Macroeconomic Effects of the Energy Transition

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Abstract

This paper builds on the results of the study "Macroeconomic Effects of the Energy Transition" in Germany conducted by Prognos/EWI/GWS for the German Federal Ministry for Economic Affairs and Energy. The goal was to analyze the effects of the German energy transition on the economy, energy system and emissions.

Two scenarios have been defined. The Counter-Factual scenario describes the development without the energy transition and is based on the assumptions of the reference scenario given in the "Energy Scenarios 2010". The Energy Transition scenario reflects historical developments up to 2013 and the expected development up to 2020 is based on the Energy Reference Forecast. The main differences between the two scenarios are the expansion of renewable energy in gross electricity production and the improvements in energy efficiency.

The model PANTA RHEI shows the interrelations between the economy, energy system and environment. The economic core of the model consists of input-output tables, system of national accounts and the labor market. The economic module is extended by an environmental module. That includes i. a. energy balances and energy prices. Both modules are linked in a consistent way.

The Counter-Factual and Energy Transition scenario have been implemented in the model. The results show that the investments in renewable energy and energy efficiency have a positive effect on GDP and employment. EEG surcharge leads to increased electricity prices for most consumer groups except the electricity-intensive industries. As a consequence the price index rises. In combination with decreasing investments in the electricity market from 2013 onwards, employment and GDP effects become lower over time.

Keywords: renewable energy, energy efficiency, macroeconomic impacts, input-output model

JEL classification: C54 - Quantitative Policy Modeling, C67 - Input-Output Models, Q43 - Energy and the Macroeconomy

1 Introduction

Germany is heading towards a secure, economically viable and sustainable energy supply. The energy transition ("Energiewende") – as defined here – starts with the energy concept in 2010 and the energy policy decisions in summer 2011. Ambitious goals are the deployment of renewable energy and further development of energy efficiency. Up to 2050, the share of renewable energy should increase at least to 80 % of gross electricity supply and primary energy consumption should halve compared to 2008. Both measures support the reduction in CO_2 emissions of at least -80 % to -95 % in 2050 compared to 1990. Sub-ordinate targets are set accordingly.

The German federal government has introduced a monitoring process to observe the progress related to the targets of the energy transition continuously (BMWI, BMU 2012). The monitoring process gives an overview about past, current and future developments. For a contemporary, compressed and annual evaluation, the indicator analysis is used. Every three years, a comprehensive analysis of actual and possible future developments in the energy transition process is carried out and published in the progress report.

This paper builds on the study "Macroeconomic effects of the energy transition" conducted by GWS, EWI, Prognos (2014) for the German Federal Ministry for Economic Affairs and Energy, which contributes to the aforementioned progress report.

In the second section of this paper, two methods for monitoring the energy transition are presented. In section 3.1 the macro-econometric input-output model PANTA RHEI for Germany is described and its key features and structure are briefly explained. Section 3.2 is about primary impulses of the energy transition and different secondary effects and feedbacks, which have to be accounted for in economic models. In section 3.3, the Counter-Factual and Energy Transition scenario are described. Next, macroeconomic results are shown (section 4). In section 5 conclusions are given.

2 Methodologies

There are two main methods for monitoring the energy transition: indicator analysis and macroeconomic model analysis.

Indicator analysis is used to compare quantifiable target values with historical developments. Suitable indicators have to be quantifiable, comparable, valid, reproducible and continuously updatable. The three energy policy targets are environmental sustainability, energy security and economic effectiveness. Some indicators are explicit targets of the energy transition such as greenhouse gas (GHG) emissions and primary energy consumption. Other indicators can be allocated to one of the dimensions. The dimensions of the target “environmental sustainability” are derived from the anthropogenic influence on nature e. g. emissions and resource consumption. Dimensions of “energy security” are for example resource availability and price stability. Cost-effectiveness and the degree of competition are dimensions of the target “economic effectiveness”.

Figure 1 shows the three energy policy targets and a selection of dimensions and indicators based on Flues et al. (2012).

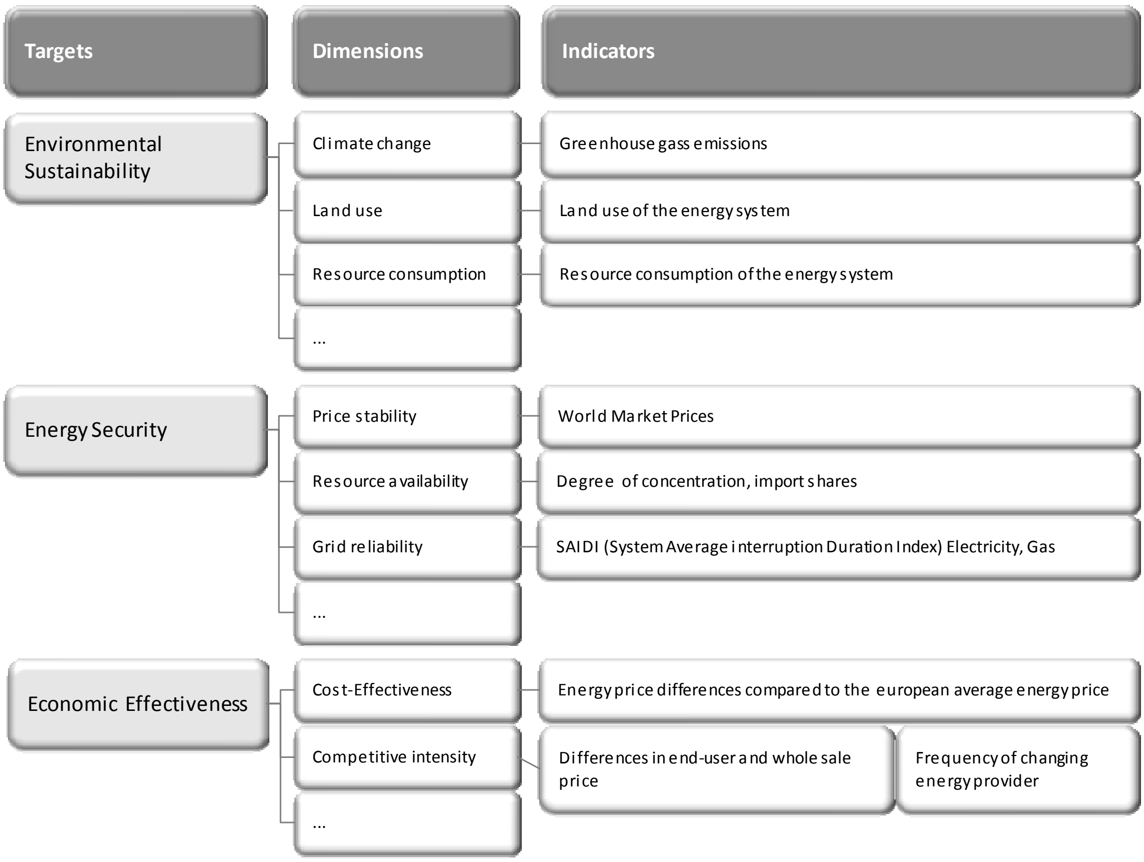

Figure 1: Energy policy targets, dimensions and indicators based on Flues et al. (2012)

Source: GWS, EWI, Prognos 2014

The monitoring report (BMWi, BMU 2012) in particular shows energy indicators and some economic indicators. Other indicator systems focus on energy efficiency indicators at a sectoral level (Graichen et al. 2011). The ODEX indicator and the "Energiewende-Index" from Mc Kinsey and Company are aggregated indicators. They show the dynamics in energy consumption for the whole economy caused by socioeconomic drivers such as population and economic growth (www.odyssee-indicators.org, www.mckinsey.de/energiewendeindex).

Advantages of indicators are that they are available in short term and provide an informative overview. One disadvantage 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" (GWS, EWI, Prognos 2014).

In contrast, the *macroeconomic model analysis* is appropriate to illustrate causal relations and feedbacks between the energy system and the economy on a macro and industry level. In a macroeconomic analysis the procedure is as follows: Firstly, different assumptions about technology and/or measures (scenario design) are selected and calculated with technology- or process-oriented (bottom up) models. Secondly, the results of these models are implemented in a macroeconomic (top down) model. Afterwards, net effects on GDP, employment and prices are derived ex post and/or ex ante (Figure 2).

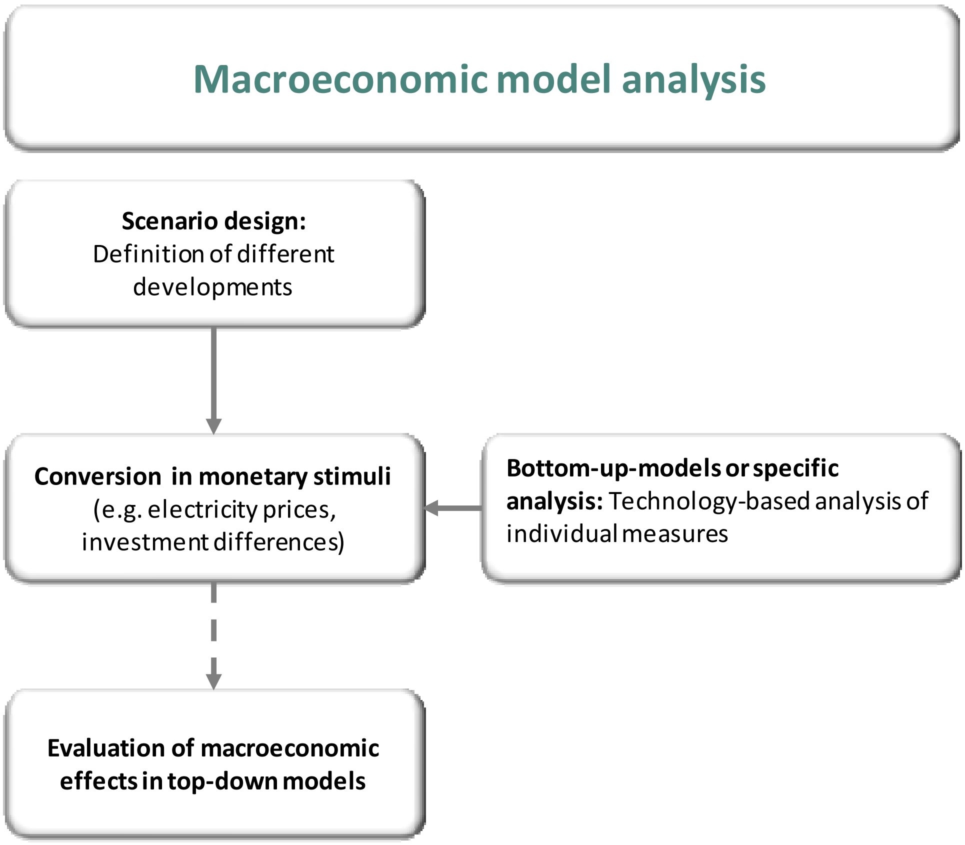

Figure 2: Schematic of a macroeconomic model analysis

Source: GWS, EWI, Prognos 2014

Macroeconomic model analysis is used in many national studies related to energy issues (Blazejczak et al. 2013, Wiegert, Hounsell 2013, Prognos, EWI, GWS 2010, Kronenberg, Kuckshinrichs, Hansen 2012). Differences in results stem from different assumptions about measures (single measures vs. package of measures), transmission channels (partial analysis vs. full macroeconomic model incl. rebound effects) and varying observation periods (short-term vs. long-term).

One key feature of macroeconomic model analysis is the comparison of different scenarios. Therefore, the chosen reference scenario is of special importance. Comparing a scenario with additional measures to a very ambitious development in the reference scenario shows smaller effects than comparing it to a less powerful development. Lehr, Lutz, Ulrich (2014) have summarized the categories of classification.

3 Macroeconomic model analysis

3.1 The German model PANTA RHEI

PANTA RHEI is classified as a macro-econometric input-output model for Germany (Eurostat 2008). The economic model part of PANTA RHEI is extended by an energy and environmental module and therefore it can be classified as an E3 (Economy-Energy-Environment) model as well.

Furthermore, PANTA RHEI is a macroeconomic model that represents the complete economic circle (from production to consumption) and the economic agents (e.g. household, firms and government) involved. Additionally, the model incorporates the economic activities and products (from agriculture to services) in detail as stated in the input-output-tables (Figure 3). A detailed description of the economic core is given in Ahlert et al. (2009) and Maier et al. (2015). The other modules are presented in Lutz (2011) and Lehr et al. (2011).

Among others it has been used for economic evaluation of different energy scenarios that have been the basis for the German energy concept in 2010 (Lindenberger et al. 2010, Nagl et al. 2011). Applications include an evaluation of green ICT (Welfens, Lutz 2012) and employment impacts of renewable energy promotion (Lehr et al. 2008, 2012). A similar model with the same structure for Austria (Stocker et al. 2011) has been applied to the case of sustainable energy deployment in Austria until 2020, and economic evaluation of climate protection measures in Germany (Lutz et al. 2014). In a recent IEA (2014, p. 57) overview, the model is classified as “input-output”, but it is rather “econometric” plus “input-output”, as parameters are econometrically estimated and input-output structures are flexible (West 1995). The overall approach is based on the INFORUM philosophy (Almon 1991).

The model parts are linked consistently (Figure 3). The relations are modeled by identities as well as behavioral equations. The application of econometric methods facilitates an empirically validated parameterization of model variables that heavily relies on agents’ past behavior.

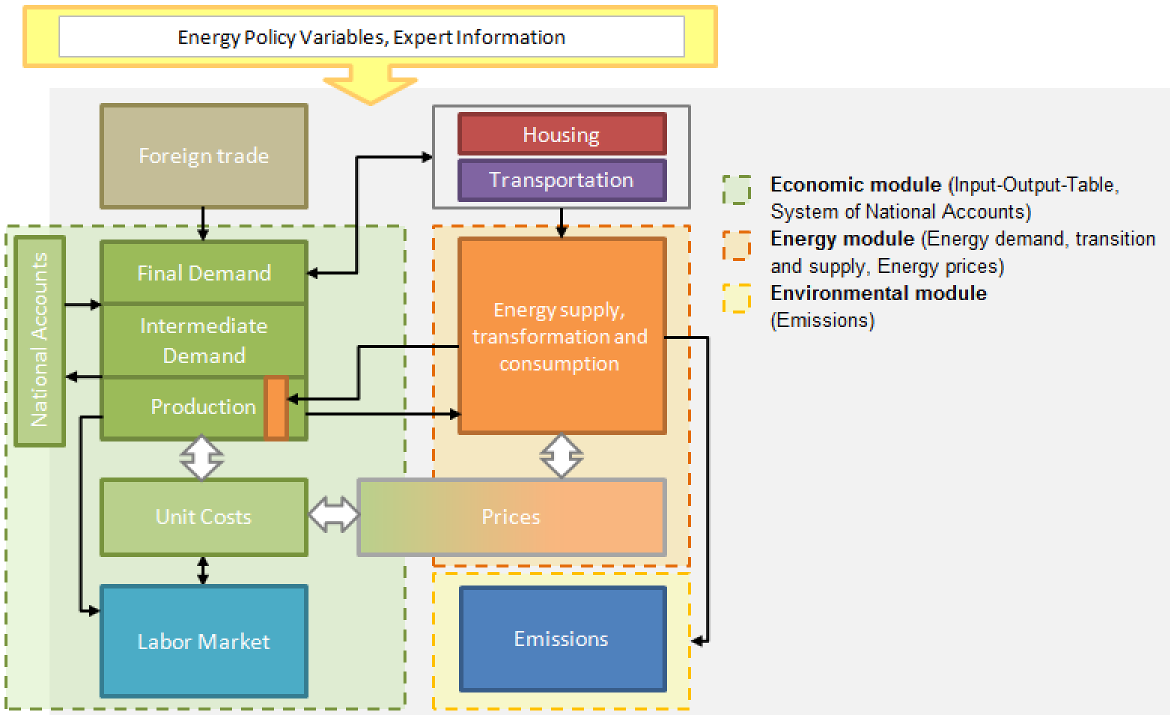

Figure 3: PANTA RHEI at a glance

PANTA RHEI is used to perform scenario analysis. In the project "Macroeconomic effects of the Energy transition", a Counter-Factual and an Energy Transition scenario are defined. The main differences between both scenarios are the expansion of renewable energy in gross electricity production and the improvements in energy efficiency (for more detail see section 3.3). These impulses are implemented into PANTA RHEI to calculate macroeconomic effects. The results are given as absolute and relative differences compared to a Counter-Factual scenario for a selected year. The differences can be interpreted as responses to the exogenous inputs including direct, indirect and induced effects.

3.2 Impulses of the energy transition

The cause-and-effect relationships are described by the investments in energy efficiency and expansion of renewable energies in the electricity market. The macroeconomic effects of both measures are different, because responses to the impulses differ in their magnitude and direction. Economic effects of energy efficiency improvements and expansion of renewable energies are discussed in many studies (e. g. IEA 2014, Ryan, Campbell 2012, Blazejczak, Edler, Schill 2014, Prognos, EWI, GWS 2014, Frondel et al. 2009, O'Sullivan et al. 2014). In GWS, EWI, Prognos (2014) the following explanations are given:

Energy efficiency investments have a direct effect on demand side. This impulse stimulates production in manufacturing and supplier industries. Employment can be positively affected in particular in labor-intensive industries.

The positive demand effect can be dampened by the so-called crowding-out effect, meaning that the energy efficiency investments are not (or only a part) additional but replace other investments. This results in a lower macroeconomic impact. A similar effect may occur if private households have to modernize their residential buildings from savings which in turn may have a negative impact on consumption.

Furthermore, investments have to be paid. Increased capital costs lead to higher depreciations, therefore to higher costs and result in higher sales prices or lower profits for the company.

Energy efficiency investments save energy. Consumers profit from lower energy-related expenditures and can spend the money for non-energy goods. Additionally, the trade balance can be improved due to reduced energy imports. Energy producers are negatively affected by reduced sales quantities.

The macroeconomic effect depends on the balance between costs from investments and benefits from energy savings. This effect varies over time.

Figure 4 shows the mechanism for investments in energy efficiency in the industrial sector.

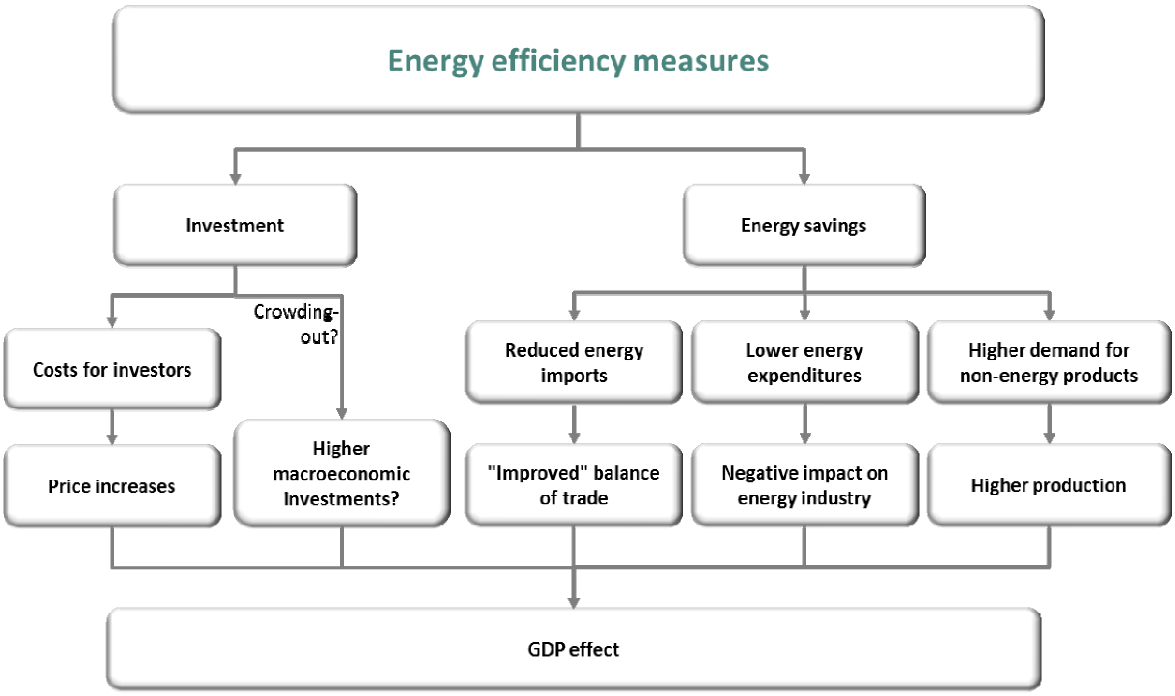

Figure 4: Macroeconomic effects of energy efficiency measures in the industrial sector

Source: GWS, EWI, Prognos 2014

In the short term, the macroeconomic effects of the *expansion of renewable energy* are derived from changes in investments. Investments in renewable energy technologies (RET) are increased while investments in conventional power plants are reduced. These effects are determined by electricity prices in the long term. Investments in RET are supported by a guaranteed feed-in tariff scheme for a period of 20 years (Renewable Energy Sources Act, EEG 2000). The EEG surcharge has to be paid by electricity consumers (e. g. households, commerce) but not by energy-intensive industries. As a result, electricity prices increase.

An opposing trend is triggered by decreasing spot and wholesale electricity prices which only affect a few consumers.

The investment in RET stimulates production and employment in manufacturing industries such as machinery, electrical apparatus, construction and installation services. If goods are manufactured in Germany, value-chain und income effects are higher (Lehr et al. 2012). Imported intermediate goods have a negative impact on GDP. Sign and magnitude of macroeconomic impacts of energy efficiency depend among others on the specific design of measures, but there is growing evidence, that their effects are positive, if accordingly designed (IEA 2014).

Figure 5 shows the mechanism for investments in expansion of renewable energy.

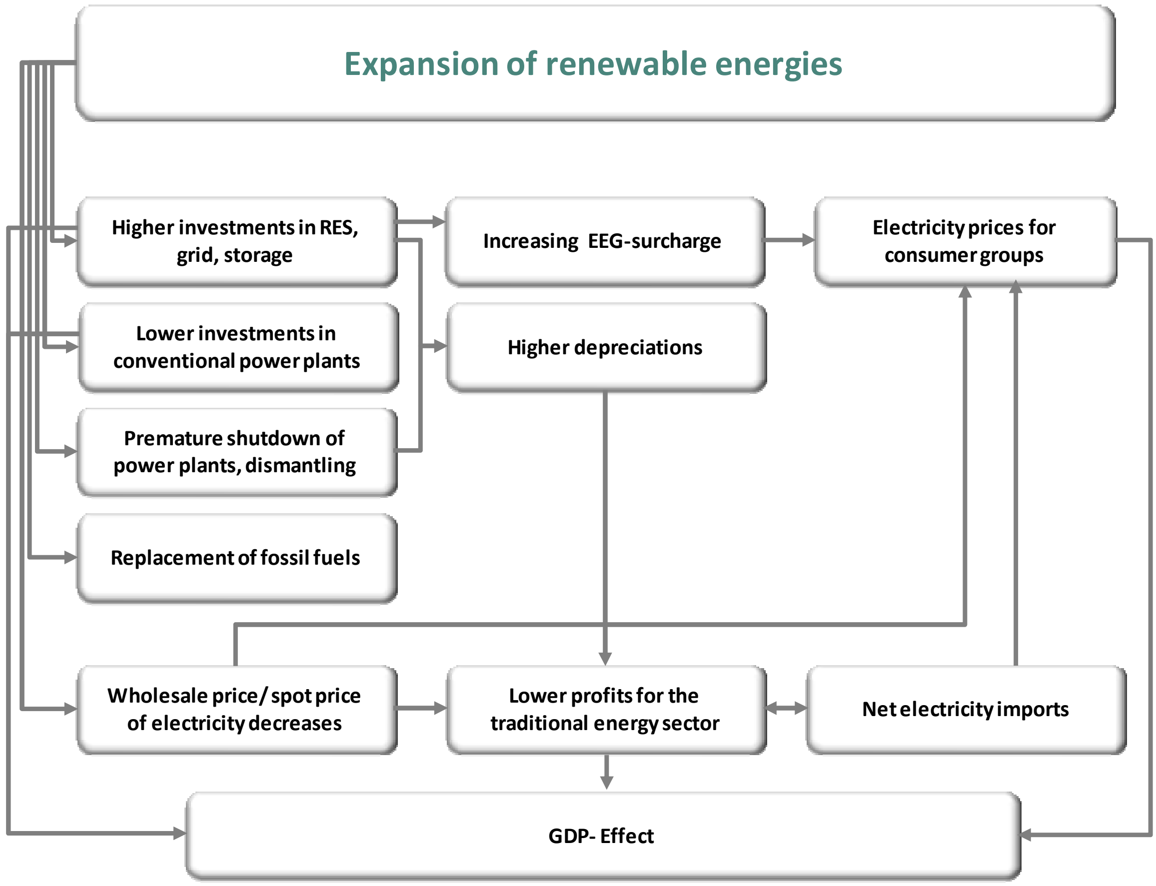

Figure 5: Macroeconomic effects of renewable energy deployment

Source: GWS, EWI, Prognos 2014

3.3 Scenario definition

For the study, two different scenarios have been defined. The Counter-Factual (CF) scenario follows the development without the energy transition and is based on the assumptions of the reference scenario given in the “Energy Scenarios 2010”. The Energy Transition (ET) scenario is based on historical developments up to 2013 (ex-post period) whereas the expected development up to 2020 (ex ante period) builds on the Energy Reference Forecast (Prognos, EWI, GWS 2014).

The main differences between the Counter-Factual and Energy Transition scenario are the expansion of renewable energy in gross electricity production and the improvements in energy efficiency. All other exogenous variables (e. g. population) and model relations are the same for both scenarios.

The exogenous impulses are given as differences compared to the CF scenario for every single year (Figure 6). After calculating the macroeconomic effects with the model PANTA RHEI, results are shown as differences as well.

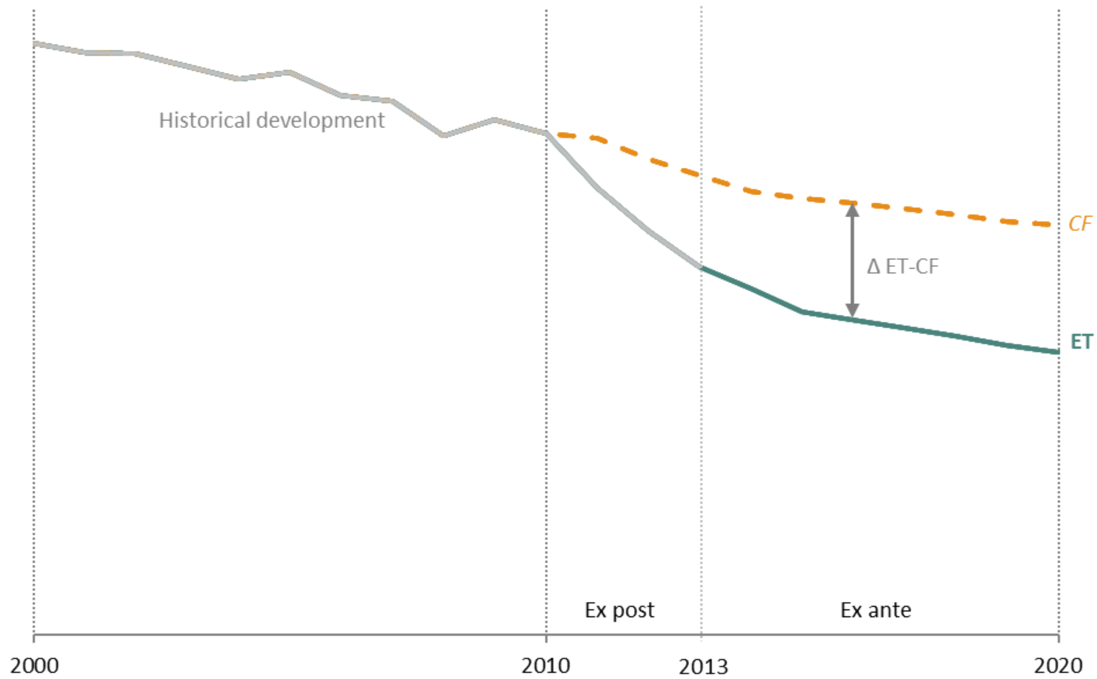

Figure 6: Comparing scenarios

The stimuli for the macroeconomic model are derived from the output of technically-oriented bottom-up models. Inputs for deployment of renewable energies are a result of the EWI electricity market model. The energy demand by sectors is taken from the Prognos models that are used to calculate energy consumption based on energy efficiency measures and socioeconomic parameters.

Electricity Market

Figure 7shows the differences in investments in the electricity market between the ET and CF scenario. Ex post– in particular from 2010 to 2012– the expansion of renewable energies dominates investments in the electricity market. At least 15 bn EUR were invested additionally in RET. PV systems have the highest share (around 80 %) of all additionally installed capacities followed by wind power onshore (around 15 %).

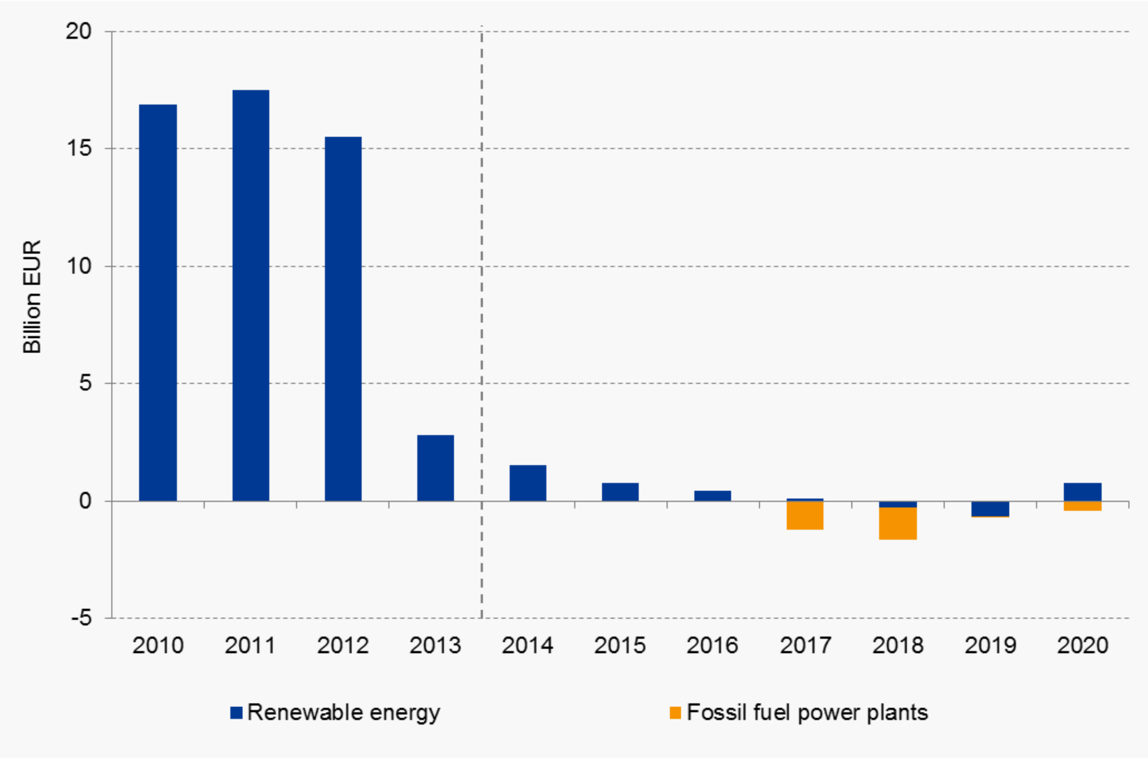

Figure 7: Differences in investments in the electricity market in the Energy Transition scenario compared to the Counter-Factual scenario, 2010–2020, in billion EUR

Source: GWS, EWI, Prognos 2014

Ex ante (2014-2020) additional investments in RET are lower than in the ex post period. Nevertheless, the installed capacity of total RET is still increasing. Only the expansion of installations of offshore wind is less dynamic in the ET scenario compared to the CF scenario. It is assumed that offshore wind installations will reach an installed capacity of 5 GW. In the energy concept 2010, this development was more optimistic.

Differences in investments in fossil fuel power plants are calculated with the electricity market model from EWI, which optimizes the development of electricity generation capacities including conventional and renewable energy technologies (Richter 2011). Due to the fast development of RET, disinvestments in fossil fuel power plants occur from 2017 onwards compared to the CT scenario (Figure 7).

Investments in RET have an impact on electricity prices. On the one hand, the EEG surcharge is increasing because of rising RET installations and a guaranteed feed-in tariff for 20 years. On the other hand, spot/wholesale prices decline due to the merit-order effect. The electricity-intensive industry can profit from the lower wholesale price and the exemption from the EEG surcharge. Other electricity consumer groups (residential, commerce, non-energy intensive industries) have to pay the EEG surcharge.

Energy demand

The energy demand in the CF scenario is taken from the reference case of the Energy scenarios 2010without the energy transition (Prognos, EWI, GWS 2010). Primary energy consumption and final energy consumption are slightly decreasing over the whole period.

In the ET ex-post scenario, energy demand modeling is based on historical data (population, value added etc.).The resulting energy demand was calibrated according to the results of the historical energy balances. In the ex-ante period, energy demand by sectors follows the current Energy Reference Forecast that presents the most probable future development.

Compared to the CF scenario, primary and final energy consumption are lower. At the beginning of the simulation period, differences between both scenarios are not that high. The use of energy sources differs, though. In the ET scenario, more renewables, but less fossil fuels are used for primary and final energy consumption.

Ex-ante differences in energy demand are higher compared to the CT scenario due to additional energy efficiency measures. In particular in the residential and commercial sectors, more investments are done (Figure 8). An average of 4 bn EUR is being invested in modernizing residential buildings, of which from 2014 onwards approximately 2 bn EUR in the commercial sector.

Promoting schemes, energy prices, legal legislation and autonomous technological progress drives the development of energy efficiency.

Figure 8 shows the differences in energy efficiency investments by sectors.

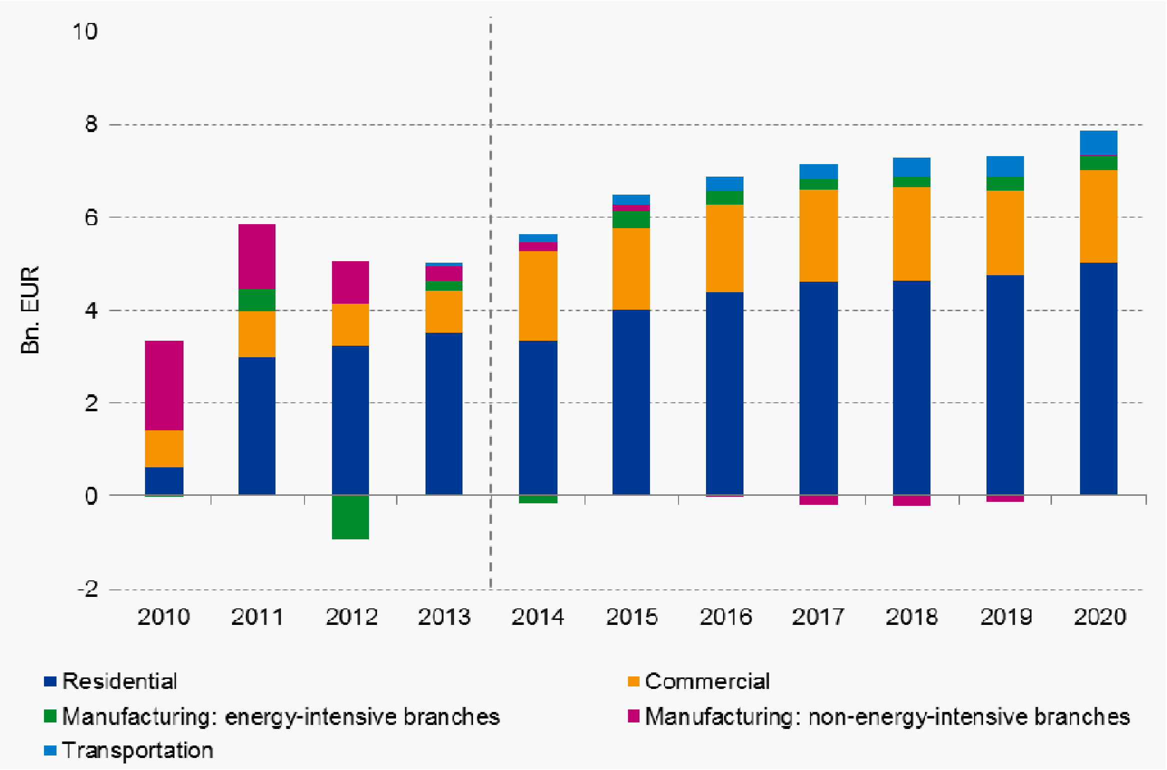

Figure 8: **Differences in investments in the demand sectors of the Energy Transition scenario compared to the Counter-Factual scenario, 2010–2020, in billion EUR**

Source: *GWS, EWI, Prognos 2014*

The differences between both scenarios regarding, for example, electricity prices and investments in energy efficiency and in the electricity sector are put into the macroeconomic model PANTA RHEI and impacts on the macro-economy are calculated.

4 Macroeconomic impacts

Two phases can be identified comparing the ET and the CF scenario. In the first phase from 2010-2012, investments in RET dominate and have positive effects on GDP (up to +0.6 % resp. +14.7 bn EUR) and employment (up to +0.3 % resp. +109,000 persons). In the second phase (from 2015 onwards), macroeconomic effects are primarily driven by investments in energy efficiency as well as higher electricity prices in the ET scenario (Figure 9).

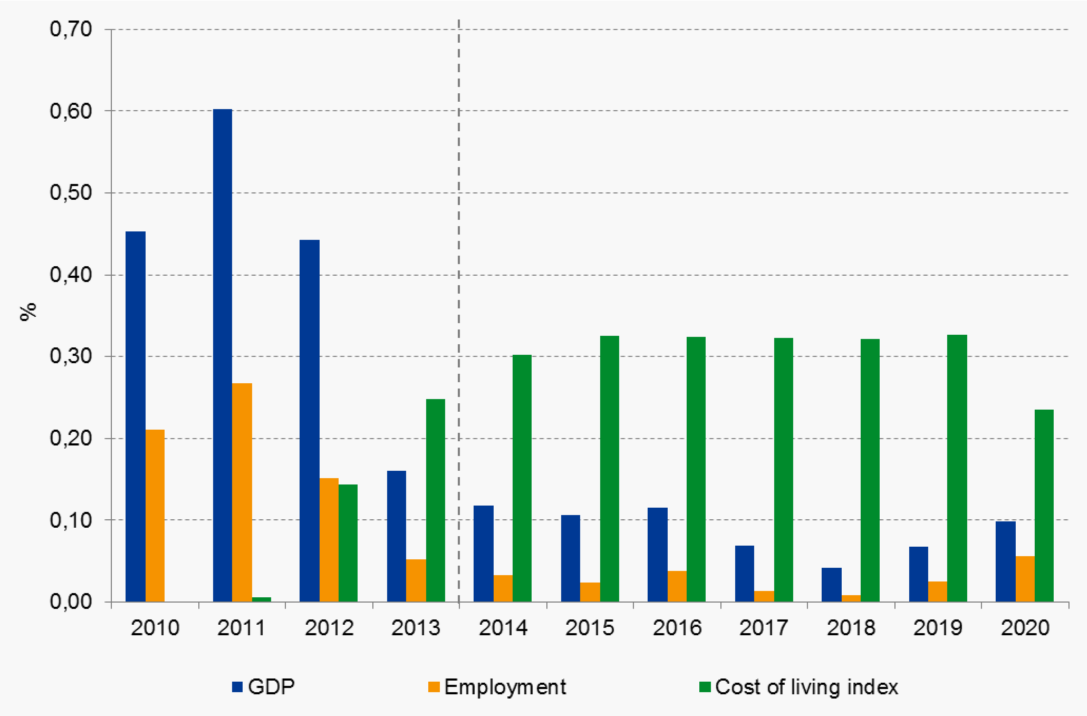

Figure 9: Deviations of GDP (price-adjusted), employment and the cost of living index in the ET Scenario from those in the CF scenario, 2010–2020, in %

Source: GWS, EWI, Prognos 2014

Additional investments in energy efficiency measures – especially in the building sector – support the construction sector and supplier industries. Positive overall employment effects can be seen, but they differ on the industry level (Figure 10). In particular in the mining and energy sector employment is lower compared to the CF scenario. In absolute terms the decrease of 1.7 % is equal to 5,000 employees. The employment in the construction sector increases up to 52,000 (+2.9 %).

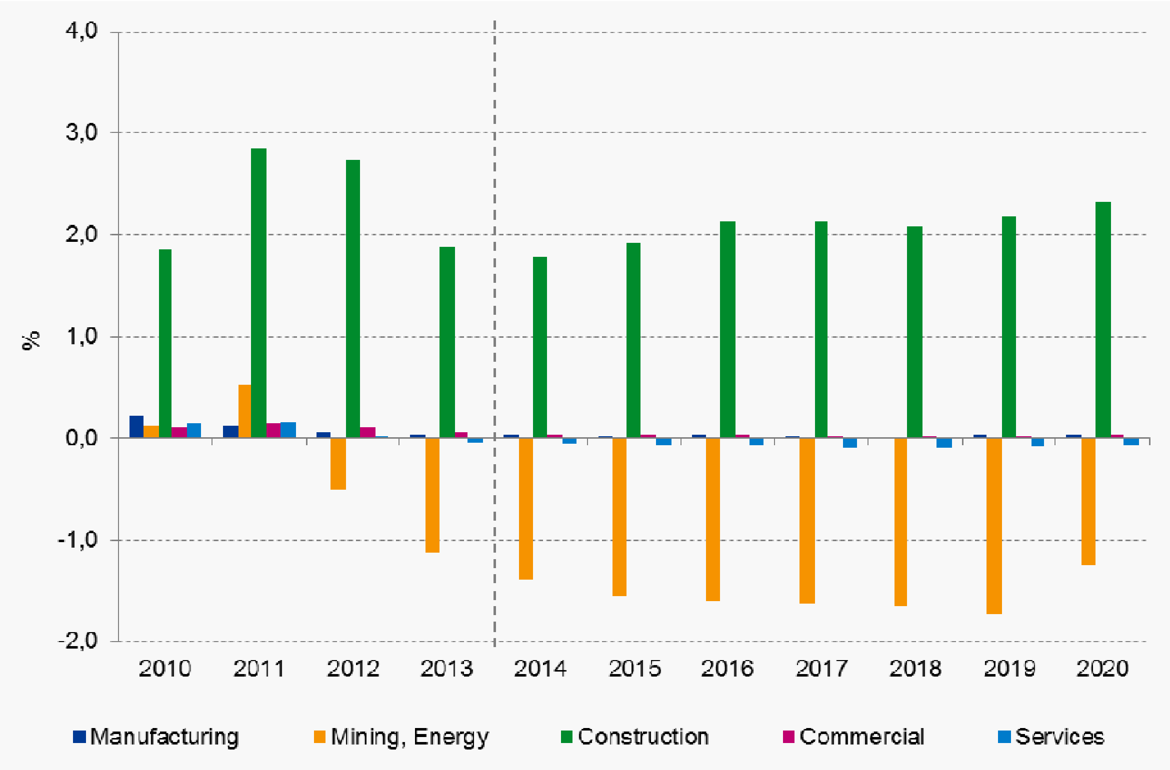

Figure 10: Differences in employment of the Energy Transition scenario compared to the Counter-Factual scenario, 2010–2020, in 1,000

Source: GWS, EWI, Prognos 2014

The price index of the cost of living is significantly affected by higher electricity prices. The production prices are also higher in the ET scenario than in the CF scenario. Only energy-intensive industries may benefit from lower wholesale electricity price and their exemptions from EEG surcharge. Therefore, effects on the international competitiveness of German companies and on their exports are extremely low (Table 1).

With increasing prices, rising wages and decreasing investment dynamics the employment effects become smaller over time.

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, EWI, Prognos 2014

In the second phase, private consumption decreases compared to the CF scenario because private consumption expenditures are displaced by expenditures for the modernization of residential buildings. These expenditures are classified as building investments in the system of national accounts (Table 1).

Higher energy efficiency and ambitious renewable energy expansion lead to decreasing demand for fossil fuel imports. This results in a decline of 534 PJ and corresponds to about 3 bn EUR in avoided import costs by 2020.

In both phases, GDP and employment are absolutely higher in the ET scenario than in the CF scenario. Even the price level remains higher because of the higher EEG surcharge in the ET scenario.

5 Conclusions

The macroeconomic effects of the energy transition, as it is defined here, are positive. The results show that the investments in renewable energy and energy efficiency have a positive effect on GDP and employment, especially ex-post between 2010 and 2013. The growing EEG surcharge leads to increased electricity prices for most consumer groups except the electricity-intensive industries. As a consequence, the price index rises. In combination with decreasing investments in the electricity market from 2013 onwards, employment and GDP effects become lower over time.

The energy transition is defined narrowly translating into rather small macroeconomic impulses. A less comprehensive definition of the CT scenario or a more ambitious definition of the ET scenario may have bigger impacts on the macro-economy as well as on the energy system and emissions.

The net effects of the Energy Transition scenario compared to a scenario wherein the corresponding steps have not been implemented, describe the balance of positive and negative effects involving all the feedback effects. They are by definition substantially smaller than the so-called gross effects. In all, the macroeconomic effects of energy transition, as it is defined here, are small. The controversial public discussion and the regulatory burden indicate more significant effects.

In the field of energy efficiency, measures attributable to energy transition are truly worthwhile when considering the corresponding payback periods of the different investors groups even from a microeconomic perspective. It is necessary to distinguish a direct demand impulse for the implementation of the measure itself, long term financing costs that partly crowd out other spending, and energy savings derived from the implementation of the measure during the financing period, which lastingly release capital for other expenses.

Much more controversial is the discussion on the macroeconomic effects of the promotion of new technologies such as renewable energies in electricity or heating market or the promotion of electro mobility. The analysis shows that the significant expansion of renewable energies, especially the photovoltaic, in the short term led to an increasing demand and employment from 2010 to 2013. The costs allocated via EEG apportionment to the majority of electricity consumers that lead to the increase of electricity prices have negative effects from the macroeconomic perspective in subsequent years. Policy responded to this with EEG amendment. If the EEG apportionment will only experience a slight increase in future, the macroeconomic effects of the foreseeable additional expansion of renewable energies will be limited until 2020. Exemptions for electricity-intensive enterprises are an important reason for this.

From the microeconomic point of view, the discrepancy between the winners and losers of renewables expansion is more significant. From the residential customer's perspective, distribution effects are due to an increase of electricity prices. On the other hand, revenues derived from remunerations among other things accrued to private home owners are substantially high. From the perspective of electricity consumers who buy at the stock exchange, prices have substantially dropped over the past years.

The future development of external trade with energy transition goods depends upon several variables. To determine the opportunities that will be available for German companies in these sectors in the future, the renewable energy expansion and energy transition related costs should be compared in an overall view.

Determining the macroeconomic effects of the energy transition, which was introduced in 2010, can only build on a limited range of data up to now. On the one hand, there is a general delay of structural data of the economic statistics. A wide range of data is available only till 2011. Specific information on renewable energies and energy efficiency is not always available in official statistical classifications and partly has to be collected in research projects using different methods. Generally, the development from 2010 to 2013 has not yet been sufficiently recorded by the official statistics. For a sustainable monitoring of energy transition, more specific data need to be collected, associated and published in the future, among others to better identify the related macroeconomic effects.

What needs to be significantly improved in general is the adequate identification and recording of macroeconomic effects related to the various distribution effects of energy transition.

References

Ahlert, G., Distelkamp, M., Lutz, C., Meyer, B., Mönnig, A., Wolter, M.I. (2009): Das IAB/INFORGE-Modell. In: Schnur, P. & Zika, G. [Hrsg]: Das IAB/INFORGE-Modell. Ein sektorales makroökonometrisches Projektions- und Simulationsmodell zur Vorausschätzung des längerfristigen Arbeitskräftebedarfs. IAB-Bibliothek 318, Nürnberg, pp. 15-175.

Almon, C. (1991): The INFORUM Approach to Interindustry Modeling Economic Systems Research, 3, pp. 1-7.

Blazejczak, J., Edler, D., Schill, W.-P. (2014): Improved Energy Efficiency: Vital for Energy Transition and Stimulus for Economic Growth. DIW Economic Bulletin 4.2014.

Blazejczak, J., Diekmann, J., Edler, D., Kemfert, C., Neuhoff, K., Schill, W.-P. (2013): Energiewende erfordert hohe Investitionen. DIW Wochenbericht No. 26.2013.

BMWi, BMU (2012): First Monitoring Report „Energy of the future“, Berlin.

Eurostat (2008): Eurostat Manual of Supply, Use and Input-Output Tables.

Flues, F., Löschel, A., Pothen, F., Wölfing, N. (2012): Indikatoren für die energiepolitische Zielerreichung, Mannheim.

Frondel, M., Ritter, N., Schmidt, C. M., Vance, C. (2009): Economic impacts from the promotion of renewable energy technologies: the German experience. Ruhr economic papersNo. 156, Bochum.

Graichen, V., Gores, S., Penninger, G., Zimmer, W.,Cool, V., Schlomann, B., Fleitner, T., Strigel, A., Eichhammer, W., Ziesing, H.-J. (2011): Energieeffizienz in Zahlen. Endbericht. Im Auftrag des Bundesministeriums für Umwelt, Naturschutz und Reaktorsicherheit, Climate Change 13/2011, Dessau-Roßlau.

GWS, EWI, Prognos (2014): Gesamtwirtschaftliche Effekte der Energiewende. Studie im Auftrag des Bundesministeriums für Wirtschaft und Energie, Osnabrück, Köln, Basel.

IEA (2014): Capturing the Multiple Benefits of Energy Efficiency, Paris.

Kronenberg, T., Kuckshinrichs, W., Hansen, P. (2012): Macroeconomic Effects of the German Government's Building Rehabilitation Program. MPRA Paper No. 38815, Jülich.

Lehr, U., Nitsch, J., Kratzat, M., Lutz, C., Edler, D. (2008): Renewable energy and employment in Germany. Energy Policy 36, pp. 108-117.

Lehr, U., Lutz, C., Ulrich, P. (2014): Bestandsaufnahme und Analyse von Studien zur Schätzung von Klimaschutznutzen und -kosten. Climate Change 20/2013, Dessau-Roßlau.

Lehr, U., Lutz, C., Edler, D., O'Sullivan, M., Nienhaus, K., Nitsch, J., Breitschopf, B., Bickel, P., Ottmüller, M. (2011): Kurz- und langfristige Auswirkungen des Ausbaus der erneuerbaren Energien auf den deutschen Arbeitsmarkt, Studie im Auftrag des Bundesministeriums für Umwelt, Naturschutz und Reaktorsicherheit, Osnabrück, Stuttgart, Berlin, Februar.

Lehr, U., Lutz, C., Edler, D. (2012): Green jobs? Economic impacts of renewable energy in Germany. Energy Policy 47, pp. 358-364.

Lehr, U., Mönnig, A., Wolter, M. I., Lutz, C., Schade, W., Krail, M. (2011): Die Modelle ASTRA und PANTA RHEI zur Abschätzung gesamtwirtschaftlicher Wirkungen umweltpolitischer Instrumente - ein Vergleich. GWS Discussion Paper 11/4, Osnabrück.

Lindenberger, D., Lutz, C., Schlesinger, M. (2010):Szenarien für ein Energiekonzept der Bundesregierung. Energiewirtschaftliche Tagesfragen 60, pp. 32-35.

Lutz, C. (2011): Energy scenarios for Germany: Simulations with the model PANTA RHEI. In: Mullins, D., Viljoen, J., Leeuwner, H. (ed.): Interindustry based analysis of macroeconomic forecasting. Proceedings from the 19th INFORUM World Conference, Pretoria, pp.203-224.

Lutz, C., Lindenberger, D., Schlesinger, M., Tode, C. (2014): Energy Reference Forecast and Energy Policy Targets for Germany. Die Unternehmung 3/2014, pp. 154-163.

Lutz, C., Lehr, U., Ulrich, P. (2014): Economic Evaluation of Climate Protection Measures in Germany. International Journal of Energy Economics and Policy, 4(4), pp. 693-705.

Maier, T., Mönnig, A., Zika, G. (2015): Labour demand in Germany by industrial sector, occupational field and qualification until 2025 -model calculations using the IAB/INFORGE model. In: Economic Systems Research 27, pp. 19-42. DOI: 10.1080/09535314.2014.997678

Nagl, S., Fürsch, M., Paulus, M., Richter, J., Trüby, J., Lindenberger, D. (2011): Energy Policy Scenarios to Reach Challenging Climate Protection Targets in the German Electricity Sector until 2050. Utilities Policy 19, pp. 185-192.

O'Sullivan, M., Edler, D., Bickel, P., Lehr, U., Peter, F., Sakowski, F. (2014): Bruttobeschäftigung durch erneuerbare Energien in Deutschland im Jahr 2013 - eine erste Abschätzung. Study commissioned by the Federal Ministry for Economic Affairs and Energy, Berlin.

Prognos, EWI, GWS (2014): Entwicklung der Energiemärkte – Energiereferenzprognose. Study commissioned by the Federal Ministry of Economics and Technology (BMWi) (today: Federal Ministry for Economic Affairs and Energy), Basel, Köln, Osnabrück.

Prognos, EWI, GWS (2010): Energieszenarien für ein Energiekonzept der Bundesregierung. Study commissioned by the Federal Ministry of Economics and Technology (BMWi), Basel, Köln, Osnabrück.

Richter, Jan (2011): DIMENSION – A Dispatch and Investment Model for European Electricity markets. EWI Working Paper No. 11/03.

Ryan, L., Campbell, N. (2012): Spreading the net: the multiple benefits of energy efficiency improvements. IEA Insight Series.

Stocker, A., Großmann, A., Madlener, R., Wolter, M.I. (2011): Sustainable energy development in Austria until 2020: Insights from applying the integrated model "e3.at". Energy Policy 39, pp. 6082-6099.

Welfens, P. J., Lutz, C. (2012): Green ICT dynamics: key issues and findings for Germany. Mineral Economics 24, pp. 155–163.

West, G. R. (1995): Comparison of input-output, input-output + econometric and computable general equilibrium impact models at the regional level. Economic Systems Research 7, pp. 209–227.

Wiegert, R. & Hounsell, S. (2013): The challenge to Germany's global competitiveness in a new energy world. IHS Report Volume 1, Frankfurt am Main.