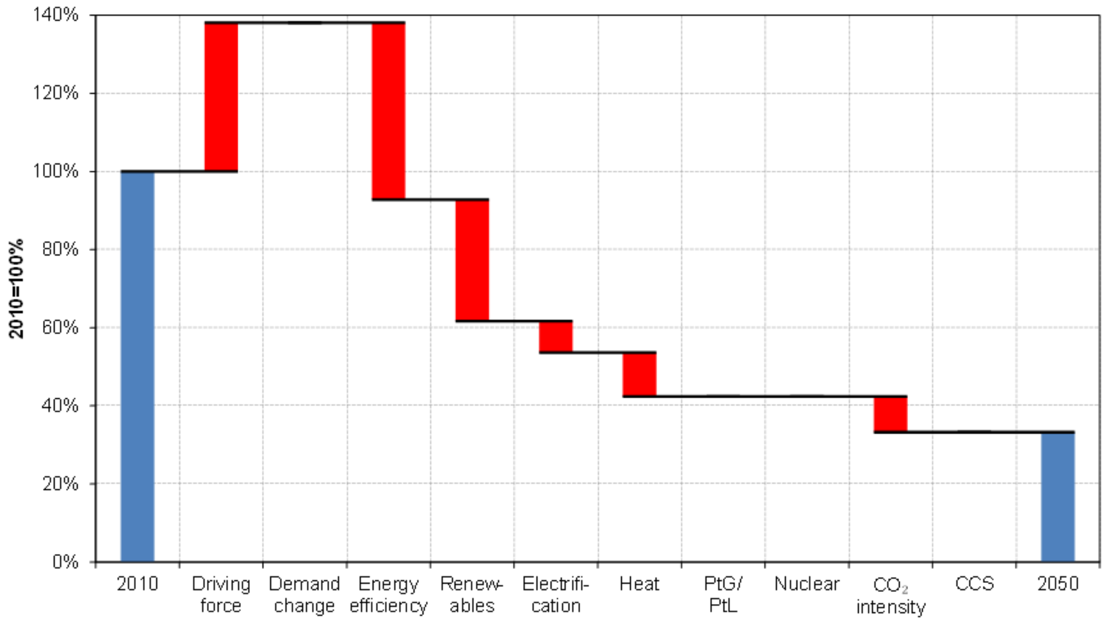
Looking at 2050 (Figure A 34), however, the structure changes strongly, and net emissions reductions reach 67%. Demand does not increase as much as in the period before due to lower growth of production. Efficiency gains now more than offset the added demand, resulting in a net reduction of 7% already without further measures. In addition to this, contributions are made by switching to electricity (-8%) and less $CO_2$-intensive fuels (-9%). Distributed heat (-11%) has a smaller share in total reductions than in 2030. However, the single largest reduction in 2050 is provided by the direct use of renewable energy sources in industry (-31%).

**Figure A 33: Energy Roadmap 2050, High Renewables Scenario: Decomposition analysis for the industry sector, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut

**Figure A 34: Energy Roadmap 2050, High Renewables Scenario: Decomposition analysis for the industry sector, 2010–2050**



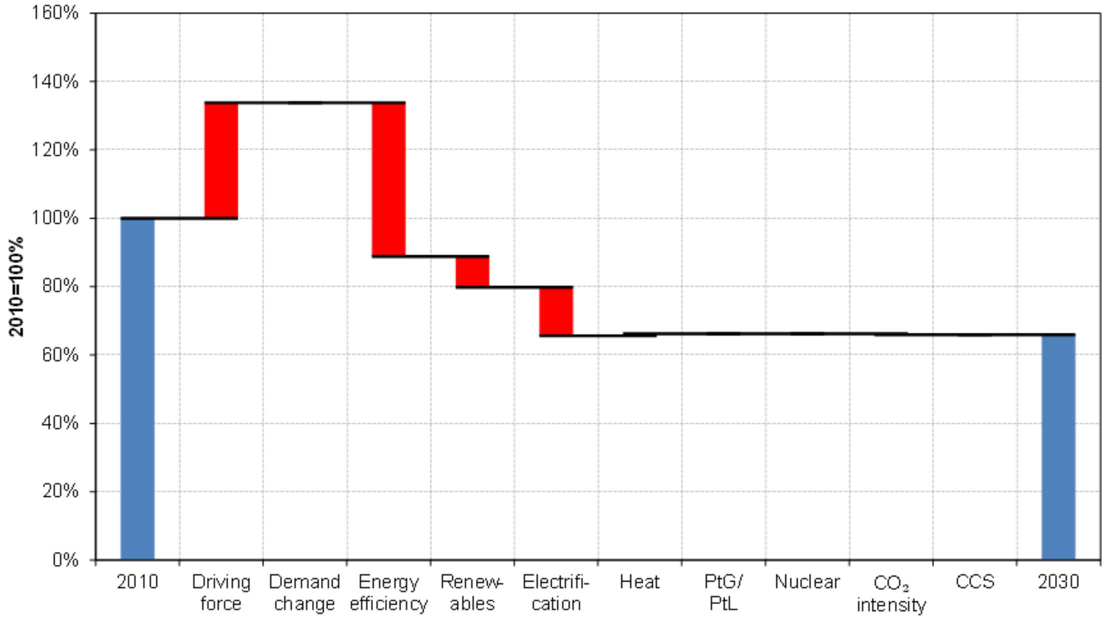

Source: European Commission 2011, calculations by Öko-Institut

#### A 2.3.2.3 Tertiary sector

The picture for the tertiary sector is very similar to the industry sector in 2030. However, here, efficiency gains manage to fully offset the increased energy demand due to the driving force of gross value added (-11% net reduction). Additional emissions reductions are reached by renewables (-9%) and electrification (-14%), while distributed heat plays a negligible role. The total reduction in 2030 (Figure A 35) is 34%.

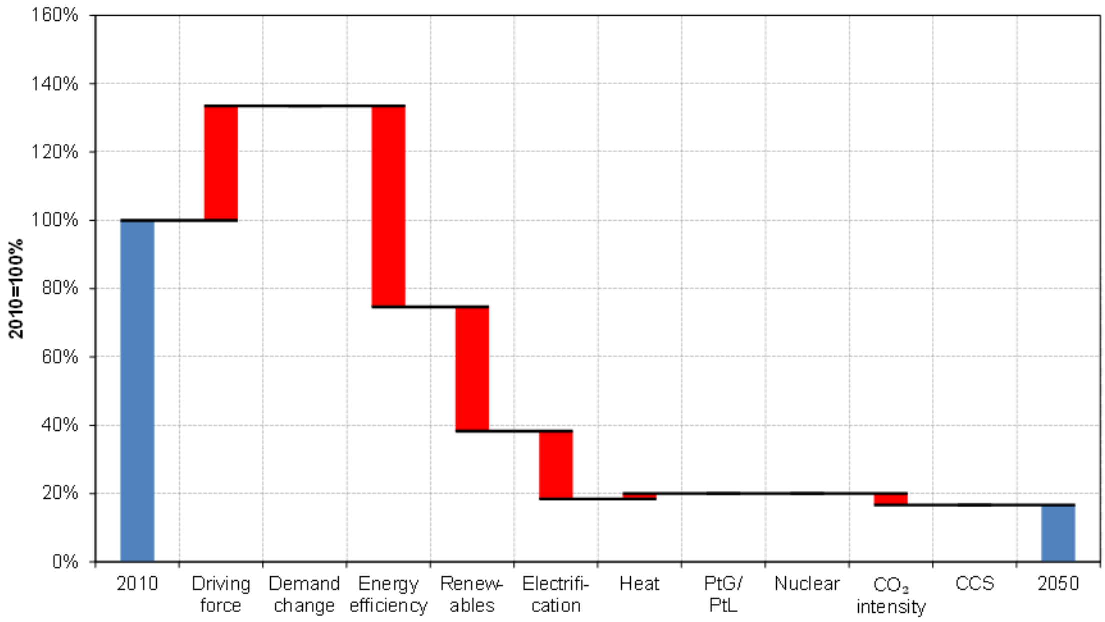
In 2050 (Figure A 36), a 83% reduction of emissions over 2010 is attained with the same drivers: Efficiency increases further, resulting in 59% reduction alone (25% net reduction in light of increased energy use). After 2030, renewables expand much faster than before, contributing 36 percentage points to the reduction, while the switch to electricity is largely finished in 2030 already. Electrification contributes only 20% reduction in 2050. Some further reduction (3%) is attained by a changeover to less $CO_2$-intensive fuels.

**Figure A 35: Energy Roadmap 2050, High Renewables Scenario: Decomposition analysis for the tertiary sector, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut

**Figure A 36: Energy Roadmap 2050, High Renewables Scenario: Decomposition analysis for the tertiary sector, 2010–2050**



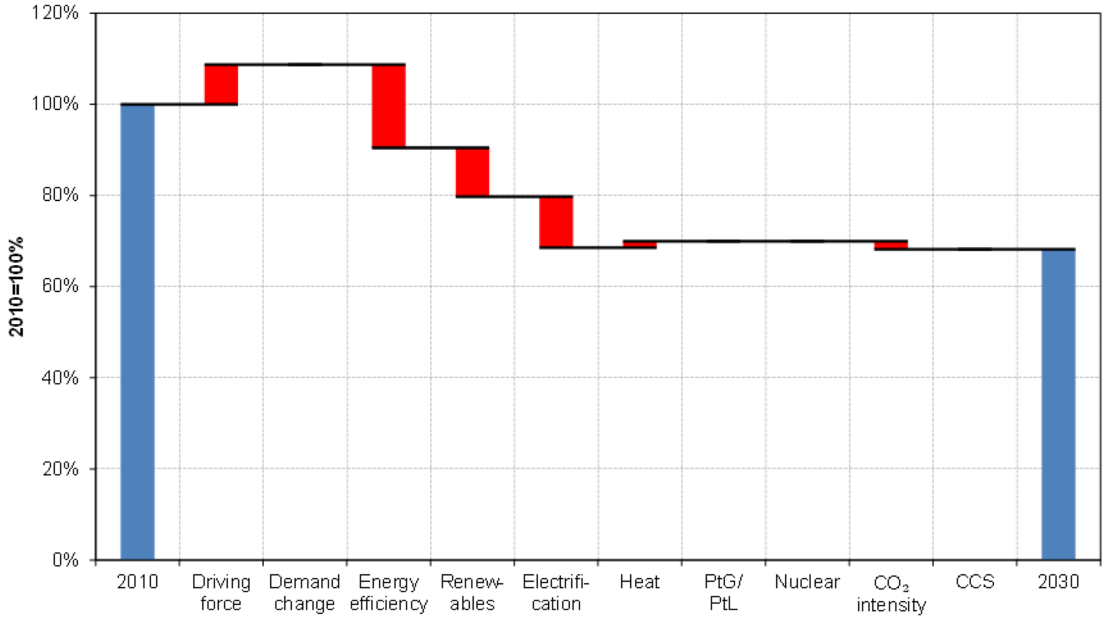

Source: European Commission 2011, calculations by Öko-Institut

#### A 2.3.2.4 Residential sector

The driving force (number of households) in the residential sector does not grow as strongly, such that efficiency gains attain a 10% net reduction of energy demand. In addition to this, a switch to renewables and electricity contributes 11% of emissions reduction each in comparison to 2010. This leads to a 32% total reduction of emissions until 2030 (Figure A 37).

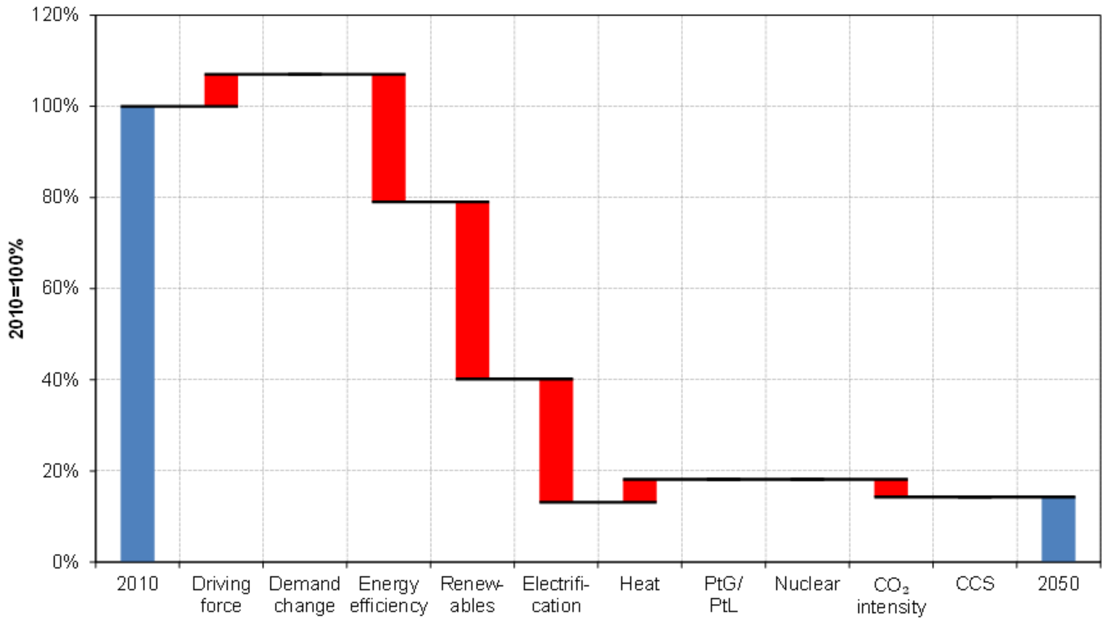
Like in the other sectors, the expansion of renewables accelerates after 2030, reaching a 36% reduction until 2050. The same holds true for energy efficiency, whose net reduction is 25% in 2050. Like in the the other sectors, electrification after 2030 does not grow as fast anymore, such that its contribution reaches only 20% in 2050. In total, the emissions reduction in the residential sector is 83% in 2050 (Figure A 38).

**Figure A 37: Energy Roadmap 2050, High Renewables Scenario: Decomposition analysis for the residential sector, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut

**Figure A 38: Energy Roadmap 2050, High Renewables Scenario: Decomposition analysis for the residential sector, 2010–2050**



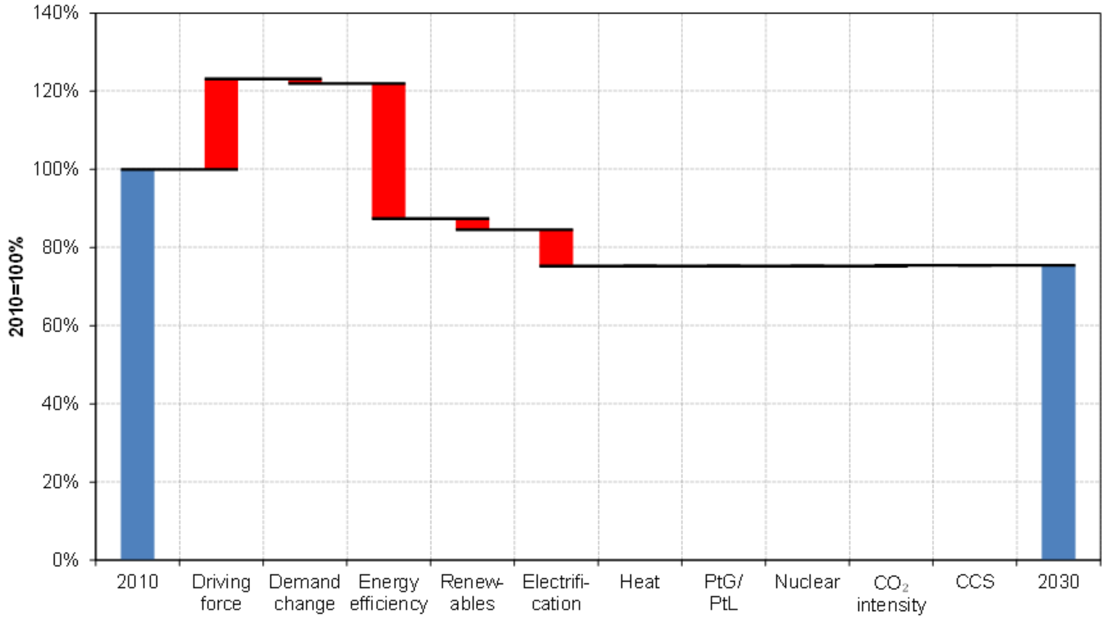

Source: European Commission 2011, calculations by Öko-Institut

#### A 2.3.2.5 Passenger transport

Passenger transport reaches only 25% reduction over 2010 by 2030 (Figure A 39). Like in other sectors, efficiency grows faster (-35%) than demand (23%), leading to a net reduction. However, unlike in other sectors, there is only a small contribution by renewables (-3%) and electrification (-9%) until 2030.

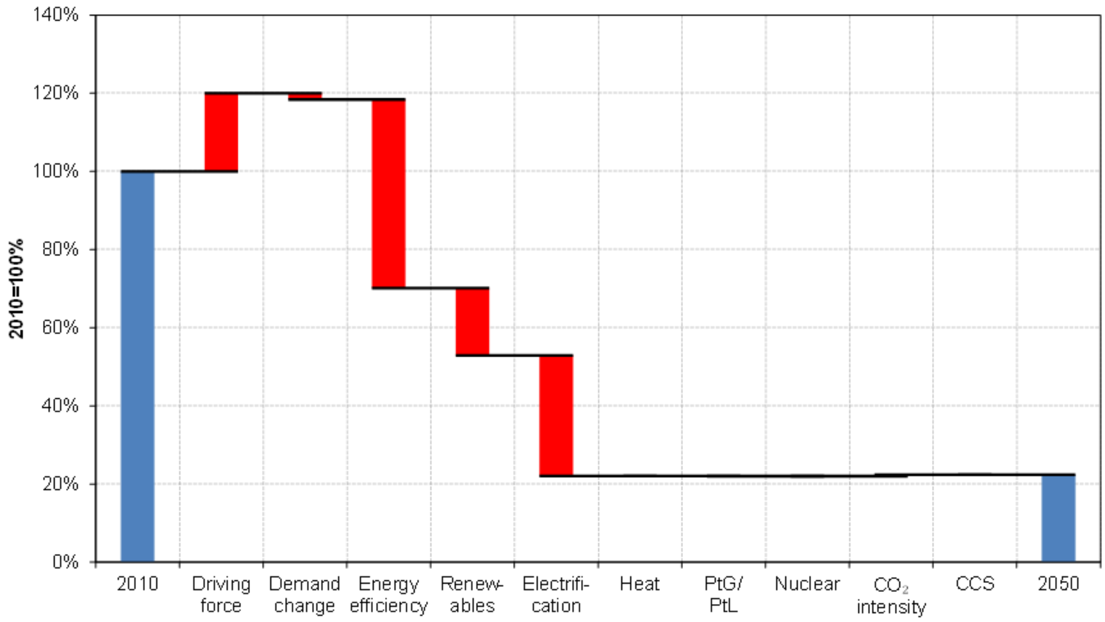
The development changes sharply after 2030 (Figure A 40). Most importantly, transport demand decreases in comparison to 2030 and stands at only 20% more than in 2010. Therefore, efficiency gains (-48%) and renewables (-17%) make large contributions to an overall reduction of 78% until 2050. Electric mobility shows the fastest growth after 2030, such that electrification becomes a significant (-31%) driver for reductions in 2050.

**Figure A 39: Energy Roadmap 2050, High Renewables Scenario: Decomposition analysis for passenger transport, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut

**Figure A 40: Energy Roadmap 2050, High Renewables Scenario: Decomposition analysis for passenger transport, 2010–2050**



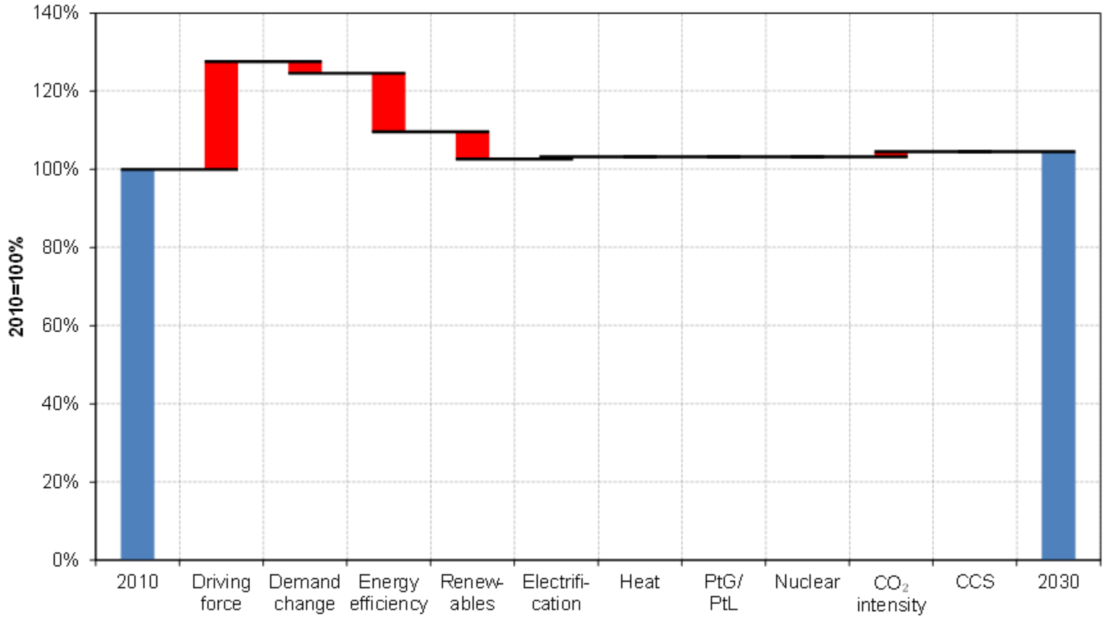

Source: European Commission 2011, calculations by Öko-Institut.

#### A 2.3.2.6 Freight transport

In contrast to passenger transport, freight transport emissions actually increase until 2030 (+5% compared to 2010, Figure A 41). This is mostly due to an increase in demand (+ 28%) that is not offset by either efficiency gains (-15%) or renewables (-7%).

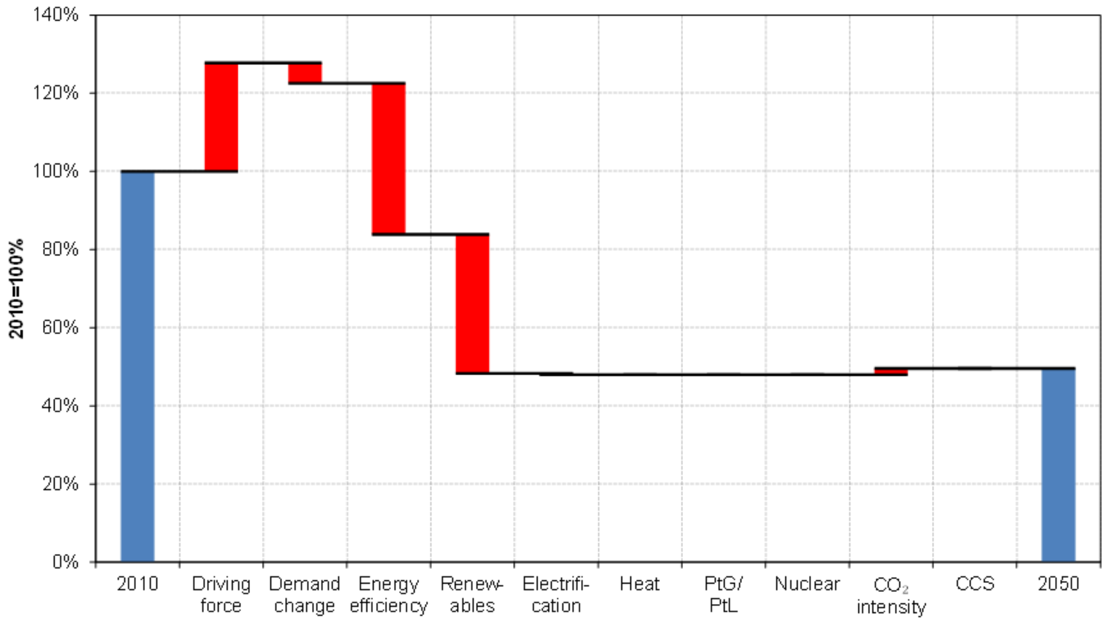
However, significant progress is made after 2030 (Figure A 42). Demand growth stops and remains at 28% in 2050. At the same time, efficiency and renewables both grow strongly, contributing 36% and 39% of emissions reductions, respectively. Other drivers are negligible. In sum, emissions in freight transport do decrease by 50% until 2050, but the sector shows the smallest reduction of all sectors in the scenario.

**Figure A 41: Energy Roadmap 2050, High Renewables Scenario: Decomposition analysis for freight transport, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut

**Figure A 42: Energy Roadmap 2050, High Renewables Scenario: Decomposition analysis for the freight transport sector, 2010–2050**




Source: European Commission 2011, calculations by Öko-Institut

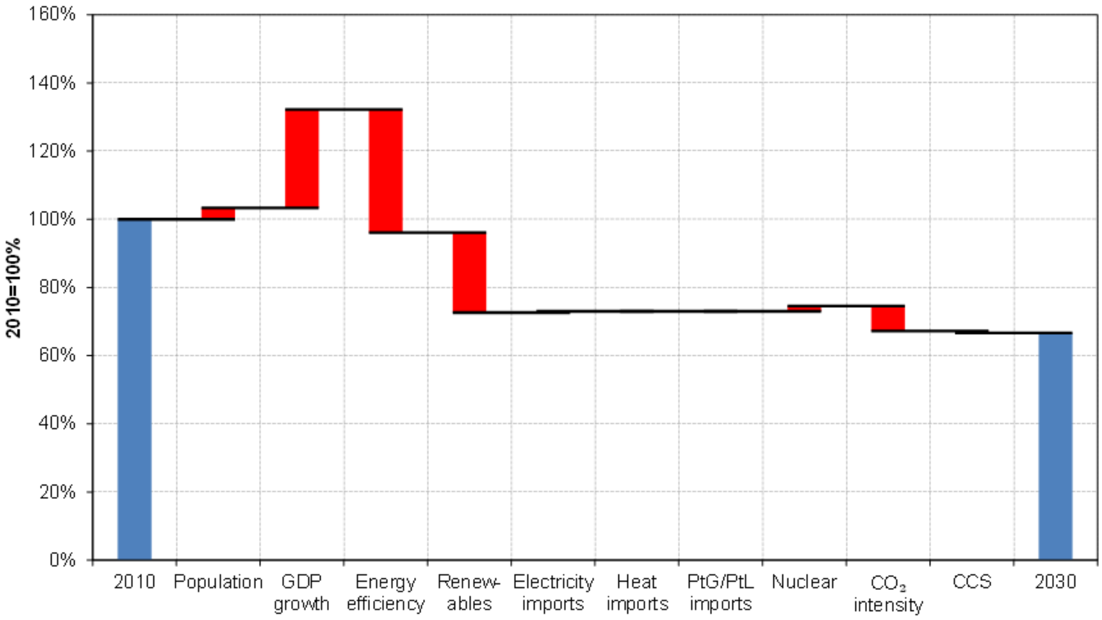
### A.2.4 Energy Roadmap 2050 – Diversified Supply Scenario

#### A 2.4.1 Aggregate trends

The Diversified Supply scenario attains a 33% reduction in total $CO_2$ emissions from energy until 2030 (Figure A 43). There is increasing pressure on emissions by growing population (+3% compared to 2010 emissions) and economic growth (+29%). However, this is offset by increased energy efficiency (–36%) and renewables use (–24%). A further contribution is made by a fossil fuel mix with a lower $CO_2$ intensity (–7%) and little CCS (–0.6%). In contrast, there is a slight increasing contribution to emissions caused by the nuclear phase-out (+2%).

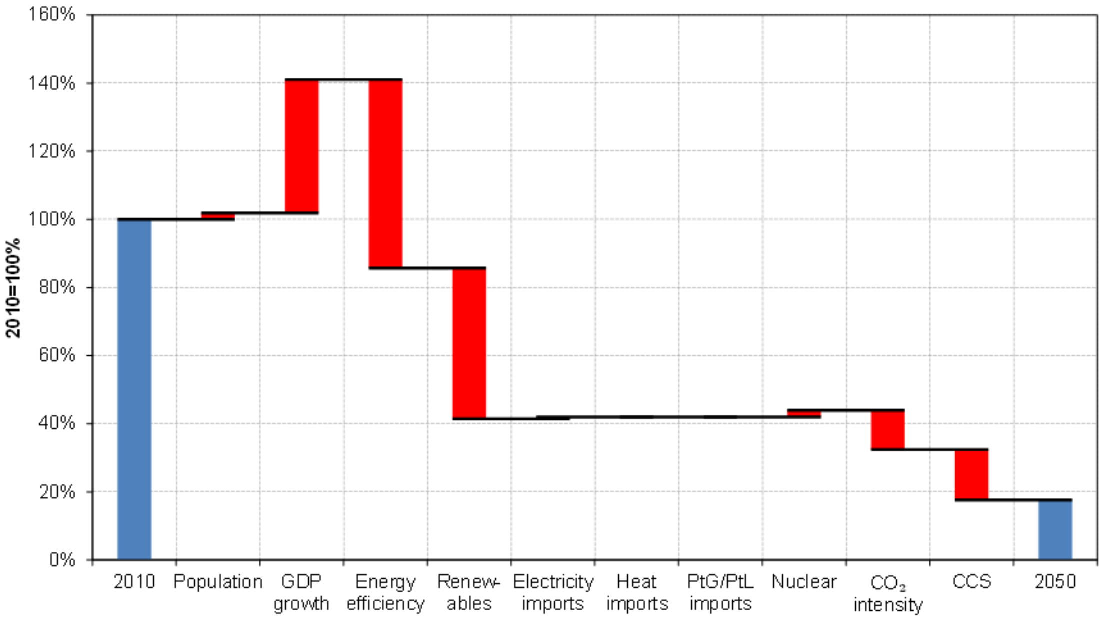
In 2050 (Figure A 44), a total reduction of 82% is attained. The contributions by efficiency (–55%) and renewables (–44%) grow strongly compared to 2030, while $CO_2$ intensity is further reduced (–15% of emissions). CCS is expanded significantly (–15% of emissions). The reductions are counterbalanced by further economic growth (+39% total contribution).

**Figure A 43: Energy Roadmap 2050, Diversified Supply Scenario: Decomposition analysis for aggregate trends, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut

**Figure A 44: Energy Roadmap 2050, Diversified Supply Scenario: Decomposition analysis for aggregate trends, 2010–2050**




Source: European Commission 2011, calculations by Öko-Institut

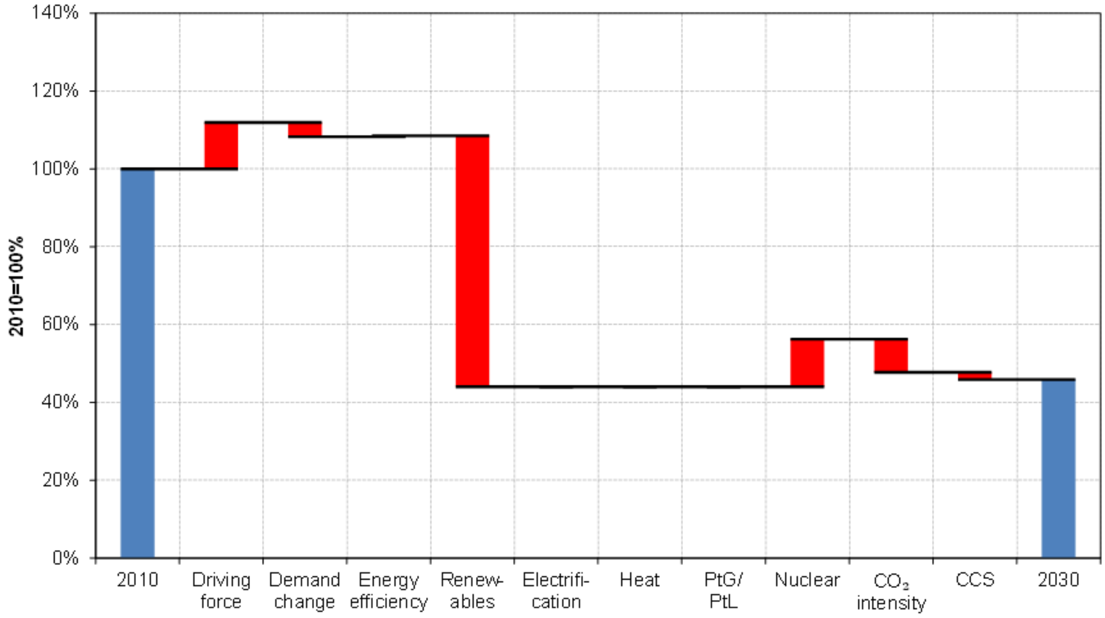
### A 2.4.2 Sectoral trends

#### A 2.4.2.1 Electricity sector

In the electricity sector, emissions are reduced by 54% compared to 2010 (Figure A 45), mainly due to strong expansion of renewables (–65% of 2010 emissions) and reduced $CO_2$ intensity (–9%). In contrast, reductions are counterbalanced by higher electricity demand (a net 8% increase of emissions) and the nuclear phase-out (+12%). CCS makes a small contribution (–2% of baseline emissions).

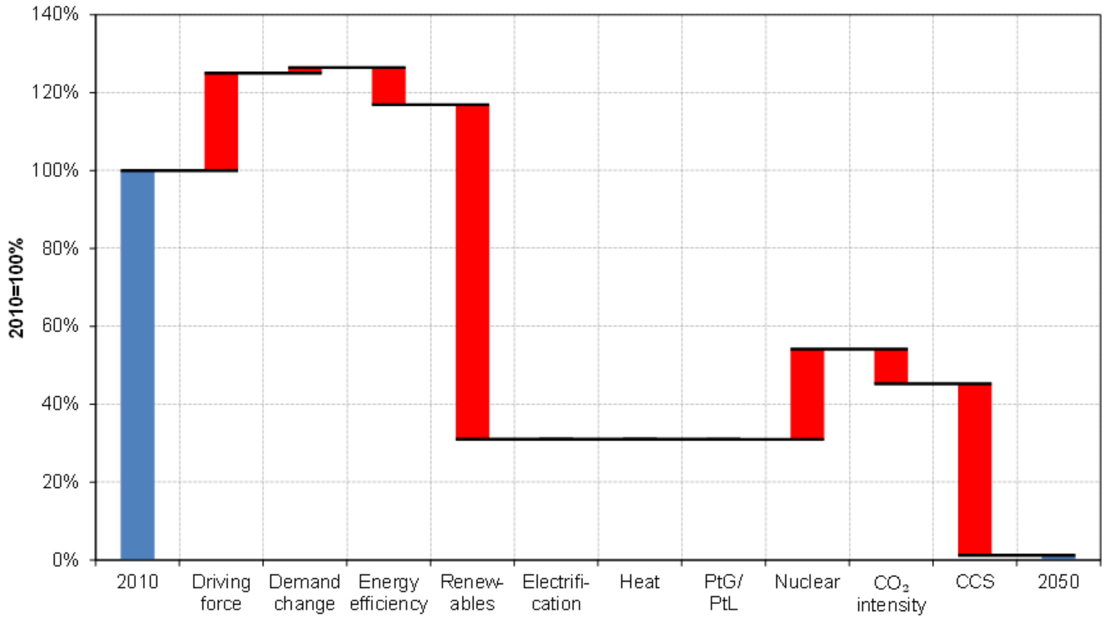
In 2050 (Figure A 46), the sector is practically fully decarbonized (–99%) mainly due to a substantial expansion of renewables (–86% of 2010 emissions), CCS (–44%), improved efficiency (–10%), and reduced $CO_2$ intensity (–9%). These drivers are strong enough to offset the emissions increase caused by demand growth (+27%) and the nuclear phase-out (+23%).

**Figure A 45: Energy Roadmap 2050, Diversified Supply Scenario: Decomposition analysis for the electricity sector, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut

**Figure A 46: Energy Roadmap 2050, Diversified Supply Scenario: Decomposition analysis for the electricity sector, 2010–2050**



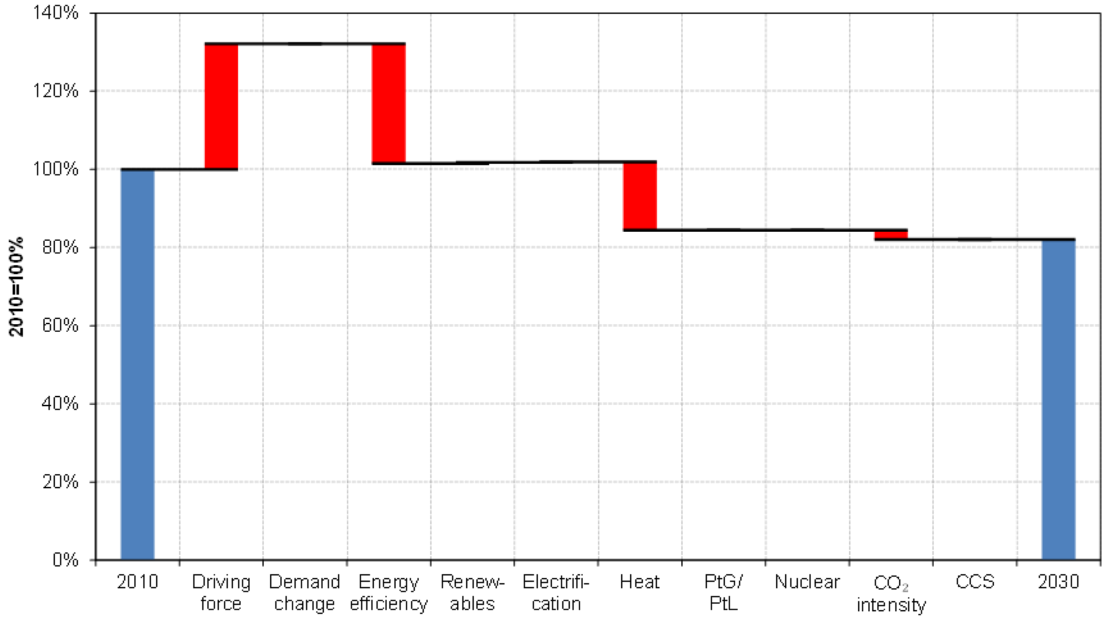

Source: European Commission 2011, calculations by Öko-Institut

#### A 2.4.2.2 Industry sector

In the industry sector, efficiency gains almost counterbalance the emissions caused by increased production (–31% vs. +32%) (Figure A 47). Additionally, a switch to distributed heat abates 18% of baseline emissions, and $CO_2$ intensity of remaining fossil fuels contributes a further –2%.

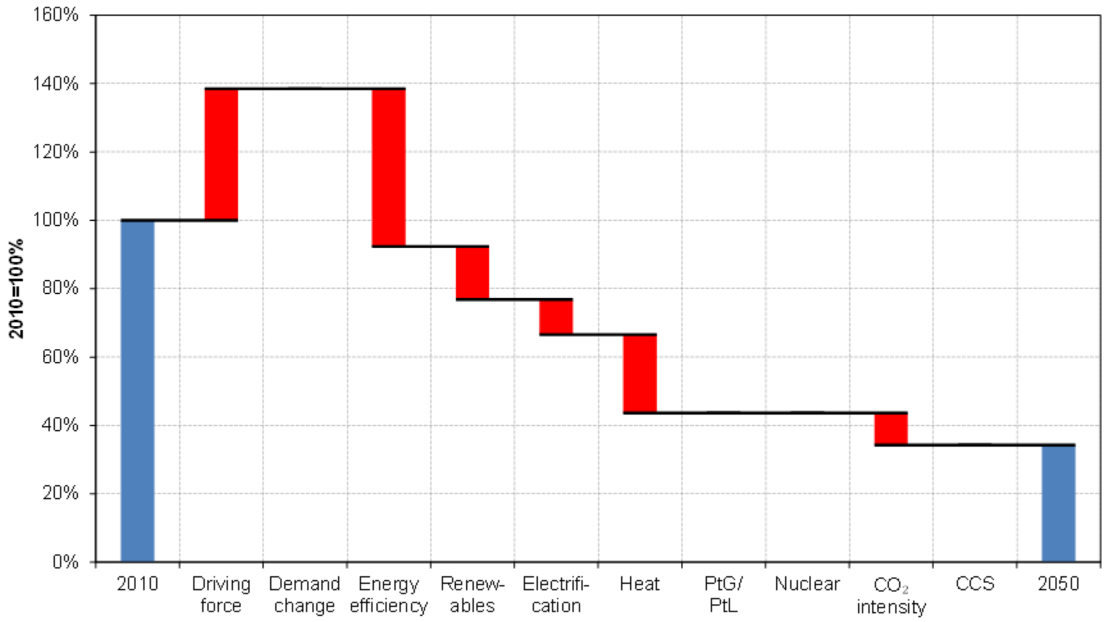
Until 2050 (Figure A 48), efficiency gains outpace production growth and lead to a net emissions reduction compared to 2010 (–46% vs. +39%). Renewables play a role and abate a further 16% of 2010 emissions. In contrast to 2030, electricity makes a contribution of 10% while the contribution of electrification further increases and now reduces 23% of baseline emissions. In sum, the drivers lead to a total reduction of –66%.

**Figure A 47: Energy Roadmap 2050, Diversified Supply Scenario: Decomposition analysis for the industry sector, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut

**Figure A 48: Energy Roadmap 2050, Diversified Supply Scenario: Decomposition analysis for the industry sector, 2010–2050**



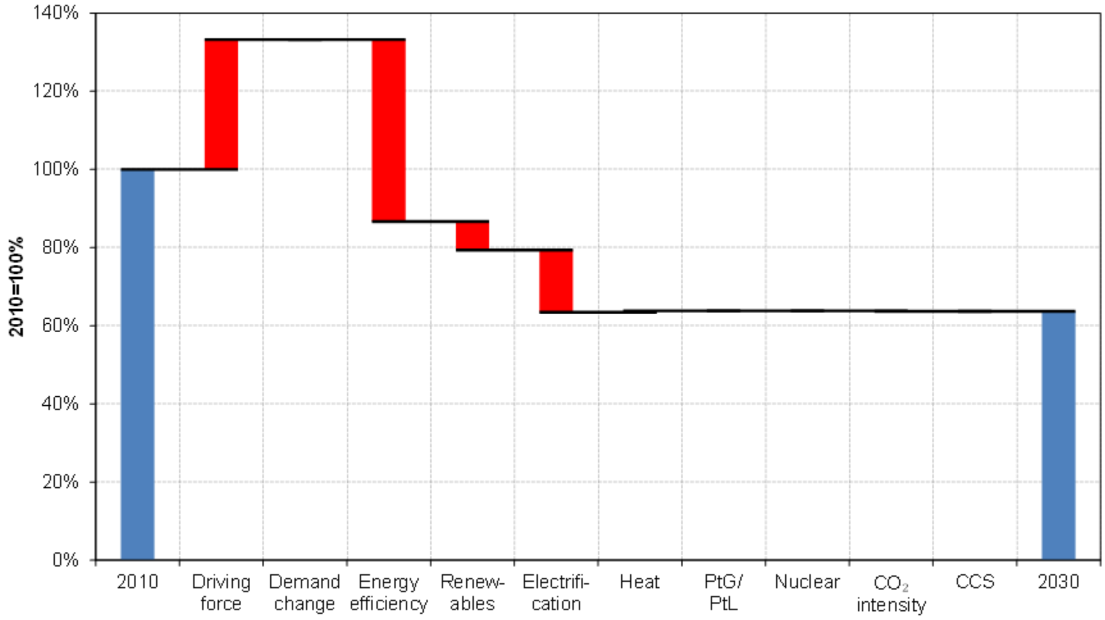

Source: European Commission 2011, calculations by Öko-Institut

#### A 2.4.2.3 Tertiary sector

Similarly to the other sectors, the tertiary sector relies largely on efficiency gains for its reductions in 2030 (Figure A 49) before renewables and electrification kick in. Increased production would add 33% to baseline emissions, but this is reduced by increased efficiency (–47%), as well as some electrification (–16%) and renewables (–7%). Total reduction in 2030 is –36%.

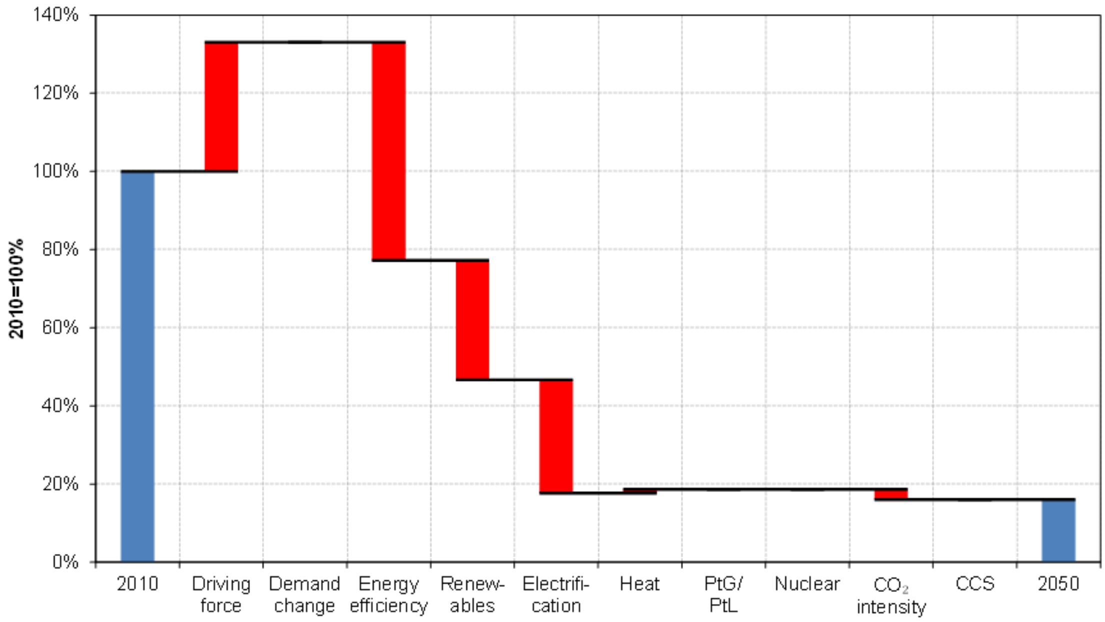
In 2050 (Figure A 50), all factors have significantly grown, but the increase in renewables and electrification is largest. They now reduce baseline emissions by 31% and 29%, respectively. Efficiency also increases its contribution to –56%, while the driving influence of increased production stays at 33% of baseline emissions. Lesser use of distributed heat adds 1% to emissions. Small contributions are made by improved $CO_2$ intensity (–3%), leading to a –84% net decrease in emissions.

**Figure A 49: Energy Roadmap 2050, Diversified Supply Scenario: Decomposition analysis for the tertiary sector, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut

**Figure A 50: Energy Roadmap 2050, Diversified Supply Scenario: Decomposition analysis for the tertiary sector, 2010–2050**



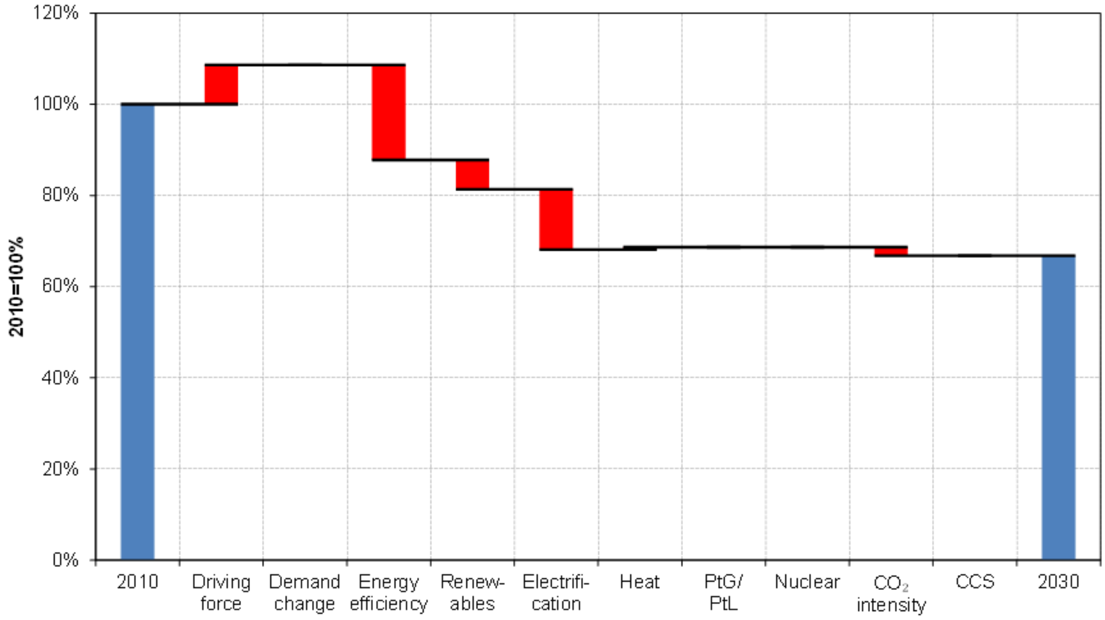

Source: European Commission 2011, calculations by Öko-Institut

#### A 2.4.2.4 Residential sector

In the residential sector, a total reduction of 33% is attained until 2030 (Figure A 51). The main drivers are energy efficiency (-21%), renewable energy (-6%), and electricity use (-13%). These contributions are counterbalanced by a higher number of households (+9%).

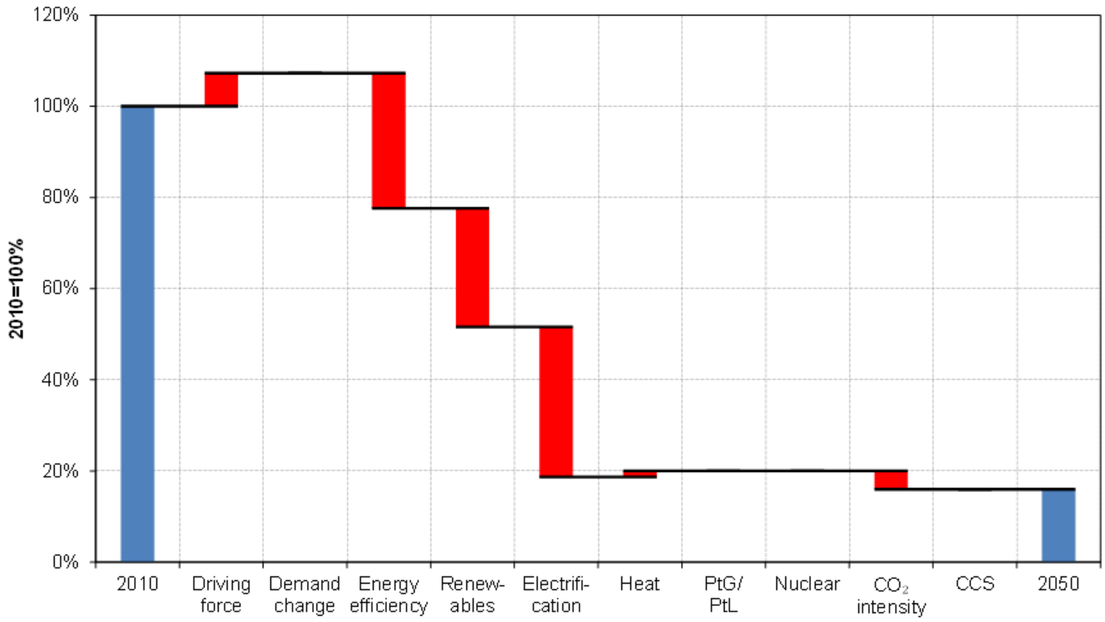
In 2050 (Figure A 52), a total reduction of -84% is attained mainly by the same three drivers, but with much higher contributions: Energy efficiency (-30%), renewable energy (-26%), and electricity (-33%). Small contributions are made by reduced $CO_2$ intensity. Emissions are increased by a higher number of households (7%) and lower distributed heat use (1%).

**Figure A 51: Energy Roadmap 2050, Diversified Supply Scenario: Decomposition analysis for the residential sector, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut

**Figure A 52: Energy Roadmap 2050, Diversified Supply Scenario: Decomposition analysis for the residential sector, 2010–2050**



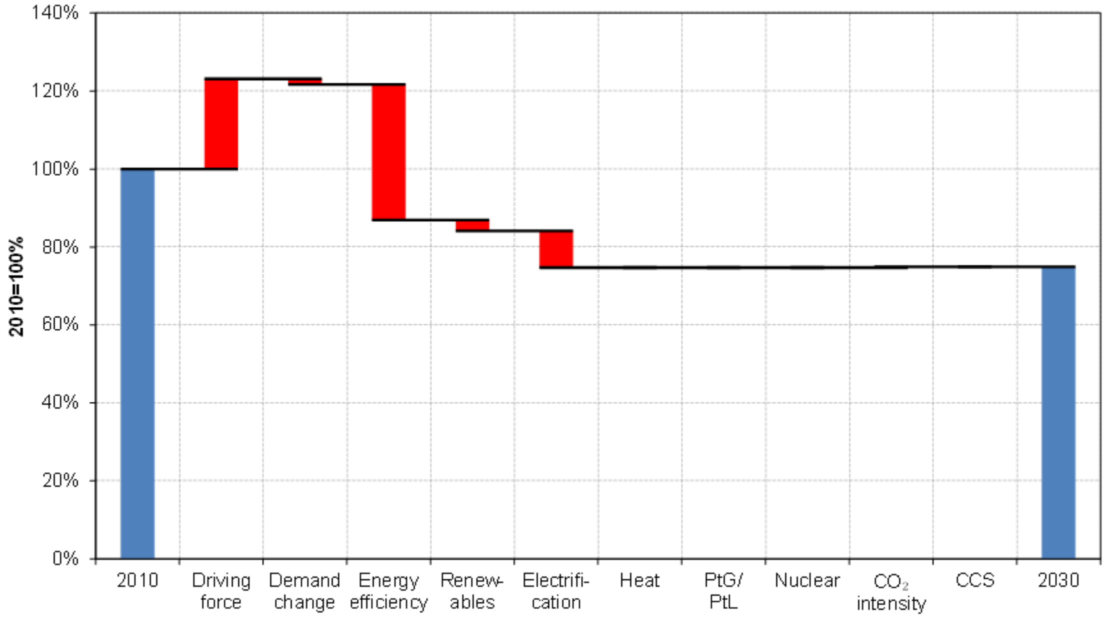

Source: European Commission 2011, calculations by Öko-Institut

#### A 2.4.2.5 Passenger transport

Until 2030 (Figure A 53), passenger transport reduces its emissions by 25% despite an increase in transport demand of 23%. Energy efficiency compensates this (-35%) as well as electrification (-9%).

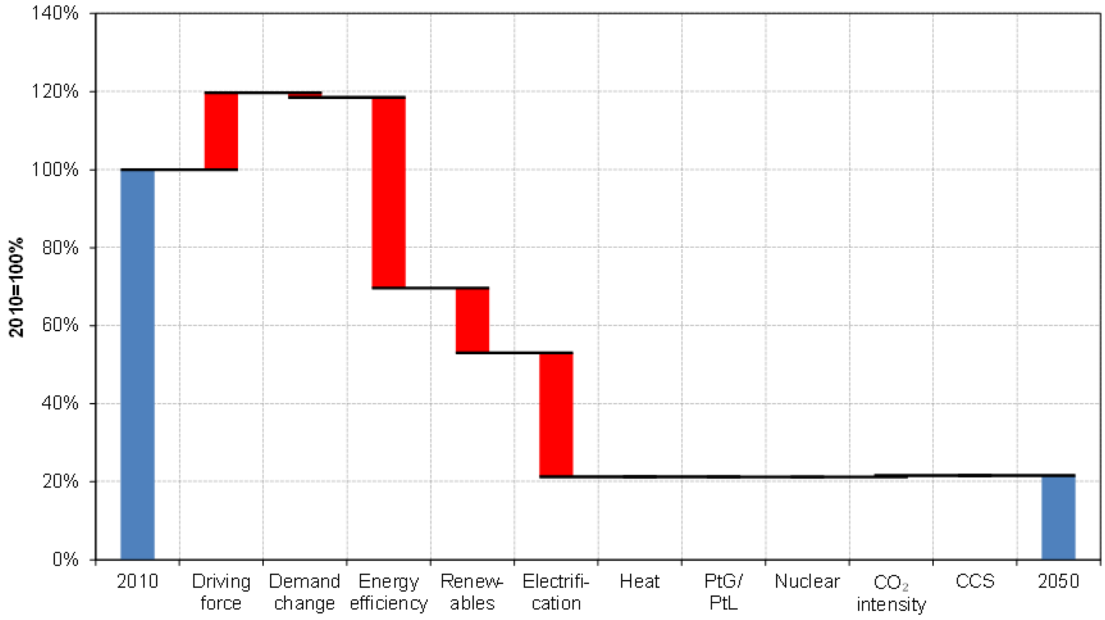
Until 2050 (Figure A 54), there is large additional reduction to -78% compared to 2010, again with energy efficiency (-49%) as the dominant driver. Additionally, larger contributions are made by renewables (-17%) and electricity (-32%).

**Figure A 53: Energy Roadmap 2050, Diversified Supply Scenario: Decomposition analysis for passenger transport, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut

**Figure A 54: Energy Roadmap 2050, Diversified Supply Scenario: Decomposition analysis for passenger transport, 2010–2050**



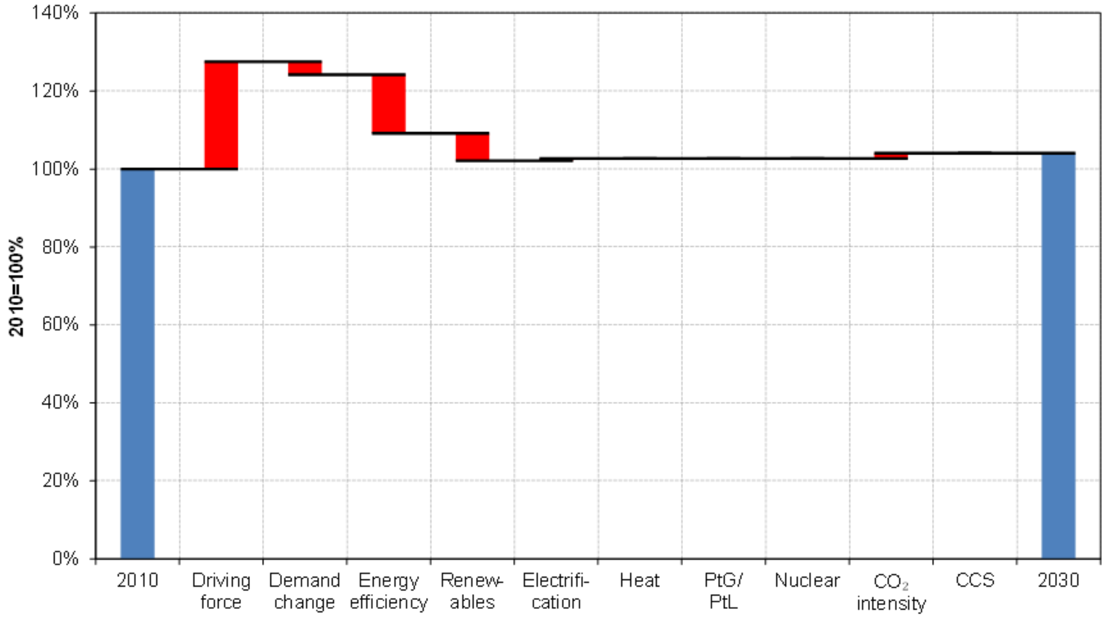

Source: European Commission 2011, calculations by Öko-Institut

#### A 2.4.2.6 Freight transport

As in other Energy Roadmap scenarios, emissions from freight transport increase until 2030 (Figure A 55) (+4%) due to a strong increase in demand (24%, 3% below reference). There are some contributions by energy efficiency (-15%) and renewables (-7%), but not enough to balance out the increase in demand.

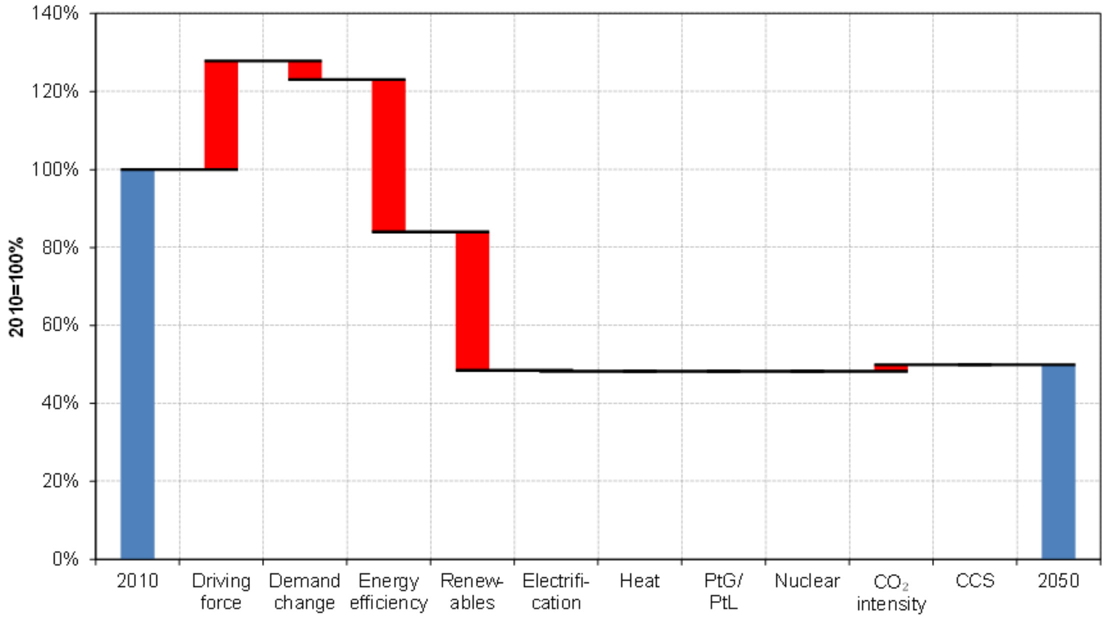
Until 2050 (Figure A 56) however, energy efficiency increases dramatically (-39%), as does renewables use (-36%). Both drivers more than offset the demand increase, resulting in a 50% net reduction of emissions.

**Figure A 55: Energy Roadmap 2050, Diversified Supply Scenario: Decomposition analysis for freight transport, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut

**Figure A 56: Energy Roadmap 2050, Diversified Supply Scenario: Decomposition analysis for the freight transport sector, 2010–2050**




Source: European Commission 2011, calculations by Öko-Institut

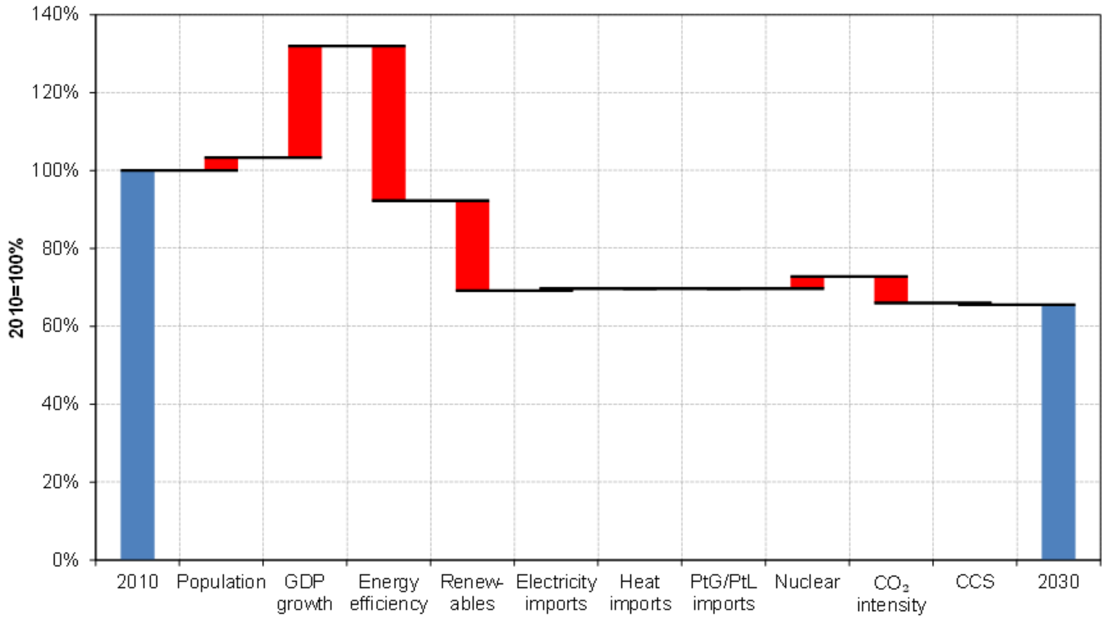
## A.2.5 Energy Roadmap 2050 – High Efficiency Scenario

### A 2.5.1 Aggregate trends

The High Efficiency scenario attains a 34% reduction in total $CO_2$ emissions from energy until 2030 (Figure A 57). There is increasing pressure on emissions by growing population (+3% compared to 2010 emissions) and economic growth (+29%). However, this is offset by strongly increased energy efficiency (-40%) and renewables use (–23%). A further contribution is made by lower $CO_2$ intensity of the fossil fuel mix (-7%) and little CCS (-0.5%). In contrast, there is a slight increasing contribution to emissions caused by the nuclear phase-out (+3%).

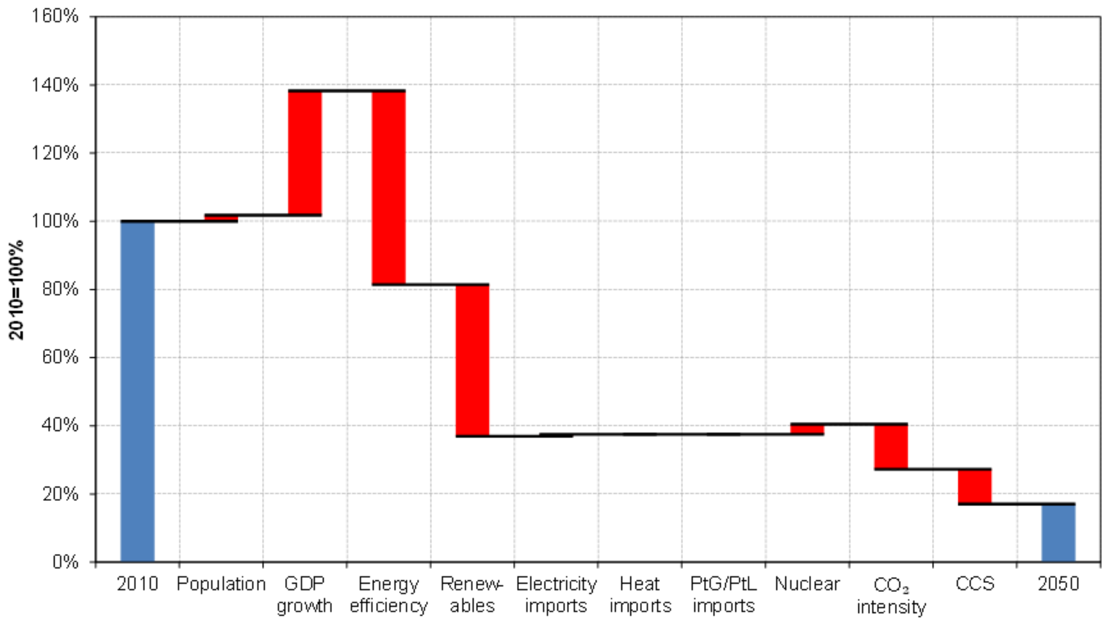
In 2050 (Figure A 58), a total reduction of 83% is attained. The contributions by mainly efficiency (-57%) but also renewables (-45%) grow strongly compared to 2030 while $CO_2$ intensity is further reduced (-13% relative contribution). CCS plays a smaller role than in other scenarios (-13% of emissions).

**Figure A 57: Energy Roadmap 2050, High Efficiency Scenario: Decomposition analysis for aggregate trends, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut

**Figure A 58: Energy Roadmap 2050, High Efficiency Scenario: Decomposition analysis for aggregate trends, 2010–2050**




Source: European Commission 2011, calculations by Öko-Institut

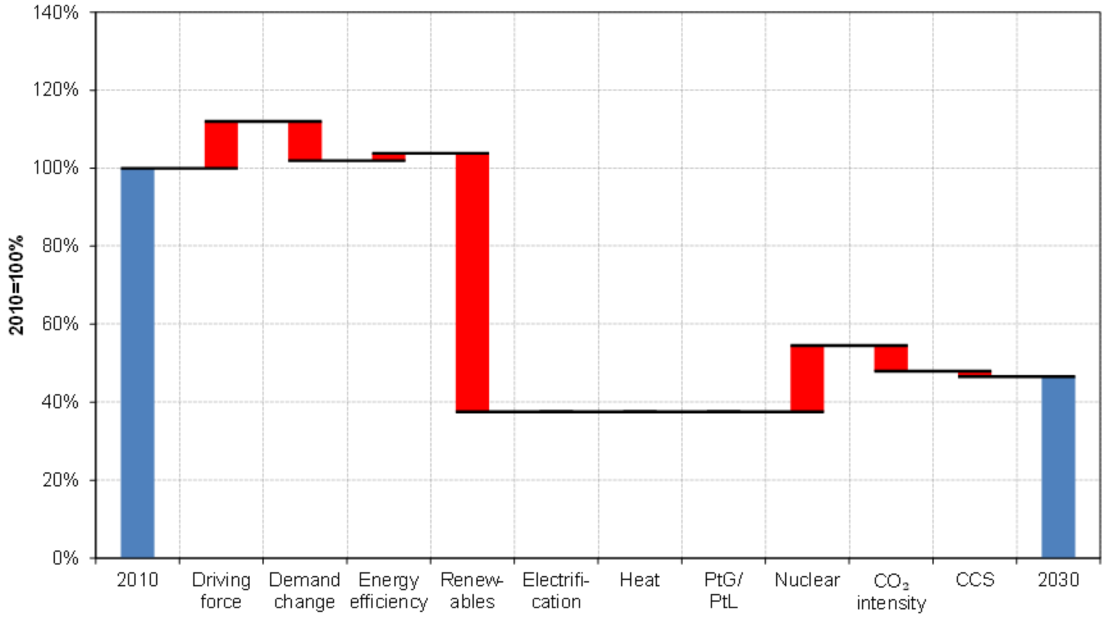
### A 2.5.2 Sectoral trends

#### A 2.5.2.1 Electricity sector

In the electricity sector, emissions are reduced by 54% compared to 2010 (Figure A 59), mainly due to strong expansion of renewables (–66% of 2010 emissions) and reduced $CO_2$ intensity (–7%). The net increase in demand (2%) is much lower than in other scenarios due to the increased efficiency (in this case, a clear separation of demand change and efficiency gains is difficult). Relatively, the nuclear phase-out has a higher increasing effect (+17%).

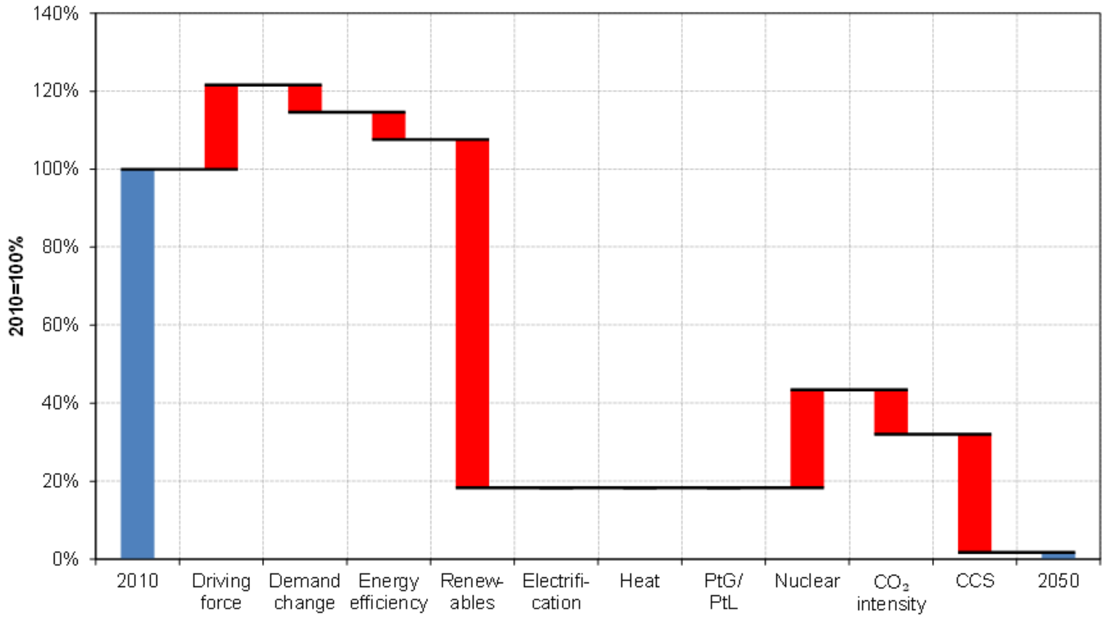
In 2050 (Figure A 60), the sector is practically fully decarbonized (-98%) mainly due to a substantial expansion of renewables (-89% of 2010 emissions). CCS plays a smaller role than in other scenarios (-30%). Interestingly, the contribution of efficiency is only at -7% of the total emissions reduction. A larger contribution (-11%) is made by reduced $CO_2$ intensity of fossil fuels.

**Figure A 59: Energy Roadmap 2050, High Efficiency Scenario: Decomposition analysis for the electricity sector, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut

**Figure A 60: Energy Roadmap 2050, High Efficiency Scenario: Decomposition analysis for the electricity sector, 2010–2050**



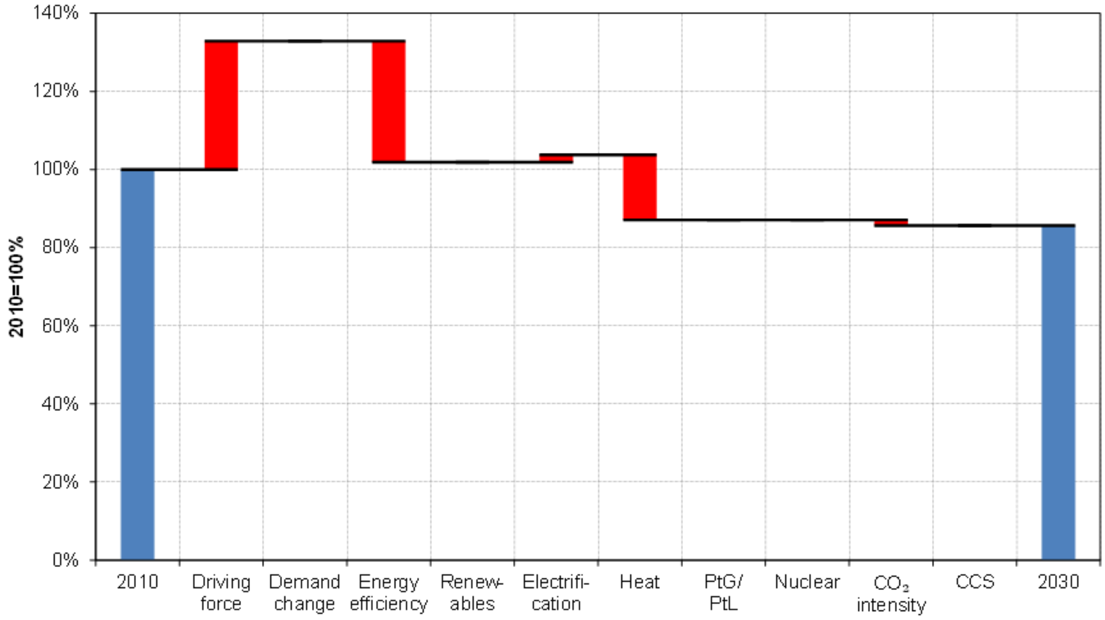

Source: European Commission 2011, calculations by Öko-Institut

#### A 2.5.2.2 Industry sector

In the industry sector, total reduction is small until 2030 (Figure A 61) by only 14%. The largest net contribution is made by use of distributed heat (-17% of emissions). Efficiency rises strongly and almost counter-balances a 33% increase in industrial output. Use of electricity declines slightly, leading to an increasing pressure on emissions.

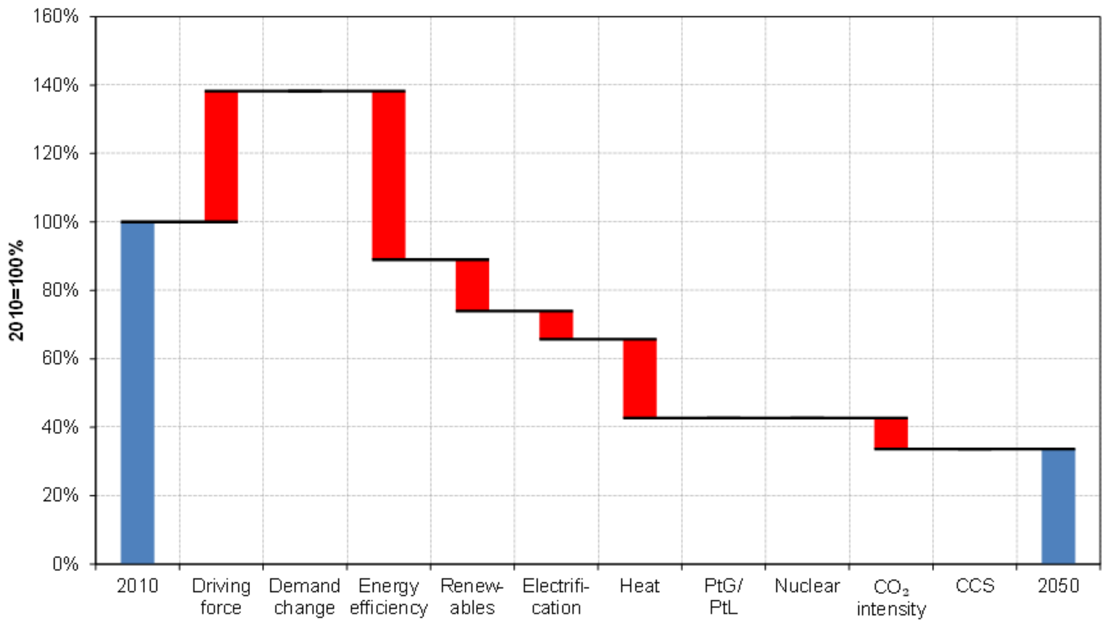
Until 2050 (Figure A 62), efficiency gains outpace production growth and lead to a net emissions reduction compared to 2010 (-11%). Renewables play a role and abate a further 15% of 2010 emissions. In contrast to 2030, electricity makes a relative contribution of -8% while the contribution of heat further increases and now reduces 23% of baseline emissions. In sum, the drivers lead to a total reduction of –66%, similar to other scenarios in the Energy Roadmap.

**Figure A 61: Energy Roadmap 2050, High Efficiency Scenario: Decomposition analysis for the industry sector, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut

**Figure A 62: Energy Roadmap 2050, High Efficiency Scenario: Decomposition analysis for the industry sector, 2010–2050**



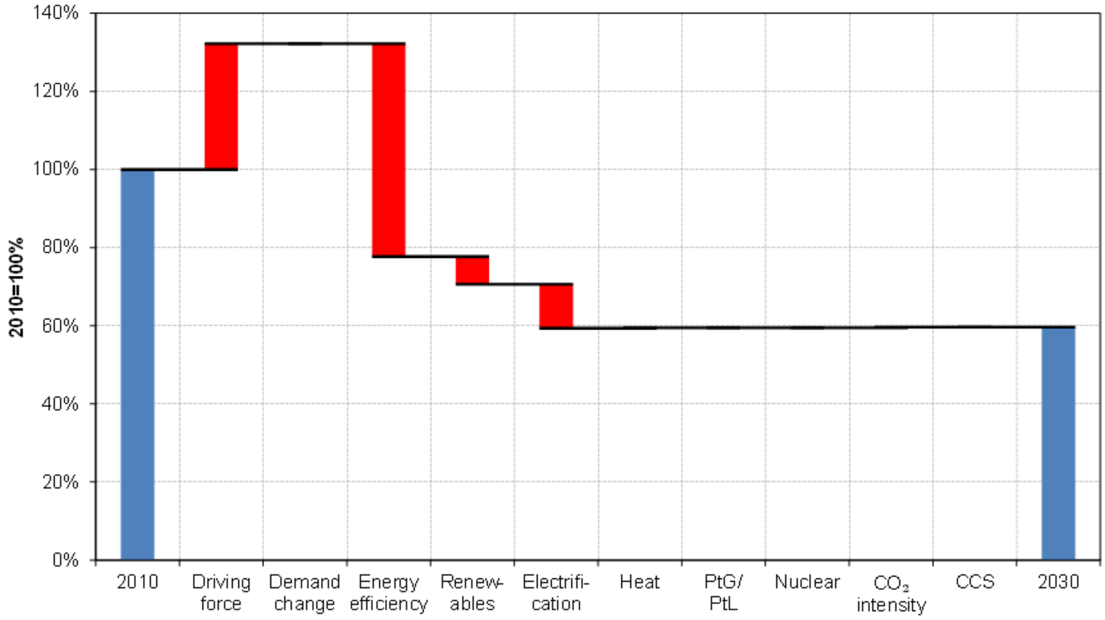

Source: European Commission 2011, calculations by Öko-Institut

### A 2.5.2.3 Tertiary sector

Efficiency in the tertiary sector increases strongly until 2030 (Figure A 63), leading to a 22% net reduction despite an increase of sector output of 32%. Additionally, there are smaller contributions by renewables use (-7%) and electrification (-11%), leading to a total reduction of 40% of 2010 emissions.

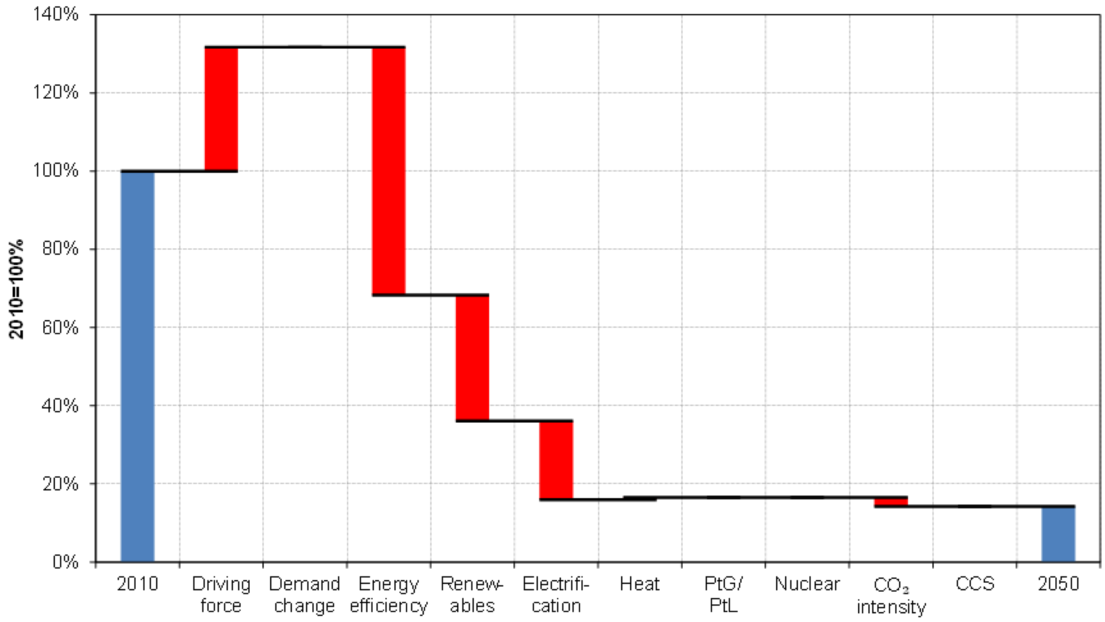
In 2050 (Figure A 64), the picture is similar with much larger contributions. Net reduction of efficiency gains is larger than in 2030, additionally, renewables contribute a 32% reduction in 2050, while electrification contributes 20%. $CO_2$ intensity plays a negligible role. In sum, total reduction in 2050 stands at 86% of 2010 emissions.

**Figure A 63: Energy Roadmap 2050, High Efficiency Scenario: Decomposition analysis for the tertiary sector, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut

**Figure A 64: Energy Roadmap 2050, High Efficiency Scenario: Decomposition analysis for the tertiary sector, 2010–2050**



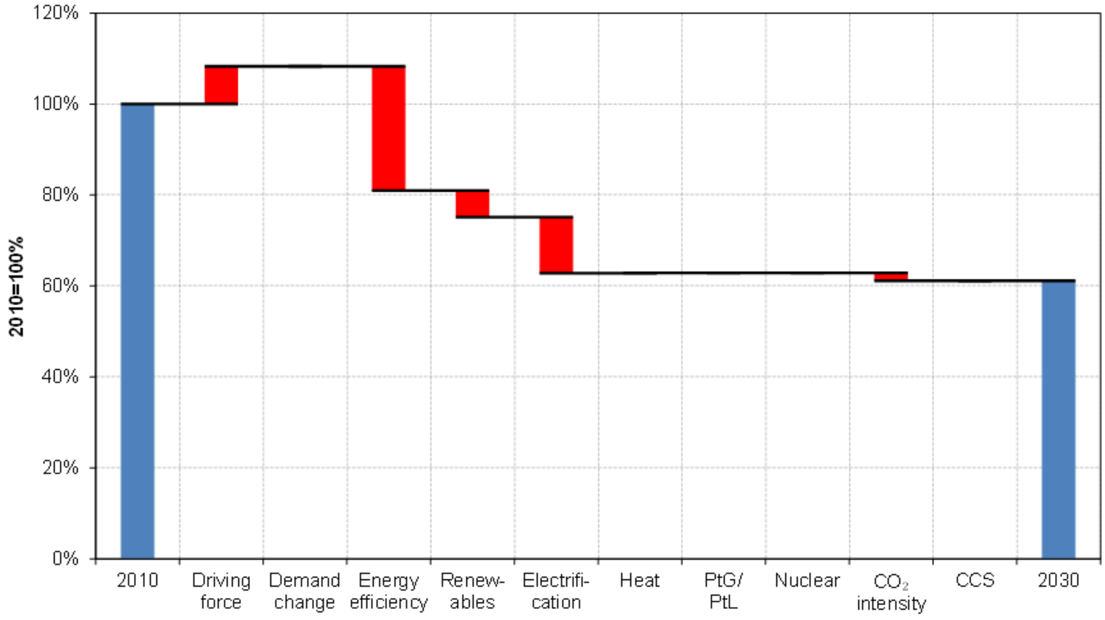

Source: European Commission 2011, calculations by Öko-Institut

#### A 2.5.2.4 Residential sector

Efficiency in the residential sector will rise sharply by 2030 (Figure A 65), resulting in a net reduction of 19%, despite an increase in sector production of 8.3%. In addition, there are smaller contributions from renewable energy (-6%) and electrification (-12%), resulting in a total reduction of 40% of 2010 emissions.

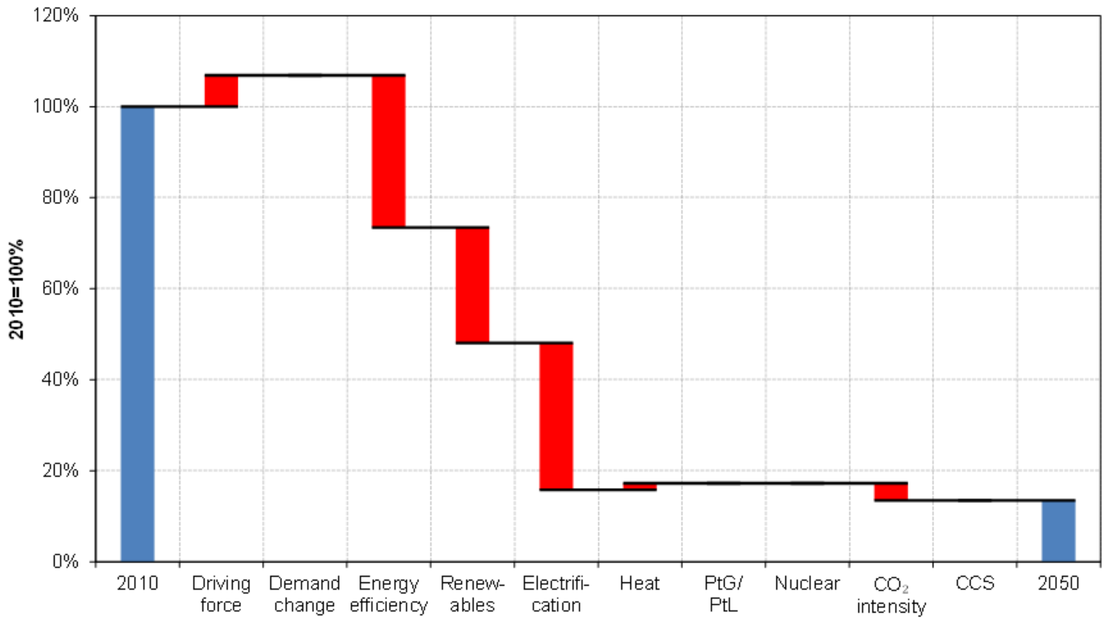
In 2050 (Figure A 66), total reduction stands at 86% of 2010 emission. That is much larger contributions as in 2030. In addition to the net reduction of efficiency with 27%, are renewables (-25%) and electrification (-32%) the main reason for the total reduction.

**Figure A 65: Energy Roadmap 2050, High Efficiency Scenario: Decomposition analysis for the residential sector, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut

**Figure A 66: Energy Roadmap 2050, High Efficiency Scenario: Decomposition analysis for the residential sector, 2010–2050**



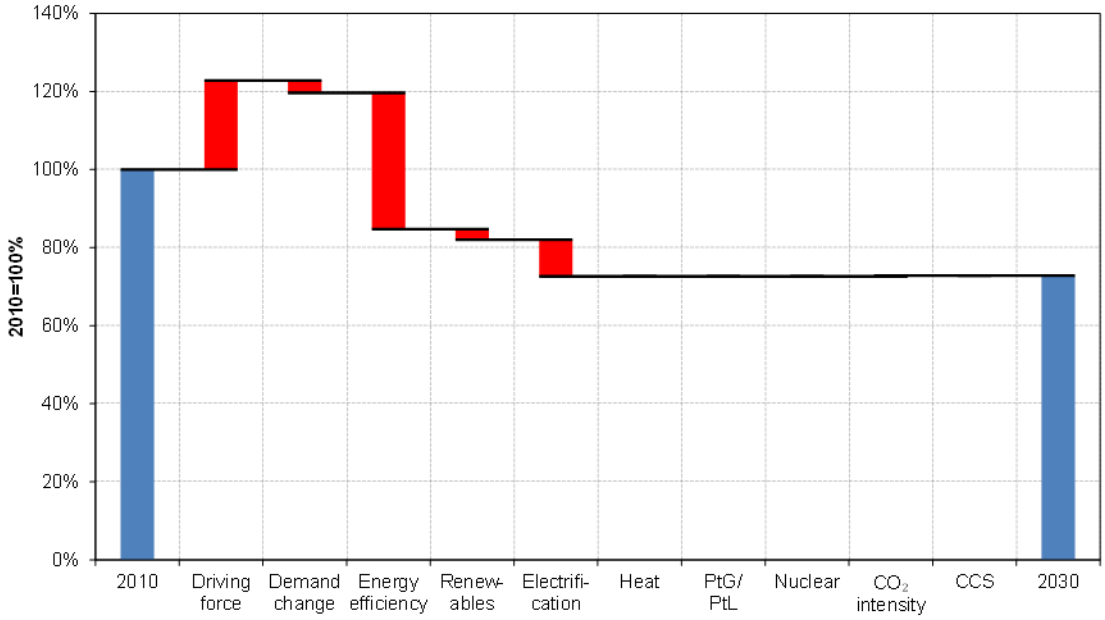

Source: European Commission 2011, calculations by Öko-Institut

#### A 2.5.2.5 Passenger transport

Until 2030 (Figure A 67), passenger transport reduces its emissions by 27% despite an increase in transport demand of 23%. The largest abatement contributions, as expected, come from improved efficiency (-35%) as well as from electrification (-9%). Biofuels (renewables) play only a minor role.

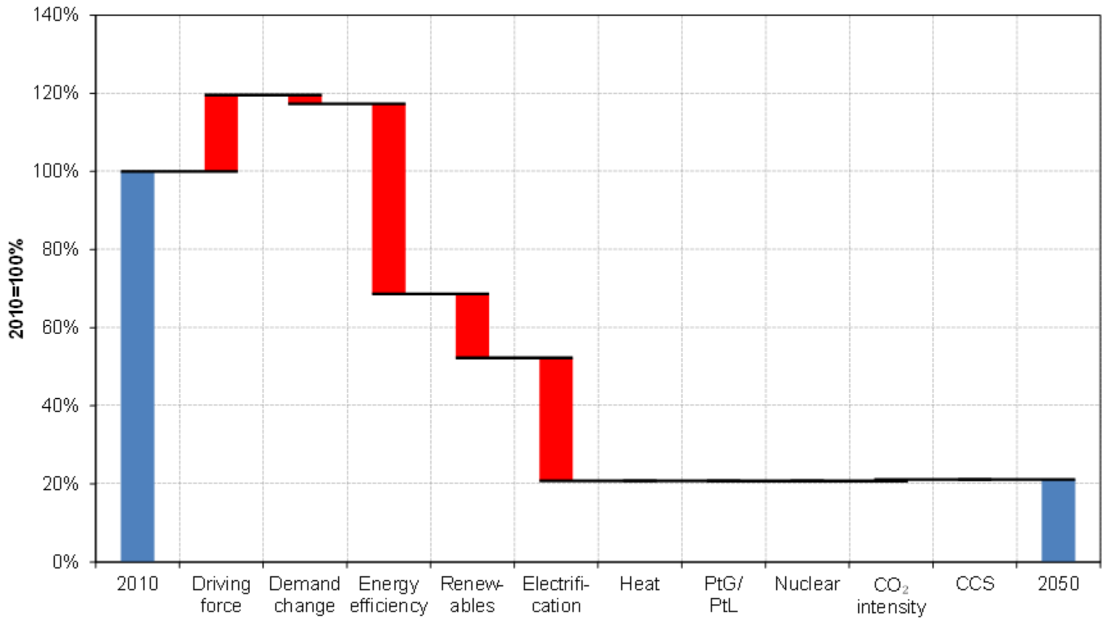
As in other scenarios of the Roadmap, abatement in the transport sector really starts after 2030. A total reduction of nearly 80% until 2050 (Figure A 68) is attained. As in 2030, efficiency remains the main driver at a 49% contribution. Very strong growth after 2030 is found in renewables and electrification, contributing 16% and 32% of emissions reductions, respectively.

**Figure A 67: Energy Roadmap 2050, High Efficiency Scenario: Decomposition analysis for passenger transport, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut

**Figure A 68: Energy Roadmap 2050, High Efficiency Scenario: Decomposition analysis for passenger transport, 2010–2050**



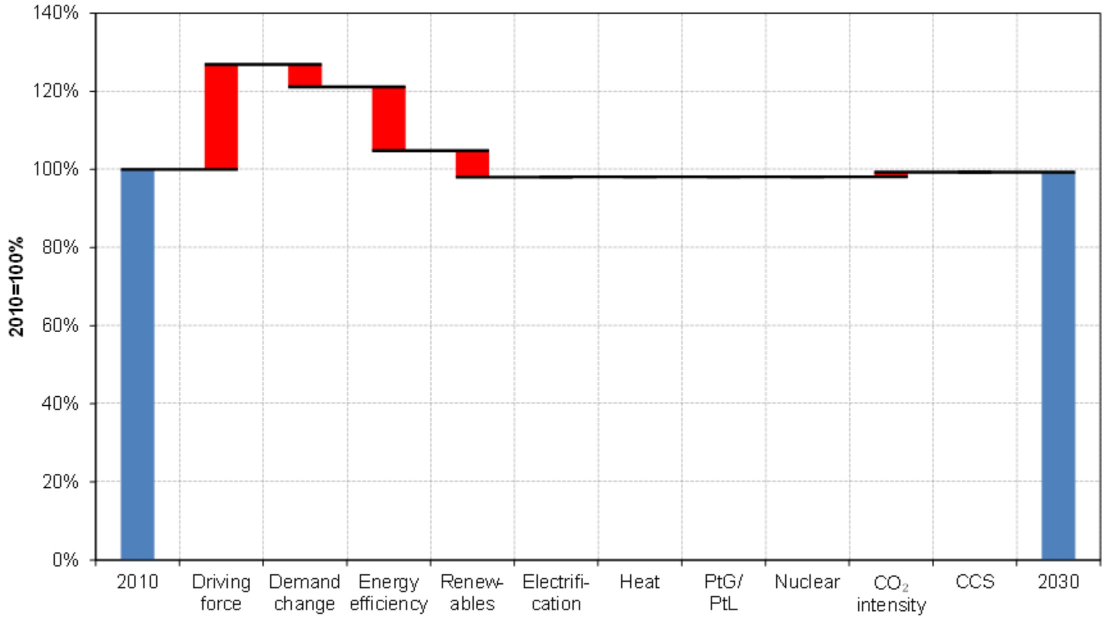

Source: European Commission 2011, calculations by Öko-Institut

#### A 2.5.2.6 Freight transport

Unlike in other Roadmap scenarios, emissions do not rise until 2030 (Figure A 69), but they do not go down significantly, either. Improvements in efficiency make a larger contribution, and there is less transport demand than in the reference case. Together with increased use of biofuels, they contribute 23% of emissions reductions compared to the 2010 baseline, leading to a 2% net reduction of emissions.

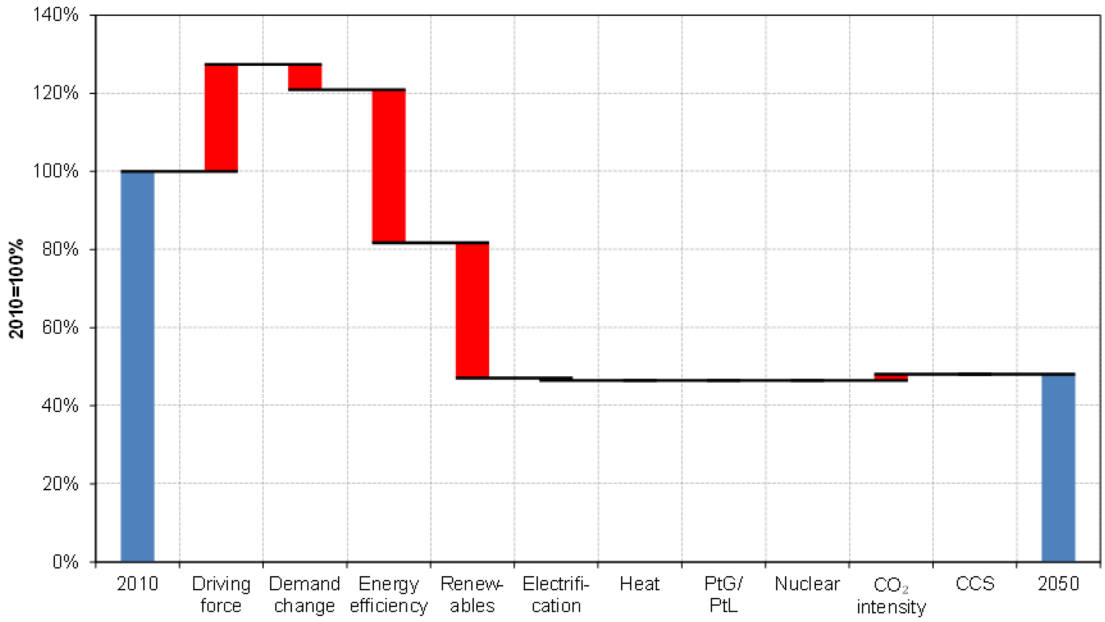
Until 2050 (Figure A 70), transport demand does not increase strongly anymore, but there are strong improvements in efficiency and increased biofuel use after 2030. Energy efficiency attains a reduction about 40% of $CO_2$, with additional 35% by renewable energy. In sum, emissions in 2050 are 52% lower than in 2010.

**Figure A 69: Energy Roadmap 2050, High Efficiency Scenario: Decomposition analysis for freight transport, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut

**Figure A 70: Energy Roadmap 2050, High Efficiency Scenario: Decomposition analysis for the freight transport sector, 2010–2050**




Source: European Commission 2011, calculations by Öko-Institut

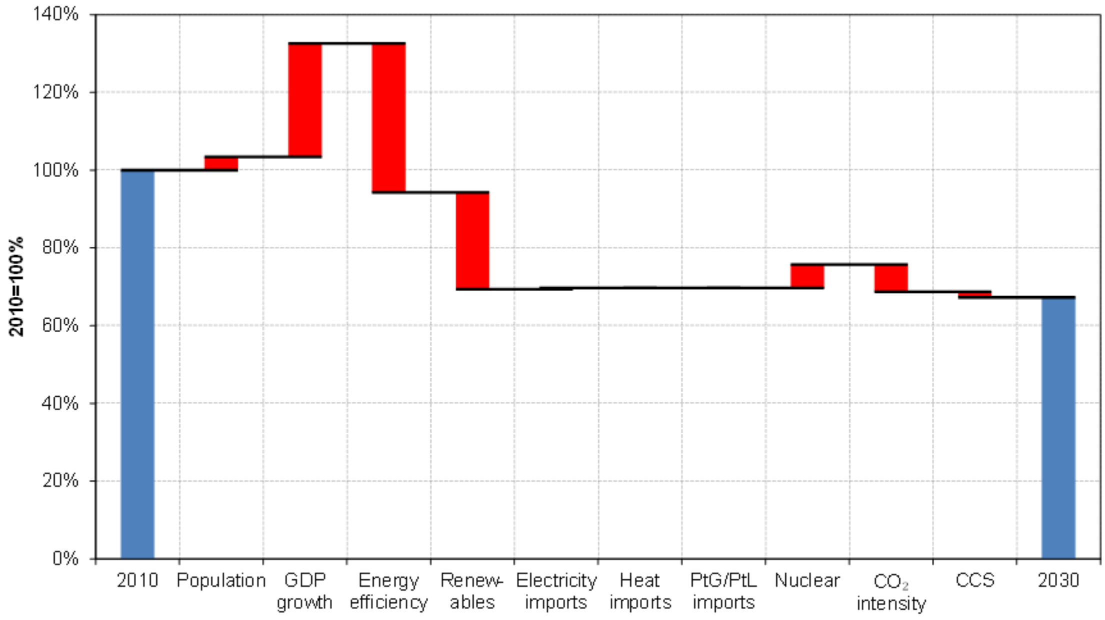
### A.2.6 Energy Roadmap 2050 – Low Nuclear Scenario

#### A 2.6.1 Aggregate trends

The Low Nuclear scenario attains a 33% reduction in total $CO_2$ emissions from energy until 2030 (Figure A 71). There is increasing pressure on emissions by growing population (+3% compared to 2010 emissions) and economic growth (+29%). However, this is offset by strongly increased energy efficiency (–38%) and renewables use (–25%). A further contribution is made by lower $CO_2$ intensity of the remaining fossil fuel mix fuels (–7%) and a very small contribution by CCS (–1.4%). Due to the faster nuclear phase-out stipulated in this scenario, there is a slight increasing contribution to emissions as electricity generation shifts to fossil fuels (+6%).

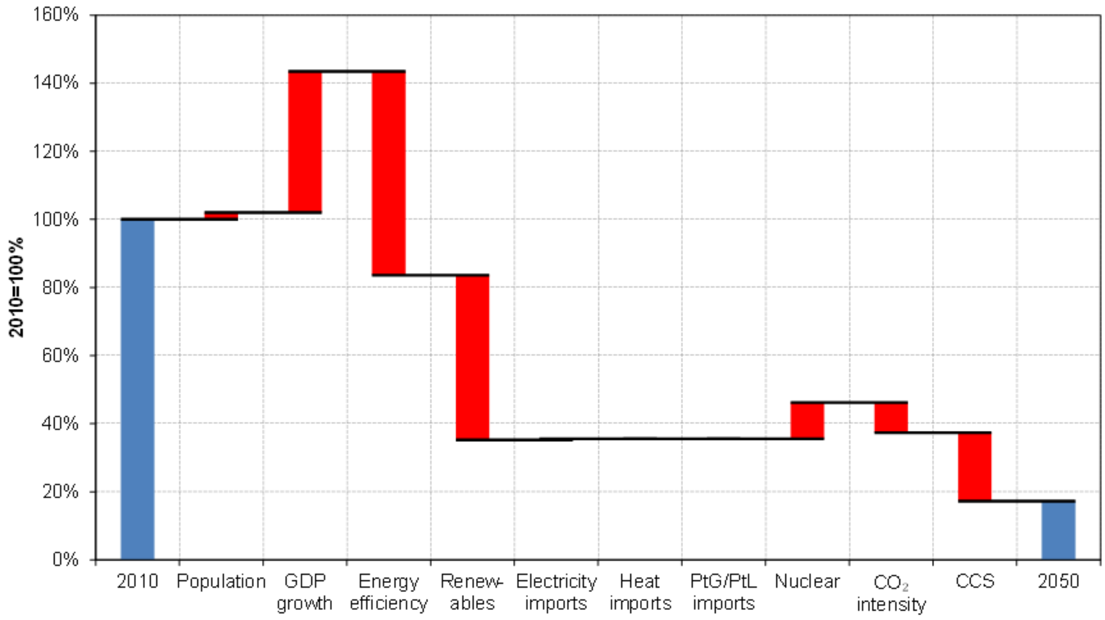
In 2050 (Figure A 72), a total reduction of 82% is attained. Despite continued population and GDP growth, efficiency gains (-60%) and renewables (-48%) are the main drivers behind the abatement, together with some CCS, offsetting the increasing pressure of the nuclear phase-out. emissions still rising by growing population (+2%) and economic growth (+41%).

**Figure A 71: Energy Roadmap 2050, Low Nuclear Scenario: Decomposition analysis for aggregate trends, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut.

**Figure A 72: Energy Roadmap 2050, Low Nuclear Scenario: Decomposition analysis for aggregate trends, 2010–2050**




Source: European Commission 2011, calculations by Öko-Institut

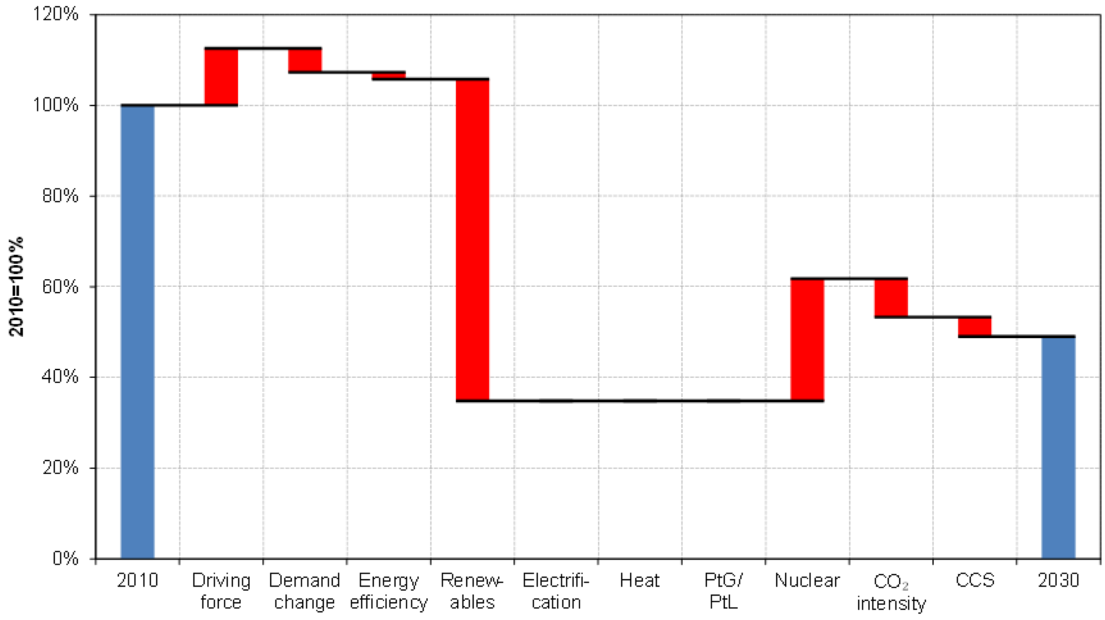
### A 2.6.2 Sectoral trends

#### A 2.6.2.1 Electricity sector

In the electricity sector, emissions are reduced by 51% in 2030 compared to 2010 (Figure A 73). The strong expansion of renewables (–71% of 2010 emissions) and reduced $CO_2$ intensity (–9%) are the main reasons for $CO_2$ reduction in the end year. However, in the electricity sector, the increasing effect of the nuclear phase-out becomes very visible (+27%). Compared to the other Roadmap scenarios, this is offset by higher efficiency, renewables, and CCS use.

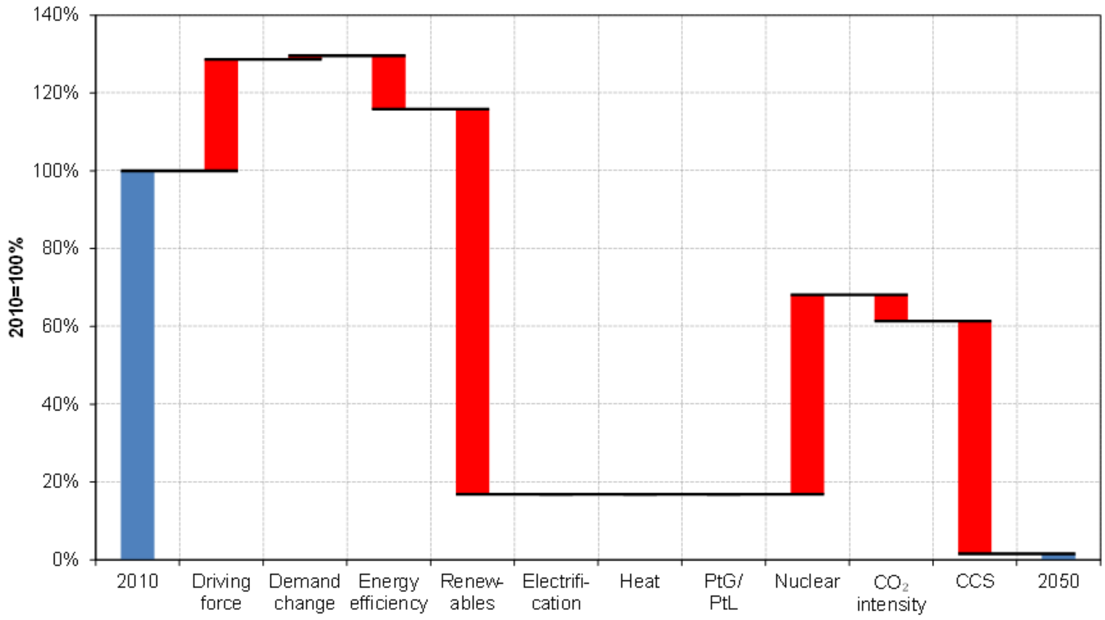
In 2050 (Figure A 74) there is nearly a complete decarbonization (-98,5%) in the electricity sector. The nuclear phase-out now causes very high pressure, almost 50% of baseline emissions, on the emissions-reducing developments. Compared to 2030, the strongest growth is in the CCS use, as 60% of baseline emissions are captured and stored per year, and further expanding renewables use, equaling 99% of baseline emissions. Improved efficiency can only contribute a small amount.

**Figure A 73: Energy Roadmap 2050, Low Nuclear Scenario: Decomposition analysis for the electricity sector, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut.

**Figure A 74: Energy Roadmap 2050, Low Nuclear Scenario: Decomposition analysis for the electricity sector, 2010–2050**



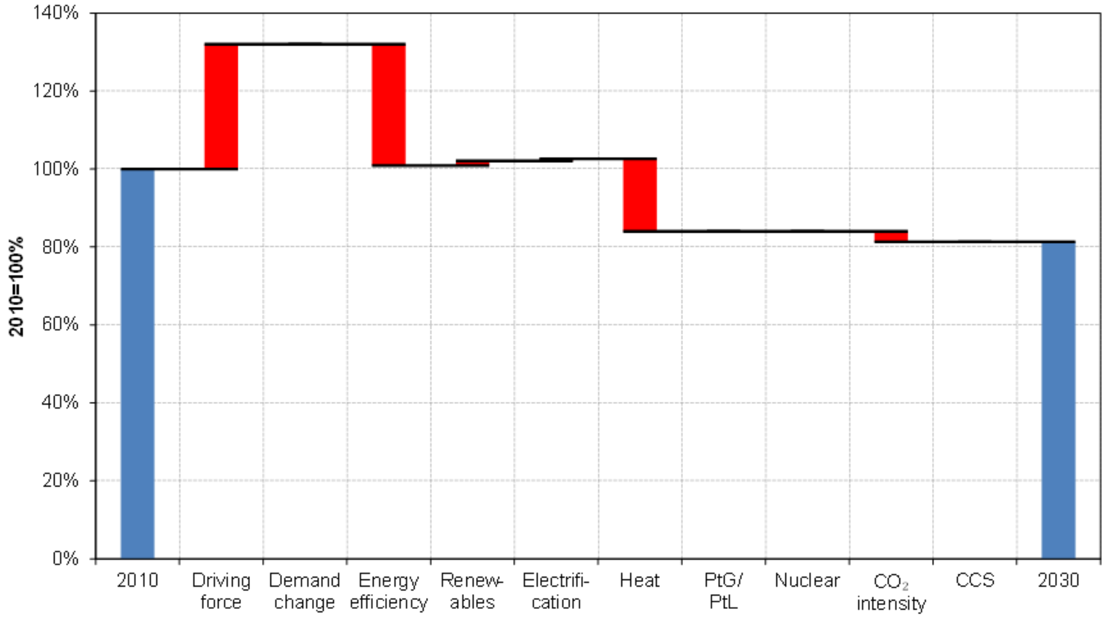

Source: European Commission 2011, calculations by Öko-Institut

#### A 2.6.2.2 Industry sector

In the industry sector, the structure is equal to most other Roadmap scenarios except High RES, with a low total reduction of 18% until 2030 (Figure A 75). This is mainly because nuclear energy plays no role in the industrial sector. The largest net contribution is made by use of distributed heat (-19% of emissions). Efficiency rises and counter-balances a 32% increase in industrial output. The other drivers play insignificant roles.

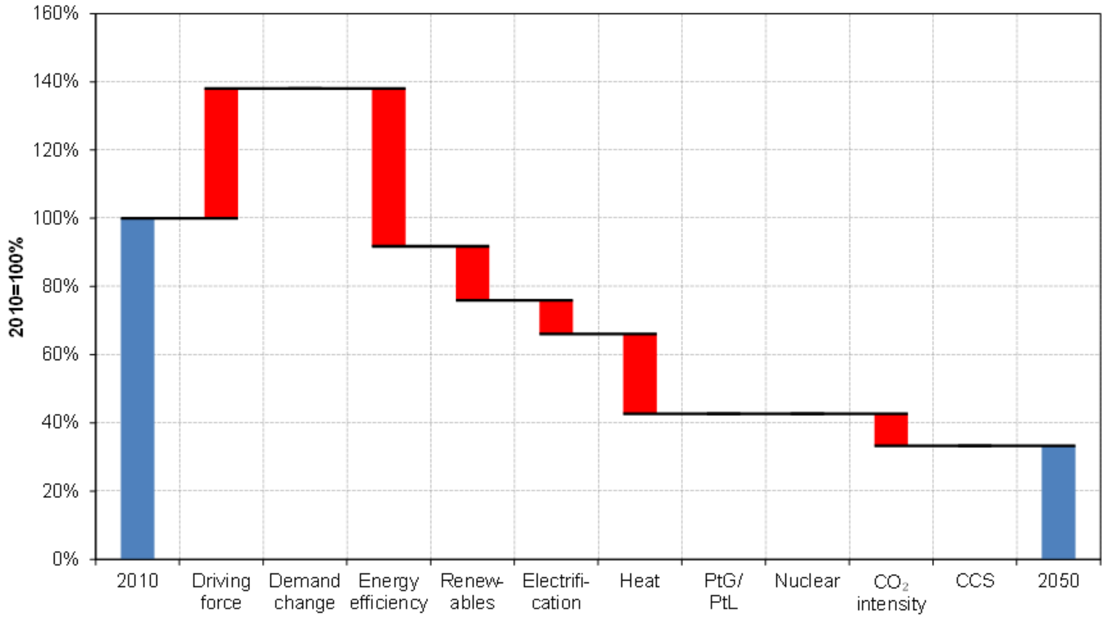
Until 2050 (Figure A 76), these drivers apart from heat grow strongly. Efficiency gains outpace production growth and lead to a net emissions reduction compared to 2010 (-8%). Renewables play a role and reduce a further 15% of 2010 emissions. In contrast to 2030, electricity makes a relative contribution of -10% while the contribution of heat further increases and now reduces 23% of baseline emissions. In sum, the drivers lead to a total reduction of –67%, similar to other scenarios in the Energy Roadmap.

**Figure A 75: Energy Roadmap 2050, Low Nuclear Scenario: Decomposition analysis for the industry sector, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut

**Figure A 76: Energy Roadmap 2050, Low Nuclear Scenario: Decomposition analysis for the industry sector, 2010–2050**



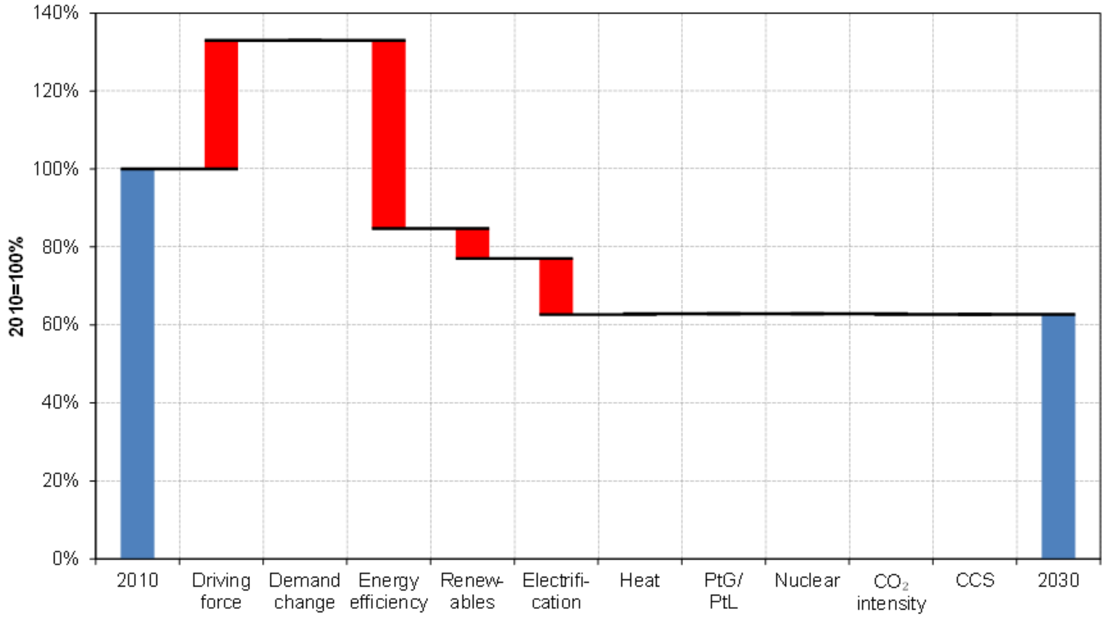

Source: European Commission 2011, calculations by Öko-Institut

#### A 2.6.2.3 Tertiary sector

Also in the tertiary sector, there is little difference to other scenarios of the Roadmap. Efficiency in increases strongly until 2030 (Figure A 77), leading to a 15% net reduction despite an increase of sector output of 32%. In addition there are smaller contributions by renewables use (-8%) and electrification (-14%), leading to a total reduction of 37% of 2010 emissions.

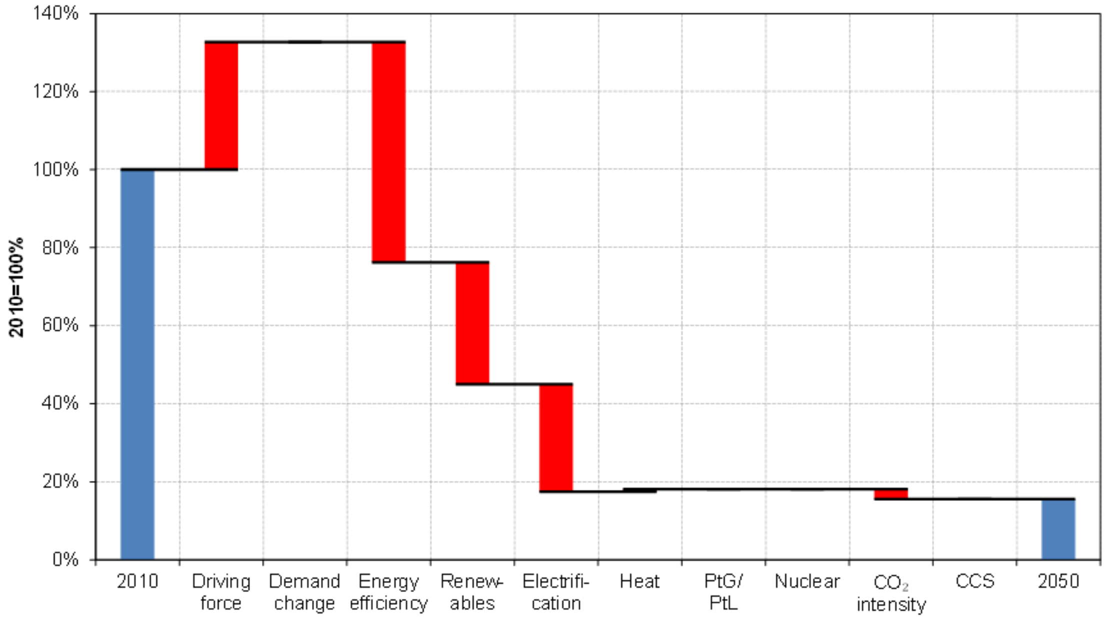
In 2050 (Figure A 78), the relations of the indicators are similar with larger contributions, but the strongest growth is found in renewables and electrification, less in efficiency. Renewables contribute a 31% reduction in 2050, while electrification contributes 28%. In sum, total reduction in 2050 stands at 85% of 2010 emissions.

**Figure A 77: Energy Roadmap 2050, Low Nuclear Scenario: Decomposition analysis for the tertiary sector, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut

**Figure A 78: Energy Roadmap 2050, Low Nuclear Scenario: Decomposition analysis for the tertiary sector, 2010–2050**



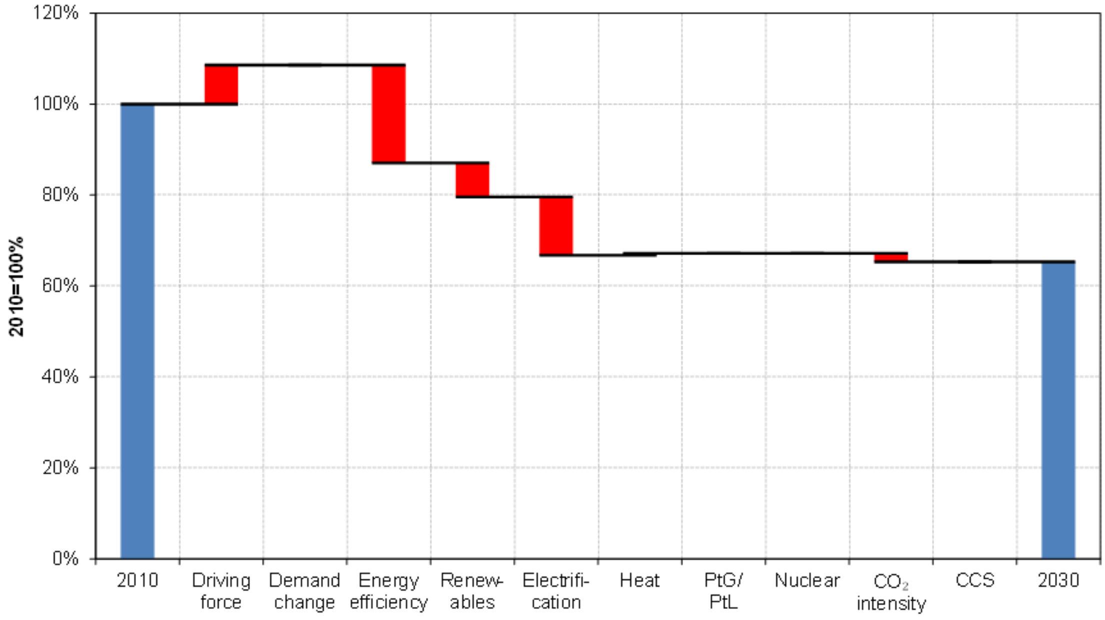

Source: European Commission 2011, calculations by Öko-Institut

### A 2.6.2.4 Residential sector

Also in the residential sector, the scenario does not deviate from the bulk of Roadmap scenarios. Until 2030 (Figure A 79), a total reduction of 35% is reached. The main drivers are renewable energy (-7.5%), energy efficiency (-22%), and electricity use (-13%). These contributions contrast with a higher number of households (9%).

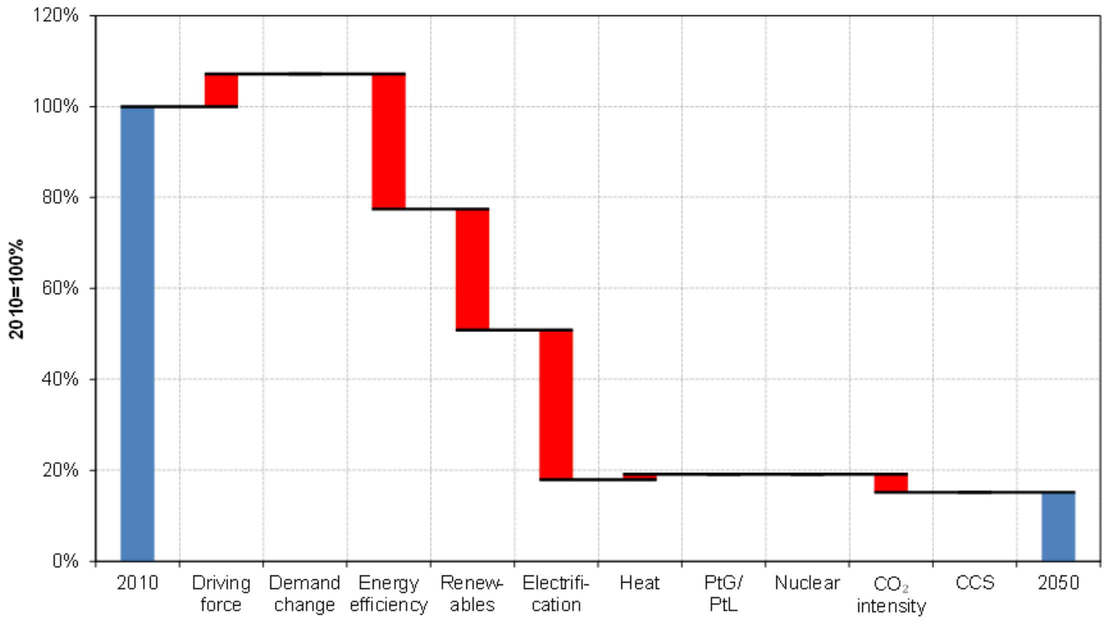
All drivers grow strongly after 2030, leading to a 85% emissions reduction (Figure A 80). Driving forces are efficiency (-30%), renewables (-27%) and electrification (-33%).

**Figure A 79: Energy Roadmap 2050, Low Nuclear Scenario: Decomposition analysis for the residential sector, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut

**Figure A 80: Energy Roadmap 2050, Low Nuclear Scenario: Decomposition analysis for the residential sector, 2010–2050**



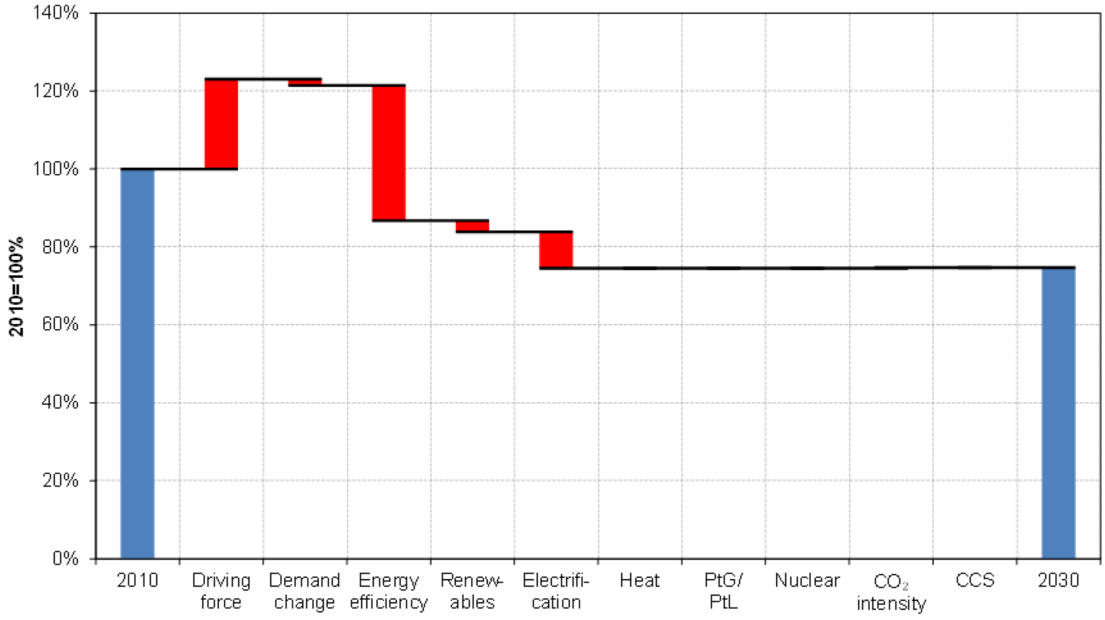

Source: European Commission 2011, calculations by Öko-Institut

#### A 2.6.2.5 Passenger transport

Passenger transport does not deviate from other Roadmap scenarios and reaches only 25% reduction over 2010 by 2030 (Figure A 81). Like in other sectors, efficiency grows faster (-35%) than demand (23%), leading to a net reduction. There is only a small contribution by renewables (-3%) and electrification (-9%) until 2030.

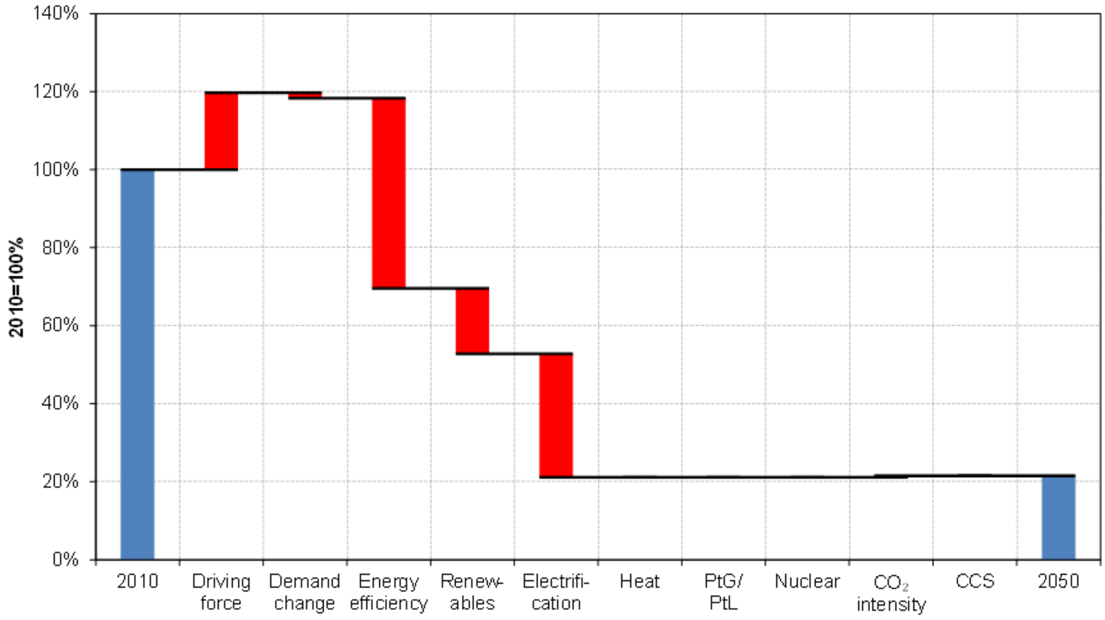
In 2050 (Figure A 82), there is a similar picture as in 2030 with much larger contributions. The relative pressure of increasing demand is lower, indicating slowed growth. Beyond efficiency, stagnating at 49% of baseline emissions, mainly renewables (-17%) and electrification (-32%) grow. In sum there is a total reduction of 79% of 2010 emissions.

**Figure A 81: Energy Roadmap 2050, Low Nuclear Scenario: Decomposition analysis for passenger transport, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut

**Figure A 82: Energy Roadmap 2050, Low Nuclear Scenario: Decomposition analysis for passenger transport, 2010–2050**



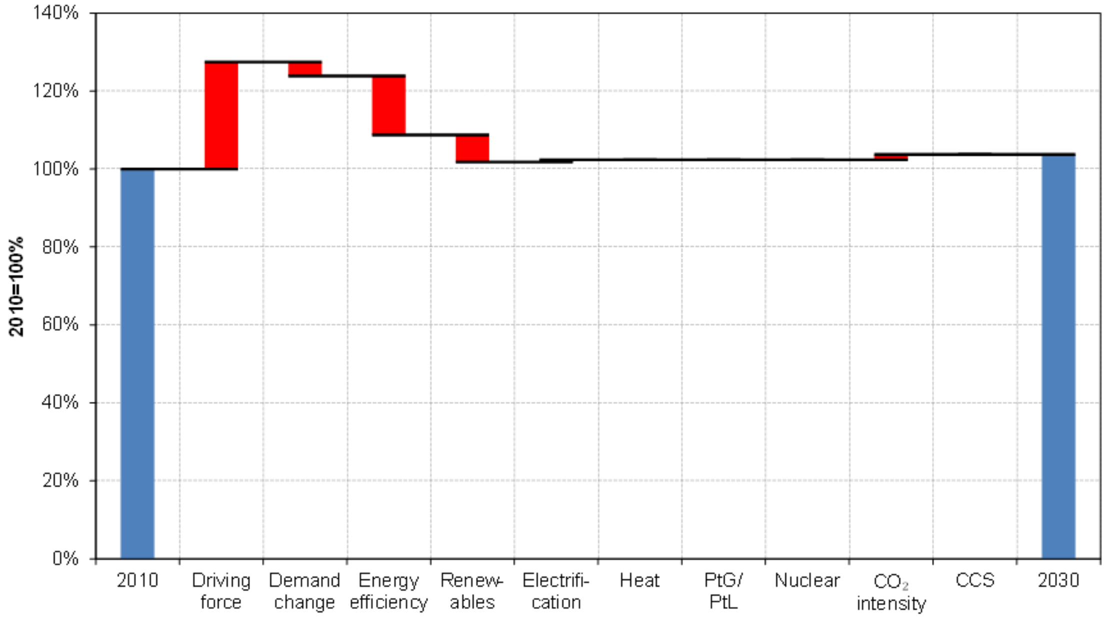

Source: European Commission 2011, calculations by Öko-Institut

#### A 2.6.2.6 Freight transport

As in other Energy Roadmap scenarios except High Efficiency, emissions from freight transport increase until 2030 (Figure A 83) (+4%) due to a strong increase in demand (28%). There are some contributions by energy efficiency (-15%) and renewables (-7%), but not enough to balance out the increase in demand.

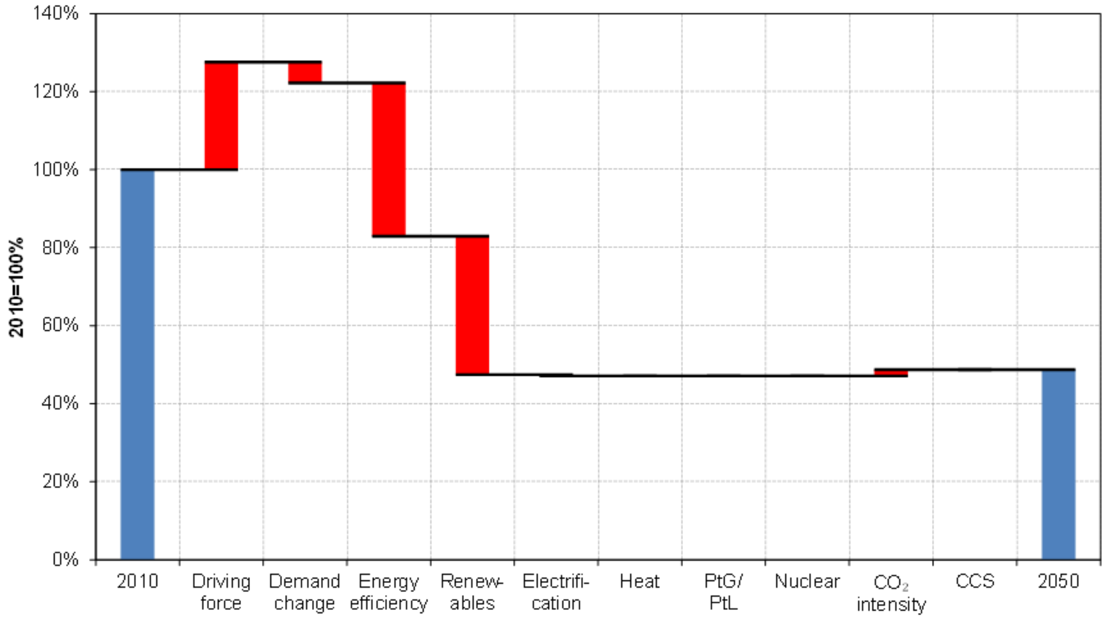
In 2050 (Figure A 84), there are more contributions to $CO_2$ reduction through increased efficiency (40% of 2010 baseline emissions) and renewables (36%), which can offset the high demand of freight transport. Total reduction in 2050 stands at 51%.

**Figure A 83: Energy Roadmap 2050, Low Nuclear Scenario: Decomposition analysis for freight transport, 2010–2030**




Source: European Commission 2011, calculations by Öko-Institut

**Figure A 84: Energy Roadmap 2050, Low Nuclear Scenario: Decomposition analysis for the freight transport sector, 2010–2050**




Source: European Commission 2011, calculations by Öko-Institut

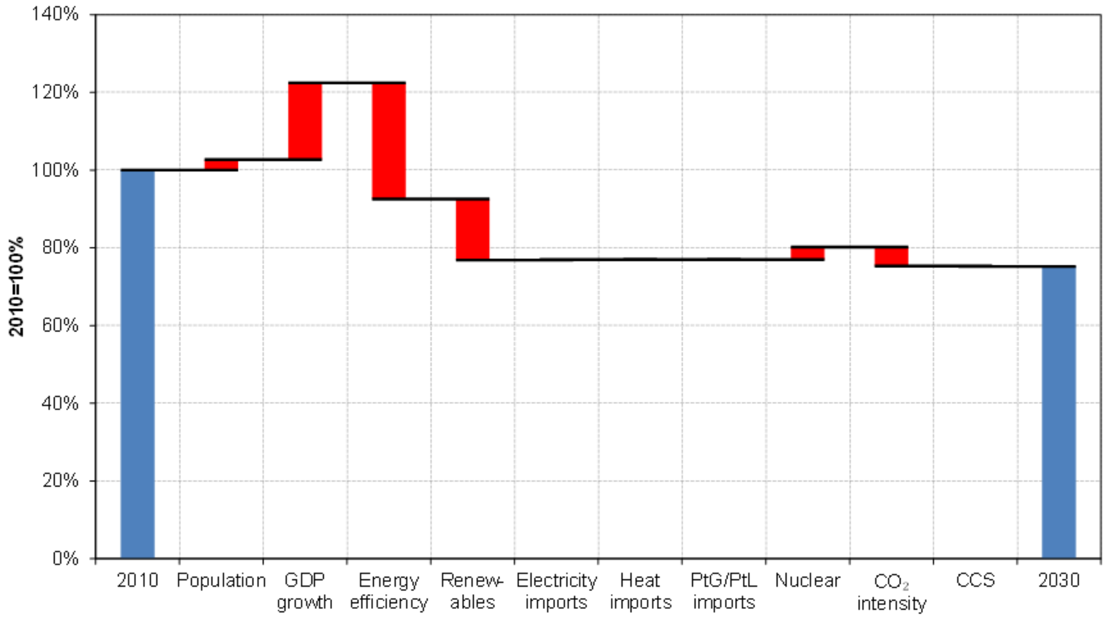
## A 2.7 PRIMES Baseline 2016 Scenario

### A 2.7.1 Aggregate trends

In this business-as-usual scenario, until 2030 (Figure A 85), population and GDP growth exert increasing pressure on emissions by 2.7% and 20%, respectively. This is offset by energy efficiency improvements that reduce 29% of the baseline emissions. Renewable energies reduce emissions by another 15%. While the nuclear phase-out increases emissions by 4% as electricity generation shifts to fossil fuels, a reduced $CO_2$ intensity of these fuels offsets this. In sum there is a total reduction of -24% of 2010.

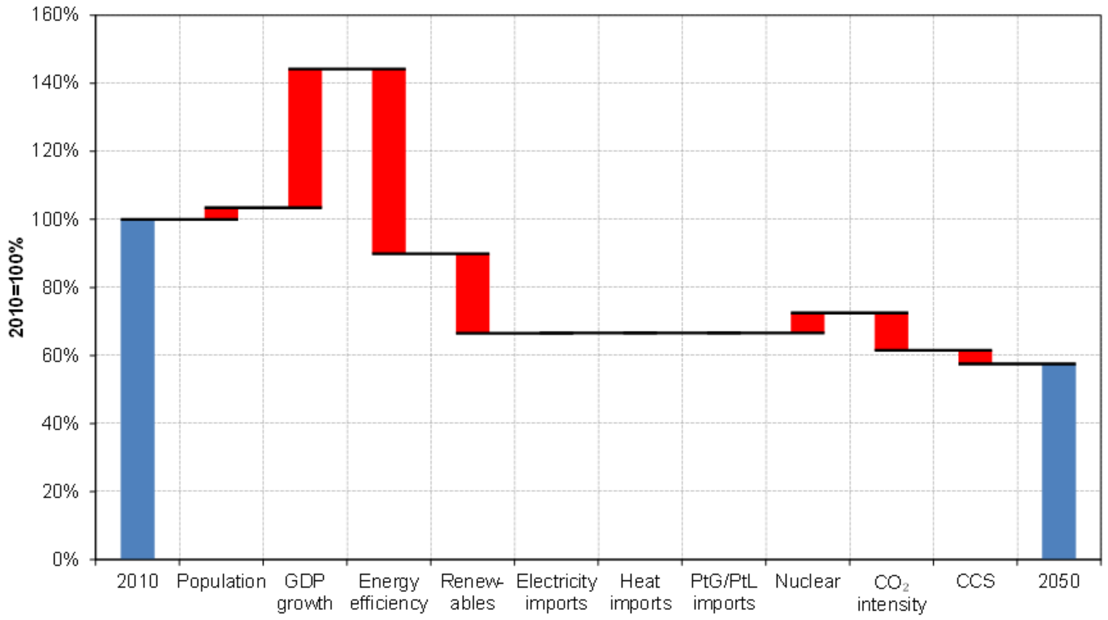
After 2030, emissions abatement stagnates, reaching only 42% compared to 2010 in 2050 (Figure A 86). The picture remains similar to 2030: Improved efficiency just offsets further population and GDP growth, leading to a 10% net reduction. There is some, but not overwhelming, growth in renewables use to 20%, and slight improvements in $CO_2$ intensity of fossil fuels. Also, CCS makes a small, but not decisive, contribution.

**Figure A 85: PRIMES Baseline 2016 Scenario: Decomposition analysis for the aggregate trends, 2010–2030**




Source: European Commission 2016, calculations by Öko-Institut

**Figure A 86: PRIMES Baseline 2016 Scenario: Decomposition analysis for the aggregate trends, 2010–2050**




Source: European Commission 2016, calculations by Öko-Institut

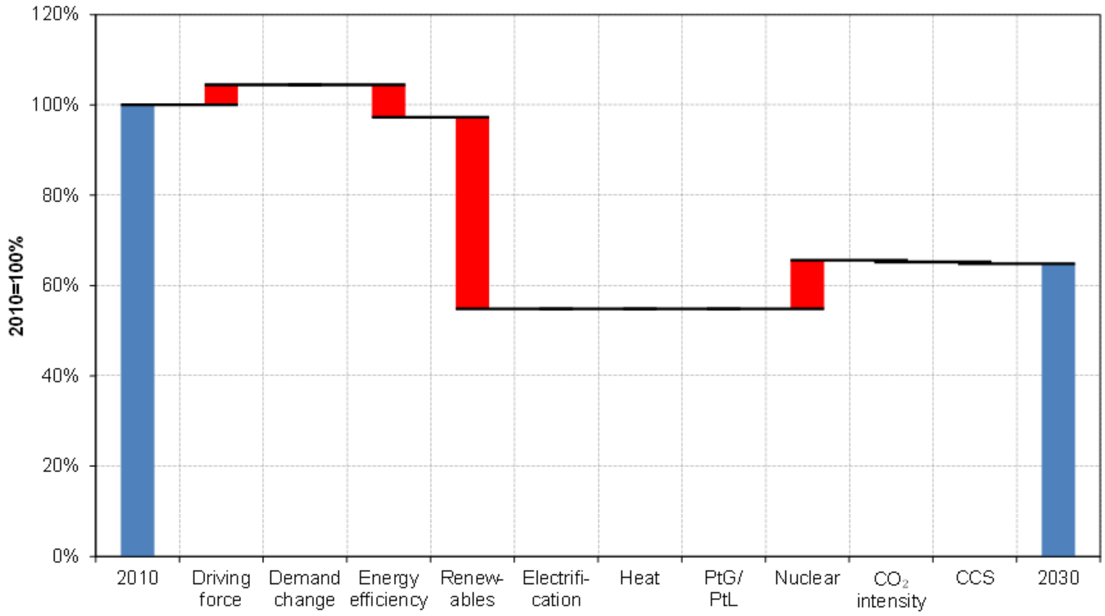
### A 2.7.2 Sectoral trends

#### A 2.7.2.1 Electricity sector

The dominant role of renewables for abatement in the electricity sector (-42% of baseline emissions) is clearly seen here once again. The scenario models a small reduction of nuclear generation, leading to a 10% increase in emissions which is not offset by stronger gas use (only 1% of reduction due to improved $CO_2$ intensity). Until 2030 (Figure A 87), the total $CO_2$ emissions can be reduced by -35% in this sector.

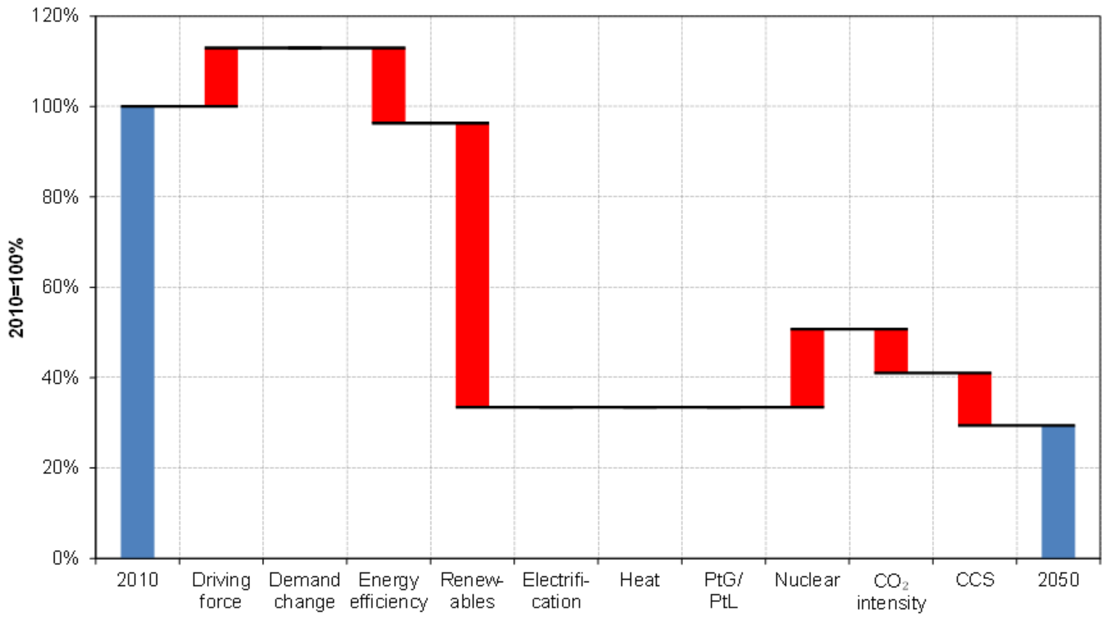
Until 2050 (Figure A 88), the development continues similarly, but with significant contributions of lowered $CO_2$ intensity (9% abatement) and CCS (12%). The total reduction stands at -71%.

**Figure A 87: PRIMES Baseline 2016 Scenario: Decomposition analysis for the electricity sector, 2010–2030**




Source: European Commission 2016, calculations by Öko-Institut

**Figure A 88: PRIMES Baseline 2016 Scenario: Decomposition analysis for the electricity sector, 2010–2050**



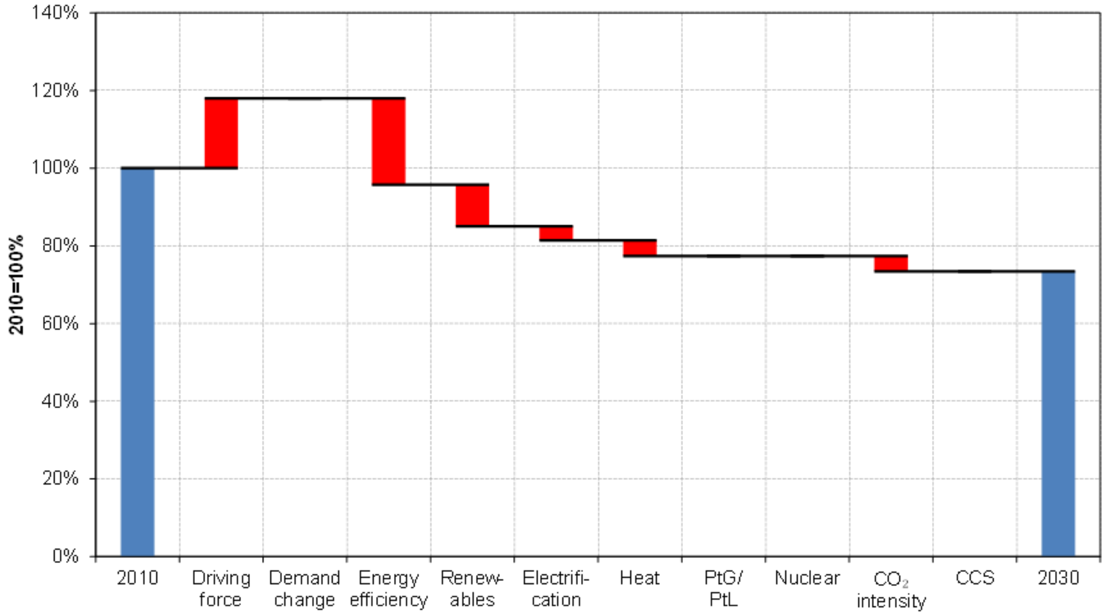

Source: European Commission 2016, calculations by Öko-Institut

### A 2.7.2.2 Industry sector

The picture (Figure A 89) shows a 18% increase in production, which is compensated by -22% efficiency gains. However, increased use of renewables (-11%) and electrification (-4%) ensure a 26% net reduction of emissions in 2030.

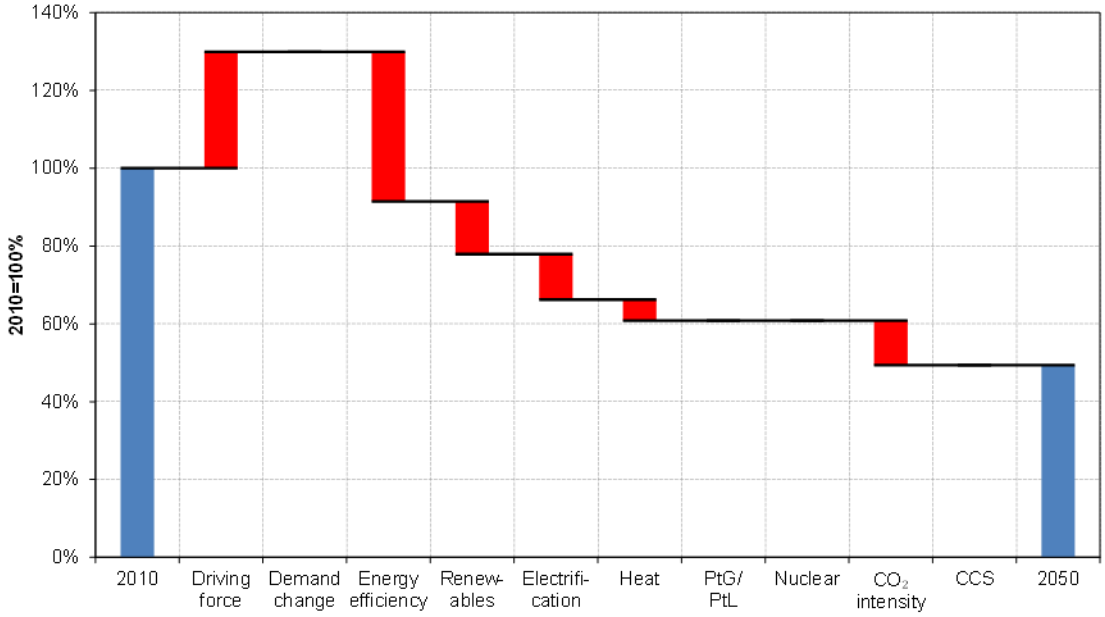
Until 2050 (Figure A 90), there is no structural change in the sector. The dominant improvement is efficiency of 38%, leading to a net reduction compared to demand increase. Other drivers grow to a lesser extent. Renewables use stays roughly there same, but there is a larger contribution from electrification. The total $CO_2$ emissions in the industry sector decrease by 51% compared to 2010.

**Figure A 89: PRIMES Baseline 2016 Scenario: Decomposition analysis for the industry sector, 2010–2030**




Source: European Commission 2016, calculations by Öko-Institut

**Figure A 90: PRIMES Baseline 2016 Scenario: Decomposition analysis for the industry sector, 2010–2050**



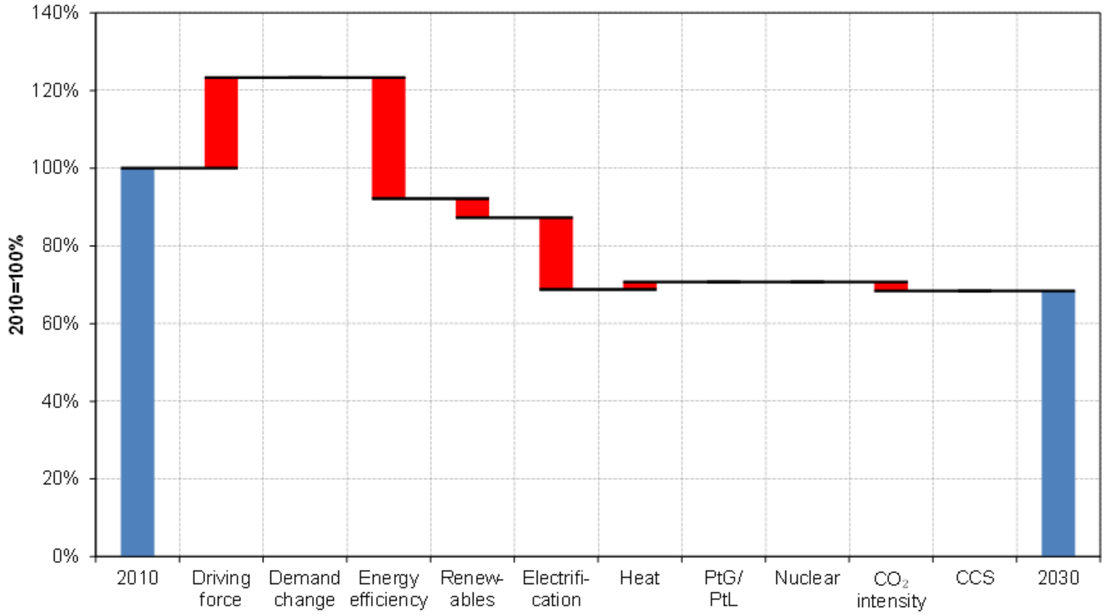

Source: European Commission 2016, calculations by Öko-Institut

#### A 2.7.2.3 Tertiary sector

Similar to the other sectors, the tertiary sector relies largely on efficiency gains for its reductions in 2030 (Figure A 91). Increased production would add approx. 23% to baseline emissions, but this is compensated by increased efficiency (−31%). However, we also see a significant contribution from electrification (−18%) and renewables (−5%). In sum there is a total reduction of 31% in 2030.

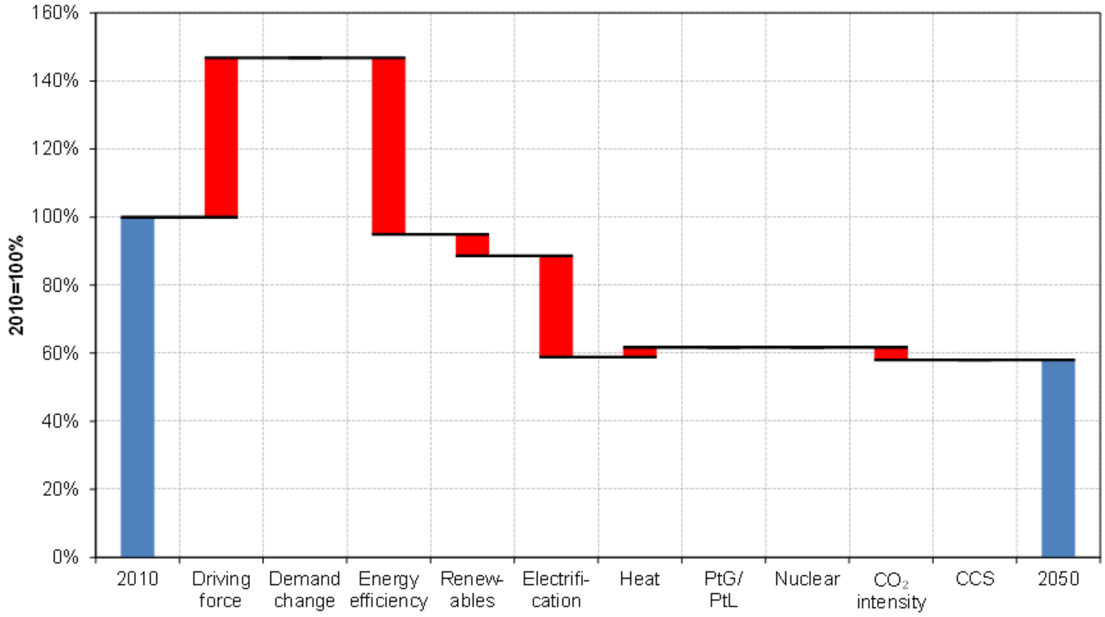
After 2030, abatement in the tertiary sector stagnates. Until 2050 (Figure A 92), there is only is a reduction to -42% compared to 2010 emissions. This is mostly due to a strongly growing demand that almost levels out further improvements in efficiency and electrification.

**Figure A 91: PRIMES Baseline 2016 Scenario: Decomposition analysis for tertiary sector, 2010–2030**




Source: European Commission 2016, calculations by Öko-Institut

**Figure A 92: PRIMES Baseline 2016 Scenario: Decomposition analysis for the tertiary sector, 2010–2050**



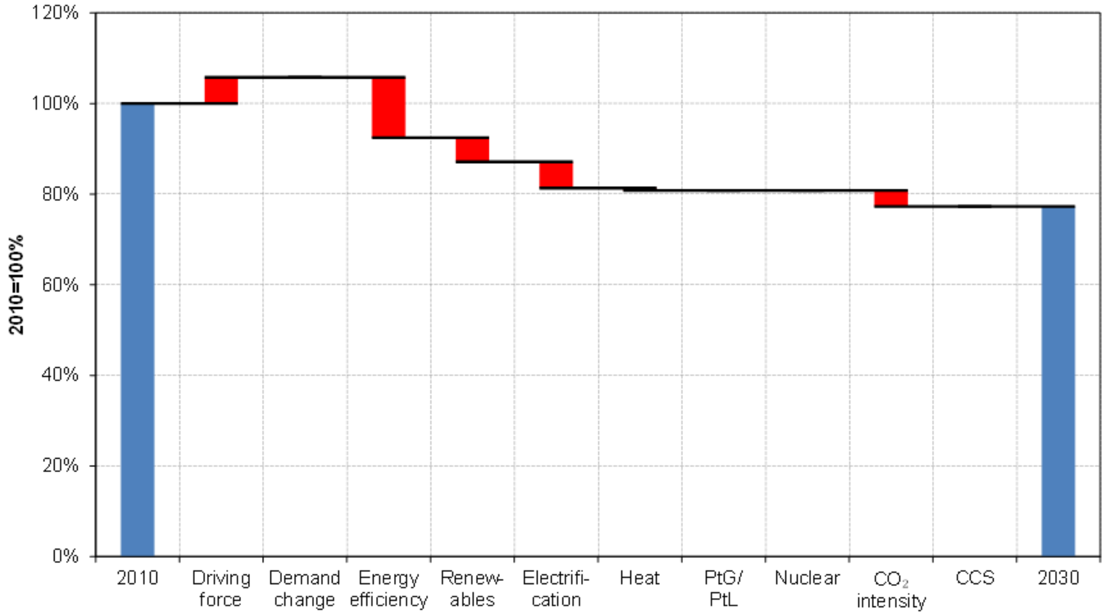

Source: European Commission 2016, calculations by Öko-Institut

#### A 2.7.2.4 Residential sector

Until 2030 (Figure A 93), only a slight decrease of -22% can be seen in the residential sector. The number of households increases by 6%, but is offset by efficiency (-13%), renewable energy (-5%) and electrification (-6%). Reduced $CO_2$ intensity (i.e. move to gas as a fossil fuel) plays a small role as well.

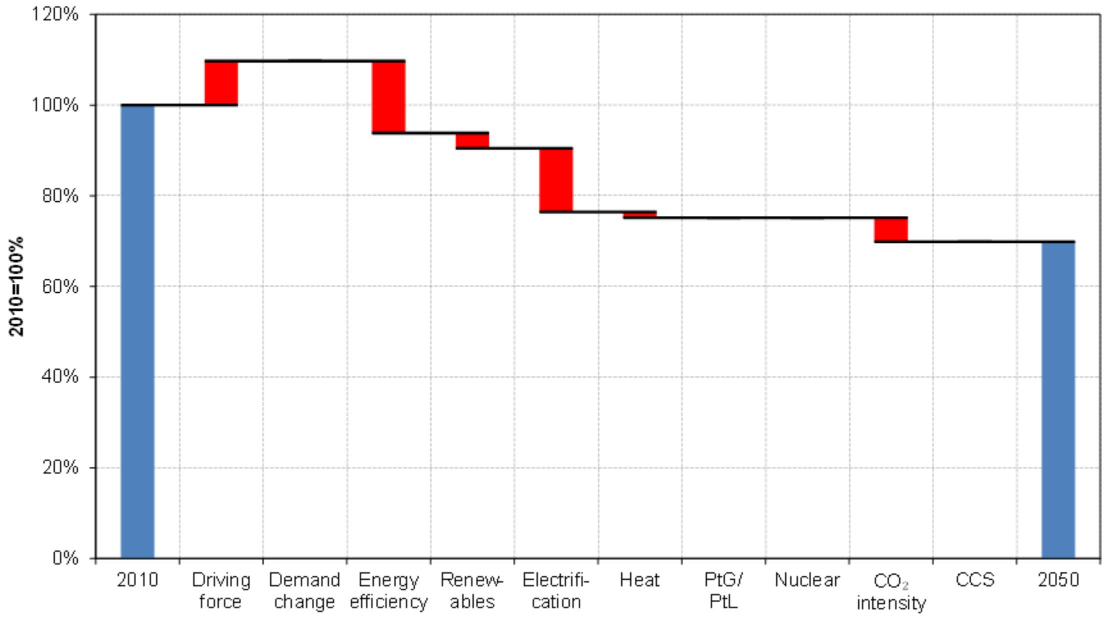
Similar to the tertiary sector, abatement stagnates after 2030. We see an increase in energy efficiency, electification, and $CO_2$ intensity that is balanced out by an increased number of households. The net reduction in 2050 (Figure A 94) stands at -30% compared to 2010.

**Figure A 93: PRIMES Baseline 2016 Scenario: Decomposition analysis for the residential sector, 2010–2030**




Source: European Commission 2016, calculations by Öko-Institut

**Figure A 94: PRIMES Baseline 2016 Scenario: Decomposition analysis for the residential sector, 2010–2050**



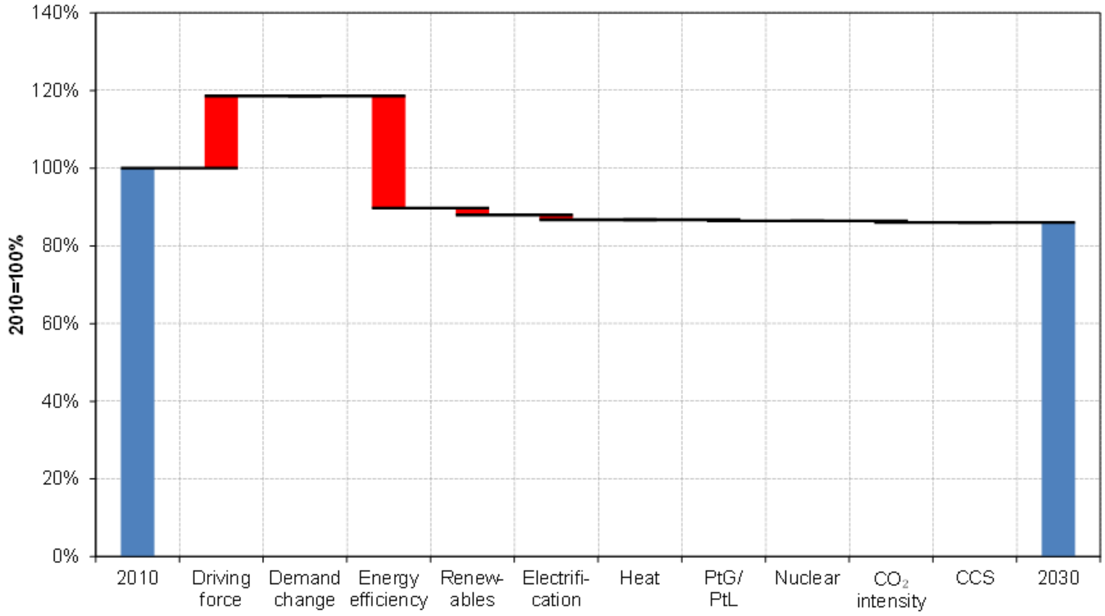

Source: European Commission 2016, calculations by Öko-Institut

#### A 2.7.2.5 Passenger transport

Until 2030 (Figure A 95), passenger transport achieves only a small $CO_2$ reduction of -14%, mostly due to efficiency gains (-30%) that more than offset increased transport demand (+19%).

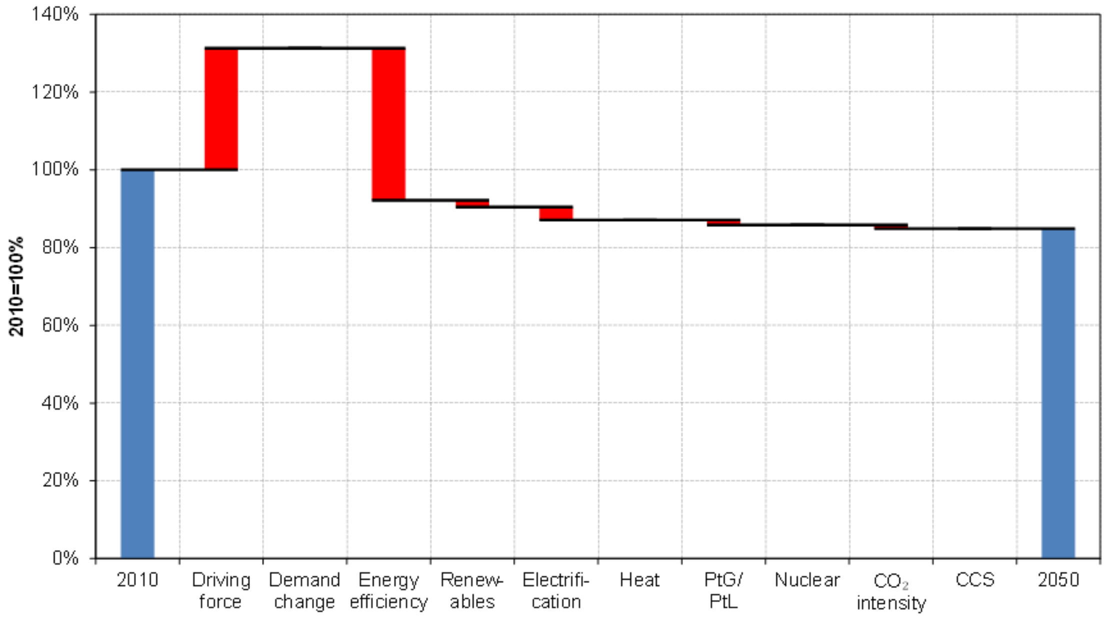
Until 2050 (Figure A 96), emissions do not go down significantly at all. All improvements in efficiency (relative contribution of 40%) are leveled out by the every growing transport demand (32%). There are very small but insignificant contributions by renewables and electrification, for a total reduction of -15% compared to 2010.

**Figure A 95: PRIMES Baseline 2016 Scenario: Decomposition analysis for passenger transport, 2010–2030**




Source: European Commission 2016, calculations by Öko-Institut

**Figure A 96: PRIMES Baseline 2016 Scenario: Decomposition analysis for passenger transport, 2010–2050**



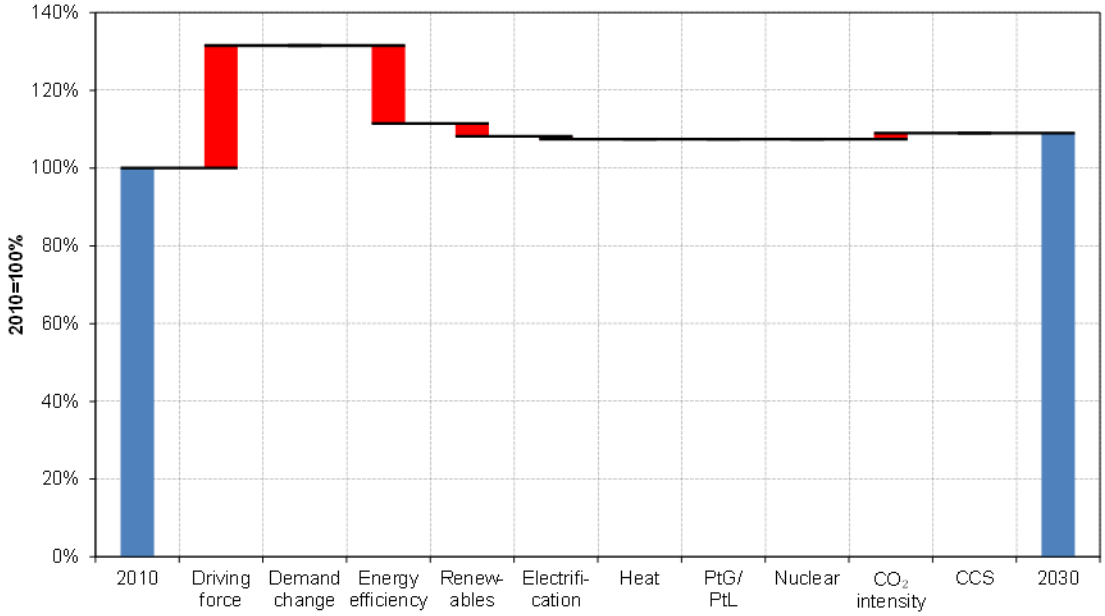

Source: European Commission 2016, calculations by Öko-Institut

#### A 2.7.2.6 Freight transport

Until 2030 (Figure A 97), freight transport increases its emissions by 9% due to strong growth in transport demand. Energy efficiency does not start to offset the high demand.

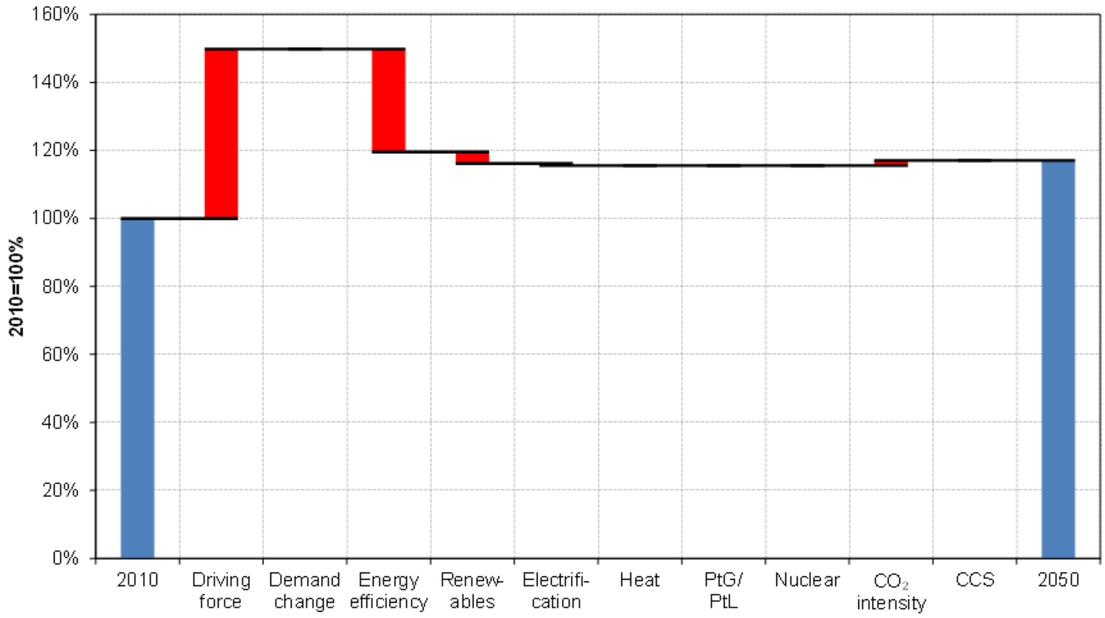
Until 2050 (Figure A 98), the situation will deteriorate even further. Despite the increasing efficiency and a small contribution by renewable fuels, emissions resulting from the high demand (50% more than in 2010) for freight transport cannot be compensated. In sum, emissions stand at 17% over 2010 levels.

**Figure A 97: PRIMES Baseline 2016 Scenario: Decomposition analysis for freight transport, 2010–2030**




Source: European Commission 2016, calculations by Öko-Institut

**Figure A 98: PRIMES Baseline 2016 Scenario: Decomposition analysis for the freight transport sector, 2010–2050**




Source: European Commission 2016, calculations by Öko-Institut

## A 2.8 EU Vision Scenario 2017

### A 2.8.1 Aggregate trends

The EU Vision Scenario for the EU-28 combines the top-down perspective of a $CO_2$ emissions budget which is compatible with the 2°C limit for the increase of global average temperature and a bottom-up analysis on how the cumulative emissions in the period from 2015 to 2050 could be limited to this emissions budget. The Vision Scenario is contrasted with a Reference Scenario that is derived from the Primes Baseline 2016. It is characterized by early $CO_2$ emission reductions which are essential for not exceeding the $CO_2$ emission budget of approx. 61.5 billion tons of $CO_2$. Total greenhouse gas emissions (including those from international aviation) decrease from 1990 to 2030 by 54% (Figure A 99) and by 93% in 2050 (Figure A 100). $CO_2$ emissions from energy decrease by approx. 56% in 2030 and by 99% in 2050.

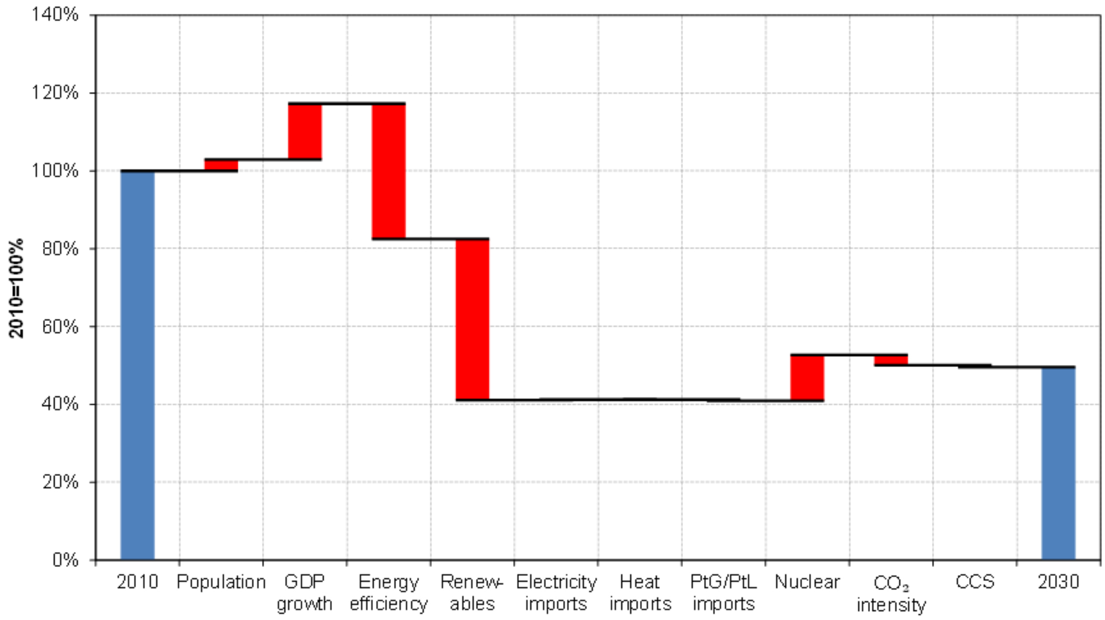
At an aggregate level the decomposition analysis for all $CO_2$ emissions from fuel combustion shows the following patterns:

- The demographic development is only a minor driver for $CO_2$ emissions. For the period from 2010 to 2030 it represents a lever of approx. 3% of base year emissions, for the period from 2010 to 2050 the corresponding lever is only slightly higher than 1%
- Economic growth (gross domestic product in constant prices) is the key driver for emissions. If all other factors would remain constant it would decrease $CO_2$ emissions by 14% from 2010 to 2030 and 13% from 2010 to 2030.[2]
- The period from 2010 to 2030 is characterized by a significant increase of primary energy productivity which represents an emission reduction lever of 35% compared to the emission levels as of 2010. For the period from 2010 to 2050 the corresponding lever is only 24% due to the increasing role of electrification and hydrogen produced by electrolysis.[3] The emission reduction lever of an increasing primary energy productivity exceeds, however, significantly the driving forces from population increase and economic growth.

[2] It should be noted that the contribution of the driving forces in terms of emission levers is not proportional to the growth of the drivers due to mixed effects for the different levers. The analysis presented here allows the consistent comparison among the different levers for one scenario and one period. For comparison between scenarios or periods requires a normalization of the decomposition results (see chapter A 1).

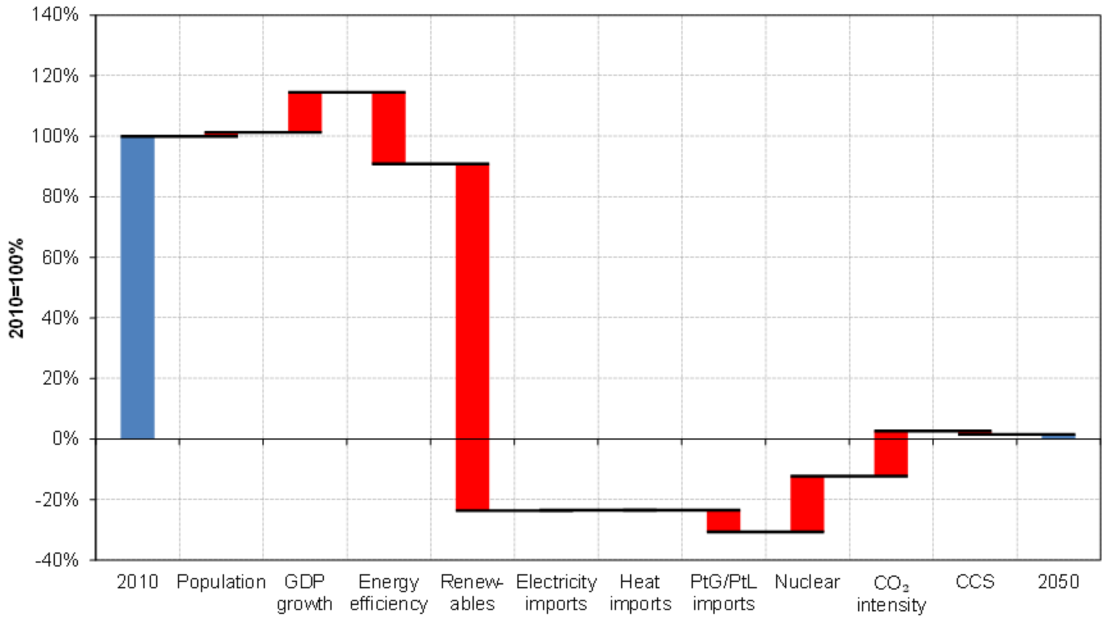
[3] The higher energy losses from hydrogen productions are obvious, the higher transformation losses for power generation result from the substitution approach which is used here for a consistent assessment of electricity production in primary energy terms.

**Figure A 99: EU Vision Scenario 2017: Decomposition analysis for aggregate trends, 2010–2030**




Source: Matthes et al. 2017, calculations by Öko-Institut

**Figure A 100: EU Vision Scenario 2017: Decomposition analysis for aggregate trends, 2010–2050**




Source: Matthes et al. 2017, calculations by Öko-Institut

- The emission reduction lever from an increasing use of renewable energy sources exceeds slightly the lever from primary energy productivity for the period from 2010 to 2030 (41 versus 35%) and clearly dominates the $CO_2$ emission trend from 2010 to 2050 with 91% of the base year emissions.
- Electricity or heat imports to the EU-28 play neither a role for the period from 2010 to 2030 nor from 2010 to 2050.

- The import of (electricity-based) synthetic fuels represents only a minor emission reduction lever for the period from 2010 to 2030 but is more significant for the period from 2010 to 2050 (7% of base year emission levels).
- The Vision Scenario is based on a phase-out of electricity generation from nuclear electricity. As a result the decrease of nuclear electricity generation represents a driver for $CO_2$ emissions which represents approx. 12% of total base year emissions for the period from 2010 to 2030 and 18% for 2010 to 2050.
- The switch to less carbon-intensive fuels plays a limited role in the period from 2010 to 2030 (3%) and represents a driver for 2010 to 2050 (12% compared to base year emission levels) due to the fact that the remaining fossil fuel is almost completely coal which is used in the iron and steel industry.
- This corresponds to the fact that CCS plays a (limited) role for the decrease of emissions from the iron and steel industry from a more long-term perspective. It represents only a minor contribution to emission reductions in the period from 2010 to 2030 (less than 1%) and plays a slightly higher role (2%) for 2010 to 2050.

The total $CO_2$ emissions from combustion of fossil fuels decrease by slightly more than 50% from 2010 to 2050, in 2050 the energy system is almost decarbonized with an emission reduction of 98% compared to 2010.

### A 2.8.2 Sectoral trends

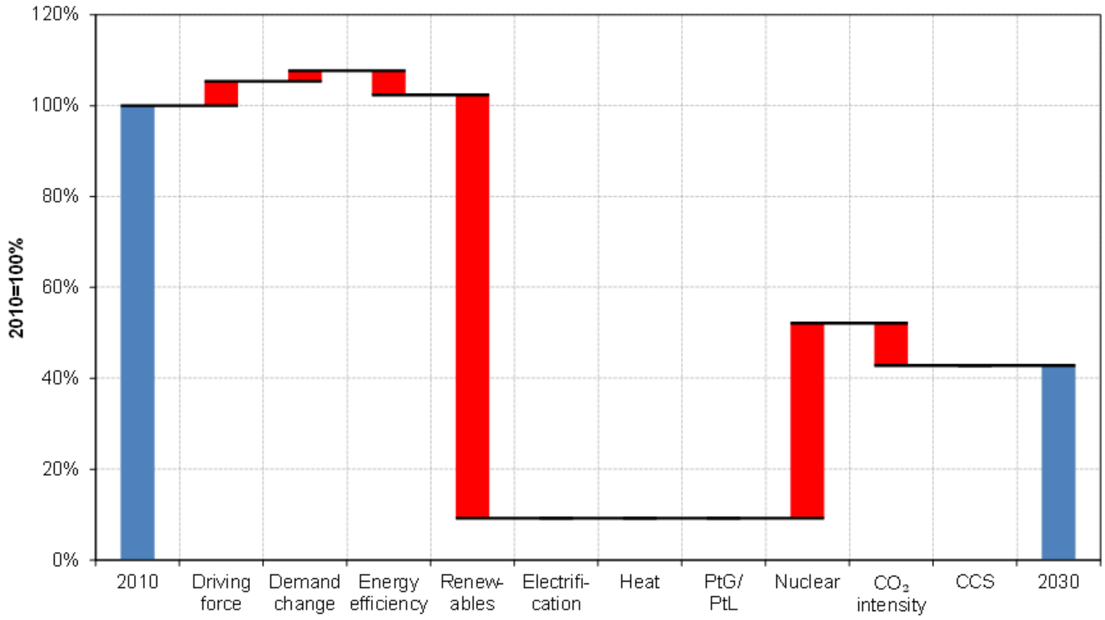
#### A 2.8.2.1 Electricity sector

The electricity sector in the EU-28 represents the largest source of $CO_2$ emissions on the one hand and is of strategic importance for the decarbonization of other (end use) sectors due to the emission reductions from electrification.

- The key driving force is the increasing demand for electricity. The demand from new applications (e.g. electric mobility) offsets fully the energy efficiency gains from more modern (traditional) applications. In the Reference Scenario the electricity demand (serving as the driving force for the Vision Scenario) represents an $CO_2$ emission increase from 2010 to 2030 (Figure A 101) by 3% (compared to the base year level). For the period from 2010 to 2050 (Figure A 102), it represents an emission increase of approx. 5%.
- Compared with the Reference Scenario the electricity demand increases slightly further in the Vision Scenario, representing an additional emission driver of approx. 2% from 2010 to 2030 as well as from 2010 to 2050.
- The efficiency of conventional electricity generation increases slightly and represents emission reduction levers of 5% from 2010 to 2030 and 1% from 2010 to 2050.
- The key determinant for the $CO_2$ emission trends in the electricity sector is the roll-out of electricity generation from renewable energy sources. From 2010 to 2030 it represents an emission reduction lever of 93% (compared with base year emissions). For the period from 2010 to 2050 the emission reduction lever amounts to 104% and offsets all levers that drive emissions upwards.
- The decreasing role of nuclear energy represents the single largest emission driver in the Vision Scenario. In the period from 2010 to 2030 it drives emissions by 43% and almost 50% from 2010 to 2050.
- The shift to less $CO_2$-intensive fossil fuels is more significant for the period from 2010 to 2030 (emission reduction lever of 9%) than from 2010 to 2050 (5%).
- In the Vision Scenario CCS is not considered as emission abatement option for the electricity sector at any time.

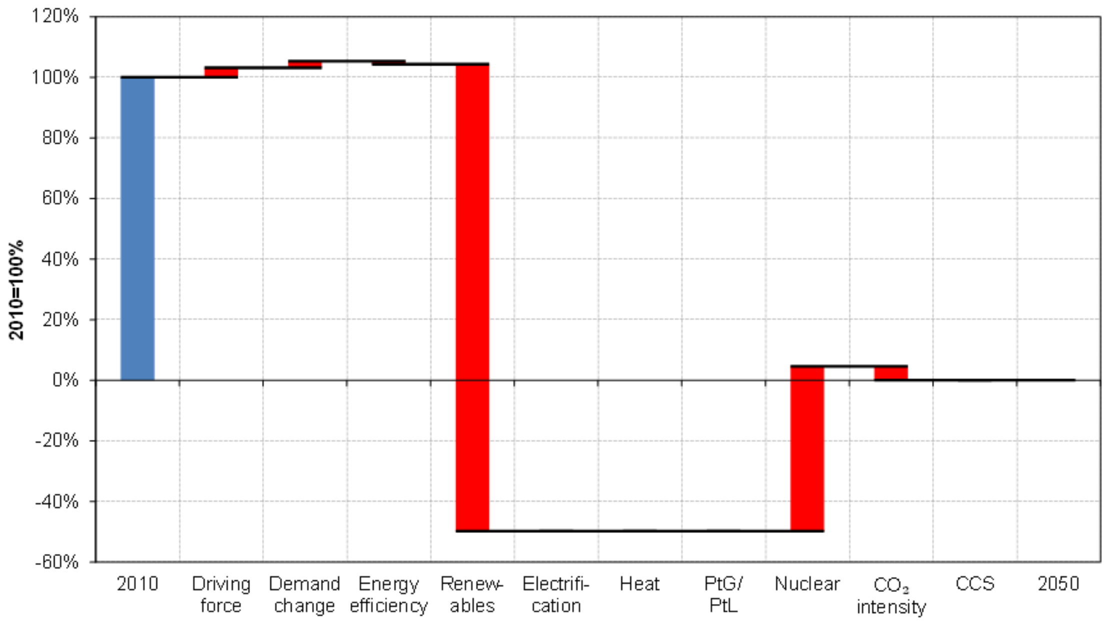
In total the $CO_2$ emission reduction for the electricity sector amounts to 57% for the period from 2010 to 2030. The electricity sector is fully decarbonized by 2050.

**Figure A 101: EU Vision Scenario 2017: Decomposition analysis for the electricity sector, 2010–2030**




Source: Matthes et al. 2017, calculations by Öko-Institut

**Figure A 102: EU Vision Scenario 2017: Decomposition analysis for the electricity sector, 2010–2050**




Source: Matthes et al. 2017, calculations by Öko-Institut

### A 2.8.2.2 Industry sector

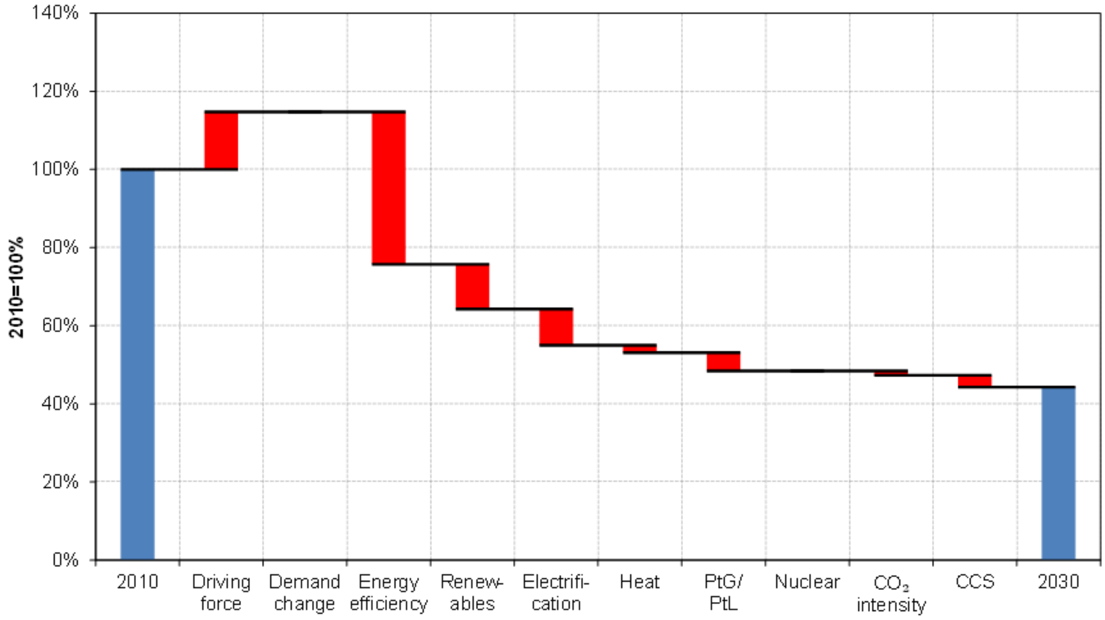
The emission abatement patterns in the Vision Scenario are much more diverse for the industry sectors than for the electricity sector[4]:

- The growth of industrial value added as the sectoral driving force represents a lever which represents approx. 15% of the base year emission levels from 2010 to 2030 (Figure A 103). For the period from 2010 to 2050 (Figure A 104), this lever increases to 17%.
- Accelerated structural change, compared to the reference case, among the different industrial sectors is not reflected in the Vision Scenario.
- Energy efficiency is the biggest single emission abatement lever. It represents 39% of base year emission for 2010 to 2030 and 43% for 2010 to 2050.
- The direct use of renewable energy sources delivers emission reductions of 11.5% for the period from 2010 to 2030 and approx. 23% for 2010 to 2050.
- Emission reductions from electrification of industrial technologies are with approx. 9% slightly lower than for renewables in the period from 2010 to 2030 with 9% but slightly higher (25%) for the time span from 2010 to 2050.
- The role of district heat for additional emission reductions in industry is comparatively low and represents an emission abatement lever of approx. 2% for 2010 to 2030 and approx. 1% from 2010 to 2050.
- The use of electricity-based fuels (for the industry this is essentially hydrogen) contributes with 4% of base year levels from 2010 and 2030 but provides significantly higher emission reduction contributions beyond 2030 and amounts to 16% for the period from 2010 to 2050.
- From 2010 to 2030 the switch to less $CO_2$-intensive fossil fuels represents an emission reduction of 1%, due to the remaining coal use in the iron and steel industry it drives emissions from 2010 to 2050 by 2%.
- CCS in the iron and steel industry represents an emission reduction lever of 3% (2010-2030) and 6% (2010-2030)

Total $CO_2$ emissions from industry decrease by 56% from 2010 to 2030 and by 95% from 2010 to 2050.

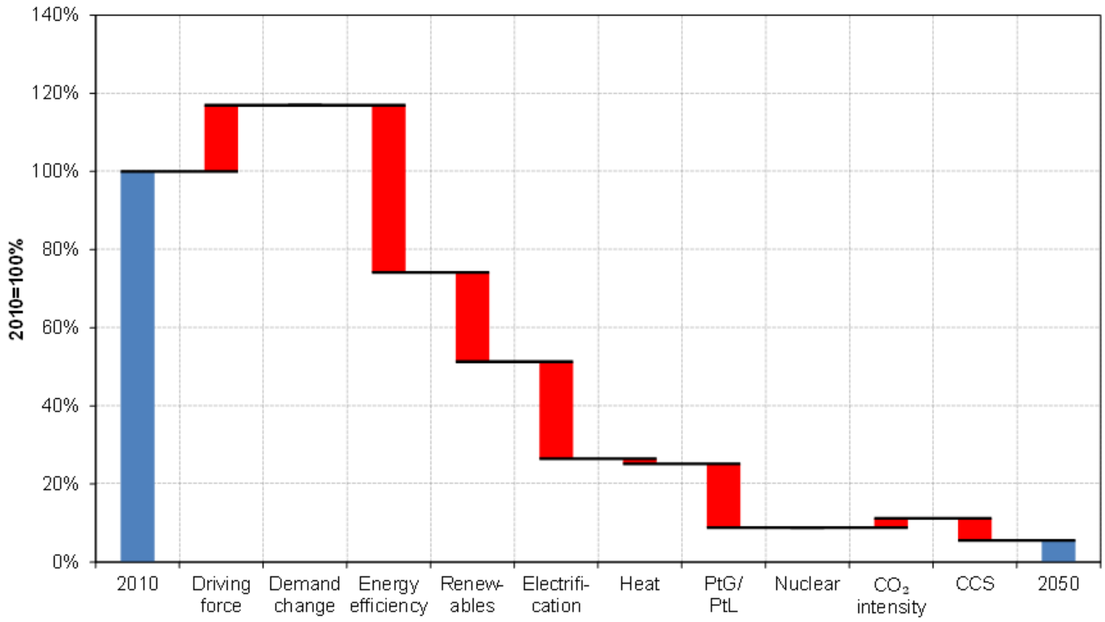
[4] In the decomposition analysis the $CO_2$ from industrial processes in the iron and steel industry were included due to fact that $CO_2$ emissions from combustion and process emissions show significant overlaps for this sector.

**Figure A 103: EU Vision Scenario 2017: Decomposition analysis for the industry sector, 2010–2030**




Source: Matthes et al. 2017, calculations by Öko-Institut

**Figure A 104: EU Vision Scenario 2017: Decomposition analysis for the industry sector, 2010–2050**




Source: Matthes et al. 2017, calculations by Öko-Institut

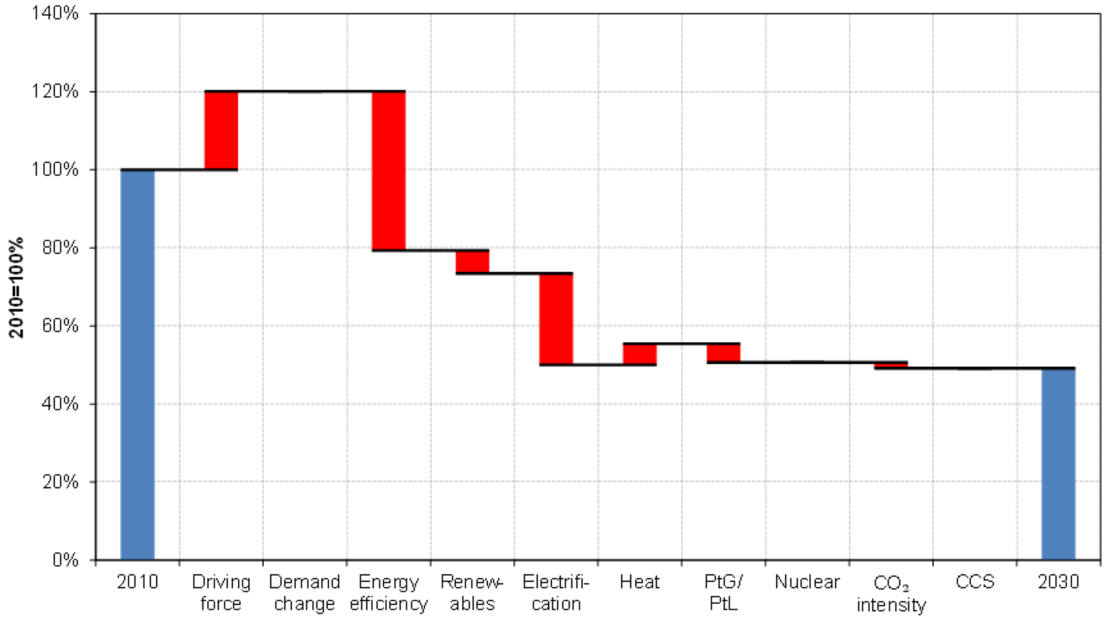
### A 2.8.2.3 Tertiary sector

The emission reduction patterns from the tertiary sectors (services, small businesses, agriculture etc.) differ from those in the industrial sectors on the one hand but also between the two different periods:

- The increase of value added in the tertiary sectors is the driving force for $CO_2$ emissions. It amounts to approx. 20% from 2010 to 2030 (Figure A 105) and also to 20% from 2010 to 2050 (Figure A 106).
- Structural change was not reflected as an additional emission reduction lever for the tertiary sectors in the Vision Scenario.
- Energy efficiency is by far the most significant emission reduction lever for the period from 2010 to 2030 (41% of base year emissions) but is of significantly less importance with 20% for the time span from 2010 to 2050.
- The direct use of renewable energy sources represents an emission reduction lever of 6% for 2010 to 2030 and 15% for the period from 2010 to 2050.
- Electrification of energy applications is a key emissions reduction lever for the tertiary sectors. It provides an emission reduction lever of 23% (in terms of base year emission levels) from 2010 to 2030 and 49% for the period from 2010 to 2050.
- The role of district heating decreases in the Vision Scenario for the tertiary sectors. Accordingly the corresponding lever drives emissions by 5% from 2010 to 2030 and by 8% for the period from 2010 to 2050.
- The use of electricity-based fuels (mainly hydrogen) represents an emission abatement lever of 5% for the period from 2010 to 2030 and a very significant contribution of 41% from 2010 to 2050.
- The switch to less $CO_2$-intensive fossil fuels represents a relatively small emission reduction lever of 1.5% for the period from 2010 to 2030. The remaining role of fossil fuels is determined by infrastructure constraints and a higher share of more $CO_2$-intensive fossil fuels beyond 2030. As a consequence the fossil fuel mix drives $CO_2$ emissions by 6.5% for the period from 2010 to 2050.

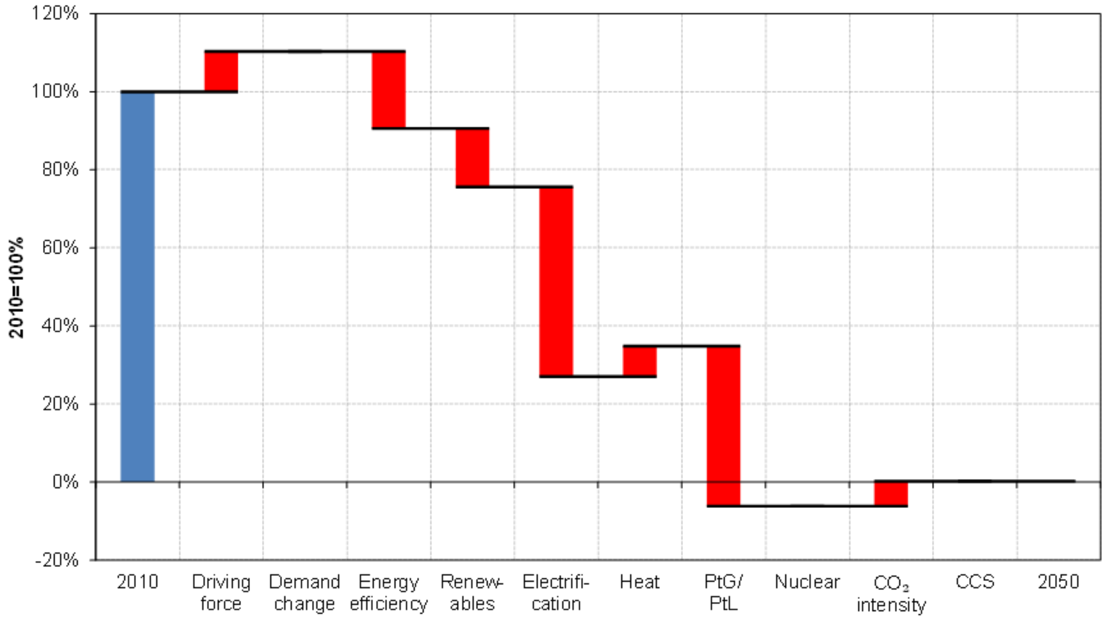
Total $CO_2$ emissions from tertiary sectors decrease by 51% from 2010 to 2030. The tertiary sectors are fully decarbonized in the Vision Scenario by 2050.

**Figure A 105: EU Vision Scenario 2017: Decomposition analysis for the tertiary sector, 2010–2030**




Source: Matthes et al. 2017, calculations by Öko-Institut

**Figure A 106: EU Vision Scenario 2017: Decomposition analysis for the tertiary sector, 2010–2050**




Source: Matthes et al. 2017, calculations by Öko-Institut

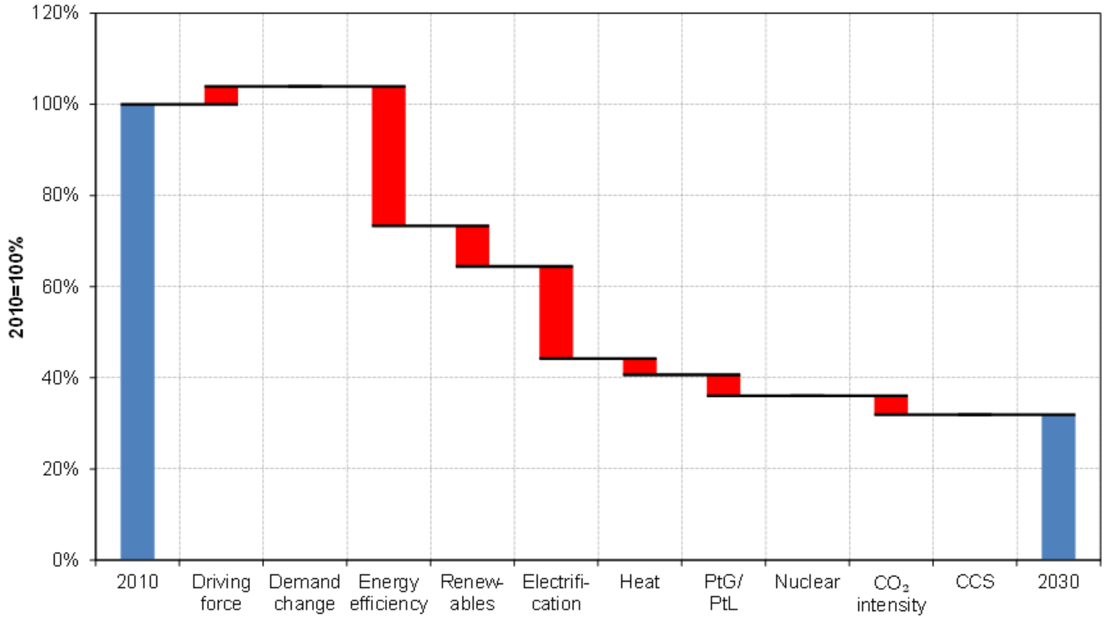
### A 2.8.2.4 Residential sector

The emission trends for the residential sector in the Vision Scenario for the European Union are determined by the different emission levers as follows:

- The number of households was considered as the metrics for the driving forces in the residential sector. It represents an emission increase of 4% (compared to base year emission levels) from 2010 to 2030 (Figure A 107), approx. 2% from 2010 to 2050 (Figure A 108) and plays only a limited role for the overall $CO_2$ emission trends.
- There were no structural changes (e.g. number of persons per household) reflected in the Vision Scenario.
- Energy efficiency (e.g. of buildings) provides an emission abatement lever of 31% from 2010 to 2030 and 17% for the period from 2010 to 2050.
- The direct use of renewable energy sources (biomass, solar heat etc.) represents an emission reduction lever of 10% from 2010 to 2030 which increases to 34% if the period from 2010 to 2050 is considered.
- Electrification plays a major role for emission reductions. The corresponding emission abatement lever amounts to 20% for the period from 2010 to 2030 and 40% from 2010 to 2050.
- District heat provides emission abatement for the period from 2010 to 2030 at a level of 4% of base year emission levels. With a view to the time span from 2010 to 2050 the role of district heat is almost neutral in terms of emission levers.
- Electricity-based fuels, i.e. hydrogen, play a limited role for emission reductions in the residential sectors. The corresponding emission reduction lever is 5% for 2010 to 2030 and 10% for the period from 2010 to 2050.
- The switch to less $CO_2$-intensive fossil fuels represents a rather small emission abatement lever of 4% from 2010 to 2030 and 1% from 2010 to 2050.

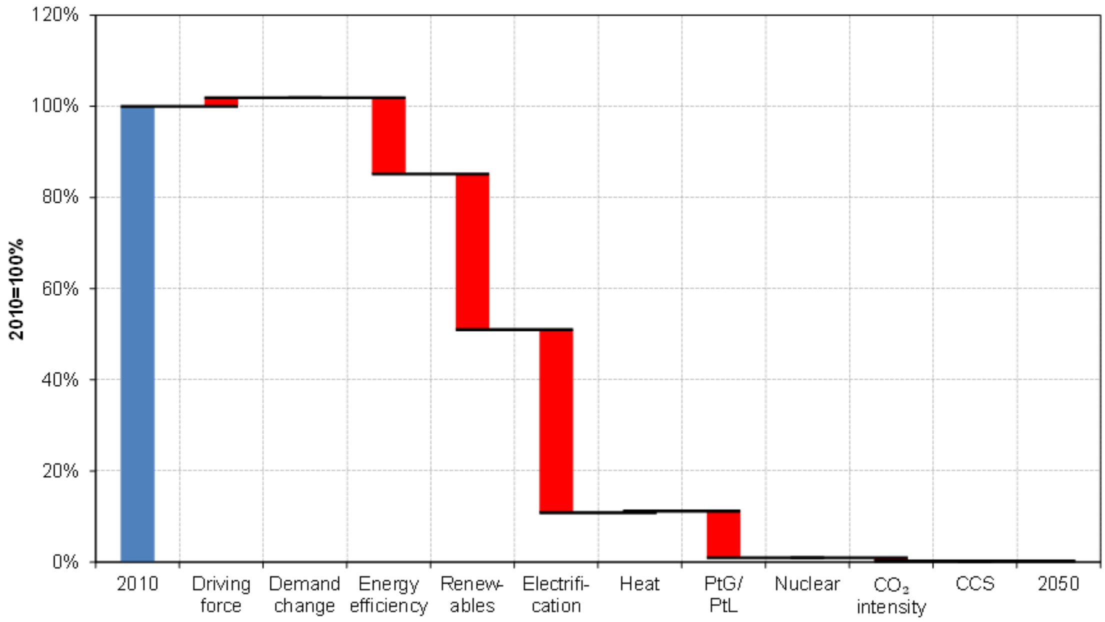
During the period from 2010 and 2030 energy efficiency and electrification dominate the total emission reduction of 68%. For the more long-term period from 2010 to 2050 full decarbonization is achieved with significantly increasing emission reduction contributions from direct use of renewables and some market penetration of electricity-based fuels (i.e. hydrogen).

**Figure A 107: EU Vision Scenario 2017: Decomposition analysis for the residential sector, 2010–2030**




Source: Matthes et al. 2017, calculations by Öko-Institut

**Figure A 108: EU Vision Scenario 2017: Decomposition analysis for the residential sector, 2010–2050**




Source: Matthes et al. 2017, calculations by Öko-Institut

#### A 2.8.2.5 Transport

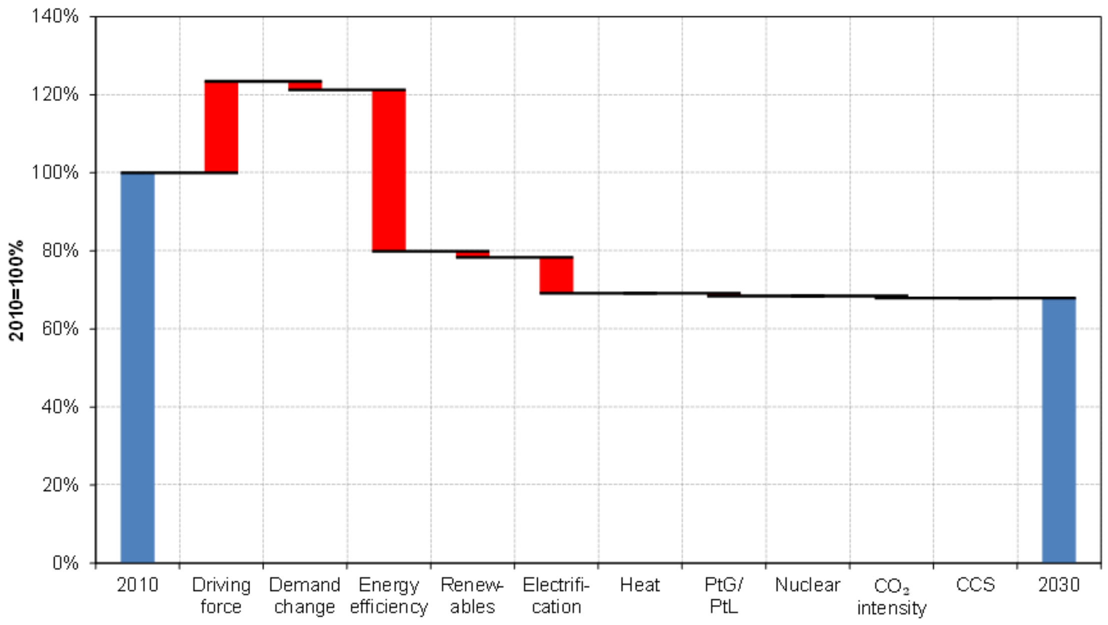
The emissions trajectories for the transport sector in total (passenger and freight transport) result from the following levers:

- The passenger and freight transport capacities in the reference case are used to identify the driving force from transport activities. The growth in transport activities represents an increase of emissions of 23% for the period from 2010 to 2030 (Figure A 109), compared to base year levels. From 2010 to 2050 (Figure A 110), the driving force amounts to 8%.
- The switch to other transport modes or transport avoidance represents an emission abatement lever of 2% for 2010 to 2030 and approx. 1% for 2010 to 2050.
- Energy efficiency is with 41% the most significant emissions abatement lever for the period from 2010 to 2030. The corresponding emission reduction lever for the time span from 2010 to 2050 is 21%.[5]
- The direct use of renewable energy sources, in case of the transport sector this is essentially biofuel, provides an abatement laver of 1.5% for the period from 2010 to 2030 and 8% from 2010 to 2050.
- Electrification of the transport sector provides a contribution for emission abatement which equals 9% of base year emissions for the period from 2010 to 2030 and amounts to 40% from 2010 to 2050.
- The use of novel fuels (e.g. electricity-based fuels that are imported from non-EU regions) contributes with less than 1% of base years emissions to the overall emission reduction from 2010 to 2030. Its role increases significantly beyond 2030 when these fuels start to cover significant market shares in long-distance freight transportation as well as aviation. The emission abatement lever for 2010 to 2050 amounts to 36%.
- The decreasing $CO_2$-intensitiy of the remaining fossil motor fuels represent an emission reduction lever of 0.5% for the period from 2010 to 2030 and 2% for the full scenario period from 2010 to 2050.

The total $CO_2$ emissions from transport activities decrease by 32% from 2010 to 2030. The transport sector is fully decarbonized in the Vision Scenario by 2050.

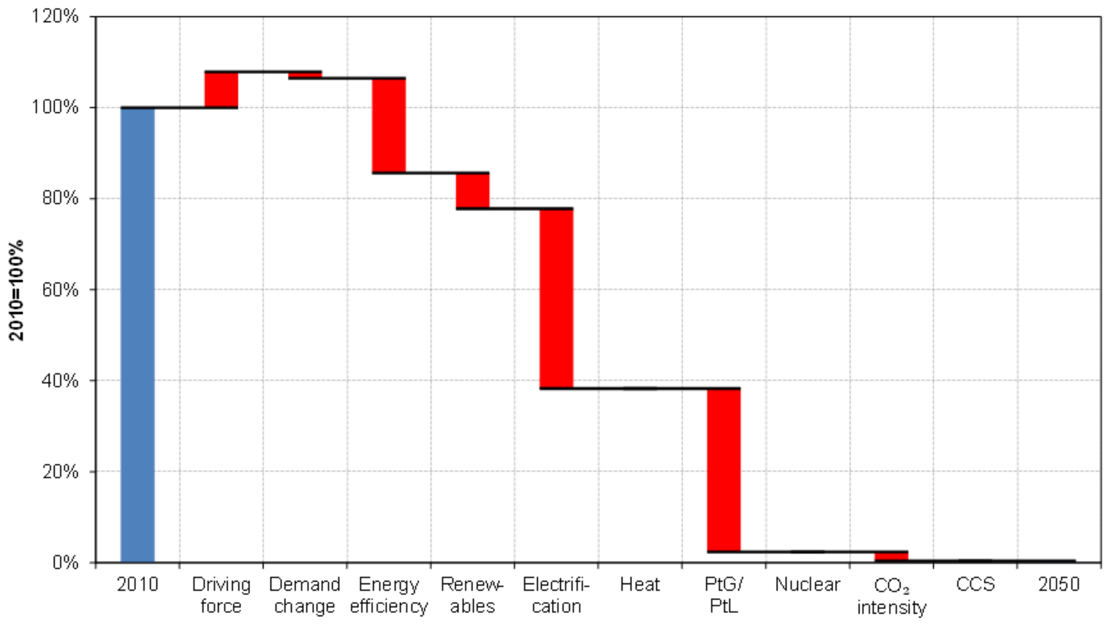
[5] It should be noted that the energy efficiency lever includes significant side effects from electrification of transport which leads to a much more efficient use of final energy.

**Figure A 109: EU Vision Scenario 2017: Decomposition analysis for transport, 2010–2030**




Source: Matthes et al. 2017, calculations by Öko-Institut

**Figure A 110: EU Vision Scenario 2017: Decomposition analysis for transport, 2010–2050**




Source: Matthes et al. 2017, calculations by Öko-Institut

## A 2.9 Greenpeace Energy Revolution 2015 for Europe – Energy Revolution Scenario

### A 2.9.1 Aggregate trends

The Energy Revolution Scenario[6] attains a 50% reduction in total $CO_2$ emissions from energy until 2030 (Figure A 111). There is increasing pressure on emissions by growing population (+5% compared to 2010 emissions) and especially economic growth (+20%). However, this is offset by strongly increased energy efficiency (–39%) and renewables use (–36%). The slight increasing contribution to emissions caused by the nuclear phase-out (+11%) can offset by a less $CO_2$-intensive fossil fuel mix fuels (-11%).

In 2045 (Figure A 112), emissions are down to 84% below 2010 baseline, and down to -92% in 2050. The drivers for this are very similar in structure, but renewable energy expansion is the strongest determinant (-63% in 2045) along with some, but not drastic, further reduction of $CO_2$ intensity.

[6] Because the Greenpeace scenarios, in their Advanced Energy Revolution version, attain a full decarbonization in 2050, LMDI decomposition is not usable there. Thus, all Greenpeace scenarios are evaluated for 2045, where the structure of decarbonization is comparable to 2050. It should be also considered that the 2015 edition of the Greenpeace Energy Revolution does not provide detailed results for the European Union but for the European OECD countries in total. Thus the EU-27 member states Lithuania, Latvia, Romania, Bulgaria, Romania, Malta and Cyprus are excluded and the non-EU countries Iceland, Israel, Norway, Switzerland and Turkey are included in the totals for OECD Europe.

**Figure A 111: Greenpeace Energy Revolution Scenario 2015: Decomposition analysis for the aggregate trends, 2010–2030**

Source: Greenpeace 2015, calculations by Öko-Institut

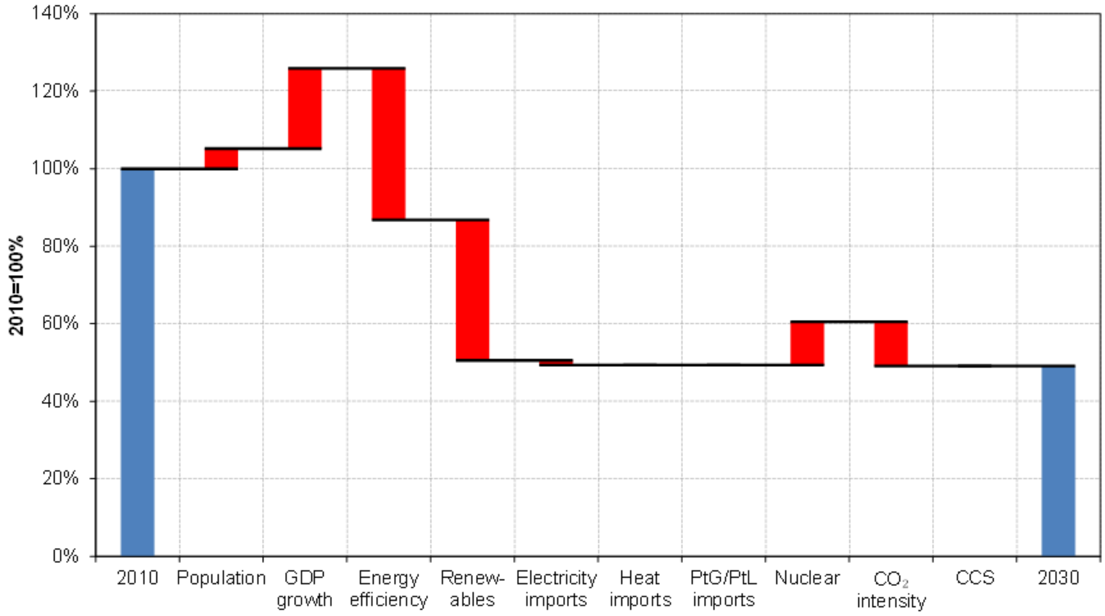
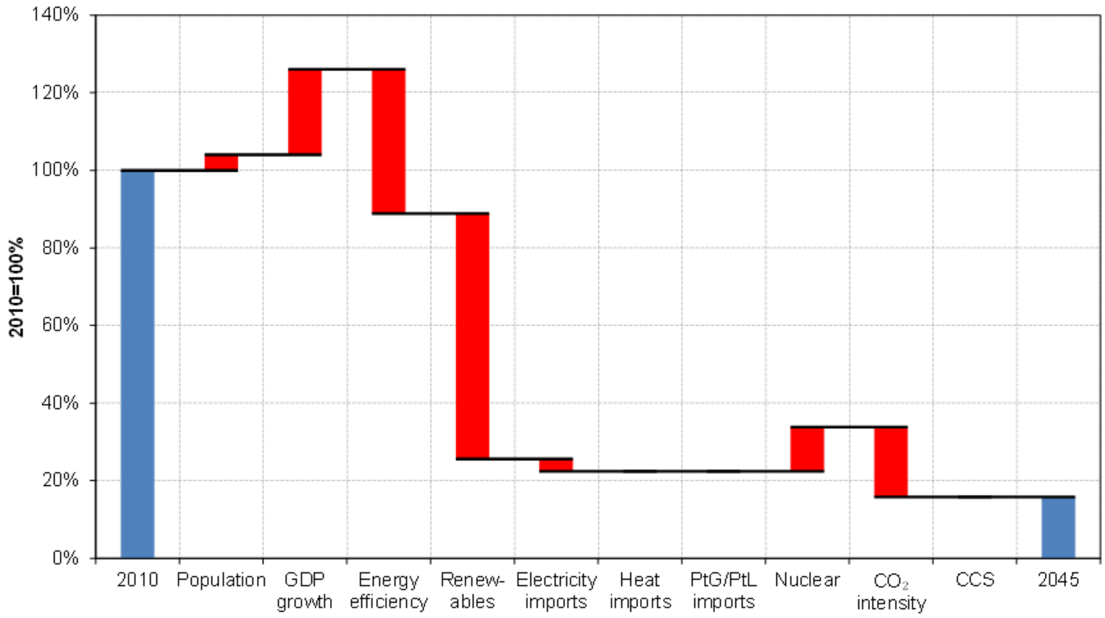



**Figure A 112: Greenpeace Energy Revolution Scenario 2015: Decomposition analysis for the aggregate trends, 2010–2045**




Source: Greenpeace 2015, calculations by Öko-Institut

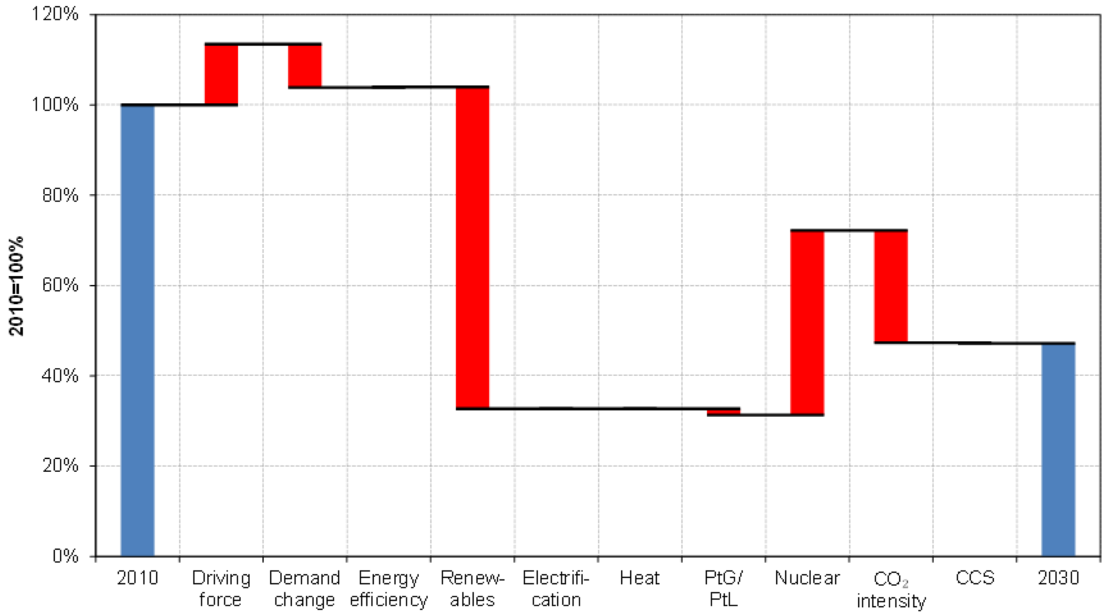
### A 2.9.2 Sectoral trends

#### A 2.9.2.1 Electricity sector

In the electricity sector, renewables play the largest role. Firstly, the nuclear phase-out causes an increase of emissions (+40%) but this is more than offset by the expansion of renewables (-71%) until 2030 (Figure A 113). Lower $CO_2$ intensity of fossil fuels contributes a further -25% reduction compared to 2010, leading to a total reduction of 52%.

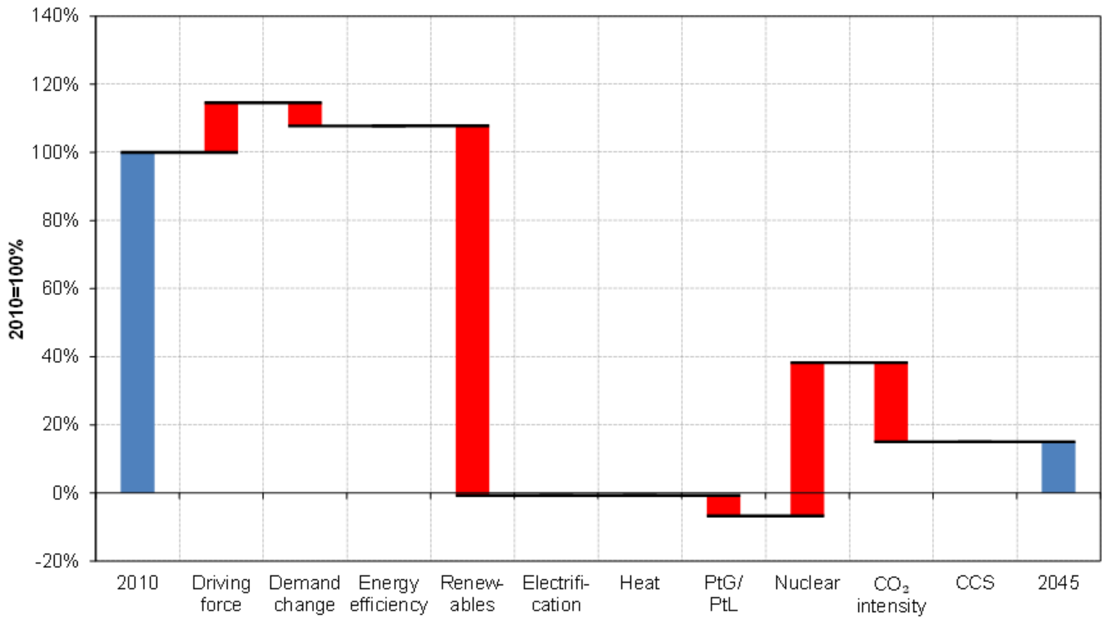
Until 2050, a reduction of 93% is attained and 85% until 2045 (Figure A 114). The change from 2030 is mainly driven by an ever stronger expansion of renewables. In 2045, they would be theoretically able to displace 108% of baseline emissions in 2010. This, tegether with lowered $CO_2$ intensity, balances out with the increasing contributions of nuclear phase-out and demand growth.

**Figure A 113: Greenpeace Energy Revolution Scenario 2015: Decomposition analysis for the electricity sector, 2010–2030**




Source: Greenpeace 2015, calculations by Öko-Institut

**Figure A 114: Greenpeace Energy Revolution Scenario 2015: Decomposition analysis for the electricity sector, 2010–2045**



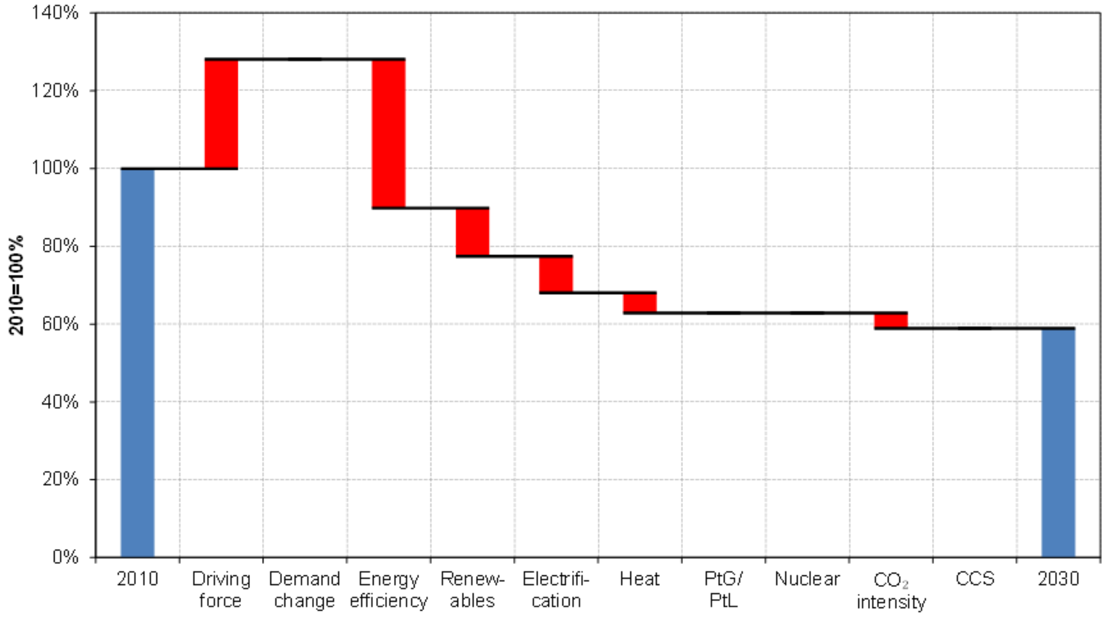

Source: Greenpeace 2015, calculations by Öko-Institut

#### A 2.9.2.2 Industry sector

In the industry sector, total reduction is small in 2030 at 41% below 2010 (Figure A 115). Efficiency rises strongly and almost counter-balances a 28% increase in industrial output. Use of renewables, electricity and heat increases as well. Additionally, $CO_2$ intensity is lower and contributes 5% of emissions reductions.

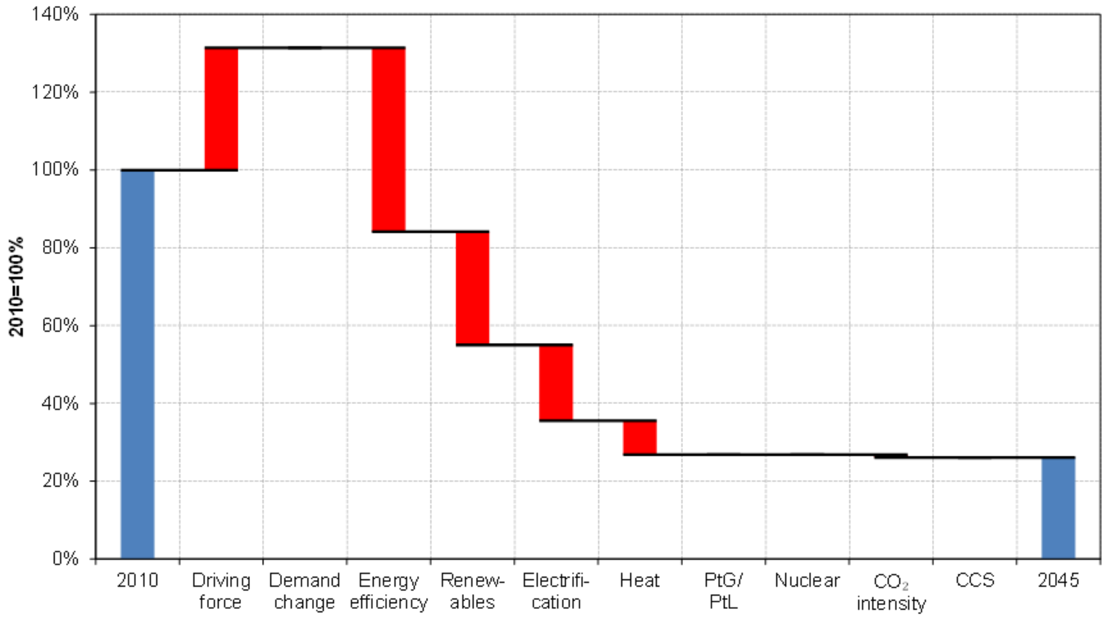
The structure of reductions is identical in 2045 (Figure A 116), but with larger contributions of efficiency (-47%), renewables (-30%), electrification (-20%) and heat (-9%). There is also a slight dip in $CO_2$ intensity. Until 2045, emissions can be reduced by -74% in the industry sector, and further down to -84% in 2050.

**Figure A 115: Greenpeace Energy Revolution Scenario 2015: Decomposition analysis for the industry sector, 2010–2030**




Source: Greenpeace 2015, calculations by Öko-Institut

**Figure A 116: Greenpeace Energy Revolution Scenario 2015: Decomposition analysis for the industry sector, 2010–2045**




Source: Greenpeace 2015, calculations by Öko-Institut

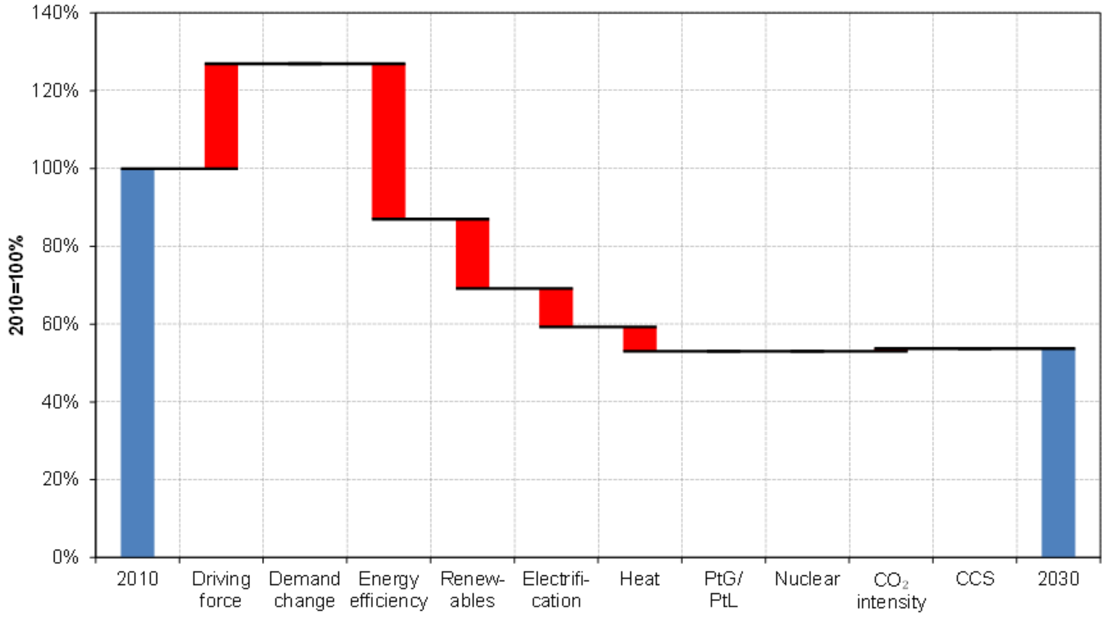
#### A 2.9.2.3 Tertiary and residential sectors

In the tertiary and residential sectors[7], efficiency gains dominate, leading to a 13% net reduction compared to output growth in 2030 (Figure A 117). Additionally, there is significant emissions abatement from switching to renewables (-40%) and electricity (-10%), leading to a total emissions reduction of 46% in 2030.

The development continues along the same lines to 2045 (Figure A 118), but renewables use grows stronger after 2030 than other drivers (to 38% relative contribution) in this scenario. In 2045, emissions stand at 80% below 2010 baseline, and at 90% below 2010 in 2050.

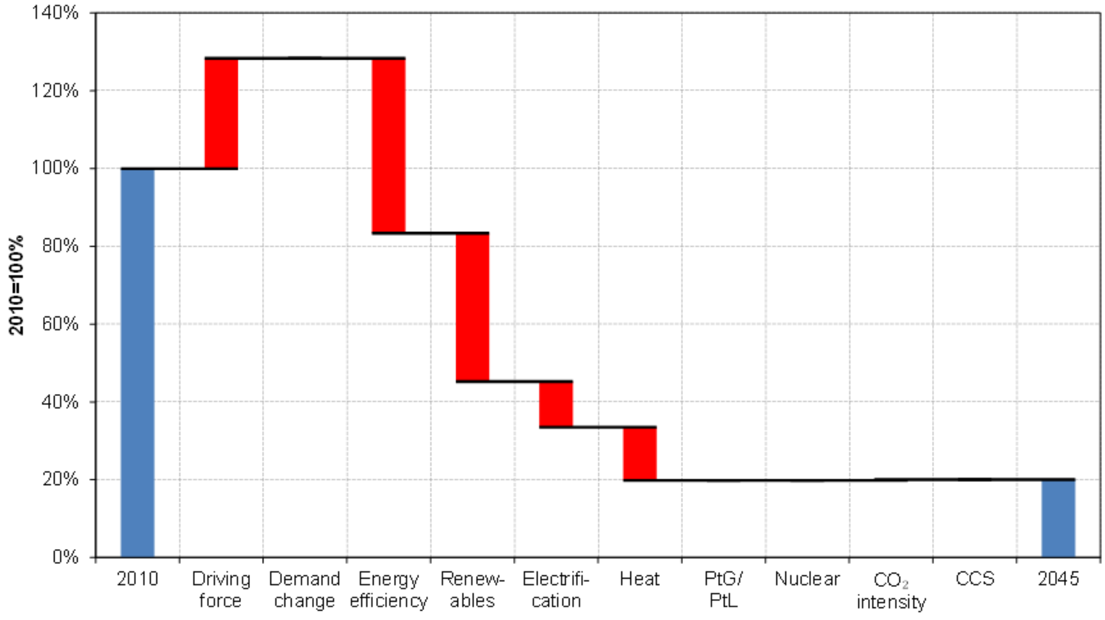
[7] The 2015 edition of the Energy Revolution scenarios provides only aggregate results for the tertiary and the residential sectors and no further disaggregation for these sectors.

**Figure A 117: Greenpeace Energy Revolution Scenario 2015: Decomposition analysis for the tertiary and residential sectors, 2010–2030**




Source: Greenpeace 2015, calculations by Öko-Institut

**Figure A 118: Greenpeace Energy Revolution Scenario 2015: Decomposition analysis for the tertiary and residential sectors, 2010–2045**



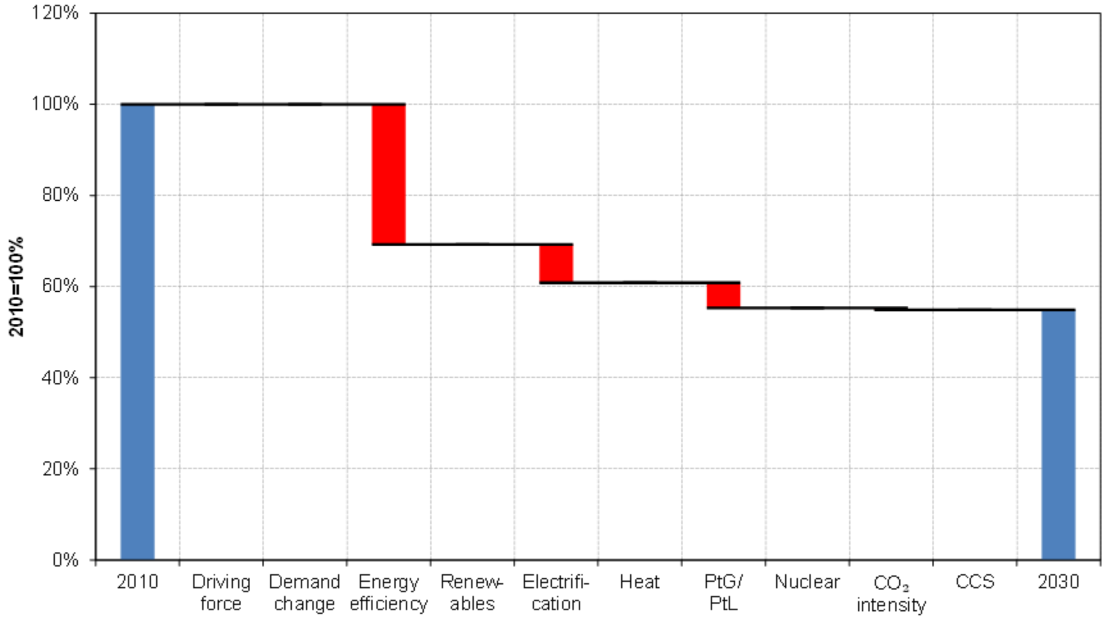

Source: Greenpeace 2015, calculations by Öko-Institut

#### A 2.9.2.4 Total transport

Energy efficiency (-31%) is the main driver to $CO_2$ reduction in 2030 (Figure A 119). Apart from it, there are contributions only by electrification (-8%) and PtX (-6%). In sum there is a reduction of -45% in transport until 2030.

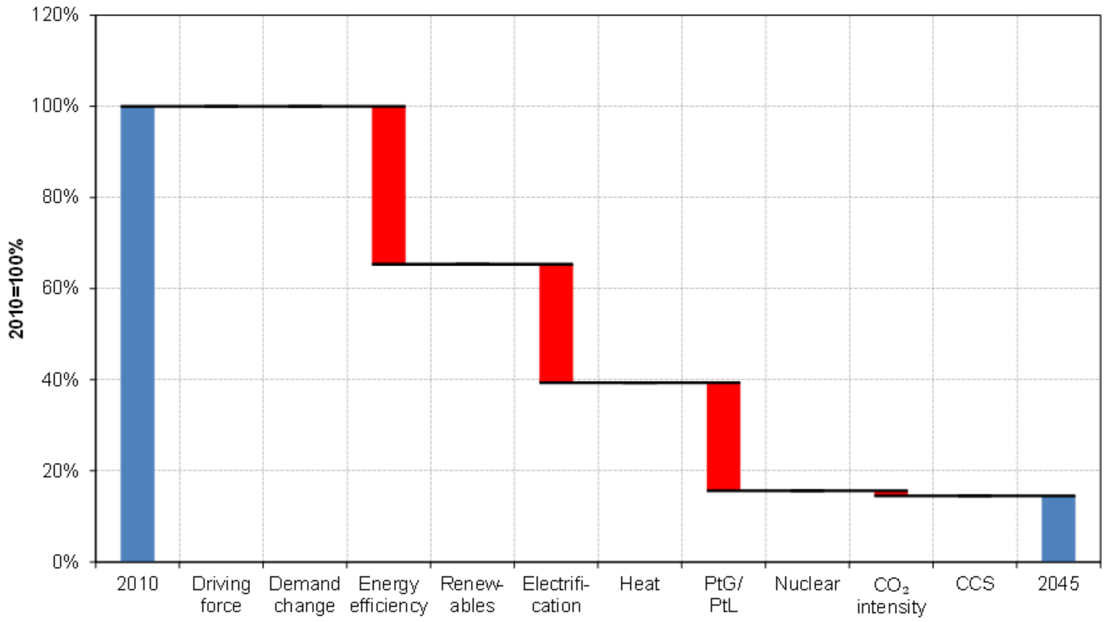
After 2030, efficiency gains stagnate, but electrification (-26%) and PtX (-24%) lead to significant further emissions abatement compared to 2010. In 2045 (Figure A 120), emissions stand at 85% below 2010 baseline, and at -92% in 2050.

**Figure A 119: Greenpeace Energy Revolution Scenario 2015: Decomposition analysis for total transport, 2010–2030**




Source: Greenpeace 2015, calculations by Öko-Institut

**Figure A 120: Greenpeace Energy Revolution Scenario 2015: Decomposition analysis for total transport, 2010–2045**




Source: Greenpeace 2015, calculations by Öko-Institut

## A 2.10 Greenpeace Energy Revolution 2015 for Europe – Advanced Energy Revolution Scenario

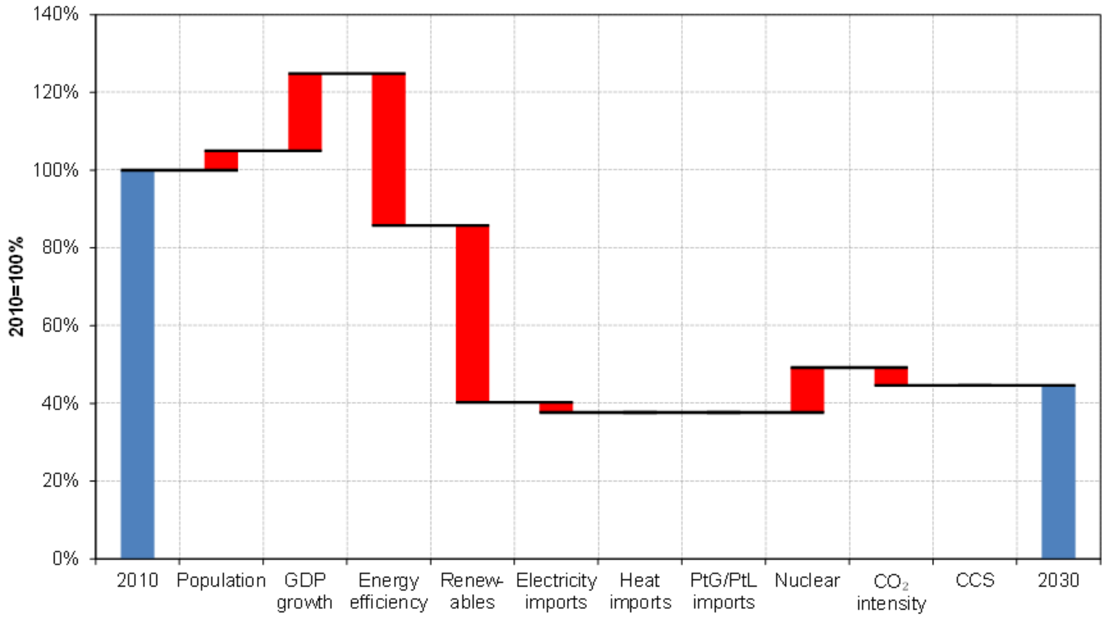
### A 2.10.1 Aggregate trends

The Greenpeace Energy Revolution 2015 – Advanced Energy Revolution Scenario[8] attains a 56% reduction in total $CO_2$ emissions from energy until 2030 (Figure A 121). Emissions increase due to population (+5%) and economic growth (20%). However, this is offset by an improvement of efficiency (-40%) and increased renewables (-46%). A further contribution is made by lower $CO_2$ intensity of the remaining fossil fuel mix (-5%). In contrast, there is a slight increasing contribution to emissions caused by the nuclear phase-out (+12%).

Until 2045 (Figure A 122), there is no large change in the structure of the decarbonization. Renewables grow most pronouncedly (-78%), followed by efficiency (-40% compared to 2010). This results in a total reduction of 92% compared to 2010. The trends continue for a full decarbonization in 2050.

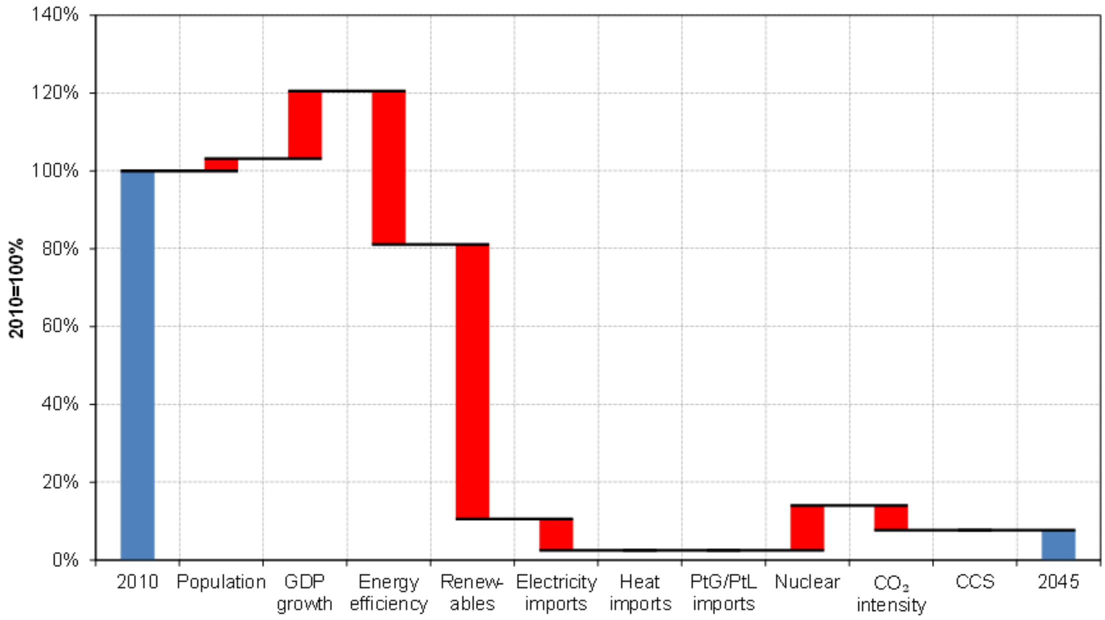
[8] Because the Greenpeace scenarios, in their Advanced Energy Revolution version, attain a full decarbonization in 2050, LMDI decomposition is not usable there. Thus, all Greenpeace scenarios are evaluated for 2045, where the structure of decarbonization is comparable to 2050. It should be also considered that the 2015 edition of the Greenpeace Energy Revolution does not provide detailed results for the European Union but for the European OECD countries in total. Thus the EU-27 member states Lithuania, Latvia, Romania, Bulgaria, Romania, Malta and Cyprus are excluded and the non-EU countries Iceland, Israel, Norway, Switzerland and Turkey are included in the totals for OECD Europe.

**Figure A 121: Greenpeace Advanced Energy Revolution Scenario 2015: Decomposition analysis for the aggregate trends, 2010–2030**




Source: Greenpeace 2015, calculations by Öko-Institut

**Figure A 122: Greenpeace Advanced Energy Revolution Scenario 2015: Decomposition analysis for the aggregate trends, 2010–2045**




Source: Greenpeace 2015, calculations by Öko-Institut

### A 2.10.2 Sectoral trends

#### A 2.10.2.1 Electricity sector

The strong contribution of renewables, as well as the increasing pressure of nuclear phaseout, is clearly seen in the electricity sector once again. Renewables grow strongly compared to 2010, attaining an 80% reduction of emissions until 2030 (Figure A 123). The remaining fossil generation becomes slightly cleaner (-25%) than in 2010. Together with the nuclear phaseout and increasing demand, $CO_2$ emissions are reduced by 55% in 2030.

In 2050, the sector is fully decarbonized, and 92% reduction is attained in 2045 (Figure A 124). Due to electrification in other sectors, demand in the Advanced Energy Revolution is actually higher than in the Energy Revolution scenario, but renewables grow strongly until 2045, reaching a potential to offset 115% of baseline 2010 emissions (counteracted by demand and nuclear phaseout). There is no further shift to gas (lower $CO_2$ intensity) after 2030.

**Figure A 123: Greenpeace Advanced Energy Revolution Scenario 2015: Decomposition analysis for the electricity sector, 2010–2030**

Source: Greenpeace 2015, calculations by Öko-Institut

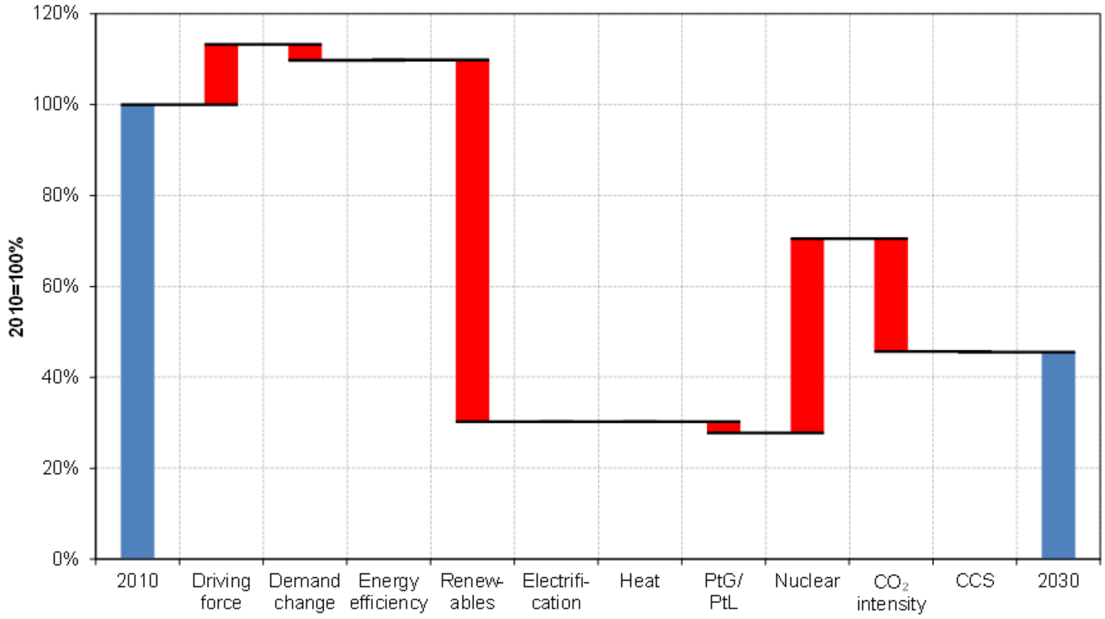
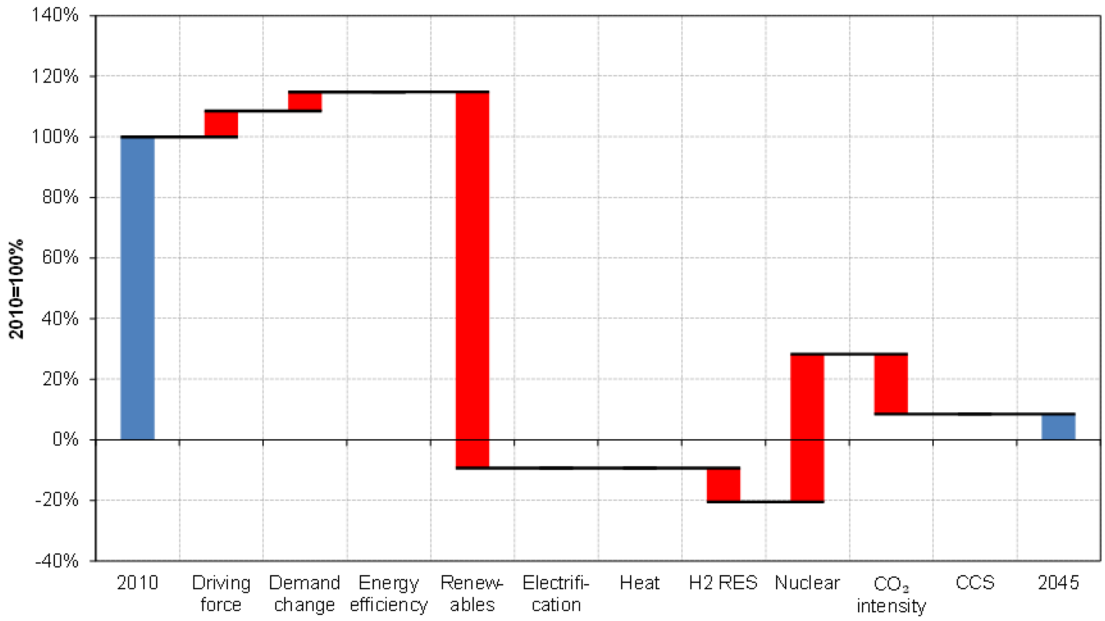



**Figure A 124: Greenpeace Advanced Energy Revolution Scenario 2015: Decomposition analysis for the electricity sector, 2010–2045**



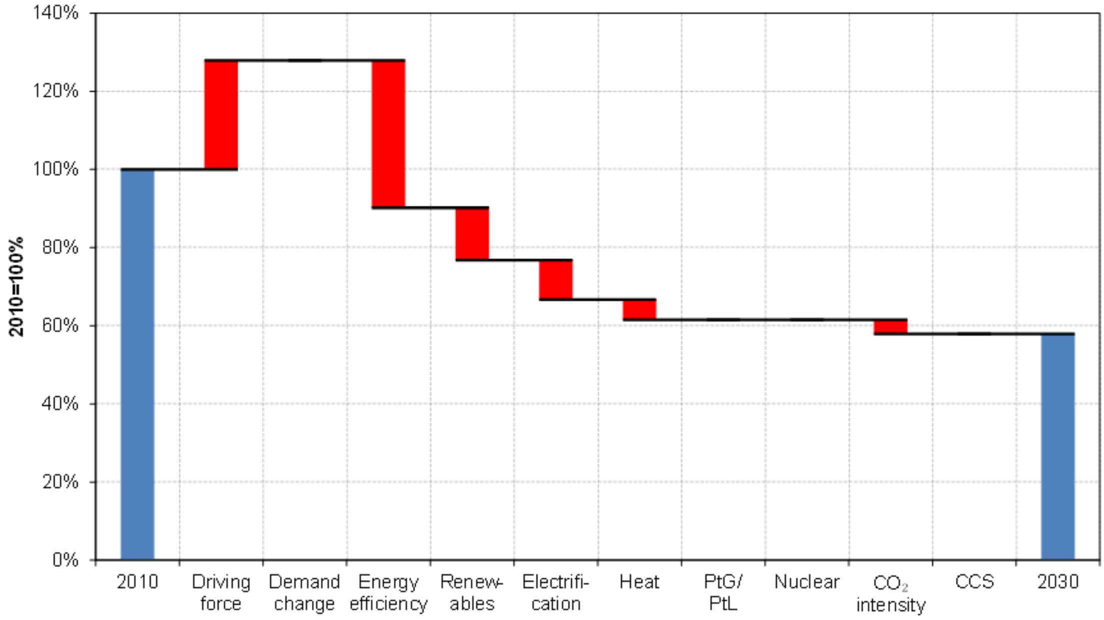

Source: Greenpeace 2015, calculations by Öko-Institut

#### A 2.10.2.2 Industry sector

The picture shows a 28% increase in production, which is compensated by efficiency gains, leading to a 10% net reduction of emissions in 2030 (Figure A 125). Additionally, increased use of renewables (-13%), electrification (-10%), and some distributed heat use and lower $CO_2$ intensity of fuels ensure a 42% net reduction of emissions in 2030.

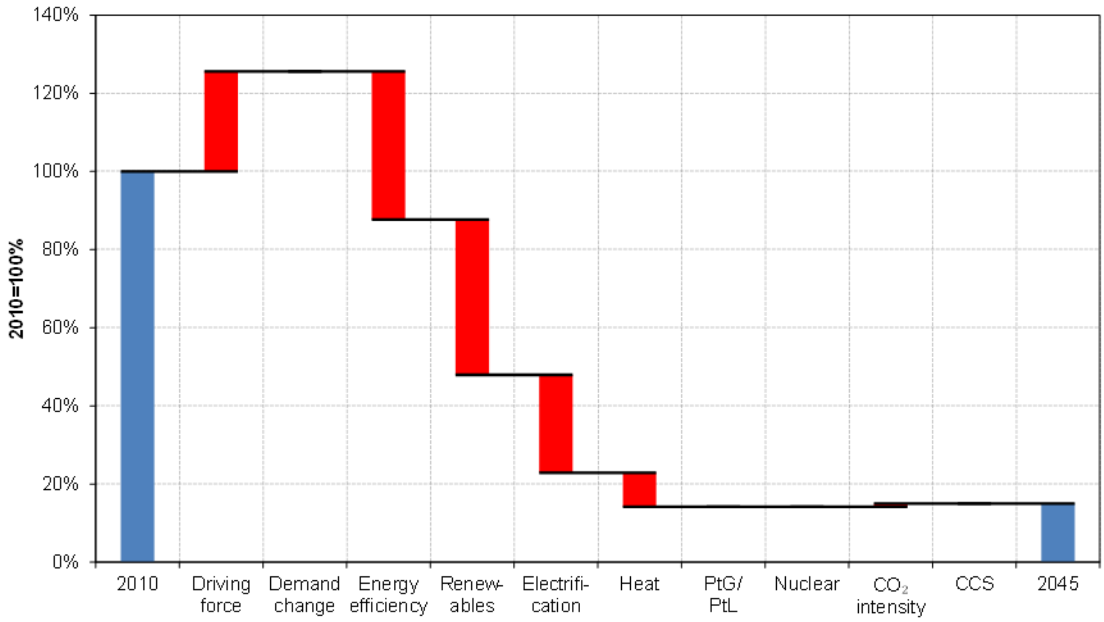
Until 2045 (Figure A 126), all drivers continue to grow differently. Renewables make the strongest contribution (-40%), followed by electrification (-25%) and distributed heat use (-9%). In sum, the drivers lead to a total reduction of –85% in 2045 and to full decarbonization in 2050.

**Figure A 125: Greenpeace Advanced Energy Revolution Scenario 2015: Decomposition analysis for the industry sector, 2010–2030**




Source: Greenpeace 2015, calculations by Öko-Institut

**Figure A 126: Greenpeace Advanced Energy Revolution Scenario 2015: Decomposition analysis for the industry sector, 2010–2045**




Source: Greenpeace 2015, calculations by Öko-Institut

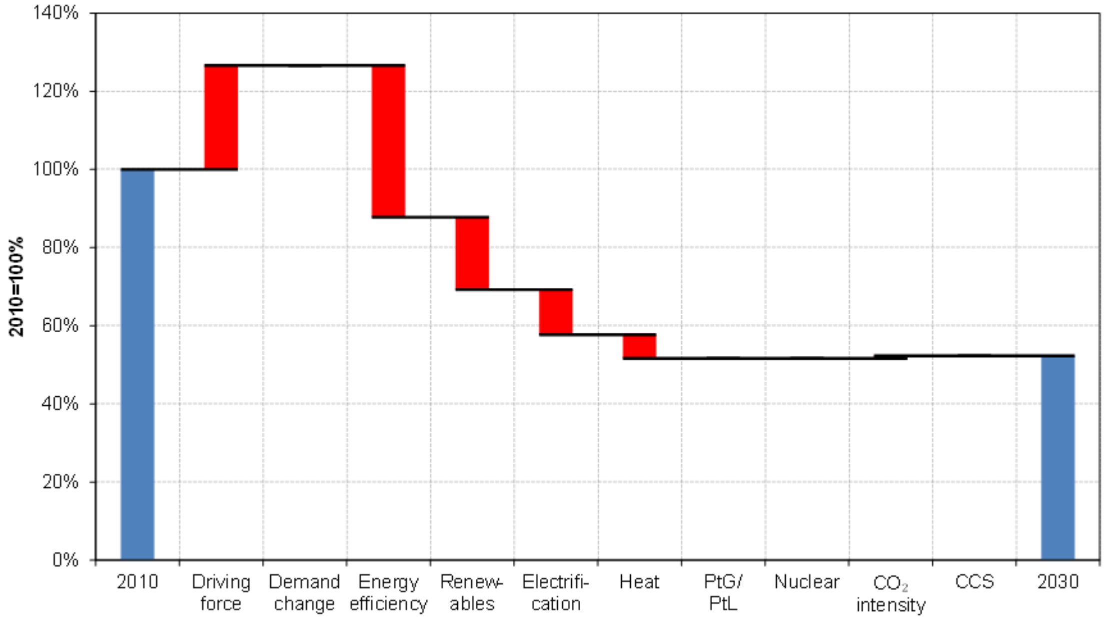
### A 2.10.2.3 Tertiary and residential sectors

Until 2030 (Figure A 127), there is a total reduction of nearly 50% in the tertiary and residential sectors[9]. The sector output increases by 27%, this is compensated by energy efficiency, leading to a 12% net decrease of emissions. Additionally, renewables, electrification and distributed heat reduce emissions by about -36% compared to 2010.

In 2045 (Figure A 128), the picture is similar to 2030 and the other sectors, with renewables as the strongest driver, followed by electrification and heat. In 2045, there is a total reduction of -89% in the tertiary sector, and full decarbonization in 2050.

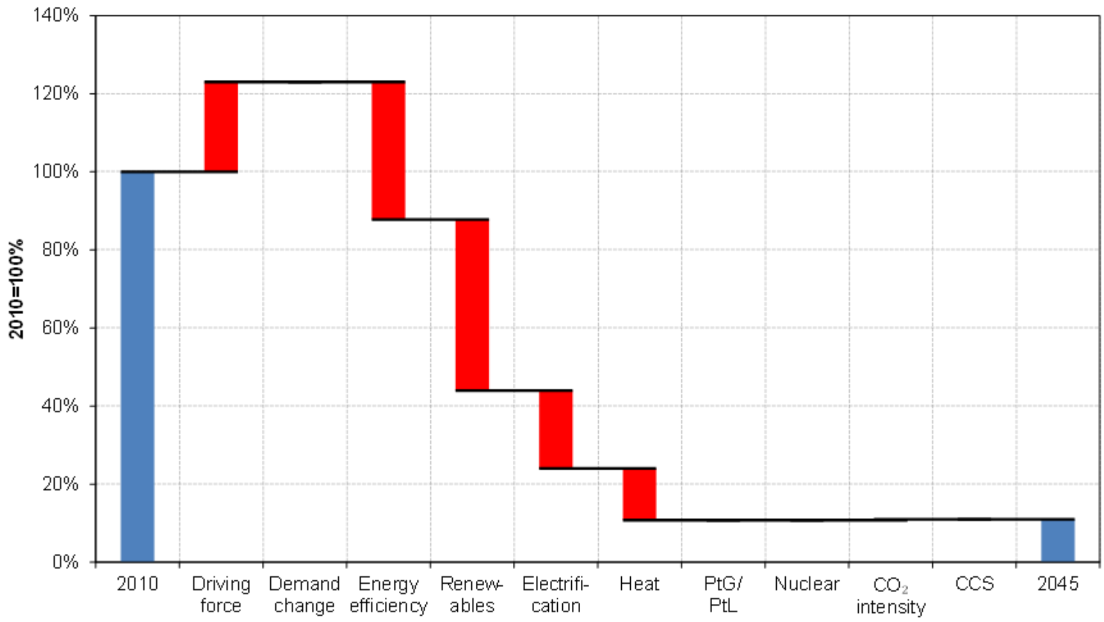
[9] The 2015 edition of the Energy Revolution scenarios provides only aggregate results for the tertiary and the residential sectors and no further disaggregation for these sectors.

**Figure A 127: Greenpeace Advanced Energy Revolution Scenario 2015: Decomposition analysis for the tertiary and residential sectors, 2010–2030**




Source: Greenpeace 2015, calculations by Öko-Institut

**Figure A 128: Greenpeace Advanced Energy Revolution Scenario 2015: Decomposition analysis for the tertiary and residential sectors, 2010–2045**



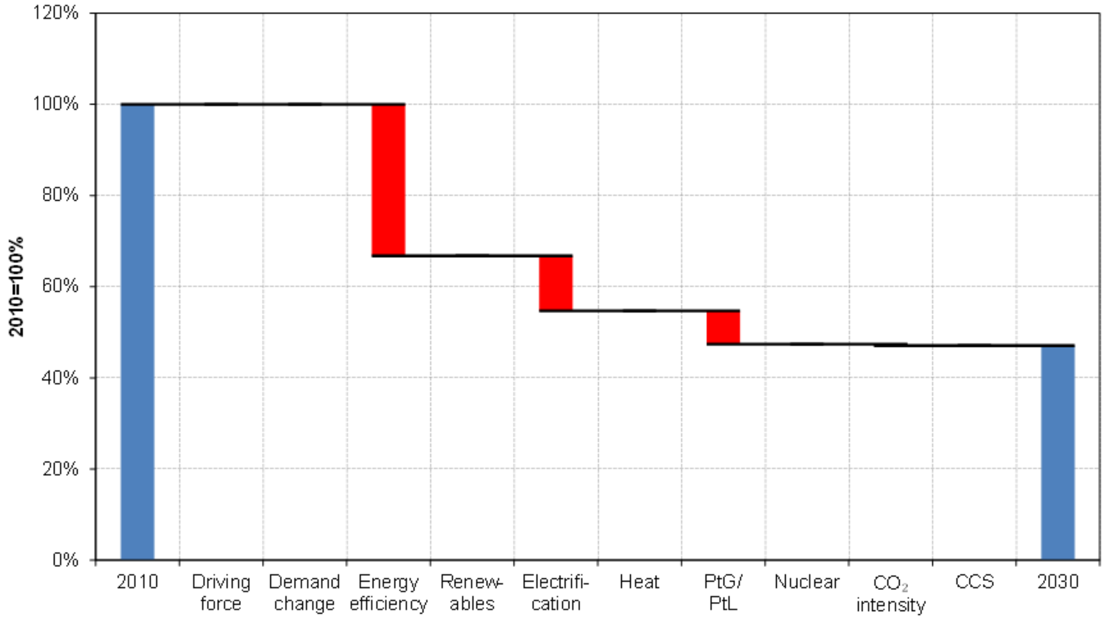

Source: Greenpeace 2015, calculations by Öko-Institut

### A 2.10.2.4 Total transport

Like in other Greenpeace scenarios, three drivers are responsible for all abatement in the transport sector. Energy efficiency (-33%) is the main driver to $CO_2$ reduction in 2030 (Figure A 129). Further, smaller contributions are delivered by electrification (-12%) as well as PtX (-7%). In sum, there is a reduction of -53% in total transport in 2030.

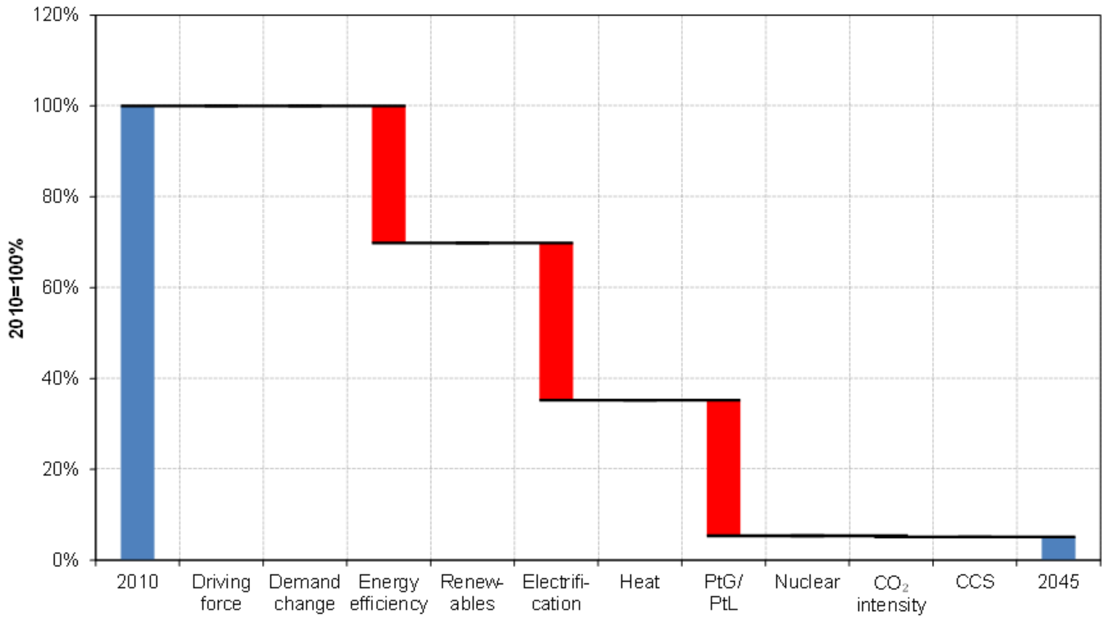
Electrification and especially PtX, continue to grow after 2030, PtX delivering a contribution of almost 30% of baseline emissions. In the end of 2045 (Figure A 130), there is a total reduction of emissions of -95%, and full decarbonization by 2050.

**Figure A 129: Greenpeace Advanced Energy Revolution Scenario 2015: Decomposition analysis for the total transport, 2010–2030**




Source: Greenpeace 2015, calculations by Öko-Institut

**Figure A 130: Greenpeace Advanced Energy Revolution Scenario 2015: Decomposition analysis for the total transport, 2010–2045**




Source: Greenpeace 2015, calculations by Öko-Institut

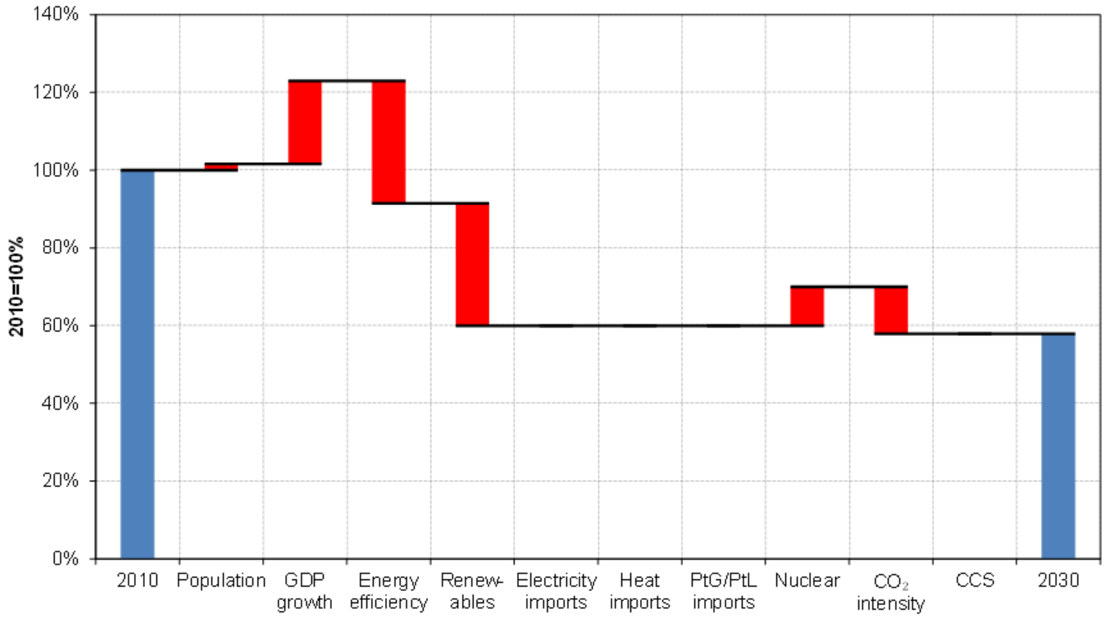
## A 2.11 Greenpeace EU Energy Revolution 2010 – Energy Revolution Scenario

### A 2.11.1 Aggregate trends

There is a 2% population and 21% GDP growth until 2030 (Figure A 131). The improvements of renewables (-32%) and efficiency (-33%) can offset this easily. Nuclear phase-out leads to 10% increase of emissions due to a shift to fossil fuels, which is also offset by lower $CO_2$ intensity. In sum there is a total reduction of -42% compared to 2010 in 2030.

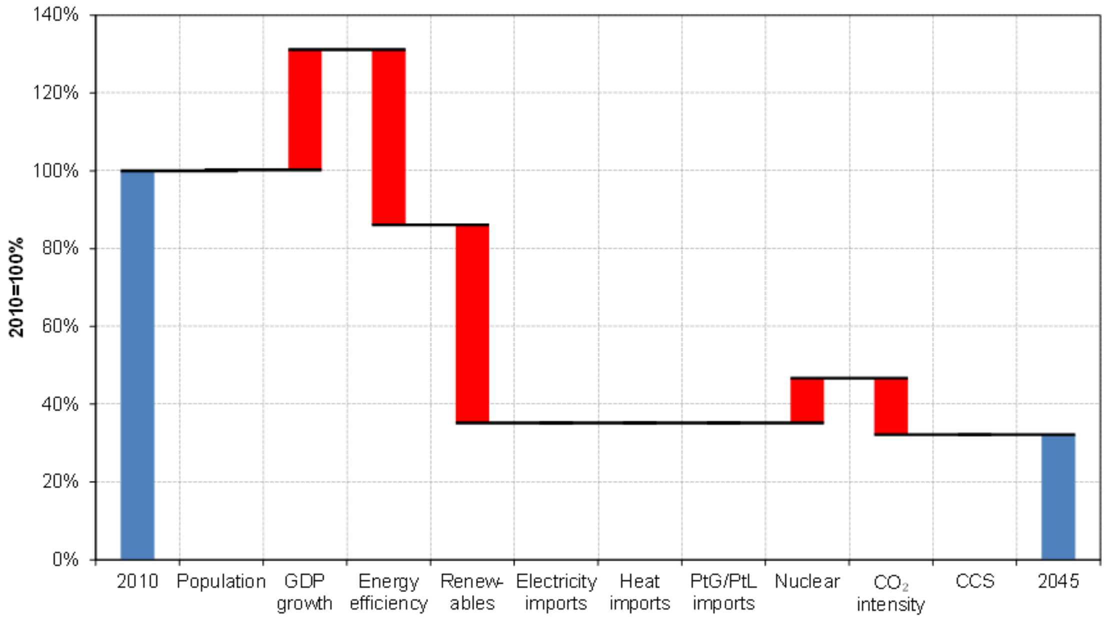
Compared to 2030, renewables show the strongest growth until 2045, leading to a 51% reduction alone (Figure A 132). The other drivers still show strong contributions, but not much larger than in 2030. These ends up in a total reduction of -68% in 2045 and -74% in 2050.

**Figure A 131: Greenpeace EU Energy Revolution Scenario 2010: Decomposition analysis for the aggregate trends, 2010–2030**




Source: Greenpeace 2010, calculations by Öko-Institut

**Figure A 132: Greenpeace EU Energy Revolution Scenario 2010: Decomposition analysis for the aggregate trends, 2010–2045**




Source: Greenpeace 2010, calculations by Öko-Institut

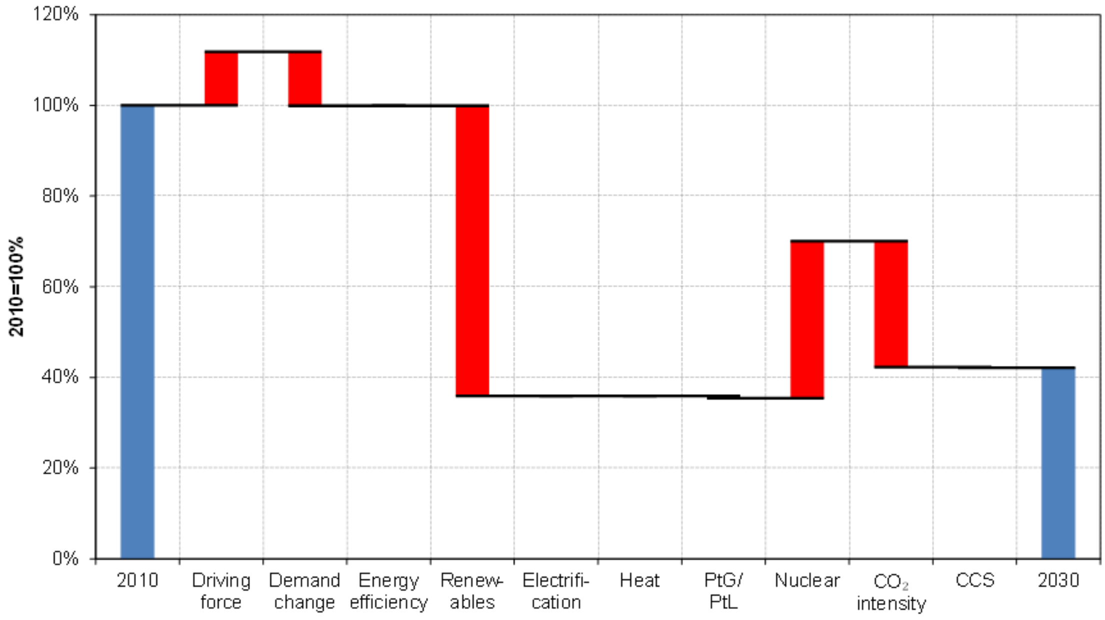
### A 2.11.2 Sectoral trends

#### A 2.11.2.1 Electricity sector

In the electricity sector, emissions are reduced by 58% in 2030 compared to 2010 (Figure A 133). The strong expansion of renewables (–64% of 2010 emissions) and reduced $CO_2$ intensity (–28%) are the main drivers in the period until 2030. However, reduced $CO_2$ intensity does not fully balance out the +34% pressure of nuclear phase-out.

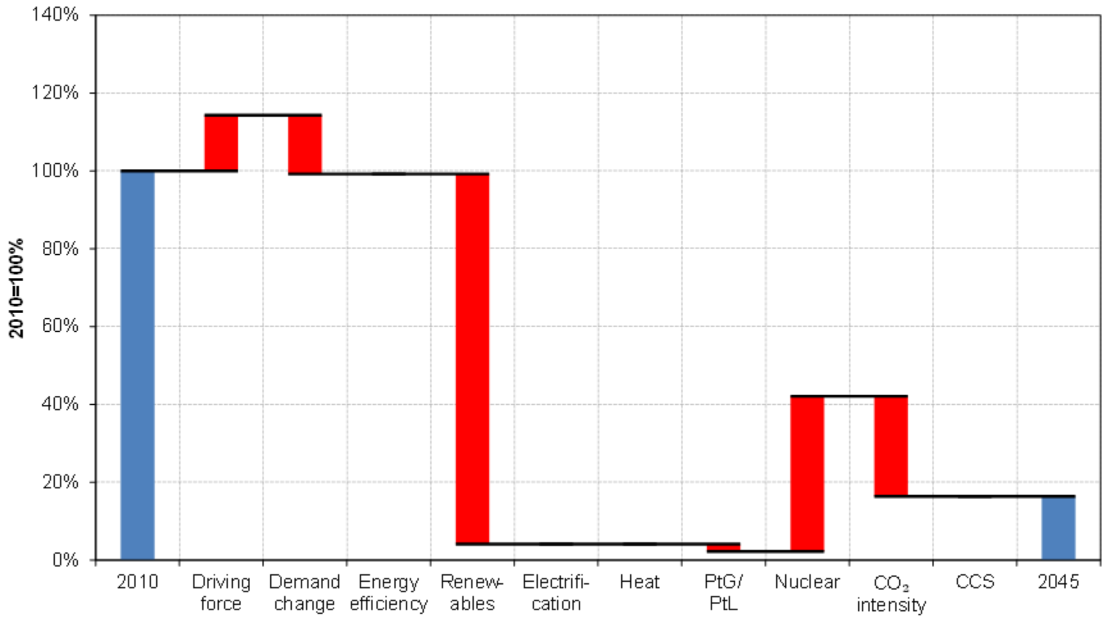
Until 2045 (Figure A 134), emissions are reduced to 83% below baseline, and to 89% until 2050. Nearly all of the additional abatement after 2030 is attained by increased use of renewables, as the nuclear phase-out is already completed by 2030 in this scenario.

**Figure A 133: Greenpeace EU Energy Revolution Scenario 2010: Decomposition analysis for the electricity sector, 2010–2030**




Source: Greenpeace 2010, calculations by Öko-Institut

**Figure A 134: Greenpeace EU Energy Revolution Scenario 2010: Decomposition analysis for the electricity sector, 2010–2045**



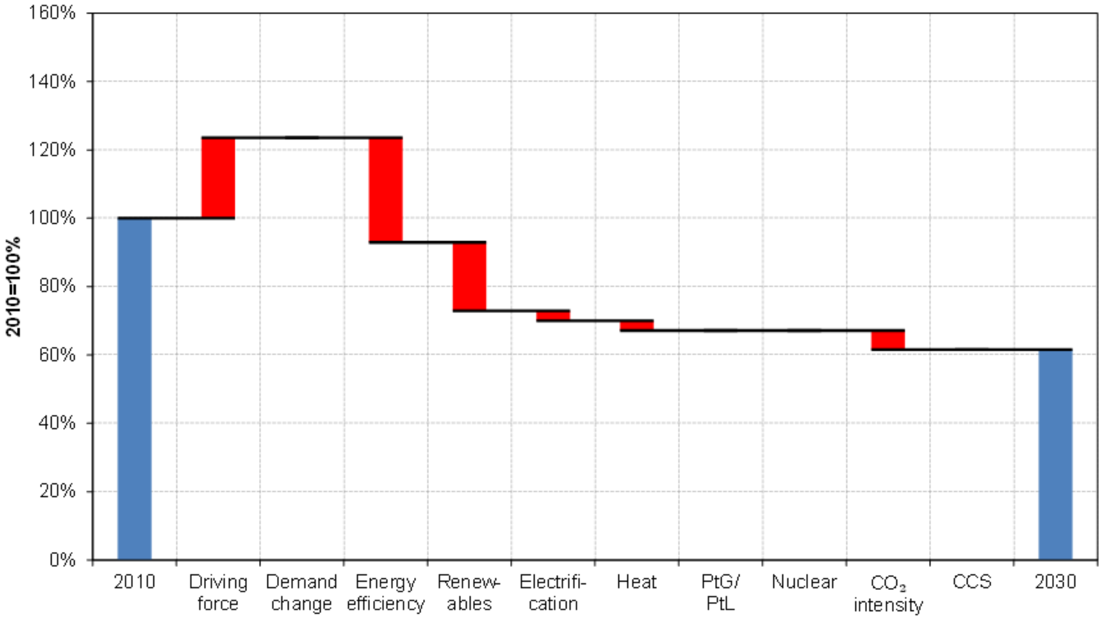

Source: Greenpeace 2010, calculations by Öko-Institut

#### A 2.11.2.2 Industry sector

In the Industry sector there is only a -38% reduction compared to base year 2010 (Figure A 135). The main drivers are improvements in efficiency (-31%) and expansion of renewables (-20%). Smaller contributions are delivered by electrification (-3%), distributed heat (-3%) and lower $CO_2$ intensity (-6%).

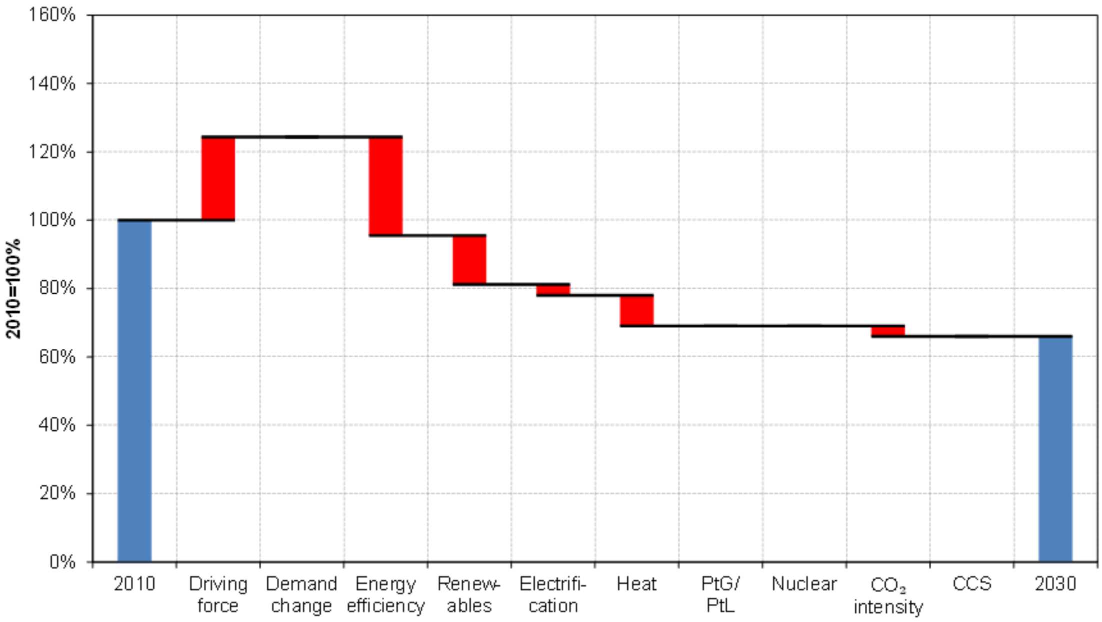
There is an additional reduction of -19% until the year 2045 (Figure A 136), leading to 57% reduction compared to 2010 in 2045, and slightly more, 61%, in 2050. The main drivers are the same with more contributions, however, there is also an increasing output of industry. Thus, the significant improvements in efficiency are largely cancelled out.

**Figure A 135: Greenpeace EU Energy Revolution Scenario 2010: Decomposition analysis for the industry, 2010–2030**




Source: Greenpeace 2010, calculations by Öko-Institut

**Figure A 136: Greenpeace EU Energy Revolution Scenario 2010: Decomposition analysis for the industry, 2010–2045**




Source: Greenpeace 2010, calculations by Öko-Institut

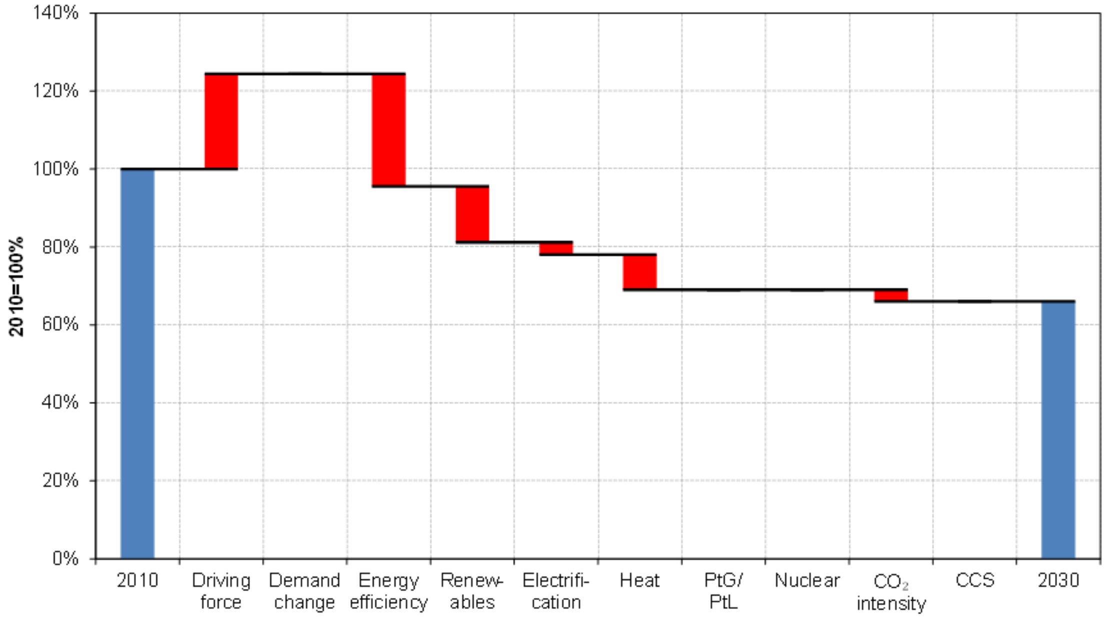
#### A 2.11.2.3 Tertiary and residential sectors

The tertiary and residential sectors[10] reach emissions reductions of 34% in 2030 (Figure A 137), with energy efficiency significantly larger than other drivers (-29% vs. a 24% increase in emissions due to higher production). Renewable energy (-14%), distributed heat (-10%), and electrification (-3%) make further contributions.

After 2030, there is little further reduction in $CO_2$ emissions. Until 2045 (Figure A 138), emissions will only decrease by a further 14% of 2010 baseline emissions, to 48% below 2010 baseline, and to 50% below in 2050. This is because production grows further, cancelling out improvements in efficiency, while growth of the other drivers slows down significantly.

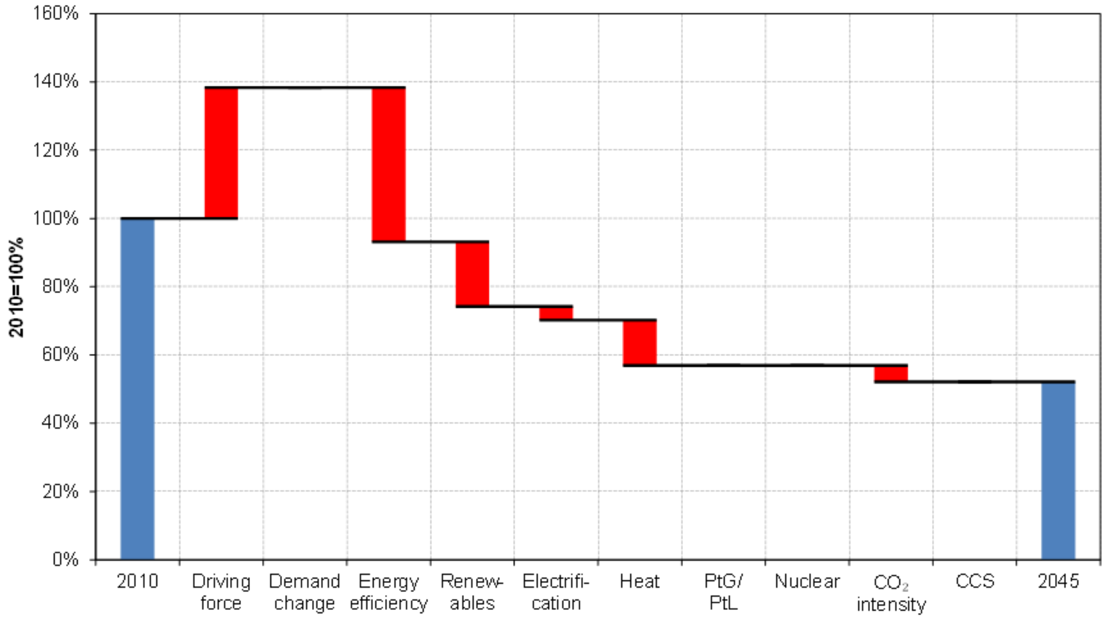
[10] The 2015 edition of the Energy Revolution scenarios provides only aggregate results for the tertiary and the residential sectors and no further disaggregation for these sectors.

**Figure A 137: Greenpeace EU Energy Revolution Scenario 2010: Decomposition analysis for the tertiary and residential sectors, 2010–2030**




Source: Greenpeace 2010, calculations by Öko-Institut

**Figure A 138: Greenpeace EU Energy Revolution Scenario 2010: Decomposition analysis for the tertiary and residential sectors, 2010–2045**




Source: Greenpeace 2010, calculations by Öko-Institut

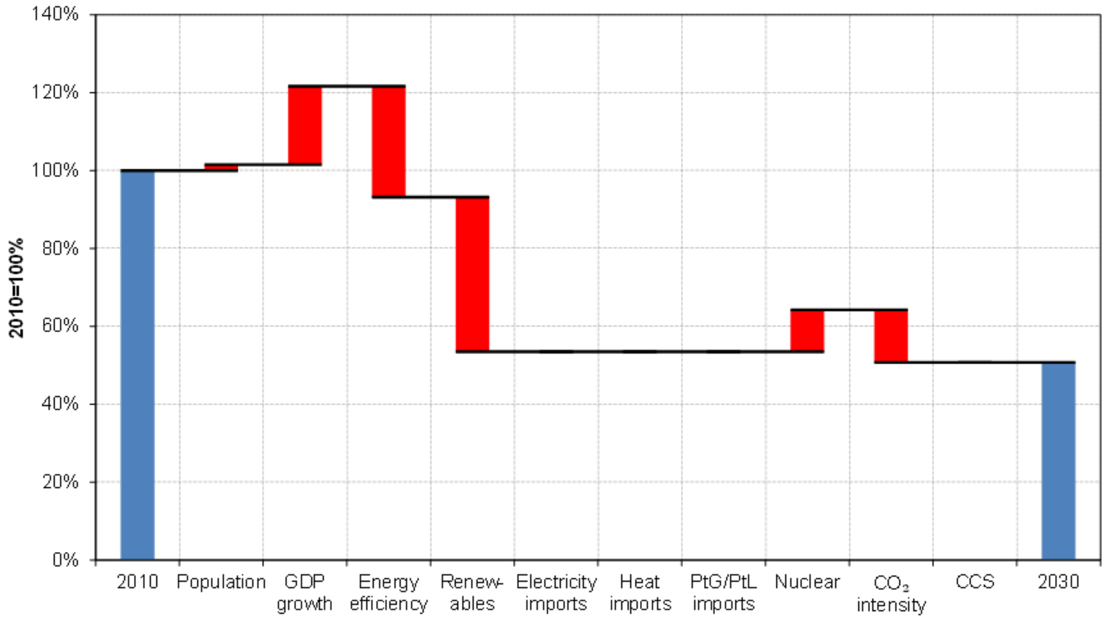
## A 2.12 Greenpeace EU Energy Revolution 2010 – Advanced Energy Revolution Scenario

### A 2.12.1 Aggregate trends

The AER scenario attains a 50% emissions reduction until 2030 (Figure A 139), largely driven by expansion of renewables (-40%) and efficiency gains that counterbalance increased GDP on one hand, as well as reduced $CO_2$ intensity that mitigates the effect of nuclear phase-out on the other hand.

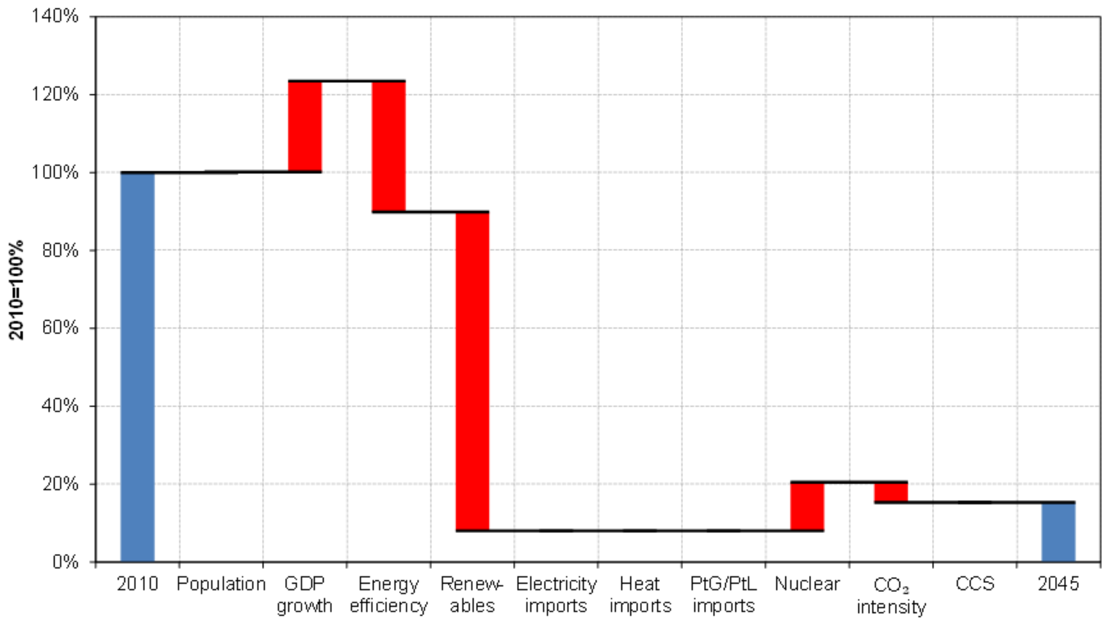
Until 2050, the economy is fully decarbonized, and the LMDI analysis can only be reliably calculated for 2045 (Figure A 140). As the nuclear phaseout progresses, improvements in $CO_2$ intensity do not fully balance it out anymore, but renewables expansion is strong enough to continue as the main driver of a very fast decarbonization. In 2045, reductions stand at 83% below baseline (further reducing to 100% in 2050!).

**Figure A 139: Greenpeace Advanced EU Energy Revolution Scenario 2010: Decomposition analysis for the aggregate trends, 2010–2030**




Source: Greenpeace 2010, calculations by Öko-Institut

**Figure A 140: Greenpeace Advanced EU Energy Revolution Scenario 2010: Decomposition analysis for the aggregate trends, 2010–2045**




Source: Greenpeace 2010, calculations by Öko-Institut

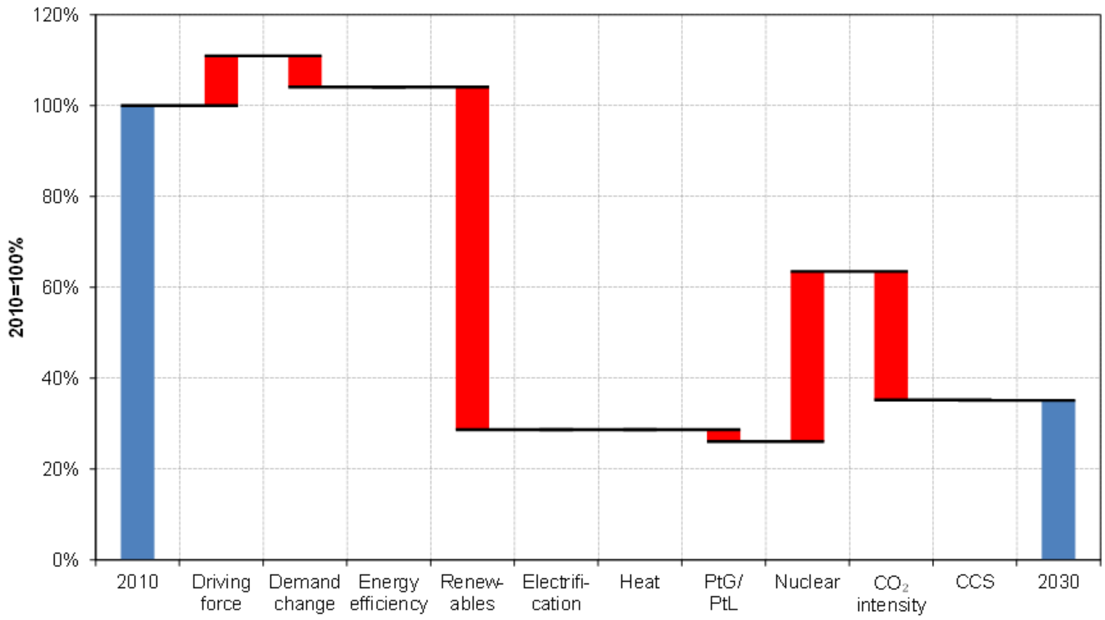
### A 2.12.2 Sectoral trends

#### A 2.12.2.1 Electricity sector

As in other scenarios, the impact of both renewables and nuclear phase-out is highest in the electricity sector, while it has the fastest reductions until 2030 (Figure A 141). In 2030, its emissions are at 65% below 2010, with moderate increases in demand (10%) and substantial contributions by renewables (-70%) and $CO_2$ intensity, i.e. move to gas electricity stations (-28%).

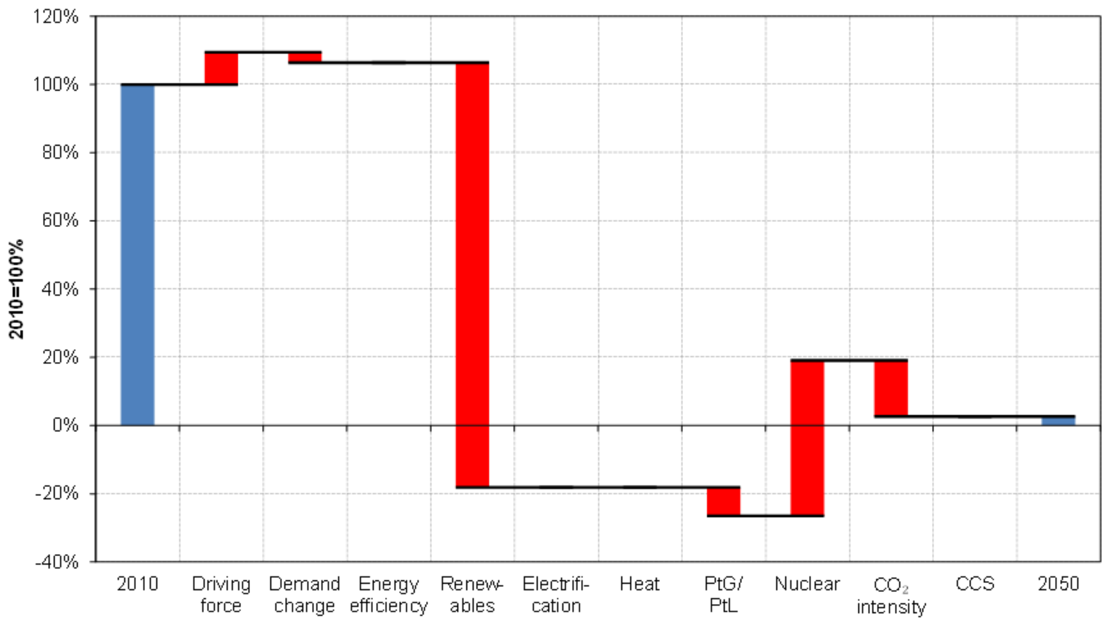
Until 2050 (Figure A 142), electricity generation is almost fully decarbonized (-97%). It is clear from the chart below how this is driven mainly by an enormous expansion of renewable energy. The Greenpeace scenario both stipulates a full nuclear phase-out as well as no permission of CCS.

**Figure A 141: Greenpeace Advanced EU Energy Revolution Scenario 2010: Decomposition analysis for the electricity sector, 2010–2030**




Source: Greenpeace 2010, calculations by Öko-Institut

**Figure A 142: Greenpeace Advanced EU Energy Revolution Scenario 2010: Decomposition analysis for the electricity sector, 2010–2050**



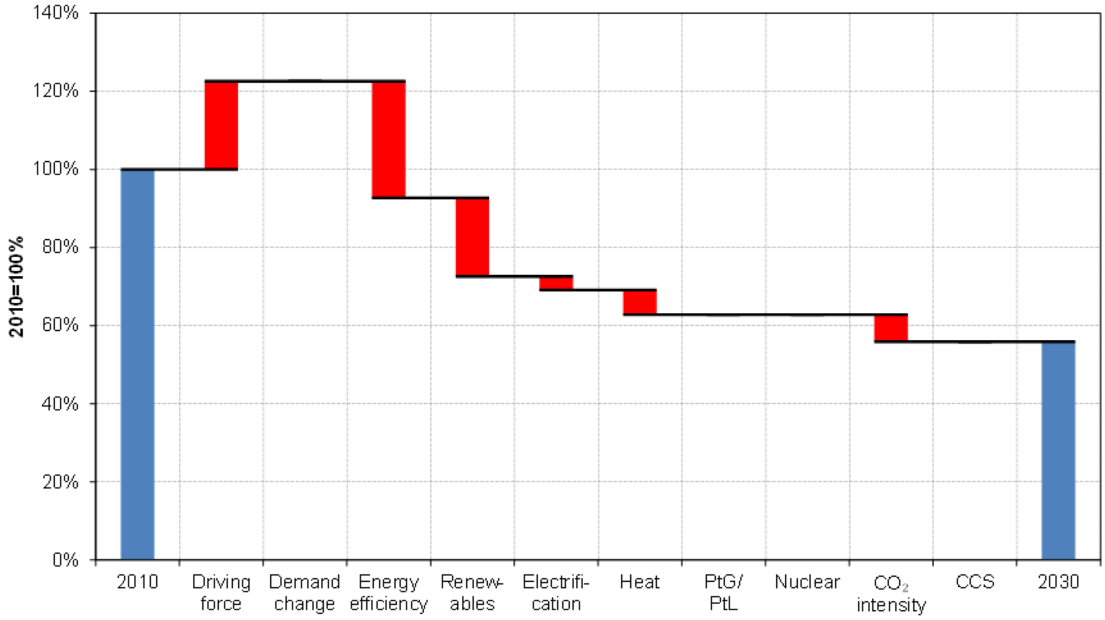

Source: Greenpeace 2010, calculations by Öko-Institut

#### A 2.12.2.2 Industry sector

The industry sector is slower to decarbonize than the electricity sector. In the period until 2030 (Figure A 143), this is driven mainly by efficiency gains (growing faster than production: -10% net emissions after taking increased output into account) and renewables use, leading to a reduction of 45% below baseline.

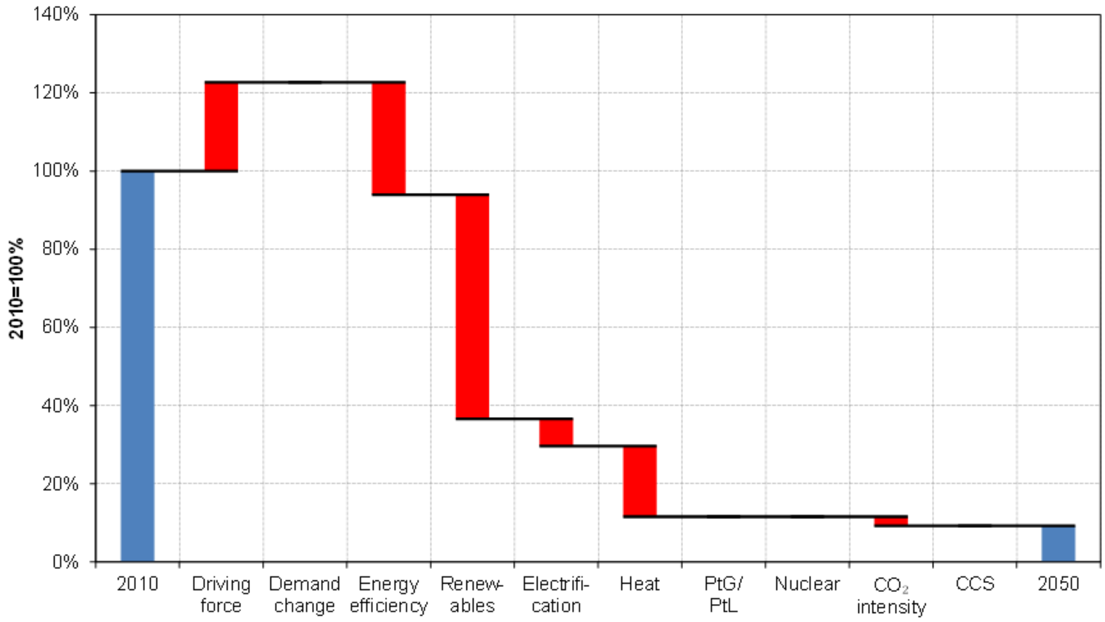
After 2030, decarbonization increases its speed, leading to a 92% reduction in 2050 (Figure A 144). In the industry sector this is mainly driven by rapidly growing use of renewables (57% of baseline emissions avoided) as well as distributed heat (close to 20%). The rest of the abatement is attained by efficiency gains (which continue to grow faster than production) and some, but not substantial, electrification.

**Figure A 143: Greenpeace Advanced EU Energy Revolution Scenario 2010: Decomposition analysis for the industry, 2010–2030**




Source: Greenpeace 2010, calculations by Öko-Institut

**Figure A 144: Greenpeace Advanced EU Energy Revolution Scenario 2010: Decomposition analysis for the industry, 2010–2050**




Source: Greenpeace 2010, calculations by Öko-Institut

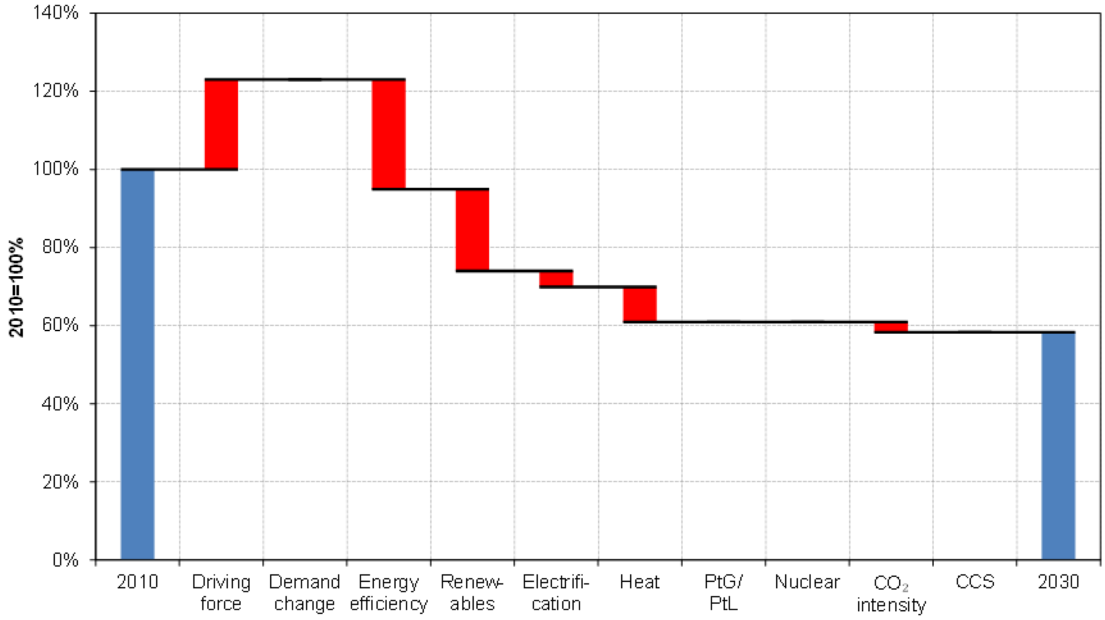
#### A 2.12.2.3 Tertiary and residential sectors

The tertiary and residential sectors[11] decarbonize in comparable speed to the industry sector, and with almost the same structure. The main driver is renewables, followed by heat and a bit more electrification than in the industry sector. Similarly, efficiency grows faster than the economic output, leading to a 42% reduction in 2030 (Figure A 145).

Just like in the industry sector, renewables remain the strongest growing driver after 2030 (Figure A 146), with a reduction of close to 60% alone. However, distributed heat and electrification also double their contributions after 2030 to 20% and 8% of baseline emissions, respectively. The remaining emissions in 2050 in the tertiary sector stand at 92% below the 2010 baseline.

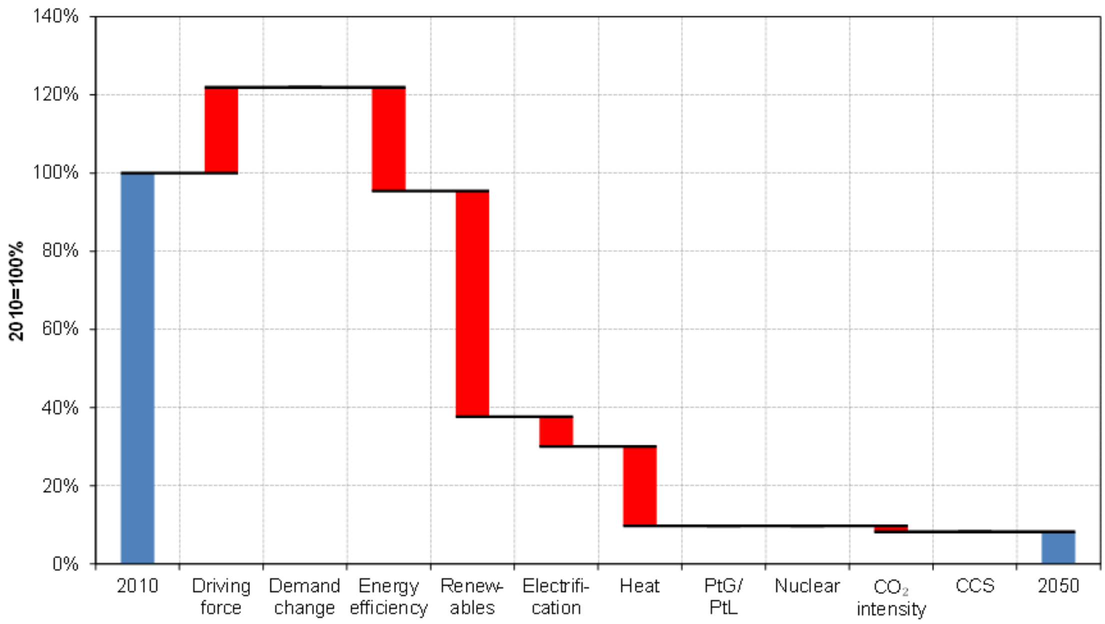
[11] The 2015 edition of the Energy Revolution scenarios provides only aggregate results for the tertiary and the residential sectors and no further disaggregation for these sectors.

**Figure A 145: Greenpeace Advanced EU Energy Revolution Scenario 2010: Decomposition analysis for tertiary and residential sectors, 2010–2030**




Source: Greenpeace 2010, calculations by Öko-Institut

**Figure A 146: Greenpeace Advanced EU Energy Revolution 2010 Scenario: Decomposition analysis for tertiary and residential sectors, 2010–2050**




Source: Greenpeace 2010, calculations by Öko-Institut

## A 2.13 IEA World Energy Outlook 2016 – New Policies Scenario

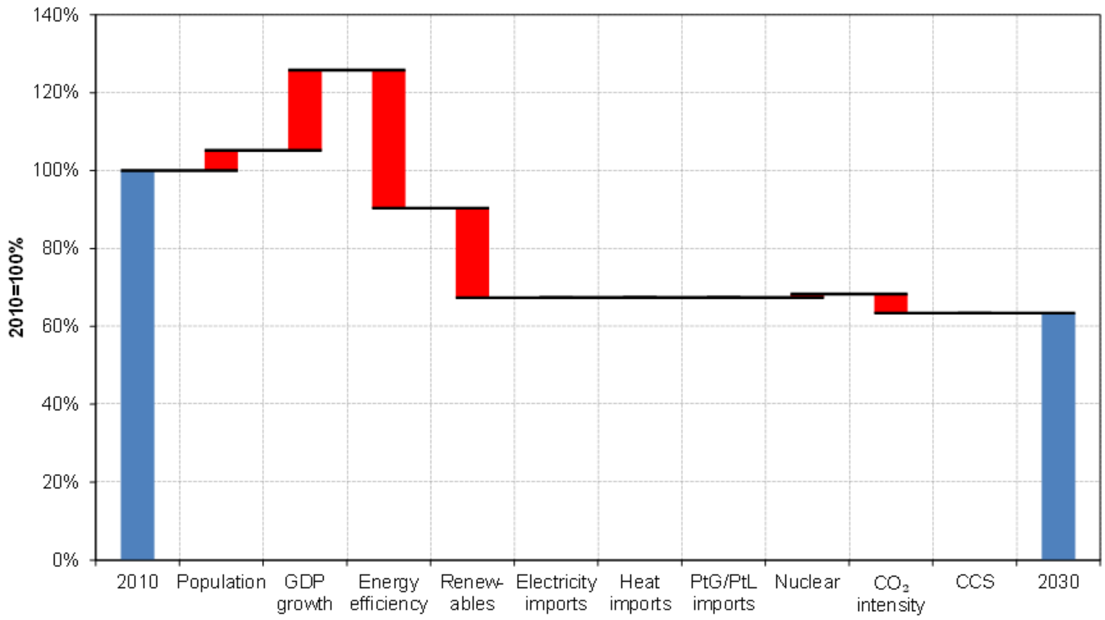
### A 2.13.1 Aggregate trends

In the News Policies Scenario[12], until 2030 (Figure A 147), there is pressure on $CO_2$ emissions due to population and economic growth of 26%. Like in other scenarios renewables (-23%) and efficiency (-35%) have a large share of the total emissions reduction of 37%. There is only a slight contribution (-5%) made by reduced $CO_2$ intensity.

Until 2050 (Figure A 148) the same development continues. Population and economic growth combined cause an upwards pressure of 39% on emissions, while efficiency improves further (-50%), and renewable energy use increases (-40%). There is comparatively little change in the $CO_2$ intensity of the remaining fossil fuels (-7%). The total reduction of emissions stands at 57% below 2010.

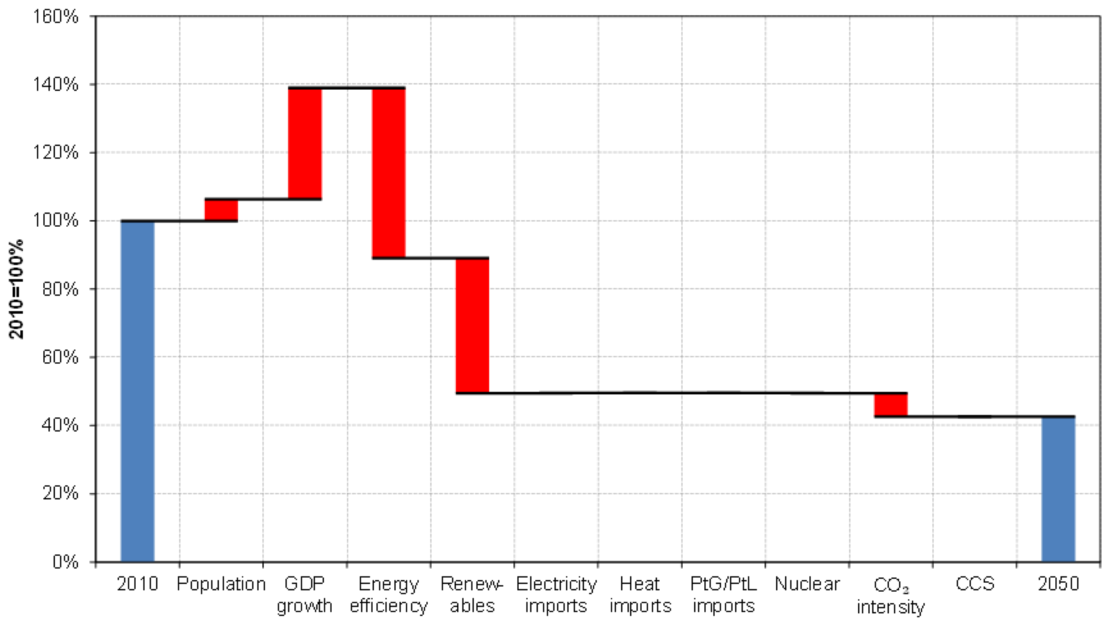
[12] The World Energy Outlook publishes model results up to 2040. Results for 2050 are based on a linear extrapolation of energy usage trends in the scenario. The New Policies scenario is the baseline against which demand changes in the 450ppm scenario are compared.

**Figure A 147: IEA World Energy Outlook 2016 – New Policies Scenario: Decomposition analysis for aggregate trends, 2010–2030**




Source: IEA 2016, calculations by Öko-Institut

**Figure A 148: IEA World Energy Outlook 2016 – New Policies Scenario: Decomposition analysis for aggregate trends, 2010–2050**




Source: IEA 2016, calculations by Öko-Institut.

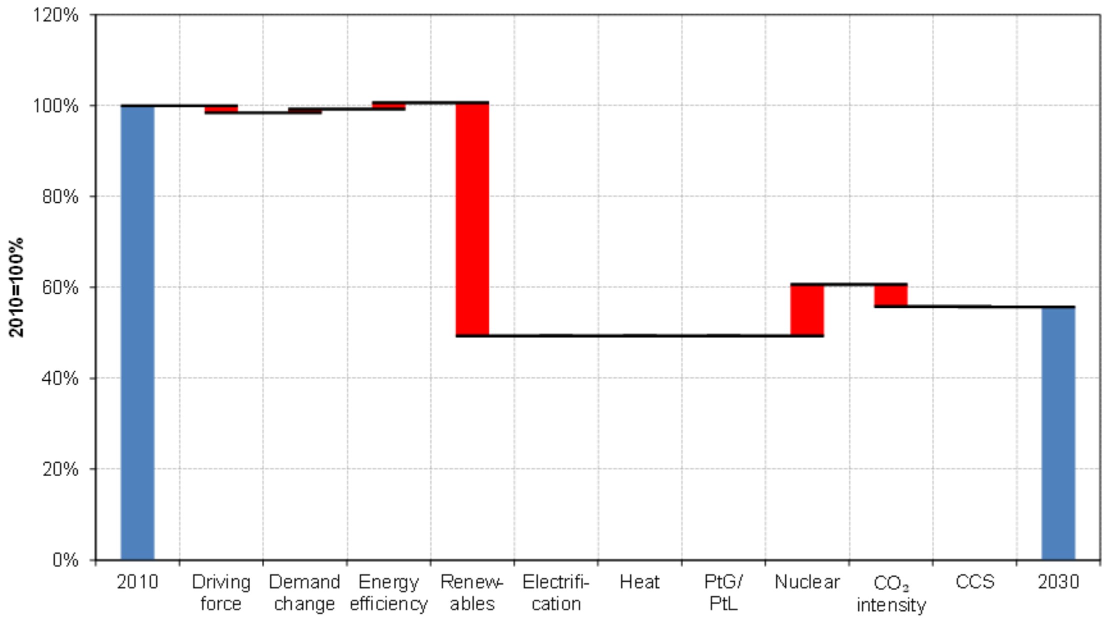
### A 2.13.2 Sectoral trends

#### A 2.13.2.1 Electricity sector

There is little upwards pressure on $CO_2$ emissions: 2030 electricity demand in the NPS scenario is lower than in the reference and even lower than in 2010 (Figure A 149). In total, a reduction of 44% is reached, way lower than in the 450ppm scenario (due to less electrification in other sectors). The largest share of the emissions reduction is caused by renewable energy (-51%). In this scenario, the decrease of nuclear generation is a significant force against emissions reduction (11% in relation to other contributions).

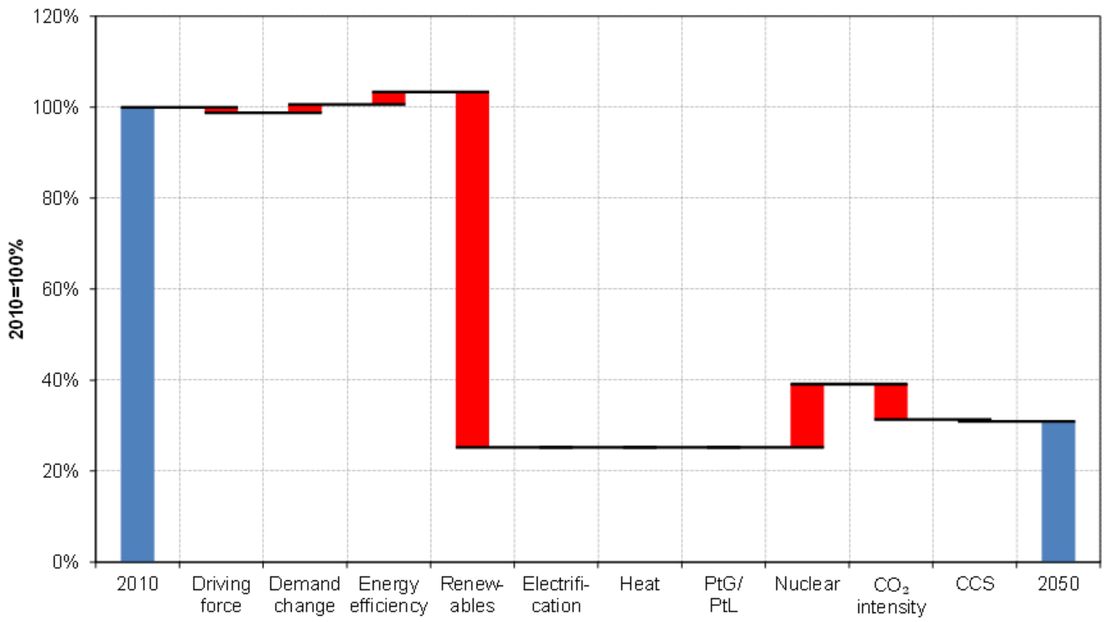
Until 2050 (Figure A 150), the structural change continues along the same lines. Renewables expand further, leading to a 78% contribution to emissions abatement and a further 8% contribution from improved $CO_2$ intensity. Because of the increasing pressure due to nuclear phase-out (+14%), the net reduction in 2050 stands at 69% compared to 2010.

**Figure A 149: IEA World Energy Outlook 2016 – New Policies Scenario: Decomposition analysis for electricity sector, 2010–2030**




Source: IEA 2016, calculations by Öko-Institut

**Figure A 150: IEA World Energy Outlook 2016 – New Policies Scenario: Decomposition analysis for the electricity sector, 2010–2050**



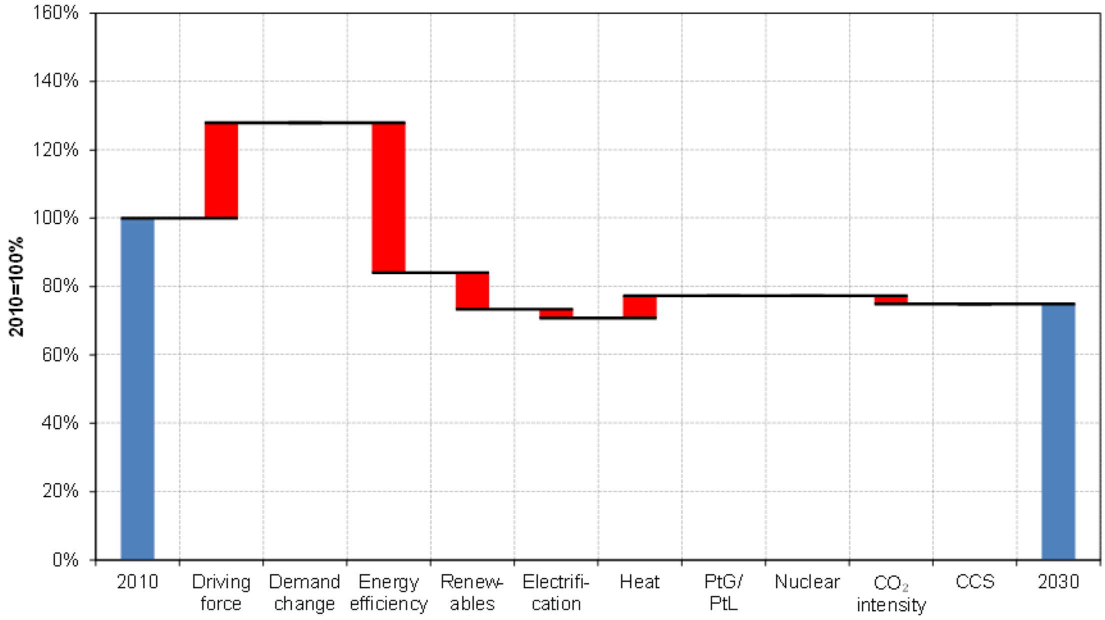

Source: IEA WEO 2016, extrapolation to 2050 and calculations by Öko-Institut

### A 2.13.2.2 Industry sector

As in the 450ppm scenario, efficiency gains are the strongest driver for abatement in the industry sector until 2030 (-44%) (Figure A 151). Additional contributions are made by renewable energy (-11%) as well as electricity and lower $CO_2$ intensity However, due to increasing pressures on emissions, total reduction stands at only -25%. These are mainly an increased industrial output (+28%) and less use of distributed heat (+7%).

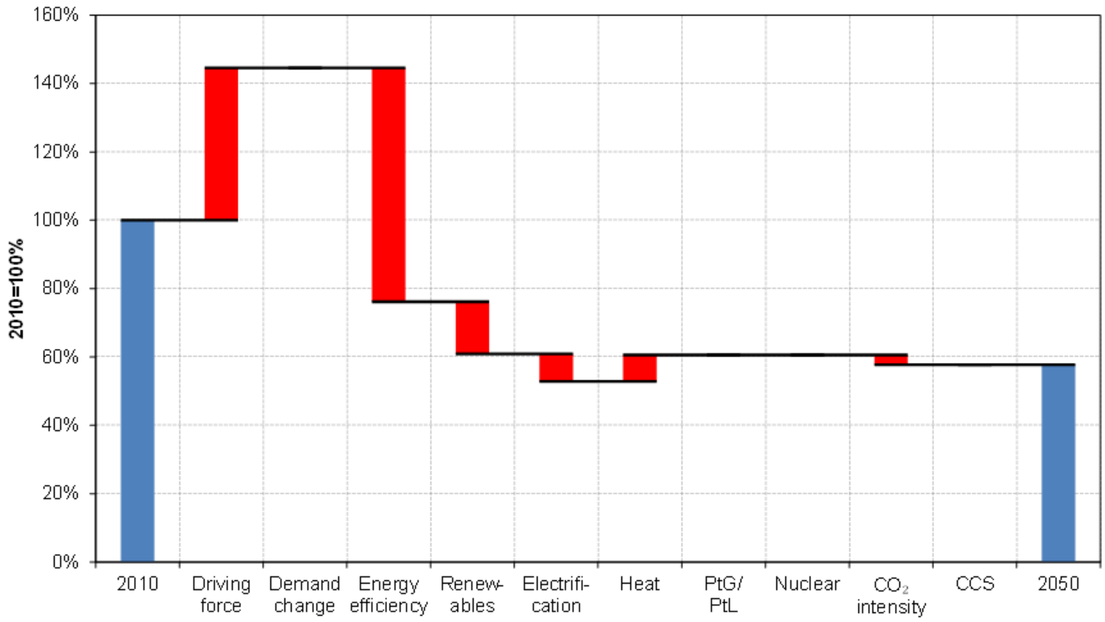
As in other WEO scenarios, the development continues largely unchanged until 2050 (Figure A 152). Total reduction now stands at -42% against increased industrial output of +45%. The reduction contributions come mainly from energy efficiency (-68%), renewables use (-15%), electricity use (-8%), and lower $CO_2$ intensity. The decline of distributed heat use slows down, its increasing pressure on emissions is only slightly higher than in 2030.

**Figure A 151: IEA World Energy Outlook 2016 – New Policies Scenario: Decomposition analysis for the industry sector, 2010–2030**




Source: IEA 2016, calculations by Öko-Institut

**Figure A 152: IEA World Energy Outlook 2016 – New Policies Scenario: Decomposition analysis for the industry sector, 2010–2050**




Source: IEA 2016, calculations by Öko-Institut

## A 2.14 IEA World Energy Outlook 2016 – 450ppm Scenario

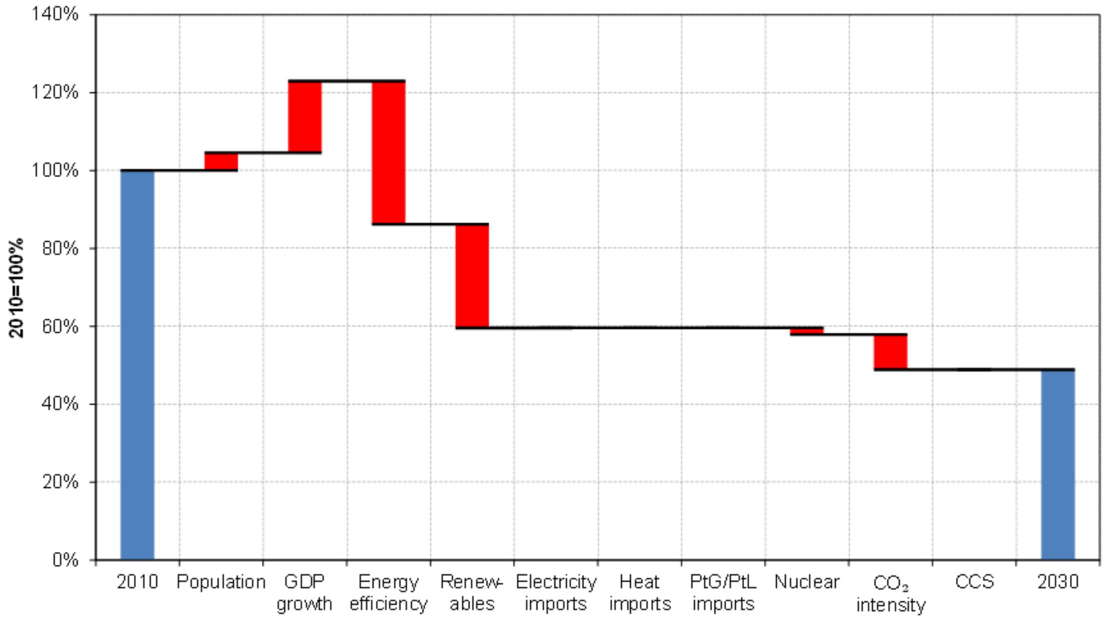
### A 2.14.1 Aggregate trends

Population and economic growth in the 450ppm Scenario[13] lead to an increasing effect on emissions of 23% in 2030 (Figure A 153). In total however, renewables (-27%) and efficiency (-37%), along with improvements in $CO_2$ intensity of fossil fuels, lead to a net emissions decrease of 51% compared to 2010.

In 2050 (Figure A 154), emissions further decline to 82% below the 2010 baseline. Compared to 2030, the relative contribution of renewables is much larger at -53%, and efficiency gains (-41%) easily offset the combined effect of population and economic growth (+28%). Additionally, $CO_2$ intensity of fossil fuels further declines (-12%).

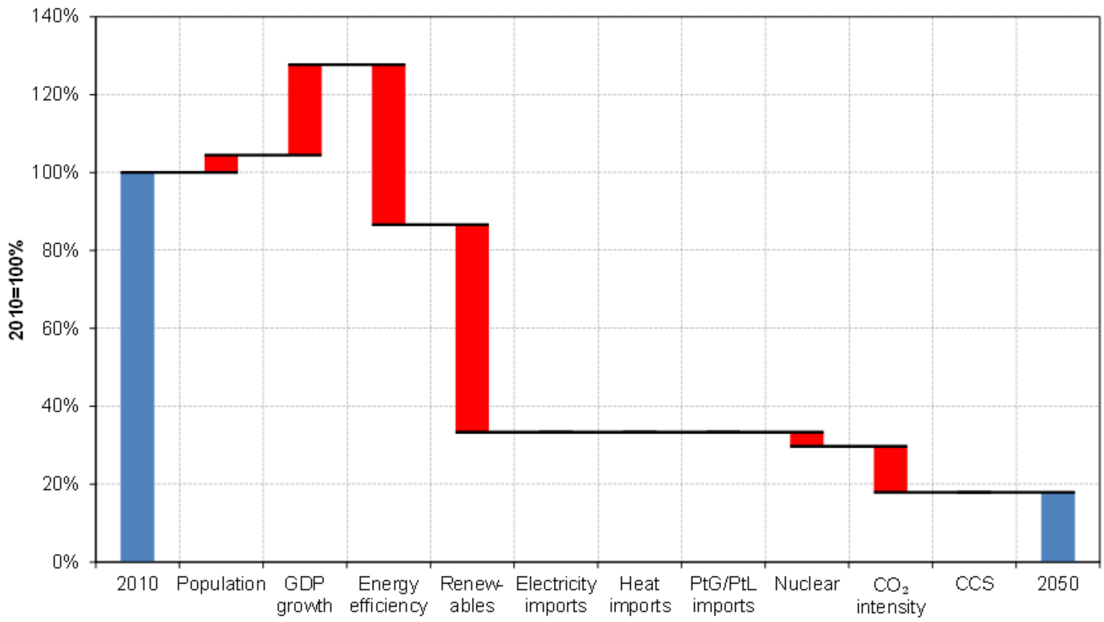
[13] The World Energy Outlook publishes model results up to 2040. Results for 2050 are based on a linear extrapolation of energy usage trends in the scenario.

**Figure A 153: IEA World Energy Outlook 2016 – 450ppm Scenario: Decomposition analysis for aggregate trends, 2010–2030**




Source: IEA 2016, calculations by Öko-Institut

**Figure A 154: IEA World Energy Outlook 2016 – 450ppm Scenario: Decomposition analysis for aggregate trends, 2010–2050**




Source: IEA 2016, calculations by Öko-Institut

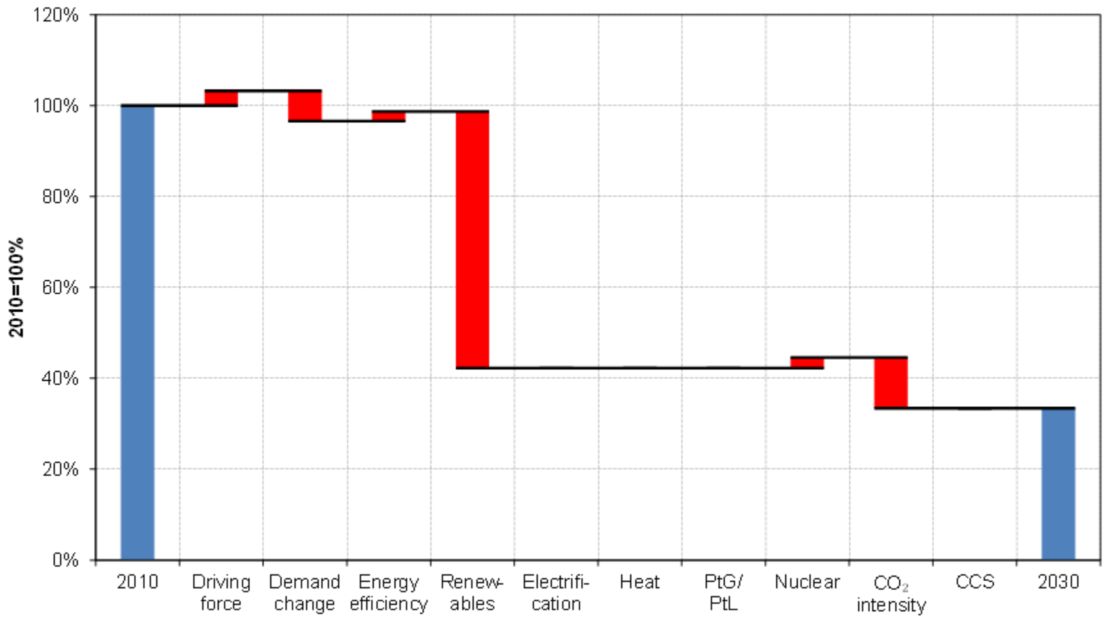
### A 2.14.2 Sectoral trends

#### A 2.14.2.1 Electricity sector

The electricity sector in the 450ppm scenario shows the highest reduction in 2030 (Figure A 155), at 67% below 2010 levels. Renewables expansion is by far the largest contributor to this (-57%). Additionally, a slightly lower electricity demand (-7% below the reference scenario), and a less $CO_2$-intensive fossil fuel mix (-11%) contribute to the emissions abatement.

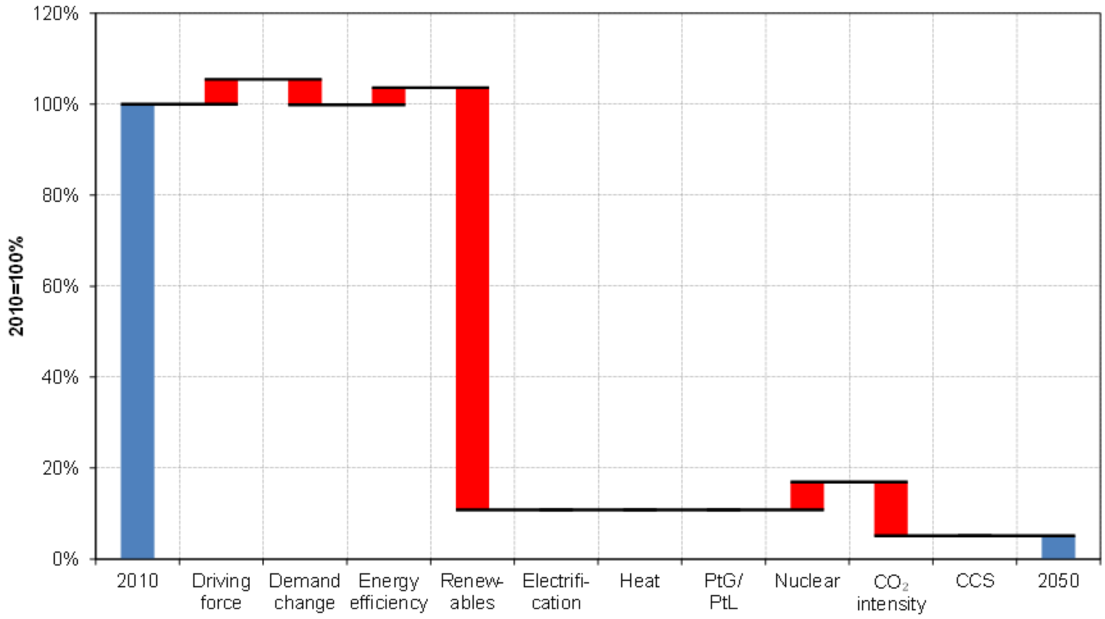
In 2050 (Figure A 156), the sector is largely decarbonized at 95% reduction compared to 2010 levels. The structure of drivers remains similar to 2030: A very large contribution from renewables (-93%) is joined by a move to less $CO_2$-intesive fossil fuels (-12%) as the main contributors to the emissions abatement. Interestingly, when focusing on the electricity sector, the share of nuclear energy decreases enough compared to the fossil fuels to cause a significant increasing pressure on emissions (+6%).

**Figure A 155: IEA World Energy Outlook 2016 – 450ppm Scenario: Decomposition analysis for electricity sector, 2010–2030**




Source: IEA 2016, calculations by Öko-Institut

**Figure A 156: IEA World Energy Outlook 2016 – 450ppm Scenario: Decomposition analysis for the electricity sector, 2010–2050**



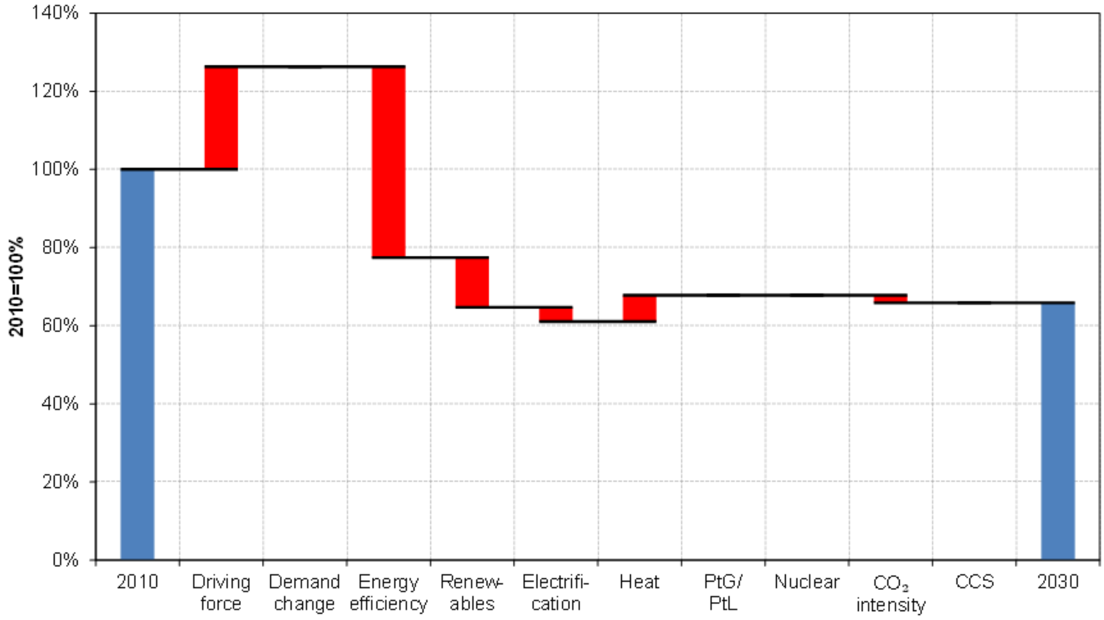

Source: IEA WEO 2016, extrapolation to 2050 and calculations by Öko-Institut

#### A 2.14.2.2 Industry sector

In the industry sector, total reduction until 2030 stands at 34% (Figure A 157). Like in other scenarios, industry is among the slower sectors to decarbonize. Here, efficiency is the main driver behind the emissions reduction at -49%, easily counterbalancing the 26% increased output. Additionally, renewables are used for a further 13% contribution to abatement. The use of district heat declines slightly.

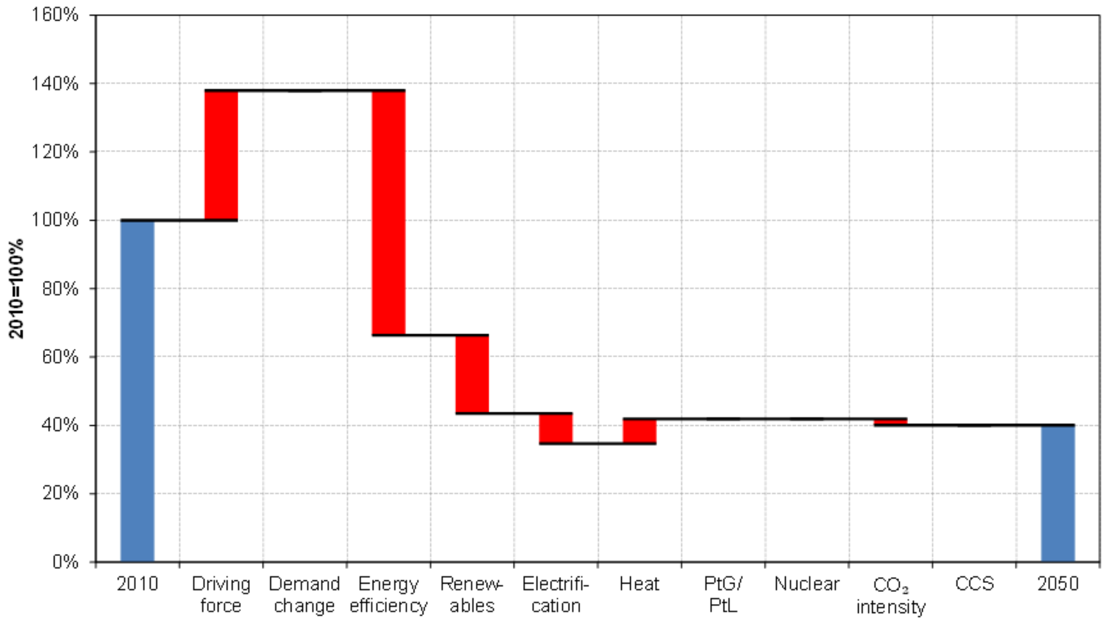
Reductions in the industry sector continue almost linearly, reaching -60% in 2050 (Figure A 158). Again, improved efficiency (-72%) is the strongest driver, but now supported by an even higher use of renewable energy (-23%) and electricity (-9%). However, output continues to grow strongly and stands at 38% above 2010 levels, only ending in a moderate net reduction of emissions.

**Figure A 157: IEA World Energy Outlook 2016 – 450ppm Scenario: Decomposition analysis for the industry sector, 2010–2030**




Source: IEA 2016, calculations by Öko-Institut

**Figure A 158: IEA World Energy Outlook 2016 – 450ppm Scenario: Decomposition analysis for the industry sector, 2010–2050**




Source: IEA 2016, calculations by Öko-Institut

## A 3 Results of decomposition analysis for national projections

In this section, we present the results of the decomposition analysis for the evaluated national scenarios for the periods 2010 – 2030 and 2010 – 2050. For each scenario, we start again with the results for the total energy-related $CO_2$ emissions. Afterwards, we provide the sectoral results for all sectors that are covered in a sufficient level of detail in the corresponding study. For a short description of the sectoral driving forces and abatement levers see the introduction of Annex 2.

### A 3.1 Germany: Climate Scenarios, 2nd round, CS80

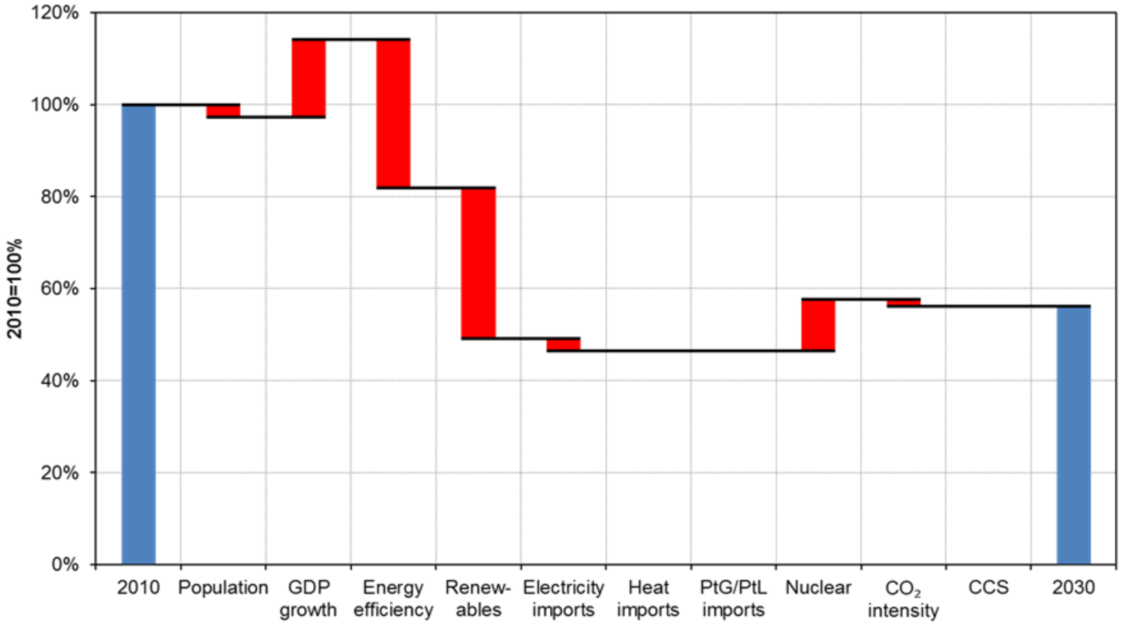
#### A 3.1.1 Aggregate trends

In the CS80 scenario in the study Climate Protection Scenario 2050 (Öko-Institut e. V. (Öko-Institut) und Fraunhofer-Institut für System- und Innovationsforschung (Fraunhofer ISI) 2015), $CO_2$ emissions from energy are reduced by 44% in 2030 and 81% in 2050, compared to 2010. The main drivers, as illustrated in Figure A 159 for 2030 and Figure A 160 for 2050, are:

- Renewables: Renewables account for $CO_2$ emission reductions of 70% in 2050 compared to 2010 and are hence the largest contributor. They account for 167 Mtoe (76%) of primary energy consumption. Already in 2030, they reduce emissions by 33% compared to 2010 with the overall amount of renewables accounting for 44% of primary energy consumption (109 Mtoe).
- Productivity gains: While GDP grows by 20% until 2050, this is more than offset by higher productivity (33% less $CO_2$ per unit of GDP). In total, the two effects result in a net decrease of $CO_2$ emission of 13% compared to 2010. Effects for 2030 are similar with an increase in $CO_2$ emissions due to GDP of 17% and $CO_2$ emissions decreasing due to decreasing $CO_2$ per unit of GDP by 32% (net-effect: 15% decrease of $CO_2$ emissions from 2010 to 2030).
- Population growth and electricity import: Both, population and electricity imports result in a decrease of $CO_2$ emissions by 4% respectively 5% in 2050 (3% and 2% in 2030) compared to 2010.
- Electricity imports: While the effect is not very pronounced at the overall level, it is worth mentioning that part of $CO_2$ emission reductions are a result of Germany becoming a net-importer of electricity instead of a net-exporter. In total, 6.7 Mtoe of electricity are imported in 2050, compared to electricity exports of 3.8 Mtoe in 2010. This results in $CO_2$ emission reductions of 5% in 2050 compared to 2010 (3% in 2030 compared to 2010).

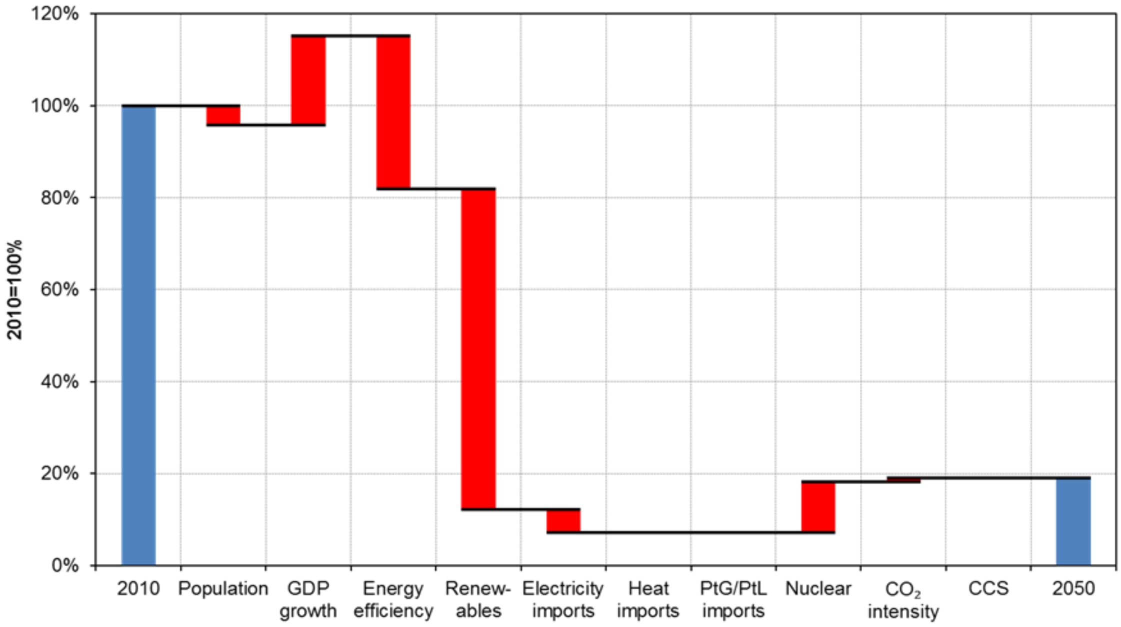
Increasing effects on $CO_2$ emissions are small. The phaseout of nuclear electricity for electricity generation results in an increase of $CO_2$ emissions by 11% in 2050 compared to 2010. Fossil $CO_2$ intensity remains stable (1% increase in 2050 compared to 2010). CCS is not applied in the CS80 scenario.

**Figure A 159: Germany, CS80 Scenario: Decomposition analysis for aggregate trends, 2010–2030**




Source: Repenning et al. 2015, calculations by Fraunhofer ISI

**Figure A 160: Germany, CS80 Scenario: Decomposition analysis for aggregate trends, 2010–2050**




Source: Repenning et al. 2015, calculations by Fraunhofer ISI

### A 3.1.2 Sectoral trends

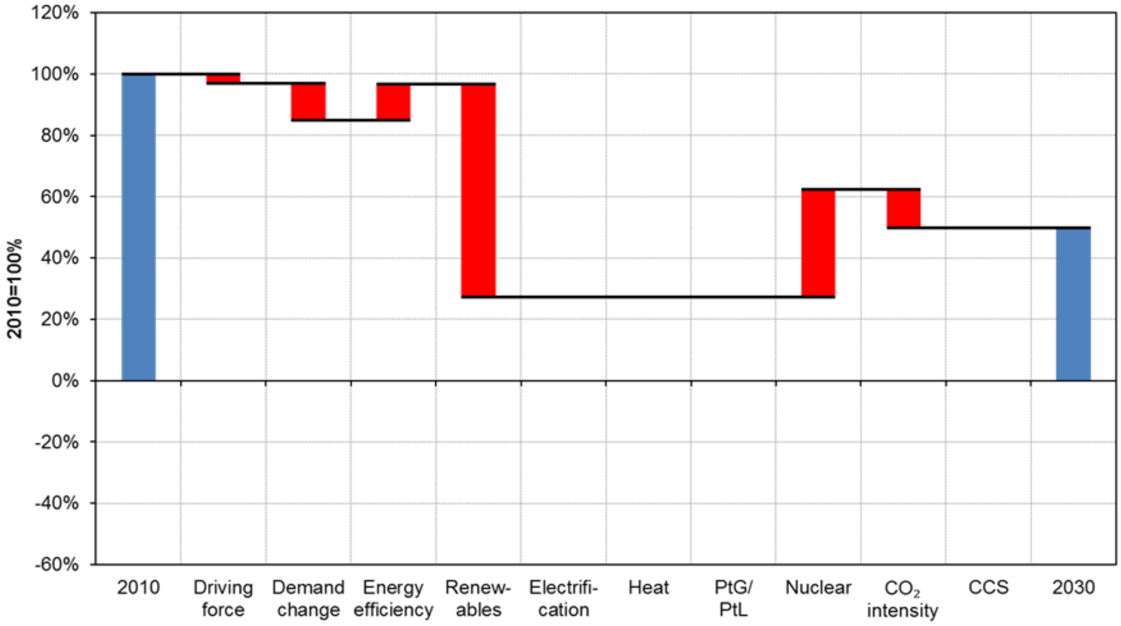
#### A 3.1.2.1 Electricity sector

In the German electricity sector, $CO_2$ emissions in the CS80 scenario decrease by 50% in 2030 (Figure A 161) and by 88% in 2050 (Figure A 162) compared to 2010. Hence, reductions in the electricity sector are slightly higher compared to reductions in total primary energy consumption. Driving forces behind the reductions in $CO_2$ emissions are similar to the ones seen on the level of total primary energy consumption:

- Renewables: Already in 2030, renewables account for $CO_2$ emission reductions of 70%, the share of renewables in the electricity sector being 65% (total production of 82 Mtoe). This share increases to 95% in 2050 (119 Mtoe), accounting for $CO_2$ emission reductions of 138%.
- Demand change and energy efficiency: Effects from demand change and energy efficiency on $CO_2$ emissions more or less cancel out each other. In 2030, the demand for electricity together with population results in a decrease in $CO_2$ emissions of 15%, while energy efficiency results in an increase in $CO_2$ emissions od 12%, resulting in a net-decrease of 3% in 2030 compared to 2010. In 2050, both effects are significantly smaller, with population and energy demand resulting in a decrease of $CO_2$ emissions of 7% compared to 2010, while energy efficiency results in an increase of emissions of 4% compared to 2010. In total, the net-effect is a reduction of 2% in 2050 compared to 2010. Overall, electricity generation decreases from 632 TWh in 2010 to 512 Twh in 2030 and only slightly increases afterwards to 540 TWh in 2050.
- Fossil $CO_2$ intensity: The $CO_2$ intensity of the remaining fossil fuel generation also changes between 2030 and 2050. In 2030, it has a negative effect on $CO_2$ emissions resulting in a decrease of $CO_2$ emissions by 13% in 2030 compared to 2050. In contrast, in 2050, an increase of $CO_2$ emissions by 10% compared to 2010 can be seen.

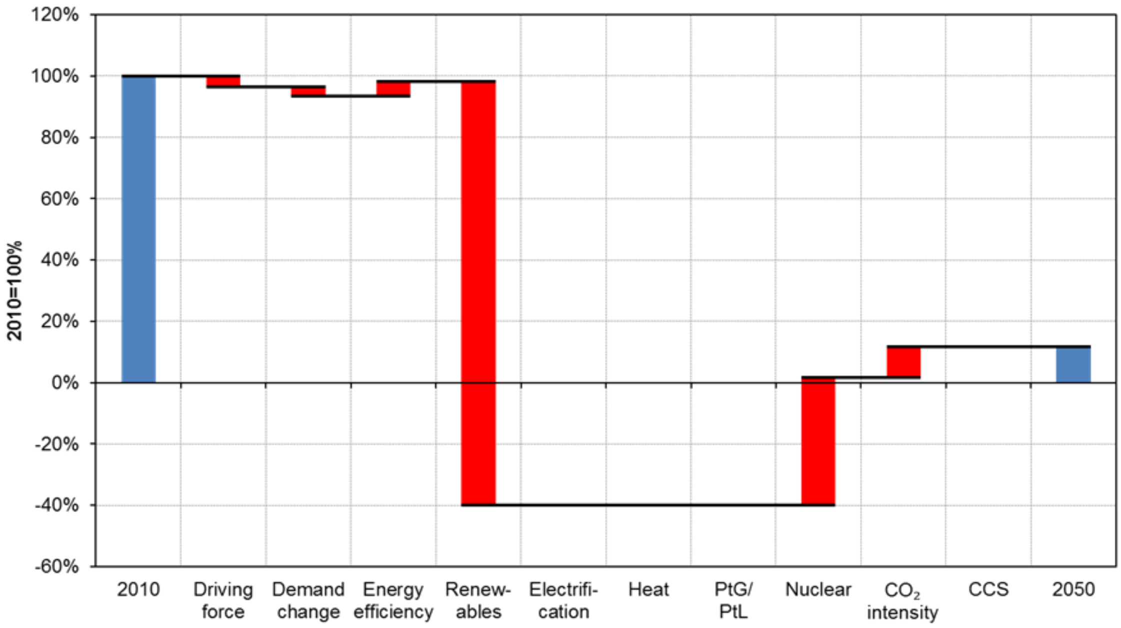
Drivers that have an increasing effect on $CO_2$ emissions in the electricity sector is the phaseout of nuclear energy, an effect that is more pronounced on the sector level (35% increase in 2030 and 42% increase in 2050 compared to 2010).

**Figure A 161: Germany, CS80 Scenario: Decomposition analysis for the electricity sector, 2010–2030**




Source: Repenning et al. 2015, calculations by Fraunhofer ISI

**Figure A 162: Germany, CS80 Scenario: Decomposition analysis for the electricity sector, 2010–2050**




Source: Repenning et al. 2015, calculations by Fraunhofer ISI

#### A 3.1.2.2 Industry sector

In the industry sector, total energy-related $CO_2$ emissions decrease by 37% in 2030 (Figure A 163) and 71% in 2050(Figure A 164) compared to 2010. Hence, $CO_2$ emission reductions are less pronounced in the industry sector compared to the overall energy $CO_2$ emission reductions. Driving factors reducing $CO_2$ emissions in the industry sector are:

- Value added and energy efficiency: The use of energy per value added decreases compared to 2010, both in 2030 as well as in 2050. The decrease in $CO_2$ emissions from energy efficiency is 24% in 2030 and 31% in 2050 compared to 2010. At the same time, value added increases, resulting in an increase in $CO_2$ emissions by 10% in 2030 and 13% in 2050 compared to 2010. Net-decrease of emissions amounts to 14% in 2030 and 18% in 2050 compared to 2010.

- Renewables: As in the electricity sector, renewables play an important role for the development of $CO_2$ emissions in the industry sector. The use of renewables results in a decrease of $CO_2$ emissions of 15% by 2030 and 33% by 2050 compared to 2010. In total, use of renewables in the industry sector increases from 1.2 Mtoe in 2010 to 4.9 Mtoe in 2030 and 9.7 Mtoe in 2050. Its share increases from 8% in 2010 to 18% in 2030 and 26% in 2050.

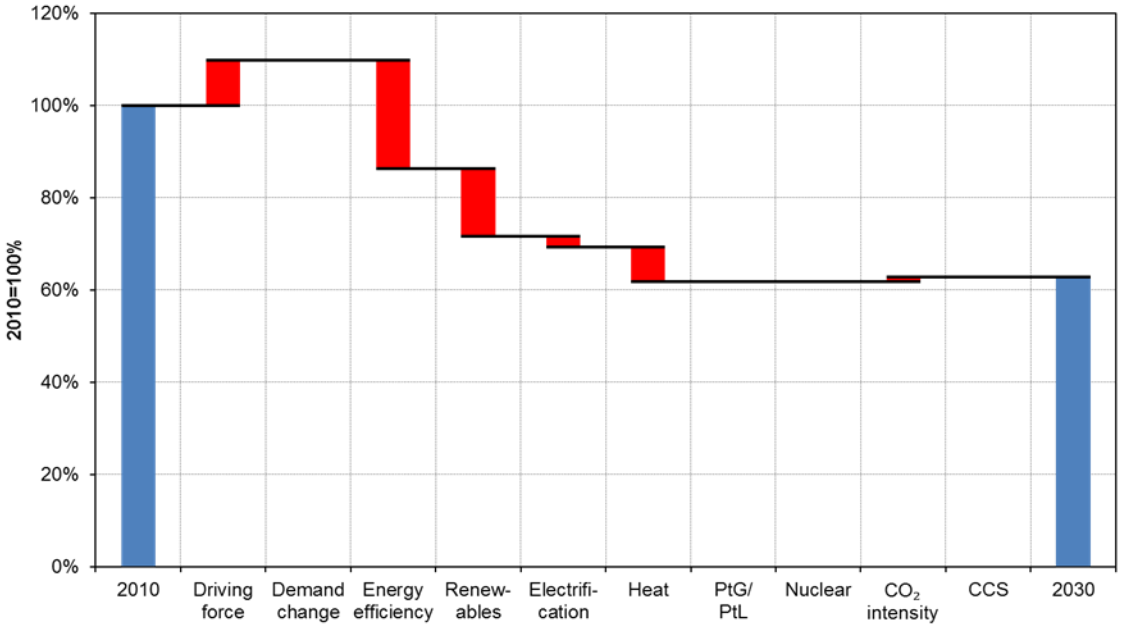
- Heat: Heat production also has a decreasing effect on $CO_2$ emissions from industry, the effect being more pronounced in the first half of the time period considered. Heat production levels result in a decrease of $CO_2$ emissions by 8% in 2030 and 4% in 2050. In absolute values, heat production increases from 7.8 ktoe in 2010 to 8.6 ktoe in 2030 and decreases to 6.6 ktoe in 2050.

- Electricity: Electricity becomes an important driver of $CO_2$ emissions after 2030. In 2030, $CO_2$ emissions decrease by 2% due to a decrease in electricity used in industry compared to 2010. Absolute electricity use decreases by 13% between 2010 and 2030 from 19.1 Mtoe to 16.7 Mtoe, with the share of electricity remaining stable at 34%. By 2050, 7% $CO_2$ emission reductions compared to 2010 are attributable to electricity, the use of which decreases by 18% compared to 2010 (15.7 Mtoe), but the share of electricity increasing to 37% of total energy use in industry.

- Fossil $CO_2$ intensity: Fossil $CO_2$ intensity results in a slight increase in $CO_2$ emissions of 1% by 2030 and in a decrease in $CO_2$ emissions of 8% by 2050 compared to 2010.

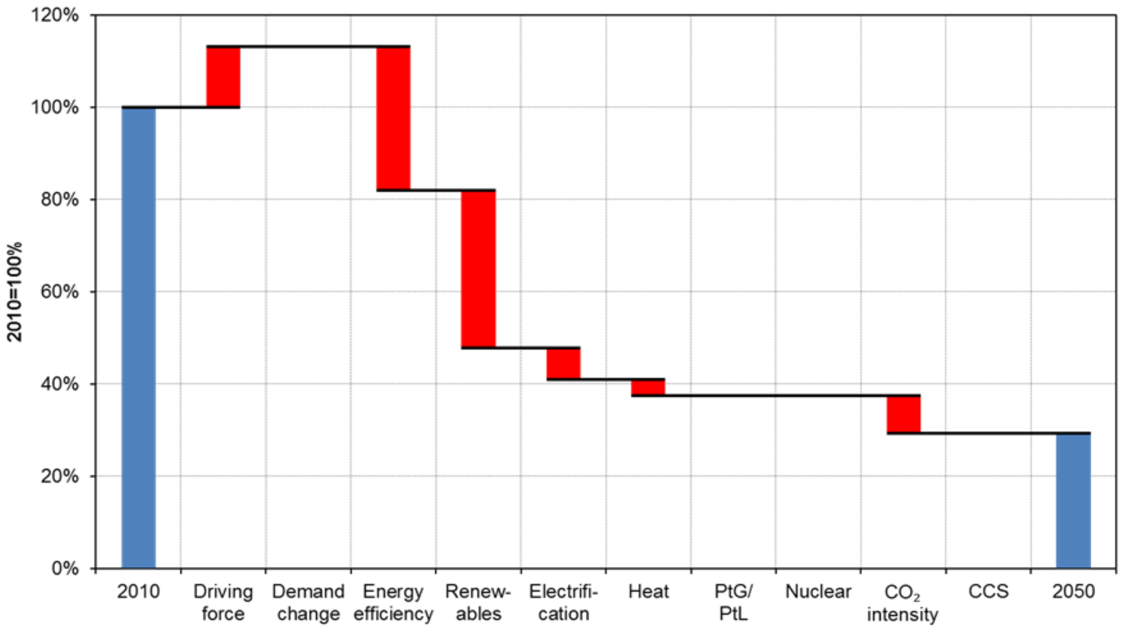
PtX and nuclear are not used as mitigation options in this scenario in the industry sector.

**Figure A 163: Germany, CS80 Scenario: Decomposition analysis for the industry sector, 2010–2030**




Source: Repenning et al. 2015, calculations by Fraunhofer ISI

**Figure A 164: Germany, CS80 Scenario: Decomposition analysis for the industry sector, 2010–2050**




Source: Repenning et al. 2015, calculations by Fraunhofer ISI

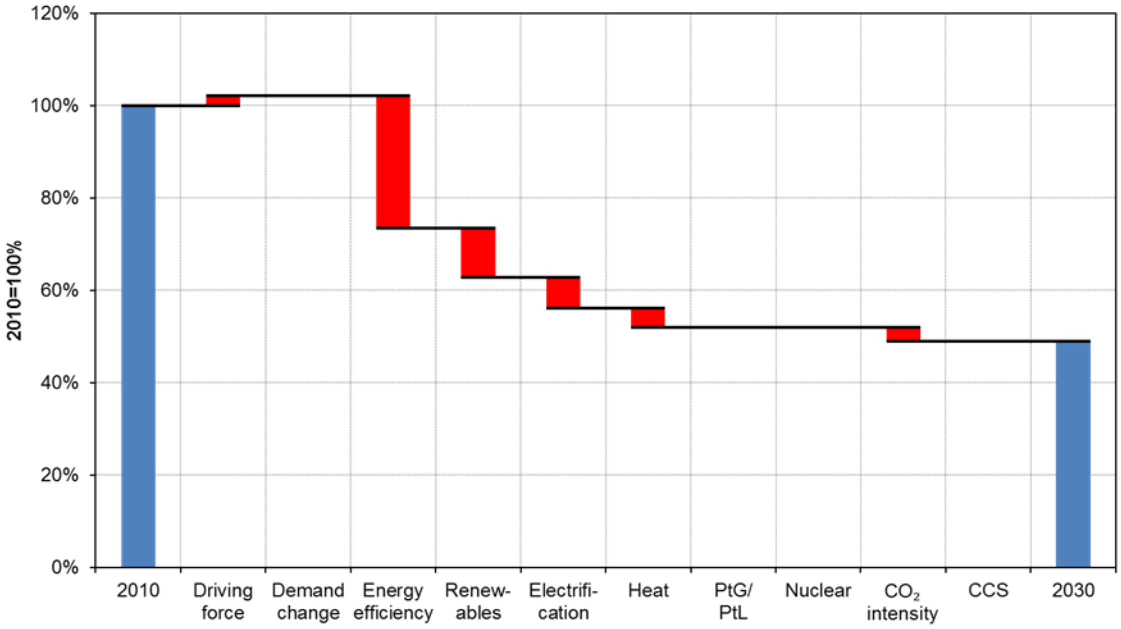
#### A 3.1.2.3 Residential sector

In the residential sector, $CO_2$ emissions are reduced by 51% in 2030 (Figure A 165) and by 85% in 2050 (Figure A 166) compared to 2010. These reductions are slightly higher in 2030 and slightly lower in 2050 compared to the overall level of ambition of the CS80 scenario. Main drivers of a decrease in $CO_2$ emissions in the residential sector are:

- Energy efficiency: Energy efficiency (use of energy per household) is the main driver, in both 2010–2030 and 2010–2050. It covers for $CO_2$ emission reductions of 29% in 2030 compared to 2010 and of 32% in 2050 compared to 2010. This effect is mainly coming from a significant decrease in energy use, while the number of households is mainly constant, with a slight increase between 2010 and 2030 (from 40 to 41 m households) and a slight decrease between 2030 and 2050 (back to 40 m households), resulting in a 2% increase in $CO_2$ emissions in 2030 compared to 2010.
- Renewables: The share of renewables use in households increases from 12% in 2010 to 20% in 2030 and 24% in 2050. Despite decreases in the use of energy in households, this means a small increase in the absolute amount of renewable energy used in the residential sector from 7.6 in 2010 to 8.7 in 2030 Mtoe and a slight decrease to 7.6 Mtoe in 2050. The increase in the share of renewables results in decreases of $CO_2$ emissions of 11% and 14% in 2050 compared to 2010.
- Electrification: The use of electricity in households decreases between 2010 and 2030 from 12.2 to 10.6 Mtoe and increases back to 11.4 Mtoe in 2050. In light of the decrease in overall energy use in households, this corresponds to an increase in the share of electricity in total energy consumption in the residential sector from 19% in 2010 to 24% in 2030 and 36% in 2050. This contributes to emission reductions by 7% in 2030 and 20% in 2050 compared to 2010.
- Heat: District heating in households remains constant between 2010 and 2030 and increases between 2030 and 2050 from 4.5 to 6.4 Mtoe despite an overall decrease in energy use in the residential sector. This results in a decrease in $CO_2$ emissions of 4% by 2030 and 16% by 2050 compared to 2010.

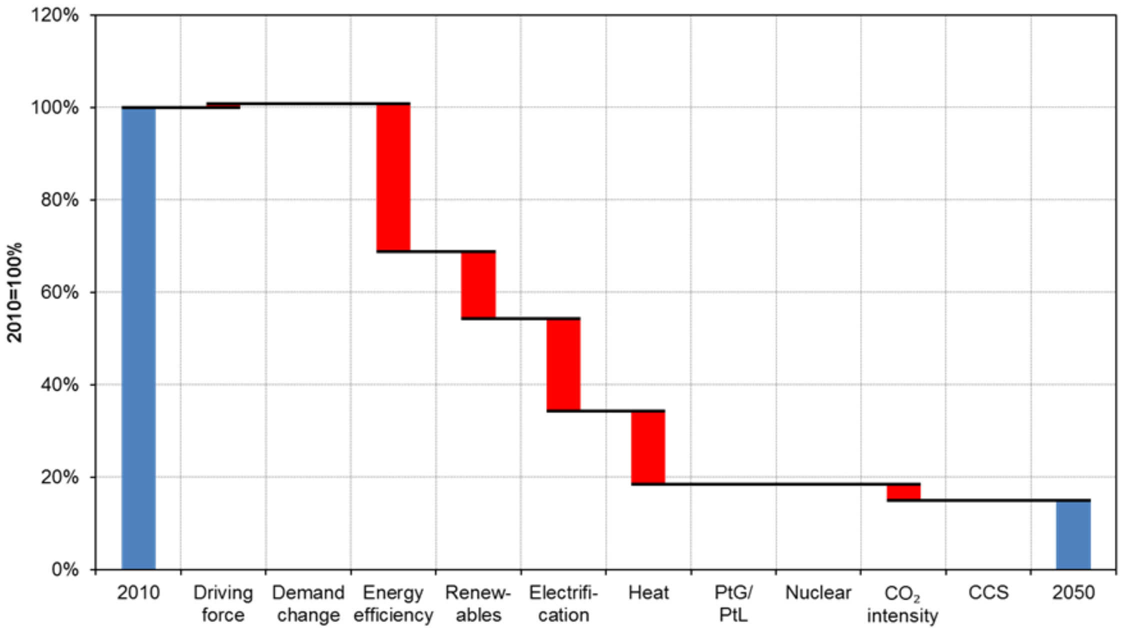
PtX and nuclear energy are not used as mitigation options in the residential sector in the CS80 scenario.

**Figure A 165: Germany, CS80 Scenario: Decomposition analysis for the residential sector, 2010–2030**




Source: Repenning et al. 2015, calculations by Fraunhofer ISI

**Figure A 166: Germany, CS80 Scenario: Decomposition analysis for the residential sector, 2010–2050**




Source: Repenning et al. 2015, calculations by Fraunhofer ISI

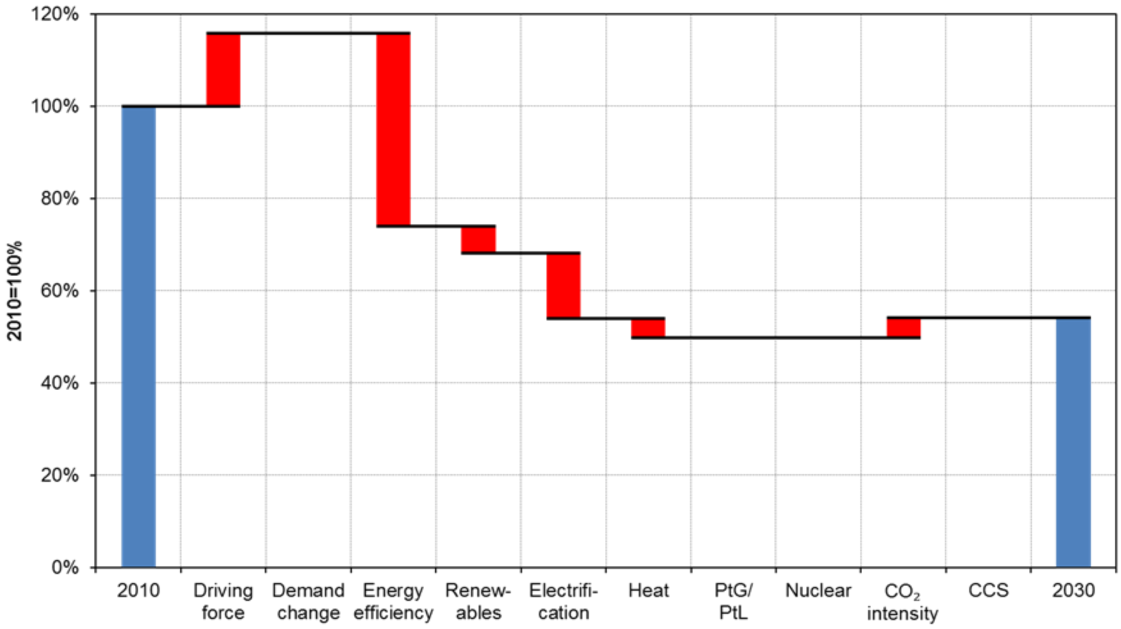
### A 3.1.2.4 Tertiary sector

In the tertiary sector, emissions decrease by 46% by 2030 (Figure A 167) and 88% by 2050 (Figure A 168) compared to 2010. These reduction levels are in line with total energy $CO_2$ emission reductions in the CS80 scenario. Important drivers for the decrease in $CO_2$ emissions are:

- Energy efficiency: Energy use per value added significantly decreases between 2010 and 2050 in the tertiary sector in the CS80 scenario. Increases in the value added amplify the effect of decreasing energy demand. This results in a decrease in $CO_2$ emissions in the tertiary sector of 42% by 2030 and 2050 compared to 2010 and offsets the increase in $CO_2$ emissions from value added, which amounts to 16% by 2030 and 14% by 2050 compared to 2010.
- Electrification: The absolute amount of electricity used in this sector only slightly decreases from 12.6 to 11.2 Mtoe in 2020 and remains stable afterwards. Hence, the share of electricity used increases from 36% in 2010 to 44% in 2030 and 63% in 2050. This contributes to $CO_2$ emission reductions by 14% in 2030 and 42% in 2050 compared to 2010.
- Renewables and heat: Absolute use of renewables increases between 2010 and 2050 making up for 9% of total energy consumption by 2050. District heating slightly fluctuates between 2.5 and 3.3 Mtoe between 2010 and 2050. Both contribute to $CO_2$ emission reductions, renewables accounting for 6% in 2030 and 10% in 2050 compared to 2010 and district heating accounting for 4% in 2030 and 12% in 2050 compared to 2010.

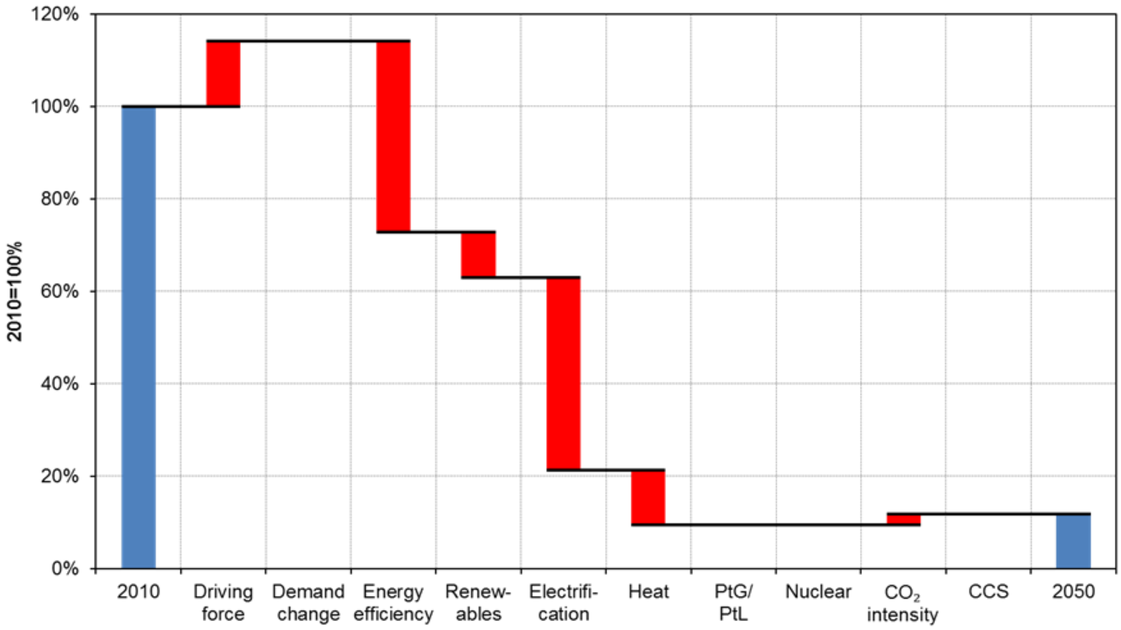
Fossil $CO_2$ intensity results in a slight increase in $CO_2$ emissions by 4% in 2030 and 2% in 2050 compared to 2010. PtX and nuclear electricity are no mitigation options applied in the tertiary sector.

**Figure A 167: Germany, CS80 Scenario: Decomposition analysis for the tertiary sector, 2010–2030**




Source: Repenning et al. 2015, calculations by Fraunhofer ISI

**Figure A 168: Germany, CS80 Scenario: Decomposition analysis for the tertiary sector, 2010–2050**




Source: Repenning et al. 2015, calculations by Fraunhofer ISI

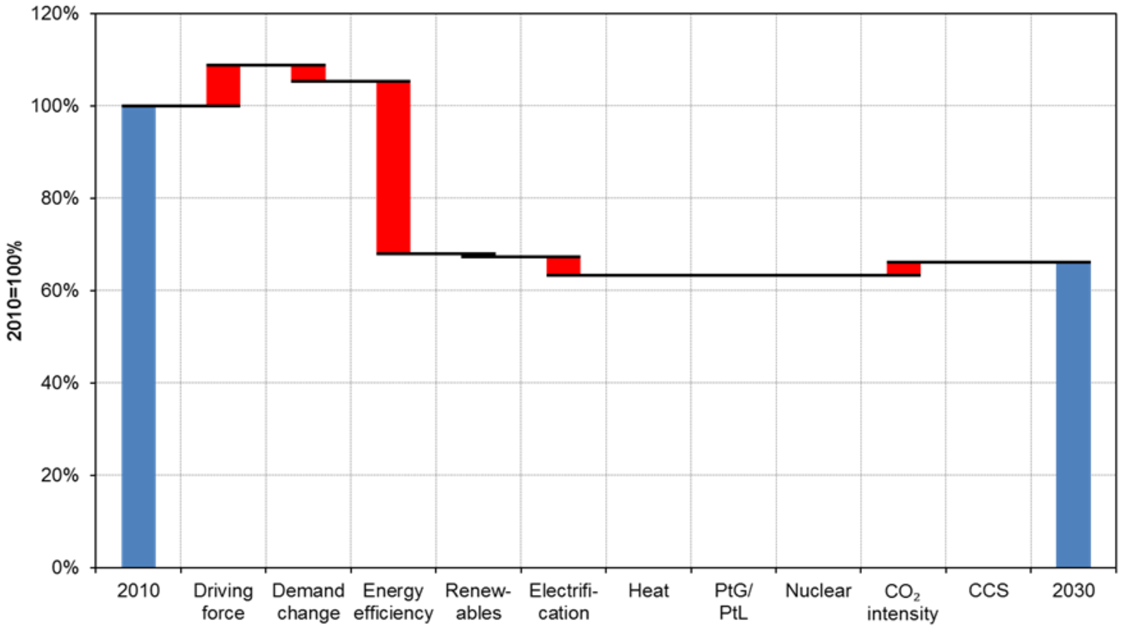
### A 3.1.2.5 Passenger transport

In the passenger transport sector, $CO_2$ emissions decrease by 34% in 2030 (Figure A 169) and by 72% in 2050 (Figure A 170) compared to 2010. This is a lower reduction compared to the overall level of ambition visible in total primary energy consumption, but a higher reduction compared to the freight transport sector. Important factors for the reductions in $CO_2$ emissions are:

- Energy efficiency: As in the freight transport sector, energy efficiency (energy use per travel distance) has the most pronounced contribution to $CO_2$ emission reductions resulting in 37% in 2030 and 56% in 2050 compared to 2010. This offsets the increase in $CO_2$ emissions from demand, which slightly decreases from 1356 Gpkm in 2010 to 1295 in 2030 (increase in $CO_2$ emissions of 5% in 2030 compared to 2010) and increases to 1423 afterwards (increase in $CO_2$ emissions of 7% in 2050 compared to 2010).
- Electrification: In contrast to freight transport, electrification plays a major role in the reduction of $CO_2$ emissions in the passenger transport sector. It accounts for $CO_2$ emission reductions of 25% in 2050 compared to 2010 (and 4% in 2030 compared to 2010). The demand for electricity increases from 1 Mtoe in 2010 to 1.2 Mtoe in 2030 and 5.9 Mtoe in 2050, despite an overall decrease in energy use from 41.3 Mtoe in 2010 to 27.9 Mtoe in 2030 and 17.5 Mtoe in 2050. By 2050 electricity has a share of 34% in total energy demand from passenger transport.

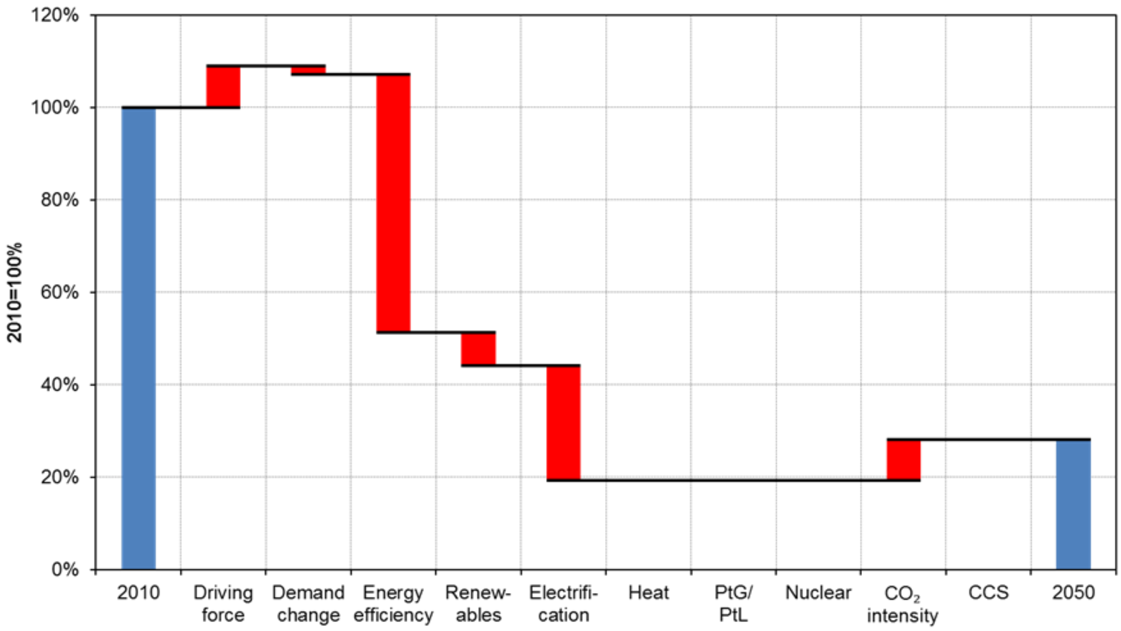
Renewables and fossil $CO_2$ intensity have minor influence on the development of the $CO_2$ emissions in passenger transport. PtX fuels are not used as mitigation options in the scenario.

**Figure A 169: Germany, CS80 Scenario: Decomposition analysis for the passenger transport sector, 2010–2030**




Source: Repenning et al. 2015, calculations by Fraunhofer ISI

**Figure A 170: Germany, CS80 Scenario: Decomposition analysis for the passenger transport sector, 2010–2050**




Source: Repenning et al. 2015, calculations by Fraunhofer ISI

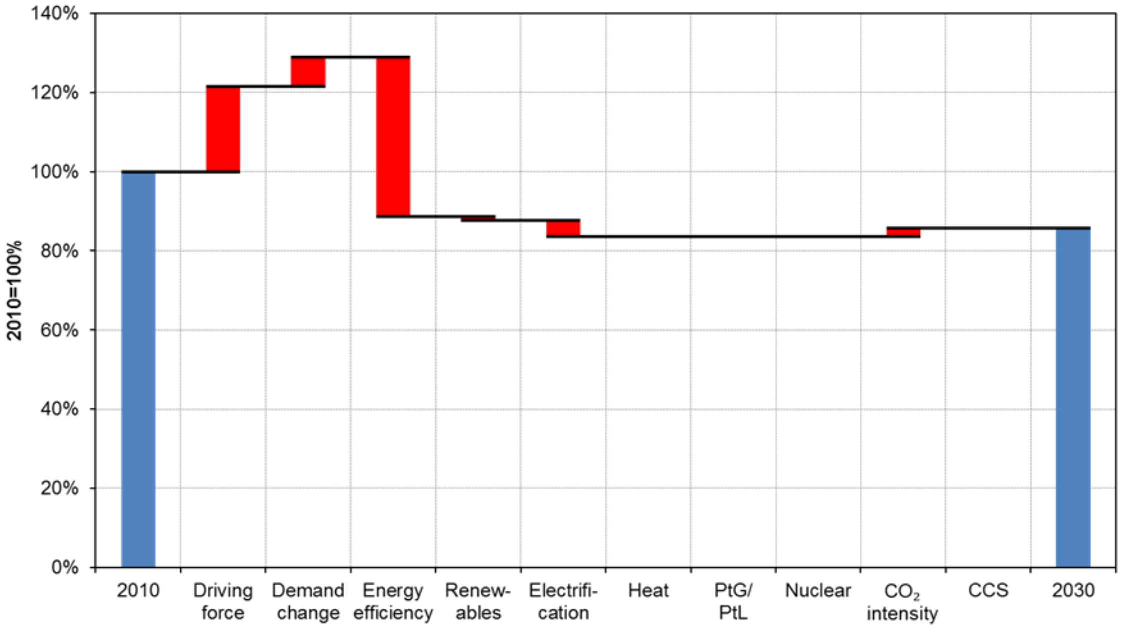
#### A 3.1.2.6 Freight transport

In freight transport, $CO_2$ emissions decrease by 14% in 2030 (Figure A 171) and 49% in 2050 (Figure A 172) compared to 2010. These reductions are significantly lower than the overall emission reductions in the CS80 scenario. Factors having a reducing effect on overall emissions are:

- Energy efficiency: Energy efficiency (energy use per freight distance) has the most pronounced contribution to $CO_2$ emission reductions resulting in 40% in 2030 and 56% in 2050 compared to 2010. This offsets the increase in demand, increasing from 615 Gtkm in 2010 to 840 in 2030 (increase in $CO_2$ emissions of 29% in 2030 compared to 2010) and 890 (increase in $CO_2$ emissions of 27% in 2050 compared to 2010).
- Renewables and electrification: The effects from renewables and electrification are mainly measurable for 2010 to 2050 amounting to $CO_2$ emission reductions of 10 and 11% in 2050 compared to 2010. While total energy demand decreases from 19.9 Mtoe in 2010 to 17.6 Mtoe in 2030 and 13.3 Mtoe in 2050, renewables remain stable at 1.2 Mtoe between 2010 to 2030 and increase to 2.3 Mtoe until 2050. The use of electricity increases between 2010 and 2050 from 0.4 Mtoe to 1.1 Mtoe in 2030 and 1.9 Mtoe in 2050.

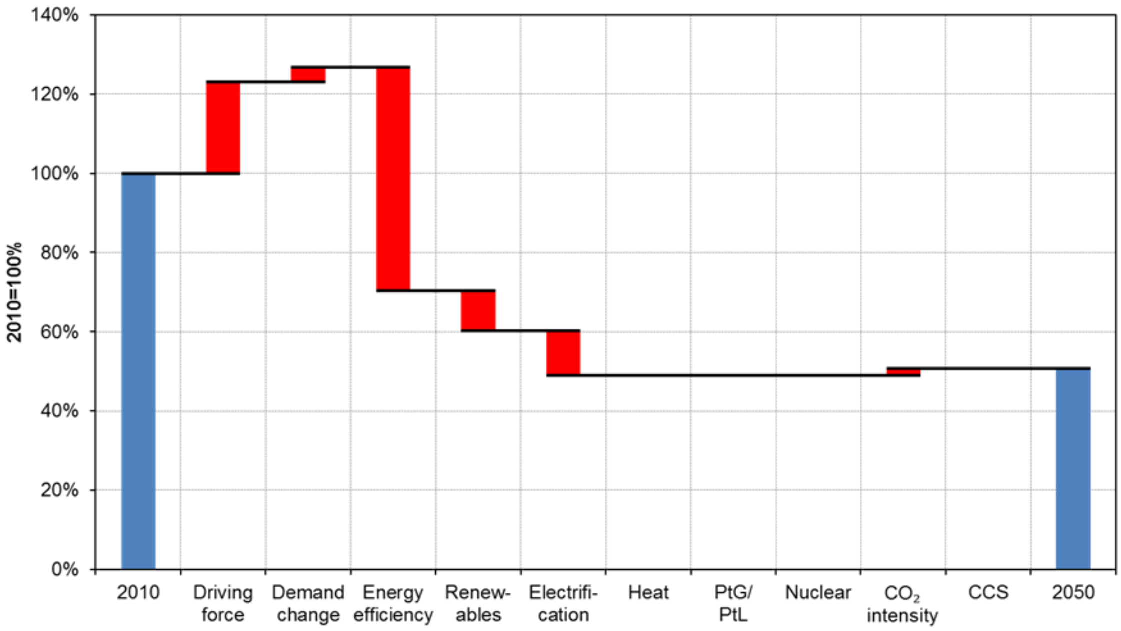
Fossil $CO_2$ intensity results in an increase of $CO_2$ emissions by 2% in 2050 compared to 2010. PtX fuels are not used as mitigation options in this scenario.

**Figure A 171: Germany, CS80 Scenario: Decomposition analysis for the freight transport sector, 2010–2030**




Source: Repenning et al. 2015, calculations by Fraunhofer ISI

**Figure A 172: Germany, CS80 Scenario: Decomposition analysis for the freight transport sector, 2010–2050**




Source: Repenning et al. 2015, calculations by Fraunhofer ISI

## A 3.2 Germany: Climate Scenarios, 2nd round, CS95

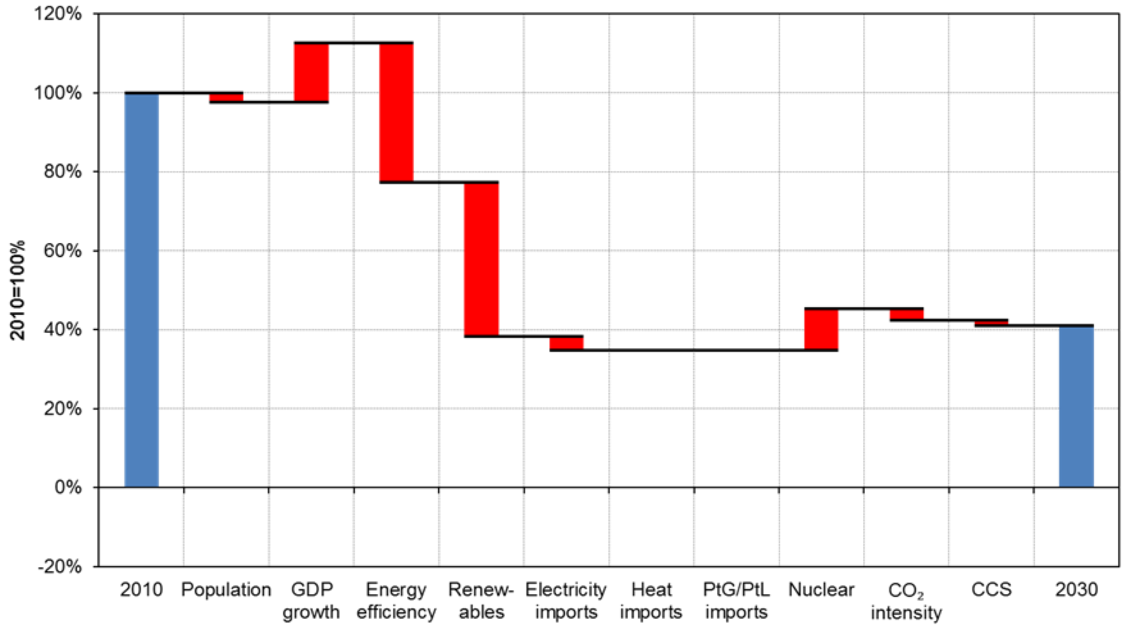
### A 3.2.1 Aggregate trends

In the CS95 scenario, $CO_2$ emissions from energy are reduced by 59% in 2030 and 97% in 2050, compared to 2010. Hence, the scenario is significantly more ambitious than the CS80 scenario in both years, 2030 as well as 2050. The main drivers, as illustrated in Figure A 173 for 2030 and Figure A 174 for 2050, are:

- Renewables: Renewables account for $CO_2$ emission reductions of 100% in 2050 compared to 2010 (CS80: 70%) and are hence the largest contributor. 216 Mtoe are produced from renewable energy sources in 2050, accounting for 92% of primary energy consumption. Already in 2030, they reduce emissions by 39% (CS80: 33%) compared to 2010 with the overall amount of renewables accounting for 51% (CS80: 44%) of primary energy consumption (115 Mtoe).
- Productivity gains: While $CO_2$ emission increase due to GDP growth by 14% until 2050 (slightly lower compared to the CS80 scenario), this is more than offset by $CO_2$ emission reductions due to higher productivity (22% less $CO_2$ per unit of GDP compared to 33% less $CO_2$ per unit of GDP in the CS80 scenario). In total, the two effects result in a net decrease of $CO_2$ emission of 8% (13% in CS80) compared to 2010. Effects for 2030 are similar with an increase in $CO_2$ emissions from GDP of 15% (CS80: 17%) and $CO_2$ per unit of GDP decreasing $CO_2$ emissions by 35% (CS80: 32%) (net effect: 20% (CS 80: 15%) decrease of $CO_2$ emissions in 2030 compared to 2010).
- CCS: In contrast to the CS80 scenario, where CCS was not applied as mitigation option, the CS95 scenario uses CCS to reduce $CO_2$ emissions. The effect is small, even in 2050. Absolute amount of $CO_2$ captured and stored in 2050 amounts to 41Mt $CO_2$, decreasing $CO_2$ emissions by 5% in 2050 compared to 2010.
- Population growth and electricity import: Both, population and electricity imports result in a decrease of $CO_2$ emissions by 3% respectively 3% in 2050 (3% and 4% in 2030) compared to 2010. Again, it is important to notice that Germany comes a net-importer of electricity in 2030 and 2050 instead of a net-export as is today, with imports however being relatively small in 2050 (1.7 Mtoe).

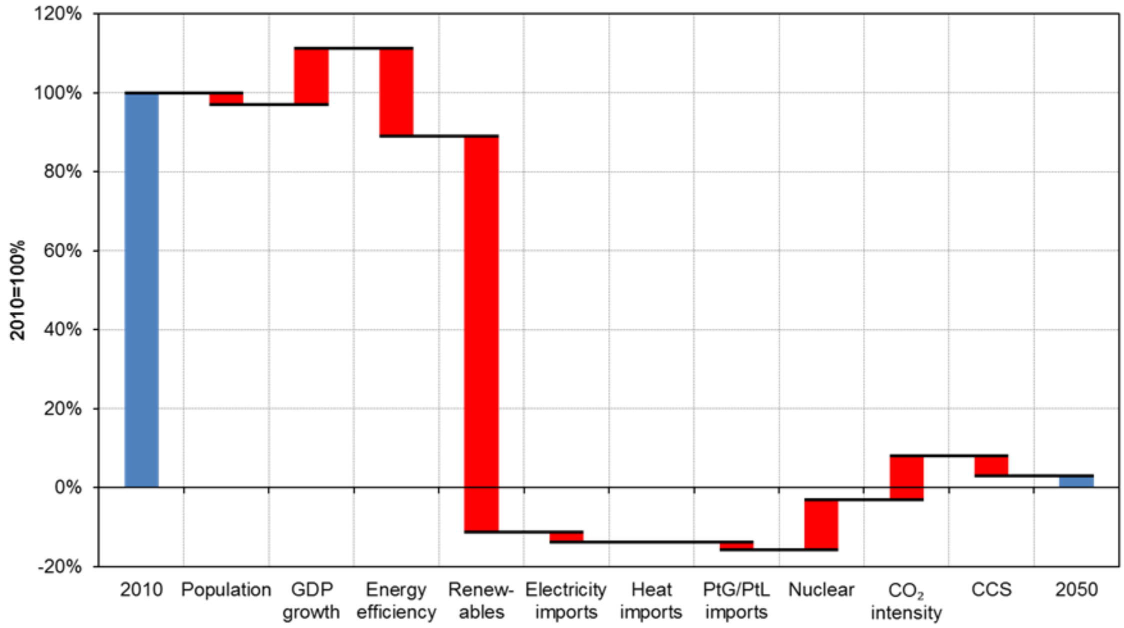
Increasing effects on $CO_2$ emissions are small. The phase-out of nuclear electricity for electricity generation results in an increase of $CO_2$ emissions by 13% in 2050 compared to 2010. In addition, fossil $CO_2$ intensity results in an increase in $CO_2$ emissions of 3% in 2030 and 11% in 2050 compared to 2010.

**Figure A 173: Germany, CS95 Scenario: Decomposition analysis for aggregate trends, 2010–2030**




Source: Repenning et al. 2015, calculations by Fraunhofer ISI

**Figure A 174: Germany, CS95 Scenario: Decomposition analysis for aggregate trends, 2010–2050**




Source: Repenning et al. 2015, calculations by Fraunhofer ISI

### A 3.2.2 Sectoral trends

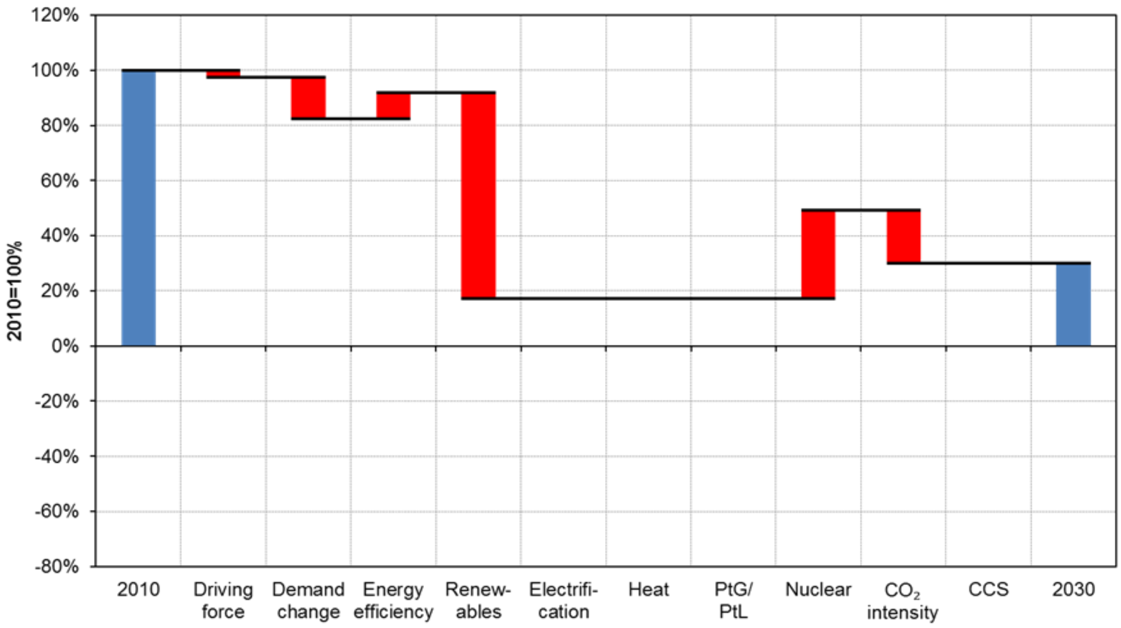
#### A 3.2.2.1 Eectricity sector

In the CS95 scenario, $CO_2$ emissions in the German electricity sector decrease by 70% (CS80: 50%) in 2030 (Figure A 175) and by 97% (CS80: 88%) in 2050 (Figure A 176) compared to 2010. As in the CS80 scenario, reductions in the electricity sector are slightly higher compared to reductions in total primary energy consumption. Driving forces behind the reductions in $CO_2$ emissions are similar to the ones in the CS80 scenario:

- Renewables: Already in 2030, renewables account for $CO_2$ emission reductions of 75% (CS80: 70%), the share of renewables in the electricity sector being 73% (CS80: 65%) (total production of 84 (CS80: 82) Mtoe). This share increases to 99% (CS80: 95%) in 2050 (182 (CS80: 119 Mtoe)), accounting for $CO_2$ emission reductions of 167% (CS80: 138%).
- Demand change and energy efficiency: For demand changes and energy efficiency, effects differ slightly from the ones seen in the CS80 scenario. In 2030, population along with demand reduce $CO_2$ emissions by 19%, while energy efficiency increases $CO_2$ emissions by 11% resulting in a net-reduction of 8%. In contrast, in 2050, population, demand and energy efficiency in total result in a net-increase of $CO_2$ emissions of 9% compared to 2010. The change in signs is a result from high energy efficiency assumptions in the first part (2010–30), which results in a decrease of electricity generation to 468 TWh in 2030 compared to 632 TWh in 2010, and an increase in demand for electricity from new consumers (e.g. heat pumps or electricity use in the transport sector) later in the first half of the century. By 2050, electricity generation reaches 764 TWh.

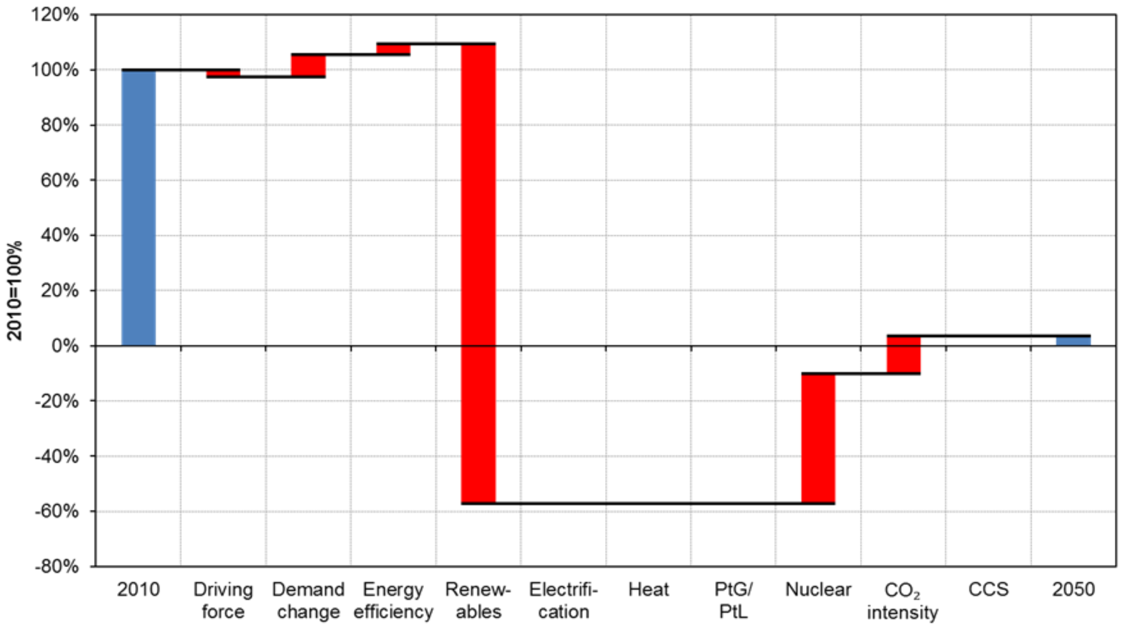
Fossil $CO_2$ intensity has a decreasing effect in the first part of the period in question, but an increasing effect when looking at the total period from 2010 to 2050 (+14%). Also an increasing effect on $CO_2$ emissions has the phase-out of nuclear energy generation, the effect being more pronounced compared to the CS80 scenario due to the higher overall $CO_2$ emissions in the electricity sector in the CS95 scenario (32% (CS80: 35%) in 2030 and 47% (CS80: 42%) in 2050 compared to 2010). CCS is not available as mitigation option in the electricity sector.

**Figure A 175: Germany, CS95 Scenario: Decomposition analysis for the electricity sector, 2010–2030**




Source: Repenning et al. 2015, calculations by Fraunhofer ISI

**Figure A 176: Germany, CS95 Scenario: Decomposition analysis for the electricity sector, 2010–2050**




Source: Repenning et al. 2015, calculations by Fraunhofer ISI

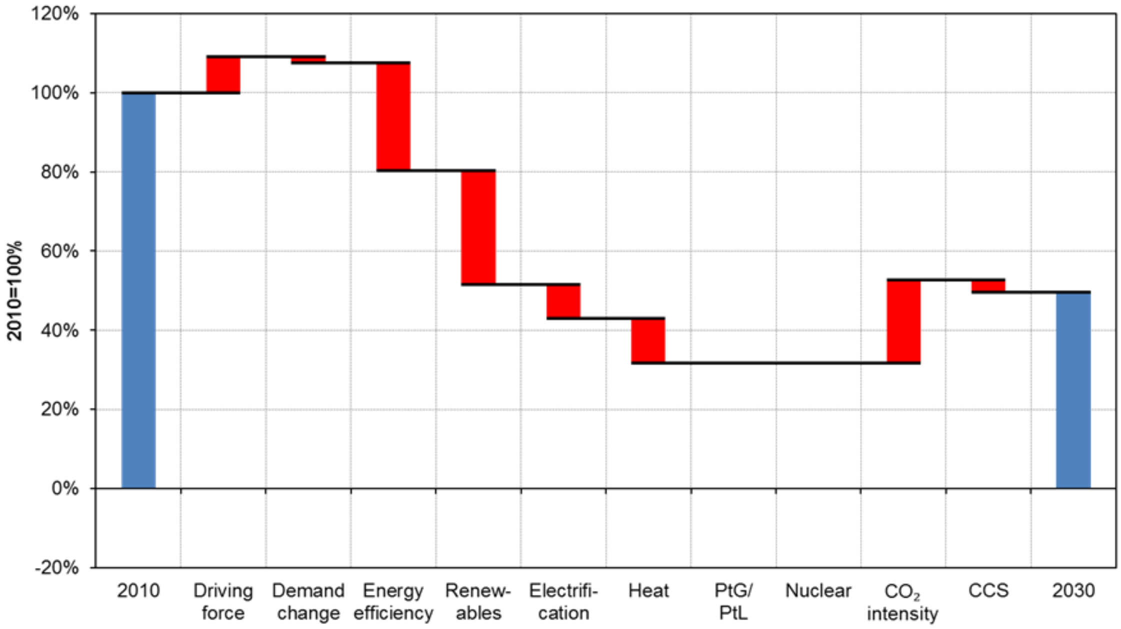
#### A 3.2.2.2 Industry sector

In the industry sector, total energy-related $CO_2$ emissions decrease by 51% (CS80: 37%) in 2030 (Figure A 177) and 103% (CS80: 71%) in 2050 (Figure A 178) compared to 2010. In contrast to the CS80 scenario, where emission reductions in the industry sector were less pronounced compared to total energy-related $CO_2$ emission reductions, the industry sector shows negative emissions in the CS95 scenario in 2050. Driving factors reducing $CO_2$ emissions in the industry sector are:

- Value added and energy efficiency: The use of energy per value added decreases compared to 2010, both in 2030 as well as in 2050. The decrease in $CO_2$ emissions from energy efficiency is 27% (CS80: 24%) in 2030 and 35% (CS80: 31%) in 2050 compared to 2010. This decrease in $CO_2$ emissions compensates for the increase in $CO_2$ emissions induced by an increase in value added (8% and 7% in 2050 compared to 2010). This decrease is offset by an increase in value added (which is lower compared to the CS80 scenario, but still significantly positive) resulting in an increase of $CO_2$ emissions by 8% in 2030 and 7% in 2050 compared to 2010. Net-decrease of $CO_2$ emissions results to 20% in 2030 and 18% in 2050 compared to 2010.
- Renewables: As in the electricity sector, renewables play an important role for the development of $CO_2$ emissions in the industry sector, the size of the effect being in the same order of magnitude for the CS80 and the CS95 scenario. The use of renewables results in a decrease of $CO_2$ emissions of 29% (CS80: 14%) by 2030 and 35% (CS80: 33%) by 2050 compared to 2010. In total, use of renewables in the industry sector increases from 1.1 Mtoe in 2010 to 7.3 (CS80: 4.9) Mtoe in 2030 and 10.1 (CS80: 9.7) Mtoe in 2050. Its share increases from 2% (CS80: 8%) in 2010 to 17% (CS80: 18%) in 2030 and 29% (CS80: 26%) in 2050.
- Electrification: In contrast to the CS80 scenario, electrification plays a more significant role in the CS95 scenario, in particular by 2050. It reduces $CO_2$ emissions by 15% in 2050 (8% in 2030) compared to 2010. Electricity reaches a share of 44% in 2050 (15.3 Mtoe), besides an absolute decrease in the use of electricity.
- Fossil $CO_2$ intensity: Fossil $CO_2$ intensity results in a significant decrease in $CO_2$ emissions of 24% by 2030 as well as 2050 (CS80, 2030: 2%, 2050: 8%) compared to 2010.
- CCS: In contrast to the CS80 scenario, the CS95 scenario allows for the application of CCS technology to reduce emissions in the industry sector. By 2050, CCS results in $CO_2$ emission reductions of 10% compared to 2010 (3% in 2030 compared to 2010). As a result, the industry sector shows negative emissions in 2050.

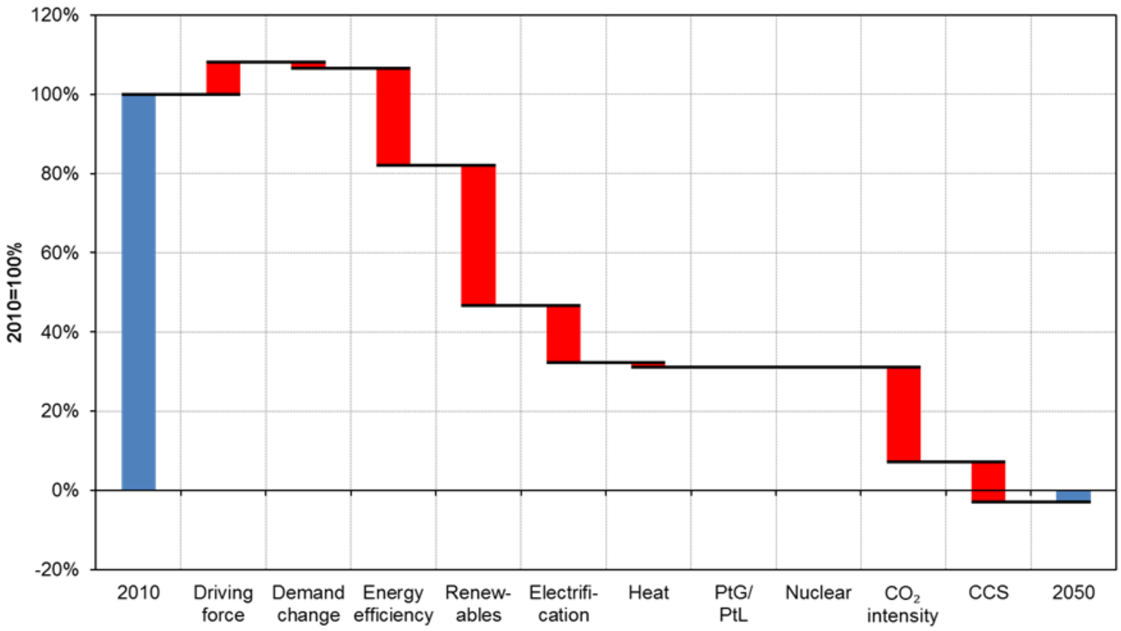
PtX and nuclear are not used as mitigation options in this scenario in the industry sector.

**Figure A 177: Germany, CS95 Scenario: Decomposition analysis for the industry sector, 2010–2030**




Source: Repenning et al. 2015, calculations by Fraunhofer ISI

**Figure A 178: Germany, CS95 Scenario: Decomposition analysis for the industry sector, 2010–2050**




Source: Repenning et al. 2015, calculations by Fraunhofer ISI

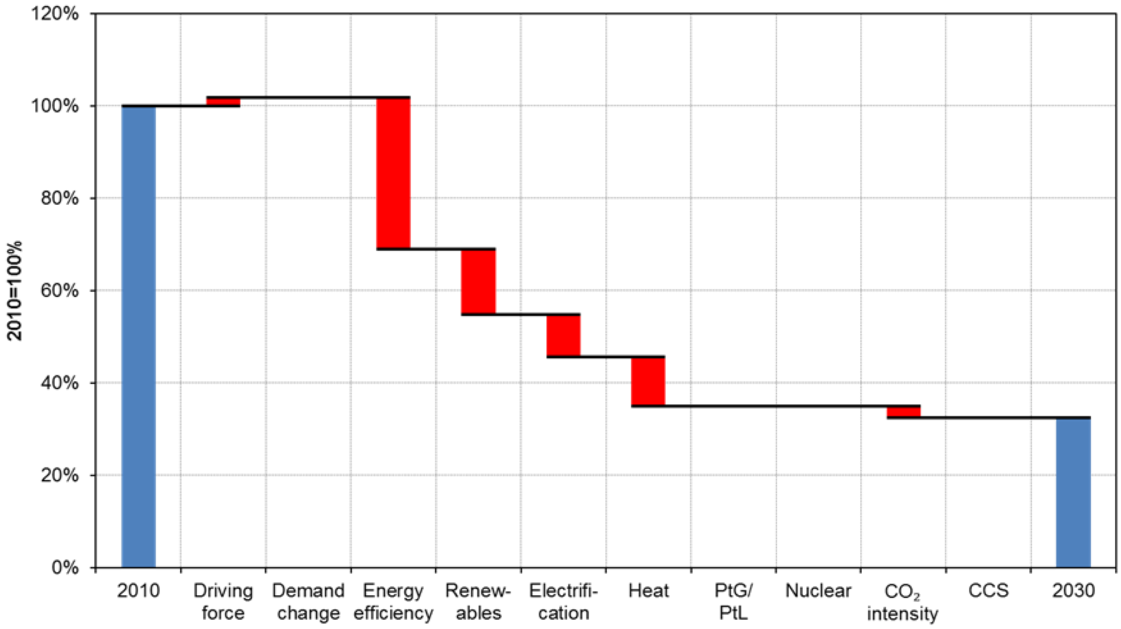
### A 3.2.2.3 Residential sector

In the residential sector, $CO_2$ emissions are reduced by 68% (CS80: 51%) in 2030 (Figure A 179) and by 96% (CS80: 85%) in 2050 (Figure A 180) compared to 2010. These reductions are slightly higher in 2030 and similar in 2050 compared to the overall level of ambition of the CS95 scenario. Main drivers of a decrease in $CO_2$ emissions in the residential sector are:

- Energy efficiency: Energy efficiency (use of energy per household) covers for $CO_2$ emission reductions of 33% (CS80: 29%) in 2030 compared to 2010 and of 26% (CS80: 32%) in 2050 compared to 2010. This effect is mainly coming from a significant decrease in energy use, while the number of households is mainly constant, with a slight increase between 2010 and 2030 (from 40 to 41 m households) and a slight decrease between 2030 and 2050 (back to 40 m households), resulting in a 2% increase in $CO_2$ emissions in 2030 compared to 2010.
- Renewables: The share of renewables use in households increases from 12% in 2010 to 23% (CS80: 20%) in 2030 and 24% (CS80: 24%) in 2050. Despite decreases in the use of energy in households, this means a small increase in the absolute amount of renewable energy used in the residential sector from 7.6 in 2010 to 8.8 (CS80: 8.7) Mtoe in 2030 and a decrease to 6.3 (CS80: 7.6) Mtoe in 2050. The increase in the share of renewables results in decreases of $CO_2$ emissions of 14% both in 2030 and 2050 compared to 2010 (CS80, 2030: 11%, 2050: 14%).
- Electrification: The use of electricity in households decreases between 2010 and 2030 from 12.2 to 10 (CS80: 10.6) Mtoe and increases back to 11.2 (CS80: 11.4) Mtoe in 2050. In light of the decrease in overall energy use in households, this corresponds to an increase in the share of electricity in total energy consumption in the residential sector from 19% in 2010 to 23% (CS80: 24%) in 2030 and 42% (CS80: 36%) in 2050. This contributes to emission reductions by 9% (CS80: 7%) in 2030 and 28% (CS80: 20%) in 2050 compared to 2010.
- Heat: District heating in households increases between 2010 and 2050 from 4.5 Mtoe in 2010 to 5.9 (CS80: 4.5) Mtoe in 2030 and 7.7 (CS80: 6.4) Mtoe in 2050. This results in a decrease in $CO_2$ emissions of 11% (CS80: 4%) by 2030 and 27% (CS80: 16%) by 2050 compared to 2010.

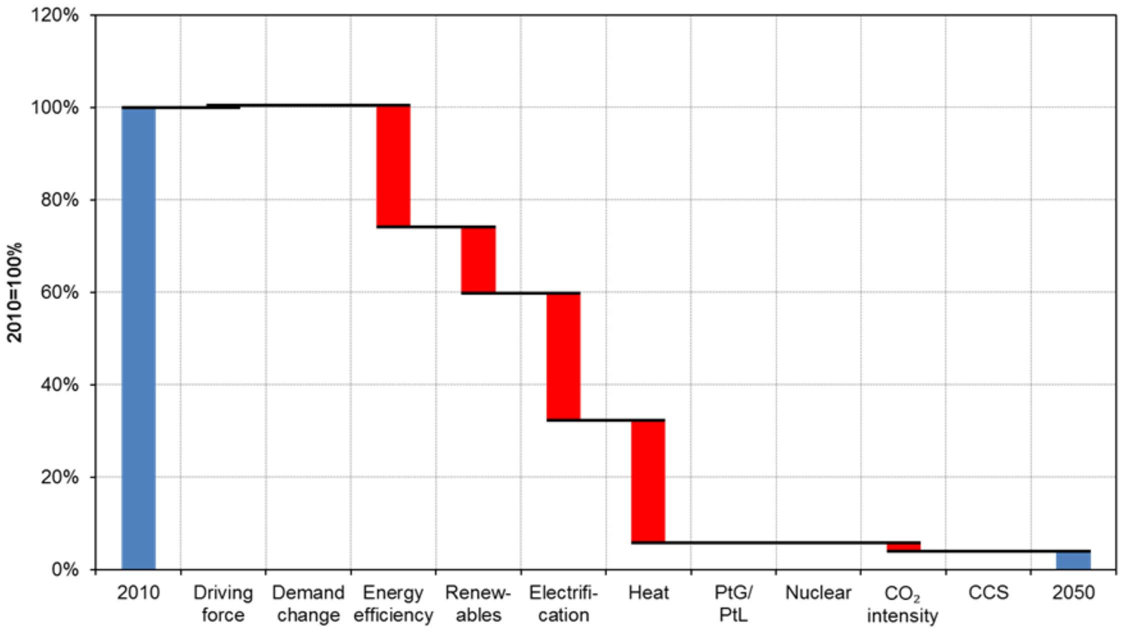
PtX and nuclear energy along with CCS are not used as mitigation options in the residential sector in the CS80 scenario. The effect of fossil $CO_2$ intensity is small.

**Figure A 179: Germany, CS95 Scenario: Decomposition analysis for the residential sector, 2010–2030**




Source: Repenning et al. 2015, calculations by Fraunhofer ISI

**Figure A 180: Germany, CS95 Scenario: Decomposition analysis for the residential sector, 2010–2050**




Source: Repenning et al. 2015, calculations by Fraunhofer ISI

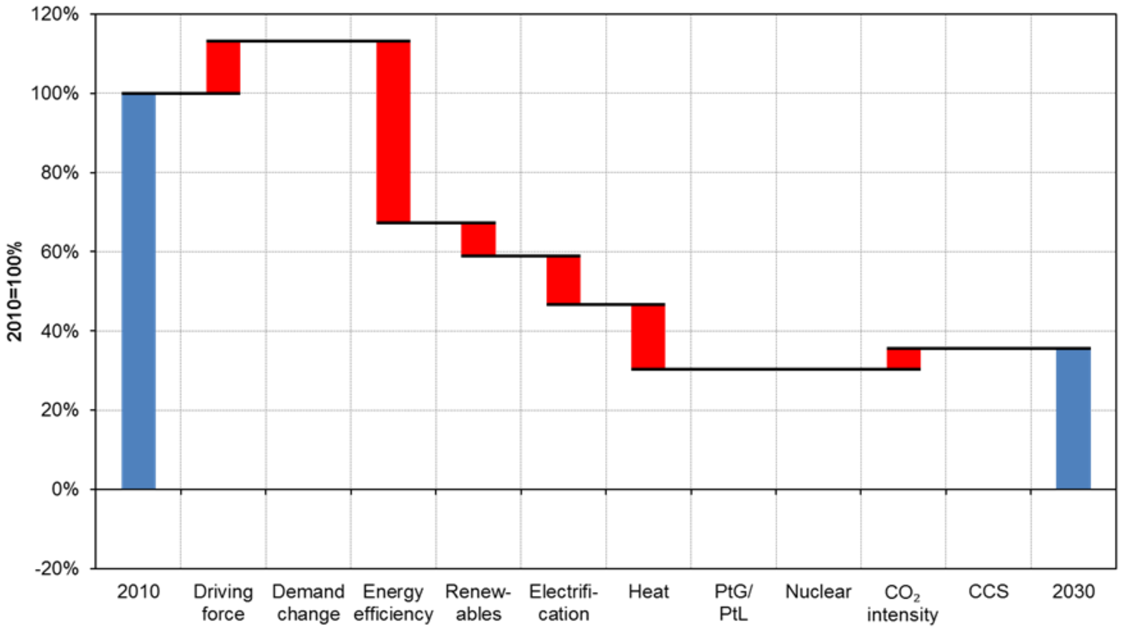
#### A 3.2.2.4 Tertiary sector

In the tertiary sector, emissions decrease by 64% (CS80: 46%) by 2030 and 97% (CS80: 88%) by 2050 compared to 2010. These reduction levels are slightly lower in 2030 but comparable in 2050 to total energy $CO_2$ emission reductions in the CS95 scenario. Important drivers for the decrease in $CO_2$ emissions to 2030 (Figure A 181) and 2050 (Figure A 182) are similar to the CS80 scenario:

- Energy efficiency: Energy use per value added significantly decreases between 2010 and 2050 in the tertiary sector in the CS95 scenario, similar but slightly more pronounced as in the CS80 scenario. Increases in the value added amplify the effect of decreasing energy demand. This results in a decrease in $CO_2$ emissions in the tertiary sector of 46% (CS80: 42%) by 2030 and 33% (CS80: 42%) by 2050 compared to 2010 and offsets the increase in $CO_2$ emissions from value added, which amounts to 13% (CS80: 16%) by 2030 and 9% (CS80: 14%) by 2050 compared to 2010.
- Electrification: The absolute amount of electricity used in this sector only slightly decreases from 12.6 Mtoe in 2010 to 9.7 Mtoe in 2050. The share of electricity used increases from 36% in 2010 to 44% (CS80: 44%) in 2030 and 66% (CS80: 63%) in 2050. This contributes to $CO_2$ emission reductions by 12% (CS80: 14%) in 2030 and 47% (CS80: 42%) in 2050 compared to 2010.
- Renewables and heat: Absolute use of renewables increases between 2010 and 2050 making up for 11% (CS80: 9%) of total energy consumption by 2050. District heating fluctuates between 2.9 and 4.1 Mtoe (CS80: 2.5 and 3.3 Mtoe) between 2010 and 2050. Both contribute to $CO_2$ emission reductions, renewables accounting for 8% (CS80: 6%) in 2030 and 13% (CS80: 10%) in 2050 compared to 2010 and district heating accounting for 16% (CS80: 4%) in 2030 and 16% (CS80: 12%) in 2050 compared to 2010.

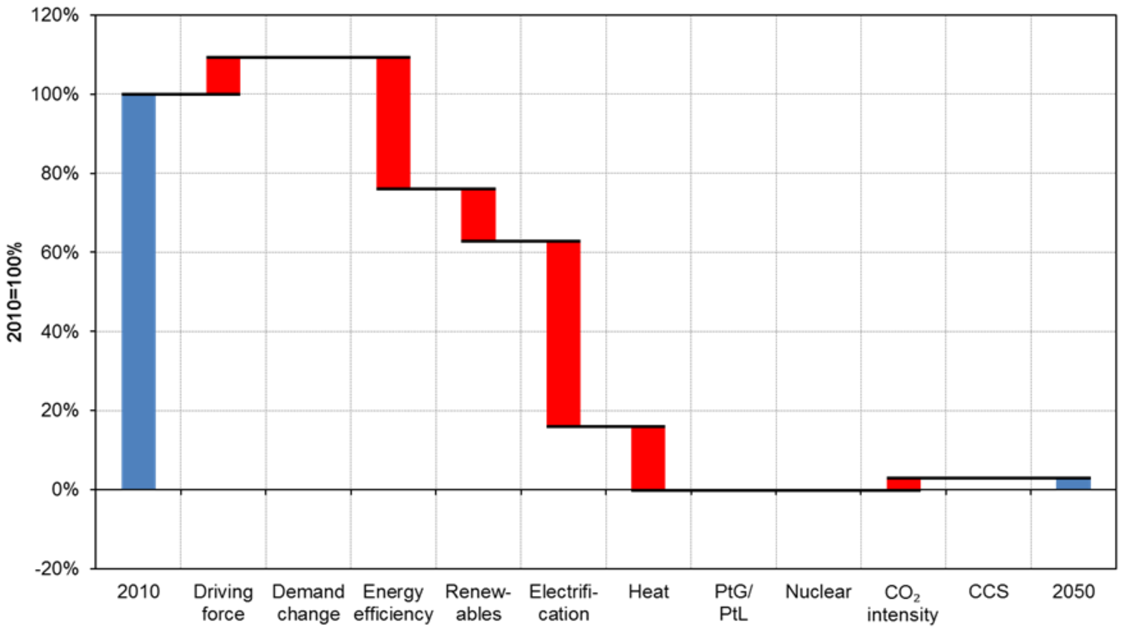
Fossil $CO_2$ intensity results in a slight increase in $CO_2$ emissions by 5% (CS80: 4%) in 2030 and 3% (CS80: 2%) in 2050 compared to 2010. PtX and nuclear electricity along with CCS are no mitigation options applied in the tertiary sector.

**Figure A 181: Germany, CS95 Scenario: Decomposition analysis for the tertiary sector, 2010–2030**




Source: Repenning et al. 2015, calculations by Fraunhofer ISI

**Figure A 182: Germany, CS95 Scenario: Decomposition analysis for the tertiary sector, 2010–2050**




Source: Repenning et al. 2015, calculations by Fraunhofer ISI

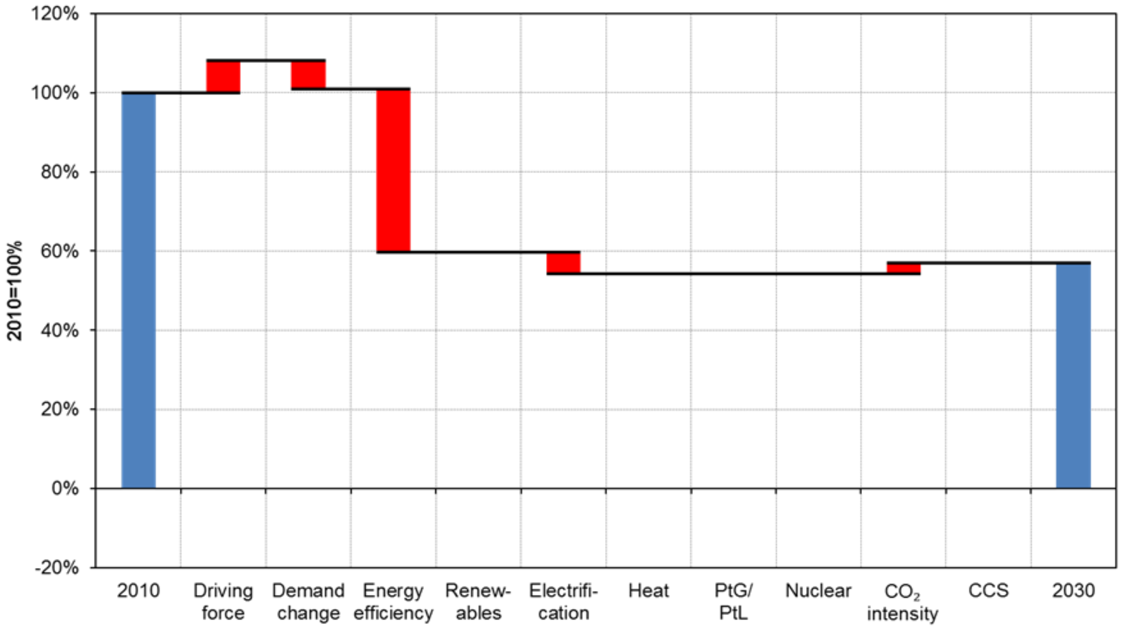
#### A 3.2.2.5 Passenger transport

In the passenger transport sector, $CO_2$ emissions decrease by 43% (34%) in 2030 (Figure A 183) and by 93% (CS80: 72%) in 2050 (Figure A 184) compared to 2010. As in the freight transport sector, contributions of the passenger transport sector to emission reductions increase compared to the CS80 scenario. Important factors for the reductions in $CO_2$ emissions are similar to the freight transport sector:

- Energy efficiency: Energy efficiency (energy use per travel distance) is the most pronounced effect in 2030 and still has an important effect on $CO_2$ emissions when looking at the time period from 2010 to 2050. In 2030, energy efficiency reduces $CO_2$ emissions by 41% (CS80: 37%) compared to 2010, in 2050 by 42% (CS80: 56%) to 2010. This offsets the increase in $CO_2$ emissions from demand, which slightly increases from 1256 (CS80: 1356 Gpkm) in 2010 to 1270 (CS80: 1295) in 2030 (increase in $CO_2$ emissions of 1% (CS80: 5%) in 2030 compared to 2010) and to 1341 in 2050 (increase in $CO_2$ emissions of 2% (CS80: 7%) in 2050 compared to 2010).
- Electrification: As in freight transport, electrification is another important driver for decarbonization of passenger transport, taking effect after 2030. Electricity use reduces the sectors $CO_2$ emissions by 38% in 2050 compared to 2010, electricity covering for 47% (6.3 Mtoe) of the sectors total energy demand.
- PtG/PtL: Another important factor, but less pronounced than in freight transport is the use of PtG/PtL fuels. They reduce the sectors $CO_2$ emissions by 23% in 2050 compared to 2010, covering for 26% (3.5 Mtoe) of the sectors total energy demand.

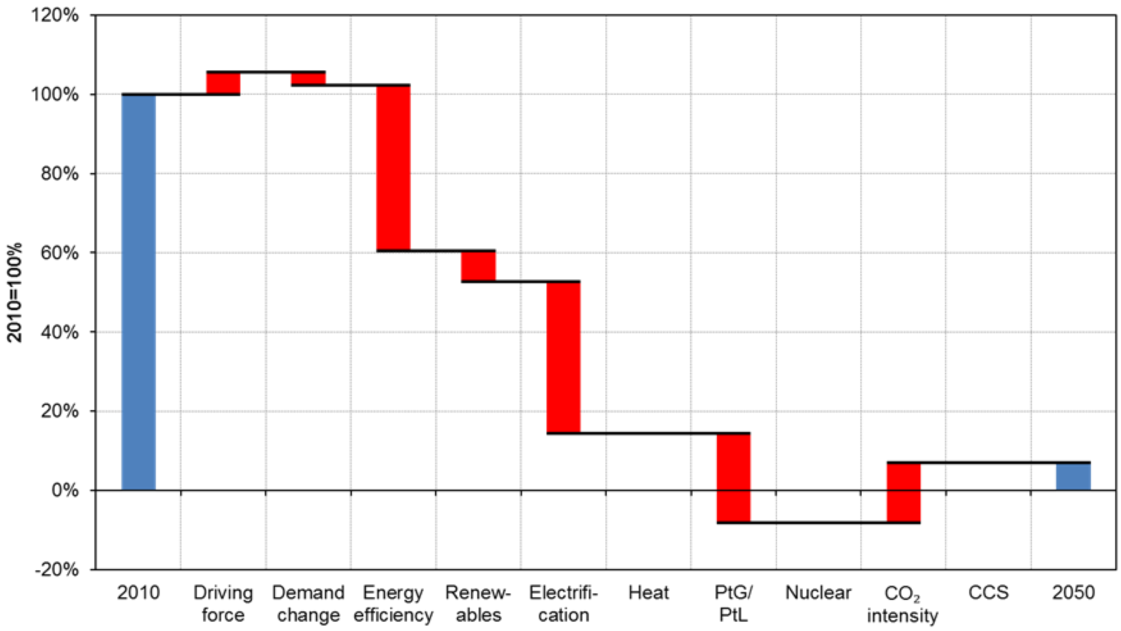
Renewables and fossil $CO_2$ intensity have minor influence on the development of the $CO_2$ emissions in passenger transport, the former one reducing emissions by 8% in 2050 compared to 2010, the later one increasing them by 15% in 2050 compared to 2010.

**Figure A 183: Germany, CS95 Scenario: Decomposition analysis for the passenger transport sector, 2010–2030**




Source: Repenning et al. 2015, calculations by Fraunhofer ISI

**Figure A 184: Germany, CS95 Scenario: Decomposition analysis for the passenger transport sector, 2010–2050**




Source: Repenning et al. 2015, calculations by Fraunhofer ISI

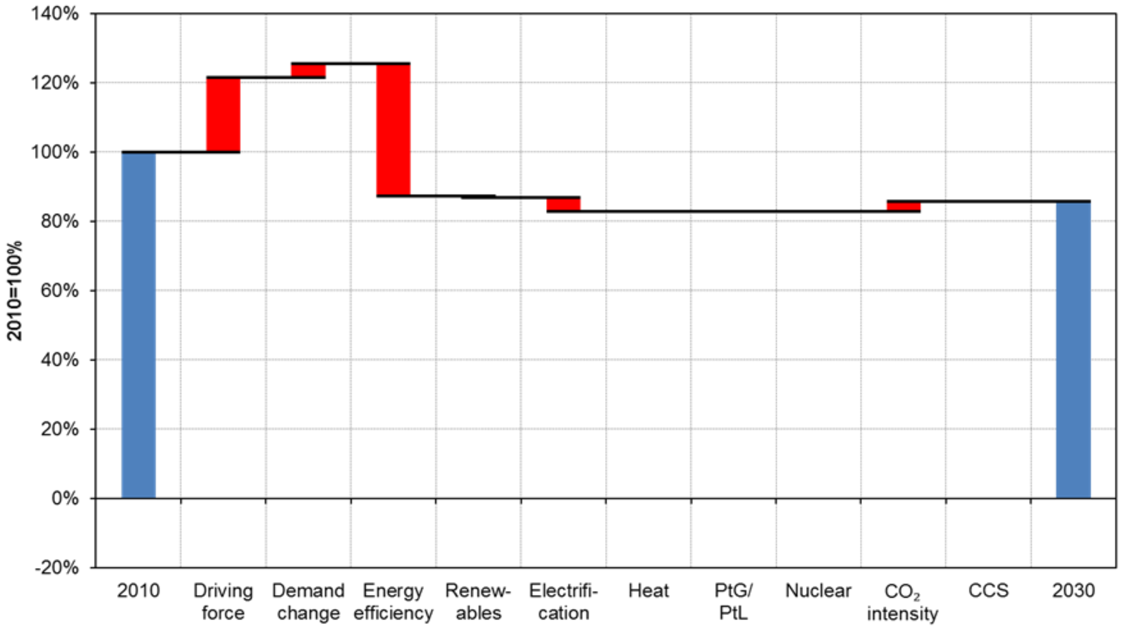
#### A 3.2.2.6 Freight transport

In freight transport, $CO_2$ emissions decrease by 14% (CS80: 14%) in 2030 (Figure A 185) and 91% (CS80: 49%) in 2050 (Figure A 186) compared to 2010. While these reductions are still lower than the overall emission reductions in the CS95 scenario, the contributions of the freight sector in the CS95 scenario in 2050 are significantly higher than in the CS80 scenario. Factors having a reducing effect on overall emissions are:

- Energy efficiency: Energy efficiency (energy use per freight distance) still has the most pronounced contribution to $CO_2$ emission reductions resulting in 38% (CS80: 40%) in 2030 and 36% (CS80: 56%) in 2050 compared to 2010. This offsets the increase in demand, increasing from 615 Gtkm in 2010 to 810 (CS80: 840) in 2030 (increase in $CO_2$ emissions of 26% (CS80: 29%) in 2030 compared to 2010) and 870 (CS80: 890) (increase in $CO_2$ emissions of 13% (CS80: 27%) in 2050 compared to 2010).
- Electrification: Electrification of freight transport is one of the key drivers influencing $CO_2$ emissions after 2030. It results in $CO_2$ emission reductions of 34% by 2050 compared to 2010. Electricity use in the freight transport sector increases from 0.4 Mtoe in 2010 to 3.7 Mtoe in 2050.
- PtG/PtL: A second important driver after 2030 is the use of PtG/ PtL fuels. It covers for 3.3 Mtoe (32%) of energy demand in the freight transport sector and contributes to $CO_2$ emission reductions with 32% in 2050 compared to 2010.
- Renewables: The third important driver are biofuels, which cover for 21% of energy demand in the transport sector. This results in a decrease of $CO_2$ emissions of 16% in 2050 compared to 2010

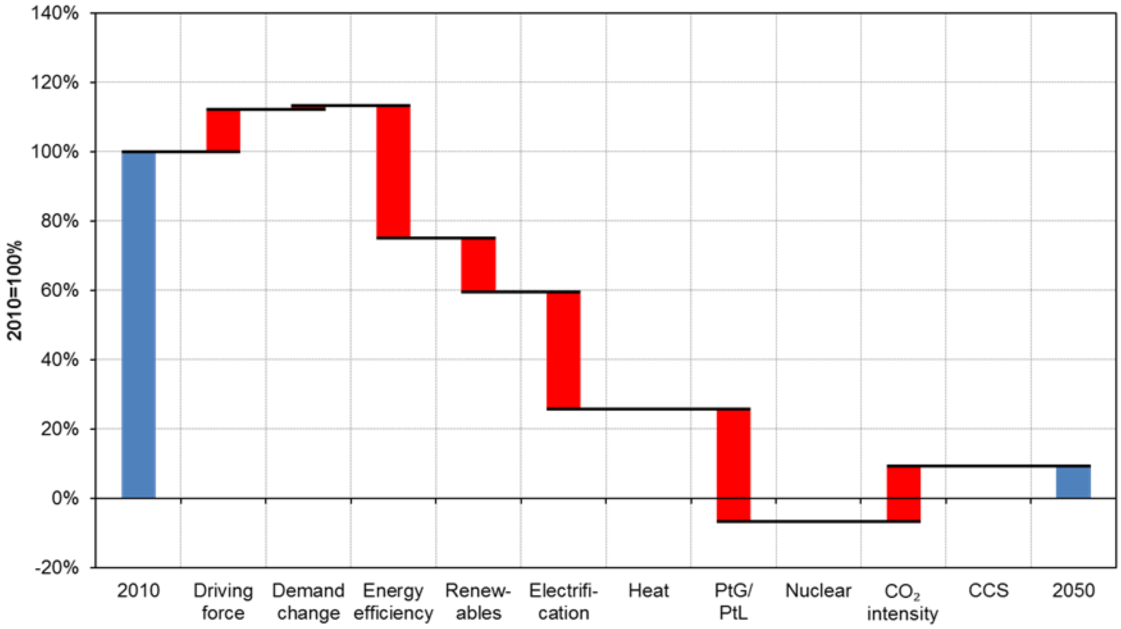
Fossil $CO_2$ intensity results in an increase of $CO_2$ emissions by 16% (CS80: 2%) in 2050 compared to 2010.

**Figure A 185: Germany, CS95 Scenario: Decomposition analysis for the freight transport sector, 2010–2030**




Source: Repenning et al. 2015, calculations by Fraunhofer ISI

**Figure A 186: Germany, CS95 Scenario: Decomposition analysis for the freight transport sector, 2010–2050**




Source: Repenning et al. 2015, calculations by Fraunhofer ISI

## A 3.3 Italy: Pathways to Deep Decarbonization, Demand Reduction Scenario

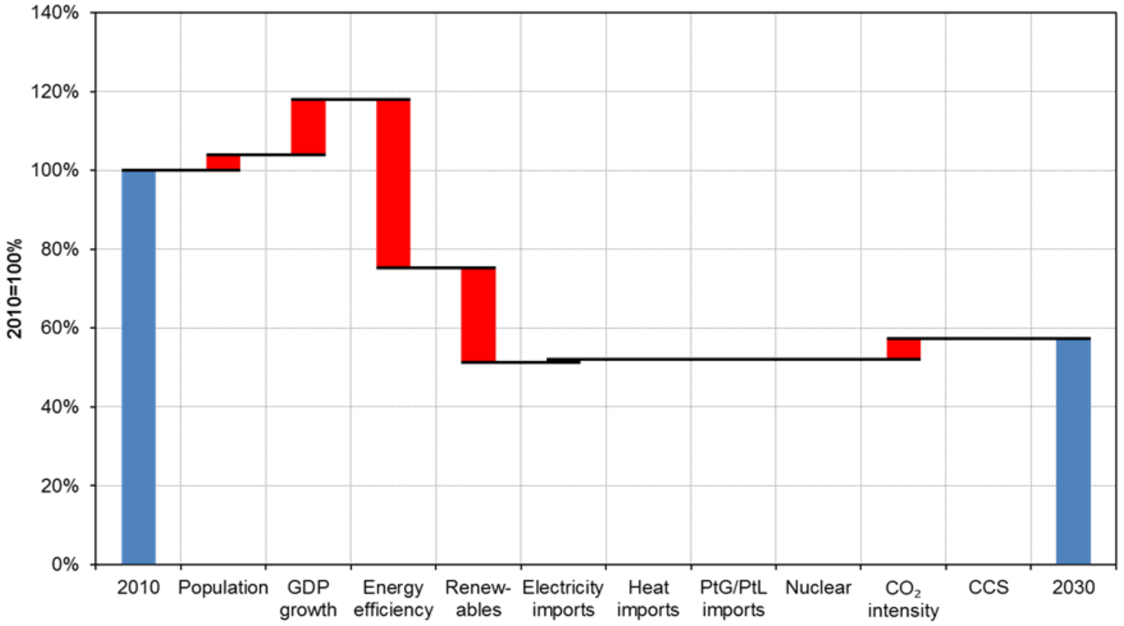
### A 3.3.1 Aggregate trends

The Demand Reduction Scenario of the study '2 Pathways to Deep Decarbonization – Italy' (Maria Rosa Virdis et al. 2015) attains a 43% reduction in energy-related $CO_2$ emissions until 2030 (Figure A 187) and 83% until 2050 (Figure A 188), compared to 2010. The main drivers of changes in the carbon emissions are the following:

- Productivity gains: While GDP per capita grows by 21% until 2050, this is partly than offset by higher productivity (45% less $CO_2$ per unit of GDP). The combination of both developments results in a 24% net decrease of emissions in 2050. Notably, the net effect is even larger in 2030 with intermediate levels of 14% of GDP growth, 43% productivity gains in 2030.
- Renewables: The expansion of renewable energy sources (RES) is the by far strongest lever for reducing carbon emissions in the scenario, in particular after 2030. Primary energy supply from RES grows from 24 Mtoe in 2010 to 45 Mtoe in 2030 and 86 Mtoe in 2050. This yields a contribution equivalent to -24% of carbon emissions in 2030 and -70% in 2050.
- Shift in fossil fuel mix: The remaining mix of fossil fuels in 2050 has a lower carbon intensity than the mix of 2010, which corresponds to an increase of carbon emissions by 8%. The shift in the fuel mix is rather continuous with an increase of carbon emissions by 5% in 2030.

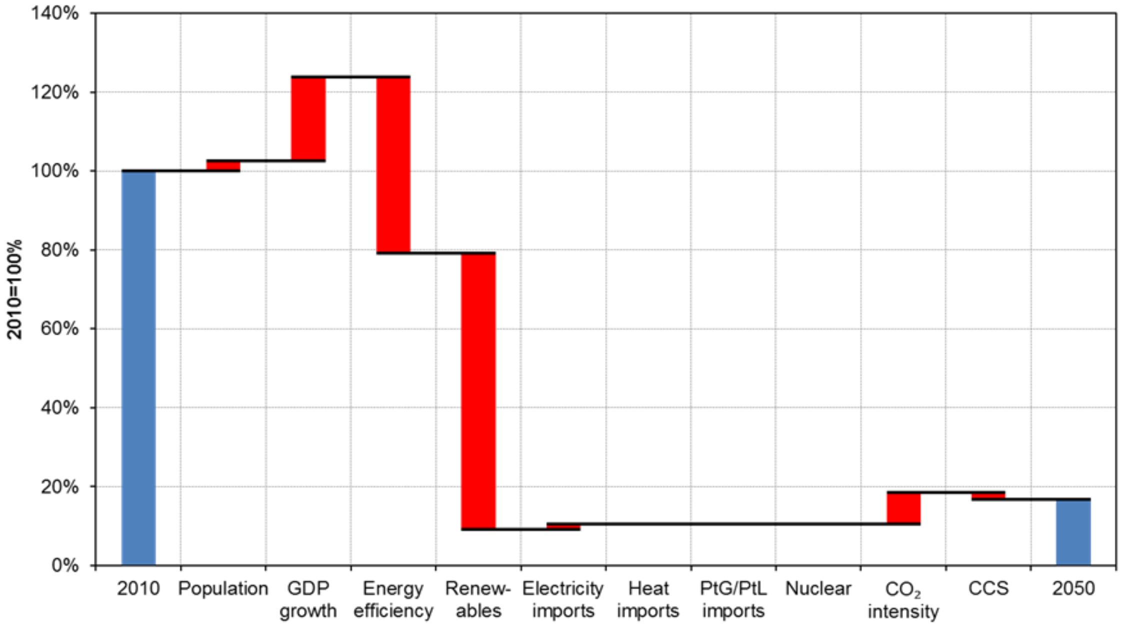
Compared to the above drivers, population decreases only slightly by 3% and electricity imports increase by only 2% until 2050. CCS is also used as a mitigation option both in the industry and the electricity sector, but results in a decrease of carbon emissions by only 2% in 2050. Finally, imports of heat and synthetic fuels do not play any role in the scenario. In summary, higher energy productivity and more primary energy supply from RES are the key levers in the Demand Reduction Scenario for Italy.

**Figure A 187: Italy, Pathways to Deep Decarbonization, Demand Reduction Scenario: Decomposition analysis for aggregate trends, 2010–2030**




Source: Virdis et al. 2015, calculations by Fraunhofer ISI

**Figure A 188: Italy, Pathways to Deep Decarbonization, Demand Reduction Scenario: Decomposition analysis for aggregate trends, 2010–2050**




Source: Virdis et al. 2015, calculations by Fraunhofer ISI

### A 3.3.2 Sectoral trends

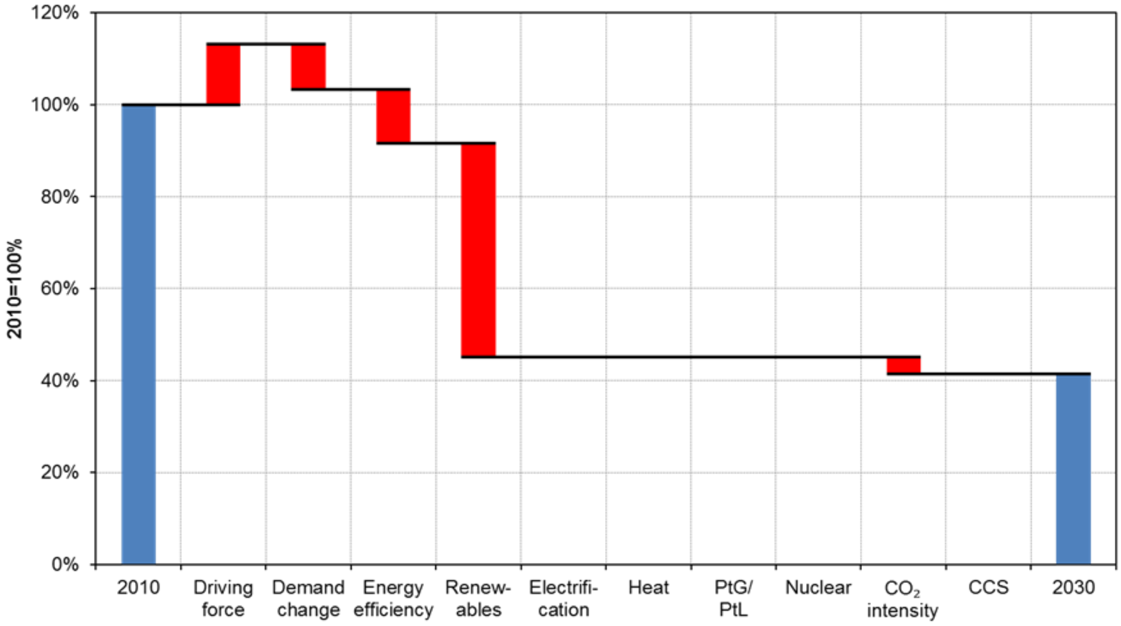
#### A 3.3.2.1 Electricity sector

In the Demand Reduction Scenario, $CO_2$ emissions in the Italian electricity sector are slightly higher compared to reductions in total primary energy consumption. They decrease by 59% in 2030 (Figure A 189) and by 98% in 2050 (Figure A 190) compared to 2010. The main driving forces of the changes in $CO_2$ emissions are the following:

- Renewables: This primary energy from renewable sources used for electrcitiy generation increases from 15 Mtoe in 2010 to 43 Mtoe in 2050, accounting for $CO_2$ emission reductions of 80%. Already in 2030, RES account for $CO_2$ emission reductions of 47%, the total production being 34 Mtoe.
- Activity and demand change: In the Reference Scenario, electricity generation increases until 2050, which corresponds to an increase of carbon emissions by 9%. This is only moderately offset by a lower electricity demand in the Demand Reduction Scenario (-2%). The offset is much stronger until 2030 with intermediate contributions of electricity generation given by +13% and of demand reduction given by -10%.
- Energy efficiency: A higher efficiency of electricity generation decreases $CO_2$ emissions significantly. This contribute a continuously growing reduction of carbon emissions by 12% until 2030 and 21% until 2050.

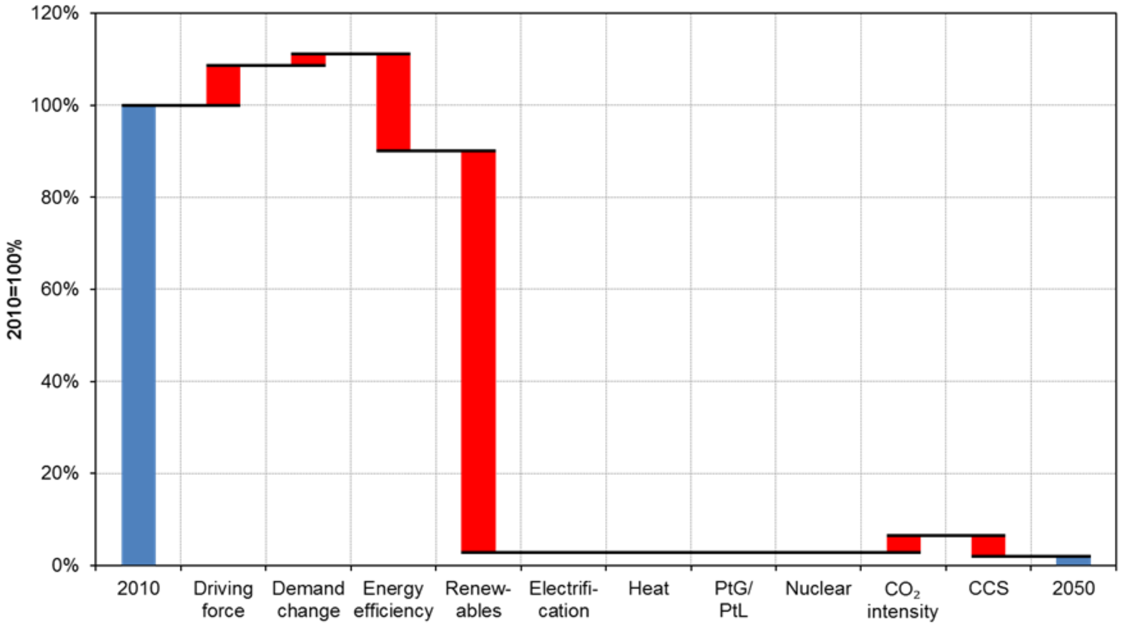
Fossil $CO_2$ intensity has a slightly decreasing effect until 2030, but an increasing effect when looking at the total period from 2010 to 2050 (+4%). CCS is applied in the electricity sector, but changes emissions only in a similar order of magnitude (-4%), too.

**Figure A 189: Italy, Pathways to Deep Decarbonization, Demand Reduction Scenario: Decomposition analysis for the electricity sector, 2010–2030**




Source: Virdis et al. 2015, calculations by Fraunhofer ISI

**Figure A 190: Italy, Pathways to Deep Decarbonization, Demand Reduction Scenario: Decomposition analysis for the electricity sector, 2010–2050**




Source: Virdis et al. 2015, calculations by Fraunhofer ISI

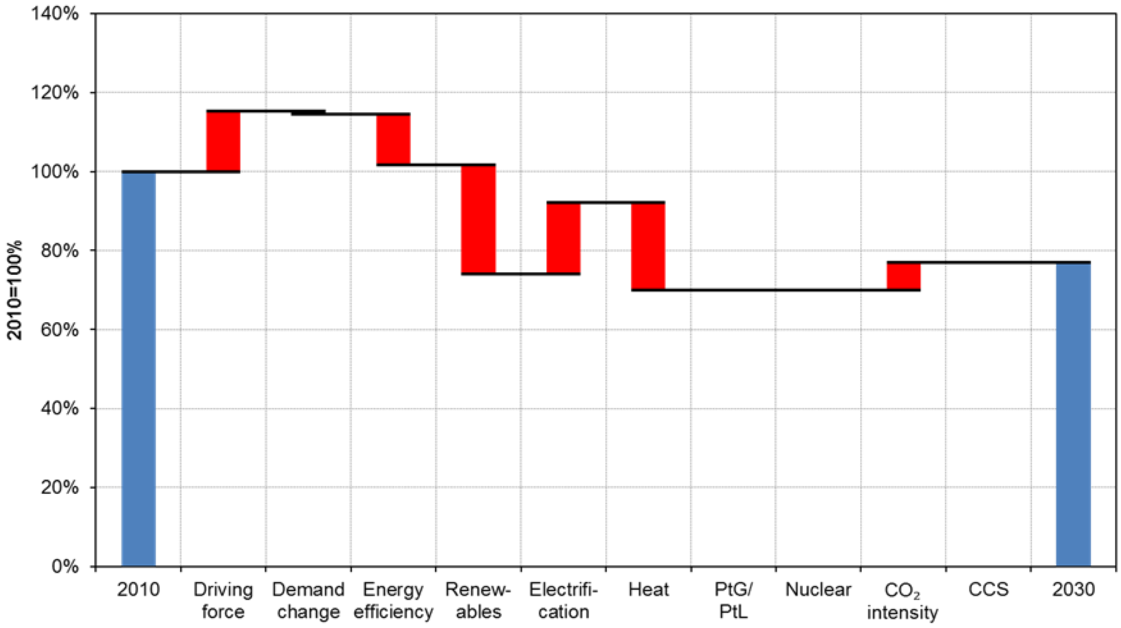
### A 3.3.2.2 Industry sector

In the industry sector, total energy-related $CO_2$ emissions decrease by 23% in 2030 (Figure A 191) and 59% in 2050 (Figure A 192) compared to 2010, which is substantially lower than the total reduction of energy-related $CO_2$ emissions. The main drivers for the reduction of $CO_2$ emissions in the industry sector are:

- Activity and demand change: In the Reference Scenario, value added by the industry sector increases until 2050, which contributes to an increase of carbon emissions by 26%. This is only marginally offset by lower levels of production in the Demand Reduction Scenario (-1%). Both effects grow rather continuously with intermediate contributions of value added given by +15% and of reduction of production levels given by -1%.
- Energy efficiency: The use of energy per value added decreases continuously from 2010 to2050. The corresponding decrease in $CO_2$ emissions is 13% in 2030 and 26% in 2050 compared to 2010.
- Renewables: As in the electricity sector, renewables play an important role for the development of $CO_2$ emissions in the industry sector. The use of renewables results in a decrease of $CO_2$ emissions of 27% by 2050 compared to 2010. Notably, the expansion of RES mainly contributes before 2030 (reduction of carbon emissions until 2030: 28%).
- Electrification: Electrification plays an ambiguous role in the Demand Reduction Scenario. While electrification of the industry sector reduces $CO_2$ emissions by 6% until 2050, a lower share of electricity in 2030 temporarily results in an increase of carbon emissions by 18%.
- Heat: The use of district strongly increases until 2030 in the Demand Reduction Scenario, but moderately decreases afterwards. This leads to a reduction of carbon emissions by 10% until 2050, while it temporarily rises to 22% in 2030.
- Fossil $CO_2$ intensity: Changes in the mix of fossil fuels result in an increase of $CO_2$ emissions by 7% until 2030 as well as 8% until 2050 compared to 2010.

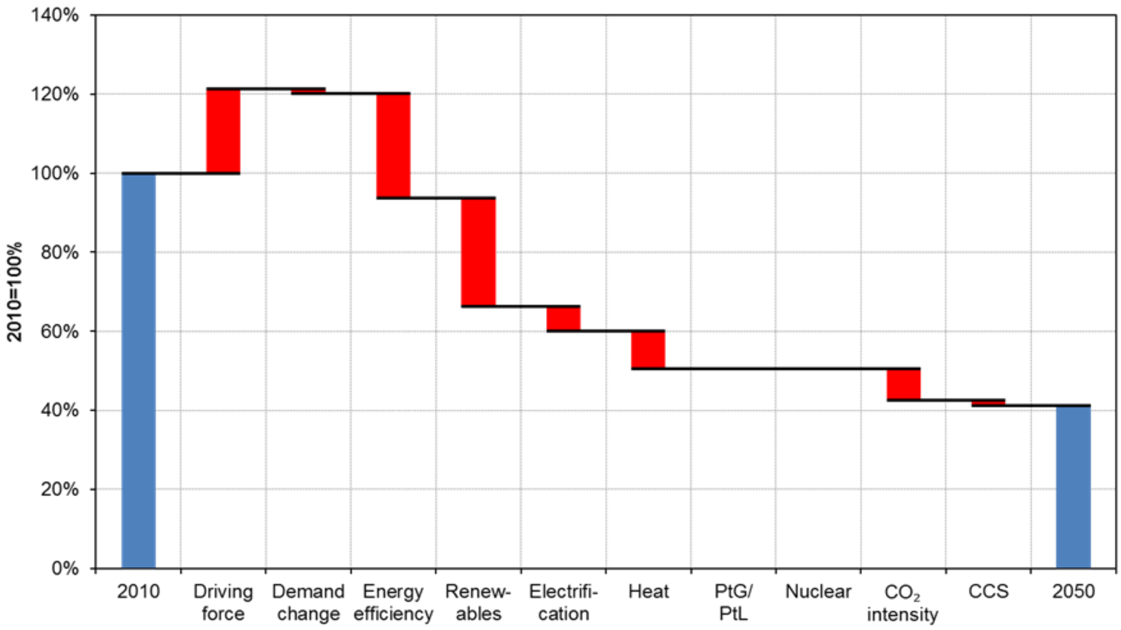
While the scenario allows for the application of CCS technology to reduce emissions in the industry sector, the use of CCS results in a reduction of energy-related $CO_2$ emission by only 1% in 2050 compared to 2010. Electricity-to-gas/liquid technologies are not applied as mitigation options in this scenario.

**Figure A 191: Italy, Pathways to Deep Decarbonization, Demand Reduction Scenario: Decomposition analysis for the industry sector, 2010–2030**




Source: Virdis et al. 2015, calculations by Fraunhofer ISI

**Figure A 192: Italy, Pathways to Deep Decarbonization, Demand Reduction Scenario: Decomposition analysis for the industry sector, 2010–2050**




Source: Virdis et al. 2015, calculations by Fraunhofer ISI

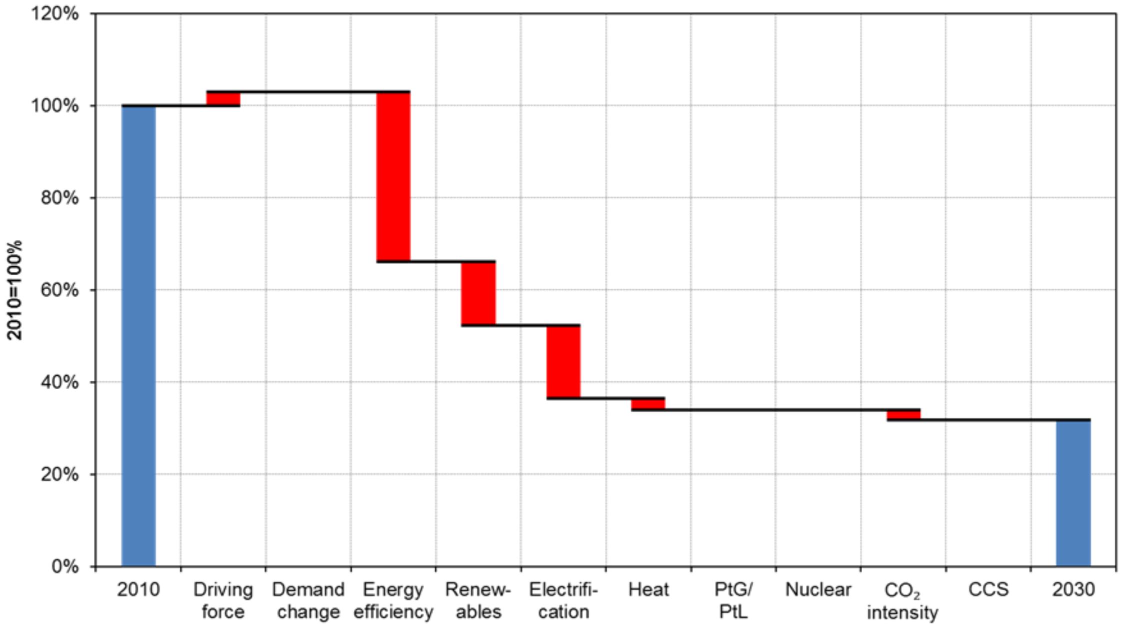
### A 3.3.2.3 Residential sector

In the residential sector, $CO_2$ emissions are reduced by 68% in 2030 and by 97% in 2050 compared to 2010. These reductions are significantly above the overall level of reductions of the scenario both in 2030 (Figure A 193) and in 2050 (Figure A 194). Main drivers of a decrease in $CO_2$ emissions in the residential sector are:

- Energy efficiency: Despite a growth in the number of households, total energy consumption in the residential sector reduces from 32 Mtoe in 2010 to 18 Mtoe in 2030 and 13 Mtoe in 2050. This means that energy efficiency (use of energy per household) contributes $CO_2$ emission reductions of 37% in 2030 compared to 2010 and of 28% in 2050 compared to 2010. Here, the lower value in 2050 reflects the overall lower carbon intensity in 2050.
- Renewables: The use of RES in the residential sector increases from 3.5 Mtoe in 2010 to 4.2 Mtoe in 2030 and 4.5 Mtoe in 2050. The resulting increase in the share of renewables leads to a continuous decrease of $CO_2$ emissions of 14% in 2030 and 27% in 2050 compared to 2010.
- Electrification: Despite the total decrease of the energy use in households, there is a small increase in the use of electricity from 6.0 Mtoe in 2010 to 6.7 Mtoe in 2050. In light of the decrease in overall energy use in households, this corresponds to emission reductions by 16% in 2030 and 37% in 2050 compared to 2010.
- Heat: District heating in households increases between 2010 and 2050 from 0.1 Mtoe in 2010 to 0.5 Mtoe in 2030 and 0.7 Mtoe in 2050. This results in a continuous decrease of $CO_2$ emissions by 3% in 2030 by 6% in 2050 compared to 2010.

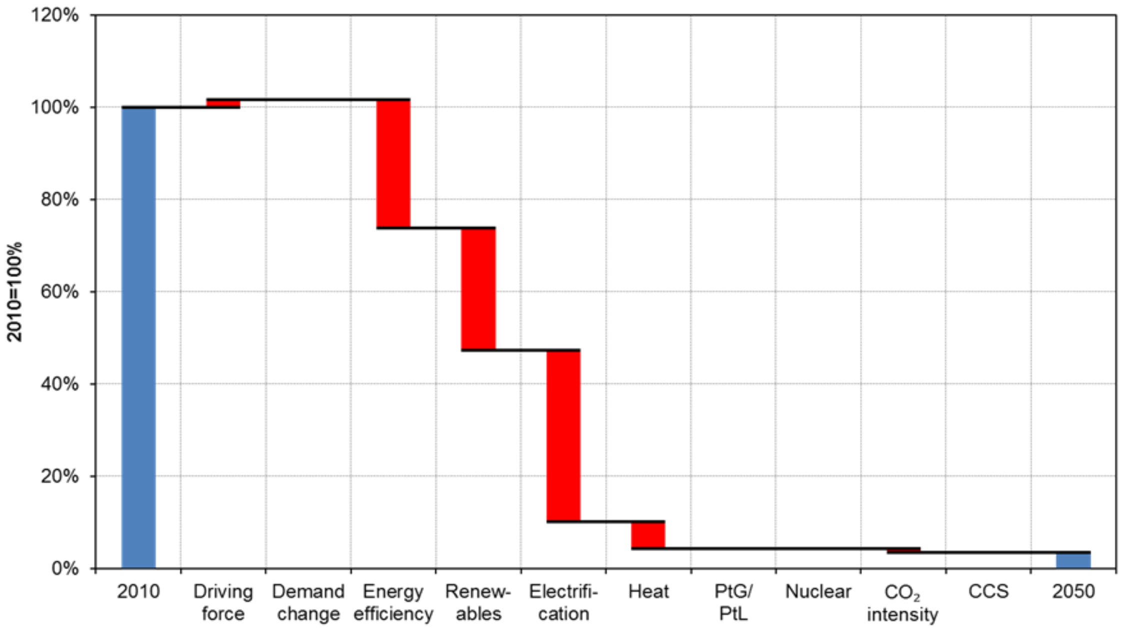
The effects of changes in numbers of households and fossil $CO_2$ intensity are small. Changes in household sizes and PtG/PtL are not used as mitigation options in the residential sector in the Demand Reduction Scenario, neither are nuclear energy and CCS.

**Figure A 193: Italy, Pathways to Deep Decarbonization, Demand Reduction Scenario: Decomposition analysis for the residential sector, 2010–2030**




Source: Virdis et al. 2015, calculations by Fraunhofer ISI

**Figure A 194: Italy, Pathways to Deep Decarbonization, Demand Reduction Scenario: Decomposition analysis for the residential sector, 2010–2050**




Source: Virdis et al. 2015, calculations by Fraunhofer ISI

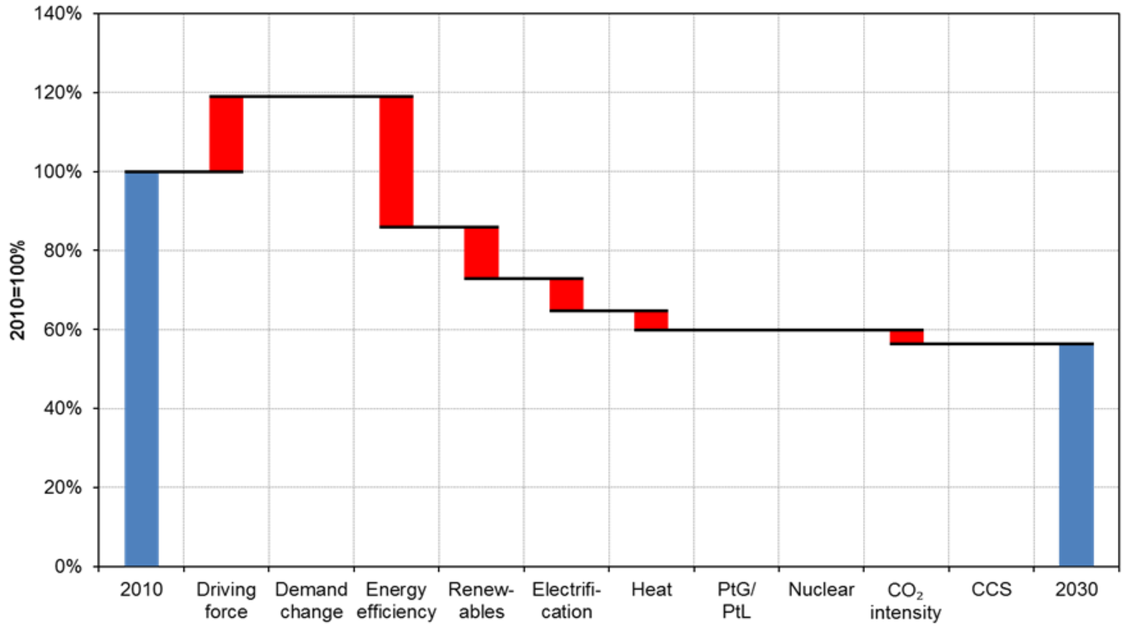
### A 3.3.2.4 Tertiary sector

In the tertiary sector, $CO_2$ emissions are reduced by 44% in 2030 and by 98% in 2050 compared to 2010. These reductions are significantly above the overall level of reductions of the scenario both in 2030 (Figure A 195) and in 2050 (Figure A 196). Main drivers of a decrease in $CO_2$ emissions in the residential sector are:

- Activity: The value added in the tertiary sector grows by 29% until 2030 and by 71% until 2050 compared to 2010. The results in a contribution to emission reductions of 19% in 2030 and 14% in 2050. Here, the higher value in 2030 reflects the overall higher carbon intensity in 2030 compared to 2050.
- Energy efficiency: Despite the growth of value added in the tertiary sector, total energy consumption reduces from 17 Mtoe in 2010 to 14 Mtoe in 2030 and 12 Mtoe in 2050. This means that energy efficiency (use of energy per value added) contributes $CO_2$ emission reductions of 33% in 2030 compared to 2010 and of 22% in 2050 compared to 2010.
- Renewables: The use of RES in the tertiary sector strongly increases from 0.1 Mtoe in 2010 to 1.2 Mtoe in 2030 and slowly rises to 1.6 Mtoe until 2050. The resulting increase in the share of renewables leads to a decrease of $CO_2$ emissions of 13% in 2030 and 20% in 2050 compared to 2010.
- Electrification: Despite the total decrease of the energy use in households, there is a strong increase in the use of electricity from 7.3 Mtoe in 2010 to 10.8 Mtoe in 2050. In light of the decrease in overall energy use in households, this corresponds to emission reductions by 68% in 2050 compared to 2010. Notably, the electricity demand temporarily reduces to 6.5 Mtoe in 2030, which results in much lower contribution to emission reductions until 2030 (8%).

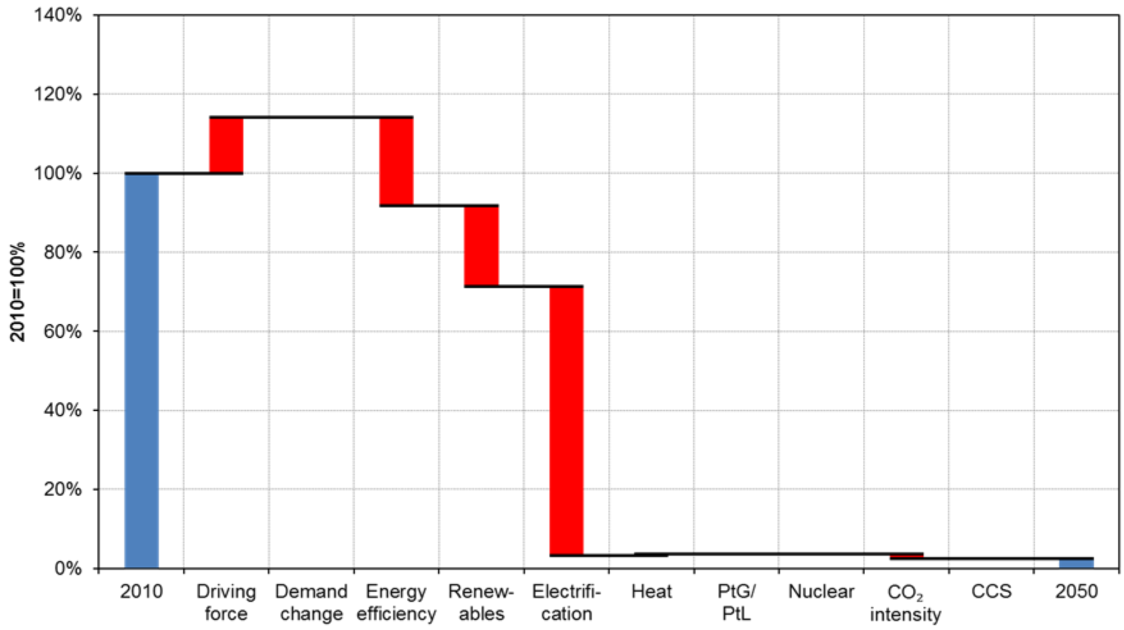
The effects of changes of the share of district heat and of fossil $CO_2$ intensity are small. Activity changes and PtG/PtL are not used as mitigation options in the tertiary sector in the Demand Reduction Scenario, neither are nuclear energy and CCS.

**Figure A 195: Italy, Pathways to Deep Decarbonization, Demand Reduction Scenario: Decomposition analysis for the tertiary sector, 2010–2030**




Source: Virdis et al. 2015, calculations by Fraunhofer ISI

**Figure A 196: Italy, Pathways to Deep Decarbonization, Demand Reduction Scenario: Decomposition analysis for the tertiary sector, 2010–2050**




Source: Virdis et al. 2015, calculations by Fraunhofer ISI

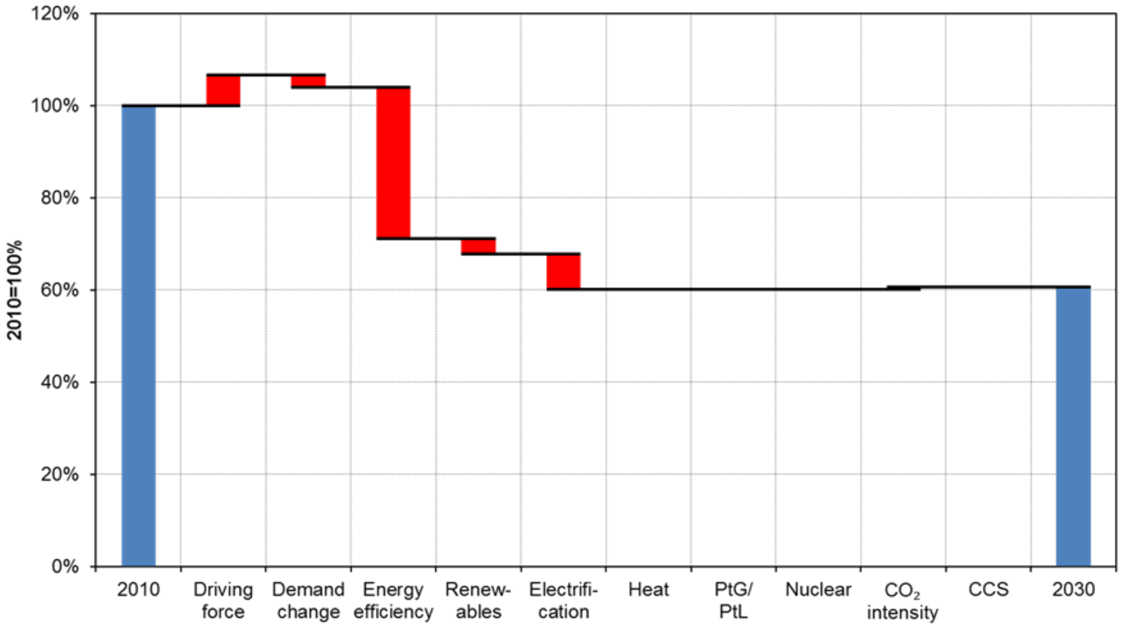
#### A 3.3.2.5 Passenger transport

In freight transport, $CO_2$ emissions increase by 39% until 2030 (Figure A 197) but decrease by 72% until 2050 (Figure A 198) compared to 2010. These reductions are moderately lower than the overall emission reductions in 2050 in the Demand Reduction Scenario. The most important drivers of changes in carbon emissions are:

- Activity growth and demand reduction: A key to the emission reductions until 2050 is the net decrease of passenger transport activity from 952 Gpkm in 2010 to 913 Gpkm in 2050. This results in a decrease of emissions from passenger transport by 2% compared to 2010. Here, the contribution of the demand reduction (-12%) more than compensates the impact of the rising activity in the reference scenario (+10%). Notably, net activity increases to 1002 Gpkm until 2030, which corresponds to an increase of carbon emissions by 4% in 2030.
- Energy efficiency: Energy efficiency (energy use per travel distance) yields the most important contribution to $CO_2$ emission reductions with a reduction of 41% until 2050 compared to 2010. The major part of the contribution is realized already before 2030 (33%).
- Renewables: Another important driver of emission reductions are biofuels, which rise from covering 16 Mtoe of energy demand in passener transport in 2010 to 58 Mtoe in 2050. This results in a decrease of $CO_2$ emissions of 7% in 2050 compared to 2010. The use of biofuels continuously increase with an intermediate level of 32 Mtoe in 2030, thereby leading to a decrease of emissions by 3% in 2030.
- Electrification: Electrification of passenger transport is one of the key drivers influencing $CO_2$ emissions. Electricity use in the passenger transport sector increases from 0.7 Mtoe in 2010 to 3.2 Mtoe in 2050 and results in $CO_2$ emission reductions of 17% by 2050 compared to 2010. Electrification continuously contributes to emission reductions with an intermediate level of 8% in 2030 (electricity consumption in 2030: 2.1 Mtoe).

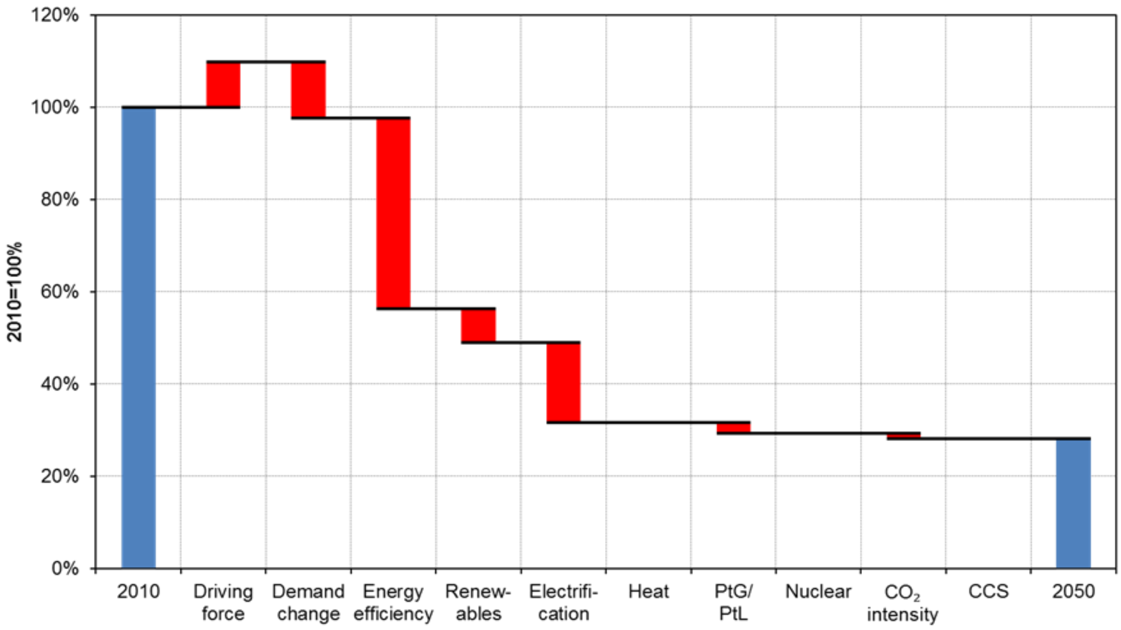
Via the use of hydrogen in fuel-cell vehicles, PtG/PtL is used as mitigation options in passenger transport sector in the Demand Reduction Scenario but with comparably low impact. The contribution from a switch to gaseous fuels is also comparably small. Neither heat, nuclear energy nor CCS are meaningful options for passenger transport.

**Figure A 197: Italy, Pathways to Deep Decarbonization, Demand Reduction Scenario: Decomposition analysis for the passenger transport sector, 2010–2030**




Source: Virdis et al. 2015, calculations by Fraunhofer ISI

**Figure A 198: Italy, Pathways to Deep Decarbonization, Demand Reduction Scenario: Decomposition analysis for the passenger transport sector, 2010–2050**




Source: Virdis et al. 2015, calculations by Fraunhofer ISI

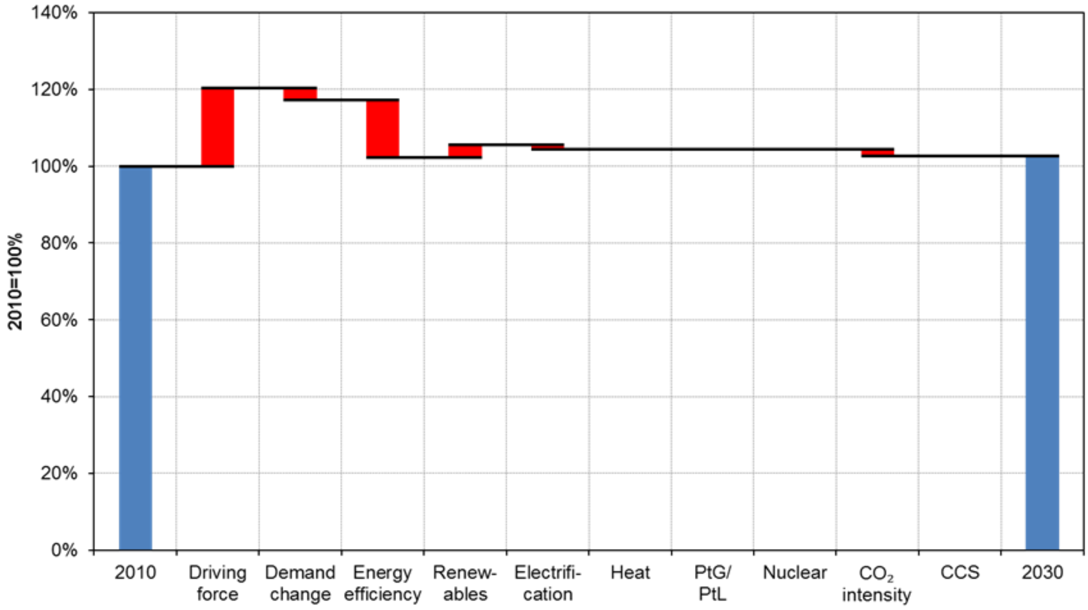
#### A 3.3.2.6 Freight transport

In freight transport, $CO_2$ emissions increase by 3% until 2030 (Figure A 199) but decrease by 76% until 2050 (Figure A 200) compared to 2010. These reductions are moderately lower than the overall emission reductions in 2050 in the Demand Reduction Scenario, but not realized before 2030 at all. Factors having a major effect on carbon emissions are:

- Activity and demand reduction: A key prerequisite for the emission reductions until 2050 is the net increase of emissions from changes in freight activity by only 1% compared to 2010. This reflects that the contribution of the demand reduction (-17%) almost completely compensates the impact of the rising activity in the reference scenario (+18%). Notably, the net activity increase corresponds to an increase of carbon emissions by 17% in 2030. This reflects the changes in activity, increasing from 189 Gtkm in 2010 to 224 Gtkm in 2030 and decreasing to 193 Gtkm in 2050.
- Energy efficiency: Energy efficiency (energy use per freight distance) yields an important contribution to $CO_2$ emission reductions 24% in 2050 compared to 2010. The contribution is substantial already before 2030 (15%).
- Renewables: The most important driver of emission reductions are biofuels, which rise from covering 0.6 Mtoe of energy demand in freight transport in 2010 to 5.6 Mtoe in 2050. This results in a decrease of $CO_2$ emissions of 45% in 2050 compared to 2010. Notably, the use of biofuels temporarily reduces to 0.1 Mtoe in 2030, thereby leading to an increase of emissions by 3% in 2030.
- Fossil $CO_2$ intensity: A second important driver after 2030 is a shift to gaseous fuels. It covers for 1.2 Mtoe of energy demand in the freight transport sector in 2050 (1.0 Mtoe in 2030). Thereby, it contributes 5.5% to $CO_2$ emission reductions in 2050 compared to 2010 (2% in 2030).

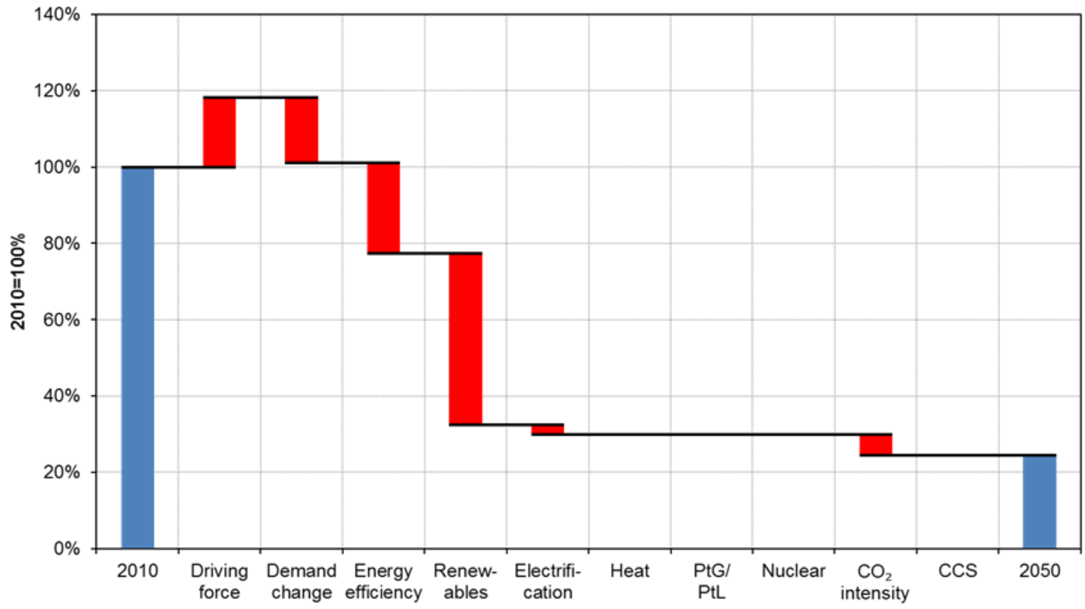
The contribution of electrification to the emission reductions in freight transport of 2% until 2050 is comparably small. PtG/PtL is not used as mitigation options in the freight transport sector in the Demand Reduction Scenario, neither are heat, nuclear energy and CCS.

**Figure A 199: Italy, Pathways to Deep Decarbonization, Demand Reduction Scenario: Decomposition analysis for the freight transport sector, 2010–2030**




Source: Virdis et al. 2015, calculations by Fraunhofer ISI

**Figure A 200: Italy, Pathways to Deep Decarbonization, Demand Reduction Scenario: Decomposition analysis for the freight transport sector, 2010–2050**




Source: Virdis et al. 2015, calculations by Fraunhofer ISI

## A 3.4 Poland: '2050.pl the journey to the low-emission future'

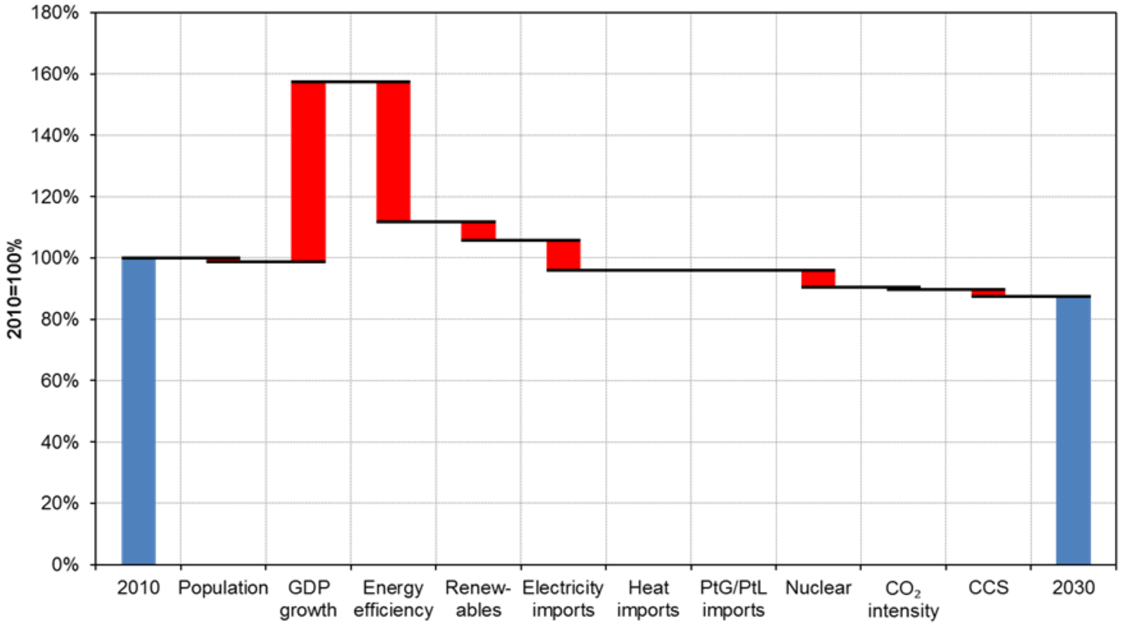
### A 3.4.1 Aggregate trends

The Scenario '2050.pl – the journey to the low-emission future' (Maciej Bukowski et al. 2013) attains a 13% reduction in energy-related $CO_2$ emissions until 2030 (Figure A 201) and 57% until 2050 (Figure A 202), compared to 2010. The main drivers, which the figures show in the following order, are:

- Productivity gains: While GDP per capita grows by 77% until 2050, this is mainly offset by a strong increase of primary energy productivity (65% less $CO_2$ per unit of GDP). The combination of both developments results in a 12% net increase of emissions in 2050. The net effect does not grow anymore after 2030 with intermediate levels of 59% of GDP growth and 46% productivity gains in 2030.
- Renewables: The expansion of RES is an important lever for reducing carbon emissions in the scenario. The primary energy supply from RES grows from 10 Mtoe in 2010 to 17 Mtoe in 2030 and 30 Mtoe in 2050. This yields a contribution equivalent to –6% of carbon emissions in 2030 and -18% in 2010.
- Increase of electricity imports and expansion of nuclear: The electricity import-export balance changes from marginal exports in 2010 to imports of 9 Mtoe in 2030 and 10 Mtoe in 2050, which results in a contribution to the decrease of carbon emissions of 9% (10% in 2030). In parallel, nuclear energy is established as an additional source for electricity production with 42 TWh in 2050 (32 TWh in 2030), which decreases carbon emission by -7% (-6% in 2030).
- Shift in fossil fuels: There is a strong shift from lignite coal to natural gas until 2050, which corresponds to a decrease of carbon emissions by 20%. Notably, the shift mainly occurs after 2030 with only – 1% emission reduction until 2030.
- Use of CCS: CCS appears as an important mitigation option in the electricity sector, in particular after 2030, with a corresponding of emission by 9% in 2050 (-2% in 2030).

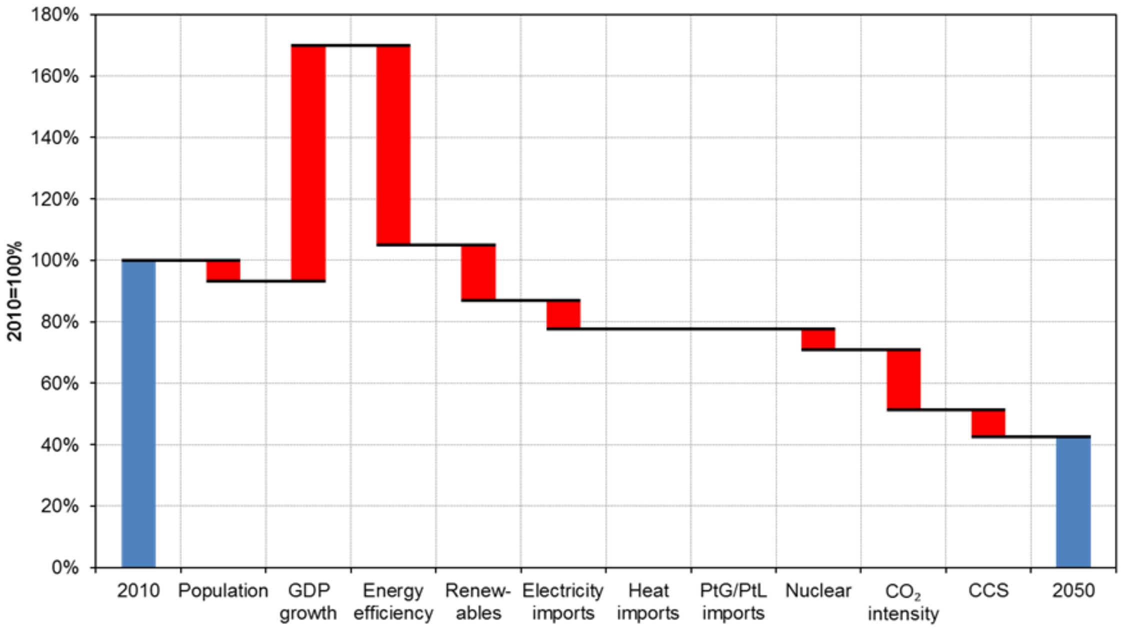
Compared to the above drivers, population decreases only slightly by 7% until 2050, and there is an import of neither heat nor synthetic fuels. In summary, the Scenario '2050.pl' uses productivity gains to establish a decoupling of economic growth and carbon emissions, while a broad set of mitigation levers is exploited to achieve additional absolute reductions of carbon emissions. The sector data available is not sufficient to apply a decomposition analysis on the sector level.

**Figure A 201: Poland, '2050.pl – the journey to the low-emission future': Decomposition analysis for aggregate trends, 2010–2030**




Source: Bukowski et al. 2013, calculations by Fraunhofer ISI

**Figure A 202: Poland, '2050.pl – the journey to the low-emission future': Decomposition analysis for aggregate trends, 2010–2050**




Source: Bukowski et al. 2013, calculations by Fraunhofer ISI

## A 3.5 Sweden: Energy Scenario for Sweden 2050

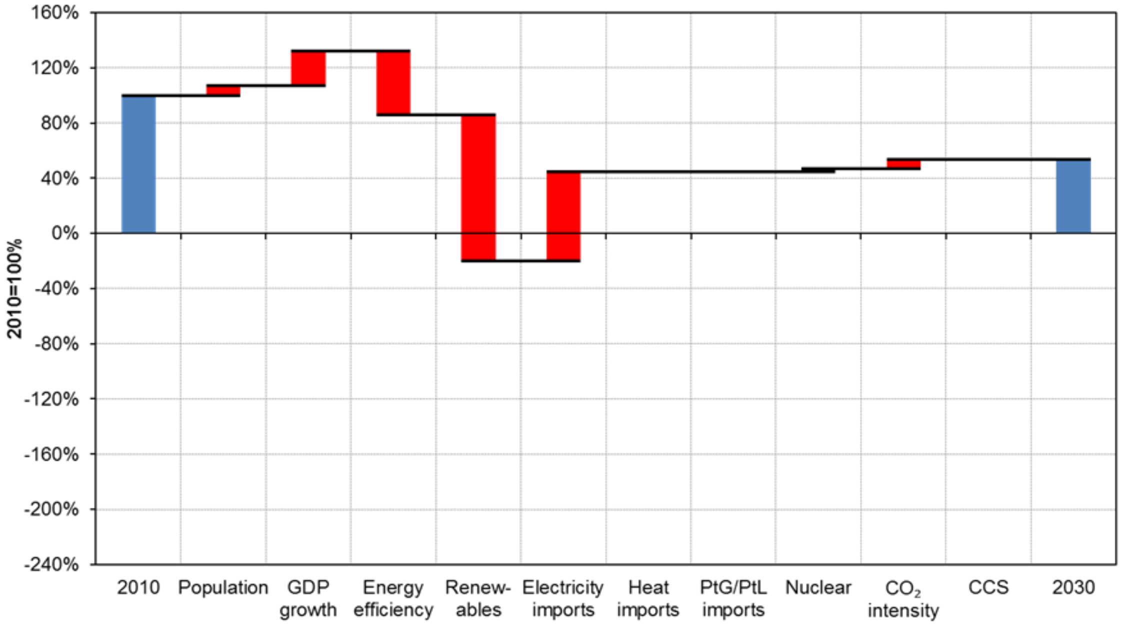
### A 3.5.1 Aggregate trends

The Energy Scenario for Sweden 2050 (Gustavsson et al. 2011) attains a 46% reduction in energy-related $CO_2$ emissions until 2030 (Figure A 203) and 85% until 2050 (Figure A 204), compared to 2010. The main drivers, which the figures show in the following order, are:

- Productivity gains: While GDP per capita grows by 34% until 2050, this is more than offset by a higher productivity in primary energy supply (56% less $CO_2$ per unit of GDP). The combination of both developments results in a 22% net decrease of emissions in 2050. The net effect does not grow after 2030 with levels in 2030 given by 25% of GDP growth and 47% productivity gains.
- Renewables: The expansion of RES is the strongest lever for reducing carbon emissions in the scenario. The primary energy supply from RES grows from 28 Mtoe in 2010 to 36 Mtoe in 2030 and 46 Mtoe in 2050. RES not only replace fossil fuels but also substitute nuclear energy and increase electricity exports thereby yielding a contribution equivalent to –106% of carbon emissions in 2030 and -298% in 2010.
- Phase out of nuclear and increase of electricity exports: Electricity exports increase to 8 Mtoe in 2030 and reach the same level in 2050, which results in a contribution to rising carbon emissions of 89% in 2050, respectively. In parallel, nuclear energy is phased-out of the electricity mix completely, which virtually increases carbon emission by 106%.
- Shift in fossil fuel mix: The remaining mix of fossil fuels in 2050 has a higher carbon intensity than the mix of 2010, which corresponds to an increase of carbon emissions by 34%.

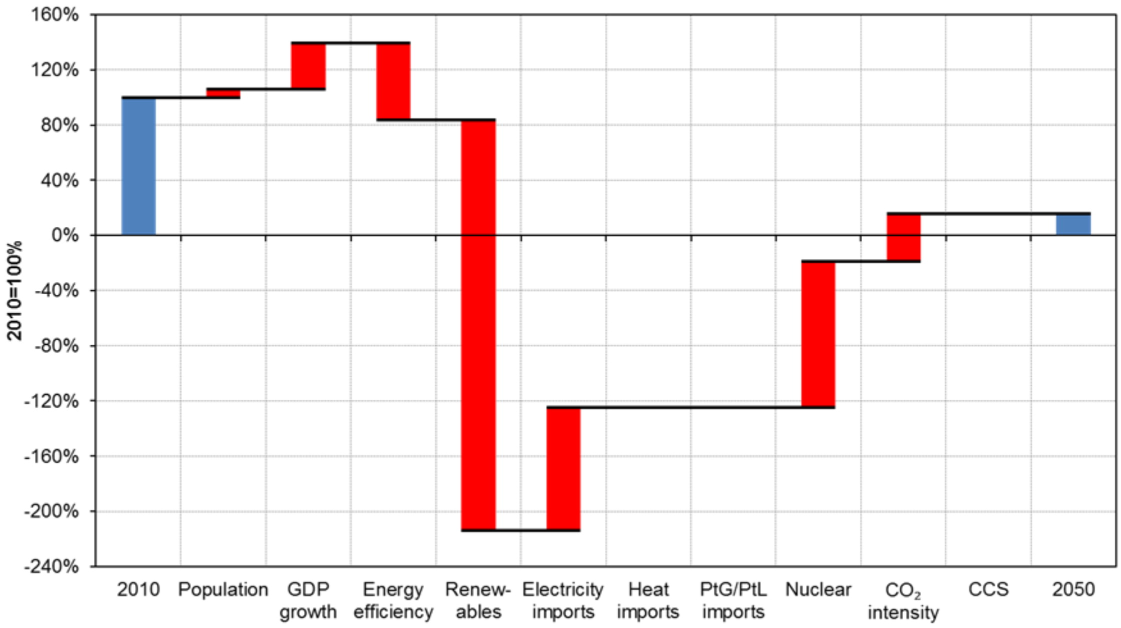
Compared to the above drivers, population changes only slightly by 6% until 2050, and the shares of imported heat, and synthetic fuels remain vanishing. In summary, the scenario exploits the large potentials of RES in Sweden and the already low share of fossil fuels to achieve both a nuclear phase-out and the national targets with regard to reducing GHG emissions at the same time. The sector data available is not sufficient to apply a decomposition analysis on the sector level.

**Figure A 203: Sweden, Energy Scenario for Sweden 2050: Decomposition analysis for aggregate trends, 2010–2030**




Source: Gustavsson et al. 2011, calculations by Fraunhofer ISI

**Figure A 204: Sweden, Energy Scenario for Sweden 2050: Decomposition analysis for aggregate trends, 2010–2050**




Source: Gustavsson et al. 2011, calculations by Fraunhofer ISI

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