Final Report Summary

Macroeconomic Effects of the Energy Transition

Project No. 31/13

For the
Federal Ministry
for Economic Affairs and
Energy

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Macroeconomic Effects of the Energy Transition

Project No. 31/13 of the Federal Ministry for Economic Affairs and Energy, Berlin

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Osnabrück/Cologne/Basel, September 2014

Main Results

The project "Macroeconomic Effects of the Energy Transition" aims at describing and evaluating the macroeconomic effects of the energy transition in Germany both ex post (2009–2013) and ex ante (2014–2020). The results are derived from a quantitative and empirical analysis of a Counter-Factual and Energy Transition scenario.

The second section gives an overview of the existing approaches used to evaluate the macroeconomic effects of the energy transition. In principle, there are two possible methods that are commonly used to account for the information gaps often related to the study of the macroeconomic costs and benefits of the energy transition.

The first option is to take into consideration the statistical indicators that are generally available in the short term, depicting the economic dimension of the energy transition. The second option relates to the calculating of macroeconomic costs/benefits that are based, as a rule, on intricate model analyses. An intermediary step includes partial analytical studies, which deal periodically and promptly with important, specific topics of the energy transition.

Two scenarios have been defined for the evaluation of the macroeconomic effects. The Counter-Factual (CF) scenario is partly based on the assumptions of the reference scenario given in the “Energy Scenarios 2010” and describes the development without the energy transition based on expectations from the beginning of 2010. The Energy Transition (ET) Scenario is based largely on the historical development ex post up to 2013, which is considered to be the implementation period for the energy transition. The expected development in the Energy Transition scenario up to 2020 is based on the 2014 Energy Reference Forecast.

The main difference between the Energy Transition scenario and the Counter-Factual scenario is the expansion of renewable energy in the electricity market. The differences in energy demand are due not only to the various developments related to energy efficiency but also to the mix of renewable energy sources used.

The gross electricity production from renewable energies in the Energy Transition scenario is clearly higher than in the Counter-Factual scenario. However, electricity production from hard coal- and gas-fired power stations is lower. Moreover, electricity exports are markedly higher than in the Counter-Factual scenario. The share of renewable energies in the total gross electricity production reaches 40% in the ET scenario and 32% in the CF scenario by 2020. The energy transition thus contributes to achieving (or even over-achieving) the German federal government’s objective of a 35% share.

The EEG surcharge is clearly higher in the ET scenario than in the CF scenario due to the increased expansion of renewable energies. This leads to higher final consumer prices for households, for trade and commerce as well as for industrial customers. Electricity prices for the energy-intensive industries are lower in comparison to the Counter-Factual scenario due to merit-order effects and exemptions from the EEG surcharge.

The energy transition has contributed to a reduction in investment costs for photovoltaic systems, shaping the global learning curve through the German expansion of PV from 2010 onwards. The influence of the expansion of the other renewable generation technologies on the corresponding learning curves is negligible. It is not possible to reach any further conclusions with respect to the innovation effect of the energy transition in the electricity market since the amount of data currently available is limited.

In the Energy Transition scenario, primary energy consumption experiences a decrease of 2.5 percentage points more than the Counter-Factual scenario from 2009 to 2020, and energy-related greenhouse gas emissions are reduced by 6 additional percentage points. The additional reduction of greenhouse gas emissions can, to a large extent, be attributed to the increased use of renewable energies in the energy sector.

The emissions and efficiency objectives as well as the combined heat and power expansion targets of the German federal government for 2020 are not achieved in the Energy Transition scenario. On the other hand, the targets of the German Energy Concept with regard to renewable energies are achieved. The share of renewable energies in gross final energy consumption is expected to increase to 21.8% in 2020 (target value: 18 %).

The actual and expected development of the energy transition is compared ex post and ex ante to a Counter-Factual scenario that assumes a development without the energy transition. The differences between the CF scenario and the ET scenario are analysed with respect to their effects on significant macroeconomic variables.

Roughly speaking, two phases can be identified. Ex post until 2012, the expansion of renewable energies dominates, especially, with respect to monetary variables, the expansion of photovoltaics. Ex ante from about 2015 onwards, the macroeconomic effects are primarily driven by energy efficiency measures as well as increased electricity prices in the ET scenario.

In the first phase, the effects are determined by the increased additional expansion of renewable energies from 2010 to 2012. Considering the significant investments made in the renewable energy sector from 2010 to 2012, the effects on the GDP are markedly positive, without the energy transition altering the overall growth path significantly. Nevertheless, long-term financing via the EEG surcharge leads to increased electricity prices in subsequent years for all consumer groups, except for the electricity-intensive industries who are able to slightly benefit from the reduction of wholesale prices. A sensitivity analysis is performed to break down the stimulus and thus clarify the cause-and-effect relationships.

Due to higher electricity prices, the price index of the cost of living rises up to 2014. Production prices are also higher in the ET scenario than in the Counter-Factual scenario. The employment effects of the ET scenario from 2010 to 2012 are clearly positive. However, with increasing prices, rising wages and decreasing investment dynamics, the employment effects become lower over time.

Investments in construction play a vital role in overall economic effects. This can be attributed to, in particular, the commercial and residential sectors. Additional investments in efficiency measures - especially in buildings - support the construction sector and lead to noticeable effects in subsequent years also in the form of lower energy costs.

The decreasing investments in the electricity market over time are compensated by higher efficiency investments compared to the CF scenario. Both GDP and employment are absolutely higher in the ET scenario than in the CF scenario. The price level which reacts delayed due to the design of the EEG surcharge, remains consistently higher in the ET scenario than in the CF scenario because of the higher EEG surcharge.

Due to the wide range of possible approaches used to define the energy transition, sensitivity calculations are also performed. The low stimulus of the EEG Amendment leads to very few changes in the macro economy compared to the ET scenario. Additional sensitivity analyses show that the key assumptions about energy transition definition (EE "Freeze"), the possible crowding out of additional investments as well as the long-term growth path, have an influence on the macroeconomic effects.

Furthermore, a brief classification of the development of innovation and new technologies within the context of the energy transition is given. The national research expenditures for renewable energies and energy efficiency have increased over the past years. However, this alone does not necessarily imply any enhanced innovation performance. The market shares of energy-efficient products have also increased. Yet it is not possible to quantify with precision the extent to which these developments were affected by the German energy transition.

Finally, the results are divided into various categories; namely benefits, costs or opportunities and risks. The perspectives of the various actors, e.g., manufacturers/mechanics, end customers or the state, were taken into consideration for the evaluation of the measures.

The promotion of renewable energies through the EEG plays a vital role in the achievement of the energy policy objectives of the German federal government; however, such a scheme gives rise to substantial expenses. Moreover, it has contributed to reductions in investment costs of photovoltaic systems.

The results of the macroeconomic analysis are consistent with the overall view derived in other similar studies with regard to the methodological limitations described in section 2. The real net effects of the energy transition, compared to a scenario without the energy transition, describe the balance of positive and negative effects including all feedbacks. They are, by definition, substantially smaller than the so-called ‘gross effects’. In all, the macroeconomic effects of the energy transition, as defined here, are small.

Currently, only a limited range of data can be used for the assessment of the macroeconomic effects. In the future, improved statistical data and information bases are necessary for monitoring purposes.

Overview of Existing Approaches

(Section 2 of the report)

This section gives an overview of the relevant scientific approaches used for the assessment of macroeconomic effects of the energy transition or of similar energy policy measures implemented in Germany.

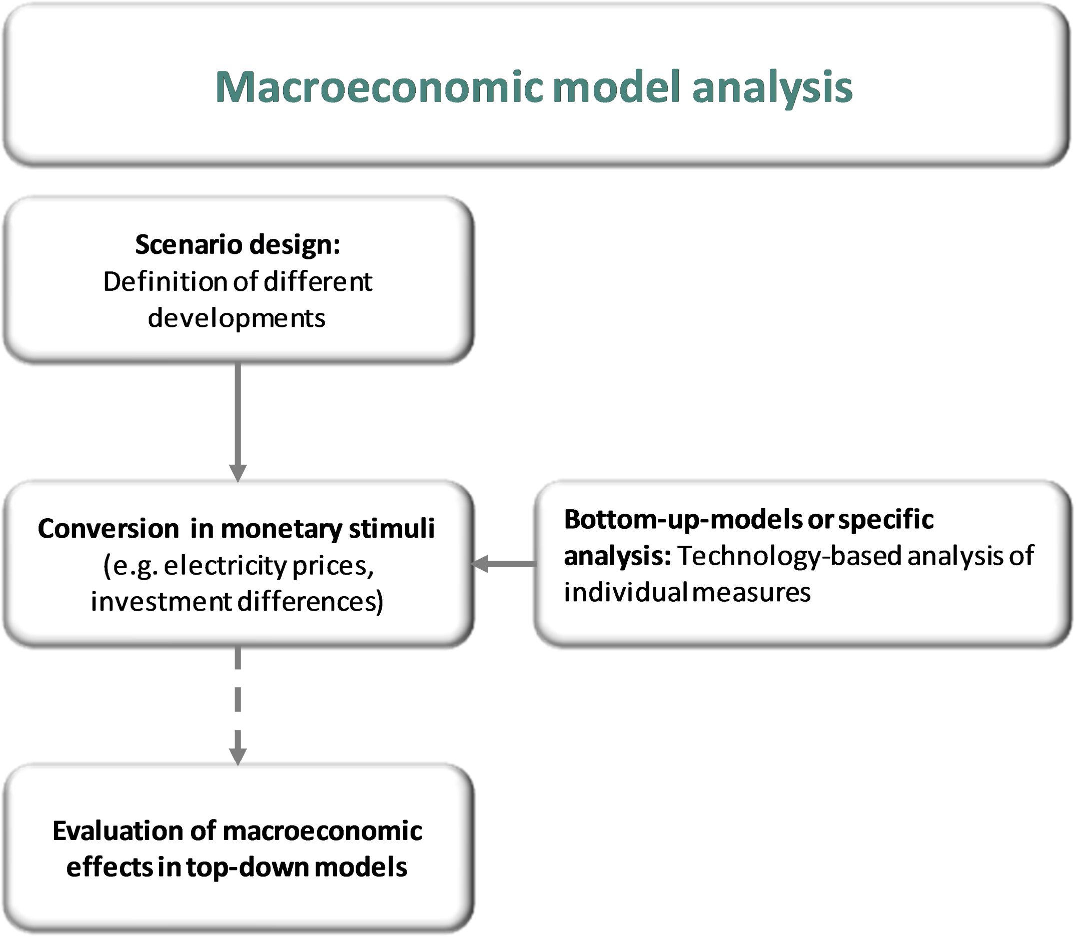
There are two main methods for monitoring the energy transition. The method using indicators is based on a descriptive analysis of historical data and is particularly suitable to analyse the achievement of targets ex post and in real time. A substantial advantage of indicators is that they are for the most part quickly available, statistically speaking. They "can offer an informative overview of the 'current situation' for the achievement of energy policy objectives" (Flues et al. 2012, p. 2), provided they are quantifiable. One disadvantage of indicators is that they cannot be used to fully assess the energy transition in its entirety. Explanations and causal relationships for specific developments cannot be illustrated using the indicator method. Indicators can only provide an informative overview.

The second fundamental method used to determine the macroeconomic effects of the energy transition is based on a full macroeconomic model analysis that can illustrate feedbacks between the energy system and the macro economy and determine gross effects at the macroeconomic and sectoral levels. In order to conduct a macroeconomic evaluation of the energy transition, technology- or process-oriented analyses are needed to measure changes in the indicators that are triggered by the implementation of specific measures or packages.

For a macroeconomic model analysis, the microeconomic effects of a measure must be determined. In that respect, specific bottom-up models that detail the technologies underlying measures as well as their application are generally used. The results for all the measures are fed into the macroeconomic model in order to calculate the macroeconomic effects (Figure 1).

An overview of select model analyses shows a wide range of macroeconomic results. After the first analysis carried out by IHS Global Insights on behalf of the Association of Chemical Industries (VCI), the effects of the energy transition were shown to be extremely negative. The analysis by the Deutsche Institut für Wirtschaftsforschung (DIW), on the other hand, reports very positive effects of the enhanced energy efficiency measures and renewable energy expansion. Finally, an analysis of the energy and climate policy measures from 1995 was performed. Many of these measures have long since been concluded and depreciated, yet the positive effects, i.e., the energy savings, are sustained. Accordingly, the macroeconomic effects throughout the 2010 to 2012 period turn out to be positive.

Figure 1: Schematic of a macroeconomic model analysis



Source: GWS/Prognos/EWI 2014

The comparison of the results becomes more difficult once different references, combinations of measures and design of the macroeconomic models are chosen. In this context, the key is the definition of the energy transition and a clear description of the measures that are necessary for its achievement compared to an appropriate reference trend.

Complex ex post studies based on the input-output analysis already capture an intermediate position between the indicator and the macroeconomic analyses. These studies deal mainly with employment effects triggered by specific measures. Examples include studies on gross employment through the expansion of renewable energies and studies on the effects of KfW building programmes. Feedback effects are not typically included in such studies.

Generally, simple cost analyses draw more public attention. These do not have anything to do with macroeconomic analyses. Instead, these studies make simple comparisons of costs and cost avoidance categories that are at least partly based on third party analyses and are not necessarily consistent.

Scenario Definitions: Counter-Factual and Energy Transition Scenarios

(Section 3 of the Report)

The project "Macroeconomic Effects of the Energy Transition" aims at comparing a Counter-Factual scenario with an Energy Transition scenario. The scenarios are first defined in terms of the basic macroeconomic parameters, electricity market and energy demand.

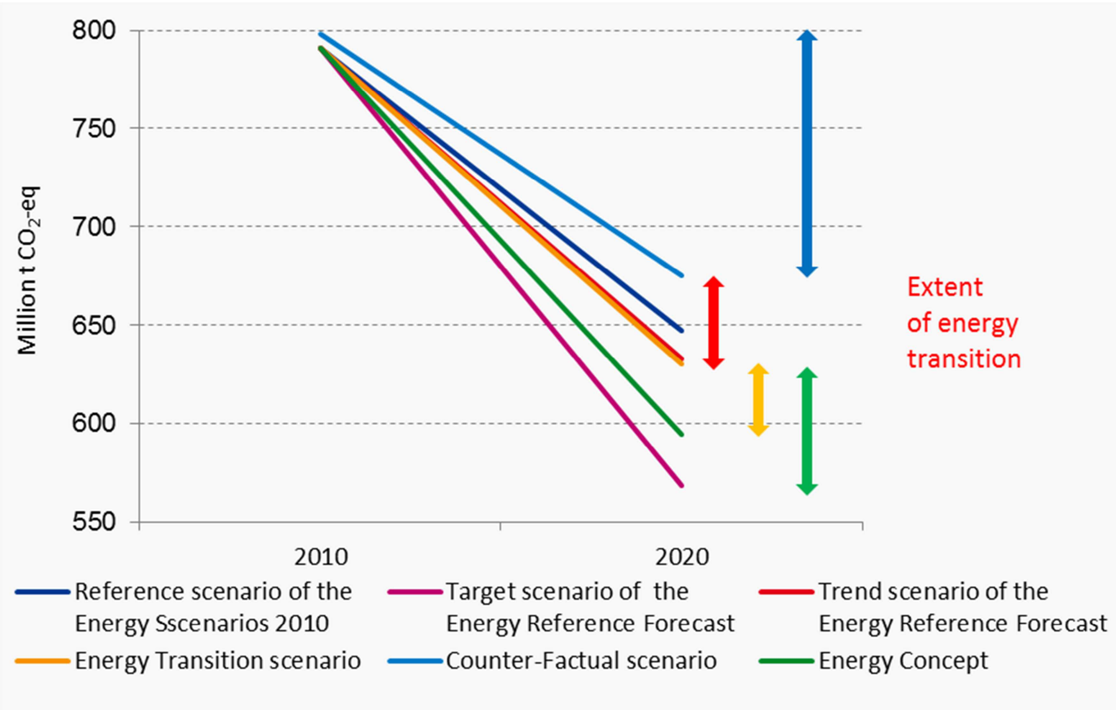
Scenario Definition

(Section 3.1 of the report)

The scenario definition is based on one basic principle: Basic macroeconomic parameters, e.g., population, economic development and international energy prices, which are available either from historical values or from medium-term forecasts, are assumed the same in both scenarios. They correspond to the current Energy Reference Forecast (Prognos, EWI, GWS 2014).

The Energy Transition scenario is based ex post on the actual development prior to 2013 and is interpreted as the implementation of the energy transition. For the years 2014 to 2020, the expected development, according to the authors, depicts the energy transition according to the 2014 Energy Reference Forecast.

Figure 2: Scope of the GHG reduction in million t CO_2 equivalents for 2010-2020, computed for different scenarios



Source: GWS/Prognos/EWI 2014

The Counter-Factual scenario is partly based on the assumptions of the reference scenario given in the “Energy Scenarios 2010” (Prognos, EWI, GWS 2010) and describes the development without the energy transition based on expectations from the beginning of 2010. The scenario assumptions are central to the macroeconomic effects of the thus defined energy transition. Figure 2 shows the extent to which the energy transition is captured in the calculations. The red arrow shows the level of GHG reduction between 2010 and 2020 as the difference between the ET scenario and the Counter-Factual scenario. The blue arrow indicates the largest amount of GHG reduction that would be attained in the CF scenario. The orange arrow shows the amount of GHG reduction that is still needed in the ET scenario in order to achieve the GHG reduction target defined in the Energy Concept. The green arrow illustrates the amount of GHG reduction that would occur if all of the Energy Concept’s objectives for 2020 were to be achieved, which in fact would exceed the target set for GHG reduction.

Electricity Market

(Section 3.2 of the report)

Assumptions derived from the 2014 Energy Reference Forecast are the basis of the Energy Transition scenario for the electricity market. In particular, these include fuel and CO_2 prices, the phase-out of nuclear power and the expansion of renewable energies.

In the Counter-Factual scenario, the fuel and CO_2 prices also correspond to the 2014 Energy Reference Forecast since prices of raw materials are subject to global and European-wide factors that are not noticeably affected by the German energy transition. Even the nuclear power phase-out is modelled the same way in both the Energy Transition scenario and the CF scenario. This avoids the distortion of results by accounting for the politically accepted nuclear phase-out. Therefore, the main difference between the ET scenario and the CF scenario is the chosen path of renewable energy expansion, which in the Counter-Factual scenario is based on the assumptions made in the reference scenarios of the study "Energy Scenarios for the Federal Government's Energy Concept".

Moreover, in the Energy Transition scenario and the Counter-Factual scenario parameters that are determined by the model outputs differ for each scenario. These parameters include the development of conventional power plants, electricity imports/exports as well as investment costs of renewable energy technologies.

Energy Demand

(Section 3.3 of the report)

The results of the ET scenario are calibrated for the years up to 2012 according to the results of the energy balance. The energy demand in the ex ante period is based on the current Energy Reference Forecast. The assumptions of the reference scenario of the 2010 Energy Scenarios are used for the modelling of the energy demand in the CF scenario.

The differences between the ET scenario and the CF scenario as far as energy demand is concerned are due to both the various developments related to energy efficiency as well as the mix of energy sources used. The development of energy efficiency is essentially determined by not only price signals (e.g., energy prices, promotion programmes) and legal regulations (e.g., standards, regulations) but also by autonomous technological progress.

Energy demand modelling in the ET scenario for the ex post period 2009–2013 is based on historical data. The energy demand for the years up to 2012 is calibrated according to the energy balance. The energy balance for 2013 is currently not available. As far as the results of the ex ante period from 2014 till 2020 are concerned, it is a scenario which presents the probable development based on the Energy Reference Forecast (Prognos, EWI, GWS 2014).

The reference scenario of the Energy Scenarios 2010 (Prognos, EWI, GWS, 2010) is used to determine the energy demand in the CF scenario. This reference scenario is a possible representation of the former "business-as-usual" policy, i.e. without the energy transition. The input values from the model in the Energy Scenarios 2010 are used in calculating the specific consumption and energy mix in the CF scenario.

Quantitative ex post and ex ante Analysis of the Counter-Factual and Energy Transition Scenarios

(Section 4 of the report)

The macroeconomic effects of the energy transition are determined for the ex post period (2009–2013) and the ex ante period (2014–2020). The results are presented for both scenarios in absolute values and as differences between the two scenarios.

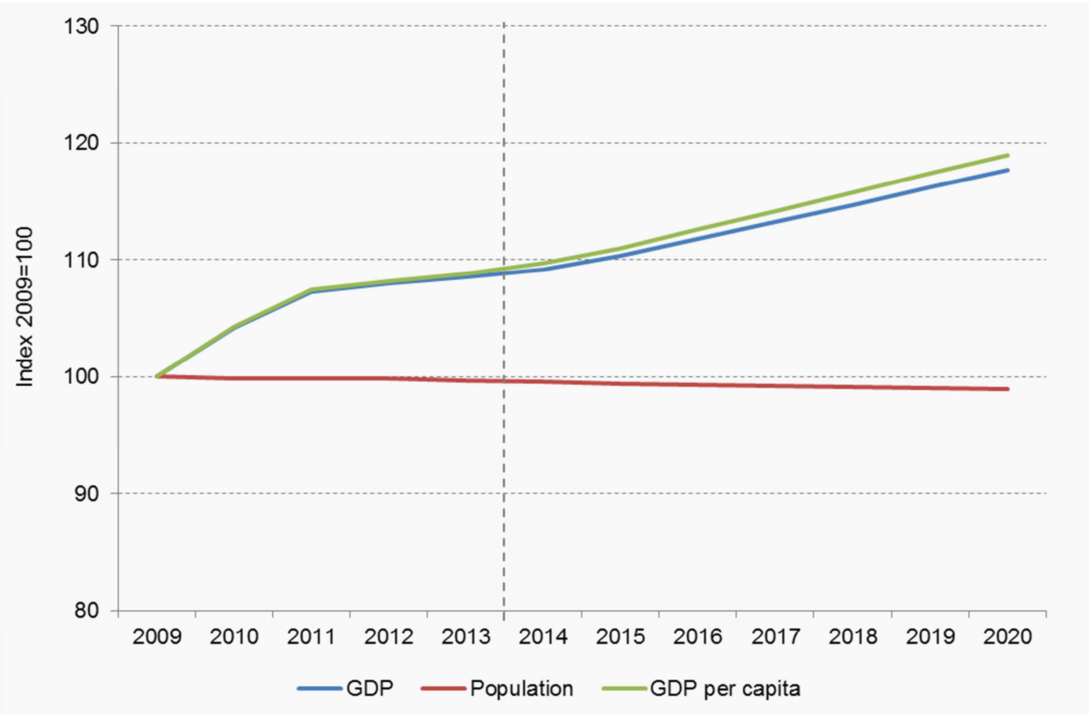
For the purpose of this study, the energy transition begins in 2010. From 2010 onwards, the energy consumption paths of the ET scenario and the CF scenario diverge. The year 2009 is the last year during which the two scenarios display identical consumption and therefore constitutes the base year of the analysis.

Macroeconomic Parameters

(Section 4.1 of the report)

The German economy grows throughout the 2009–2020 period by an average of about 1.5% p.a. The population and the labour force drop slightly. There is an increase in the real consumer energy prices.

Figure 3: GDP, population, and per capita income in Germany, 2009–2020, Index 2009=100



Source GWS/Prognos/EWI 2014

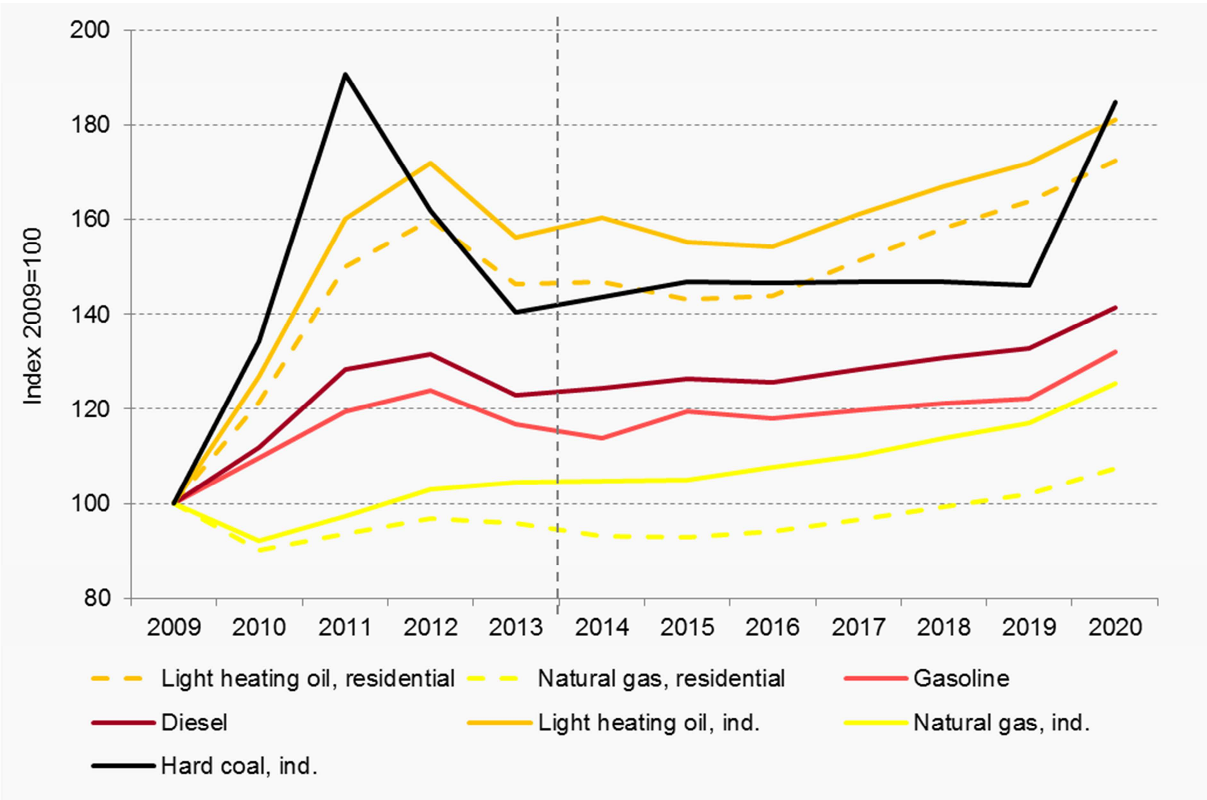
The population decreases during the observation period from 80.3 million in 2009 to 79.4 million in 2020 (-1.1 %). The labour force drops by 1.5%.

Real GDP has increased during the ex post period by an average of 2.1% p.a. In the ex ante period, the average growth rate is 1.2% p.a. Together with the slight decrease in population, this leads to an increase in the average and real per capita income of about 9% by 2013 and 19% by 2020.

GDP development deviates from assumptions of the German government. In the current midterm projection (2014–2018) the government expects GDP growth rates of about 1.6% p.a.

Consumer prices for petroleum products, natural gas and coal are essentially determined by the global market prices and exchange rates, as well as by the associated taxes and fees. In addition, CO_2 surcharges are expected to be implemented by 2020. In line with the assumptions made, businesses that are not participating in emissions trading as well as private households will pay a surcharge at a rate consistent with CO_2 certificate prices and the specific CO_2 content of the energy source used.

Figure 4: Consumer prices for petroleum products and natural gas, household prices with VAT, industrial prices without VAT, 2009–2020, Index 2009=100



Source: GWS/Prognos/EWI 2014

The real price for residential natural gas dropped in the ex post period by about 5%, and the price for light heating oil rose by 46%. By 2020, the natural gas price has increased by 7% and heating oil by 73% compared to 2009 values. The considerable price increase for heating oil compared to natural gas is especially due to the more quickly increasing cross-border prices of crude oil.

For industrial customers, relative price increases are higher than for residential users. The reason for this is that industrial customers are subject to lower taxes and fees for energy sources. The prices of heating oil and hard coal are expected to experience the sharpest increase. The assumed CO_2 surcharge plays a vital role from 2020 onwards.

Gasoline and diesel prices increase in the ex post period by 17% and by 23%, respectively. By 2020, prices have increased by 32% (gasoline) and by 41% (diesel) compared to 2009 values. The comparatively small increase is a consequence of the major burden of the petroleum tax, which is assumed to remain constant in real terms during the observed time period.

Energy Consumption and Emissions

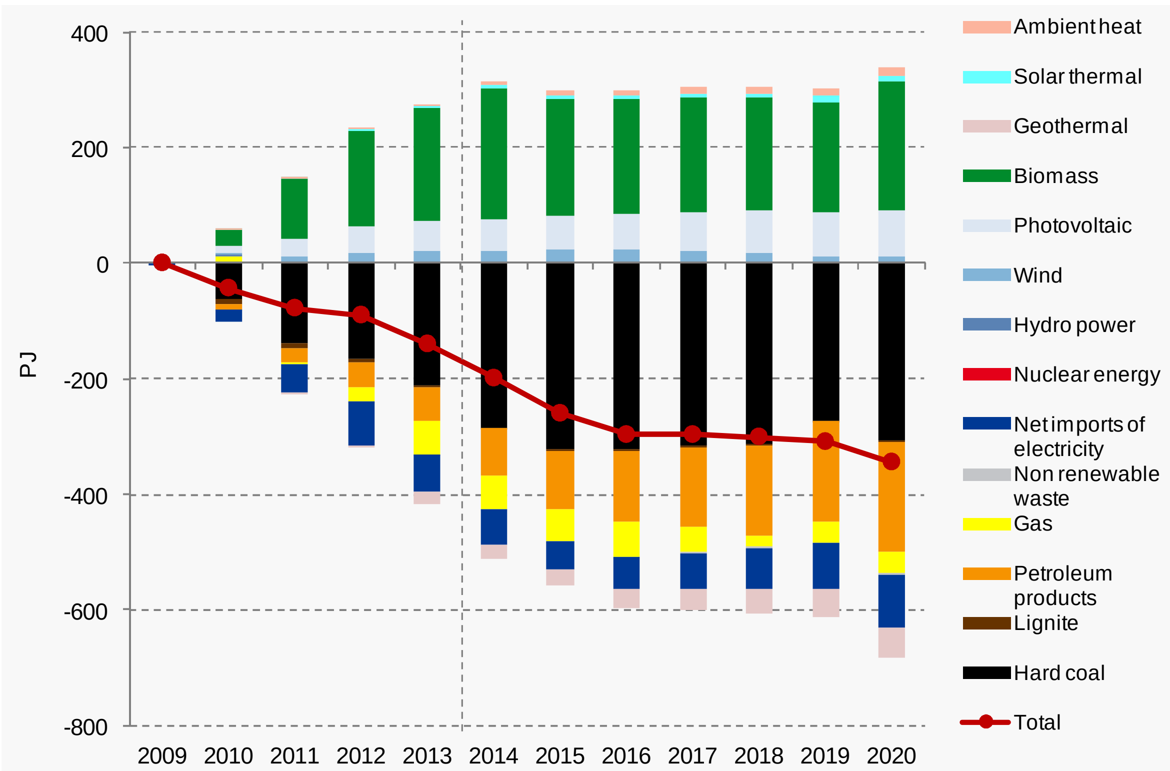
(Section 4.2 of the report)

Results are presented according to the Energy Balance, as published by AG Energiebilanzen, in terms of both primary energy consumption and final energy consumption. The resulting greenhouse gas emissions from the burning of fossil fuels are also discussed.

Primary Energy Consumption

Primary energy consumption is reduced in the ET scenario by 2.5 percentage points more (+344 PJ) than in the CF scenario by 2020. Furthermore, the share of renewable energies in the ET scenario is higher than in the CF scenario. However, fossil fuels constitute the basis of energy supply (share >75 %).

Figure 5: Difference in primary energy consumption between the scenarios by energy source, 2009–2020, in PJ



Source: GWS/Prognos/EWI 2014

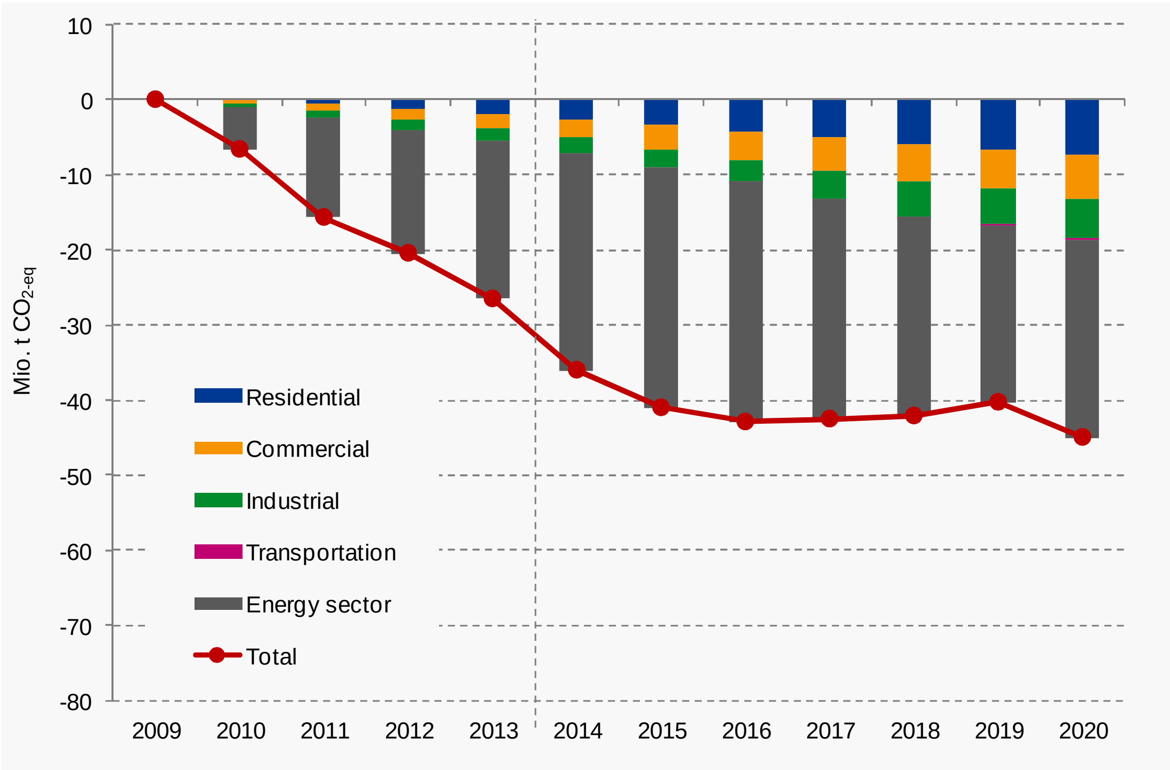
In the ET scenario, primary energy consumption under increasing GDP shows a 1% decrease by 2013 and a 13% decrease by 2020 compared to 2009 values. In the CF scenario, the decrease is about 10% by 2020. The additional savings of about 2.5 percentage points in the ET scenario corresponds to a reduction of about 344 PJ.

Fossil fuels lose market shares but dominate the energy mix in both scenarios in 2020, with shares of 76% (ET scenario) and 79% (CF scenario). A significant increase in the shares of renewable energy resources is expected. Their contribution to meeting the primary energy demand in 2020 is 19% for the ET scenario and 16% for the CF scenario. In 2011, the corresponding value is 9%.

Energy-Related Greenhouse Gas Emissions

Energy-related GHG emissions decrease between 2009 and 2020 by about 15% in the ET scenario and 9% in the CF scenario. The additional reduction in the ET scenario of about 45 million t CO_2 equivalents can be mainly attributed to the trends in the energy sector.

Figure 6: Additional greenhouse gas emissions avoided in ET scenario by sector, 2009–2020, in million t CO_2 equivalents



Source: GWS/Prognos/EWI 2014

Between 2009 and 2013, the energy-related GHG emissions rise in the ET scenario by about 2% (CF scenario: +5.5 %). During the ex ante period, emissions are reduced: In the ET scenario, the emissions in 2020 are about 15% lower than in the base year 2009 (CF scenario: -9 %).

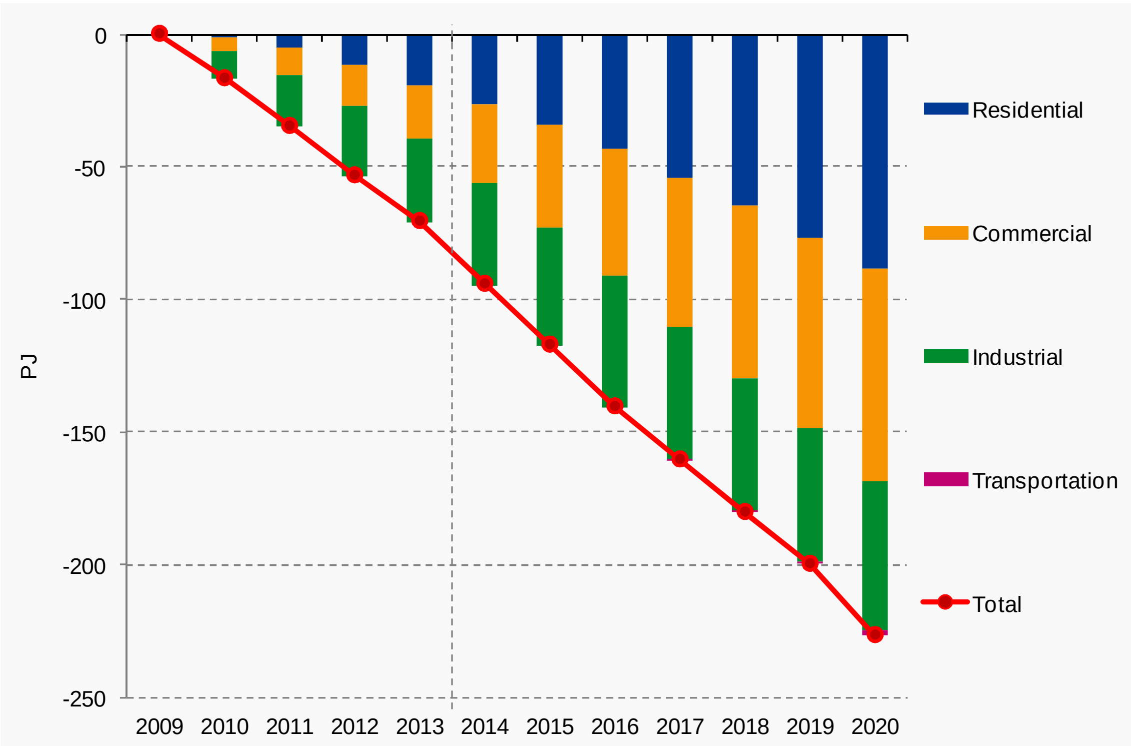
The additional emissions reductions in the ET scenario are the consequence of two factors: the steeper decline in primary energy consumption and the increasing role of low- or non-CO_2 emitting energy sources, especially in electricity production. About 60% of the additional reduction in 2020 can be attributed to the energy sector. The transportation sector does not contribute significantly to additional reductions.

In the analysis, two phases can be seen. The additional reductions of energy-related greenhouse gas emissions almost completely fall into the first phase from 2010 to 2015/2016. From 2016 to 2020, the additional savings do not increase significantly. Furthermore, the contributions of the sectors change over time. During the first phase (up to 2015/2016), the additional reductions mostly occur in the energy sector. During the second phase, the contribution of the energy sector slightly drops, whereas the contributions of the industrial, commercial and residential sectors become increasingly significant.

Total Final Energy Consumption

The final energy consumption drops within the 2009-2020 time period by 6% in the ET scenario and 3% in the CF scenario. Fossil fuels decrease and the share of renewable energies increases. Additional savings in the ET scenario can be primarily attributed to the commercial and residential sectors as well as the use of space heating and mechanical energy.

Figure7: Additional saved final energy in ET scenario by sector, 2009–2020, in PJ



Source: GWS/Prognos/EWI 2014

Final energy consumption increased during the ex post period by about 2 % in the ET scenario and 3% in the CF scenario. In the CF scenario, the final energy consumption declines between 2013 and 2020 by about 6%. In the ET scenario, the final energy consumption sinks by an additional 227 PJ (-8 % compared to 2013). The consumption decreases between 2009 and 2020 in all sectors except for in the industrial sector. However, from 2011 onwards, consumption also begins to decline in the industrial sector.

The additional reduction in the ET scenario seen in 2020 is due to a large extent to the residential (39%) and commercial (35%) sectors. The share of the industrial sector is 25%. The additional savings in the transportation sector are low (1%).

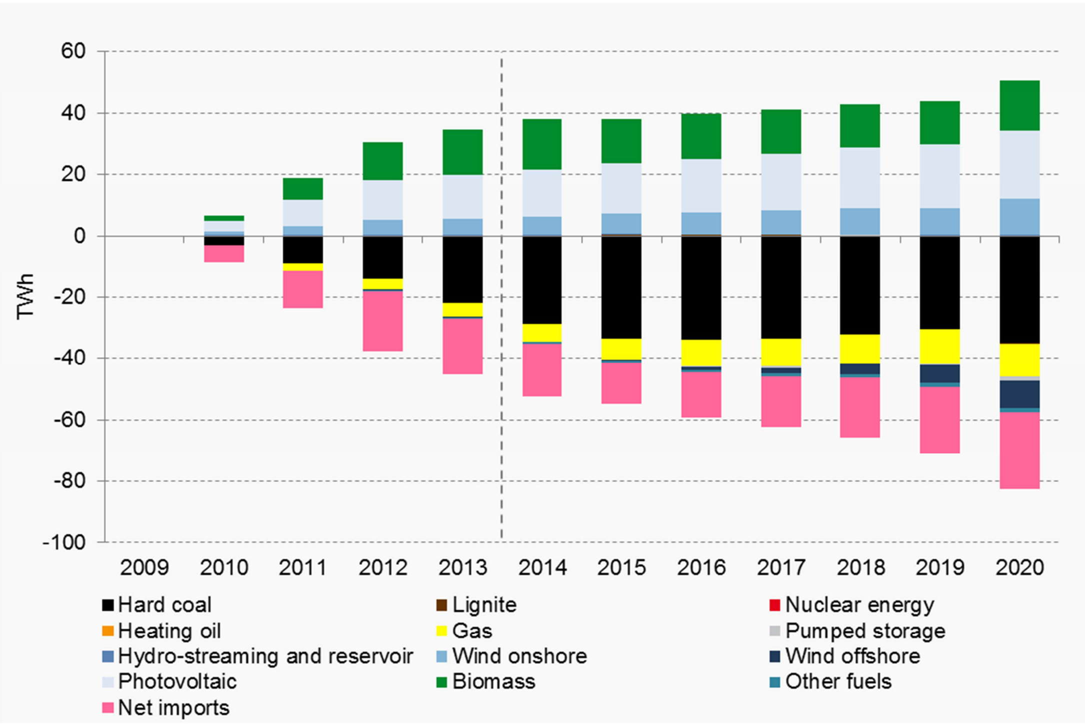
Apart from the increasing energy demand for process heat, cooling, ventilation and building automation, less total energy is required for all other purposes in 2020 compared to 2009. In the ET scenario, consumption by space heating and mechanical energy drops more significantly than in the CF scenario. The additional reduction is 82 PJ for space heating and 68 PJ for mechanical energy.

Electricity and Heat Generation

(Section 4.3 of the report)

The additional electricity generation from renewable energies in the ET scenario leads to lower electricity generation from hard coal- and gas-fired power stations than in the CF scenario. Electricity exports in the ET scenario are significantly higher than in the CF scenario.

Figure 8: Difference in gross electricity production between ET scenario and CF scenario by energy source, 2010–2020, in TWh



Source: GWS/Prognos/EWI 2014

The gross electricity production from renewable energies in the Energy Transition scenario is clearly higher than in the CF scenario. However, the electricity production from hard coal- and gas-fired power plants is lower. At the same time, electricity exports in the ET scenario are higher than in the Counter-Factual scenario since additional renewable energy generation capacities can only provide a limited secured capacity and thus require a sufficiently large conventional power plant fleet, as is the case in the ET scenario.

The share of renewable energies in global gross electricity production is 40% by 2020 in the Energy Transition scenario. The German federal government's objective of 35% is thus exceeded by 5 percentage points. In the Counter-Factual scenario, the share is only 32%, indicating that the energy transition contributes to the achievement of the political objectives.

The EEG surcharge in the Energy Transition scenario is clearly higher than in the Counter-Factual scenario. Households, trade and commerce as well as industrial customers are subject to significantly higher final consumption prices in the ET scenario. The wholesale price in the Energy Transition scenario is slightly lower than in the CF scenario as a result of the merit-order effect. Electricity prices for the energy-intensive industries are lower than those in the CF scenario due to the exemption from EEG surcharge and the lower wholesale price in the ET scenario.

Macroeconomic Effects

(Section 4.4 of the report)

Model analyses constitute a key method for describing the macroeconomic effects of the measures of energy and climate protection policies.

In this respect, the following steps need to be performed: We define a reference case and specify individual technical measures or packages of measures, in principle, based on technically-oriented bottom-up models (e.g., EWI electricity market model, Prognos energy demand models). The next step deals with the conversion of individual measures into economic stimuli. Monetary flows underlie the changes in energy use as well as the corresponding technical developments. The reference case and the stimuli are then applied in a macroeconomic model, a so-called ‘top-down model’ (henceforth referred to as the PANTA RHEI model). The comparison of the alternative scenarios with the stimuli (Energy Transition scenario) and the reference case (Counter-Factual scenario) in the macroeconomic model framework shows the effects of the measures, including various second-round and feedback effects.

The quality of the model calculations depends on how adequately the model captures the macroeconomic and energy sector development, and how accurately the stimuli are described via the bottom-up models and can be included in the macroeconomic models.

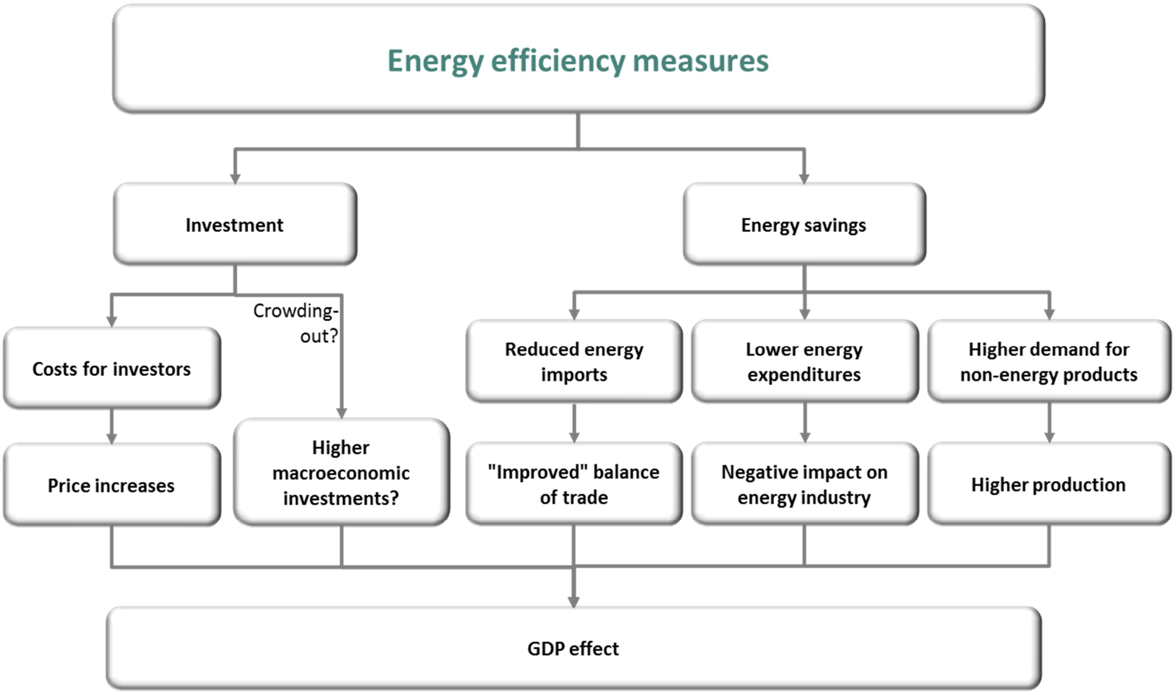
The stimuli partly trigger opposing effects that impact certain sectors more than others. The direction and magnitude of the effects depend on various factors and can change over time. The cause-and-effect relationships are described by the investments in energy efficiency and expansion of renewable energies in the electricity market. Figure 9 shows the fundamental mechanism for investments in efficiency in the industrial sector.

Energy efficiency measures are linked to investments. Investments have, on the one hand, a direct demand effect in the sectors, which manufacture those products. On the other hand, the investments must be funded. The costs of capital lead to increasing costs via increased depreciation. Depending on the market environment, higher costs can be passed on to the sales prices. If this does not work, profits drop in the sectors with investments. A crucial issue for the macroeconomic effects is the possible crowding out of other investments by using limited financial means for the efficiency measures, the so-called "crowding-out effect".

In the economy, energy savings shift demand from energy towards other goods. A decreasing energy demand alters profit and sales opportunities for the existing providers that (only) sell energy. However, lower energy expenditures outside the industrial sector make it possible to buy other goods, generating producer profits. The global effect depends on the balancing of additional burdens from investments (and their funding) with the benefits from energy cost savings. The global effect varies over time. As a result, the impact on the GDP is open.

Since Germany imports most energy, the reduction of energy expenditures may help to improve the trade balance. In the light of high trade surplus, the effect of reduced energy imports due to improved energy efficiency should be analysed in detail.

Figure 9: Macroeconomic effects of energy efficiency measures in the industrial sector



Source: GWS/Prognos/EWI 2014

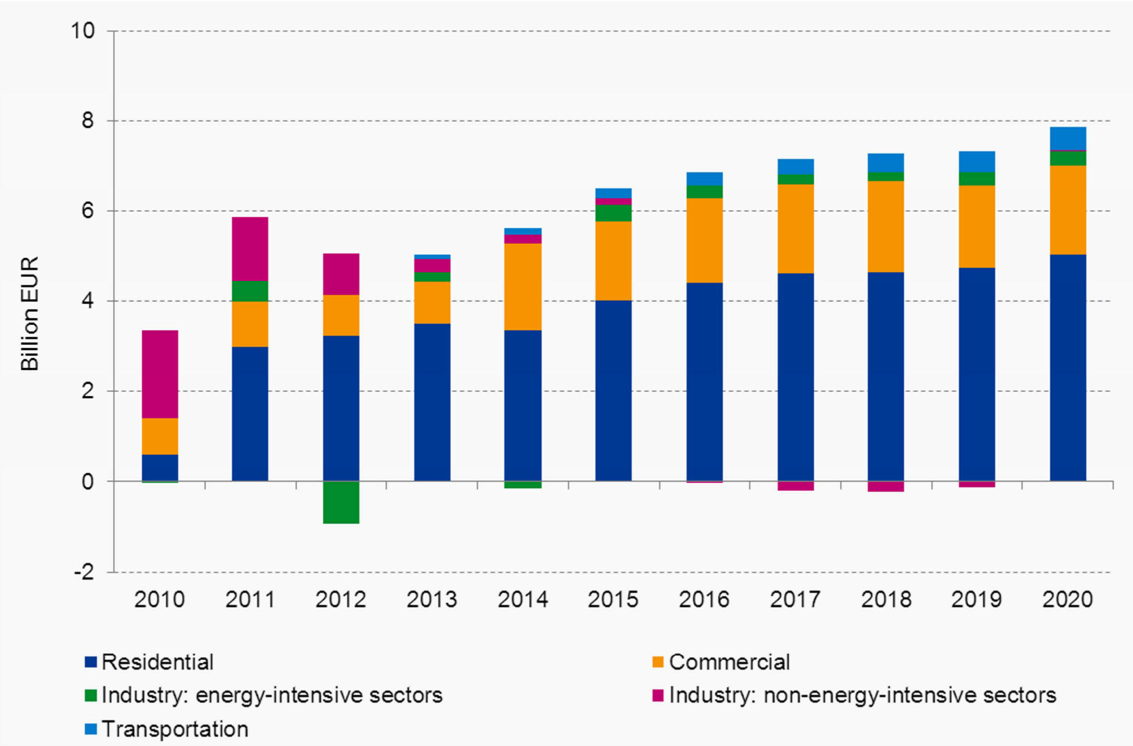
The macroeconomic effects of the expansion of renewable energies are derived in the short term from changes in investments. In the long term, the effects are markedly determined by electricity prices. In this context, redistribution is connected with surcharges in addition to reallocation.

Stimuli from the Model Linkage

The ET scenario and CF scenario are fundamentally based on the same socio-economic assumptions, for example, for international economic development, international energy prices and demography. The scenarios are nonetheless differentiated with regard to electricity generation and the resulting electricity prices as well as the additional investments that are necessary (in the ET scenario) to increase energy efficiency and enhance the expansion of renewable energy.

The quantitative analysis compares the ET scenario and the CF scenario in detail. Figure 10 shows the monetary stimulus on the energy demand side, concentrating especially on buildings for the residential and the commercial sectors.

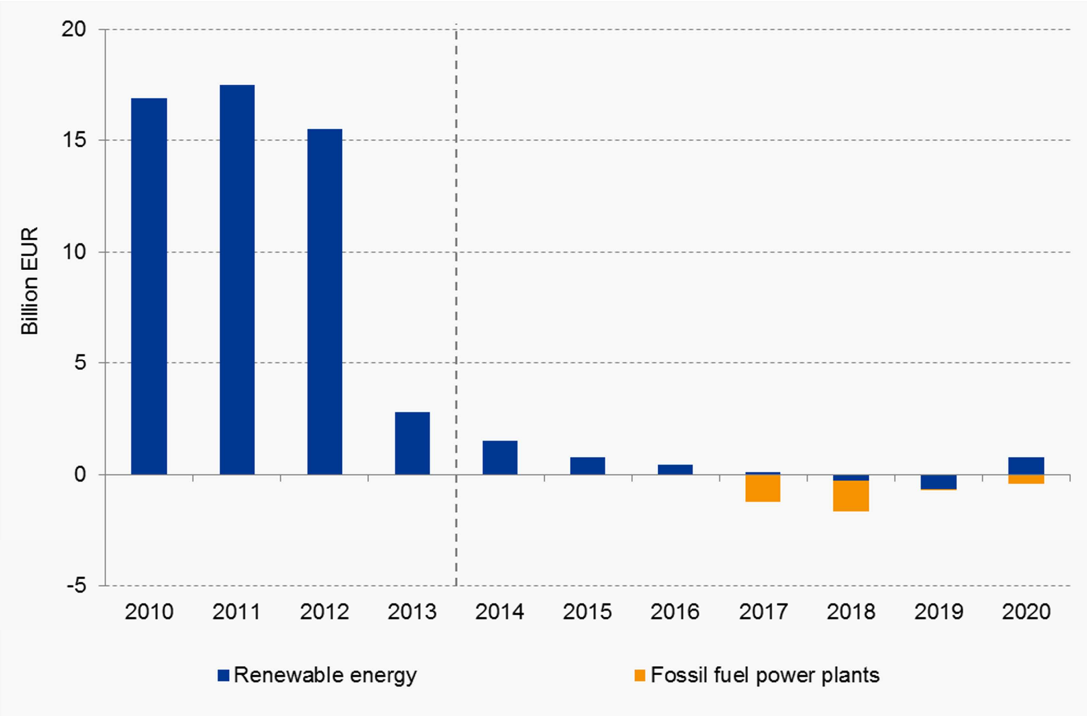
Figure 10: Differences in investments in the demand sectors of the Energy Transition scenario compared to the Counter-Factual scenario, 2010–2020, in billion EUR



Source: GWS/Prognos/EWI 2014

The comparison of the differences in investments in the electricity market, as shown in Figure 11, illustrates the importance of developments in the electricity market for the ex post analysis. From 2010 to 2012, additional investments in the electricity market dominate with between 15.5 and 17.5 billion EUR. Predominantly, this is a result of the expansion of PV systems: In the ET scenario, five gigawatts of additional PV capacity is installed in 2011 and six gigawatts in 2012.

Figure 11: Differences in investments in the electricity market in the Energy Transition scenario compared to the Counter-Factual scenario, 2010–2020, in billion EUR



Source: GWS/Prognos/EWI 2014

The design of the support instrument, the EEG surcharge, delays the price increases for consumers from the costs of the respective investments and spreads it over 20 years. In 2011, electricity prices in the ET scenario are only slightly higher than those in the CF scenario. The maximum price difference is not achieved until 2019 and is equal to about 2.1 Ct/kWh (1.8 Ct/kWh without VAT). By 2020, the price difference is still 1.4 Ct/kWh for residential customers.

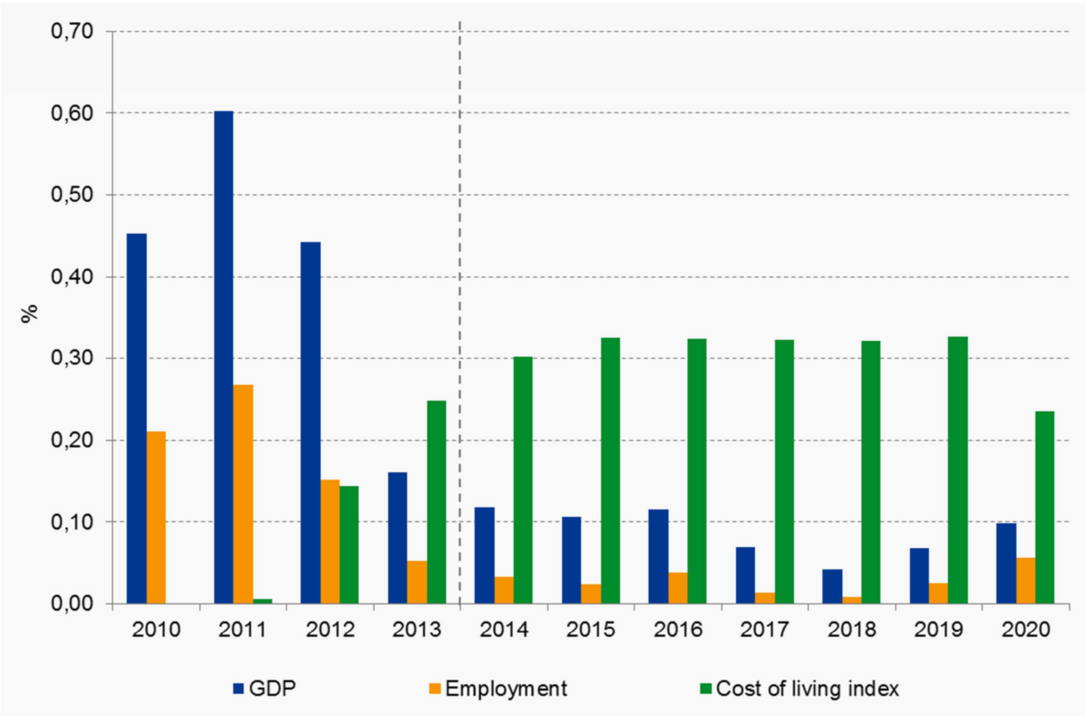
ET Scenario vs. CF Scenario

The Energy Transition scenario, which largely corresponds to the actual development until 2013, is compared to the Counter-Factual scenario. Roughly speaking, two phases can be seen. Ex post up to 2012, the expansion of renewable energies dominates, especially, in monetary variables, the expansion of photovoltaics. Ex ante from about 2015, the macroeconomic effects are primarily driven by energy efficiency measures as well as increased electricity prices in the ET scenario.

Considering the significant investments made in the renewable energy sector from 2010 to 2012, the effects on the GDP are markedly positive (Figure 12). Nevertheless, long-term financing via the EEG leads to increased electricity prices in subsequent years for all consumer groups, except for the electricity-intensive industries who are able to slightly benefit from the reduction of wholesale prices. This and further exceptions are assumed to be equal in both scenarios. The price index of the cost of living rises significantly up to

2014 as a result of higher electricity prices (Figure 12, Table 1). The production prices are also higher in the ET scenario than in the CF scenario. Furthermore, the employment effects of the ET scenarios in 2010 to 2012 are clearly positive. With increasing prices, rising wages and decreasing investment dynamics, the employment effects become smaller over time. Investments in construction play an important role in the macroeconomic effects. In particular, the residential and commercial sectors contribute significantly. Additional investments in efficiency measures - especially in the building sector - support the construction sector and lead to noticeable effects in subsequent years, also in the form of lower energy costs.

Figure 12: Deviations of GDP (price-adjusted), employment and the cost of living index in the ET Scenario from those in the CF scenario, 2010–2020, in %



Source: GWS/Prognos/EWI 2014

Table 1: Differences between selected macroeconomic variables in the ET scenario and the CF scenario, 2010-2020, in absolute terms

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
	Ex post				Ex ante						
Components of price-adjusted GDP (differences in billion EUR)											
Gross domestic product	10.7	14.7	10.9	4.0	3.0	2.7	3.0	1.8	1.1	1.8	2.7
Private consumption	0.0	2.7	1.9	0.4	-1.2	-2.0	-2.5	-3.4	-4.4	-5.1	-5.3
Government consumption	0.0	-0.3	-0.1	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	0.0
Machinery and equipment	9.5	10.1	6.8	1.8	0.7	0.6	0.3	-0.8	-1.2	-0.5	0.2
Construction	4.5	6.2	5.6	2.8	3.7	3.9	4.7	4.4	4.4	4.8	5.1
Exports	0.4	0.1	-0.5	-0.9	-1.0	-1.0	-1.0	-0.9	-0.8	-0.6	-0.2
Imports	3.2	3.5	2.3	-0.5	-1.7	-2.1	-2.4	-3.3	-4.0	-4.1	-3.6
Government budget in current prices (differences in billion EUR)											
Net borrowing/net lending	0.7	3.8	0.3	-0.3	0.3	0.7	1.1	0.5	0.5	0.9	1.3
Price indices (differences in percentage points)											
Cost of living	0.00	0.01	0.16	0.29	0.35	0.38	0.38	0.39	0.39	0.40	0.29
Production	0.01	0.05	0.23	0.34	0.39	0.40	0.39	0.38	0.36	0.34	0.23
Imports	-0.03	-0.11	-0.10	-0.06	-0.09	-0.10	-0.12	-0.15	-0.18	-0.21	-0.27
Labor market (differences in 1.000)											
Employment	85.1	108.8	61.9	21.6	13.6	9.5	15.2	5.5	3.5	9.8	22.2
Unemployed persons	-54.4	-65.8	-36.8	-12.0	-7.0	-4.5	-8.0	-2.0	-0.8	-4.7	-12.3

Source: GWS/Prognos/EWI 2014

For private households expenditures for building renovations displace private consumption. The former are classified as building investments in the system of national accounts. For this reason, private consumption is lower in the ET scenario than in the CF scenario from 2014 onwards. The decreasing investments in the electricity market over time are compensated by higher investments in efficiency, compared to the CF scenario. The GDP and employment are absolutely higher in the ET scenario than in the CF scenario. Even the price level, which reacts delayed due to the design of the EEG surcharge, remains consistently higher in the ET scenario than in the CF scenario because of the higher EEG surcharge.

The effects on the international competitiveness of German companies and on their exports are extremely low because of the vast exemptions for electricity-intensive industries. The section "Classification of Results into Benefits, Costs, Opportunities or Risks" addresses possible consequences of the energy transition for German companies at the international level.

The analysis makes use of the concept of price competitiveness. International competitiveness is difficult to capture in general, especially in relation to non-price factors.

Higher energy efficiency and ambitious renewable energy expansion lead to a smaller demand for fossil fuel imports. This results in a decline of 534 PJ and corresponds to about 3.2 billion EUR in avoided import costs by 2020.

Sensitivity Analyses

(Section 5 of the report)

The assumptions in the study of the ex post counter-factual development as well as the ex ante scenarios are always subject to uncertainties. In order to investigate the robustness of the results and to better understand the partial effects, several sensitivity calculations are performed.

In the sensitivity analyses, specific assumptions or parameters are varied. All other model variables are not changed exogenously but can change endogenously in the model. Changes in the results as well as differences in economic growth or in employment can then be attributed to parameter variations in the sensitivity analyses.

Two sensitivity analyses (EEG Amendment, EE-"Freeze") are firstly calculated for the electricity market. Results of these sensitivity analyses from the microeconomic model are then included in the macroeconomic model. Further, the macroeconomic model is used to carry out additional sensitivity analyses.

Sensitivity Analysis 'EEG-Amendment'

(Section 5.1 of the report)

The sensitivity analysis 'EEG-Amendment' examines how the results of the Energy Transition scenario change if, by 2020, an expansion of renewable energies is achieved according to the expansion path from the law for EEG-Amendment.

The gross electricity production from wind rises more significantly in the sensitivity analysis than in the ET scenario. The production from biomass and photovoltaic is, on the other hand, slightly below the values of the Energy Transition scenario. In terms of the conventional power plant fleet, there are only minor changes. In all, this leads to an increase in electricity exports since German electricity generation with low variable costs, for example, from renewable energies, nuclear or lignite, replaces comparatively more expensive forms of electricity generation in other European countries.

From 2014 onwards, annual investments in renewable energies are about 1.6 to 1.7 billion EUR higher than in the ET scenario. The investment stimuli in the ex ante period lead to slightly higher economic growth and positive employment effects as compared to the ET scenario. However, in general, the effects are very low.

The significant expansion of renewable energies leads to increasing electricity prices for non-privileged electricity consumers from the surcharge. The slightly higher electricity prices for residential and other consumers lead to a negligible increase in the price index for the cost of living. The employment effects are slightly positive, especially for the construction and services sectors.

The overall conclusion is that the low stimuli of the EEG Amendment cause only minor changes in the economy as a whole.

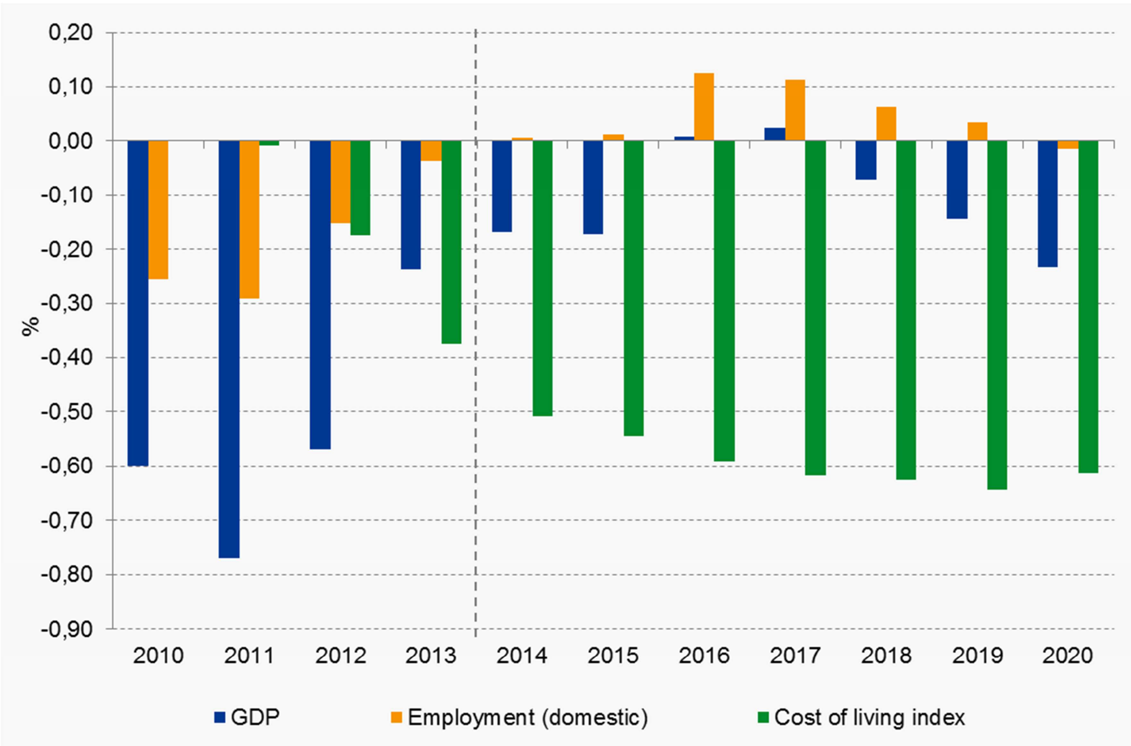
EE-"Freeze"

(Section 5.2 of the report)

In the sensitivity analysis EE-"Freeze", the installed capacities of renewable energy generation technologies are held constant at the 2009 values. The overall increase in renewable energies from 2010 onwards and the related effects are thus attributed to the energy transition.

The gross electricity production as well as the installed capacities of renewable energies is markedly lower in the sensitivity analysis than in the Energy Transition scenario. The gross electricity production of conventional power plants is correspondingly higher. Moreover, the electricity exports in the sensitivity analysis are significantly smaller in the long term as less electricity generation in other European countries is being replaced by German electricity generation from renewable energies with low variable costs.

Figure 13: Deviations of GDP (price-adjusted), employment and the cost of living index in the EE-"Freeze" sensitivity analysis from those in the ET Scenario, 2010–2020, in %



Source: GWS/Prognos/EWI 2014

The overall, particularly 2010 to 2012, significantly lower investments in the EE-"Freeze" as opposed to the Energy Transition scenario lead to a lower growth path, with the exception of the years 2016 and 2017. In these years, more investments in fossil fuel power plants take place. Investments in equipment and exports are positive. Employment increases significantly during this period compared to the ET scenario.

The lower investments in renewables increase the dependence on fossil fuel imports. At the same time, the lower expansion of renewable energies softens the increase in the EEG Surcharge. The non-privileged end consumers benefit from lower electricity prices. The cost of living price index is lower than that of the ET scenario.

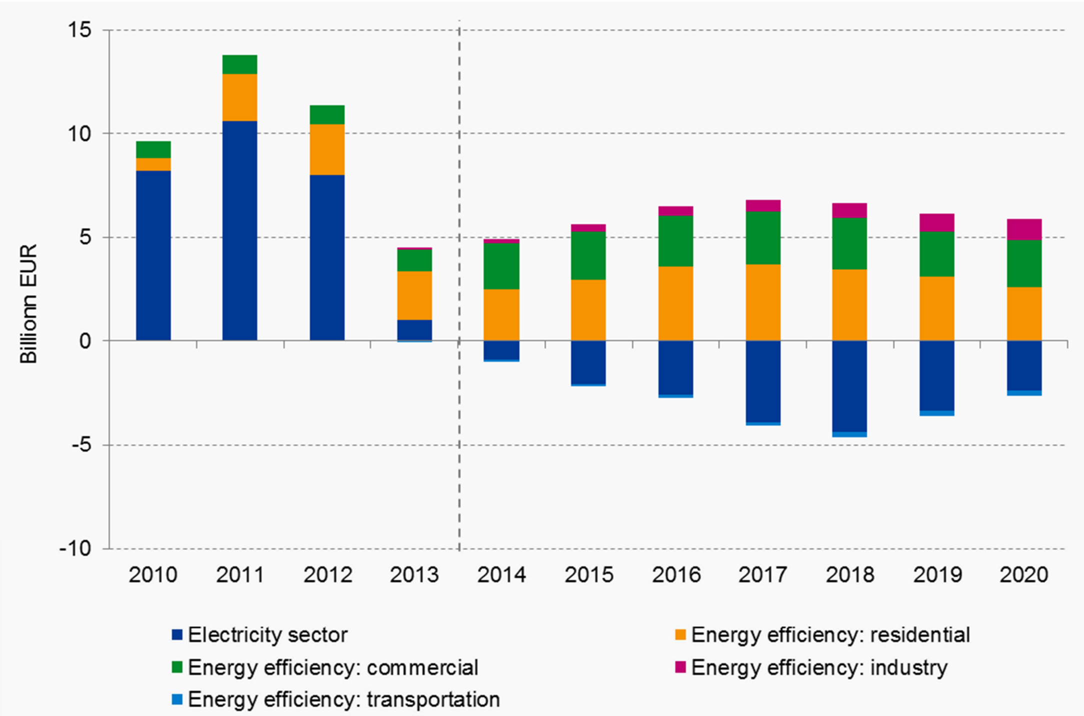
Breaking Down of Stimuli

(Section 5.3 of the report)

In the Energy Transition scenario, the stimuli from the demand side and from the electricity market are analysed and evaluated. To relate the macroeconomic effects to individual measures, the trigger factors within this sensitivity analysis are considered separately.

Important inputs from the electricity market model for the macroeconomic analysis include investments (especially in renewable energies), electricity prices per consumer group and net electricity imports. The demand stimuli are broken down into investments in energy efficiency for the residential, commercial, industrial and transportation sectors.

Figure14: Breakdown of GDP effects, 2010–2020, in billion EUR



Source: GWS/Prognos/EWI 2014

From the analysis ex post, it is clear that investments in the electricity market dominate the GDP and employment effects. In the following ex ante period, the initially positive influence on GDP and employment is reversed due to increasing electricity prices. In this context, higher energy efficiency constitutes an efficient means to limit energy costs.

Crowding Out

(Section 5.4 of the report)

The additionality assumption of investments in efficiency and renewable energy is examined in this sensitivity analysis from the perspective of the macroeconomic effects. In doing so, it is assumed that additional investments are completely crowding out other private investments.

As a result, comparing the sensitivity analysis "complete crowding out" with the ET scenario reveals that GDP and employment are markedly lower in the first years.

At the end of the observation period, the employment effects are close to zero, whereas the GDP effect is slightly positive. The price level, in the event of complete crowding out in the later years, is lower than in the ET scenario. To classify the sensitivity analysis it has to be stressed that full crowding out is a 'worst-case' assumption.

However, a comparison with the CF scenario shows that part of the positive macroeconomic effects cannot be attributed to the crowding-out assumptions. Even under the assumption of a complete crowding out, slightly positive effects of the sensitivity analysis can be seen in the long term compared to the Counter-Factual scenario.

Higher GDP Growth

(Section 5.5 of the report)

In this sensitivity analysis, the growth path is assumed to follow the current spring projection of the German federal government (BMWi, BMF 2014). Up to 2018, the GDP grows faster than in the Energy Transition scenario.

The results of this sensitivity analysis show that a higher GDP would also imply increased energy consumption and GHG emissions. The (implicit) macroeconomic elasticity of demand is about 0.5. Consequently, greater efforts would be necessary to achieve a specific GHG reduction target by 2020.

Technological Development and Innovation

(Section 6 of the report)

Indicators for measuring innovation within the scope of monitoring the German energy transition

(Section 6.1 of the report)

The government's research expenditures in the areas of renewable energies and energy efficiency have increased over the past years. However, this alone does not imply any enhanced innovation performance. The market shares of energy-efficient products have also increased. Yet, it is not possible to quantify with precision, the extent to which this development has been affected by the energy transition in Germany.

Innovation is a critical component in the implementation of the energy transition. It includes research and development (invention) as well as the successful introduction of new products onto the market. In this context, there is a close correlation between the speed of technological progress, legal minimal standards and public funding. In principle, developments are realised on a global scale. For this reason, the influence of the energy transition on the innovation process in Germany from 2010 onwards cannot be accurately quantified.

In the second monitoring report of the energy transition, the federal research expenditures for energy are used as indicators for the innovation stimuli of the energy transition (BMWi 2014 b). The relative increase in expenditures shows a slightly increasing importance of energy research. Yet the indicators currently available in the monitoring report cannot be used to fully assess the contribution of the energy transition to innovation (Löschel et al. 2014). Not only state research funds but also R&D expenditures of private companies contribute to innovations necessary for the energy transition. It should not be deducted from research expenditures or the number of patent applications that there are new and marketable products.

Electricity Sector

(Section 6.2 of the report)

The energy transition has contributed to reductions in the investment costs of photovoltaic systems.

Presently, the innovation effects of the energy transition in the electricity sector cannot be fully evaluated because of the limited data currently available and the short period after 2010. Using learning curve effects, it can, however, be shown that within the scope of the energy transition, the forced expansion of photovoltaics had an influence on the global learning curve of PV and thus contributed to the reduction of investments costs. Consequently, investments costs are about 6% lower in 2013 in the Energy Transition scenario than in the Counter-Factual scenario. For other renewable generation technologies, no similar effect can be shown since the share of German capacities in the generation capacities installed worldwide is relatively small. As a result, the influence of the

German energy transition on the global learning curve from 2010 onwards is negligible for all other technologies.

Energy Demand

(Section 6.3 of the report)

The following analysis takes into consideration the distribution of energy-efficient products in the market. For large electrical appliances (white goods) and lamps, the shares of the sales of higher efficiency goods increase significantly. As far as heating systems are concerned, the shares of boiler systems and electric heat pumps increase, whereas the share of low temperature systems, especially that of oil-fired heating systems, decline. In the building sector, windows with triple heat-insulating glass become more common. This leads to a decline in the average U-value of windows sold. For energetic recapitalisation efforts within the framework of KfW subsidies, a significant increase had been recorded from 2006-2012 for the group having the lowest thermal transmittance values.

In principle, the development for these products and technologies was steady. An influence of energy transition from 2010 is not directly noticeable.

As for solar thermal energy, the area of newly installed solar collectors per year becomes smaller from 2008 onwards. The decline can be attributed to, among other things, the competition in the PV systems. The energy transition does not lead to a significant reassessment of solar thermal energy.

The share of "alternative" engines in new car registrations remains low at ca. 1% from 2008 onwards.

Classification of Results into Benefits, Costs, Opportunities or Risks

(Section 7 of the report)

The energy transition can be assessed according to different economic criteria. The following analysis takes into account the effectiveness and the impact on the main macroeconomic aggregates. In addition, the key elements of the energy transition within the framework of a BCOT (Benefits, Costs, Opportunities and Threats) analysis are examined and classified into categories. The results of the macroeconomic analysis are consistent with the overall view derived in other similar studies with regard to the methodological classifications described in section 2.

Evaluation according to economic criteria

(Section 7.1 of the report)

In order to assess as a whole the effectiveness of measures taken over the period of the energy transition, the results of the ET scenario are compared with the objectives of the Energy Concept of the German federal government. The medium-term objectives for 2020 are taken into consideration.

Table 2: Comparison of select results of the ET scenario with the federal government's goals; 2011 and 2012 data of the second monitoring report

	2011	2012	2020
Greenhouse gas emissions			
Greenhouse gas emissions compared to 1990	-25.6%	-24.7%	**-40%**
Result ET-Scenario			-36%
Efficiency			
Primary energy consumption compared to 2008	-5.4%	-4.3%	**-20%**
Result ET-Scenario			-18%
Energy productivity TFEC	1.7% (2008–2011)	1.1% (2008–2012)	**2.1%** (2008-2050)
Result ET-Scenario			1.9% (2008-2020)
Gross electricity consumption compared to 2008	-1.8%	-1.9%	**-10%**
Result ET-Scenario			-7%
CHP			
CHP share in electricity generation	17.0%	17.3%	**25%**
Result ET-Scenario			16%
Renewable energy			
RE share in gross electricity consumption	20.4%	23.6%	**mind. 35%**
Result ET-Scenario			40.4%
RE share in gross final energy consumption	11.5%	12.4%	**18%**
Result ET-Scenario			21.8%

Source: GWS/Prognos/EWI 2014

The GHG emissions targets, the efficiency targets and the targets for CHP expansion are not achieved under the ET scenario. On the other hand, the objectives of the Energy Concept related to renewable energies are achieved. The share of renewable energies in gross electricity consumption in 2020 is 40.4% (targeted value: 35 %). The share of renewable energies in gross final energy consumption increases to 12.4% in 2012 and 21.8% in 2020. Thus, the target value of 18% is exceeded.

Determining the cost efficiency of individual targets is difficult enough when keeping in mind, among others, the time frame as well as the static, i.e., short-term or dynamic, long-term efficiency. For a complex combination of targets, as is the case with the energy transition, assessing overall cost efficiency is not possible.

BCOT Analyses

(Section 7.2 of the report)

BCOT analyses are modified SWOT analyses (Strengths, Weaknesses, Opportunities and Threats). Such an analysis examines the costs and benefits of internal factors that can be influenced by the actors of the energy transition and compares these to external factors that are categorised into opportunities and risks (Benefits, Costs, Opportunities and Threats). This framework, which represents many single economic aspects, should simplify the structured evaluation of the energy transition under the related macroeconomic effects. Potential "winners" or "losers" of the energy transition can thus be identified.

Specific measures that are of particular importance for the energy transition are taken into account. The evaluation of energy transition measures in the electricity sector focuses on the promotion of renewable energies and CHP, advancement of energy storage systems, implementation of smart meters and guaranteed security of supply in the long term.

In the energy efficiency sector, the BCOT analysis evaluates building insulation, expansion of solar thermal energies for the generation of warm water, installation of efficient air-conditioning and ventilation systems, introduction of a unified energy efficiency monitoring system for industrial process technologies, battery electric vehicles, low-consumption cars with conventional motors as well as increased use of biofuels. The perspectives of the various actors, e.g., manufacturers/mechanics, end customers or the state, were taken into consideration when evaluating the measures.

The promotion of renewable energies through the EEG, a key element of the energy transition, plays a vital role in the achievement of the energy policy objectives of the German federal government; yet it gives rise to substantial expenses. Through this promotion scheme and the resulting increase in electricity generation capacities in the form of renewable energies, CO_2 emissions are prevented in Germany and the political targets of the German federal government for renewable energies are achieved. However, these benefits are associated with substantial production costs that are borne by the end consumers via the EEG surcharge. Furthermore, it should be noted that a national promotion of renewable energies, due to the European Emissions Trading Scheme, does not contribute to CO_2 emissions reductions on the pan-European level, potentially displacing other more cost-effective measures for CO_2 prevention in other countries, as long as the two instruments are not adjusted. The long-term advancement of renewable energies depends on the incentives for innovation and the acceleration of "learning curves", which also benefit foreign companies while being paid for by German electricity consumers. Furthermore, risks associated with an excessive promotion of renewable energies, disruption of supply security, technological lock-in effects and inefficiencies in electricity supply system are existent and should be considered.

Contribution to the Current Discussion on the Energy Transition

(Section 7.3 of the report)

The results of the macroeconomic analysis are consistent with the overall view derived in other similar studies with regard to the methodological classifications described in section 2.

The net effects of the Energy Transition scenario compared to a scenario without the corresponding measures illustrate the balance of positive and negative effects as well as all feedback effects. These are, by definition, substantially smaller than the so-called 'gross effects'.

In all, the macroeconomic effects of the energy transition, as it is defined here, are small. The BCOT analyses as well as the controversial public debate and the regulation efforts seem to indicate greater effects.

Measures in energy efficiency attributable to the energy transition are worthwhile when considering the corresponding payback periods of the different investor groups, even from a microeconomic perspective. It is necessary to distinguish between the direct demand stimulus from the implementation of the measure, the long-term financing costs that partly displace other funds, and the energy savings from the implementation of the measure over a financing period, which creates funds available for other expenses.

A much more controversial discussion centres on the macroeconomic effects of the deployment of new technologies such as renewable energies in the electricity or heating market or the promotion of electro-mobility. The sensitivity analysis for the electricity market and the BCOT analysis show that the significant expansion of renewable energies, especially photovoltaics, leads to increasing demand and employment in the short term from 2010 to 2013. The costs allocated to the majority of electricity consumers via the EEG surcharge, which lead to the increase of electricity prices, have negative effects from the macroeconomic perspective in the subsequent years. Policy makers respond to this with an EEG amendment. According to the sensitivity analysis for the EEG amendment, the EEG surcharge will only slightly increase in future years. The macroeconomic effects of the foreseeable expansion of renewable energies is limited up to 2020 due to, in particular, the exemptions for electricity-intensive industries.

From the microeconomic standpoint, the discrepancy between winners and losers under renewables expansion is more significant. From the residential customer's perspective, distribution effects arise due to increased electricity prices. On the other hand, revenues from remunerations payments to among others eligible private homeowners are substantially high. From the perspective of electricity consumers participating on the spot market, prices have dropped substantially over the past years.

The future development of foreign trade of goods resulting from the energy transition depends on several factors. The opportunities available for German companies in the future should be compared with the total costs of renewable energy expansion and the energy transition as a whole.

Necessary Data and Information Improvements in the Future

(Section 7.4 of the report)

In determining the macroeconomic effects of the energy transition, which was introduced in 2010, we are currently only able to rely on a limited range of data. On the one hand, there is a general delay of structural data on the economic statistics. A wide range of data is available only up to 2011. Specific information on renewable energies and energy efficiency are transverse to official statistical databases and is collected in part through research projects using different methods. In general, the development from 2010 until 2013 has not yet been sufficiently recorded in official statistics. For a sustainable monitoring of the energy transition, more specific data needs to be collected, linked and published in the future in order to better identify the related macroeconomic effects.

In particular, appropriate identification and recording of macroeconomic effects related to the various distribution effects of the energy transition need to be significantly improved.