Macroeconomic effects of energy transition

Christian Lutz[1,*], Markus Flaute[1], Ulrike Lehr[1]

[1] *Gesellschaft für Wirtschaftliche Strukturforschung mbH, Osnabrück, Germany*

* *Corresponding author. Tel: +4954140933120, Fax: +4954140933110, E-mail: lutz@gws-os.com*

Abstract

In order to determine the macroeconomic impacts of the energy transition in Germany in the past and future, two model-based scenarios are compared. The Energy Transition Scenario (ETS) represents a world in which the energy transition since the year 2000 developed as it actually took place and in which the targets of the energy transition will be achieved in the future. The Counterfactual Scenario (CFS) represents a consistent alternative development that can be described as follows: Since the year 2000, no support for renewable energy and energy efficiency took place and will not take place in the future. Only those technologies will be used for energy transformation that are market-driven.

The ETS and CFS scenarios are implemented into the national macroeconomic model PANTA RHEI, combining a time series of national IO tables with national accounts and energy balances. The comparison of the macroeconomic results in the two scenarios shows consistently positive effects of the energy transition. Results have been calculated until the end of 2018 in a project for the German Ministry of Economic Affairs and Energy. The results are in the same order of magnitude and point in the same direction as our own previous studies and other related studies, both at the national and international level. In contrast to previous studies, the energy transition starts already in 2000 and ex-post results have been

calculated. Also recent developments such as the excellent macroeconomic situation, which could foster crowding out of investment in the energy transition are accounted for.

1. Introduction and background

The central aim of the Paris Agreement against climate change is to keep global temperature rise below 2° C above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5° C. Climate change mitigation that will meet the targets of the Paris Agreement requires a fundamental transformation of the global energy system.

Energy efficiency measures and the promotion of renewable energy sources are two of the main pillars of the German and EU energy concept. The German government decided in autumn 2010 on its energy concept (BMU, BMWi 2010). Key components have been 8 to 14 years lifetime expansion for nuclear power plants and the need for further measures to foster renewable energy and energy efficiency. On the demand side, insulation of buildings is the most important of a number of measures. For the electricity sector, the continued expansion of partly fluctuating renewable energy sources, such as wind and photovoltaic generation, calls for new market design. Feed-in-tariffs for renewable energy sources will remain at least until 2020, but are to be adjusted to enforce the market entry of renewables.

The central targets of the energy concept are to reduce greenhouse gas emissions by 40% by 2020, 55% by 2030, 70% by 2040 and 80-95% by 2050 (compared with 1990 levels). By 2020, the share of renewables in final energy consumption is to reach 18%, and then gradually increase further to 30% by 2030 and 60% by 2050. The share in electricity production is to reach 80% by 2050, new targets foresee a share of 65% in 2030 already.. Concerning energy efficiency, the concept aims to reduce primary energy consumption by 20% by 2020 and 50% by 2050 compared to 2008. The building renovation rate is to be doubled from currently 1% to 2%. It is planned to cut energy consumption in the transport sector by around 10% by 2020 and around 40% by 2050 (BMU, BMWi 2010). While the power sector and large industrial energy consumers take part in the EU-ETS, about half of German energy consumption stems from other sources. Energy efficiency plays a major role to reduce these emissions.

This paper results from a study on the „Macroeconomic effects and distributional issues of energy transition" (Lutz et al. 2018), commissioned by the Federal Ministry for Economic Affairs and Energy (BMWi). In order to determine the macroeconomic impacts of the energy transition in Germany in the past and future, two model-based scenarios are compared. The Energy Transition Scenario (ETS) represents a world in which the energy transition since the year 2000 developed as it actually took place and in which the targets of the energy transition will be achieved in the future. The Counterfactual Scenario (CFS) represents a consistent alternative development that can be described as follows: Since the year 2000, no support for renewable energy and energy efficiency took place and will not take place in the future. Only those technologies will be used for energy transformation that are market-driven. To measure the socio-economic impacts of the energy transition, the two scenarios ETS and CFS are implemented in the macroeconomic model PANTA RHEI.

In Lutz & Breitschopf (2016), international studies on the economic effects of energy system transformation have already been compared. The macroeconomic effects of the energy system transformation are unanimously positive in the studies. A study for DG Energy on the macroeconomic effects of additional energy efficiency measures has been published in the meantime. According to Pollitt et al. (2017), a macroeconometric model shows clearly positive effects of energy efficiency measures in the EU. If energy efficiency were to be increased by 40% by 2030, the GDP of the EU would be a good 4% higher than in the reference period if no crowding out were to occur. For Germany alone, the GDP effect is even higher at 5.9%. Assuming partial crowding out, the GDP effect at EU level would be

2.2%. In percentage terms, the employment effects are almost half as high as the GDP effects, where employment in Germany reacts below average to a high GDP compared to the EU. With lower efficiency targets, the positive GDP effects are also lower, and the importance of crowding out assumptions is significantly lower with weaker efficiency targets. The effects for Germany in the study are above-average overall. In a CGE model, on the other hand, the effects on GDP are much smaller and, depending on the assumptions, sometimes negative. In this case, too, the results for Germany are above the EU average, i.e. they are more positive (E3MELab 2016). The EU Commission has described the scenario showing positive macroeconomic results in the CGE model as the more realistic variant in the Impact Assessment (EC 2016, S 51f). The alternative variant is based on the assumption that companies and households must fully finance efficiency investments because they have no means of loan financing future energy savings. The IMF (2016) and OECD (2017) also see the global transformation of energy systems as positive from an overall economic perspective. Investments in climate protection can help to raise the growth path, especially if they are combined with appropriate structural reforms. According to OECD calculations, GDP in the G20 countries could be 2.8% higher by 2050 than without climate protection.

For Germany, the impact assessment of the national climate plan (Öko-Institut et al. 2019) finds positive economic effects in terms of GDP in a range of 1.5% to 1.6% in the scenario, that reaches the climate mitigation targets compared to the reference in 2030.

The paper is organized as follows: In section 2 the methodology to measure costs and benefits of climate mitigation measures are described. The macro-econometric input-output model PANTA RHEI, which is applied to compare costs and benefits of scenarios ETS and CFS in section 5, is described in section 3. In section 4 the scenarios are introduced. In Section 6 results are briefly summarized and some conclusions drawn.

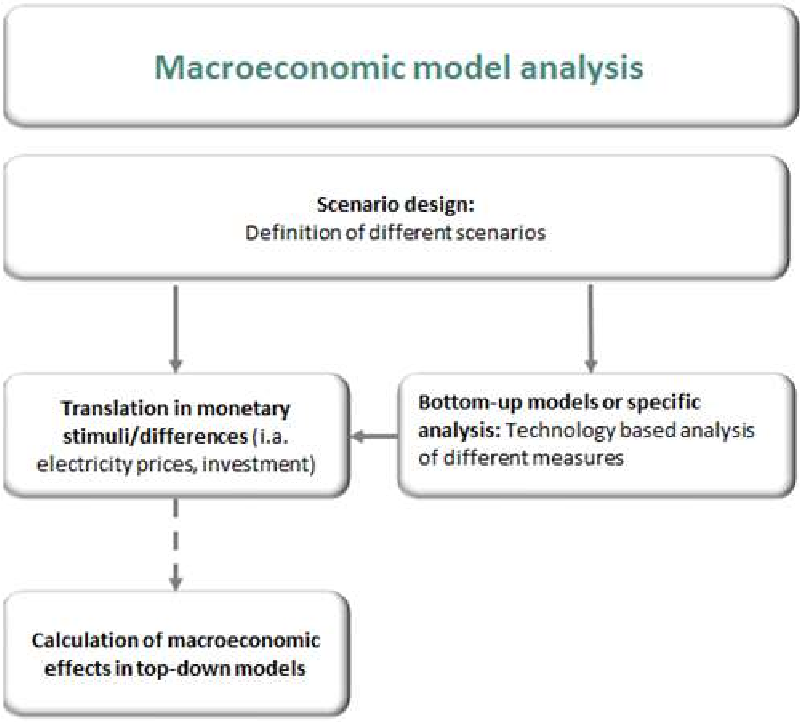
2. Methodology

To determine the macroeconomic effects of the energy transition a macroeconomic model analysis can illustrate feedbacks between the energy system and the overall economy and determine net effects at the macroeconomic and sectoral levels. Scenario analysis is the established technique to evaluate the effects of a political instrument or a bundle of instruments such as the energy transition. Economic quantities from a scenario, which includes all the measures, are compared with the results of a scenario without the measures – the so-called counterfactual. The comparison shows in which scenario the economic performance will be better. Typical indicators are GDP, both level and growth rates, employment, consumption, the trade balance and others.

Figure 1 depicts the different steps of the impact assessment. The scenarios describe possible specifications of the energy system for Germany since the year 2000. Bottom-up models help to translate the scenarios into a set of monetary stimuli. Investment in energy efficiency or renewable energy technologies, price changes due to different heat and power generation costs or savings from reduced energy costs due to increased efficiency are the monetary effects of a change in the energy system. These monetary stimuli trigger many effects in the overall economy: relative price changes induce behavioral changes, investment leads to additional employment and demand for the respective goods in the short run and will increase depreciation in the longer term, energy savings shift demand to other goods than energy.

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.

Figure 1: Macroeconomic model impact assessment



Source: Lutz et al. 2018

The next section briefly explores the modelling tool and explains the relevant links. In section 4 the scenarios are described and the main drivers for each of the two scenarios explained.

3. Model PANTA RHEI

The national economy-energy-environment model PANTA RHEI is an environmentally extended version of the econometric simulation and forecasting model INFORGE for Germany (Ahlert et al., 2009, Zika et al. 2018). A detailed description of the economic part of the model is presented in Maier et al. (2015), which builds on the INFORUM philosophy

(Amon (1991). For details of the complete model see Lutz (2011) and Lutz et al. (2005). 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). Applications include an evaluation of employment impacts of renewable energy promotion (Lehr et al., 2012), socio-economic impacts of the German energy transition (Lutz et al. 2018, Lehr et al. 2018, Lutz, Lehr 2016), and impacts of the transition to a green economy (Lutz et al. 2017).

The behavioral equations reflect bounded rationality rather than optimizing behavior of agents. All parameters are estimated econometrically from time series data (1991 – 2016). Producer prices are the result of mark-up calculations of firms. Output decisions follow observable historic developments, including observed inefficiencies rather than optimal choices. The use of econometrically estimated equations means that agents have only myopic expectations. They follow routines developed in the past. This implies in contrast to optimization models that markets will not necessarily be in an optimum and non-market (energy) policy interventions can have positive economic impacts.

The model is empirically evaluated: The parameters of the structural equations are econometrically estimated. In the model-specification stage various sets of competing theoretical hypotheses are empirically tested. As the resulting structure is characterized by highly nonlinear and interdependent dynamics the economic core of the model has furthermore been tested in dynamic ex-post simulations. The model is solved by an iterative procedure year by year.

Structural equations are modeled on the 63 sector level (according to the European 2 digit NACE classification of economic activities) of the input-output accounting framework of the official system of national accounts (SNA) and the corresponding macro variables are then endogenously calculated by explicit aggregation. In that sense the model has a bottom-up structure. The input-output part is consistently integrated into the SNA accounts, which fully reflect the circular flow of generation, distribution, redistribution and use of income.

The core of PANTA RHEI is the economic module, which calculates final demand (consumption, investment, exports) and intermediate demand (domestic and imported) for goods, capital stocks, and employment, wages, unit costs and producer as well as consumer prices in deep disaggregation of 63 industries. The disaggregated system also calculates taxes on goods and taxes on production. The corresponding equations are integrated into the balance equations of the input-output system.

Another important outcome of the macro SNA system is net savings and governmental debt as its stock. Both are important indicators for the evaluation of policies. The demand side of the labor market is modeled in for 63 industries. Average hourly wages are explained using Philips curve specifications. The aggregate labor supply is driven by demographic developments.

The energy module describes the interrelations between economic developments, energy consumption and related emissions. Economic activity such as gross production of industries or final consumer demand influence respective energy demand. Vice versa, the expenditures for energy consumption have a direct influence on economic variables, as they represent demand and costs.

The energy module contains the full energy balance with primary energy input, transformation and final energy consumption for 20 energy consumption sectors, 27 fossil energy carriers and the satellite balance for renewable energy. In total, the balances divide energy consumption into 30 energy carriers. Prices, also in Euros per energy unit, are modeled for different energy users such as industry, services and private households for all energy carriers. The energy module is fully integrated into the economic part of the model.

Final energy consumption of industries is explained by sector output, the relation of the aggregate energy price – an average of the different carrier prices weighted with their shares in the energy consumption of that sector – and the sector price and time trends, which mirror exogenous technological progress. For services, the number of employees turned out to be a better proxy for economic activity than gross output. Average temperatures also play a role for the energy consumption of the service sector. For private households, consumption by purpose as heating or by fuels is already calculated in the economic part of the model in monetary terms. Additional information can be taken from stock models for transport and heating from the specific modules, as only new investments in cars, houses or appliances, or expensive insulation measures will gradually change average efficiency parameters over time.

Final demand of each energy carrier for industries can be calculated by definition, multiplying the share of the carrier with overall final energy demand of the sector. For the shares, the influence of relative prices, i.e. the price of the energy carrier in relation to the weighted price of all energy inputs of the sector, and of time trends are econometrically tested.

Energy carrier prices depend on exogenous world market prices for coal, oil and gas and specific other price components such as tax rates and margins. For electricity different cost components such as the assignment of the feed-in-tariff for electricity are explicitly modeled. For services, households and transport specific prices are calculated, as for example tax rates partly differ between end users.

For energy-related carbon emissions, fix carbon emission factors from the German reporting to the United Nations Framework Convention on Climate Change (UNFCCC) are applied.

Multiplication with final energy demand gives sector and energy carrier specific emissions. All detailed information in the energy balance for 30 energy carriers is consistently aggregated and linked to the corresponding four industries of the IO table.

4. Scenarios and results of bottom-up modelling

In order to determine the macroeconomic impacts of the energy transition in the past and future, two model-based scenarios are compared (Lutz et al. 2018): The Energy Transition Scenario (ETS) and the Counterfactual Scenario (CFS). The starting points of a scenario are technology or process-related changes that are triggered by the implementation of individual measures or respective bundles of measures. On the one hand, they include investment differences including differences in the costs of operation and maintenance. On the other hand, energy consumption and thus energy costs differ between the scenarios, which can be related to changes in entire submarkets.

Specific bottom-up models are used to calculate these changes, which reflect the technologies behind the measures and the application of the technologies in detail. Subsequently, the results of all the measures and different developments that have to be considered are implemented into the macroeconomic model. The macroeconomic effects, in particular on GDP, employment and prices, are determined using the macroeconometric model PANTA RHEI. The bottom-up effects are calculated using the model system of Prognos, which considers energy transformation (especially the electricity market) and energy demand separately for individual sectors. The interfaces between the two models are energy consumption, differences in investments and different electricity prices in both scenarios. Harmonized assumptions on framework data, policy and technical developments form the different scenarios that are described in detail in Lutz et al. (2018).

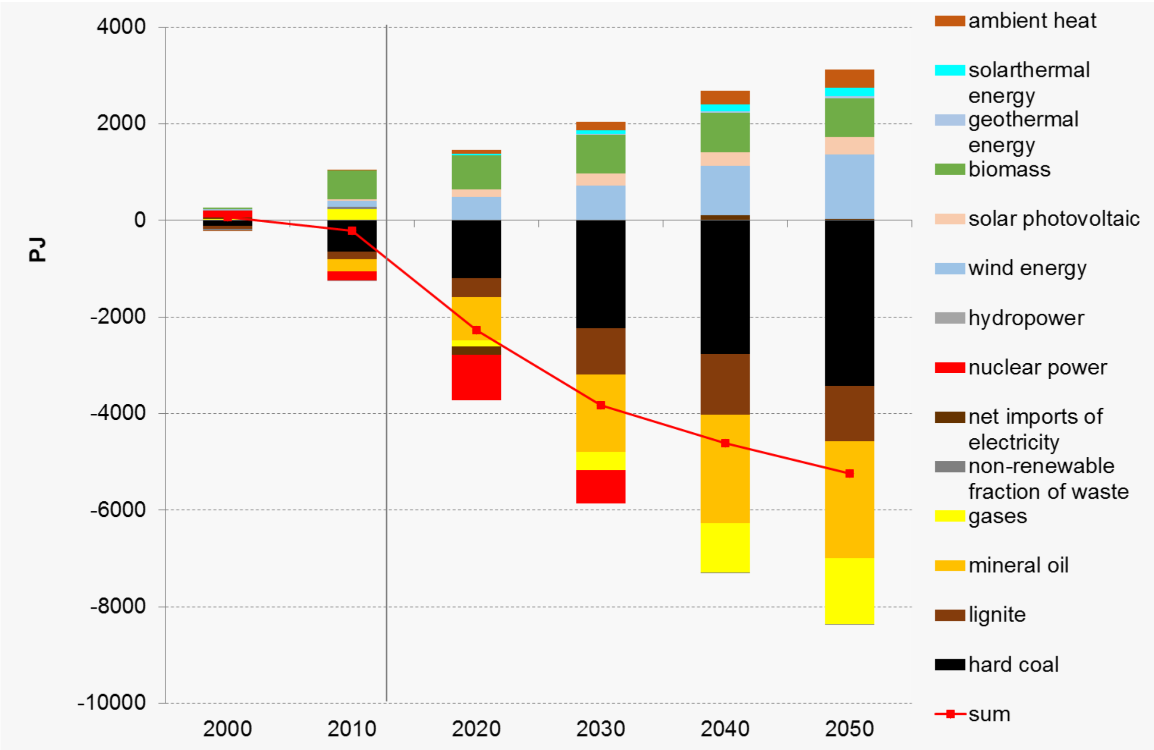
The Energy Transition Scenario (ETS) is based ex post (2000–2014) on the actual values, the variables of energy consumption, prices and investments in the energy system. The development of the years 2015 to 2050 is interpreted as the realization of energy transition. The ETS has the character of a target scenario in which the long-term reduction targets for greenhouse gases are achieved. The Counterfactual Scenario (CFS) describes an alternative development in which the path of energy transition is not followed from the year 2000 onwards.

The CFS is used to analyse the interdependency effects of the energy transition. By considering the differences between ETS and CFS, the effects of the energy transition completed so far in the ex-post period (2000–2014) and the foreseeable effects of the energy transition ex ante (2015–2050) can be shown.

The two scenarios are defined for the electricity market and energy demand. The definition of a scenario has a major influence on the model results. Their plausibility is therefore important for the acceptance of the results. For this reason, the scenarios were defined in consultation with the client and the scientific advisory board of the project.

Figure 2 shows the differences between the two scenarios for primary energy supply. The overall energy supply is significantly lower in ETS due to the higher energy efficiency. The share of renewable energy is rising strongly, while the use of fossil fuels is much lower.

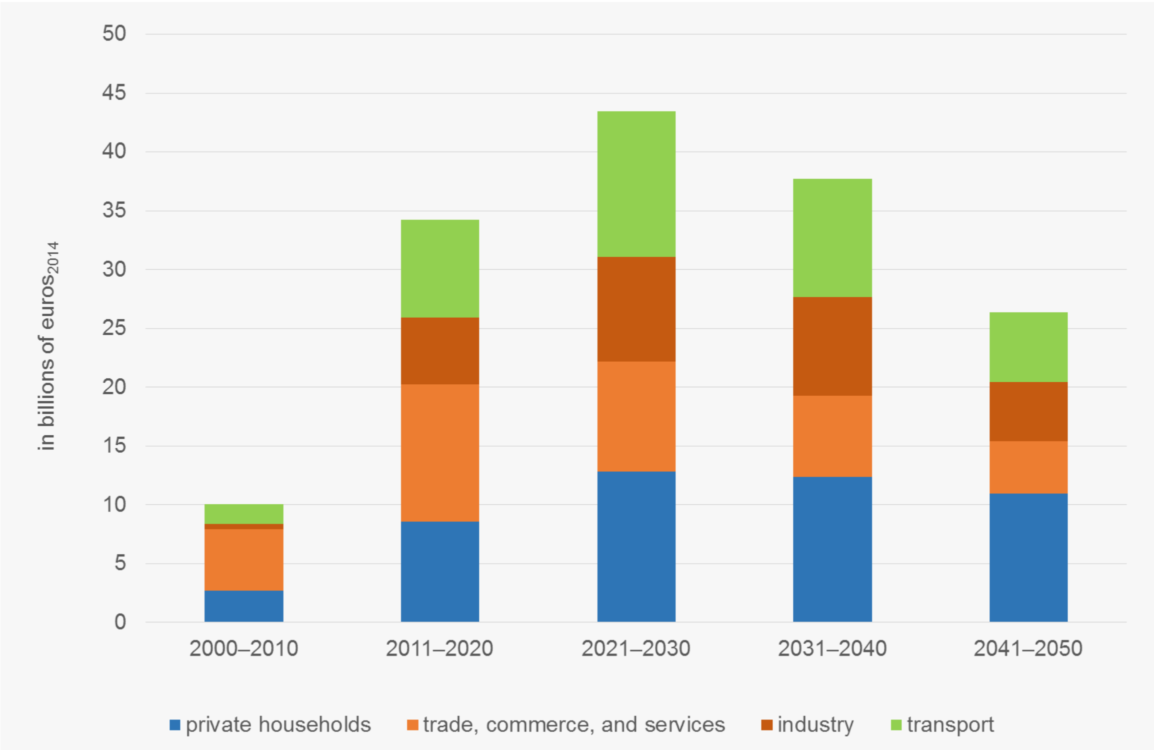
Figure 2: Difference in primary energy supply between ETS and CFS, by energy sources, 2000–2050, in PJ



Source: Prognos

Figure 3 below shows the key differences in investments between the energy transition scenario and the counterfactual scenario in the four end-use sectors. 32 % of these additional investments are made in private households, 25 % in the sector of trade, commerce, and services, 19 % in industry and 24% in transport sector. About 30 % of the additional investments are accounted for the building envelope (building insulation) and 13 % in space heating (including water heater). Investments also vary in the electricity sector (see Lutz et al. 2018).

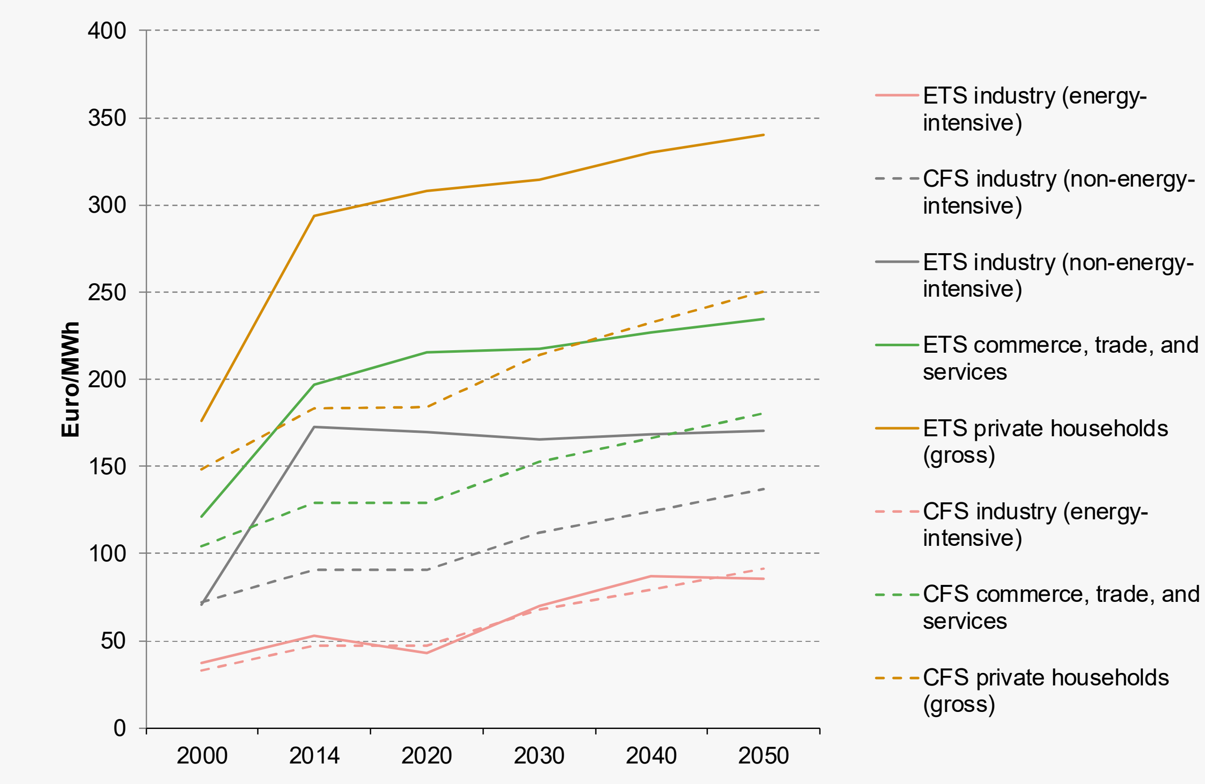
Figure 3: Annual additional investment in the end-use sectors in ETS compared to CFS, in billion euros, mean values per decade, by sectors (real prices 2014)



Source: Prognos

Under these assumptions, electricity prices for households in ETS increase from EUR 176/MWh to EUR 294/MWh in the ex-post period from 2000–2014 (Figure 4). From 2015 to 2050, the price increases only slightly compared to the past to 340 EUR/MWh (real prices). The flattening increase is due, among other things, to the fact that renewable technologies are becoming cheaper and the renewable energy levy (EEG) is becoming smaller and smaller. The electricity price for households in the CFS will also rise in the period 2000–2050 due to increasing energy prices for natural gas and hard coal. At 250 EUR/MWh, the price in 2050 is about 35 % lower than in the ETS. Value-added tax is not included in the prices in the sector of trade, commerce, and services.

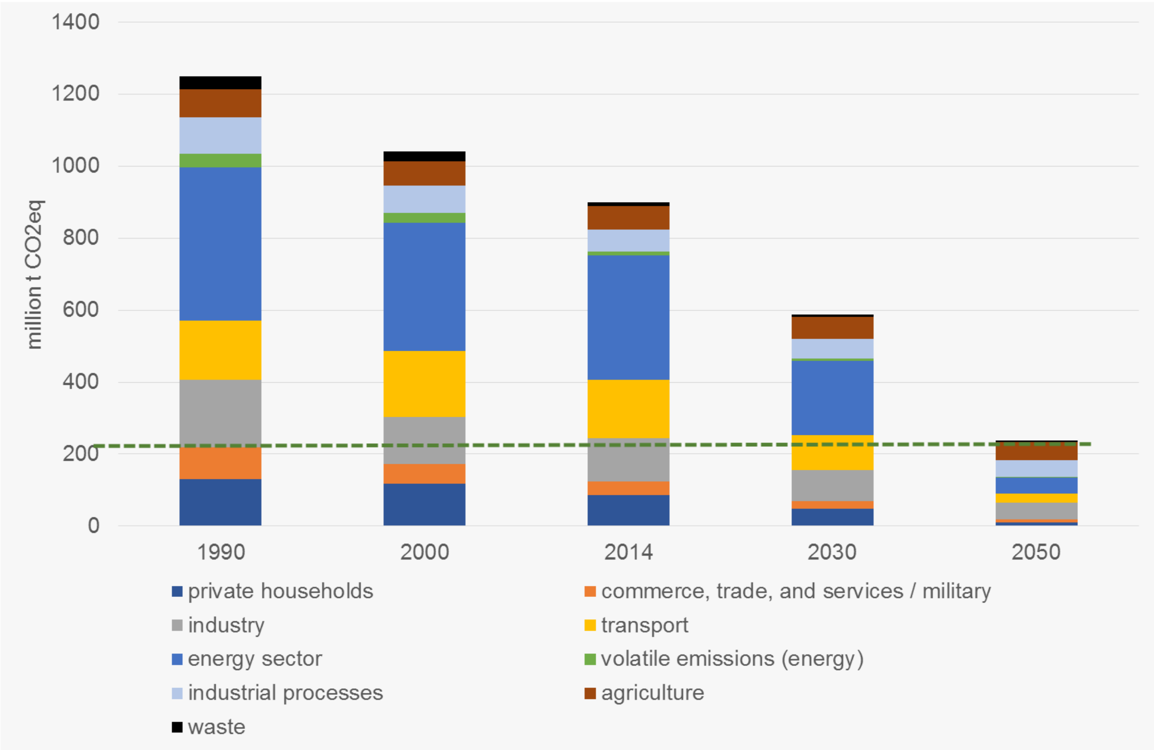
Figure 4: Development of electricity prices in ETS and CFS by consumer groups, 2000–2050, in euro/MWh (real prices 2014)



Source: Prognos

In the energy transition scenario, GHG emissions will be reduced to 238 million t CO_2eq by 2050 (excluding LULUCF and international transport). Compared to 1990, this corresponds to a reduction of 81 % (Figure 5). So the policy target of a GHG reduction of 80 to 95% until 2050 is just reached.

Figure 5: Development of GHG emissions in ETS by sectors, in million t CO_2eq, and lower policy target in 2050 (green dotted line)



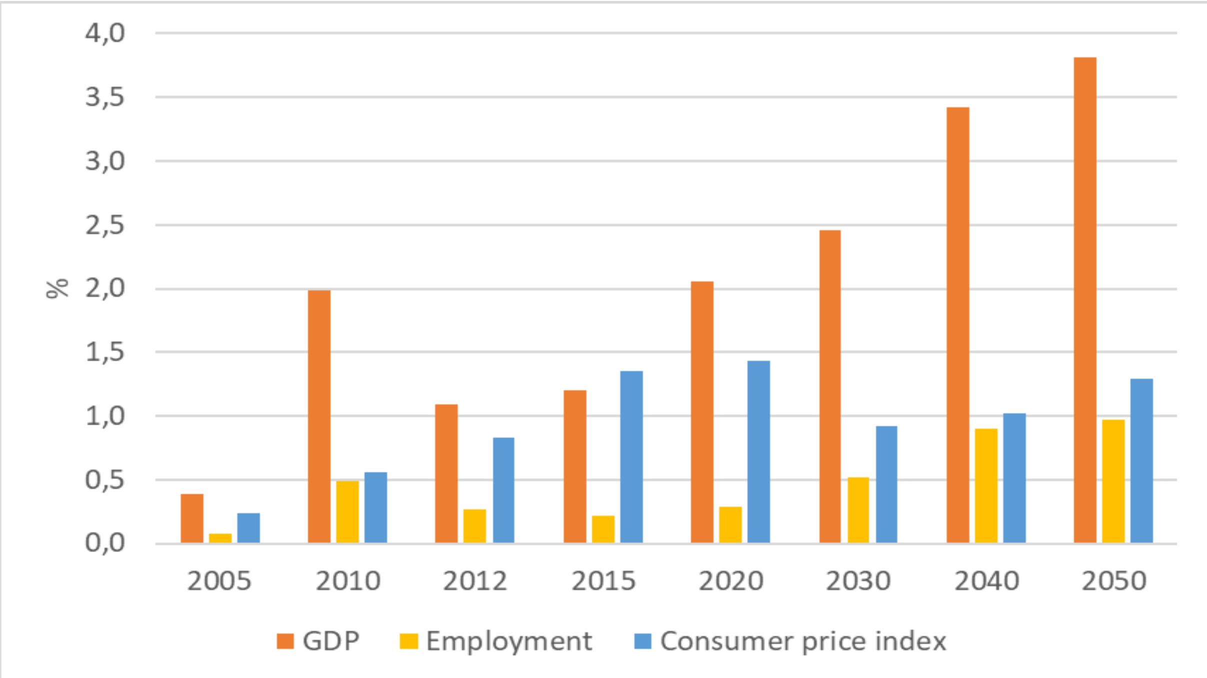
Source: Prognos

5. Macroeconomic effects

The ETS and CFS scenarios briefly described above are implemented into the macroeconomic model PANTA RHEI. The basic approach for determining the macroeconomic effects of the energy transition is to conduct comprehensive macroeconomic model analyses that show feedback between the energy system and the macro economy and can determine net effects at the macroeconomic and sector level. The model is fully interdependent and solved in annual steps, i. e. the effects of a measure on all model variables are recorded simultaneously and no effects are neglected.

Compared to a counterfactual development without energy transition since the year 2000, the energy transition leads to positive macroeconomic effects. The price-adjusted gross domestic product is higher due to the energy transition and the effects increase over the years (Figure 6). In the year 2010, the high investment in photovoltaic (PV) installations in particular can be seen. In the economic crisis of 2009, the energy transition stabilized the economic development. With the end of the PV boom the positive macroeconomic effect has also decreased in the following years, but will remain clearly positive throughout at over 1 %. In the long term, the macroeconomic effects triggered by the energy transition will continue to increase, reaching a level of almost 4 % by 2050.

Figure 6: Gross domestic product, employment and consumer price index – percentage deviation between ETS and CFS



The main reasons for the positive effect on GDP are the consistently higher total investment, decreasing differences in electricity prices for small-scale users after 2020, the far-reaching exemption of the energy-intensive industry from the EEG-levy and thus small differences in electricity prices compared to the CFS. Growing final energy savings due to higher energy efficiency and thus also falling expenditure on energy imports also contribute. In the long term, energy will be substituted by capital and labour (energy efficiency) and the supply will stem more from domestic sources with a higher employment intensity (renewable energy). In the long term, these permanent positive effects of the energy transition will determine the macroeconomic effects.

Table 1: Gross domestic product, and components in prices of 2010 – percentage deviation between ETS and CFS

	2005	2010	2012	2015	2020	2030	2040	2050
GDP	0,38	1,99	1,10	1,21	2,05	2,45	3,42	3,81
Private cons.	0,38	1,23	0,36	0,43	1,76	2,45	3,58	3,77
Public cons.	-0,01	-0,07	-0,07	-0,04	1,02	2,07	4,00	5,99
Equipment inv.	2,99	16,60	11,02	13,15	8,30	5,50	5,68	4,83
Construction inv.	-0,59	5,09	3,44	2,74	4,93	4,70	4,66	3,27
Exports	0,07	0,18	0,17	0,28	-0,18	-0,24	0,03	0,48
Imports	0,32	2,23	1,23	1,58	0,49	-0,16	0,13	0,43

The comparison of the macroeconomic results in the two scenarios ETS and CFS in the PANTA RHEI model shows consistently positive effects of the energy transition on the labour market. Employment is about 1 % higher. Real wages are also rising. No additional exports of goods for the energy transition are considered, which are likely to result if other countries adapt themselves to German policy and corresponding technologies.

The results depend on a large number of assumptions and model relations. Sensitivity analyses in Lutz et al. (2018) offer the opportunity to examine the significance of sensitive variables on macroeconomic effects and to compare model characteristics with other analyses. The breakdown of the ETS into input data from the bottom-up models for the electricity market and for the field of final demand shows that the macroeconomic effects of the energy transition on the electricity market are much smaller than the effects triggered by the measures on the final demand side. The sensitivity analyses with restrictions on the labour market and on the financing of additional investments show that these aspects should also be observed more closely in the future, especially with regard to the very good economic situation in Germany.

6. Summary and conclusions

In order to determine the macroeconomic impacts of the energy transition in Germany in the past and future, two model-based scenarios are compared. The Energy Transition Scenario (ETS) represents a world in which the energy transition since the year 2000 developed as it actually took place and in which the targets of the energy transition will be achieved in the future. The Counterfactual Scenario (CFS) represents a consistent alternative development that can be described as follows: Since the year 2000, no support for renewable energy and energy efficiency took place and will not take place in the future. Only those technologies will be used for energy transformation that are market-driven.

The ETS and CFS scenarios are implemented into the national macroeconomic model PANTA RHEI. The comparison of the macroeconomic results in the two scenarios shows consistently positive effects of the energy transition. GDP and employment will be higher due to the energy transition. The effect is driven by higher investment and lower energy imports. At the same time smart policy design keeps energy prices close to their levels in the CTS scenario.

The results are in the same order of magnitude and point in the same direction as our own previous studies and other related studies, both at the national and international level. However, it should be taken into consideration that these studies are optimistic with regard to the efficient governance and to the international cooperation in climate mitigation. The achievement of policy targets is expected without significant distortions with the exception of mining and energy supply, among other things because no concrete instrumentation of the energy transition is depicted.

On the other hand, the energy transition offers benefits that are not accounted for in the national accounts and the economic model (IEA 2014). It offers additional export opportunities for the German industry, improves energy security by reducing energy imports and it reduces other local air emissions such as nitrogen oxides and particles from transport.

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