Energy Efficiency Trends and Policies in Germany – An Analysis Based on the ODYSSEE and MURE Databases

Report prepared by

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Karlsruhe, August 2018

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Co-funded by the Horizon 2020 programme
of the European Union

CONTENT OF THE REPORT

This publication explores the overall and sectoral development of energy consumption and energy efficiency in Germany between 2000 and 2016, by means of different indicators together with a review of policy instruments that are currently implemented to improve energy efficiency. All this material was condensed and made available within ODYSSEE-MURE, a project for monitoring efficiency trends and policy evaluation in EU countries, Norway, Serbia and Switzerland.

The first part of the report is dedicated to the introduction to the ODYSSEE and the MURE databases and to their support tools for non-expert users. This section also includes the comparison between Germany's comprehensive performance on energy efficiency and one of the other project members, in the form of a scoreboard or ranking. Germany's overall results are disaggregated into specific rankings: energy efficiency level, energy efficiency trends and policies. The position in each one of them is explained throughout the document, based not only on the improvement of energy efficiency but also on other drivers affecting the energy demand, such as industrial growth, structural changes, lifestyle effect and other.

Next, the current energy efficiency context, as well as the description of the German policy background since 2010, constitute the first insight of the country's performance on energy efficiency. Looking toward a more detailed analysis, indicators on trends, drivers for energy use and policies are analysed by sector (residential, tertiary, transport and industry). The examined indicators also cover the previously mentioned ODYSSEE and MURE tools.

Finally, Germany's progress on energy efficiency and the missing efforts to accelerate it in the framework of the 2020 and 2030 targets establish the closing discussion of this report.

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1. INTRODUCTION

1.1. THE ODYSSEE AND MURE DATABASES

This report relies on data contained in two complementary databases: the ODYSSEE database on energy efficiency indicators (

Box **1: The ODYSSEE database and its tools**

The ODYSSEE database contains more than 180 indicators that have the purpose of monitoring and evaluating the annual energy efficiency trends and energy-related CO2 emissions in all the sectors and in priority areas to address EU policies. This database encompasses several types of indicators, calculated at a macro-economic, sectoral, sub-sector, specific industry and/or end-use level. Some of them are:

- *Energy and CO2 intensities*, which relate the energy used (or CO2 emissions) by sector to macro-economic variables (GDP, value added, etc.).
- *Specific energy consumption* (or CO2 emissions), which measures the energy efficiency progress by comparing consumption to physical units (e.g. consumption per ton of steel, per car or per dwelling, gCO2/km).
- *Energy efficiency indices (ODEX)* that evaluate energy efficiency progress by main and for the whole economy.
- *Energy savings* or the amount of energy saved through energy efficiency improvements.
- *Adjusted indicators* that allow the comparison of indicators across countries (adjustments for differences in climate, general price level, fuel mix, industry and economic structure).
- *Indicators of diffusion* that monitor the market penetration of energy-efficient technologies and practices.
- *Benchmark indicators*, which compare specific energy consumption of energy intensive products among countries.

Those indicators are accessible under different **data tools** that are publicly accessible (Figure 1): the *key indicators* and the *five specific data facilities* that focus on relevant issues. They aim to enable an easy and simple interface to policy makers, interested parties and non-trained users.

The *five specific data facilities* are:

- *Market diffusion:* monitors the progress in the market penetration of energy efficient technologies.
- *Decomposition analysis*: displays the various factors behind changes in energy consumption in a given period (e.g. activity changes, structural changes, behaviour, efficiency improvement).
- *Comparison*: compares of the energy efficiency performance of a country with selected others by adjusted indicators.
- *Energy saving*: overview of historical and projected energy savings as compared to targets to be achieved.
- *Energy efficiency indicator scoreboard*: it assesses and scores the energy efficiency performance by sector and country.

Figure 1: The ODYSSEE support tools and facilities for indicators

Box 2: The MURE database and its tools

The MURE database provides an overview of the most important energy efficiency policy measures in the EU Member States, Norway, Switzerland, Serbia, and the EU as a whole. The database is structured by final energy consumption sectors (household, tertiary, industry and transport) and also includes a general cross-cutting section. At the level of sectors, the focus is on single policy measures whereas programs comprising several measures are mainly described in the cross-cutting section. The homogeneity of measure descriptions over sectors and countries is ensured by detailed guidelines. All measures are classified according to specific keywords such as:

- their *status* (completed, on-going or proposed);
- their *year of introduction and completion*;
- their *type* (legislative/normative, e.g. standards for new dwellings, legislative/informative, e.g. obligatory energy labels for appliances, financial, e.g. subsidies, fiscal, information/education and cooperative);
- the targeted *end-uses* and the *main actors* involved by the policy measures;
- their *semi-quantitative impact (*low, medium or high impact, based on quantitative evaluations or expert estimates);
- the involved *end-uses* and the *quantitative impact* of the policy measure related to a specific end-use.

There are two additional categories in the MURE database that allow a separate analysis of policy measures from specific sources:

- If a measure is included in the National Energy Efficiency Action Plan under the former EU Energy Efficiency and Service Directive ESD (2006/32/EC) and the current Energy Efficiency Directive (2012/27/EU, EED) respectively, it is classified as "NEEAP measure". Distinction is also made between the 1st, 2nd, 3rd and 4th NEEAPs, the reporting on energy efficiency obligation schemes and alternative measures under Article 7 of the EED. This allows an easy identification of policy measures reported in the NEEAPs and under Article 7 EED.
- Measures that are common to all countries ("EU measures") are separated from pure national measures.

MURE comprises six *policy facilities* (

Figure 2) that focus on specific topics and facilitate the analysis:

- *Specific policy topics* enables to query energy efficiency policies by selected topics (for example policies aiming at buildings, small and medium sized companies SMEs, etc.).
- *Successful policies*: aims at identifying successful and promising energy efficiency policies.
- *Policy interaction*: enables to characterise packages of policies and their interaction.
- *Policy mapper*: provides a visualisation of all policies aiming at a given end-use and related energy

efficiency indicators.

- *Energy efficiency policy scoreboard* assesses and scores the energy efficiency policies by sector and country.
- *Impact evaluation*: provides a structured approach to evaluation methods and good practices of impact evaluations in all countries considered in the MURE database.

) and the MURE database on energy efficiency policies (Box 2). Both databases are regularly updated (one or twice a year) by a network of national correspondents from all EU Member States, Norway, Switzerland and Serbia. Enerdata provides the technical coordination for ODYSSEE and Fraunhofer-ISI MURE.

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ODYSSEE

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Figure 1: The ODYSSEE support tools and facilities for indicators[1]

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[1] http://www.indicators.odyssee-mure.eu/ (Public access)

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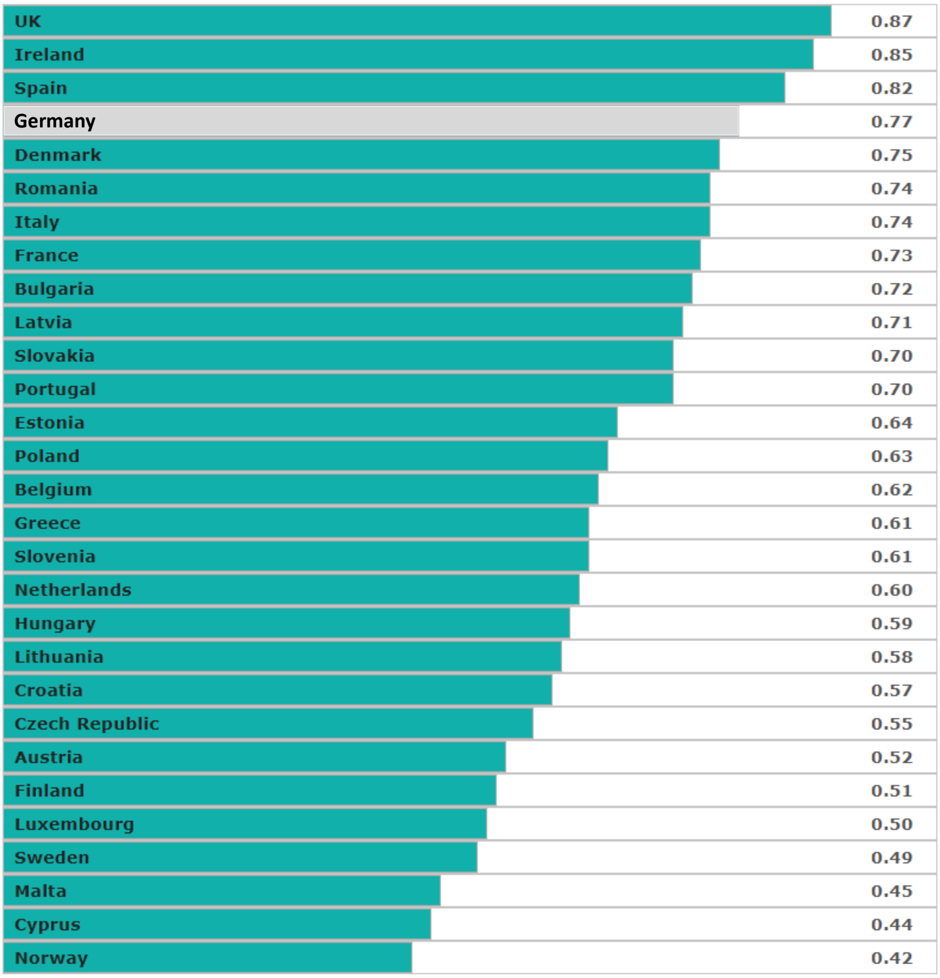
Figure 2: The MURE support tools and facilities for indicators[2]

[2] http://www.measures-odyssee-mure.eu/ (Public access)

1.2. THE COMBINED ODYSSEE AND MURE SCOREBOARD

The overall energy efficiency efforts of the member countries are compared via scoreboards on energy efficiency indicators and policies. This should help them understand whether they can learn from other countries and encourage them to climb higher up the ranking. The notion of scoring efforts is present in nearly all areas of life due to its continuous improvement effect. In the case of energy efficiency, there are widely differing scoring instruments such as the ACEEE International Energy Efficiency Score Board (for 2012, 2014 and 2018)[3], the IEA Energy Efficiency Score Boards (for 2009 and 2011)[4], among others. Despite the great value of the existing metrics and rankings, a scoreboard composed of the gathered information within ODYSSEE-MURE, and matching its methodological approach, has been built (Figure 3).

Figure 3: The Combined energy efficiency scoreboard, 2016[5]



Source: ODYSSEE database

The **Combined Scoreboard** for energy efficiency indicators and policies is obtained as an average (i.e. one third weighting) of three criteria: the energy efficiency level and the energy efficiency trend (that come from the

[3] http://aceee.org/research-report/i1801
[4] https://www.iea.org/publications/freepublications/publication/IEA_Scoreboard2011.pdf
[5] http://www.indicators.odyssee-mure.eu/energy-efficiency-scoreboard-combined.html (Public access)

ODYSSEE Scoreboards for Indicators) and the results and impacts of energy efficiency policies (resultant from the MURE Scoreboard for Energy Efficiency Policies).

Germany is among the top five countries in this overall energy efficiency scoreboard, just behind the UK, Ireland and Spain. In order to understand Germany's position, the scoreboards per criteria are presented next, followed by the detailed analysis on energy efficiency trends and implemented policies in the subsequent sections.

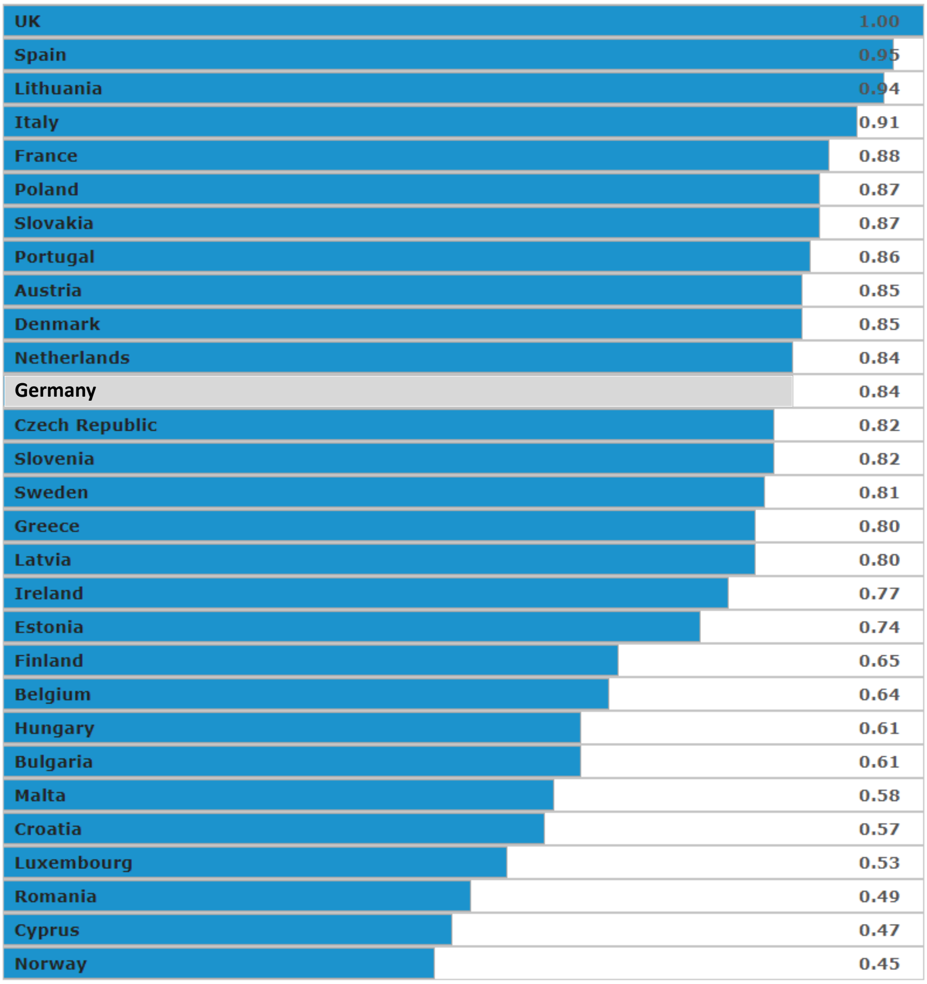
The scoreboards of energy efficiency **level** and **trend** (the ODYSSEE Scoreboards for Indicators) are a composite of an independent sector scoring, which is based on a group of indicators that to show either the country's state of unit energy consumption or energy intensity in a specific period (i.e. the **energy efficiency level**), or their progress or evolution as to a base year (i.e. **the energy efficiency trend**).

With respect to **energy efficiency level**, Germany is ranked 12th (

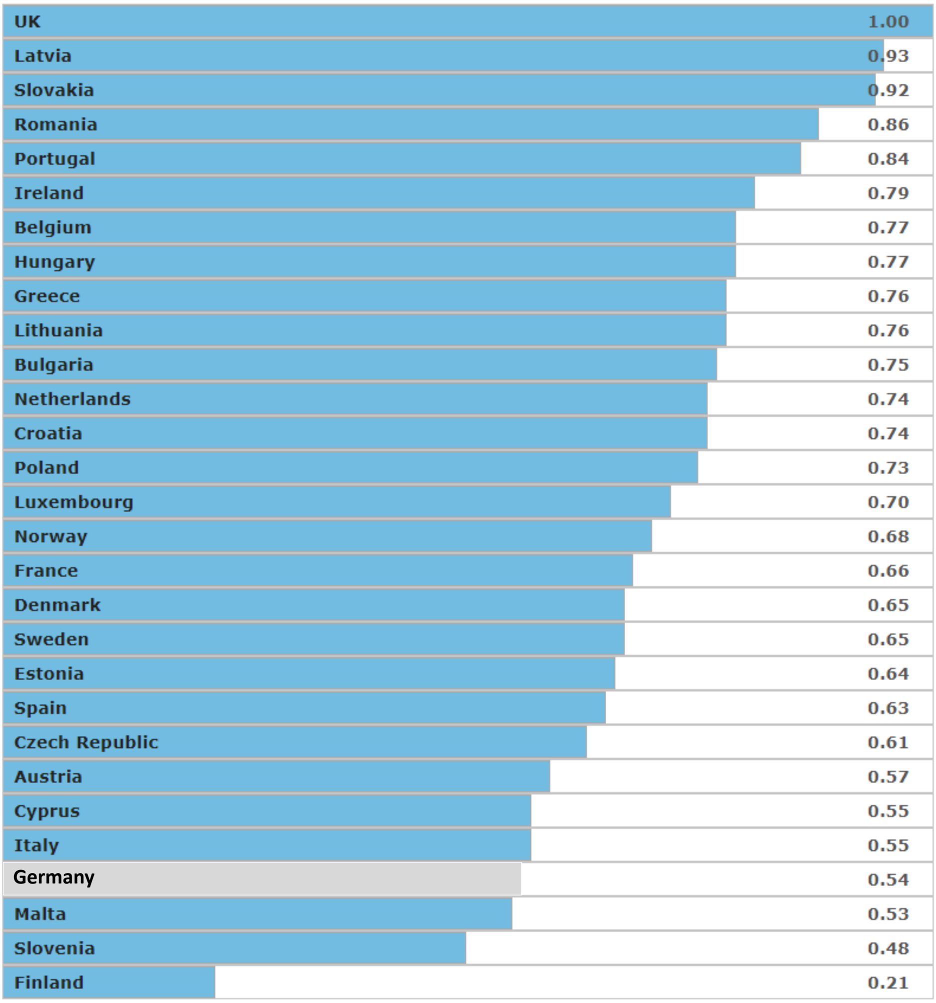
Figure 4). It is a less advantageous post than the one in the Combined Scoreboard, but it still corresponds to the first half of the scored countries. On the other hand, the country falls back in terms of **energy efficiency trend** and occupies a position at the bottom, which may have negative repercussions on the energy efficiency level in the coming years.

Figure 4: The ODYSSEE Scoreboards for Indicators, 2016

SCOREBOARD FOR ENERGY EFFICIENCY LEVEL



SCOREBOARD FOR ENERGY EFFICIENCY TREND



Source: ODYSSEE database

Annex 1 contains the scoring methodology of both ODYSSEE and MURE Scoreboards of calculation and

Table 1 outlines the indicators that are the input of this methodology and upon which the rankings are obtained. They comprise specific consumption indicators, i.e. total consumption per physical units, and development over time of consumption or energy savings. The most important will be included in the analysis of Germany's score results, together with other energy efficiency, energy consumption and economic trends.

Table 1: Components behind the scores of energy efficiency level and trend[6]

HOUSEHOLD

End-use	Indicator	Weighting factor
Heating	Consumption for heating per square meter scaled to EU climate and equivalent to central heating	Share of heating in total households consumption
Other thermal uses	Consumption per dwelling for cooking and water heating	Share of cooking + ½ of water heating in total households consumption
Applicances	Specific consumption of electricity per dwelling for appliances (including AC) and lighting	Share of appliances (incl. AC) & lighting in households consumption
Solar penetration	% of dwellings with solar water heater	½ share of water heating in households consumption

SERVICES

End-use	Indicator	Weighting factor
Thermal end-uses	Thermal end-uses consumption per employee scaled to EU climate	Share of thermal end-uses in total services
Electricity	Specific consumption of electricity per employee (including AC and excluding thermal uses)	Share of specific electricity consumption in total services

TRANSPORT

End-use	Indicator	Weighting factor
Cars	Specific consumption (l/100km)	Share of cars in total transport consumption
Trucks and light vehicles	Specific consumption (goe[7]/tkm)	Share of trucks and light vehicles in total transport consumption
Air	Specific consumption (koe/pass)	Share of air in total transport consumption
Modal split: **- Passengers** **- Goods**	% of traffic by public mode % of traffic by rail and water	Share of buses and rail passengers in total transport consumption Share of water and rail freight consumption in total transport

INDUSTRY

Catergory	Indicator
Indicator of trend	ODEX (energy efficiency index)
Indicator of level	Adjusted energy intensity at EU industry structure

[6] See further information in the methodology of the ODYSSEE scoreboard: http://www.indicators.odyssee-mure.eu/php/odyssee-scoreboard/documents/methodology-odyssee-scoreboard.pdf

[7] goe: grams of oil equivalent; tkm: ton-kilometer (transport of one ton of payload a distance of one kilometer)

The MURE **Scoreboard for Energy Efficiency Policies** has also a bottom-up approach. The net energy savings achieved thanks to adopted energy efficiency measures ("policy output") are calculated per sector (residential, services, transport and industry) and then compared to the final energy consumption. Afterwards, the weighted average of this percentage of attained savings is obtained per country using each sector's share.

Germany's success on the Combined Scoreboard is evidently propelled by the second position in the Scoreboard for Energy Efficiency Policies (Figure 5). This levels up the more modest performance on energy efficiency level and trend and may provide the basis of future improvement in the general score, as the "Energiewende" policies translate into practice. The top-level result in the Scoreboard for Energy Efficiency Policies is the outcome of positive policy results across all sectors, according to the breakdown displayed in Table 2.

Figure 5: The MURE Scoreboard for Energy Efficiency Policies, 2016

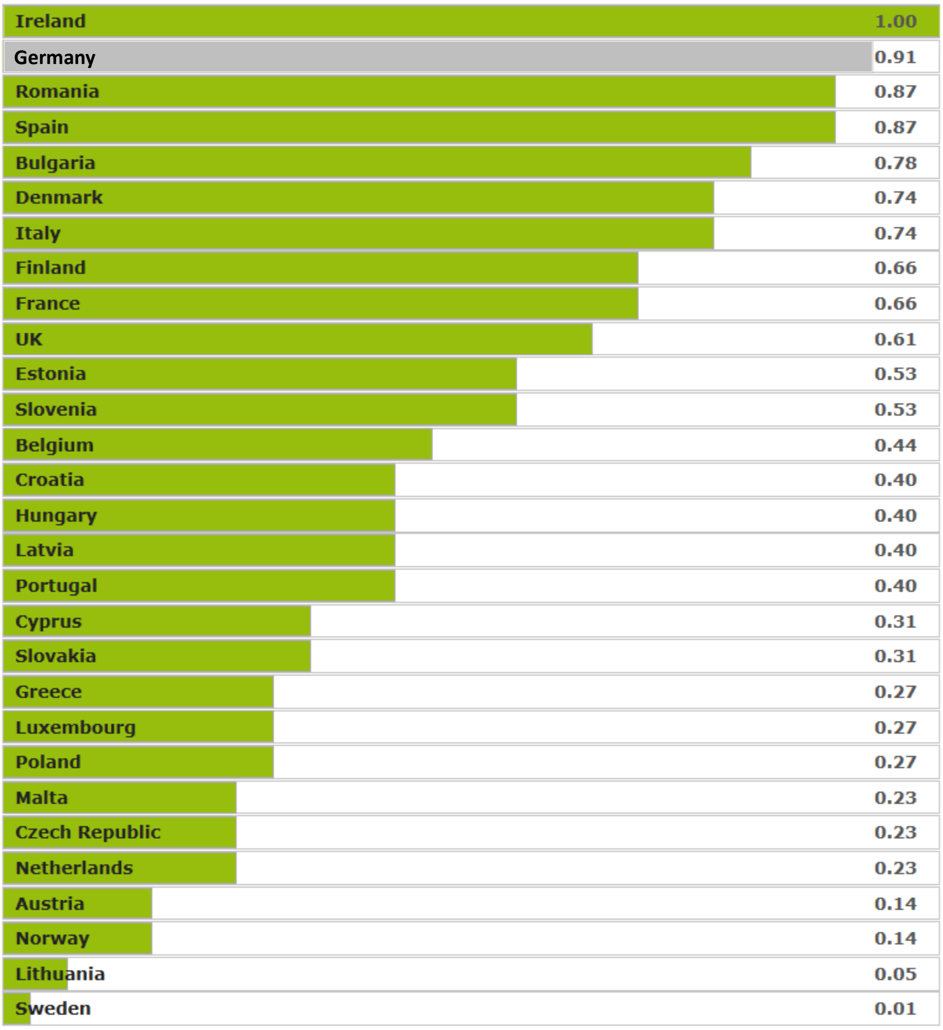


Table 2 displays a disaggregated overview of the scores per sector. More details on how sectoral performance influenced the results of Germany's energy efficiency performance are outlined in the coming chapters.

Table 2: Germany's overall and sectoral position by criteria in the combined Scoreboard[8]

Sector / Country		Level	Trend	Policies	Combined
Overall	Germany	12 / 29	26 / 29	2 / 29	4 / 29
	Highest score (benchmark)	UK	UK	Ireland	UK
Industry	Germany	9 / 28	27 / 28	4 / 29	13 / 29
	Highest score (benchmark)	Italy	Lithuania	Denmark	Denmark
Transport	Germany	16 / 29	15 / 29	3 / 29	7 / 29
	Highest score (benchmark)	Italy	UK	Spain	Spain
Households	Germany	13 / 29	16 / 29	2 / 29	3 / 29
	Highest score (benchmark)	Bulgaria	Ireland	Ireland	Ireland
Services	Germany	18 / 29	7 / 29	5 / 29	5 / 29
	Highest score (benchmark)	Lithuania	Hungary	Ireland	Ireland

[8] http://www.indicators.odyssee-mure.eu/energy-efficiency-scoreboard-combined.html (public access)

1.3. THE MULTIPLE BENEFITS TOOL IN ODYSSEE-MURE

For a more holistic assessment of the benefits of energy efficiency measures it is necessary to consider as many of their effects as possible. To cover other aspects of energy efficiency then energy savings and provide a proper quantification an online tool regarding the so-called multiple benefits of energy efficiency was integrated into the ODYSSEE-MURE tool set[9]. For this "web facility" a comprehensive set of 20 indicators was developed classified into three main groups: environmental, economic and social (see Figure 6).

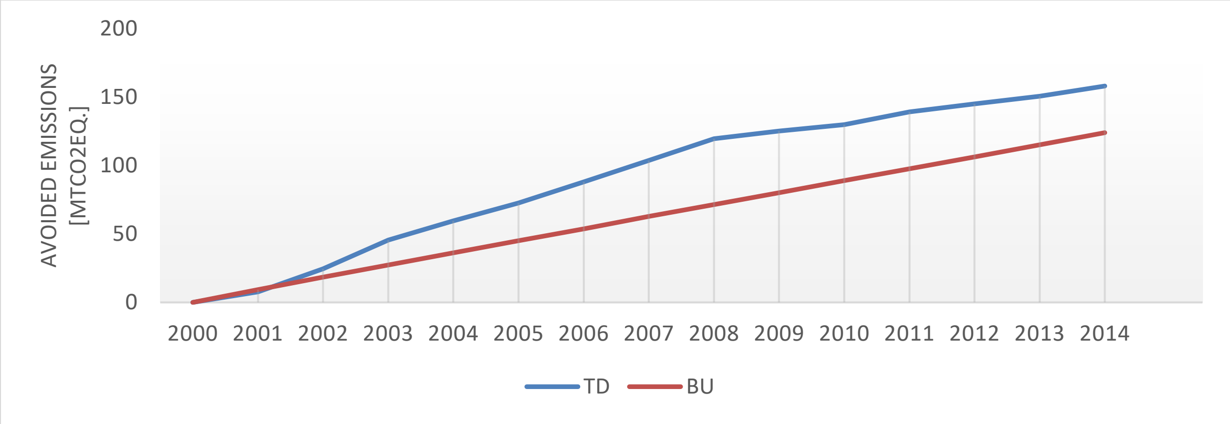
Figure 6 : Indicators of the Facility on Multiple Benefits of Energy Efficiency

The first group contains most relevant and direct aspects of energy efficiency such as energy savings and reduced GHG emissions. The second group comprises, among others, positive macro-economic impacts on economic growth, for innovation and competitiveness as well as import dependency. The third group of impacts covers aspects such as health benefits, poverty alleviation and employment. In order to calculate the various indicators, the energy savings are used as input wherever possible. These energy savings are top-down saving on the one hand and bottom-up savings on the other. Top-down (TD) results are based on savings calculated using the energy statistics of the ODYSSEE database. In contrast, bottom-up (BU) results are based on the policy evaluations from the MURE database.

As an example for Germany, we only consider a selection of indicators in this report. These include the emissions avoided by energy efficiency, the effect of energy efficiency on disposable household income and the impact on Germany's dependence on imports.

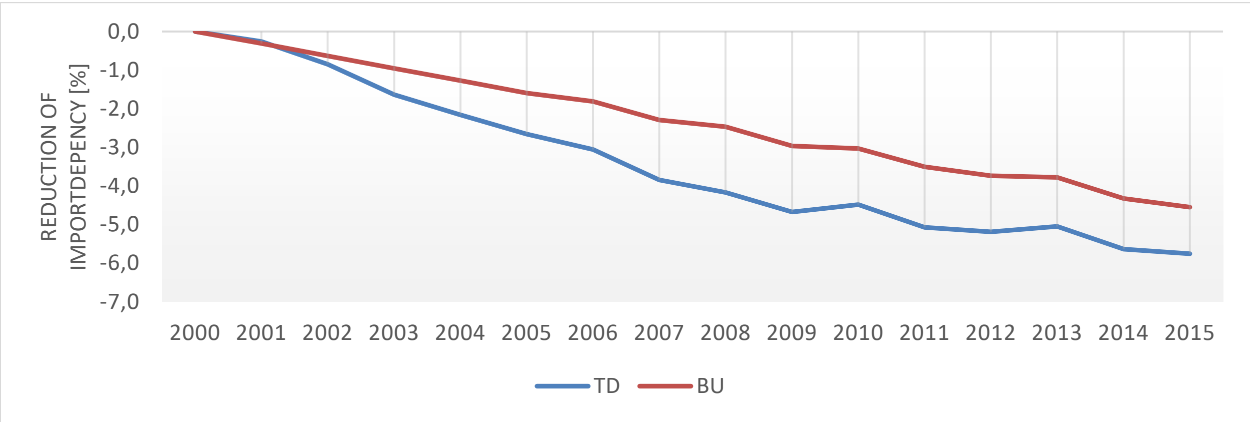
[9] http://www.odyssee-mure.eu/data-tools/multiple-benefits-energy-efficiency.html

Figure 7: Emission avoided by energy efficiency compared to the year 2000 for Germany (2000-2014)



CO_2 savings are calculated by multiplying the total energy savings by sector by the average emission factor of the sector (tCO_2/toe). This ratio is calculated by dividing the total CO_2 emissions of the sector (including the indirect CO_2 emissions from the power sector and heat production) by its final energy consumption, both data coming from the ODYSSEE database. The CO_2 savings are expressed in relation to 2000. As Figure 7 shows energy savings in Germany resulted in around 160 Mt of CO_2 equivalent in 2014 due to top-down savings. Considering bottom-up saving the saved emissions amount to 124 $MtCO_2eq$.

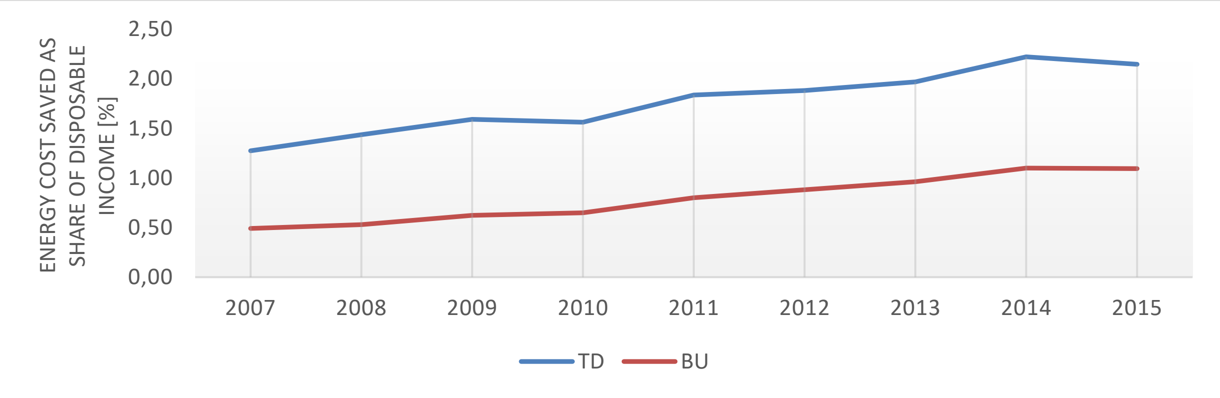
Figure 8: Changes in import dependency of Germany due to energy efficiency (2000-2015)



To estimate the impact of energy efficiency on the import dependency of a country as a first step the energy consumption avoided by energy efficiency by energy carrier (i.e. electricity, fossil fuels, etc.) is calculated. These are translated to energy savings by fuel based on typical energy carrier breakdown per end-use. Ensuing we calculate the resulting avoided primary energy supply by energy carrier using national primary energy factors, which is then used to calculate a counterfactual import dependency (for the sum of actual imports and calculated avoided imports). The difference between this counterfactual value and the actual import dependency (e.g. provided by Eurostat) represents the estimated effect of energy efficiency on the import dependency of a country. Figure 8 shows the difference between the two calculated values, thus giving the reduction of import dependency. In 2015 the import dependency of Germany was reduced by almost 5.8 percentage points (TD-savings) or 4.6 percentage points (BU-savings) due to the reduction of primary energy consumption and the accompanied avoided imports linked to the increased energy efficiency.

Energy efficiency can have a range of social benefits to households. Most important, disposable household incomes can be increased by energy efficiency in space heating, hot water generation or energy-using products like fridges or TVs, given that the measures conducted are cost-effective. In order to be able to quantify this social aspect in private households, we have here calculated the influence of energy efficiency in the household sector on disposable household income.

Figure 9: Impact of energy effiiciency on the share of energy costs in disposable household income in Germany



For this purpose, we have broken down the energy savings in households based on the typical energy mix into the various energy sources at which we can calculate the reduction of the burden on households through energy costs with the respective specific costs. Using the statistics on the shares of energy costs in household disposable income and their absolute amounts, we can calculate the reduction of the share through energy efficiency. These calculations result in a reduction of the share of energy costs in the total disposable household income in Germany between 1.3 and 2.1% (TD-savings) or 0.5 to 1.1% (BU-savings) in the period 2007 to 2015 (see Figure 9).

These three indicators from the set show only a small part of the overall picture of the effects energy efficiency has, but this already makes clear the importance of energy efficiency for all kinds of different aspects, be they economic, environmental or social. This underlines the need to consider these side effects as fully as possible, in addition to energy savings.

2. OVERALL ECONOMIC AND ENERGY EFFICIENCY CONTEXT

2.1. ECONOMIC CONTEXT

Given the influence of economic growth over energy consumption, this chapter starts by evaluating the German economic context for the period between 2000 (base year) and 2016. This is approached from a global perspective with the Gross Domestic Product (GDP) and from the national production and consumption standpoints, with the industry value added and the private consumption of households respectively

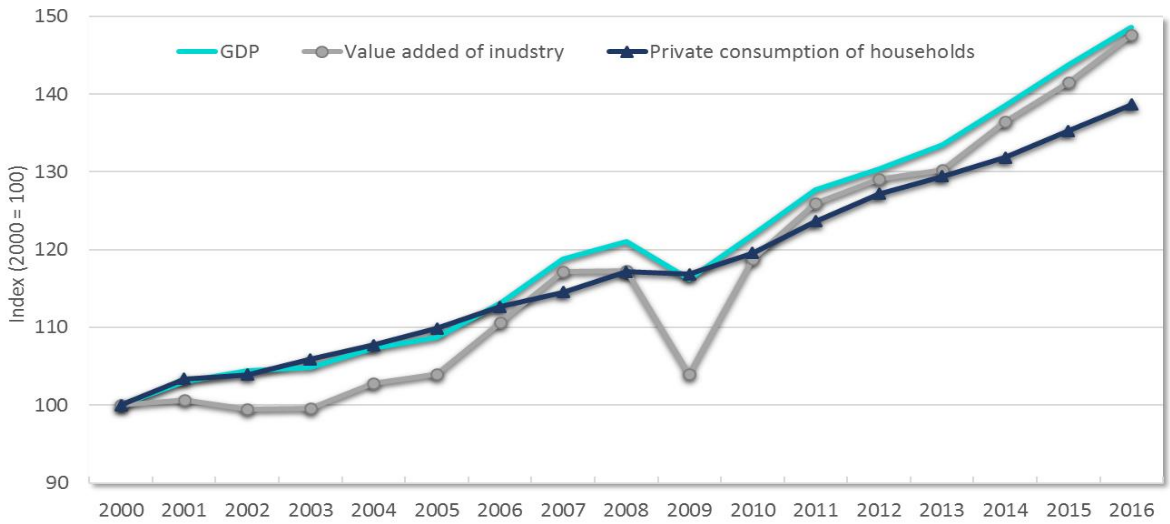
Figure 10).

The financial and economic crisis, which had its first impacts in 2008, sharply affected the industry growth compared to other sectors. For instance, the industry value added dropped 11% between 2008 and 2009, whereas the tertiary sector only fell 1%.

As the industry represents 27% over the GDP, this dip had substantial repercussions on the overall economic growth during this period. However, the German GDP, that today amounts to 3.144 billion € (or 2.843 billion €10), has continuously increased thereafter, with a yearly steady expansion of roughly 3% since 2008 and 4,2% since 2014.

After the financial slump, the industry took the spotlight from private consumption as an economic growth driver. In fact, the industry value added has increased in average at a more rapid rate than the private consumption since 2008. The reasons behind are the economic stimulus efforts undertaken by Germany even before the recession (e.g. the "Kurzarbeit[10]" or subsidy for short-time employment) and the post-crisis austerity measures adopted by the household.

Figure 10: Macro-economic development in Germany, 2000 - 2016[11]



Source: ODYSSEE database

[10] https://www.bmas.de/DE/Themen/Arbeitsmarkt/Arbeitsfoerderung/kug.html

[11] The macro-economic indicators are shown as an index with 2000 as base year. In other words, it shows the annual variation with respect to the year 2000. "Current national currency" is the unit of the data of origin.

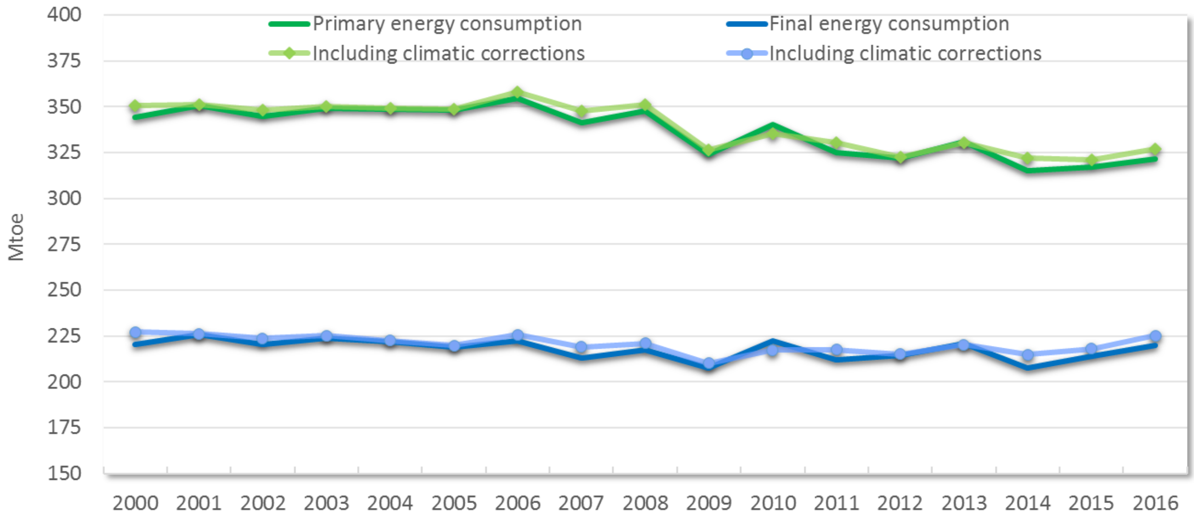
2.2. DEVELOPMENT OF ENERGY CONSUMPTION AND ENERGY EFFICIENCY TRENDS

2.2.1. ENERGY CONSUMPTION

The total energy consumption in Germany (or primary energy, not temperature-corrected) declined 6% between 2000 and 2016, a fall from about 344 to 322 Mtoe in 2016 [12] (Figure 11). Taking a closer look, the decrease has been pulled by the period after the financial recession (-5.32%), with 2014 as the lowest point after the drastic drop in 2009 due to the slump. Between 2000 and 2007 the variation remained stable. Peculiarly, the energy required by the end users (or final energy, not temperature-corrected) has minimally increased 0.7% over 2000-2016, also driven by the post-recession period.

The impact of weather fluctuations on energy consumption is shown by the different development of the actual and the climate-corrected consumption[13] (Figure 11). Except for the colder years 2010 and 2013, the climate corrected primary and final energy consumptions are higher than the actual consumption. 2000, 2007 and 2014 are among the 10 warmest years since 1881[14], and both 2015 and 2016 continued with this upward behaviour, making more meaningful the gap between temperature-corrected and the non-corrected consumption. This means that since 2014 the actual yearly consumption gradually decreases and moves further away from the expected consumption under the experienced weather conditions.

Figure 11: Development of primary and final energy consumption in Germany, 2000 – 2016



Source: ODYSSEE database

Additionally,

Figure 12 shows a larger decoupling between the GDP and the primary energy consumption from 2008. A higher economic growth was possible (3% yearly GDP increase since 2008) with a much lower progression of the energy consumption (-0.6% per year since 2008). Although 2015 and 2016 show a consecutive rise in

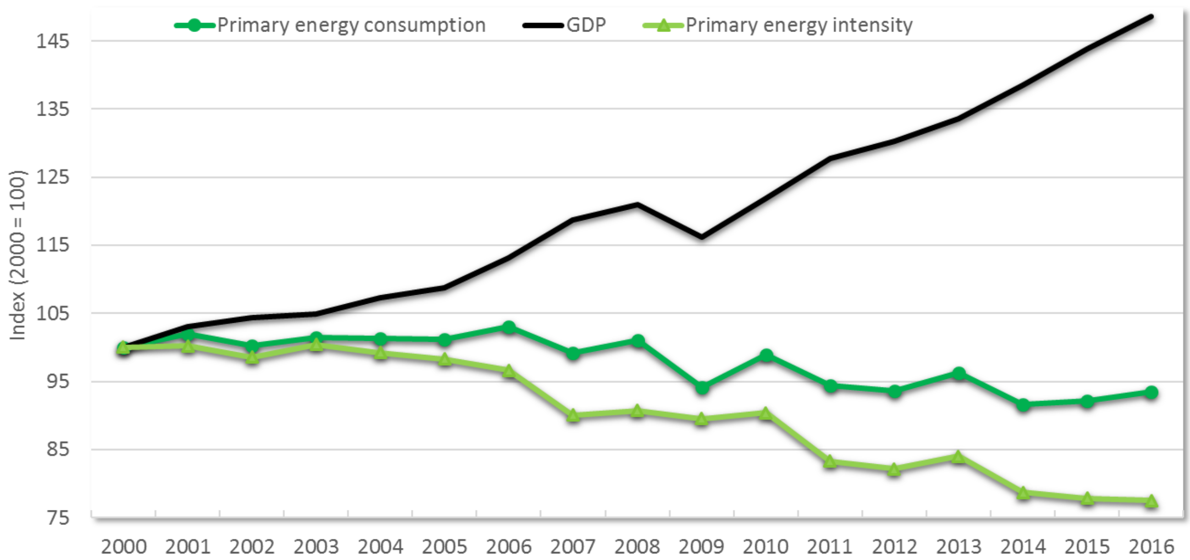
[12] Both consumption variations are non-climate-corrected values.

[13] The climatic correction refers to an adjustment of the space heating part of the consumption of the residential and service sectors, to the levels of a normal winter (long term average). The purpose of it is to leave out the influence of cold winter. This is particularly important when there are large climatic variations from one winter to the other.

[14] https://www.dwd.de/EN/ourservices/nationalclimatereport/download_report_edition-3.pdf?__blob=publicationFile&v=4

energy consumption after the 2014 steep fall, future data will confirm if the decoupling trend is strengthened or undermined.

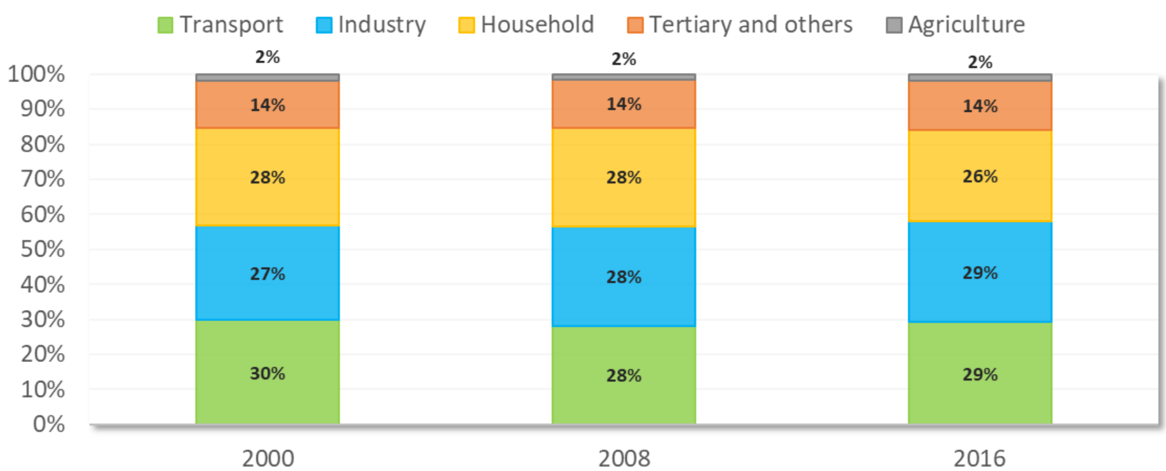
Figure 12: Decoupling of energy consumption and GDP, 2000 - 2016



Source: ODYSSEE database

The transport and industry sectors account for two-thirds of the final energy consumption with a relatively equal share. To their benefit, the residential sector has gone down 2% during the past 8 years. (Figure 13). However, there have been no fundamental changes since 2000. The variation of each sector has stayed at about 2 percentage points. Therefore, the three just mentioned sectors are of great importance for the analysis of energy efficiency.

Figure 13: Final energy consumption by sectors in Germany, 2000 – 2016



Source: ODYSSEE database

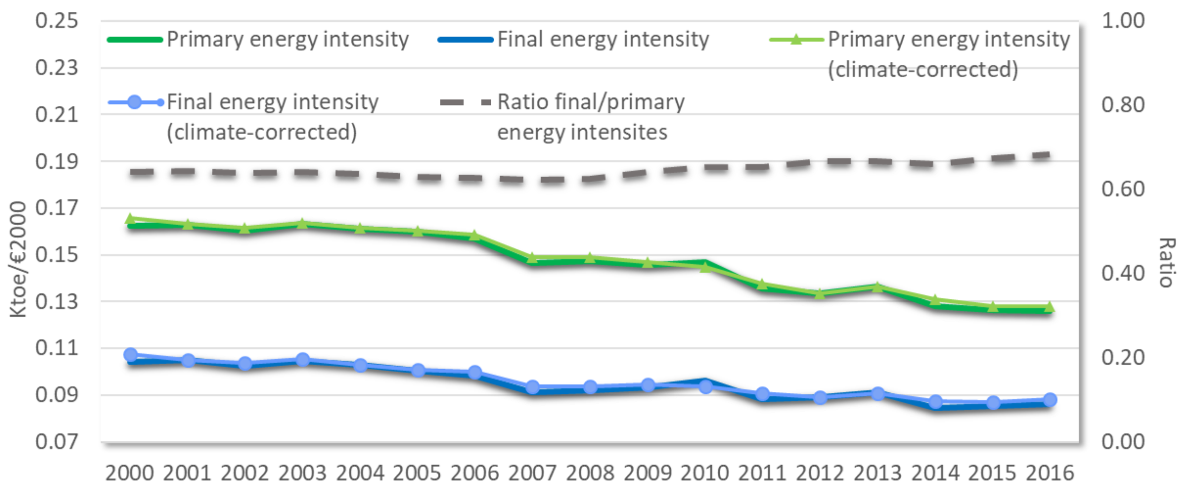
2.2.2. ENERGY INTENSITY

Germany's overall energy efficiency from an economic viewpoint is next characterized through the primary and final energy intensities, i.e. the ratio between the energy consumption and the GDP. The reverse of this ratio or the "energy productivity" is also a measure of how well the energy resources are being used. The effects of economic growth from 2000, as measured by GDP, are removed from the indicator in order to avoid the impact of inflation. Likewise, the weather fluctuations are taken out through the temperature-corrected intensities for the residential and tertiary sectors.

Since 2000, the temperature-corrected primary and final energy intensities have had a yearly descending progression of 1.6% and 1.2% respectively. The strong fluctuations in the economic development due to the financial and economic crisis and the subsequent revival of the economy had an impact on the energy intensity. In 2009, the main year of the recession, the final energy intensity even began to increase, which was mainly caused by developments in the industrial sector (see Section 0). Since then, the yearly energy intensity reduction is less than the half to the one between 2000 and 2007.

On average, the energy intensity variation between the primary and the final energy intensities became more pronounced after 2008 (Figure 14). This certainly led the ratio between them to climb just under 70% and to acquire an upward tendency. Behind this behaviour lay the improvement in power generation efficiency linked to the important penetration of wind and solar power as replacements of less efficient energy conversion technologies like thermal or nuclear power[15].

Figure 14: Development of primary and final energy intensities in Germany between 2000 and 2016



Source: ODYSSEE database

2.2.3. ENERGY EFFICIENCY PROGRESS (ODEX INDICATOR)

Although the overall energy intensities described above already take into account the impact of short-term weather fluctuations and changes in activities, clearly capturing energy efficiency improvements is limited by many structural effects across the different energy consumption sectors (e.g. sector or product structure in the industrial and tertiary sectors) and several comfort effects (e.g. larger living area per household, higher room temperature, larger appliances). In addition, energy intensities which are based on monetary activities at a highly aggregated level (i.e. total GDP or added value of a sector) only give a limited understanding of the pure energy efficiency developments. ODYSSEE tackles these limitations by providing a re-aggregated energy

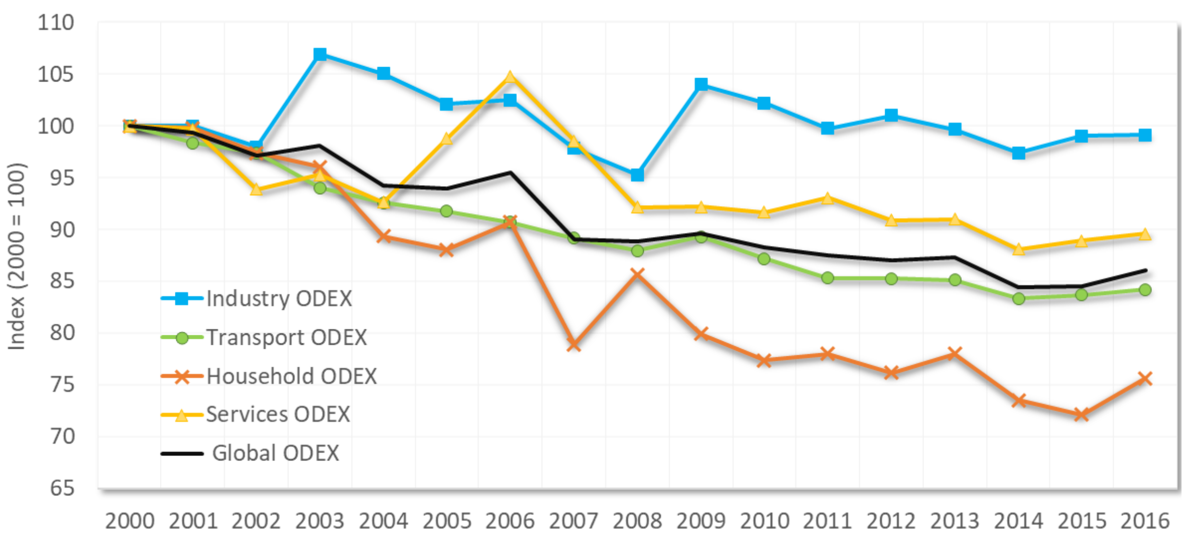
[15] Thermal and nuclear power generation have average efficiencies below 40% and of 33%, while solar and wind have a 100% efficiency. https://www.iea.org/statistics/resources/questionnaires/faq/

efficiency indicator called "ODEX". This index is obtained by aggregating the unit consumption changes at detailed levels (by sub-sector or end-use), observed over a given period. The unit consumption variation is measured in terms of a ratio that use physical instead of monetary activities, which is more suitable to evaluate pure energy efficiency trends (see e.g. Farla et al., 1998; Farla and Blok, 2000; Neelis et al., 2007).

ODYSSEE went further in isolating the pure energy efficiency evolution. Even all effects considered, apparent (or observed) energy efficiency could increase from year to year, resulting in negative energy efficiency improvement. However, the pure technical energy efficiency should not be reverse, as it is not likely that private consumers and companies are acquiring less efficient equipment from a technical point of view. They can however underutilize it, what leads to a less efficient consumption (mainly in the industry). With the intention to provide better proxy of technical energy efficiency progress, the observed ODEX is cleaned from effects of equipment's less efficient use as well as from strong fluctuations linked to of statistical errors, imperfect climatic corrections and influence of business cycles. The "technical" ODEX is the result of these adaptations.

According to the development of the observed ODEX indicator (Figure 15), in the year 2016, the global ODEX in Germany was 86 which represents an improvement of 14% on the overall energy efficiency since the base year 2000, or 0.9% per year on average. However, the pace of progress has slowed down since the economic recession: the annual gain has dropped from 1.6% per year between 2000 and 2007 to 0.4% per year thereafter. This post-crisis stagnation of the energy efficiency progress was mainly caused by the reversal in development in industry and it was triggered by a drop in equipment's capacity utilization. Its energy efficiency worsened during and after the recession, what levelled off the gains so far obtained. On the other hand, the transport and household ODEX further improved, though at a slower rate since 2008.

Figure 15: Development of the observed energy efficiency index (ODEX), 2000-2016

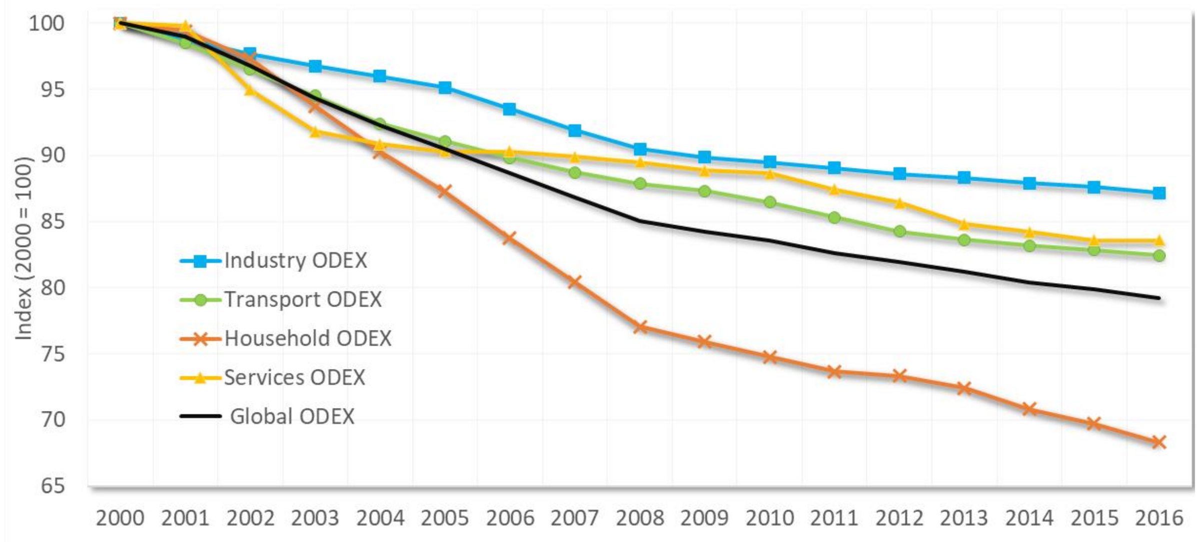


Source: ODYSSEE database

Free from the inefficient use of equipment, the technical ODEX indicator reveals in Figure 16 that between 2000 and 2016 the energy efficiency progress in Germany has steadily improved by 1.4% per year and 21% over the period. Before the economic slump, the yearly average energy at the level of the whole economy was 2%, but it was also divided by two in the period from 2009-2016 to an average of around 0.9% per year, mainly in the transport and household.

A more detailed analysis of the development of the ODEX at the level of final energy consumption sectors will be given in the following sections.

Figure 16: Development of the technical energy efficiency index (ODEX), 2000-2016



Source: ODYSSEE database

2.2.4. DECOMPOSITION OF PRIMARY AND FINAL ENERGY CONSUMPTION

As described above, the ODEX measures the impact of energy efficiency gains (or losses) at the level of the overall economy. However, other factors influencing final energy consumption, which are not primarily attributable to energy efficiency are removed. The Decomposition Tool (Box 3) shows the impact of these external factors on the variation of the energy consumption and relates it to energy efficiency trends as measured by the ODEX.

Box 3: The Decomposition facility[16]

With an eye toward an easier analysis of the driving forces of energy consumption, the ODYSSEE-MURE project has developed a decomposition tool that separates the impacts of the main drivers for energy consumption. In particular, this tool shows the role of (technical) energy savings coming from efficiency improvements at the level of the different sub-sectors and end-uses.

The consumption variation from year to year is calculated per a selected explanatory component (among which, the economic activity and energy savings are the most important). The summation of yearly variations results in the change in energy consumption per driver force over a period.

The decomposition analysis can be shown for primary and final energy consumption (without non-energy uses) and for the power, industry, transport, household, service and agriculture sectors. For some of the latter, a sub-sector can be selected (e.g. heating for households, cars for transport).

[16] http://www.indicators.odyssee-mure.eu/decomposition.html

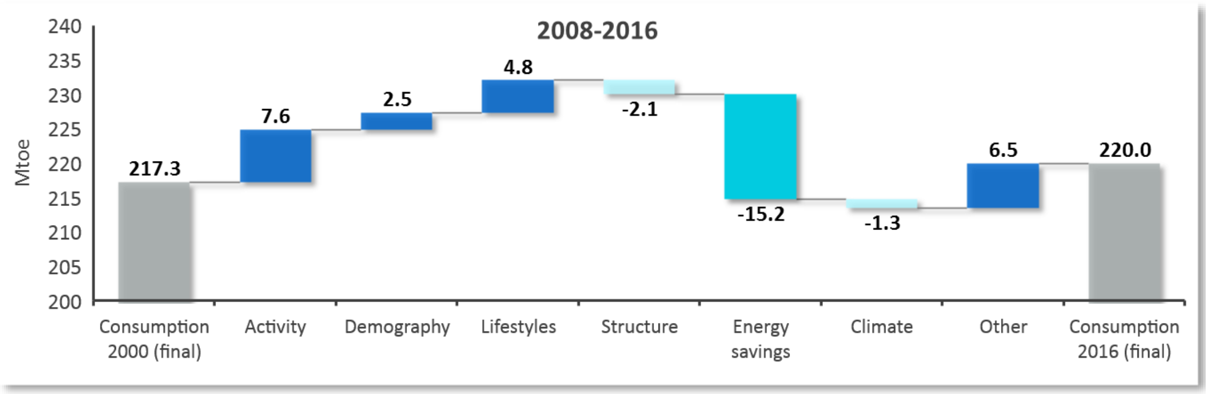
The variation of the **final energy consumption** between two years can be decomposed into several effects for each end-use sector:

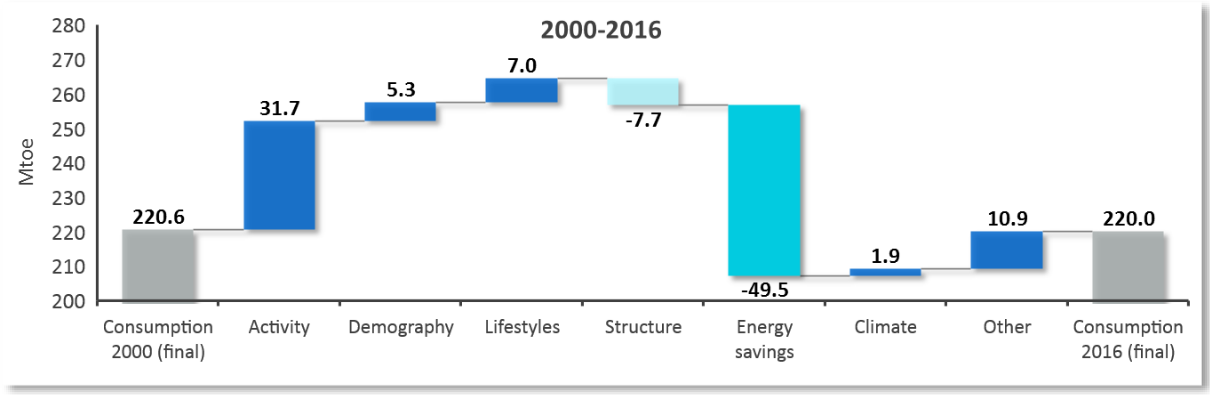
- An *activity* effect due to an increase in the economic activity, measured in economic or physical units.
- A *demographic* effect linked to the increase in the number of inhabitants or households.
- A *structural* effect due to a change in the share of the value added in sectors or sub-sectors.
- A *lifestyle effect* due to an increase in comfort and in the number of appliances in a private household because of a growing income.
- *Energy savings* linked to energy efficiency improvements and measured with the technical ODEX.
- A *climate effect* for households and services, measuring the effect of the different winter severity between two years.
- *Residual or other effects* that are defined differently in the sectors and totaled; they mainly include behavioural changes and comfort effects in the household sector, changes in the value of products in the industry, changes in labour productivity in the tertiary sector and the impact of statistical differences especially in the transport sector.

During the period 2000-2016, total final energy consumption in Germany decreased by almost 0.6 Mtoe (from 220.6 to 220 Mtoe) (

Figure 17). The activity, demographic, lifestyle and other effects, as well as the weather fluctuations contributed to a total increase in final energy consumption by around 56.7 Mtoe, being the activity effect the main driver with a share of 56%. These were, however, compensated by the energy savings achieved through a considerable improvement in energy efficiency as measured by the ODEX and, to a lesser extent, some structural changes and other effects that also caused decreasing energy consumption over the period 2000-2016. The main drivers of the energy consumption variations were the growth of economic activity on the one hand and the reversal effect of the energy efficiency improvements in all final energy consumption sectors on the other.

Figure 17: Decomposition of total final energy consumption in Germany for the periods 2000-2016 and 2008-2016





Source: ODYSSEE tools

After the financial downturn of 2008, which is also the base year of the “Energiewende” final energy targets (see Table 3), the final energy consumption stepped up by 2.7 Mtoe, as already mentioned in the "Energy Consumption" section (2.2.1). The activity effect is the main driver of the increase over 2000-2016, with 56% of share, and also over 2008-2016, with 33% of share. The falling impact of the economic growth in the energy consumption evidences the decoupling trend of both variables as shown in

Figure 12. Energy savings are the most important source of energy efficiency improvement of both time frames, with a share of around 87% of the energy consumption drop. Despite this, there is a slowdown of the perceived savings: the improvements in the 2008-2016 period became a third of those in the longer 2000-2016 period.

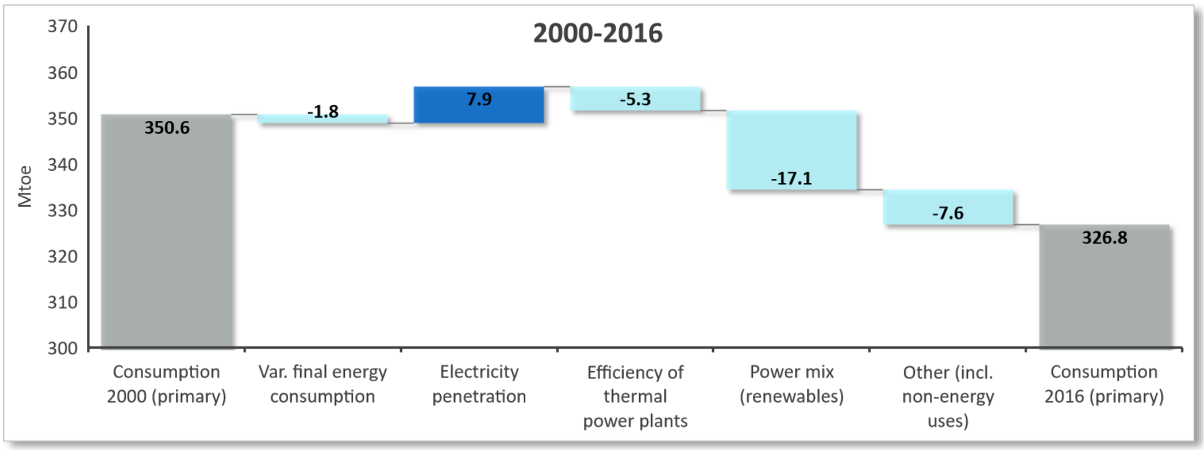
In the subsequent chapters, the disaggregated decomposition analysis (per sector) will be carried out.

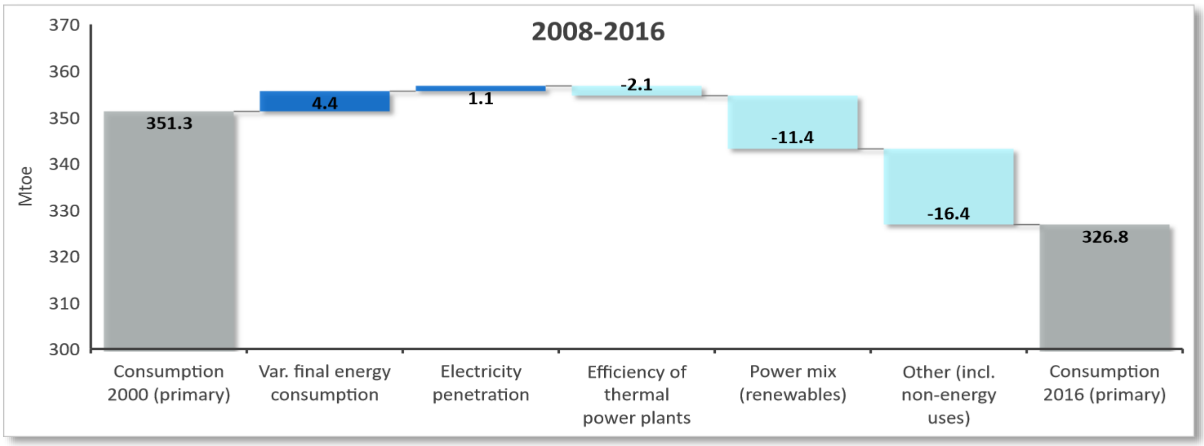
The variation of **primary energy consumption** analysed here is the sum of the variation of final energy consumption, the variation of the net consumption of the power sector, and the variation in the consumption of other transformations (incl. non-energy uses). The variation of the net consumption of the power sector is further decomposed into three underlying effects, which contribute to the total change:

- The effect of *electricity penetration* measuring the impact of increased electricity consumption in terms of additional losses in power generation.
- The impact of changes in the *efficiency of thermal power plants*.
- The impact of changes in the *power mix*, i.e. the shares of renewable energies, nuclear energy and thermal power plants in total power production.

As Figure 18 shows, the temperature-corrected primary energy consumption of Germany fell from 344.1 to 321.5 Mtoe (i.e. -21.6 Mtoe or almost 7%) in the time period 2000-2016 and from 347.7 to 321.5 Mtoe (i.e. -26.2 Mtoe or almost 8%) between 2008 and 2012. Changes in the power mix had a significant effect on this development in both periods (mainly due to the switching to renewable energy sources). It accounted for a decrease of 17.1 Mtoe from the year 2000 and 11.4 Mtoe from 2008, which are respectively 56% and 42% of the total savings. Changes in demand reduced primary energy consumption by 0.5 Mtoe in the period 2000-2012, an improvement that was slowed down from 2008-2016 with an increase of 7.2 Mtoe. A less significant rise of 0.8 Mtoe in the period of 2008-2016 is attributed to the electricity penetration. However, it constitutes the whole increase of the primary energy development from 2000 to 2016 (7.9 Mtoe). Compared to these effects, the contribution from changes in the efficiency of the thermal power plant was relatively small. On the contrary, energy use in other transformational changes gains importance after 2008 and becomes the savings' driver in the second part of the considered timeline. Overall, the analysis of primary energy consumption shows that most of Germany's efforts to reduce its primary energy consumption, by pushing the development of renewable energies, pay off. However, these efforts were pushed down by contradicting effects like the growing consumption of electricity (or rebound effect).

Figure 18: Decomposition of total primary energy consumption for the periods 2000-2016 and 2008-2016





Source: ODYSSEE tools

2.2.5. CALCULATION OF ENERGY SAVINGS

The energy efficiency progress can be also analysed by expressing the variations of the ODEX in terms of the amount of energy saved compared to a situation without energy efficiency progress. For this purpose, ODYSSEE made the Energy Savings tool available. The Box 4 provides detailed insight.

Box 4: The Energy Savings facility[17]

Another facilitator of the analysis of energy consumption and efficiency is the Energy Savings facility. This tool represents the effect of a reduction in specific consumption per sub-sector due to technical improvements. In other words, it shows the energy that was not consumed because of a decrease of a unit consumption at the level of up to 30 sub-sectors or end-use.

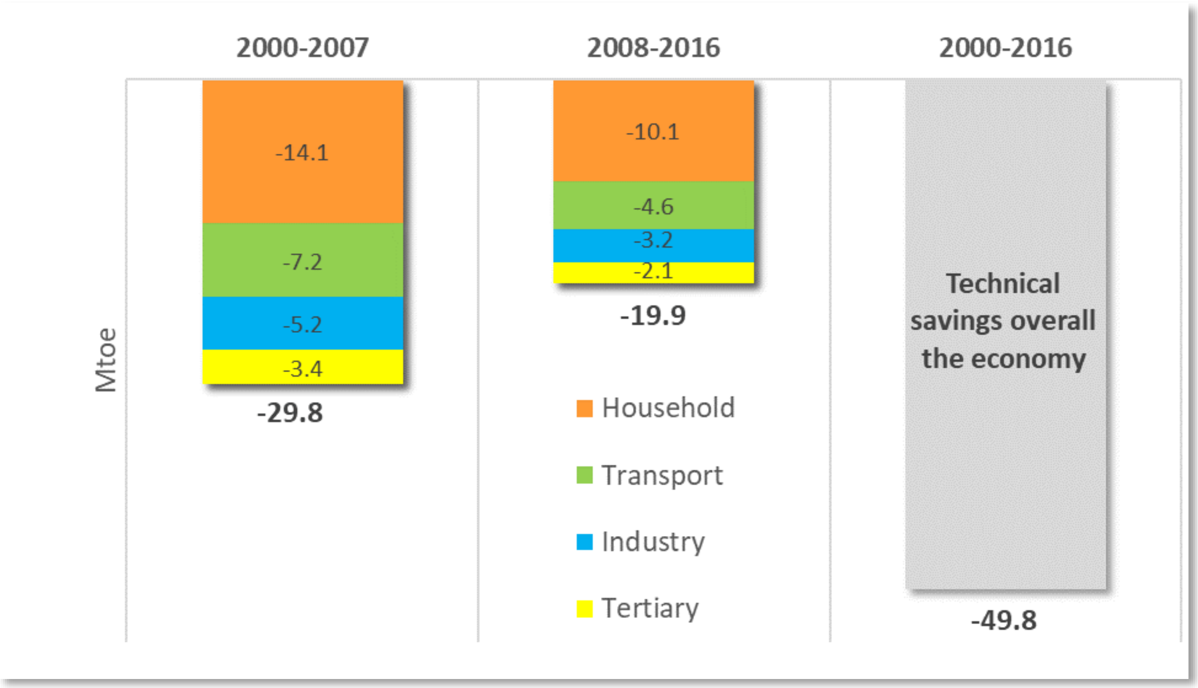
The savings can be obtained from the multiplication of the variation of a unit energy consumption by an indicator of activity over a reference period. For instance, the energy savings of a given appliance (e.g. refrigerators) are calculated from the variation in the average specific energy consumption per appliance (in kWh/year) multiplied by the stock of refrigerators. The savings can be also derived from the technical ODEX or development of energy efficiency. As energy savings fluctuate a lot, in this publication thye will be presented as cumulated savings since a reference year and it will show the non-consume energy over a period.

Savings from international air transport and ETS sector in the industry are included. In industry and freight transport, savings may be negative for some years due to a deterioration of energy efficiency (because of equipment operation at lower capacity).

The cumulated energy savings between 2000 and 2016 reached 49.8 Mtoe in Germany (Figure 19). Without them, the final energy consumption would have been 22% higher in 2016 with respect to the year 2000. Although there is a downward trend in terms of energy consumption over this timeframe, 60% of the cumulative energy reductions over the 16 years was achieved between 2000 and 2007, what implies a deceleration of the energy efficiency improvements. The household sector played a major role, as its non-consumed energy represents nearly half of the total cumulated savings since 2000. This led Germany to the 13th position in terms of energy efficiency level, out of the 29 countries part of the ODYSSEE-MURE project. The decreasing progression of the energy savings is also in line with Germany's worse stand on the trend ranking (16th/29), as Table 2 displays. Regarding the industry sector, the savings have a lower share in the total cumulated savings until 2016, but the energy reduction efforts in this sector better located Germany in the scoreboard of energy level (9th/29).

[17] http://www.indicators.odyssee-mure.eu/energy-saving.html

Figure 19: Amount of technical energy savings, 2000-2016



Source: ODYSSEE tools

2.2.6. COMPARISON OF ENERGY CONSUMPTION

One way to understand a country's position in the Combined Scoreboard of energy efficiency (Figure 3) is by comparing it with another country, for instance, with one that performed better globally or in a specific sector. The Box 5 explains the comparison criteria and adjustments offered by ODYSSEE.

Box 5: The Comparison facility[18]

This facility enables a benchmark between the energy efficiency performances of one country and selected others based on adjusted indicators by sector and end-uses (in some cases).

For the cross-country comparisons, energy consumption values are scaled to the climate and/or the power/fuel mix of the reference country. Adjustments to the same monetary units and cost-of-living as well as to the same economic structures are also considered. This allows a comparison of differences in technical performance between countries.

ODYSSEE provides the actual indicator as well as the adjusted indicator to the characteristics of the studied country. The available indicators per sector are:

- at a *Macro* level, the primary and final energy intensities;
- for the household sector, the energy use per dwelling and per m^2;
- for the industry, the energy intensity;

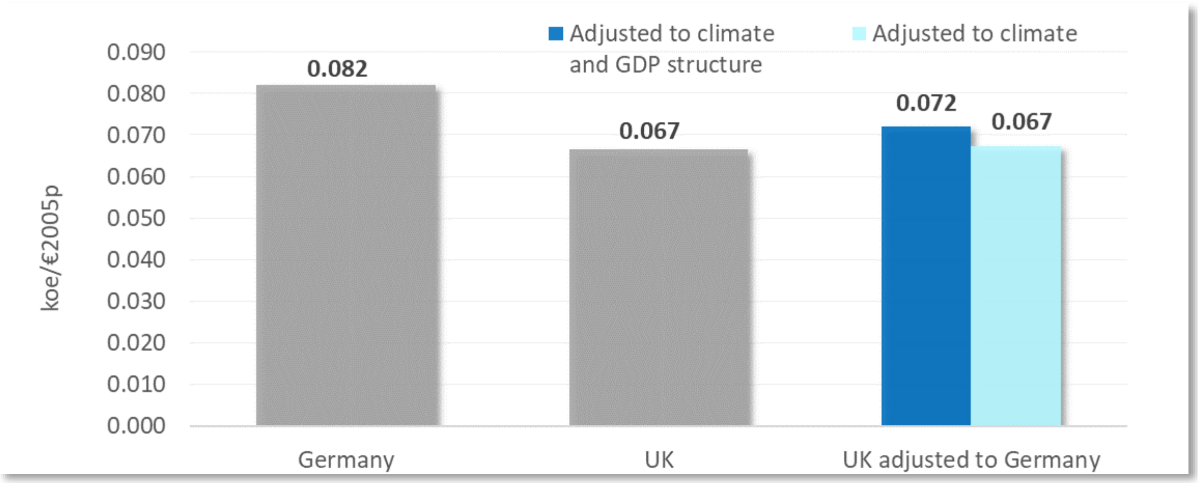
[18] http://www.indicators.odyssee-mure.eu/benchmarking.html

- and for the tertiary sector, the energy use per employee.

When comparing Germany's energy efficiency level to the head of the ranking, the UK (Figure 20)

Figure 4, the 14% higher final energy intensity of Germany stands out[19]. It is a gap of 0.0102 koe/€2005p, i.e. from 0.0822 to 0.072 intensity level, which is adjusted to Germany's climate and economic structure. This difference in final energy intensities is somewhat higher than the one between Germany and Norway, the worst performer on the scoreboard, what confirms Germany's upper-middle position. Worst yet, when disregarding the structural adjustment, Germany shows a 22% higher final energy intensity thank the UK because the latter's results were supported by a lower share of high-energy intense sectors, i.e. industry[20].

Figure 20: Final energy intensity in the UK adjusted to the climate and power mix in Germany, 2016



Source: ODYSSEE tools

[19] Based on intensities adjusted to at German weather conditions, considering a GDP at adjusted currency and at 2005 price level

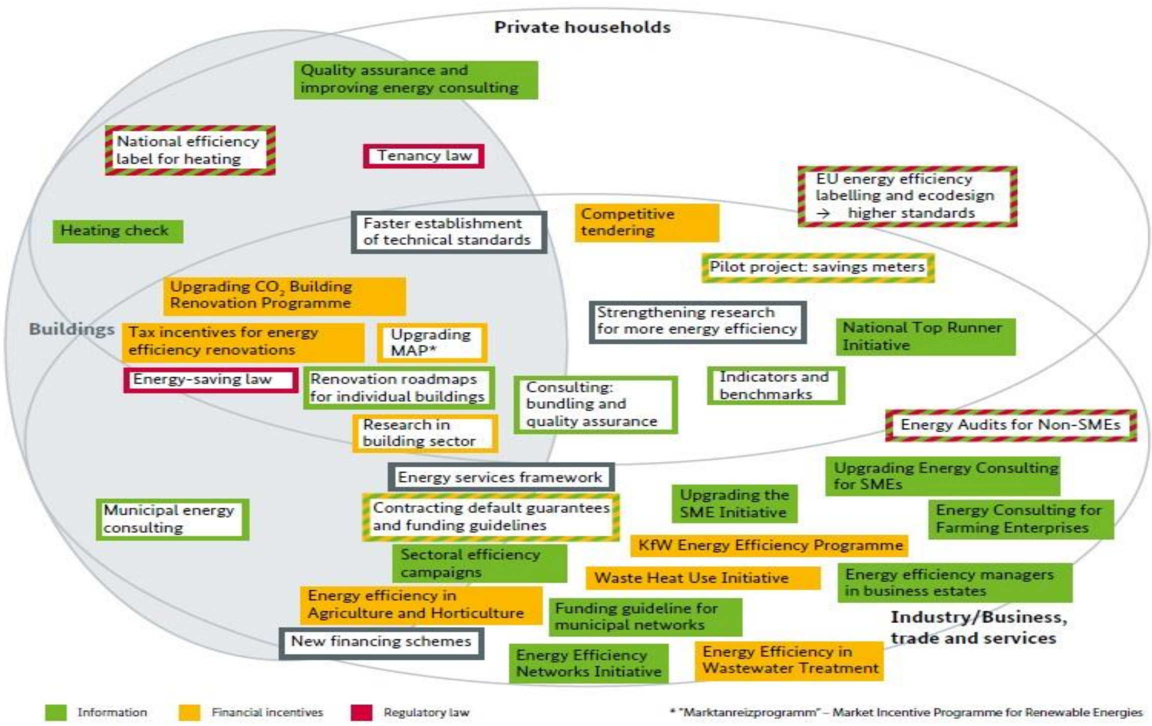
[20] In 2016, the share of the industry in the final energy consumption (not climate-corrected) is 11% higher in Germany than in the UK. The transport sector, which gained those 11 percentage points in UK, is less energy intense that the industry.

2.3. OVERALL ENERGY EFFICIENCY POLICY BACKGROUND

2.3.1. ENERGY EFFICIENCY STRATEGY IN GERMANY SINCE 2010

With its Energy Concept from September 2010 and the decisions from summer 2011, Germany initiated a far-reaching transformation of its energy system, the so-called "Energiewende" (BMU, 2011). Alongside intensifying the use of renewable energies, reducing energy consumption by increasing energy efficiency is a key pillar of the Energiewende. The Energy Concept also includes ambitious energy efficiency targets for Germany. The overall energy efficiency target demands a reduction of primary energy consumption by 20% until 2020 (and by 50% until 2050). However, a remaining shortfall to meeting the primary energy target in 2020 was estimated to be around 10 to 13% based on current forecasts and an extrapolation of the statistical development of primary energy consumption observed up to 2013. This is equivalent to a decrease in primary energy consumption of between 1440 and 1870 PJ (or 34.4 to 44.7 Mtoe) which is necessary to reach the 2020 target. In order to fill this gap, the German Federal Ministry for Economic Affairs and Energy (BMWi) presented the "National Action Plan on Energy Efficiency" (NAPE) in early December 2014 (BMWi 2014). The NAPE includes new and further developed policy measures to increase energy efficiency in buildings, industry and the tertiary sector (Figure 21). The highest contributions to energy and CO_2 savings are expected from a newly introduced competitive tendering scheme for energy efficiency and the establishment of up to 500 energy efficiency networks in industry.

Figure 21: Short-term measures and long-term work processes of National Energy Efficiency Action Plan (NAPE)



Source : BMWi, 2014

At the same time, the German Federal Ministry for the Environment, Nature Conservation, Buildings and Nuclear Safety (BMUB) presented a "Climate Action Programme 2020" which includes – among others – the whole set of NAPE measure as well as some further policy measures for buildings and the transport sector (BMUB, 2014). The Climate Action Programme 2020 aimed at an additional reduction of CO2 emissions by 62-78 Mt CO_{2eqv}. However, in the second quantification report of the programme (Oeko Institute and Fraunhofer ISI 2017), the reduction effect is only estimated at 40-53 Mt. CO_{2eqv}, based on the present implementation status of the newly introduced policies.

The fact that the new energy efficiency and climate policies introduced since 2015 delivered less and later savings as expected are one main reason why Germany is not on track to achieve its energy efficiency and climate targets for 2020 which were laid down in the Energy Concept from 2010. Table 3 gives an overview of the overall and sectoral targets of the "Energiewende" in Germany and the actual status of target achievement. The only targets which will probably be achieved in 2020 are the renewable energy targets. With regard to the overall CO2 reduction target as well as the overall energy efficiency targets and the specific targets for buildings and transport, there was still a large gap in 2016. Further reasons for the low grade of target achievement are a higher growth of key activities influencing energy consumption as expected when setting those targets (especially GDP, population and traffic) as well as the slowing-down of the energy efficiency progress in the last decade, as it is shown by the ODEX (Figure 16).

Table 3: National energy and climate targets for 2020 in Germany and status of target achievement in 2016

Indicator	2016	2020
Greenhouse gas emissions		
Greenhouse gas emissions (comp. to 1990)	-27.3%	at least -40%
Renewable energy sources		
Share in gross electricity consumption	31.6%	at least 35%
Share in gross final consumption	14.8%	18%
Energy efficiency		
Primary energy consumption (comp. to 2008)	-6.5%	-20%
Gross electricity consumption (comp. to 2008)	-3.6%	-10%
Final energy productivity	1.1%/a	2.1%/a
Buildings		
Heat demand (comp. to 2008)	-6.3%	-20%
Transport		
Final energy consumption (comp. to 2005)	+4.2%	-10%

Sources: BMWi 2018

Apart from the new policies in order to fill the gap to the 2020 targets, the Climate Action Programme 2020 also announced the development of a long-term strategy for meeting the energy and climate targets for 2050. A national "Climate Action Plan 2050" was finally adopted by the German government in November 2016. The long-term plan includes interim sectoral GHG emission reductions targets for 2030, covering the following sectors: Energy, Buildings, Transport, Trade & Industry, Agriculture & Forestry. The development of the Plan was accompanied by a broad dialogue and participation process with the Federal Laender and local authorities, as well as the private sector, stakeholder organisations (churches, associations and trade unions), but also direct public participation for the first time. [21]The implementation of the Climate Action Plan 2050 is still going on (status as of summer 2018).

In order to further enforce the energy efficiency progress, the Federal Ministry for Economic Affairs and Energy also presented a discussion paper on energy efficiency with the perspective 2030 in August 2016. It includes, among others, a discussion on further policy instruments for energy efficiency (as e.g. higher energy or CO2 taxes) as well as a proposal for the implementation of the "Energy First" principle in Germany, which was later taken up in the Coalition Agreement of the new government in March 2018.

Table 4 summarizes the milestones of the German "Energiewende".

Table 4: Milestones of the German Energiewende

Date	Action of the German Government
Sept. 2010	**Energy Concept** including ambitious targets for GHG emissions, renewable energies and energy efficiency for 2020 and 2050
March 2011	Decision on a **phase-out of nuclear energy** by 2022
July 2011	Decisions on accelerating the transformation of the energy system ⇨ starting point of the **German "Energiewende"**
Oct. 2011	Implementation of an official **Monitoring Process** ⇨ yearly check of the success of the energy transition (targets / policies)
Dec. 2014	New programs to achieve 2020 targets: **National Action Plan on Energy Efficiency (NAPE)** Action Program on Climate 2020 (APC)
August 2016	**Green Paper on Energy Efficiency** ⇨ perspective 2030
Nov. 2016	**Climate Action Plan 2050:** GHG reduction targets for 2030 by sector
March 2018	Coalition Agreement of the new government: Ambitious Energy Efficiency Strategy ⇨ "**Efficiency First"-Principle + NAPE 2.0**

Sources: own compilation, BMWi 2018

2.3.2. POLICY ANALYSIS USING THE MURE TOOLS

Energy savings, the key driver of final energy consumption decrease, is the effect of successful policy instruments. In order to help improve the policy-making process and help formulate more impacting measures, MURE provides a tool that highlights, characterises and provides an evaluation of policies that showed positive outcomes (Box 6).

[21] A detailed description of this process is e.g. given in Schlomann et al. 2017.

Box 6: The Successful Policies facility

SUCCESSFUL POLICIES

As introduced in Section 1.1, this facility allows an identification of successful measures by a consistent set of criteria that answers the question *what characterises a successful energy efficiency policy?*

The methodology approach to develop such a set of criteria occurred in two steps. For the step one, a pre-choice of 10-15 policy measures per country (2-3 per sector) was conducted based on the following criteria:

- only high and medium impact measures;
- measures with some experience;
- ongoing and not too old measures (> year 2000),
- representation of several measure types;
- and expert choice.

The pre-choice focused the efforts on around 300 to 400 measures instead of all 2 350 measures of the MURE database.

The second step was the evaluation of the chosen policy measures, which enables to rank the pre-chosen set of policy measures according to their success. For this:

- 12 criteria, displayed here below, have been identified to define the success level of a measure, with a distinction between "high" (criteria from 1 to 6) and "low" priority (criteria from 7 to 12).

1. High impact/ high number of applicants	7. Transferability between countries
2. Cost for the implementor/ administrative support	8. Link to other measures/ policy packages
3. Potential for market transformation and for promotion of energy service market	9. Previous experience with measure
4. Suitability to overcome barriers for EE	10. Avoidance of negative side-effects
5. Ease and stability of re-financing	11. Support of positive side-effects
6. Persistency of savings induced by measure	12. Ease of acceptance by stakeholders

- A Quantitative evaluation of each policy was performed, with a score between 1 (worst) and 5 (best) for each of the 12 criteria

As to the 2016 update, 343 successful measures form the group of the most successful policies.

In Germany, the evaluation was performed on 16 policies that were pre-defined as "successful" according to the mentioned criteria (Box 6). The top-level position in the Scoreboard for Energy Efficiency Policies (Figure 5) might be influenced by the high quality of these successful policies that were deployed in Germany between the years 2000 and 2016. With an overall score of 3,6 points (being 5 the best), Germany is above the average for the rest of the evaluated successful policies in Europe. The household sector emerges with the highest score among all sectors in Germany (4.2 points), which is probably linked to the sector's performance in terms of (technical) energy savings (almost 50% of total savings, see Figure 19).

2.3.3. IMPACT EVALUATION

Quantitative methods used for determining observed and expected impacts of policy measures provide credibility and sturdiness to the evaluation results. MURE allows tracking the policies from its database, for which quantitative impact evaluation methods have been used, and also offers further helpful information (

Box 7).

Box 7: The Impact Evaluation facility[22]

MURE facilitates different overviews of impact evaluation methods for energy efficiency policies and measures that were used to assess the ones available in MURE's database. One of them is a graph with the distribution of the number of policies among ten listed methods. It is displayed per country and per sector (private households, transport, industry, services and cross-cutting). The list and description of measures per country, per sector and per method are available as well.

Moreover, this facility enables information on the ideal impact evaluation per type of measure. The around 2500 measures that are available in MURE were collected and classified by National Teams that cooperate with the ODYSSEE-MURE project. This characterization was developed in the frame of the European EMEEES[23] project and resulted in a three-dimensional matrix that includes the list of considered methods classified into four groups (evaluation types), which is crossed with the types and list of measures. Inside the matrix appears the number of policies that have been assessed with each evaluation type. Annex 3: Matrix of impact evaluation methods contains an example of this matrix for the household sector.

The four evaluation types and methods are:

- *Bottom-up evaluations (BU),* such as direct measurement, billing analysis, enhanced engineering estimates, mixed deemed/ex-post estimate and deemed estimate unit savings. They make use of measure specific data.
- *Top-down evaluations (TD)*, including specific consumption indicators and econometric modelling. They make use of statistical data.
- *Suitable as BU or TD* like stock modelling and diffusion indicators.
- *Integrated BU/TU*

The list of measures together with the information on impact evaluation is collected an verified by the National Teams which are typically energy efficiency agencies or expert institutes in the evaluation of energy efficiency measures.

Out of the 90 energy efficiency policy measures that were registered and characterized by the German National Team, 59 are evaluated with quantitative methods. The distribution per method is contained in Figure 22. This number seems high when comparing it to the 36 quantitatively evaluated policies that are registered for Ireland, which is the first country in the Scoreboard for Energy Efficiency Policies. It seems even higher

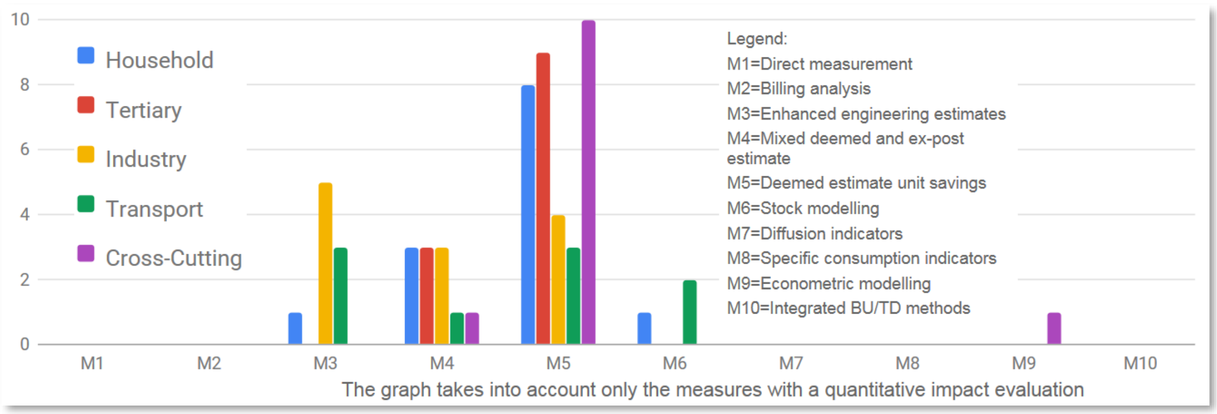
[22] http://www.measures-odyssee-mure.eu/impact-evaluation-option.asp (public access)

[23] Evaluation and Monitoring for the EU Directive on Energy End-Use Efficiency and Energy Services. Available at: http://www.emeees.eu/emeees/en/home/index.php

compared to the country located at the bottom of the ranking, Sweden, with only two of its measures evaluated with quantitative methods. In fact, Germany is the country with the highest number of policies utilizing these methods after Spain. The compelling results expected from this type of measurements should positively affect Germany's future policy design.

Figure 22 shows the highest concentration of measures in the bottom-up impact evaluation group (methods 1 to 5). It means that Germany gives importance to evaluations based on specific data measurements, closer to the source of savings. For 58% of the measures, a deemed estimate is used, which is a recommended method for most of the measure types in every sector (according to the matrix mentioned in **Erreur ! Source du renvoi introuvable.**). Besides cross-cutting measures, the household takes the lead with the greatest number of policies that use quantitatively impact assessments (14 in total), contrary to the transport, with the least policies which using these methods.

Figure 22: Number of measures with quantitative impact evaluations for the different sectors, 2016



Source: MURE tools

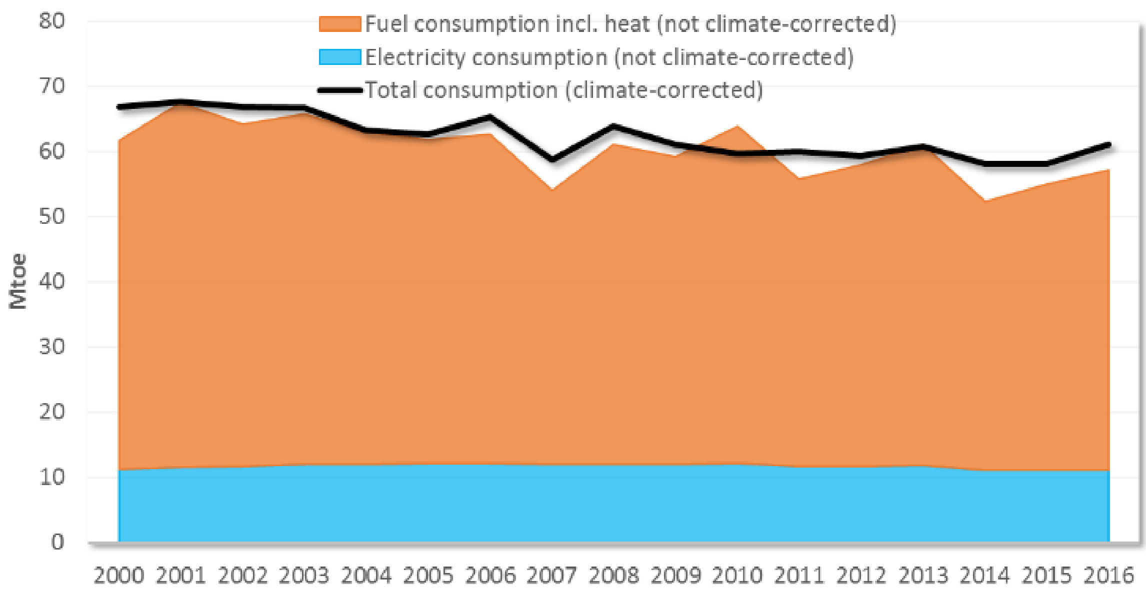
3. ENERGY EFFICIENCY IN HOUSEHOLDS

3.1. ENERGY EFFICIENCY TRENDS

3.1.1. ENERGY CONSUMPTION

Between 2000 and 2016, energy consumption in the household sector (not climate-corrected) fell from 62 to 57 Mtoe, i.e. by around 3% (Figure 23), a continuous downward tendency from 2007 when comparing each year's consumption to the base year (2000). There have been some significant yearly variations partly due to weather fluctuations (2007, 2010, 2011 and from 2014). The sharp decline in 2007 corresponds to the most representative energy carriers in households: heating oil with a 2000-2007 drop of 44% and gas with a decline of 8%[24]. Despite the good performance when comparing consumption after 2007 to the base year, special attention needs to be drawn to the decreasing rate of the yearly consumption improvements as, after the sharp decline of 2007, the total consumption rises by 1% per year on average, compared to the -2% variation before 2007 (non-climate-corrected values). This behaviour is somewhat less sharp when regarding the temperature-correct total consumption. The previous tendency is mostly steered by the heating consumption, since the electricity not only has a low share in the total demand (19.2%) but also has remained stable at around 12 Mtoe since 2000.

Figure 23: Fuel and electricity consumption in households (not climate-corrected), 2000-2016



Source: ODYSSEE database

3.1.2. UNIT CONSUMPTION

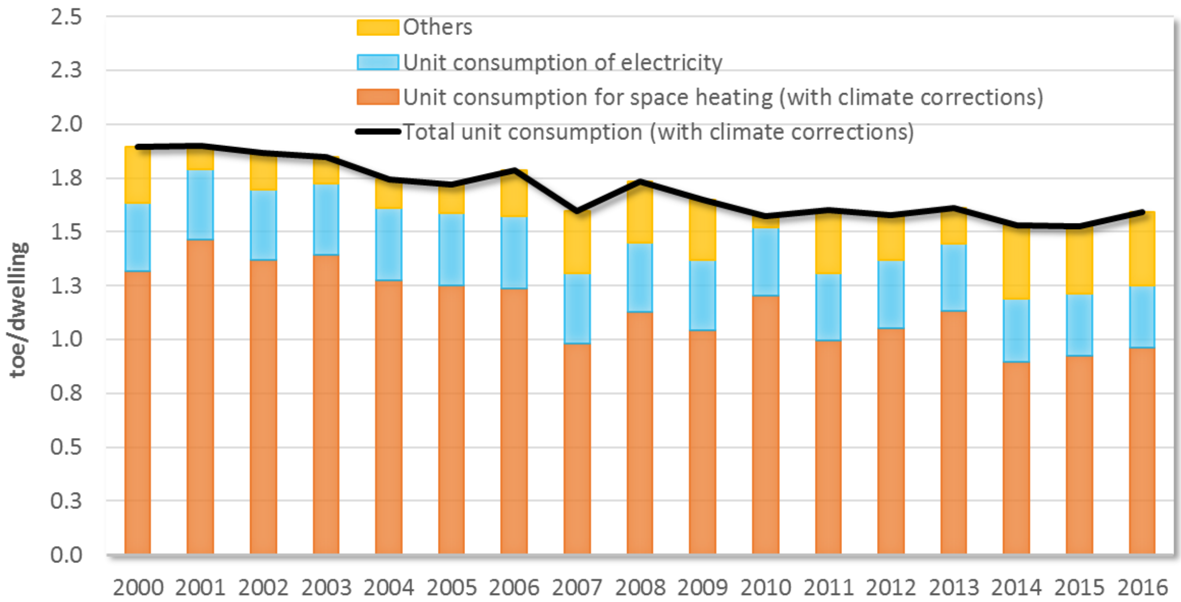
Unit consumption is calculated both for total energy and electricity consumption of private households and for space heating alone. Energy consumption is related to physical factors (number of dwellings or square meter)

[24] This is partly explained by variations in stocks. But a recording error may be suspected, too, since survey data do not confirm this sharp decrease.

and the total energy consumption and space heating figures are temperature-corrected, to remove the effect of weather fluctuations. Over the last 16 years, there has been a 30% cumulative decline in (climate-corrected) energy consumption per dwelling, generally following the development of unit consumption of space heating, because it represents about 60% of total household energy consumption in Germany (Figure 24). Differently explained, there is a 0.52% yearly increase of the number of permanently occupied dwellings since 2000 that in total use less energy for space heating (there is a rather small yearly decrease of fuel consumption).

Although total unit consumption and unit consumption for space heating declined over the period, electricity consumption per dwelling remained quite static. After a consecutive increase until the mid-2000s, electricity unit consumption decreased by around 0.4% per year. Even after removal of the impact of the activity drivers (i.e. number of dwellings or square meter) and weather fluctuations from the unit consumption indicator of private households, consumption is still influenced by several factors that partly compensate for each other: fuel substitution, higher energy efficiencies due to thermal regulations, changes in dwelling size or heating system (trend to central heating), changes in the share of single and multi-family dwellings and last but not least behavioural factors (e. g. a trend to higher indoor temperature or a more intensive use of electrical appliances and lamps).

Figure 24: Unit consumption of private households in toe/dwelling (total and space heating climate corrected), 2000-2016



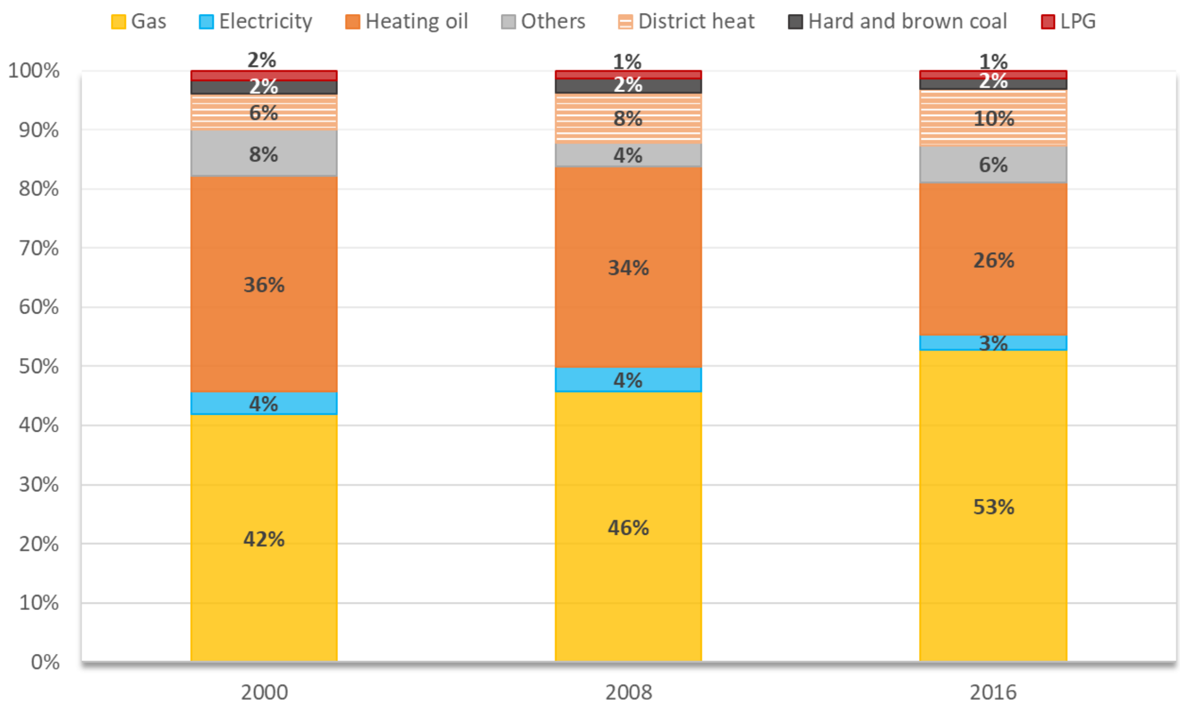
Source: ODYSSEE database

Unfortunately, the downward trend of unit consumption needs to accelerate so Germany is able climb up in the Scoreboard for Energy Efficiency Level, where it has an above-average position (

Figure 4). Bulgaria, the head in energy efficiency level (Table 2), showed 46% and 36% lower heating consumptions per dwelling and per square meter than Germany (at 2015 levels due to missing data). However, other points of reference as the Netherlands and Ireland (5th and 3rd in the level ranking) should be considered, since their overall performance is more stable and there is more recent data. The Netherlands consumes 3% more energy in heating per dwelling and 33% less in heating per square meter than Germany. Ireland has also 2% higher heating consumption per dwelling and its heating consumption per square meter slips back by 21% compared to Germany's. In reality, even being at the 13th position (out of 29), Germany is not far away to the top regarding the most influential end-use, however has many competitors where there is more potential to further unlock energy efficiency.

According to Figure 25, heating oil for space heating and other less representative energy carriers have been gradually replaced by gas and to lesser extent by district heat (-11% for oil between 2000 and 2016; +11% for gas, +4% for district heat). The effect of these different substitutions to more efficient fuels is a decrease on the specific space heating consumption per square meter of 1.8% and 1.3% per dwelling. A switch to biomass would lead to CO_2 emissions reduction but also to a decrease of efficiency. However, other energy carriers, which are mainly biomass, remained roughly stable at 7% in average over the whole period.

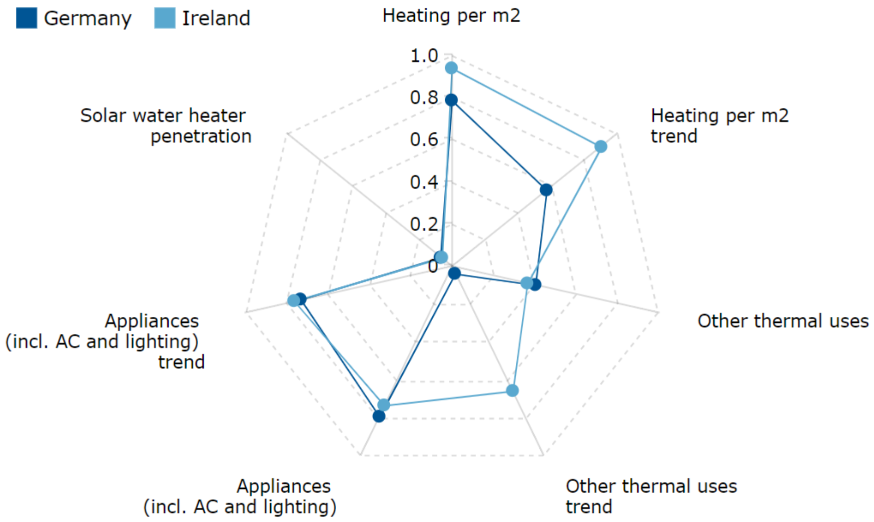
Figure 25: Household energy consumption for space heating by energy carriers



Source: ODYSSEE database

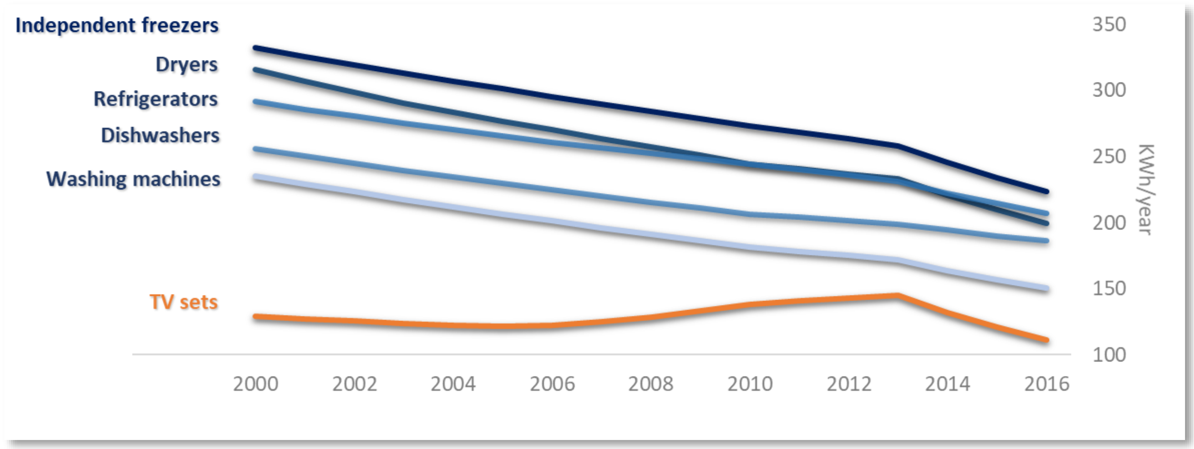
Together with cooking and water heating, which correspond to other thermal uses, the energy-specific consumption by electric appliances shows a better energy efficiency level than the leader of the ODYSSEE indicators ranking (Figure 26), partly counteracting the inferior stand regarding heating. The specific electricity consumption of most of the major household appliances in Germany decreased considerably between 2000 and 2016, thus improving the energy efficiency (Figure 27). Only for TV sets, the appliance with the greatest stock in Germany, an increasing trend was observed from 2006 to 2013, which was mainly due to the increasing size of TV screens. However, It must be noted that these data are not available from yearly statistics or surveys but had to be taken from modeling calculations and therefore may not fully reflect the yearly status of the appliance stock.

Figure 26: German positioning in the household sector compared to Ireland (leader in the ODYSSEE Scoreboard for Indicators)[25]



Source: ODYSSEE tools

Figure 27: Specific consumption of electrical household appliances



Source: ODYSSEE database

3.1.3. ODEX INDICATOR

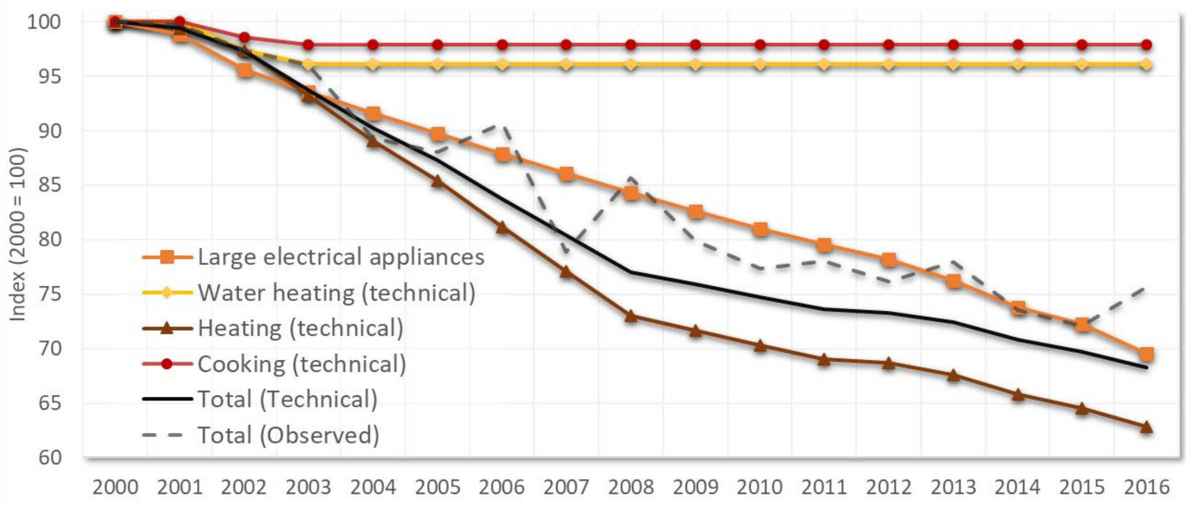
For the residential sector, the bottom-up energy efficiency index (ODEX) is calculated at the level of the total sector and of eight end-uses: heating, water heating, cooking and five large appliances (refrigerators, freezers, washing machines, dishwashers and TV). Figure 28 displays not only their technical improvement in energy efficiency with the technical ODEX, but also the observed energy efficiency performance for the whole sector,

[25] Branches of the spider graph correspond to indicator scores, from the ODYSSEE scoring approach. The score scale on the graph is between 0-1 with 1 corresponding to the 3 best countries and 0 to the 3 countries with the lowest performance. See more details in Annex 1: .

which is the one still including the behavioural trends that often compensate energy efficiency gains (as e. g. a higher indoor temperature, increasing use and number of lamps, increasing use of TV, increasing use of hot water).

The technical ODEX in the household sector decreased by about 32% compared to 2000 (as the ODEX is 68 for 2016), which represents an average energy efficiency improvement of 2% per year. The development of the household ODEX is strongly influenced by the heating sector, similar to the unit consumption, as seen in section 3.1.2. Here, the improvement accelerated between 2002 and 2008, which was also reflected in the total household ODEX. Since 2009, however, a flattening of the incline can be observed. The efficiency improvements of the five large appliances also contributed considerably to the total energy efficiency gains in the household sector, whereas the improvement for water heating and cooking was less pronounced. The consequences of the flattening behaviour of all heating applications are noticeable when comparing Germany with Ireland (Figure 26), the head of the scoreboard for energy efficiency trend. Conversely, the downward trend in terms of energy efficiency of the large electrical appliances better position Germany in front of the ranking leader.

Figure 28: Development of the energy efficiency index (ODEX) in households, 2000-2016



Source: ODYSSEE database

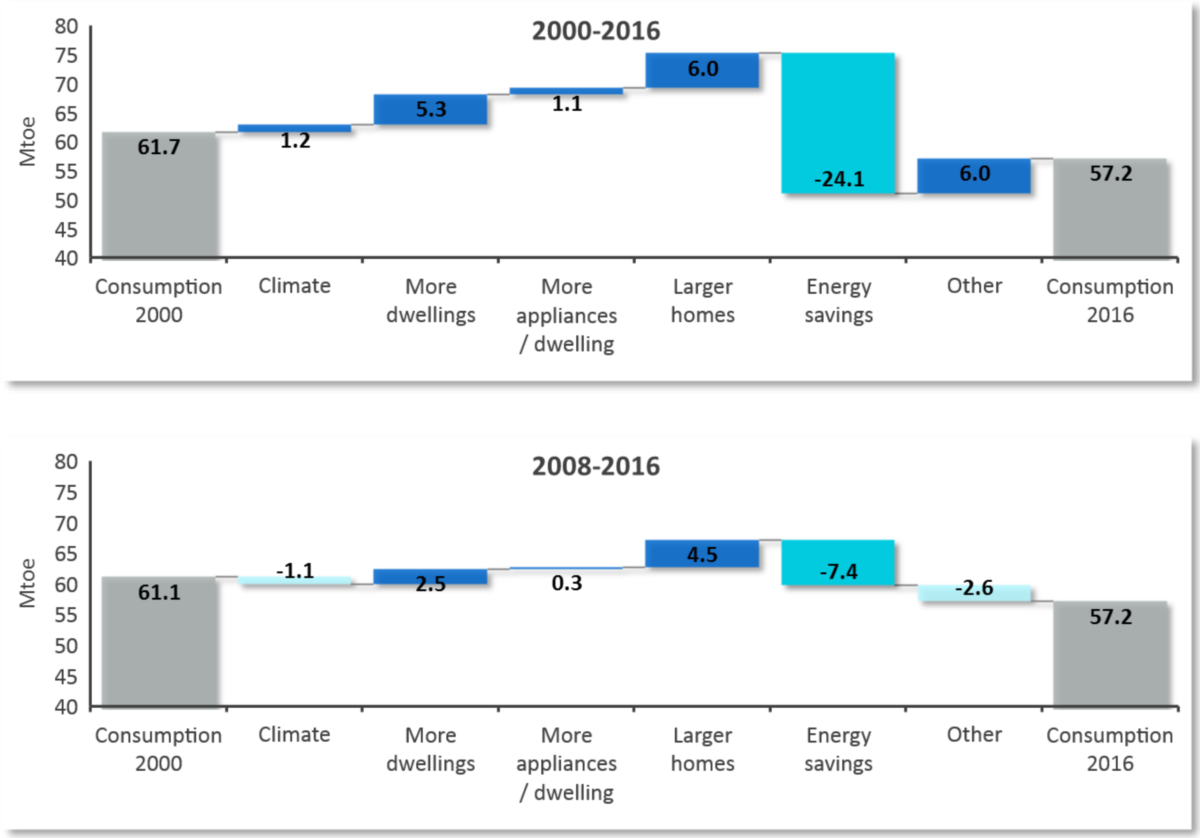
3.1.4. DECOMPOSITION OF ENERGY CONSUMPTION

With the Decomposition Facility, introduced in Box 3, it is possible to break down the variation of energy consumption. Over the period 2000-2016, the residential sector perceived a decrease of around 4.5 Mtoe or 0.25 Mtoe per year in the total energy consumption (from 61.7 to 57.2 Mtoe) (Figure 29). This variation was mainly due to the energy efficiency improvement of 24.1 Mtoe that exceeded the consumption rise linked to the increasing number of dwellings (demographic effect), living changes space (lifestyle effect), weather fluctuations and other effects (primarily behavioural changes and residual errors[26]).

[26] Why the “other effects” are non-negligible energy consumption increase in the period 2008-2016 cannot be fully explained by the decomposition method applied here. The effect is a residual and can therefore also include the impact of changes in the underlying statistical database.

Even though there was a deceleration of energy savings between 2008 and 2012 (Figure 29), the variation of energy consumption considering all the effects propelled the whole period under review. 86% of the net consumption decrease (3,92 out of 4,5 Mtoe) were obtained in the second half of the period.

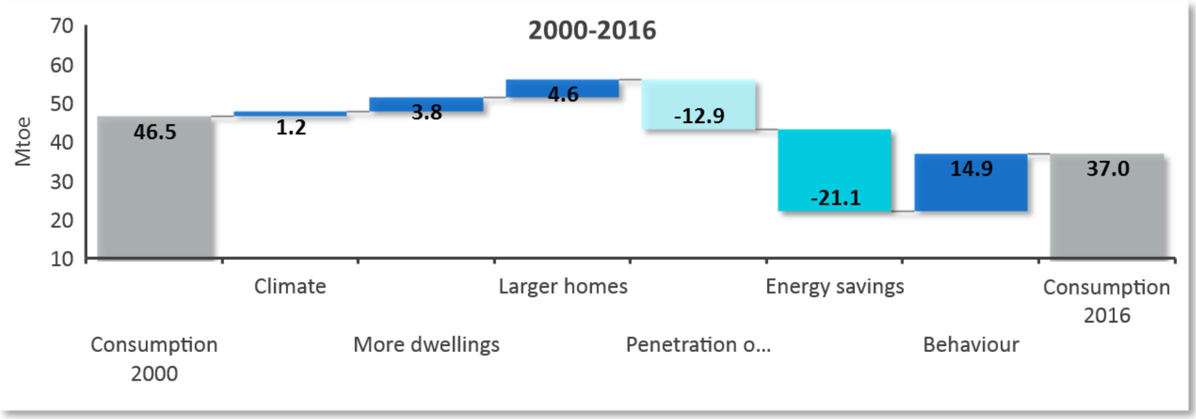
Figure 29: Decomposition of final energy consumption in the household sector for the periods 2000-2016 and 2008-2016



Source: ODYSSEE tools

The decomposition of the space heating clearly shows that the energy consumption reduction in the household sector follows the behaviour of this representative energy application (Figure 30). 88% of the technical savings are the result of efficiency efforts in space heating (i.e. diffusion of more efficient heating technologies as condensing boilers). They pioneered, coupled with the penetration of central heating, the reduction of energy consumption in the period of 2000-2016, against all consumption rises due to larger or more dwellings and consumption behaviour. In other words, the net decline in consumption of space heating (9.5 Mtoe) was mainly influenced by 21.1 Mtoe of technical energy savings and 14.9 Mtoe increase due to behavioural effects.

Figure 30: Decomposition of final energy consumption for space heating for the periods 2000-2016



Source: ODYSSEE tools

On the contrary, the consumption reduction of electrical appliances was not very influential to the residential sector. Half of the energy savings in electricity (1.08 Mtoe) was offset by an increase linked to equipment ownership (0.56 Mtoe).

3.2. ENERGY EFFICIENCY POLICIES

Additional to the policy instruments that aim at reducing primary energy consumption and pursue EU's Energy Efficiency Directive, Germany has adopted specific instruments in its National Energy Efficiency Action Plan (NEEAP 2017) that points at the final energy consumption (BMWi 2017). A large part of them has been taken from the "National Action Plan Energy Efficiency" (NAPE) which was launched in December 2014 (see section 2.3.1). In the following, some of the key energy efficiency policy measures from the NEEAP 2017 are described. More information on these policies including their quantitative impact can be gathered directly from the MURE database[27].

3.2.1. MEASURES FROM THE NEEAP 2017

The **KfW Energy-efficient Construction Programme** is preceding the KfW (reconstruction bank) CO_2 Building Renovation programme since 2009. Support is provided for new buildings in the area of energy-efficient construction that surpass the applicable building standard. Energy-efficient homes require innovative heating technology based on renewable energies and very good thermal insulation. Since the 3rd NEEAP, only houses which meet the conditions receive funding. They need to be a KfW Energy Efficient House 70, 55 or 40 or to be a Passive House. A KfW Energy Efficient House 50 has an annual consumption of only 50% of the primary energy of a similar normal house. In 2016, the funding for the type 70 ended. Support is granted through long-term soft loans and is arranged in a staggered manner.

Another financial instrument involved with building's energy efficiency was launched in January 2016. The **Energy Efficiency Incentive Programme** promotes investments for heating efficient systems and primarily targets private owners. It started with two funding components: "heating package" and "ventilation package". In August 2016, funding eligibility was expanded to stationary fuel cell heating systems. In terms of the heating component, funding is offered for the individual switch to heating technologies based on condensing boiler technologies or renewable energies, as well as for measures to optimise the entire heating system. Financial

[27] http://www.measures-odyssee-mure.eu/

support provided for the installation of ventilation systems in combination with energy-efficient renovation of the building envelope, represents the second funding package. Finally, subsidies for fuel cells with an electrical output of up to 5 kW will be initially available for renovation and new-build projects in privately owned residential buildings and homes (natural persons).

The efforts to reduce energy consumption in form of heating are expanded through informative measures such as the **national efficiency label for heating systems**, effective since January 2016 and operated by the KfW and the Federal Office for Economic Affairs and Export Control (BAFA). It involves the free-of-charge affix of an efficiency label to existing heating systems. Coupled with on-site energy advice, it aims at improving consumer knowledge about the energy efficiency of their boiler and encouraging them to purchase a replacement. Around 13 million boilers will be labelled over eight of the project's duration, what should result in a 20% yearly boiler replacement.

Since 2009, Caritas offers free **energy efficiency checks for low-income households**. In the first appointment, a power saving check is made, including the measurement of electricity consumption of refrigerator and lighting. For the second visit, the energy-saving assistants will install the needed utilities. The energy-saving assistants performing the energy efficiency check can be a trained long-term unemployed.

3.2.2. INTERACTION BETWEEN ENERGY EFFICIENCY POLICIES

A specific energy-use may be targeted by several policies. Measures in the package may reinforce each other but they could also counteract against each other. In order to assess the impact of the policy actions in a realistic manner, the interaction between measures needs to be considered. The Policy Interaction Facility available on the MURE platform catches these impacts in a visual-friendly way (Box 8).

Box 8: The Policy Interaction facility

This facility allows defining the positive or negative net effect of within a group of policies aiming at the same end-use by characterizing these packages of measures and evaluating their interactions in a quantitative way. Its methodology is based on the assessment of interaction of a matrix containing policy types and an independent semiquantitative impact of each measure (low, medium, high, unknown). The semiquantitative impact is re-calculated into a quantitative energy saving and, based on the assumptions in the interaction matrix, the interaction impact is calculated.

In the matrix interaction among policy types, it is defined if, for example, if financial instruments (strongly, slightly) reinforce, (strongly, slightly) overlap or simply do not interact with another type of measures, such as information instruments.

The semiquantitative impact is re-calculated into a quantitative energy saving and, based on the assumptions in the interaction matrix, the interaction impact is given for the complete measures package of a selected energy end-use (i.e. space heating in existing dwellings). The combined impact (energy savings) with and without interaction (or reinforcement or counteracting influence among all measures) is displayed. The energy savings lost or gained by the complete package are proof of ineffective or effective policy design.

The tool is very flexible so that the user can change the assessment in the interaction matrix, the measures package itself and the semi-quantitative impact evaluation.

After policy experts set up the Policy Interaction tool in terms of the generic influence between types of policy measures and of energy savings per individual measures, Figure 31 was obtained. This policy interaction analysis focuses on the energy application for space heating in existing dwellings (with insulation and boiler), the one with the highest energy savings in the household sector. Thanks to this facility, it is observed that this end-use has also the highest negative policy interaction effect since around 30% of the potential savings are not perceived owning to counteracting effect among the 22 considered measures. From all the targeted end-uses (heating for new dwellings, hot water preparation, renewable energy), the electric appliances one is the solely with a positive effect regarding the combined impact. There is an excess of 2% of savings, resultant of a reinforcement among all policy measures that target this energy application.

Figure 31: Assessment of the policy interaction for space heating in existing dwellings (household sector)

Measure Title	Types group	Qualitative Impact	En. Saving (PJ)	% of Saving
EU-related: Energy Performance of Buildings (Directive 2002/91/EC) - Energy Savings Ordinance	Leg-norm/invest	High	16,895	0,70%
EU-related: Energy Performance of Buildings EPBD Recast (Directive 2010/31/EU) - Energy Savings Ordinance - revision 2013-2014	Leg-norm/invest	High	16,895	0,70%
Further development of Energy savings ordinance 2014	Leg-norm/invest	Medium	7,241	0,30%
Energy Efficiency Strategy for Buildings	Leg-norm/invest	Unknown	-	0,00%
National efficiency label for old heating systems	Leg-norm/invest	Low	2,414	0,10%
Small-Scale Combustion Plant Ordinance	Leg-norm/use	Low	2,414	0,10%
Ordinance on Heat Consumption Metering	Leg-norm/use	High	16,895	0,70%
EU-related: Revised Directive for Labelling of Energy-related Products (Directive 2010/30/EU) - Energy Consumption Labelling Ordinance – revised version	Leg-inform/focus (label)	Medium	7,241	0,30%
Smart Metering	Leg-inform/broad (audit)	Medium	7,241	0,30%
On-site energy consultation (BAFA Vor-Ort-Beratung)	Finan-fiscal/info (audit)	Low	2,414	0,10%
Energy Consultancy and Energy Checks of the Federation of German Consumer Organisations	Finan-fiscal/info (audit)	Low	2,414	0,10%
Replenishment of the KfW programmes for energy-efficient construction and renovation	Finan-fiscal/invest	Medium	7,241	0,30%
Quality assurance and the optimization of existing energy consultation	Finan-fiscal/invest	Medium	7,241	0,30%
Upgrading the CO2 Building Renovation Programme	Finan-fiscal/invest	Medium	7,241	0,30%
Energy-Related Urban Renewal — Grants for Integrated District Concepts and Renovation Managers	Finan-fiscal/invest	Low	2,414	0,10%
Heating Check (Heizungscheck)	Finan-fiscal/invest	Low	2,414	0,10%
Energy efficiency checks for low-income households (Caritas)	Finan-fiscal/info (audit)	Low	2,414	0,10%
Market Incentive Programme for Renewable Energies in Heat Market	Finan-fiscal/invest	Medium	7,241	0,30%
KfW Programme "Energy-efficient refurbishment" (former CO2 Building Rehabilitation Programme)	Finan-fiscal/invest	High	16,895	0,70%
Energy Efficiency Campaign (Initiative EnergieEffizienz)	Inform/broad (center, etc.)	Low	2,414	0,10%
National Top Runner Initiative (NTRI)	Inform/broad (center, etc.)	Medium	7,241	0,30%
Ecological Tax Reform (Energy and Electricity Tax)	Cross-cutting/taxes	High	16,895	0,70%
Sum of impacts (without interaction)			161,707	6,70%
Combined impact (with interaction)			115,309	4,78%
Difference (combined impact - sum of impacts)			**-46,397**	-28%

Source: MURE tools

3.2.3. THE LINK BETWEEN INDICATORS AND POLICIES

Before defining whether the policies inside a package positively or negatively influence each other and promote or harm the energy savings of the commonly targeted end-use, the overview and information of those measures should be accessible and available in a structured way. Box 9 introduces the MURE's tool in charge of this: The Policy Mapper.

Box 9: The Policy Mapper facility

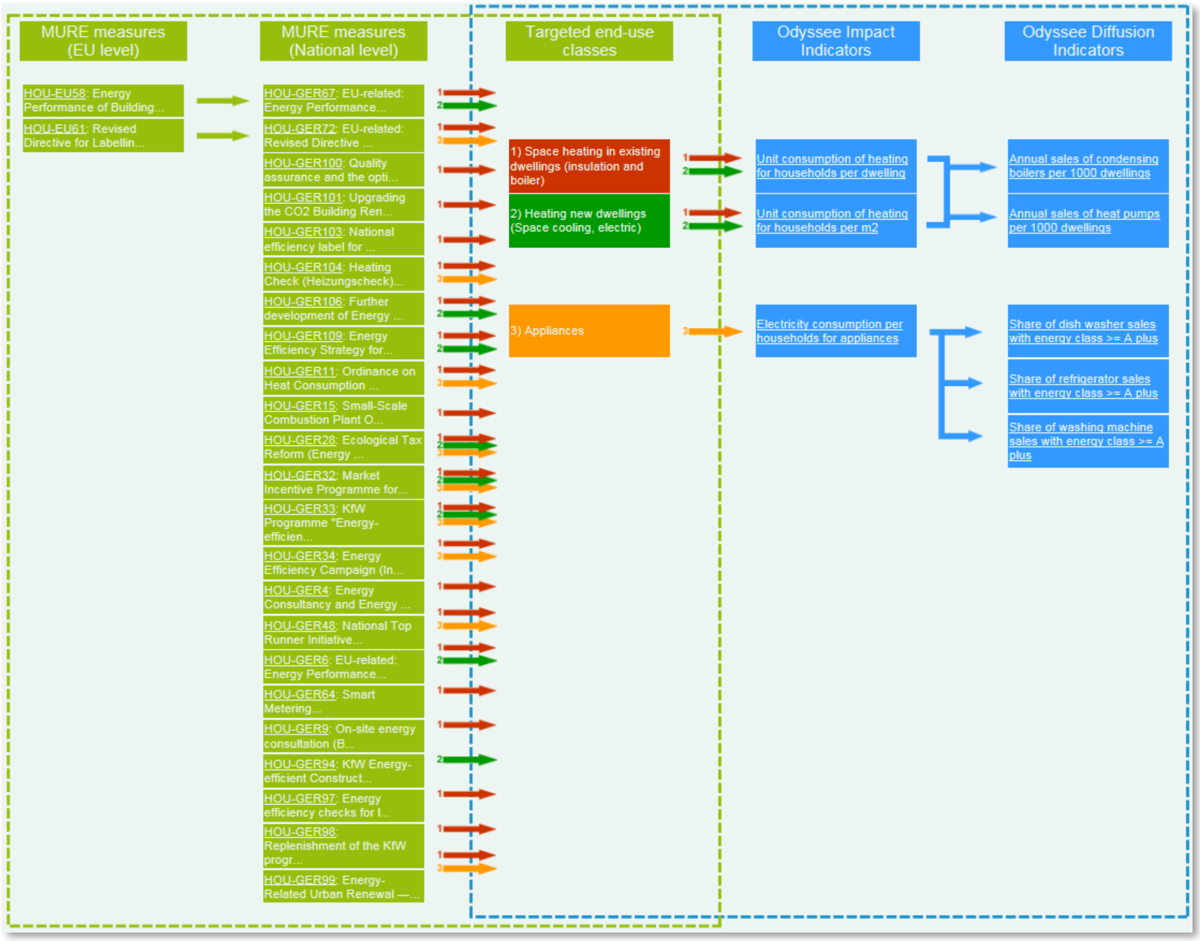
POLICY MAPPER

The Policy Mapper provides a clear visualization of policies aiming at the same-targeted end-use and relates them to the suitable energy efficiency indicators from the ODYSSEE database. The search is narrowed down to a clean policy overview by selecting a country, a sector and finally and a maximum of three energy uses. Including cross-cutting measures is optional. This tool is a key input of the Interaction Facility (**Erreur ! Source du renvoi introuvable.**) and together can contribute to the design of effective policy mixes.

Figure 32 presents the overview of policies targeting three end-uses of the household sector in Germany: space heating in existing dwellings, heating in new dwellings and appliances. Policies involving one or several end-uses are clearly distinguished through the colour and the number next to the arrows (e.g. the red arrow, accompanied by the number "1", denotes the end-use "space heating"). For instance, the measure "Market Incentive Programme for Renewable Energies in Heat Market" is involved in the energy efficiency promotion of the three selected end-uses.

Furthermore, the impact of the undertaken policies is directly associated to each end-use in the form of ODYSSEE indicators (i.e. unit or specific consumptions) and indicators about market penetration (or diffusion) of energy efficient technologies. These indicators are also affected by autonomous developments such as world-market prices for energy carriers. It provides nevertheless some hints on the impacts of the policy measures, that can be complemented with the above-mentioned Interaction facility.

Figure 32: Measures addressing several targeted end-uses in the residential sector in Germany



Source: MURE tools

4. ENERGY EFFICIENCY IN THE SERVICE SECTOR

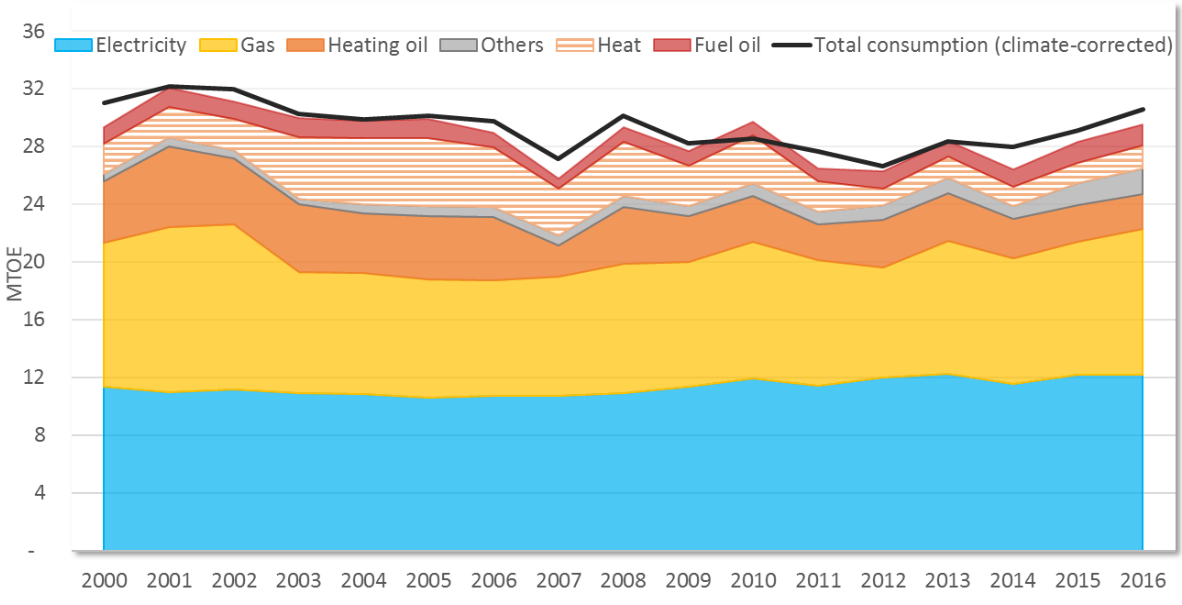
The German energy balance only shows energy consumption of the total **tertiary sector**, broadly defined as private and public services, agriculture, construction industries and military. In 2016, the energy consumption of this aggregate amounted to 33.3 Mtoe, which is around 15% of total final energy consumption in Germany. The focus of the ODYSSEE database is on energy consumption of the **service sector** only, including private and public services (such as public lighting and other services provided to shops, schools and hospitals). For Germany, energy consumption data for this aggregate is available from a regular survey that distinguishes several branches. In 2016, energy consumption of the service sector was around 94% of total consumption of the tertiary sector as defined in the German energy balance (AGEB, 2018).

4.1. ENERGY EFFICIENCY TRENDS

4.1.1. ENERGY CONSUMPTION

The total energy consumption in the service sector fluctuated between 26 and 32 Mtoe (not climate corrected) over the period 2000-2016 (**Erreur ! Source du renvoi introuvable.**). In fact, there has been a marginal increase of 0.3% per year, which was mainly driven by the upward progression of consumption since 2008. The overall increase becomes less important when regarding the climate-corrected consumption (0.04% on average per year from 2000). Significant variations took place at the heat and fuel oil ends, whereas the gas and the electricity consumption have remained stable, with a slight upward trend since 2008. The latter energy carriers represent 34% and 41% of the total energy consumption by services in Germany.

Figure 33 : Energy consumption by energy carrier in the service sector in Germany, 2000-2016[28]



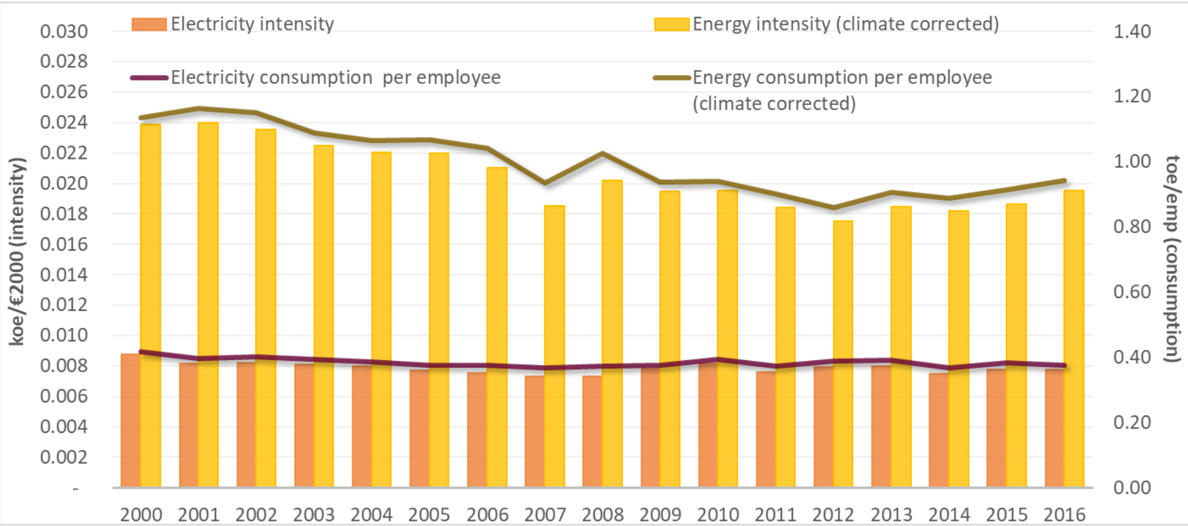
Source: ODYSSEE database

[28] Not climate-corrected unless indicated

4.1.2. ENERGY INTENSITY

Between 2000 and 2016, both the energy intensity (energy consumption of services per unit of value added) and unit consumption per employee (both temperature-corrected for energy) show a decreasing trend and an almost parallel behaviour, with variations of -1.12% per year and -1% per year respectively. There were however specific periods of stagnation in 2001, 2005 and 2008, followed by a continuous rise since 2013 (Figure 34). This decreasing behaviour over the whole period was mainly caused by thermal applications. The energy intensity of the equally important end-use, electricity, remained practically stable, with a few rises that did not cause much harm to the sectoral trend. The favourable progression deaccelerated from 2008, leading Germany to an inferior place in the ranking of energy efficiency level. Germany's service sector consumes 37% more energy per employee than in Lithuania[29], the most energy efficient country at 2016 level. Likewise, this specific consumption is 22% higher in Spain, the third country in the sectoral ranking of energy efficiency level.

Figure 34: Energy intensity and energy consumption by employee in the tertiary sector (private and public services), 2000-2016

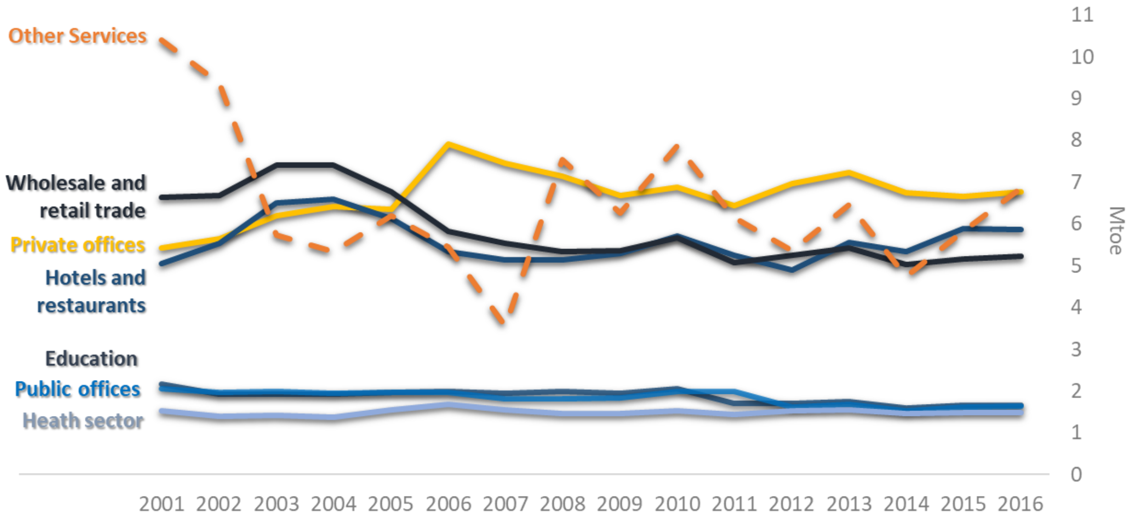


Source: ODYSSEE database

In the past 16 years, the total consumption has followed the trend of the subsectors wholesale and retail, private offices, hotels and restaurants and other services, since they represent around 80% of the energy consumption, with similar but differing individual shares throughout the period (Figure 35). The highly fluctuating behaviour of other services cannot be fully explained because it is a residual and can, therefore, include the impact of changes in the underlying statistical database. The consumption at education, public and health services has remained steady at a level of one to two Mtoe.

[29] Based on values scaled to EU climate, as it is also done for the Scoreboard of Energy Efficiency Level

Figure 35 : Energy consumption in the service sector in Germany by branches (in Mtoe), 2000-2016[30]

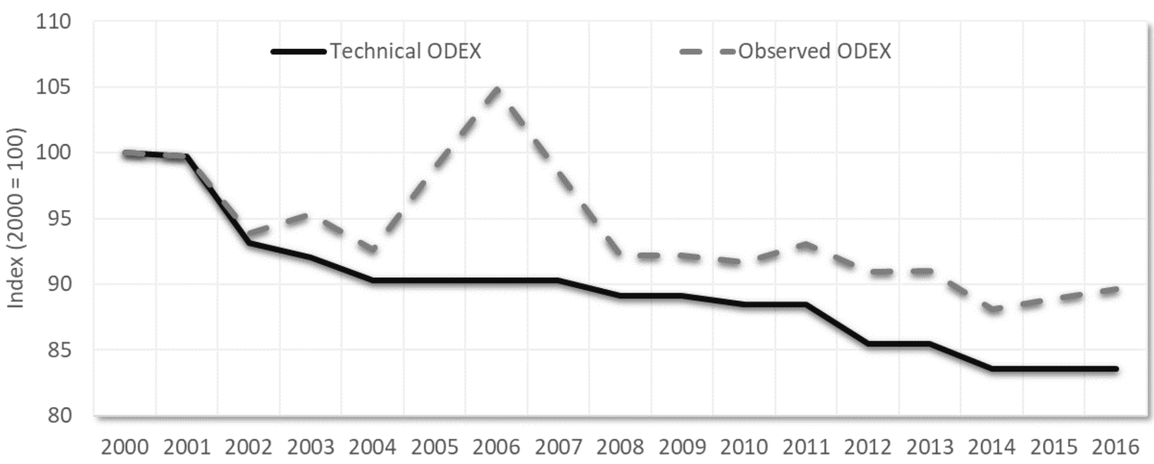


Source: ODYSSEE database

4.1.3. ODEX INDICATOR

The so far achieved energy efficiency, related to the aggregate of unit consumption changes over time, has placed Germany in a disadvantageous stand in the Scoreboard for Energy Efficiency Level. However, the yearly evolution of the change in energy consumption seems satisfactory. Unlike the rest of assessed sectors, services hold a position among the top ten in terms of energy efficiency trend (Table 2). The energy efficiency improvement is represented by the ODEX in Figure 36. The observed ODEX, the energy efficiency index that contains climatic, behavioural, inefficient use of equipment and other effects, shows a positive progress that is stained in few years by the mentioned effects. The 16% improvement in energy efficiency since 2000 shown by the technical ODEX (being ODEX 84 in 2016), proves the penetration of more efficient energy systems in the services sector.

Figure 36: Development of the energy efficiency index (ODEX) in the service sector, 2000-2016



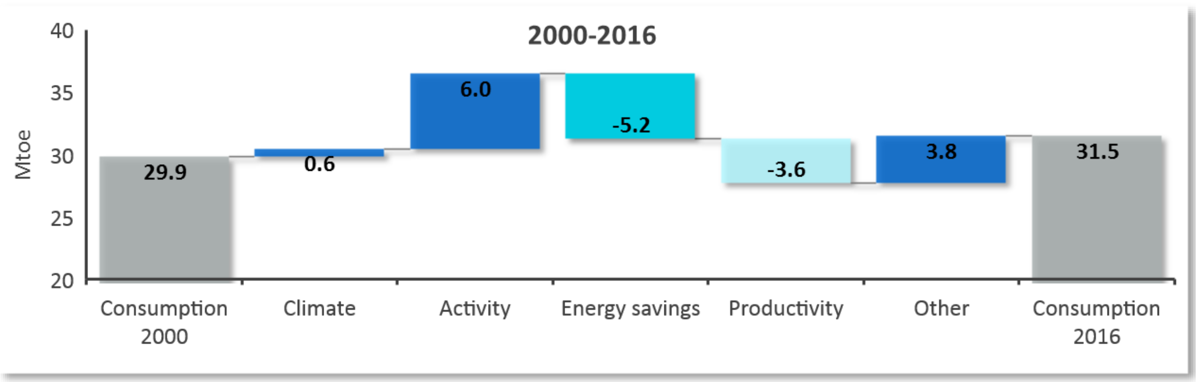
30 Not climate corrected

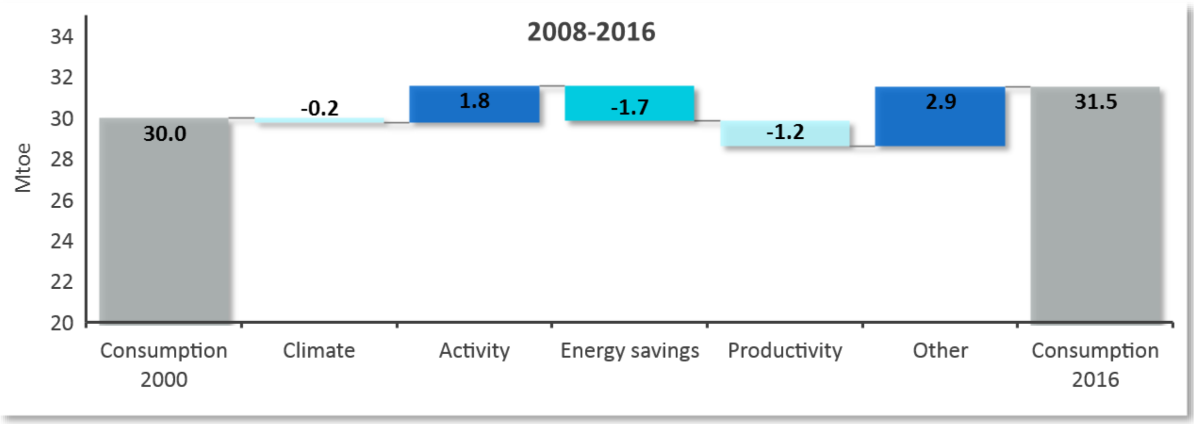
Source: ODYSSEE database

4.1.4. DECOMPOSITION OF ENERGY CONSUMPTION

The drivers of final energy consumption changes in the service sector are displayed in Figure 37. In the period 2000-2016, the total consumption went up 1.6 Mtoe, from 29.29 to 31.5 Mtoe. This value is comparable to the change that occurred during the second half of this period (1.54 Mtoe, from 30 to 31.5). The activity effect, which is measured by changes in added value, highly contributed to an increase in energy consumption. Due to the recession, it was less pronounced in the period from 2008. Weather fluctuations also contributed to an increasing consumption during the whole period, although they show a minor decrease in the period 2008-2016. The drop in total consumption was mainly caused by the efficiency effect, which counteracted the increasing effect of the other factors in both periods. Overall, the productivity effect, which measures the change in the ratio of added value to employment, also had a reducing impact on energy consumption.

Figure 37: Decomposition of final energy consumption in the service sector for the periods 2000-2016 and 2008-2016





Source: ODYSSEE tools

4.2. ENERGY EFFICIENCY POLICIES

As for the household sector (Section 3.2) the most relevant policies from the National Energy Efficiency Action Plan (NEEAP 2017) are next introduced for the service sector.

4.2.1. MEASURES FROM THE NEEAP 2017

For the service sector, there are financial instruments pointing at energy efficiency such as the **KfW investment programmes in municipalities and social facilities - IKK Energy-Efficient Renovation**. Funding is from 2009 provided for renovation work to obtain KfW Efficient House Standard 100, 85, 70 and 55 and for energy-efficient individual measures. Specifically, KfW offers loans or sub-loans for this purpose for the renovation of schools, school sports halls, day nurseries and buildings used for work with children or young people.

The efficiency of heating systems is also promoted. The 4th NEEAP encompasses a **Funding Program for Heating Optimisation.** This measure was launched in 2016 and is intended to help citizens, companies and municipalities to replace old heating pumps and hot water pumps and to optimise the operation of heating systems through hydraulic balancing and additional low-investment measures (e.g. the replacement of thermostatic valves). Owners of heating systems are eligible for funding which covers up to 30% of costs, with a ceiling of maximum €25,000.

Germany's measures can be also found in research in the project "**Solar Construction/Energy-Efficient City".** It is a joint research initiative for energy-efficient and climate-friendly buildings and districts launched in 2016. It wants to demonstrate how innovations and smart networking can be used to create houses and districts, which are not only highly energy-efficient but also highly liveable. Technological factors, as well as social policy and socio-economic issues will be considered. The Federal Government has earmarked up to €150 million for this project.

In 2016, the Federal Government also launched the pilot programme **Energy-Saving Meters**, which promotes, through funding, the development, testing and market launch of innovative digital metering systems in the household, “Commerce, trade and services” and industry sectors. These “energy-saving meters” allow users to monitor their consumption of electricity, gas, heating or cooling on a continuous basis and even to identify how much is being consumed by which devices. The earmarked funding was increased in March 2017 from €30 million to around €55 million until December 2018 in response to the high demand.

5. ENERGY EFFCIENCY IN TRANSPORT

5.1. ENERGY EFFICIENCY TRENDS

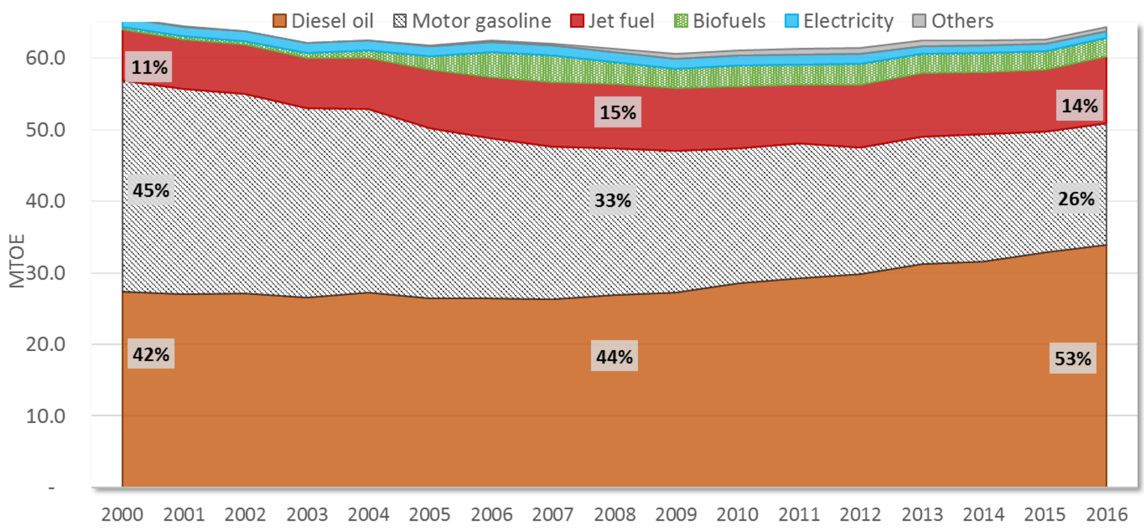
5.1.1. ENERGY CONSUMPTION

Between 2000 and 2016, the total energy consumption in the transport sector fell by about 2% from 65.7 to 64.4 Mtoe (Figure 38). However, compared to 2005, the base year for the final energy consumption reduction target for the transport sector set in the "Energiewende", consumption in 2016 was around 4.3% higher. This means that there is still a considerable gap to meet the 2020 reduction target of 10% compared to 2005. In fact, the gap is widening. While there is a downward trend in energy consumption between 2000 and 2009, a growth behaviour prevails thereafter. As the decomposition analysis will exhibit in Figure 47, the rise of passengers traffic and goods traffic, in a lesser degree, are major contributors to the energy consumption climb that almost outweigh the technical saving efforts.

Diesel oil is the main fuel in the transport energy basket, with 53% of share in 2016. It has had a yearly increase of 1.4% over the whole period, without any reductions since 2008. On the contrary, the highest consumption reduction per year (-3.4%) is attributed to motor gasoline, which might be an outcome of the German legislative framework that accentuates road transport of passengers (by car)[31].

Alternative fuels and electricity together supply around 5% of the consumption in 2016. Both had an increasing trend before the economic downturn of 2008 but a descending one thereafter.

Figure 38 : Energy consumption by fuel in the transport sector, 2000-2016

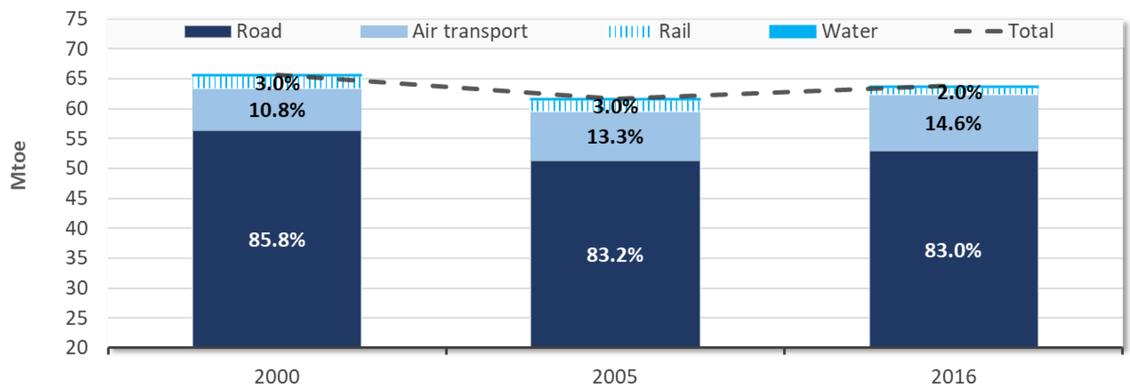


Source: ODYSSEE database

[31] There are 10 sector-specific measures targeting road traffic of passengers issued since 2000, followed by six measures dedicated to modal shift. In terms of freight traffic, two policy measures target goods transport and four, modal shift. The Policy Interaction facility can also confirm that the impact and energy savings of passengers-traffic-related policies are higher http://www.measures-odyssee-mure.eu/interaction-energy-efficiency-policy-transport.asp

With a share of more than 80%, road transport dominates the energy consumption in the transport sector (Figure 39). Therefore, in the following paragraphs, special emphasis is placed on this transport mode. Air transport (international and domestic) presented a considerably above-average growth. Therefore, its share in total consumption increased from 10.8% in 2000 to 14.6% in 2016. The role of rail transport for this sector's energy consumption is rather small and has further lost importance during the last 10 years. The share of inland navigation is insignificant.

Figure 39: Development of transport energy consumption by mode, 2000, 2005, 2016

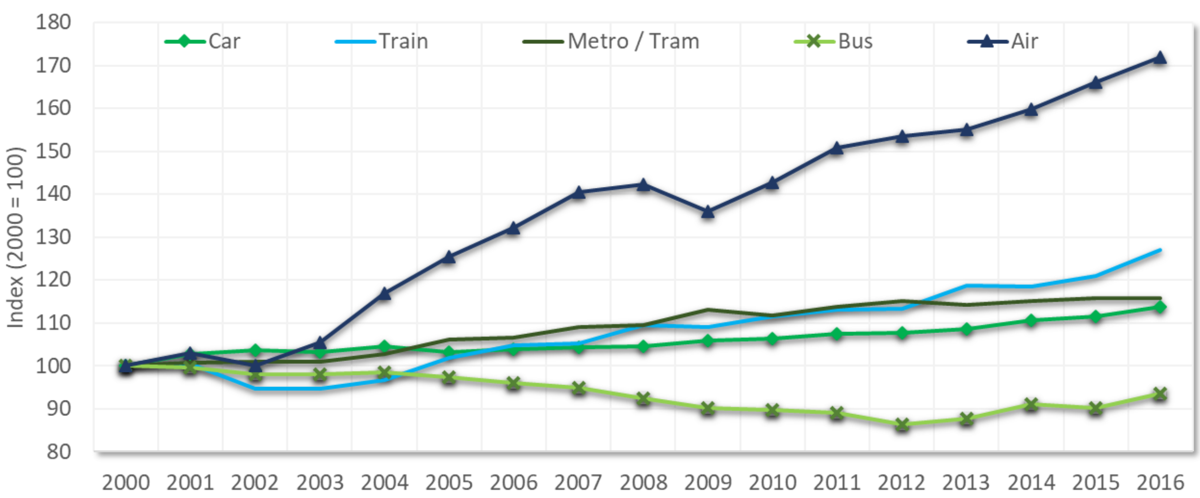


Source: ODYSSEE database

With regard to passenger traffic by means of transportation, the number of passenger kilometers (pkm) for cars is slightly increasing since 2000 (taken as the base year in Figure 40). The transport by train showed a stronger upward trend, whereas traffic by bus has been losing weight in passenger transport since 2004. This trend started to be reversed since 2013, as the market for long-distance buses is growing rapidly linked to the termination of the ban of long-distance buses in January 2013 by the Passenger Transportation Act.

In contrast to road and rail transport, energy consumption for air transport, measured in quantity of passengers, strongly increased, especially in the periods 2004-2008 and after 2011. This can be explained by the relatively strong growth of GDP by 3.2% per year during that period and by the increasing market entry of low-cost carriers.

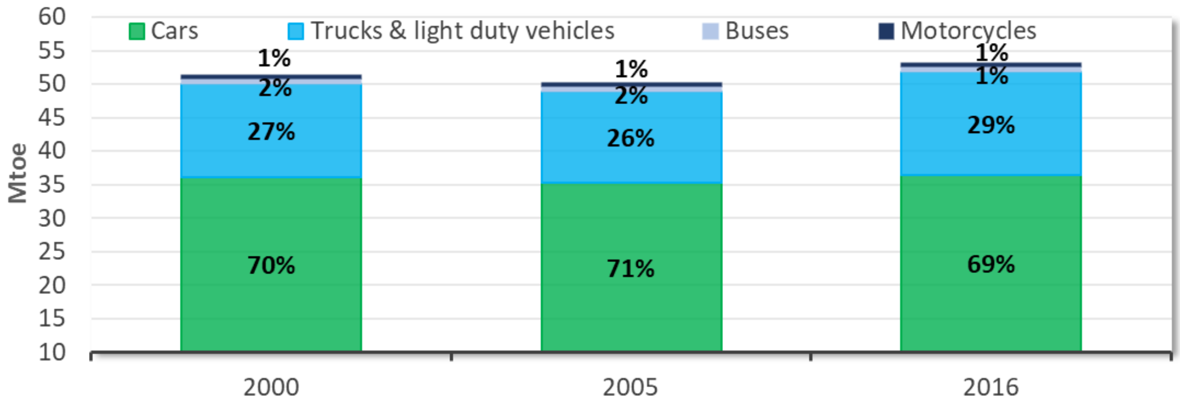
Figure 40: Passenger traffic by means of transportation, 2000-2016 *Source: ODYSSEE database*



5.1.2. ROAD TRANSPORT

In road transport, cars account for 69% of the sector's energy consumption and trucks and light vehicles follow with 29% of share in 2016. Compared to the year 2000, the consumption share of the first mean of transportation in road energy consumption marginally decreased, whereas the share of trucks and light vehicles raised. The consumption of other vehicle types (motor cycles, buses) is not representative (Figure 41).

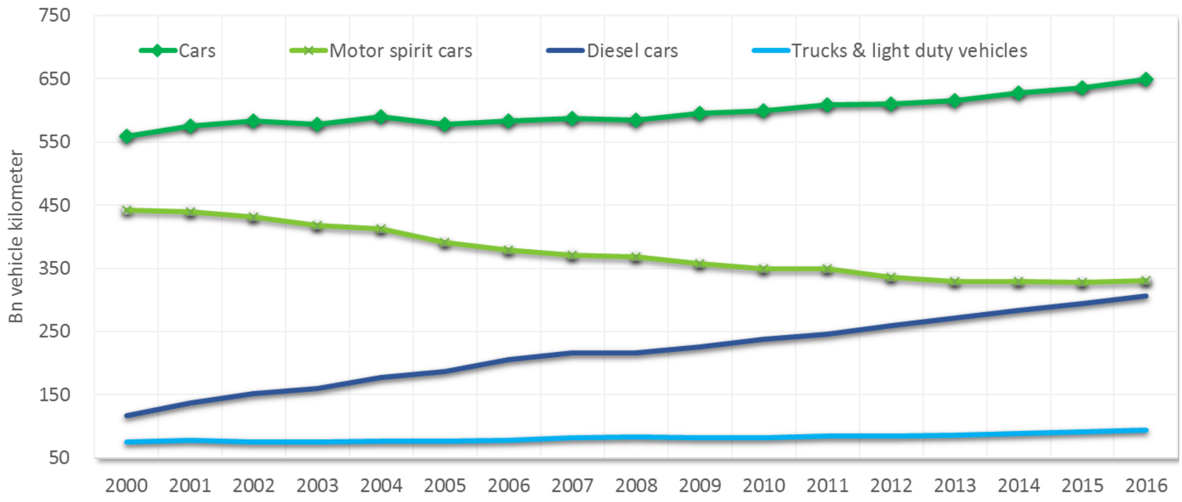
Figure 41: Energy consumption by vehicle type (road transport), 2000, 2005, 2016



Source: ODYSSEE database

The slightly decreasing trend of energy consumption in road transport since 2000, shown in Figure 39, is mainly driven by petrol-driven (or motor spirit) cars whose number of vehicle kilometers has dropped, contrary to the upward progression of the diesel-driven cars (Figure 42). Between 2000 and 2016, the share of the latter in the total car stock more than doubled, moving from 14% in 2000 to 32% in 2016. Domestic truck transport has almost remained constant since 2000.

Figure 42: Development of vehicle kilometers in road transport by type of vehicles, 2000-2016

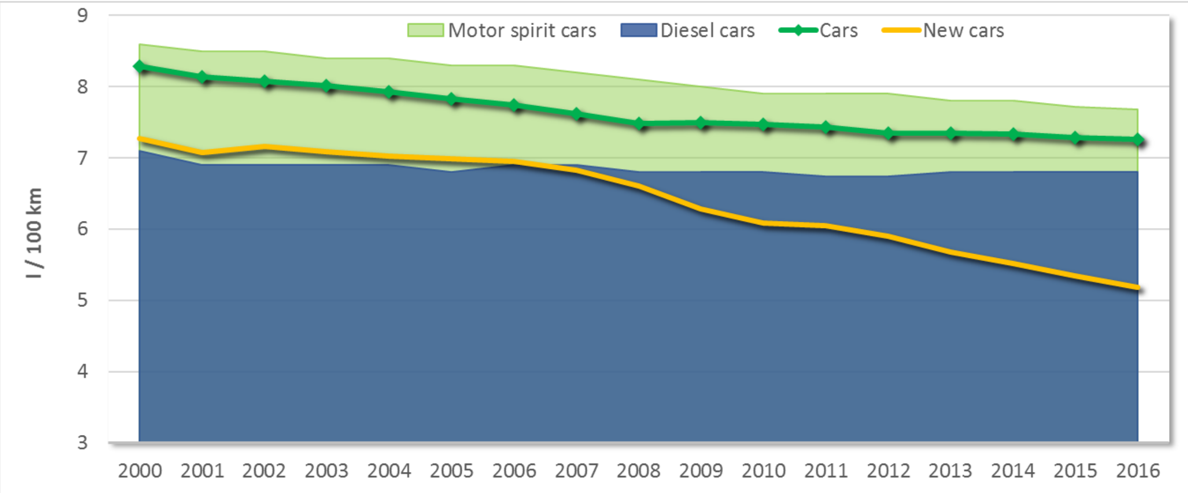


Source: ODYSSEE database

The increasing share of diesel cars in Germany, which have a lower specific fuel consumption than gasoline-driven cars, is another influencing factor in the reduction in energy consumption of road transport. In addition, fuel consumption per vehicle (in l/100 km), both of petrol- and of diesel-fuelled cars, has steadily dropped over time (Figure 43). It has been more pronounced in the first ones (motor spirit private cars) with an annual decrease of 0.7%. Specific fuel consumption of diesel cars has had a progress of 0.3% that stagnates at the end of the period 2000-2016.

The slowdown in fuel efficiency suggests that the purchasing trend towards large cars outweighed the efficiency benefits of engine improvements. The efficiency offered by new cars was higher than the efficiency of the diesel cars in stock until 2006. From this point, improvement in the specific consumption of cars strongly sped up, reaching an advantage of 2.1 l/100km from the existing fleet, which doubled since 2000.

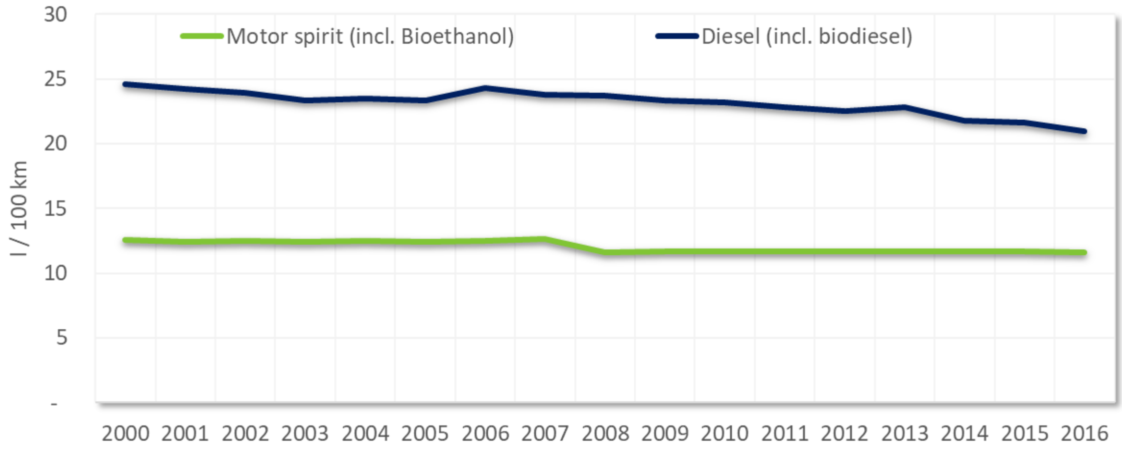
Figure 43: Specific fuel consumption of cars, 2000-2016



Source: ODYSSEE database

The stalled efficiency improvement of the second most influential mean of road transport, trucks and light vehicles, did not beneficiate the reduction of energy consumption in the transport sector. The average diesel consumption of trucks has only decreased from 13 to 12 l/100 km (or 7%) between 2000 and 2016 (Figure 44). Average consumption of gasoline trucks has remained constant over the whole period, apart from a break in 2007. Since only 3% of all trucks are gasoline-driven, this is only of minor importance for the development of energy consumption in road transport.

Figure 44: Specific fuel consumption of trucks and light-duty vehicles, 2000-2016



Source: ODYSSEE database

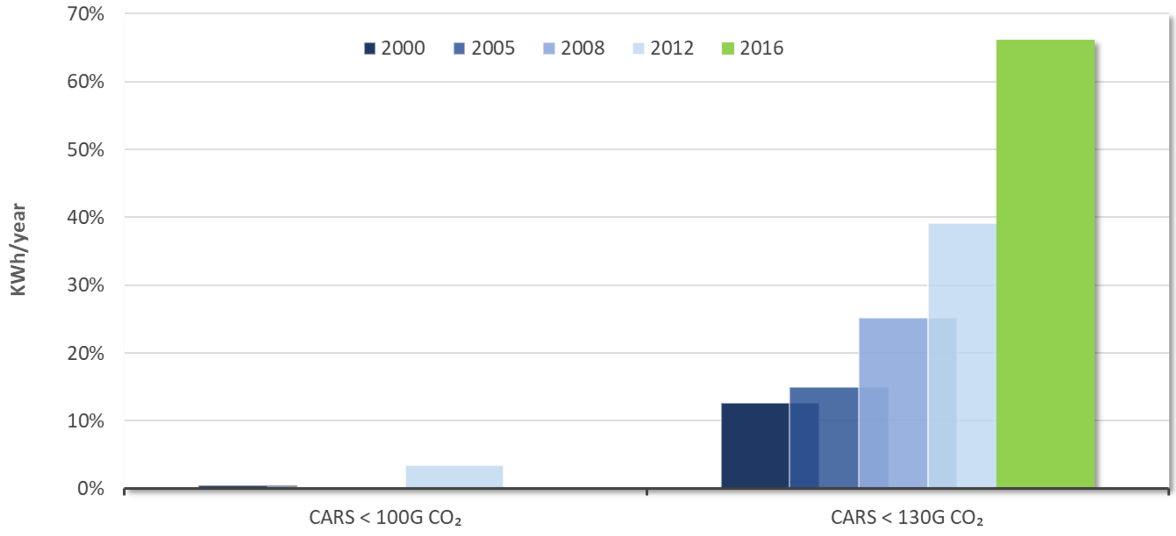
In order to understand Germany's performance in energy efficiency, unit consumptions of road transport can be regarded against Italy, the head of the Scoreboard for Energy Efficiency Level (Table 2). Germany has 22% lower car efficiency than the southern European country, i.e. lower unit consumption of cars (l/100 km). This is the indicator with the biggest gap between both countries (among all indicators that compose the scoreboard,

Table 1). In the matter of road freight, which is less representative in road consumption, Germany takes the lead with a 23% lower specific consumption of truck and light-duty vehicles (in goe/tkm[32]). Yet, this is not able to compensate for the general average performance of this sector in the ranking, where it holds the 16th position (out of 29) in terms of energy efficiency level.

CO2-emissions decreased between 2000 and 2016 as a result of its positive correlation with fuel consumption. Besides, technologies reducing the CO2-Emissions have been improved for new cars and have gained ground in the market. Awareness of consumes seems to have risen, since the share of low-emission cars (i.e. below 100 gCO2/km) increased from 0.5% in 2000 to 9.9% in 2016. Moreover, 66% of new registered cars had emissions below 130 gCO2/km in 2016, compared to 12.6% in 2000 (Figure 45). The Market Diffusion facility that will be introduced in Box 10 provides deeper insight on the extent of Germany's accomplishment in terms of market penetration of more efficient and less pollutant transport technologies, compared to other EU countries.

Figure 45: Share of new low emission cars, 2000-2016

[32] goe: grams of oil equivalent; tkm: ton-kilometer (transport of one ton of payload a distance of one kilometer)

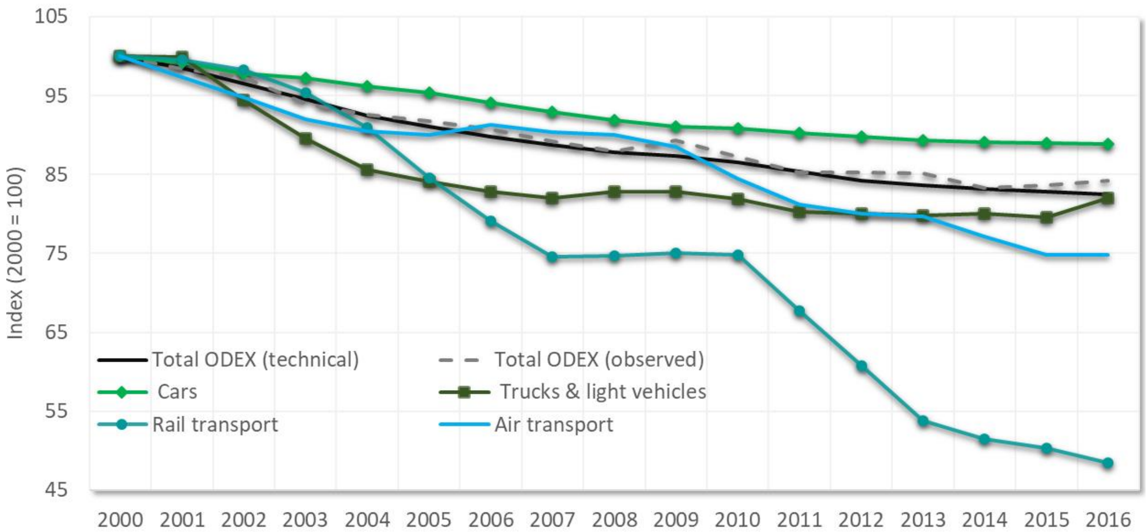


Source: ODYSSEE database

5.1.3. ODEX INDICATOR

The energy efficiency progress in the transport sector is measured by an aggregated energy efficiency index (ODEX), which is calculated at the level of seven transport modes or vehicle types: cars, trucks/light duty vehicles, motorcycles, buses, rail, water and domestic air transport (Figure 46). The calculation is based on the unit consumption indices for these modes. The development of the total transport ODEX strongly follows the car and truck energy efficiency behaviours. To ensure clarity and because of their small influence, water transport, buses and motorcycles are not included in the following figure.

Figure 46: Development of the energy efficiency index (ODEX) in transport, 2000-2016



Source: ODYSSEE database

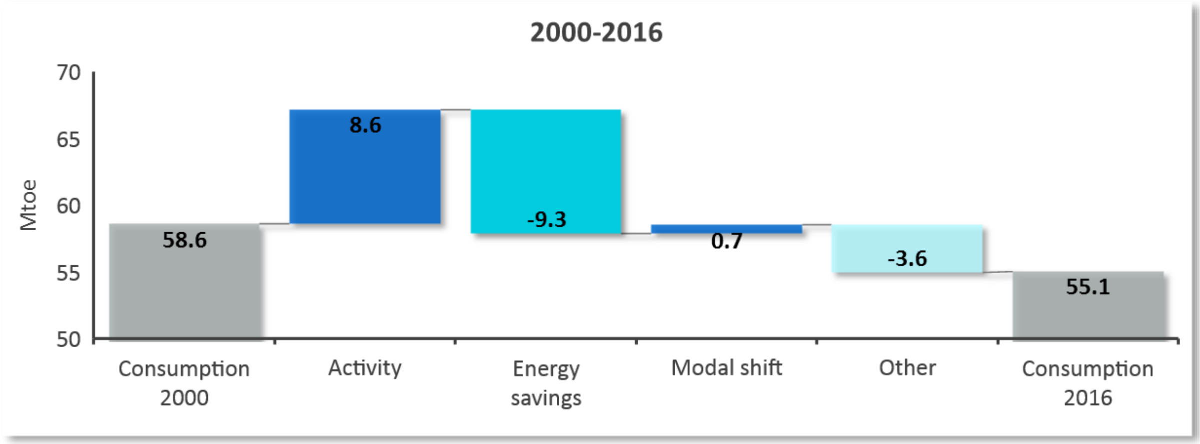
In 2016, the technical energy efficiency index of transport improved by 17.5% compared to 2000. The observed ODEX is much closer to the technical index because temperature changes and use behaviour do not have a major impact on the specific consumption. Efficiency improvements in the car stock contributed steadily to this development as a consequence of the penetration of new efficient cars (measured by a specific consumption in l/km) and a continuous trend to diesel cars. Since 2009, however, the energy efficiency improvement for cars has slowed down. The energy efficiency index for trucks and light duty vehicles also contributed to energy efficiency gains in transport, especially over 2001-2006. Between 2007 and 2009, the ODEX for trucks somewhat increased, which represents a worsening of energy efficiency during the economic crisis (as in industry, utilization at lower capacity does not lead to a proportional reduction of energy consumption). Since 2011, the index for trucks and light duty vehicles remained constant. The contribution of the other transport modes (air, train) is less important due to their small shares in consumption. Besides, the modal shift or changes in the share of transport modes in total consumption has remained stable over the period 2000-2016. This is confirmed by the consumption decomposition analysis that comes next.

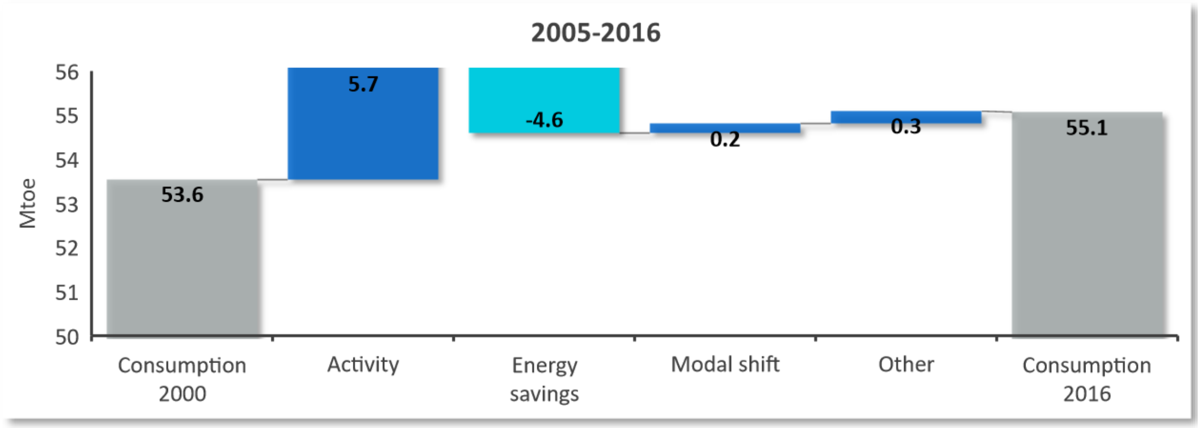
5.1.4. DECOMPOSITION OF ENERGY CONSUMPTION

The decomposition of transport energy consumption is mainly aimed at road transport, which is still by far the dominant transport mode in Germany. Therefore, air transport is not included in the analysis. As already stated above, the variation of transport energy consumption is dominated by an growing traffic of passenger and goods (activity effect, Figure 40), which contributed to an increase in energy consumption by around 8.6 Mtoe in the period 2000-2016 (Figure 47). This effect was compensated by technical energy efficiency improvement, resulting in a total decrease of transport energy consumption by around 3.5 Mtoe over the period or 0.22 Mtoe per year (from 58.6 to 55.1 Mtoe). The slight increase of modal shift, i.e. changes in the distribution of each mode in total passenger and goods traffic had a comparatively small impact on transport energy consumption between 2000 and 2016. The performance from 2005, the base year for the German energy consumption reduction target of 10% (Table 3), has a similar behaviour in terms of direction of impacts, but the energy efficiency savings did not keep the variation pace of the period 2000-2004 and decelerated to 4.6 Mtoe, becoming incapable of outweighing the increase due to activity changes. As a result, total energy consumption raised by 1.52 Mtoe (from 53.6 to 55.1 Mtoe) since 2005. Energy consumption further increased in the period 2008-2016 (by 2.75 Mtoe) due to the non-linear reduction of consumption with respect to the activity slowdown during the economic crisis. This slowing progression helps explain why Germany was ranked 15th (out of 29) in the Scoreboard for Energy Efficiency Trend (

Figure 4). Further reduction in the traffic and/or an improvement of energy efficiency are necessary to improve Germany's performance.

Figure 47: Decomposition of final energy consumption in the transport sector for the periods 2000-2016 and 2005-2016





Source: ODYSSEE tools

5.1.5. DIFFUSION OF ENERGY EFFICIENCY TECHNOLOGIES IN MOBILITY

Replacement of old equipment with less energy-consuming units is a strategy for energy efficiency growth. The ODYSSEE Market Diffusion tool (Box 10) helps track the progress of the market adoption of more efficient practices and technologies.

Box 10: The Market Diffusion facility[33]

MARKET DIFFUSION

This data tool gathers indicators that show the market penetration of energy efficient technologies and practices as well as end-use renewables in the household, services and transport sector. They comprise the diffusion of:

- efficient cars and cars using alternative fuels,
- efficient transport modes (rail and water transport for freight, public transport for passengers),

[33] http://www.indicators.odyssee-mure.eu/market-diffusion.html (public access)

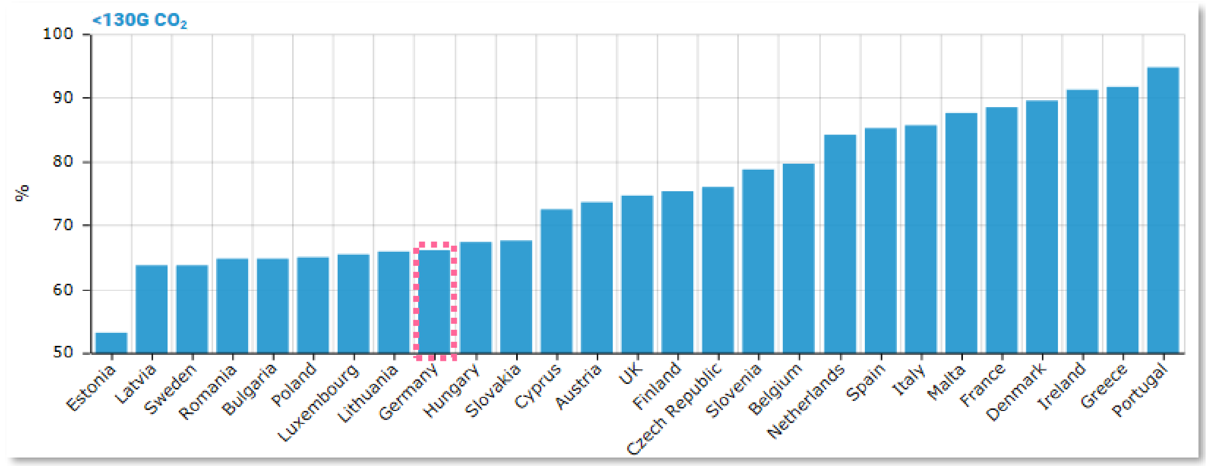
- bioenergy by sector,
- efficient heating equipment (heat pumps, condensing boilers),
- solar water heaters, efficient appliances (with efficiency labels equal to or above A+),
- compact fluorescent lamps,
- efficient buildings
- and smart meters.

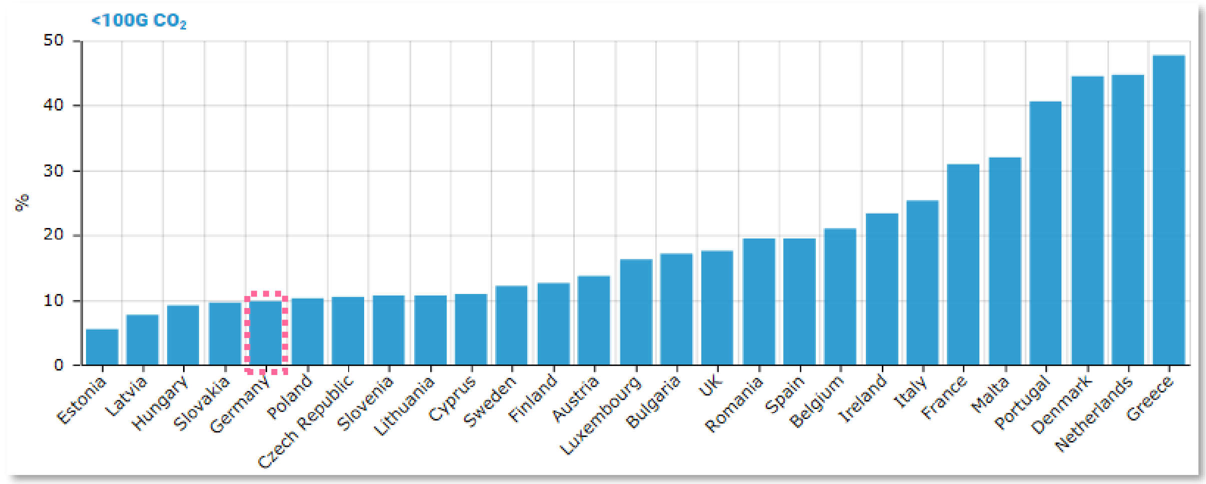
The information is presented as a map or a bar chart that compares the diffusion of each technology or practice among the member countries of the ODYSSEE-MURE project. Yearly information from 2000 is available.

The market diffusion of more efficient technologies in the transport sector is covered by the two first technologies mentioned in Box 10. As stated in previous paragraphs, Germany has had a non-negligible increase in the shares of efficient and low-CO_2-emission cars during the past years (Figure 45). Nevertheless, compared to other EU countries, this increase can be rated as modest. Although 66% of new cars in 2016 emit less than 130g per kilometer, Germany lies within the 10 lowest positions, where Portugal is the leader with a share of 95% (Figure 48). Worse yet, Germany constitutes the top five lowest performers with respect to the penetration of <100g CO_2 cars with a share of about 10%, which seems especially small when comparing it to Greece's share of 45%.

This MURE tool also delves into the proportion of current and new alternative fuel vehicles, covering electric, hybrid, flex and CNG-natural gas cars, where Germany has an average performance as well. In Germany, 0.5% of total cars in stock and 1.5% of cars sold in 2016 are alternatively fuelled, where natural gas and hybrid cars account for the greatest numbers. Norway takes the lead and conversely, 4.6% of cars in stock and 45.3% of new cars are alternatively fuelled. More efforts are necessary to increase awareness and shape a more suitable market for efficient vehicles exchange in Germany.

Figure 48: Share of efficient cars in total sales, 2016





Source: ODYSSEE tools

5.2. ENERGY EFFICIENCY POLICIES

The 4th Energy Efficiency Action Plan (NEEAP 2017) published in 2017 (BMWi 2017) contains most of the ongoing measures in Germany that were undertaken in previous NEEAPs (mainly in the 3rd NEEAP; BMWi 2014b). Additional policy measures for the transport sector are included in the Climate Action Programme 2020 (BMUB 2014). The following text summarizes a few of them.

5.2.1. MEASURES FROM THE NEEAP 2017

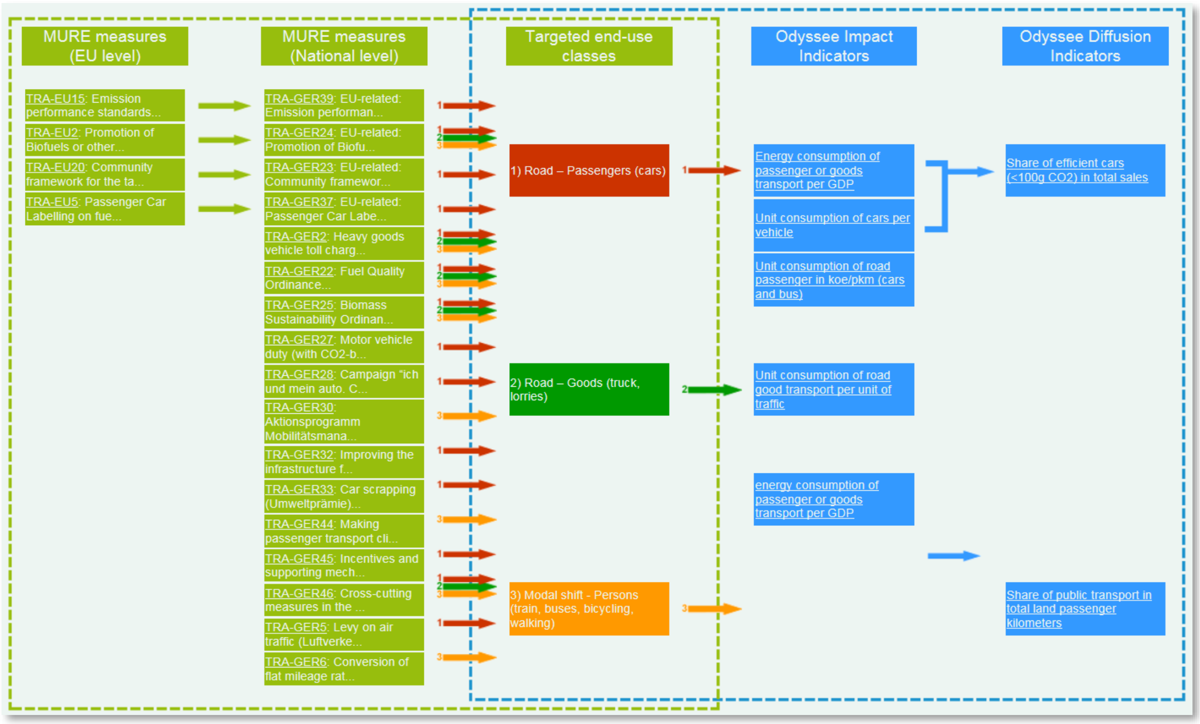
A **levy on air traffic** for all flights from German airports has become valid from 1 January 2011 and it is still part of the 4th NEEAP. The levy must be paid by the airline and depends on the distance of the flight. It ranges between €7.46 a for short-haul flight, 23.31 EUR for medium-haul flights, and €41.97 for long-haul flights. Since 2011, the air-traffic levy has been increased. This increase is usually included in flight tickets for the passengers who visit any airport in Germany. The increase in the levy considers the destination of the flight and the flight distance/travel time. The levy has been classified in three classes since January 2013.

Some cross-cutting measures that concern the transport sector and which impact is still tracked in the 3rd NEEAP, such as the **KfW Energy Efficiency and Environmental Programmes**. They provide loans for the financing for environmental protection and energy saving investments to private companies and self-employed persons, for example for the procurement of low-emission commercial vehicles in the case of transport. The loan application is done via local banks, which set interest rates according to a risk assessment. In the energy efficiency programme the maximum amount loaned is €25 million.

5.2.2. THE LINK BETWEEN INDICATORS AND POLICIES

The above-mentioned policies and other national measures are approached by MURE in a visual-friendly way with its Policy Mapper facility (already mentioned in Box 9). As an example, Figure 49 shows three end-uses of the transport sector with their respective ongoing policies that target energy efficiency directly or indirectly. They are the road transport of passengers (by car), the road transport of goods (by truck and light-duty vehicles) and the use of alternative means of transportation (shift to train, buses or bicycles). The road transport of passengers stands out since it is targeted by 14 measures (including crosscutting policies), whereas freight transport and modal shift are covered 5 and 8 measures. This makes sense given the high importance of road transport and cars in the sector's total consumption (as seen in Figure 39 and Figure 41). This facility also provides the connection to related measures at EU level, as well as to efficient technology diffusion indicators and energy efficiency indicators that, to some extent, assess policy impacts. The Policy Mapper example of Figure 49 is a good summary of the topics and indicators covered by the analysis of this chapter section.

Figure 49: Measures addressing several targeted end-uses in the transport sector in Germany



Source: MURE tools

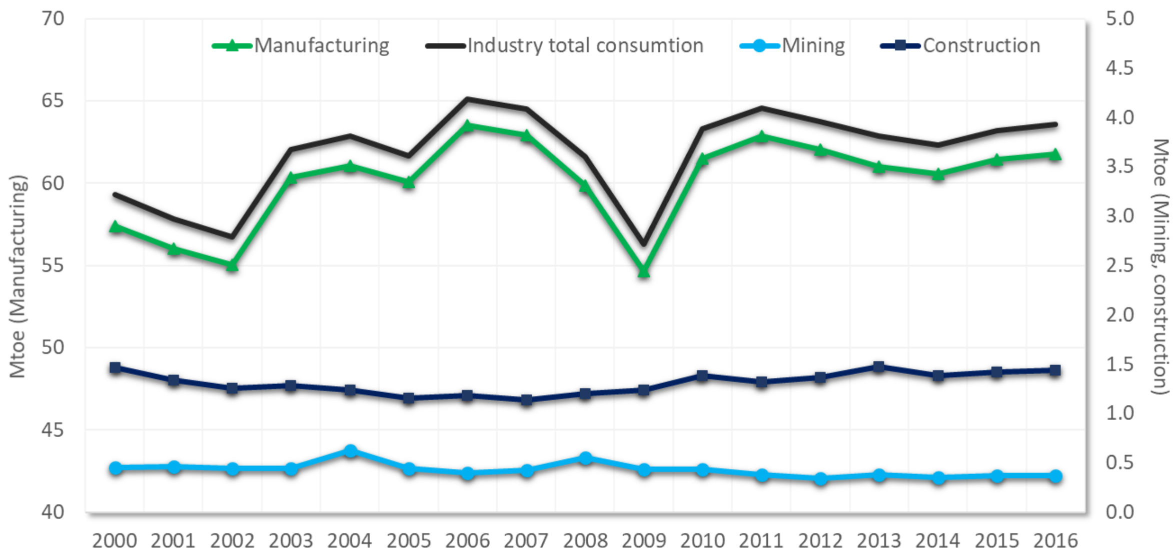
6. ENERGY EFFICIENCY IN INDUSTRY

6.1. ENERGY EFFICIENCY TRENDS

6.1.1. ENERGY CONSUMPTION

The industry is a large consumer of final energy in Germany with a share of around 29%. In 2016, total final energy consumption of this sector (consisting of manufacturing, construction and mining[34]) amounted to 63.57 Mtoe, which is 7% higher than the consumption of 59.30 Mtoe in 2000 (Figure 50). Today's consumption level was reached by an average yearly increase of 0.55%, that was strengthened by a similar the consumption rise just after the contraction of the economy in 2008 and 2009. This upward trend is principally shaped by the manufacturing industry, which contributes about 97% of total final consumption in industry with 61.76 Mtoe. Manufacturing is, therefore, the focus of the following analysis. The lower-consuming, although energy-intense, construction and mining industries reached a consumption level of 1.43 Mtoe and 0.37 Mtoe respectively.

Figure 50: Final energy consumption in industry in Germany, 2000-2016

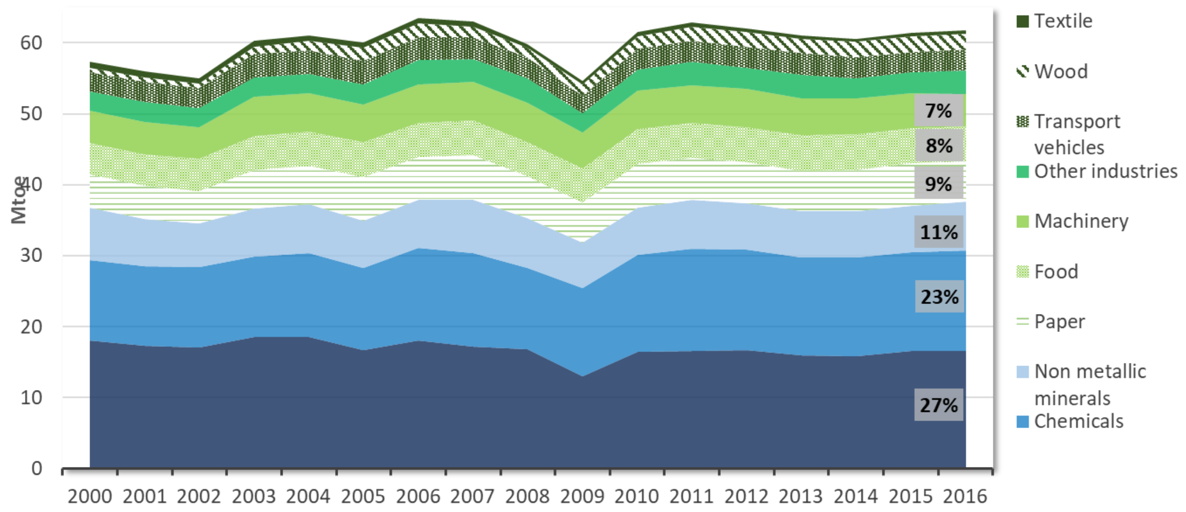


Source: ODYSSEE database

Over the period 2000-2016, energy consumption by manufacturing branches did not change significantly (Figure 51). Primary metals and chemicals account for half of the consumption. The first one had a stable behaviour while the second presents a yearly increase of about 1.6%, which decelerated since 2008. In addition to primary metals and chemicals, other energy-intensive branches such as non-metallic minerals, paper and food are also representative, and all together constitute almost the 80% of energy consumption in industry.

Figure 51: Final energy consumption in the manufacturing sector by branches since 2000

[34] Industry is defined in ODYSSEE as manufacturing industry (consisting of 10 branches), mining and construction, which are defined in accordance with the statistical classification of economic activities in the European Community (NACE, Rev. 2, 2008). It excludes the energy used for non-energy uses. http://ec.europa.eu/eurostat/ramon/index.cfm?TargetUrl=DSP_PUB_WELC



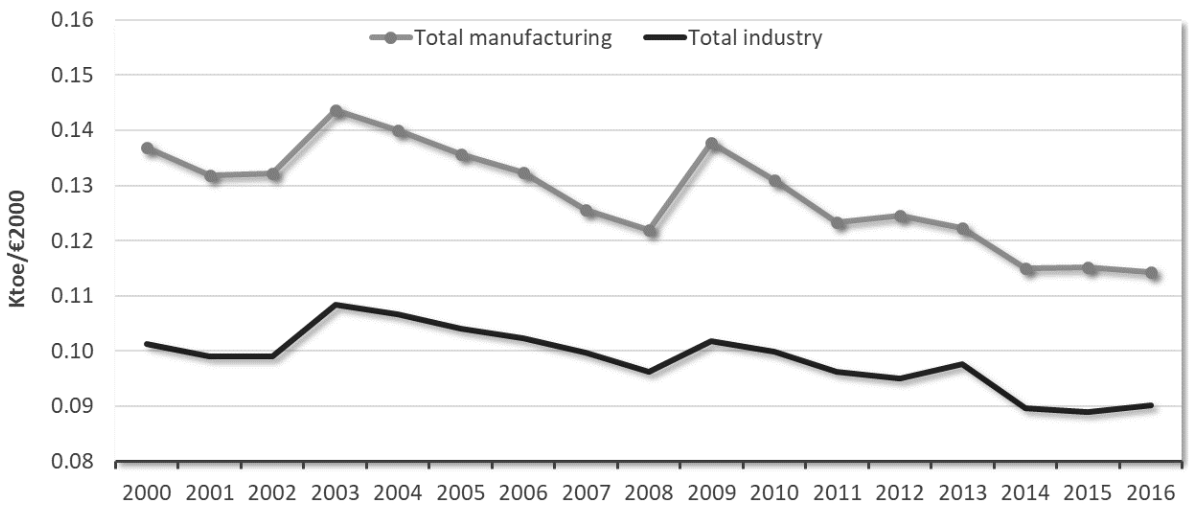
Source: ODYSSEE database

6.1.2. ENERGY INTENSITY AND UNIT CONSUMPTION

Energy efficiency in industry is described by the aggregate indicator of energy consumption compared to value added per branch (i.e. energy intensity). Even though there is an expanding decoupling of these two variables, the energy intensity drop in industry between 2000 and 2008 was 27% higher than the decrease thereafter (Figure 52In terms of the most representative branches of the manufacturing sub-sector, only chemicals and non-metallic minerals showed an improvement. Other both energy-consuming and energy-intensive branches, such as primary metals, paper and food, increased their energy intensity over the whole period.

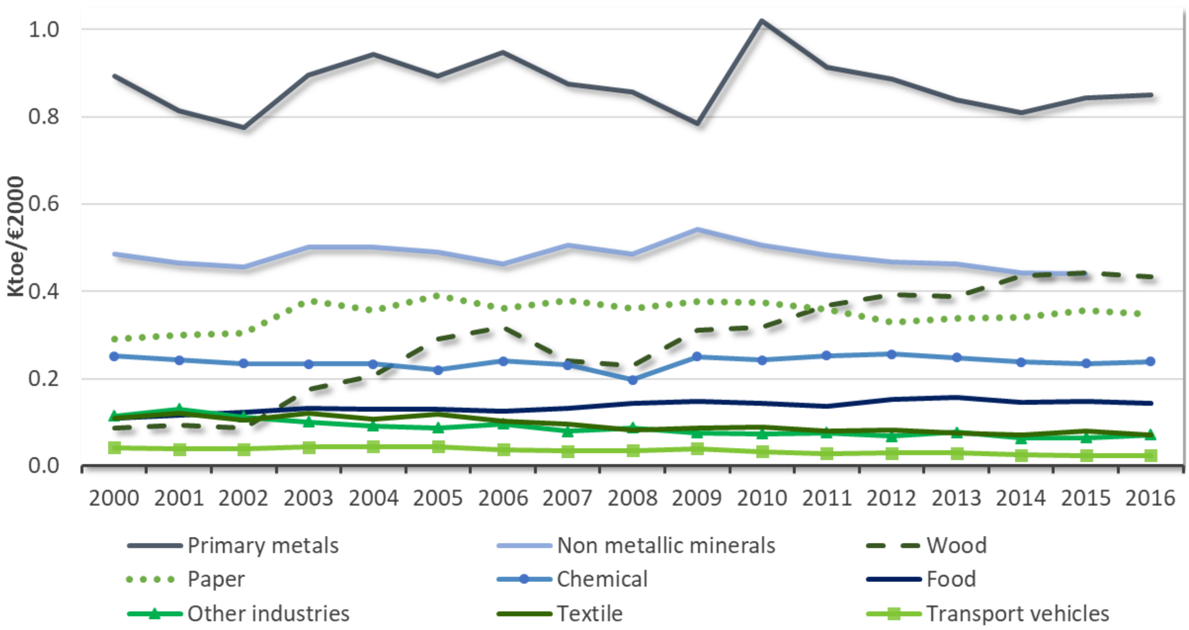
). This slowdown behaviour is explained by the fact that the energy consumption is not proportionally reduced to the activity changes during a period of crisis. Yet, it seems that other countries in Europe faced a larger struggle. Despite Germany's rather stagnant improvement in energy intensity, the ratio of 0.09Ktoe/€2000 between energy consumption and industry's value added that was reached in 2016, placed Germany in the 9th place of the sectoral Scoreboard for Energy Efficiency Level (Table 2).

Figure 52: Development of energy intensity in industry and manufacturing, 2000-2016



In terms of the most representative branches of the manufacturing sub-sector, only chemicals and non-metallic minerals showed an improvement. Other both energy-consuming and energy-intensive branches, such as primary metals, paper and food, increased their energy intensity over the whole period.

Figure 53: Development of energy intensity in manufacturing branches, 2000-2016

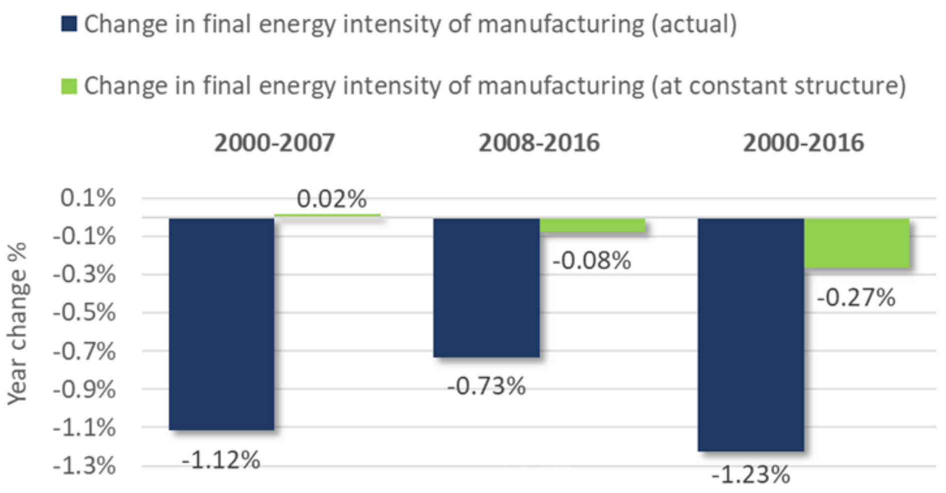


Source: ODYSSEE database

As already stated above, the development of energy intensity does not only reflect energy efficiency improvements; structural changes within manufacturing (i.e. changing shares of the energy-intensive branches in total industrial output), may also have an important influence. This is shown by the energy intensity calculated within a constant structure of manufacturing. The intensity at constant structure better reflects the predominantly technically induced efficiency changes in manufacturing since the impact of structural changes is removed.

On the one hand, the decrease of the actual energy intensity of manufacturing by around 1.12% per year before the economic recession was mainly caused by structural changes towards less energy-intense branches. There were therefore not any energy efficiency gains (Figure 54). On the other hand, the structural changes did not completely counteract the energy intensity reduction as much during the period 2008-2016, leading to a marginal yearly intensity decrease at constant structure of 0.08%. The actual drop in energy intensity of this second period of 0.73% per year was, however, lower than the previous period due to the backwardness effect of the crisis. Over the whole period, the energy progress is sorely diminished by the structural changes and results in an energy progress of 1.23% per year on average.

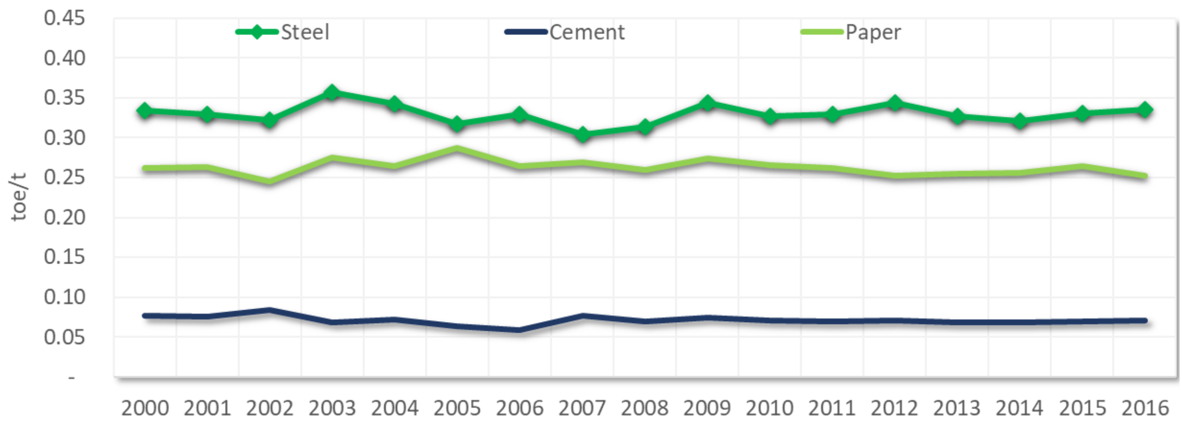
Figure 54: Change of energy intensity in manufacturing, 2000–2016



Source: ODYSSEE database

The meaningfulness of final energy intensity of manufacturing is restricted by the fact that it is calculated based on added value, i.e. activity calculated in monetary units. The use of physical factors is widely advocated since they better reflect the energy efficiency development (see e.g. Neelis et al., 2007; Salta et al., 2009). Therefore, unit consumption indicators (defined as energy consumption per ton) for some energy-intensive products in manufacturing are calculated in addition to energy intensities (Figure 55).

Figure 55: Unit consumption of energy-intensive products, 2000-2016



Source: ODYSSEE database

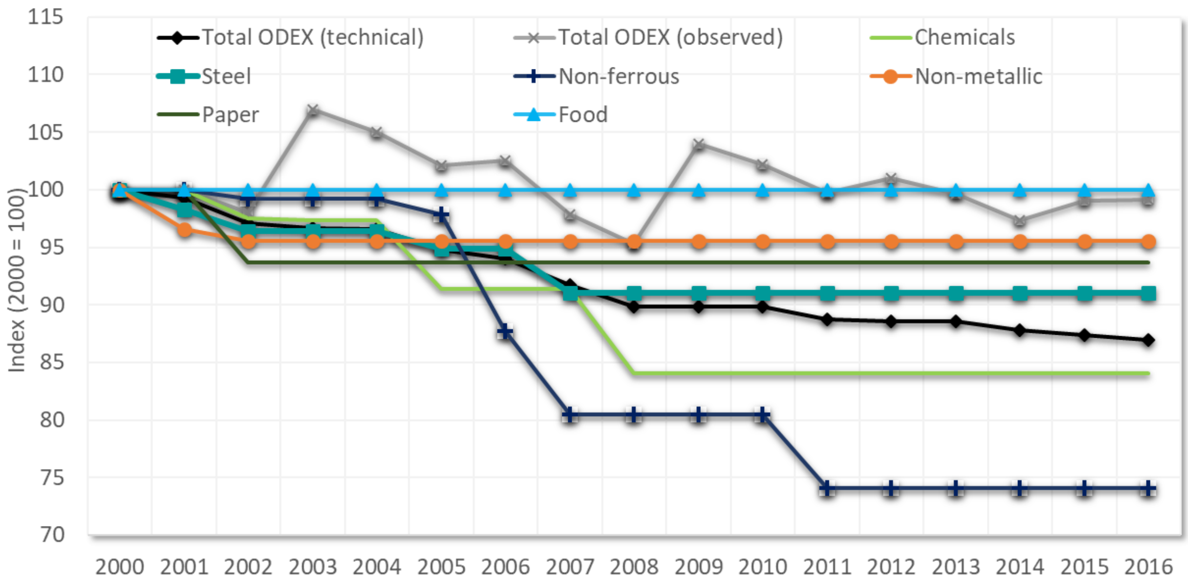
During the period 2000-2016, unit consumption of the selected products (crude steel, paper, cement) did not change significantly. In fact, in some years an increase was observed, especially in the case of steel and paper, and this was mainly linked to business cycles. The trend in unit consumption confirms the observation of rather modest energy efficiency improvement in industry which was already shown by the intensity indicator (Figure 53), where only some branches showed a relevant fluctuation as the economy reactivated after the crisis. This was also a reversal of the trend during the 1990s, when both energy intensity and unit consumption of energy-intensive products considerably decreased and an improvement in energy efficiency was observed.

6.1.3. ODEX INDICATOR

In addition to the energy intensity at constant structure and the unit consumption of energy-intensive products, the efficiency progress in the industrial sector is also shown with the ODEX. It measures the efficiency development at the level of manufacturing branches and then aggregates this development to the whole sector (Figure 56). For the energy-intensive products (cement, steel, paper), the calculation is based on unit consumption per ton. For the other branches, the energy used per production index is used instead of added value, in order to exclude the impact of a changing value of products from the ODEX.

The fluctuating behaviour of the observed ODEX (dashed line) is due to the efficiency or inefficiency of equipment use and not to changes of equipment that are technically more or less efficient. That is why efficiency drastically drops in 2008, as machines were not used at their rated capacity. In addition, part of energy consumption is independent of the production level. Under these conditions, it is difficult to assess the real technical energy progress. Therefore, the efficiency progress of the adopted technology over the past 16 years is given by the technical ODEX, which show an improvement in energy efficiency of 13% for the industry from the year 2000. The development within the industrial branches, however, varied significantly, both between the branches and over the whole period under review. There were some branches with a considerable energy efficiency progress (e.g. cement, non-ferrous metals and chemicals), and others with an increasing ODEX, i.e. a worsening of energy efficiency (e.g. steel, paper, non-metallic minerals and food). The ODEX seems to slowly leave the stagnation state caused by the crisis.

Figure 56: Development of the energy efficiency index (ODEX) in manufacturing, 2000-2016



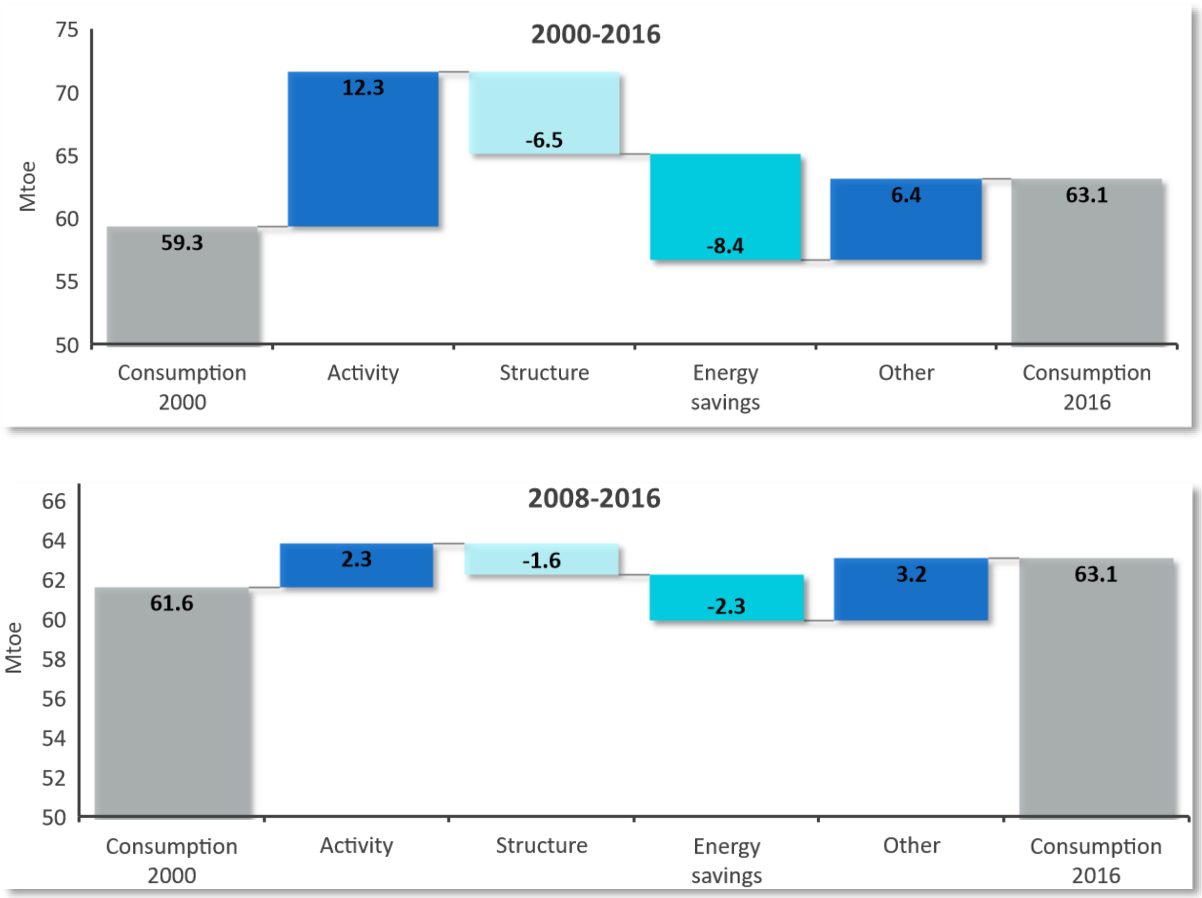
Source: ODYSSEE database

The energy efficiency progress contributed by the industry (13%) is the lowest among all sectors. As it is not only an important energy consumer, but also the most energy intense sector, its bad performance is expected to be translated in bad results for Germany in front of other countries. In fact, industry's position at the very bottom of the sectoral Scoreboard for Energy Efficiency Trend (Table 2) greatly drives the lowermost place in the global ODYSSEE ranking for trends.

6.1.4. DECOMPOSITION OF ENERGY CONSUMPTION

The decomposition of energy consumption confirms the minimal progress in energy efficiency that was achieved in industry over the period 2000-2016. The activity effect, i.e. the industrial growth, had an increasing impact on energy consumption, whereas structural changes towards less energy-intensive branches caused a significant reduction that compensated for almost half of the activity impact (Figure 57). The remaining difference, together with other effects (mainly negative savings due to inefficient operations), counteract the 8.4 Mtoe achieved technical savings and finally resulted in an energy consumption rise of 3.79 Mtoe. In the period 2008-2012, the decreasing impact of structural changes and the gained energy savings leaned towards energy efficiency progress, but their impact was less significant. However, energy consumption increased by 1.5 Mtoe due to activity notwithstanding the critical drop in value added, which was a consequence of the economic downturn. As already explained above, this trend in industry is due to the fact that during an industrial recession, the energy consumed per unit of production tends to increase as process energy does not decrease in proportional to activity (as the efficiency of equipment drops when not used at full capacity) and as the other energy uses (e.g. for heating and lighting of the premises) remains roughly constant.

Figure 57: Decomposition of final energy consumption in the industry for the periods 2000-2016 and 2008-2016



Source: ODYSSEE database

6.1.5. COMPARISON OF ENERGY EFFICIENCY PERFORMANCE

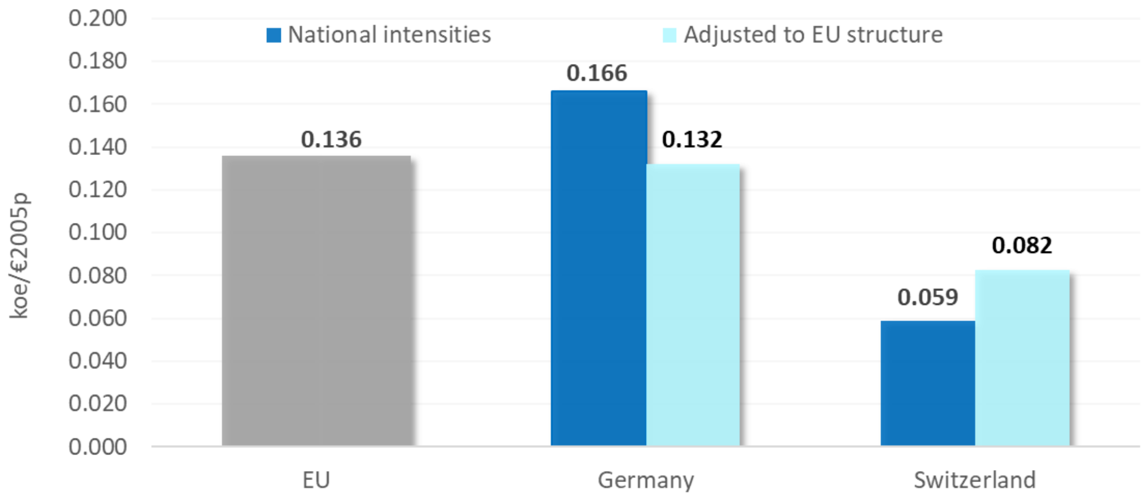
Besides the adjustment to constant structure that was previously featured in the industry's energy intensity section, an adjustment to another country's economic and industry structures allows for a clearer comparison of technical performance regarding the necessary energy to produce a unit of value added. The Comparison facility (Box 5) enables this benchmark, which, in this case, will be carried out between Germany and Switzerland, the country leading the ranking of energy efficiency level (

Figure 4). The average EU energy intensity is also included to further explain Germany's performance against the rest of the project members. In fact, all energy intensity values are adjusted at EU industry structure[35] as well as converted to 2005 prices and to a common currency (euro), as it is also done for the calculation of the scoreboards[36]. This structures and price differences modifications clean each country's economic and financial performance and reveal the technical performance in energy efficiency.

Between Germany and Switzerland, there is a difference of 0.05 koe/€2005p, which means a 60% higher energy intensity in Germany (Figure 58). Since this difference is quite big, the comparison with the second best in the ranking should be brought into consideration. The 24% difference to Spain's energy intensity is indeed lower but still important. However, Germany is 3% below the average (when compared to EU energy intensity) and 65% below Norway (the worst performer), which helps explain Germany's position among the top 10 countries in the Scoreboard for Energy Efficiency Level (

Figure 4) but has an substantial gap close in order to move up in the classification.

Figure 58: Comparison between final energy intensities of the industry in EU, Germany and Switzerland, 2016



Source: ODYSSEE tools

6.2. ENERGY EFFICIENCY POLICIES

Several policies targeting industry's energy consumption and CO_2 emissions are included in 3rd and 4th National Energy Efficiency Action Plans (NEEAP) (BMWi 2014b, BMWi 2017). Some additional measures are part of the "National Action Plan Energy Efficiency" (NAPE) that was launched in December 2014 (BMWi 2014a). In the following paragraphs, some of the key energy efficiency policy measures are described.

[35] The energy intensity of industry at EU structure represents a fictitious value of the industrial intensity calculated by taking for each industrial branch the actual sectoral intensity of the country and the EU industrial structure (i.e. the share of each branch in the value added of industry).

[36] Using purchasing power parities (ppp) instead of exchange rates.

6.2.1. MEASURES FROM THE NEEAP 2017

Thanks to the **KfW Energy Advice (or consultations) for SMEs**, supervised by the Federal Office of Economics and Export Control (BAFA), small and medium-sized enterprises (SMEs) can be eligible for a financial support that covers 80% of advisory services that point to the exploitation of their energy efficiency potential since January 2015. The highest granted amount is €800 or €8000 according to the SME's annual energy costs. This measure was implemented in 2012, however, the guidelines and application requirements changed in 2015.

Also, the Federal Ministry for Economic Affairs and Energy (BMWi) has launched an **Energy Efficiency Fund** starting in 2008. Therein are two programmes called "**Promotion of energy-efficient cross-cutting technologies in SMEs**" and "**Promotion of energy-efficient and climate-friendly production processes**". The first one provides funding in form of investment grants for energy-efficient pumps, drivers or compressed-air systems. Especially SMEs can benefit since January 2014 as additional financial incentives were created. Implementation and execution of the support programme are by the Federal Office of Economics and Export Control (BAFA). Besides the promotion for investment in technologies available on the market, the exchange of individual technologies like systematic optimisation is equally promoted. Up to 30% of the investment costs can be reimbursed if the achievable energy saving amounts at least 25% compared to the old system.

In May 2016, a new programme was launched under the 4th NEEAP to provide funding for waste heat avoidance and waste heat utilization in commercial enterprises. This "**Waste Heat Utilization**" initiative is open to all applicants and technologies. Investments in the replacement, modernization, expansion or new construction of installations are funded if they will result in the avoidance of waste heat or the utilisation for the first time (internally or externally) of waste heat.

Operated by the BMWi, **STEP up!** is a competitive funding programme that aims at providing financial support for corporate investments in power efficiency improvements, on the basis of a tendering procedure. The intention is to incentivise companies to invest in highly efficient power-saving technologies, to reduce their power consumption and to become more competitive. Funding is awarded for the efficiency measures with the best cost/benefit values. Two rounds of competitive tendering take place each year (one in the spring and one in the autumn). €300 million of funding is available for the pilot phase that will run until 31 December 2018. It would be extended from 2019 onwards if the programme proves successful.

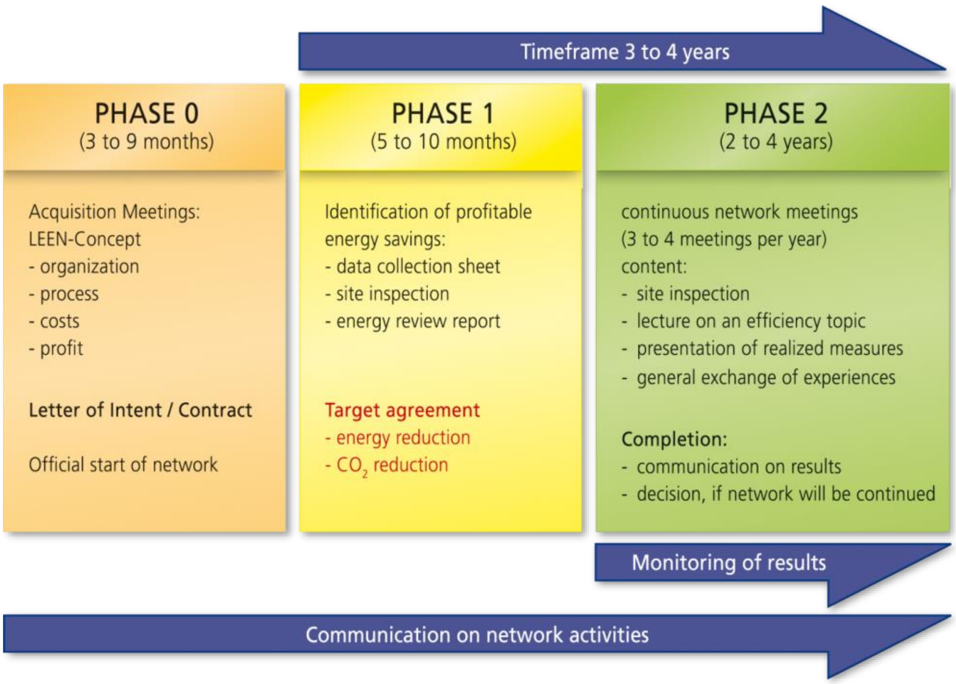
The initiative "**Energy Efficiency Networks"** is based on the concept of Learning Energy Efficiency Networks (LEEN[37]), which targets energy efficiency in companies from different sectors. The energy efficiency current situation is measured and experiences around this topic are shared in moderated meetings among a group of 10-15 companies, which is recruited by the network operator. After joining this energy efficiency network, energy review or audits are performed, highlighting energy efficiency potentials. This is followed by the networking process of information exchange among member companies and external experts, aiming at finding solutions on how to exploit the energy efficiency potential of each company. The focus of this exchange of experience is on a set of common cross-cutting technologies, and in order to secure an open exchange of ideas, plans and experiences, the companies participating in the network should not be in competition in the same sector. The performance of each company is continuously monitored and controlled on a yearly basis. The network operating period is typically from three to four years (EnAW 2014; Köwener 2011).

[37] www.leen.de

The concept was originally developed in Switzerland in the late 1980s and later transferred to Germany, where there presently are two types of networks. These networks became immediate actions within the National Action Plan on Energy Efficiency (NAPE) and are now included in the NEEAP 2017. The idea is to extend these networks from around 60 to 500 in 2020, as defined in a voluntary agreement that signed by the German Government and 18 associations of industry in 2014. The outcome of the networks running so far in Germany is that energy efficiency progress is doubled compared to the autonomous progress[38]. Around 75 PJ of energy savings per year are expected by the 500 energy efficiency networks in 2020 (about 3% of total industrial energy use in Germany) and avoided CO_2 emissions of around 5 million tonnes (Köwener 2011).

The programme has three phases (Figure 59). After the definition of the groups, the companies fill in a data form concerning their energy situation and the certified consultant engineer carries out the energy audit. Each participant sets an efficiency target (confidential) and commits to a voluntary target and to achieve it during the second phase. All network participants report on planned or implemented measures so that the other participants can benefit from their experiences. Besides, there are regular exchange meetings regulated by a certified moderator. Within the process, the participants have the chance to benefit from exchange of information and experience, site visits during the meetings, and the possibility to utilize synergies in the networks.

Figure 59: LEEN network process



Source: www.leen.de

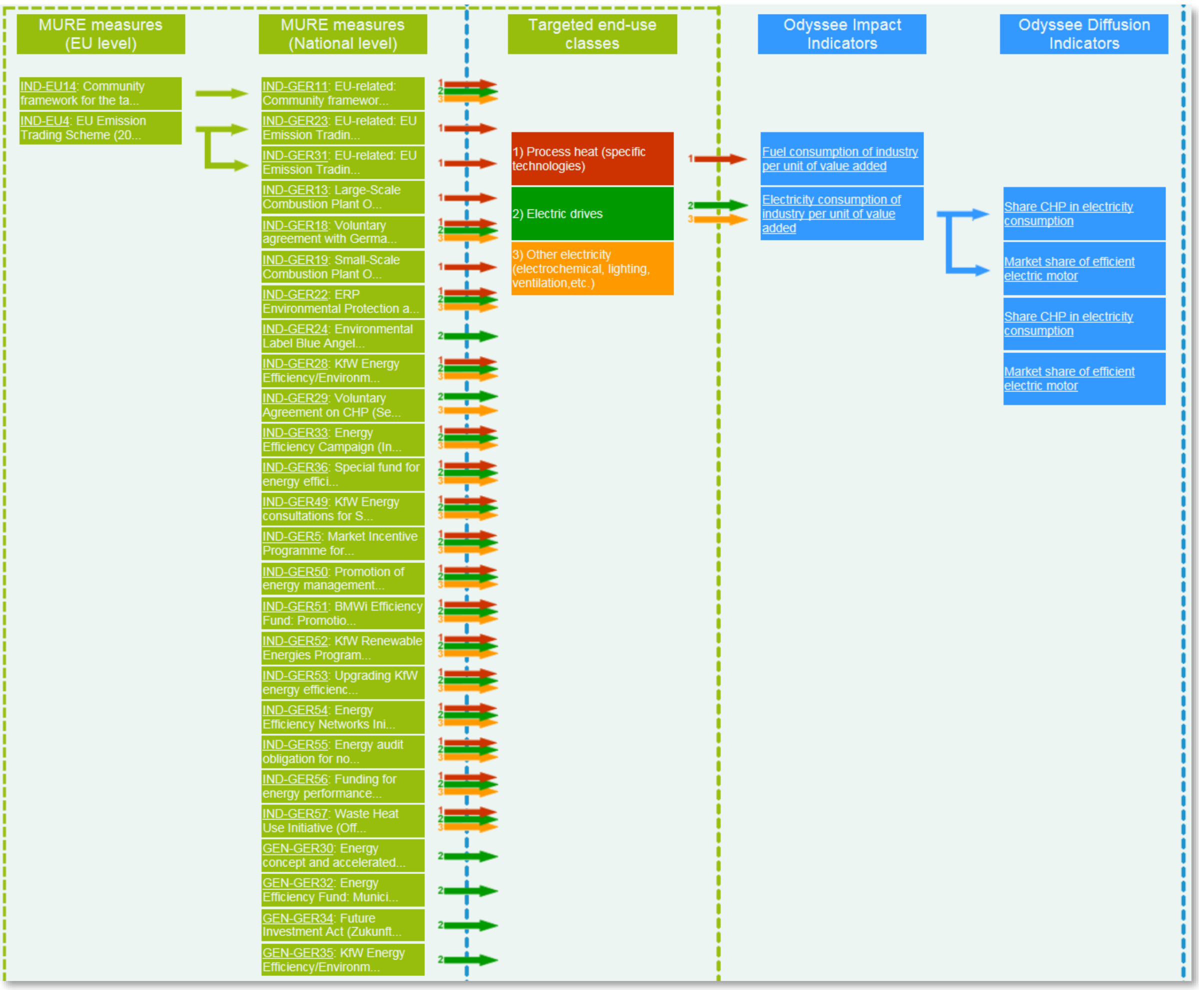
6.2.2. THE LINK BETWEEN INDICATORS AND POLICIES

The ongoing policy measures that were just mentioned can be visualized per specific end-use in the Policy Mapper. As seen in Box 9, this MURE tool enables to identify policy packages for a given targeted application

[38] I.e.progress that occurs on the average for non-participants

and relates them to the suitable energy efficiency indicators from the ODYSSEE database. In the case of industry, Figure 60 shows the policies and indicators overview for three end-uses: process heat, electric drives and other electricity uses (such as electrochemical, lightning and ventilation). CHP and consumption of buildings are also available. These end-uses are covered by two European and more than 20 national measures, including NEEAP and cross-cutting measures. It is clear which policy corresponds to each end-use thanks to the colour and number assigned to the arrows. The characteristics of each measure can be directly accessed from this overview. Different to the example of the transport sector (section 5.2.2), the distribution of the number of measures among the studied end-uses is almost equally distributed and not any energy application is dominating. Two ODYSSEE indicators partly show the impact of the measures and the penetration of energy efficient technologies resultant from their undertaking.

Figure 60: Measures addressing several targeted end-uses in the industry in Germany



Source: MURE tools

6.2.3. INTERACTION OF ENERGY EFFICIENCY POLICIES IN INDUSTRY

The visual and clear overview of the list of policy measures per end-use, which is available in the Policy Mapper tool, prepares the ground for a deeper policy impact analysis (in terms of energy savings), including the overlap or reinforcing of measures within a policy package. A combined impact can be calculated with the Policy

Interaction facility for a package of measures based both on a matrix that contains the interaction among policy types and a semi-quantitative impact of each measure (low, medium, high, unknown) (see **Erreur ! Source du renvoi introuvable.** for more details). These parameters are modifiable and in the example in Figure 61, they were set up by policy experts. There is a negative interaction among the measures addressing process heat in Germany's industry, the individual and isolated benefits are smaller than the combined ones due to overlap. This is what the negative number at the bottom of the figure indicates. However, the interaction is 8.5% of the gross savings, which shows a relatively small overlap between the different policies. This negative effect is greater for end-uses such as CHP and buildings, and smaller important for electric drives and other electric applications.

Figure 61: Assessment of the policy interaction for process heat (household sector)

Code	Measure Title	Types group	Qualitative Impact	En. Saving	% of Saving
IND-GER56	Funding for energy performance contracting (including default guarantees)	Leg-inform/focus (label)	Low	2,414	0,10%
IND-GER31	EU-related: EU Emission Trading Scheme (2003/87/EC) - Law on the national allocation plan for greenhouse gas emissions allowances	Leg-inform/focus (label)	Medium	7,241	0,30%
IND-GER23	EU-related: EU Emission Trading Scheme (2003/87/EC) - Greenhouse Gas Emissions Trading Act	Leg-inform/focus (label)	High	16,895	0,70%
IND-GER33	Energy Efficiency Campaign	Leg-inform/focus (label)	Low	2,414	0,10%
IND-GER54	Energy Efficiency Networks Initiative	Leg-inform/focus (label)	High	16,895	0,70%
IND-GER18	Voluntary agreement with German industry II	Leg-inform/focus (label)	Medium	7,241	0,30%
IND-GER11	EU-related: Community framework for the taxation of energy products and electricity (Directive 2003/96/EC) - Ecological tax reform	Leg-inform/focus (label)	Medium	7,241	0,30%
IND-GER13	Large-Scale Combustion Plant Ordinance	Leg-norm/invest	Medium	7,241	0,30%
IND-GER19	Small-Scale Combustion Plant Ordinance	Leg-norm/invest	Low	2,414	0,10%
IND-GER55	Energy audit obligation for non-SMEs	Leg-inform/focus (label)	High	16,895	0,70%
IND-GER36	Special fund for energy efficiency in SME´s	Leg-inform/focus (label)	Medium	7,241	0,30%
IND-GER51	BMWi Efficiency Fund: Promotion of energy-efficient cross-cutting technologies in SMEs / promotion of energy-efficient and climate-friendly production processes	Leg-inform/focus (label)	Medium	7,241	0,30%
IND-GER53	Upgrading KfW energy efficiency programmes for Industry	Leg-inform/focus (label)	Medium	7,241	0,30%
IND-GER57	Waste Heat Use Initiative	Leg-inform/focus (label)	Low	2,414	0,10%
IND-GER5	Market Incentive Programme for Renewable Energies in Heat Market	Leg-inform/focus (label)	Medium	7,241	0,30%
IND-GER49	KfW Energy consultations for SMEs	Leg-inform/focus (label)	Medium	7,241	0,30%
IND-GER50	Promotion of energy management systems (EMS) under the Energy Efficiency Fund	Leg-inform/focus (label)	Low	2,414	0,10%
IND-GER22	ERP Environmental Protection and Energy Efficiency Programme	Leg-inform/focus (label)	High	16,895	0,70%
IND-GER52	KfW Renewable Energies Programme (Standard / Premium)	Leg-inform/focus (label)	Low	2,414	0,10%
IND-GER28	KfW Energy Efficiency/Environmental Programme	Leg-inform/focus (label)	High	16,895	0,70%
			Sum of impacts (without interaction)	164,120	6,80%
			Combined impact (with interaction)	150,173	6,22%
			Difference (combined impact - sum of impacts)	-13,948	-8,50%

Source: MURE tools

7. DISCUSSION AND CONCLUSIONS

This report analyses the development of the energy efficiency in Germany at the level of the overall economy and all final energy consumption sectors between the years 2000 and 2016. It also explores the reasons behind Germany's position in the Combined Scoreboard for Energy Efficiency, one of the decision-support tools of the ODYSSEE-MURE European project. This publication then converges detailed monitoring efforts that reveal a deeper insight into the underlying processes (i.e. activity, structure, behaviour and efficiency) of Germany's progress towards the "Energiewende" targets.

Germany has achieved economic growth while improving efficiency. This decoupling is larger from 2008, with an increase in GDP of 3% per year and a decrease in primary energy consumption of around 0.4% per year (around 7% in the period 2008-2016). However, there is still a considerable gap to meet the target of 20% by 2020 that was set out in the "Energiewende", a situation that replicates to the other energy-efficiency-related targets. This report brings to light some relevant reasons of Germany's stand on the targets achievement, besides outlining the country's performance on energy efficiency compared to other countries, with the use of several types of energy efficiency bottom-up indicators presented by sector and end-use.

In 2016, Germany was placed 4th in the Combined ODYSSEE-MURE Scoreboard, a joined evaluation of the current energy efficiency level, the efficiency development over time (or trend) and the energy savings due to implemented efficiency-related policies. According to the breakdown of the overall ranking (Table 5), it becomes clear that the positive results of the deployed policies have leveraged the total scores. Regarding policy results, Germany is ranked among the top five countries in each of the studied sectors (household, services, transport and industry). In general, this might be an evidence of the solid policy package that Germany has deployed with the NEEAP, NAPE and Climate Action. On the contrary, the energy efficiency level moves back to the rather average 12th position (out of 29), where the transport sector becomes the matter of concern, due to its 16th post in the sector-specific ranking and to its high importance in the energy consumption in Germany. The energy efficiency level is susceptible to further detriment by the slow evolution in efficiency, mainly in the industry, a high consuming sector likewise. Germany's lowermost position (26th/29) in the scoreboard for energy efficiency trend is clearly influenced by the industry's penultimate stand regarding energy efficiency trend in the sectoral results.

Table 5: Germany's overall and sectoral position by criteria in the combined Scoreboard[39]

Sector / Country		Level	Trend	Policies	Combined
Overall	Germany	12 / 29	26 / 29	2 / 29	4 / 29
	Highest score (benchmark)	UK	UK	Ireland	UK
Industry	Germany	9 / 28	27 / 28	4 / 29	13 / 29
	Highest score (benchmark)	Italy	Lithuania	Denmark	Denmark
Transport	Germany	16 / 29	15 / 29	3 / 29	7 / 29
	Highest score (benchmark)	Italy	UK	Spain	Spain

[39] http://www.indicators.odyssee-mure.eu/energy-efficiency-scoreboard-combined.html (public access)

Households	Germany	13 / 29	16 / 29	2 / 29	3 / 29
	Highest score (benchmark)	Bulgaria	Ireland	Ireland	Ireland
Services	Germany	18 / 29	7 / 29	5 / 29	5 / 29
	Highest score (benchmark)	Lithuania	Hungary	Ireland	Ireland

Different from the primary energy consumption, the energy required by the end users (final energy) has yearly increased by 0.7% over the last 16 years but becomes smaller when applying climate corrections. The final energy consumption only increased in the services sector. On top of this, its energy intensity and energy consumption per employee show an important deceleration from 2008, leading this sector to the 18th position in the ranking of energy efficiency level, with much higher specific energy consumption than Lithuania and Spain (37% and 22% respectively), countries located in the summit of the sectoral scoreboard for efficiency level. However, the transport sector gets the spotlight due to its high share in final energy consumption and its also average results in this scoreboard (16th/29). The development of energy consumption in transport is strongly dominated by opposite and almost equal impacts of an increasing activity effect and the decreasing energy efficiency effect. The unit consumption of cars (l/100km), the predominant transport mode, has steadily decreased since 2000 but at the slow yearly rate of 0.8%, reaching a lower car efficiency in 22% than Italy, the head of the ranking for the sectoral energy efficiency level.

The industry has had also a very low improvement in energy efficiency over the last 16 years. It has a marginal drop in energy intensity (more than half than the other sectors) and a substantial impact of the activity effect that counteracted all technical energy savings between 2000 and 2016. In fact, the unfavourable results of the index for technical energy efficiency ("ODEX") in industry explain the inferior position in the sectoral scoreboard for energy efficiency trend. Although both transport and service sectors do not come near the progress in energy efficiency obtained by the residential sector (32% with respect to 2000), the industry is by far the sector with the most stagnant improvement in technical energy efficiency (13%).

As mentioned, the household sector achieved the greatest progress according to the energy efficiency index among all sectors in Germany, which was mainly influenced by the efficiency improvements in the consumption of space heating. The technical energy savings offset the consumption increases linked to demographic, climate and lifestyle effects. Almost 50% of the total energy savings gained in Germany in the period 2000-2016 are attributed to the residential sector. All of this unveils the positive impact of the strong policy measures targeting buildings and heating in Germany and the importance of having a target pointing at a specific sector (or end use). The high quality of the household policies measured by the ODYSSEE tool "Successful Policies" is also a proof thereof. The residential sector achieved the highest scores among all sectors in an evaluation of pre-selected successful policies. The positive results provided by this sector seem to lack strength in front of other European countries since its position in the scoreboards for energy efficiency level and trend is somewhat middle.

Even though today's overall results in the Combines Scoreboard for Energy Efficiency are mainly boosted by the deployed policies (including the ones from the NEEAP, NAPE and Climate Action), they are not sufficient to reach the national 2020 and 2030 targets. Therefore, more emphasis should be placed on measures that point at transport and industry as these promise large saving potential, which are currently untapped. Correspondingly, Germany could achieve better results in the scoreboards for energy efficiency level and trend in the coming years.

Finally, the energy efficiency improvements monitored within the ODYSSEE-MURE project bring benefits beyond the desire of better performance, solid and efficient policy design and the achievement of energy efficiency targets. Positive impacts on environmental, economic and social aspects are also derived from energy efficiency development. A comprehensive set of indicators measuring these "Multiple benefits of energy efficiency" was implemented in a web tool incorporated into the project website[40].

[40] http://www.odyssee-mure.eu/data-tools/multiple-benefits-energy-efficiency.html

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ANNEX 1: SCORING METHODOLOGY FOR THE THREE MAIN COMPONENTS OF THE ODYSSEE-MURE SCOREBOARD ON ENERGY EFFICIENCY INDICATORS AND POLICIES

The scoring methodology for the three main components of the ODYSSEE:MURE Energy Efficiency Scoreboard is summarized here in brief:

- ***Scoring methodology for ODYSSEE Indicators:*** based on OECD Composite Indicators methodology, normalized scores across countries in a range 0-1. To get the average score by sector, each indicator is weighted with the same weight for all countries, taking into account a typical share of end-use or subsector. The total score is calculated from the scores by sector with a weight representative of the share of the sector in the country's final energy consumption. The scores are calculated with the latest date available. The trend values are calculated as the annual growth rate over the period 2000 to latest year available.
- ***Scoring methodology for MURE Policies:*** makes use of information in the MURE database on energy savings ("policy output") and compares the savings with the final energy consumption of the sector for a given year (Output-based scoring based on energy savings). The whole is normalised to a range 0-1. By default the scoring period comprises measures from 2000 to present but other periods can be selected.
- Each of the components "energy efficiency level", "energy efficiency progress" and "energy efficiency policies" enter the combined scoreboard **with a weight of one third**. Each component is also presented individually.

ODYSSEE SCOREBOARD METHODOLOGY

The scoring methodology is based on the OECD Composite Indicator methodology[41]. This method allows the countries to be compared in a relevant range where minimum and maximum values indicators define the best and worst scores and countries are ranked between these two extrema. The indicators are calculated and normalized so that they range between 0 and 1 following this formula:

$$Normalized\ score = \frac{Indicator - Min\ indicator}{(Max\ indicator - Min\ indicator) * direction} + 0.5 * (1 - direction)$$

- Indicator: The indicator value of the country.
- Min indicator: The minimum indicator value across all countries.
- Max indicator: The maximum indicator value across all countries.
- Direction: The favoured direction in the level of indicator; -1 if the decline is favoured, 1 if the incline is favoured.

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The main characteristics of the scoring methodology are as follows:

- Scoring is done separately for four sectors (households, transport, industry and services) and for all sectors together.
- The score by sector is based on scores calculated for selected indicators representative of end-uses in buildings or modes in transport. For industry the score is directly based on an aggregateindicator that already accounts for the energy efficiency characteristics of the various industrial branches. For each indicator, three scores are calculated:
  - The first score, based on the present level of the indicator, is calculated as a moving average of the last three years indicator values to smoothen yearly variations.
  - The second score is based on the trend indicator since 2000 (variation 2000-2015).
- The score by sector is calculated as a weighted score of each indicator. The weights correspond to the average shares over the last 3 years of each end-use or transport mode in the sector consumption.
  - The global score results from the sectoral scores weighted by the share of each sector in the total final energy consumption.
  - The global and sectoral scores are finally normalized to 1, with 1 corresponding to the highest score value

The list of indicators by sector is given below.

Households

End-use	Indicator	Weighting factor
Heating	Consumption for heating per m^2 scaled to EU climate and equivalent to central heating	Share of heating in total households consumption
Other thermal uses	Consumption per dwelling for cooking and water heating	Share of cooking + ½ of water heating in total households consumption[5]
Appliances	Specific consumption of electricity per dwelling for appliances (including AC) and lighting	Share of appliances (incl. AC) & lighting in households consumption
Solar penetration	% of dwellings with solar water heater	½ share of water heating in households consumption

Transport

Modes	Indicator	Weighting factor
Cars	Specific consumption (l/100km)	Share of cars in total transport consumption
Trucks and light vehicles	Specific consumption (goe/tkm)	Share of trucks and light vehicles in total transport consumption
Air	Specific consumption (koe/pass)	Share of air in total transport consumption
Modal split: -Passengers -Goods	 % of traffic by public mode % of traffic by rail and water	 Share of buses and rail passengers in total transport consumption Share of water and rail freight consumption in total transport

Services

End-use	Indicator	Weighting factor
Thermal end-uses	Thermal end-uses consumption[6] per employee scaled to EU climate	Share of thermal end-uses in total services
Electricity	Specific consumption of electricity per employee (including AC and excluding thermal uses[7])	Share of specific electricity consumption in total services

Industry

Category	Indicator
Indicator of trend	ODEX (energy efficiency index)
Indicator of level	Adjusted energy intensity at EU industry structure[8]

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[5] Two indicators are related to water heating: the other thermal end-uses and the solar penetration. In order to have consistent weights (totalling 100%), we apply an equal weight between the two indicators equal to half of the share of water heating in total households consumption.

[6] For countries for which the data by end-use are not available, the total fuel consumption is taken.

[7] For countries for which data by end-use are not available, the total electricity consumption is taken.

[8] The energy intensity of industry at EU structure represents a fictitious value of the industrial intensity calculated by taking for each industrial branch the actual sectoral intensity of the country and the EU industrial structure (i.e. the share of each branch in the value added of industry). For Finland and Sweden, as pulp & paper represents around half of the total industrial consumption, the adjusted indicator is based on physical quantities instead of value added for pulp & paper (production of paper and pulp) and on VA for the other branches.

MURE POLICY SCOREBOARD METHODOLOGY

The objective of the energy efficiency scoreboard tool is to assess and score the energy efficiency policies of the EU28 by country and by sector (households, transport, industry and services). The scoreboard shall provide for a suitable presentation of policy results and impacts through an energy efficiency policy scoreboard. The main advantage of such scoreboards is to present progress in policy development according to selected criteria over time and across countries. The scoring methodology is based on the energy efficiency measures gathered in the MURE database.

The scoring methodology implemented is "Output-based scoring" (based on energy savings): This scoreboard makes use of the information in the MURE database on energy savings ("policy output") and compares the savings with the final energy consumption of the sector or total final energy consumption for a given year (at present 2010). By default the scoring period comprises measures from 2000 to present but other periods can be selected.

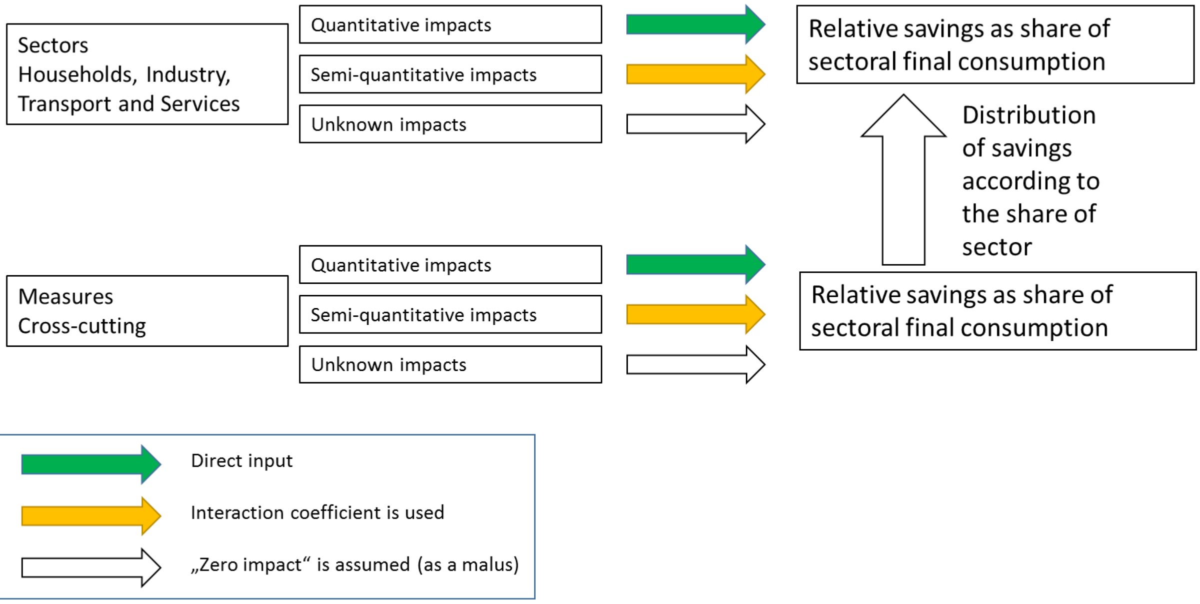
The information on impacts in terms of energy savings for each measure in the MURE database may take two forms:

- **Quantitative information** from dedicated evaluations of measure impacts, mostly from evaluations at national level. This information is gathered in formal tables and can be retrieved for the policy scoreboard. At present around 40% of all 2400 policy measures in the MURE database have such a quantitative policy impact evaluation.

- **Semi-quantitative expert estimates on measure impacts** which group the measures in three categories: measures saving less than 0.1% of the sector energy consumption (low impact measures), measures saving 0.1 to less than 0.5% of the sector energy consumption (medium impact measures), and measures saving more than 0.5% (high impact measures). For measures in the cross-cutting database the percentages refer to the overall final energy consumption of the country. These estimates have been made by the National Teams in the MURE project, who have an excellent knowledge of the policy in their countries. Nearly 90% of all measures in the database have been classified in such a manner.

The scoreboard makes use of both the quantitative and the semi-quantitative estimates (see the Figure below).

Basic methodology for the Output-based Scoreboard (related to energy consumption)



Quantitative impacts are expressed as a percentage of the information sectoral final energy consumption. For measures in the cross-cutting database the percentages refer to the overall final energy consumption of the country (for the year 2010). It is assumed that measures with quantitative estimates already include the interaction with other measures. Semi-quantitative estimates are converted to quantitative estimates by using 0.1%, 0.3% (as the average of the category 0.1 to less than 0.5%) and 0.5% to characterize the measures. In order to consider interaction between those measure, a default interaction coefficient of 0.01% per measure is integrated into the calculation. Measures without a quantitative or semi-quantitative estimate are considered as "zero impact" in order to give a malus to measures which are not characterized. In such a manner the monitoring practice in the country is also taken into account. Savings from the cross-cutting sector are established in a similar manner. The savings from the cross-cutting measures are then distributed over the four sectors (residential services, transport and industry) according to the sector share in final energy consumption. The sector results are then normalized with the sector shares in overall final energy consumption of the country which is set to 100%. The scale of the policy scoreboard can at first then be read as percentage savings achieved with the energy efficiency measures of a country (compared to the energy consumption of the year 2010). This is then normalised with respect to the best country which is set to a value of 1.

ANNEX 2: MAIN DATA SOURCES FOR GERMANY IN THE ODYSSEE DATABASE

Data in ODYSSEE and MURE	Data source for Germany	Classification of data source*
Overall economy		
GDP, added value, private consumption	Federal Statistical Office (2018), National Accounts	A
Population	Federal Statistical Office (2017), Statistical Yearbook	A
Primary and final energy consumption by sector	National energy balances (AGEB 2018)	A
Electricity generation by energy carriers	AGEB 2017; BMWi 2018	A
Degree days	Based on Deutscher Wetterdienst (DWD)	B
Tertiary sector		
Value added/employment by sub-sectors	Federal Statistical Office (2018), National Accounts	A
Floor area by subsector Energy consumption by end-uses and subsectors	Regular surveys on energy consumption in the tertiary sector (Fraunhofer ISI et al. 2015)	B
Household sector		
Number of households and dwellings, floor area	Federal Statistical Office (2017), Statistical Yearbook	A
Stock and sales of electrical appliances	ZVEI/GfK (2014)	B
Energy consumption by end-uses	National end-use balances (AGEB 2018)	A
Specific consumption of electrical appliances	Stock model data (Prognos, internal information)	B
Industry		
Value added by industrial branches	Federal Statistical Office (2018), National Accounts	A
Production index	Federal Statistical Office (2017), Statistical Yearbook	A
Physical production	Statistics of industrial associations	B
Energy consumption by branches	National energy balances (AGEB 2018); Federal Statistical Office (2016)	A
Transport		
Stock of cars and kilometres for passenger and freight traffic	Verkehr in Zahlen (DIW Berlin 2017 and BMVBS 2015)	A
Energy consumption by sub-sectors	National energy balances (AGEB 2018)	A
Energy consumption by vehicle types	Verkehr in Zahlen (DIW Berlin 2017 and BMVBS 2015)	A

* A = Official Statistics (Statistics/surveys by national Statistical Offices, Eurostat/IEA, Ministries; model estimations used as official statistics; data "stamped" by ministries)
B = Surveys/modelling estimates by research institutes, universities, consultants, industrial associations
C = Estimate / expert guess

ANNEX 3: MATRIX OF IMPACT EVALUATION METHODS

Figure 62 corresponds to a portion of the matrix used in the Impact Evaluation facility (

Box 7), in this case for the household sector, which includes the list of considered methods classified into four groups (evaluation types) crossed with the types and list of measures.

Figure 62: Recommended evaluation methods and actual measures distribution of evaluation methods per measure type

Sector: Household

***= the method is recommended, **= the method provides reliable results, *= it is possible to use this method if the others are not possible, nr.= number of measures

nr.		Measure	Bottom Up					Bottom Up/Top Down		Top Down		Integrated BU/TD
			Direct measurement	Billing analysis	Enhanced engineering estimates	Mixed deemed and ex-post estimate	Deemed estimate unit savings	Stock modelling	Diffusion indicators	Specific consumption indicators	Econometric modelling	Integrated BU/TD methods
Legislative/Normative												
Mandatory Standards for Buildings												
28	1	Energy Performance Standards	* 0	*** 1	** 4	8	4	*** 2	** 0	*** 3	1	*** 5
13	2	Minimum thermal insulation standards	* 0	0	** 2	3	1	*** 0	** 0	*** 1	0	6
Regulation for Heating Systems and hot water systems												
5	3	Minimum efficiency standards for boilers	* 0	0	0	1	*** 1	*** 1	0	*** 0	0	2
0	4	Compulsory replacement of old boilers above a certain age	* 0	0	0	0	*** 0	*** 0	0	*** 0	0	0
0	5	Thermostatic zone control	** 0	0	0	0	*** 0	0	*** 0	*** 0	0	0
1	6	Control systems for heating (Regulation)	** 0	0	1	0	*** 0	0	*** 0	*** 0	0	0
4	7	Mandatory heating pipe insulation	* 0	1	1	0	*** 0	0	*** 0	*** 0	0	2
7	8	Periodic mandatory inspection of boilers	** 0	1	0	3	*** 2	0	0	*** 1	0	0
6	9	Periodic mandatory inspection of Heating/Ventilation/AC (HVAC)	** 0	1	0	3	*** 2	0	0	*** 0	0	0
4	10	Mandatory use of solar thermal energy in buildings	* 0	0	*** 1	1	*** 0	*** 0	** 0	1	0	1
Other Regulation in the Field of Buildings												
3	11	Individual billing (multi-family houses)	** 0	*** 1	0	1	** 1	0	** 0	*** 0	0	0
2	12	Maximum indoor temperature limit (s)/limitation heating period	** 0	1	0	0	*** 0	0	0	*** 0	0	1
Mandatory Standards for Electrical Appliances												
5	13	Minimum efficiency standards for electrical appliances	* 0	0	1	0	*** 0	*** 1	*** 0	*** 0	0	** 3
11	14	Mandatory measures for efficient lighting	* 0	0	2	2	0	1	*** 0	*** 1	0	5

ANNEX 4: INTERACTION MATRIX

The interaction matrix that assesses the grade of reinforcement or overlap between different types of policy instruments within a package, which was mentioned in **Erreur ! Source du renvoi introuvable.**, is displayed in Figure 63.

Figure 63: Interaction matrix for measures addressing space heating in existing dwellings

	Leg-norm/invest	Leg-norm/use	Leg-inform/focus (label)	Leg-inform/broad (audit)	Finan-fiscal/invest	Finan-fiscal/use (tariff)	Finan-fiscal/info (audit)	Inform/focused-invest	Inform/broad (center, etc.)	Coop/focused (VA-manufacturers)	Coop/broad (VA-sector)	Cross-cutting/taxes
Leg-norm/invest												
Leg-norm/use	Some overlap											
Leg-inform/focus (label)	Strong overla	Not interactin										
Leg-inform/broad (audit)	Strong overla	Not interactin	Strong overla									
Finan-fiscal/invest	Strong overla	Some overlap	Strong reinfor	Reinforcing								
Finan-fiscal/use (tariff)												
Finan-fiscal/info (audit)	Strong overla	Overlap	Overlap	Strong overla	Some reinforc							
Inform/focused-invest												
Inform/broad (center, etc.)	Some overlap	Strong overla	Not interactin	Some overlap	Not interactin		Some overlap					
Coop/focused (VA-manufacturers)												
Coop/broad (VA-sector)												
Cross-cutting/taxes	Overlap	Overlap	Some reinforc	Some reinforc	Overlap		Some reinforc		Strong reinfor			