Impact of renewable energy on jobs and growth

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Abstract

The objective of the contribution is twofold. Firstly, it provides a systematic analysis of the recent development of renewable energy and its impact on the often neglected sectors of public administration and research facilities. Secondly, it analyses the overall net-impacts of renewable energy on the labor market.

These objectives are pursued using scenario techniques and a macro-econometric model (PANTA RHEI). To be able to model the total effects of a shift from a solely fossil fuel based economy to significant shares of renewable energy, we have to develop two scenarios. A reference scenario without any support for renewable energy in the future and also in the past has to be specified. The development of renewable energy technologies is "frozen" at the point in time, when policy support in Germany started. Only economically feasible technologies will develop under such a scenario. Obviously, fossil technologies will have to be employed to a larger extend instead. This scenario will be the counterpart of a scenario with significant shares of the relevant renewable energy technologies and the tax breaks and tariffs for their support. The macro-econometric model is then applied to calculate net economic effects on growth, employment, public budgets as well as on the environment in terms of emissions.

The contribution studies these effects for Germany. Due to the heavy political support for renewable energy applications and the market size, relevant conclusions for other European countries follow. It turns out that the overall effect of a strong promotion of renewable energy led to positive economic results. Growth and employment effects can only be maintained under certain continuity assumptions.

Keywords: Renewable Energy, Input-output analysis, employment, net economic effects.

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Introduction

Energy supply has been an issue on the political agenda for the last years and will continue to be. The public debate on global change and its impact on the global economy, the scarcity of resources and the growing dependence of some countries on imported oil and gas and on the goodwill of the resource owners have spurred the interest in domestic, clean and safe energy supply. While some years ago renewable energy sources were considered clean enough, but too expensive, the recent boom of RES technology in some countries led to an interest in the economic benefits of these technologies. Germany has been among the early movers in terms of RES support through legislation and thus far seems to have been able to capture the early mover advantages on international markets. Earlier studies have shown the economic impacts of an increase in RES compared to the current business as usual case. But how much did the overall support of RES cost and what were the benefits? How much employment is generated not only in the production sector, but also in research and in the public sector? How do increasing production capacities affect the employment in the sectors that provide the machinery for this capacity increase?

The following contribution tries to shed some light on these questions. Methodological the paper relies heavily on an earlier approach. It combines an empirical based input-output vector for the RES industries with an econometric macro model (net effects) and uses scenario techniques for the future development. It therefore can be considered as an update and an extension to earlier work (cf. BMU 2006, Lehr et al. 2008).

The remainder of this contribution is organized as follows. This introduction is followed by a brief overview of the modeling approach and the scenarios used. Chapter 3 provides insight in the gross employment effects and considers for the first time also the employment in the research sector, the public sector and the equipment industry. Chapter 4 calculates net economic effects and chapter 5 concludes and gives an outlook on ongoing research.

The Modeling approach

To examine these effects our analysis consists of three steps: Firstly, a detailed picture of the current status of the industries involved in the production of systems for the use of renewable energy sources (RES) is used. Secondly, we present scenarios for the future national and international development of energy from renewable sources, including price paths. And thirdly, the results of the first two steps are fed into the macro-econometric model PANTA RHEI and (net) economic effects are analyzed.

Input-output analysis is typically used to answer questions about the indirect and direct employment effects of an industry. Theoretically, the sectors in the input-output tables are defined by homogeneous products, homogeneous production technologies and unique production. Though this theoretical definition obviously has to be relaxed due to data restrictions, the structural differences between the new technologies and systems for the use of renewable energy sources and the fossil fuel technologies seem to call for the definition of an own vector. Especially, the technologies for the use of solar, geothermal and wind energy require new and different input combinations from different sectors compared to the respective sectors for the fossil fuel industries in the current system[2].

[2] The current input-output system for Germany is laid down in Fachserie 18, Reihe 2, Input-Output-Rechnung, German Statistical Bureau. It mostly follows the European System of Accounts, but differs with respect to the treatment of sector immanent inputs. Disaggregation is for 59 or 71 sectors.

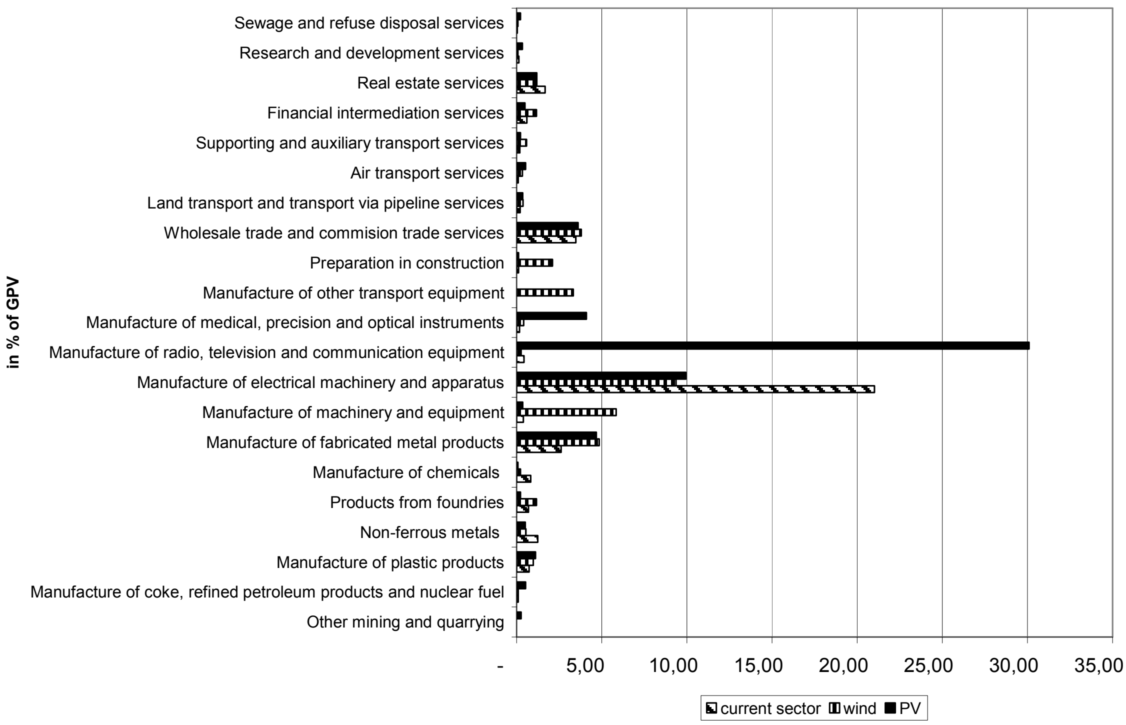
Input-output tables provide detailed insights in the flows of goods and services and the interdependence of the economy of a country and with the rest of the world. The input-output tables of the German Statistical Bureau consist of 59, production sectors. They find use in a variety of economic analyses, especially for disaggregated modeling activities and can be combined with other databases and satellite systems, for instance with the environmental accounting system.

Input-output tables are closed accounting schemes where the identity of the sum of inputs and the sum of outputs has to hold in each sector. This consistency check has to also hold for the newly created sector “Production of systems for the use of RES”. If the original structure is expanded consistently one can derive a lot of structural information on the flow of goods and services, on intermediary effects and on induced and indirect employment.

In the input-output framework the structure of a new sector is defined by the amounts obtained from all other sectors, the amounts delivered to all other sectors, imports to and added value from the new sector. Inputs to the new sector go into a new additional column to the table, outputs from the new sector into a new row.

This new vector is created to show the interdependence of the production of systems and components for the use of renewable energy with the economy in a systematic and fact based way. Statistical information on RES is disaggregated by source; therefore the new input-output vector has been constructed for each source and aggregated to the sector thereafter. The different sources considered are: wind, hydro, solarthermal heat, photovoltaic, geothermal biomass and biogas.

Figure 1: Cost structure fort he production of systems for the use of different energy types (calculations of the DIW)



Each of these subsections has a rather high degree of homogeneity, although even within each a variety of technologies and products are involved. Figure 1 shows examples of the cost structures in percent of gross production value derived for the production of systems for the use of wind energy and photovoltaic systems in comparison to systems for the use of fossils. The difference in structures shows the importance of creating a new vector in the system, since the intermediary inputs used come from very different sectors.

Scenarios provide a structured description of possible future development paths, depending on current and future framework conditions. In contrast to earlier work on the overall economic effects of increased shares of renewable energy in Germany (Lehr et al. 2008), this study tries to model the net effects compared not to a BAU (business as usual) scenario, but the *overall* economic effects of the increasing shares of RES as such. Therefore, the reference scenario describes a development without any support of renewable energy.

The analysis is based upon the following set of scenarios:

- a German *target oriented scenario* (TOS) that comes close to reach the national target of a 40% (2030) or 80% CO_2 reduction by 2050, respectively (BMU04, Leit06, BMU05)
- a reference scenario that describes a “frozen” state, where no support of RES took place and which derives from the prolonged development up to 1995,
- international scenarios (*reference* and *dynamic current policy*) (IEA-REF04, EREC-DCP04) and
- the dominant scenario for the development of exports from Lehr et al. 2008 and BMU 2006.

The new reference scenario responds to the public discussion of the results of BMU 2006. In this discussion, the quantification of the overall effects of RES on employment and therefore the overall effects of the support of RES has been demanded. Since economic quantities typically are given as the difference between the quantity under one set of framework conditions compared to another, a reference scenario without any external support of RES , has to be constructed. This, however, has to be rather fictitious and speculative. To be able to yield the desired quantification, increases in RES can only occur as long they are not connected to additional costs, since no external support is given.

The base year of the development is 1995 since the substantial growth of RES in Germany started at this point in time. Energy supply in the “ZERO”-scenario solely relies on fossil fuels. The economic indicators, the path for energy demand and the phasing out of nuclear are the same as in BMU 2006. Existing electricity generation from wind and biomass in 1995 (2 TWh/a) contribute until 1025 reflecting their life time. For 1995 there is a base amount of RES of 260 PJ RES primary energy (including hydro). Table 1 gives an overview of the electricity generation in the ZERO-scenario.

Table 1: Total gross electricty generation ZERO scenario1993 til 2050 (TWh/a)

year	1993	1996	2000	2010	2020	2030	2040	2050
Power plants	**436,2**	**458,7**	**477,0**	**435**	**356**	**301**	**267**	**247**
-hard coal.	123,7	134,8	139,4	138	125	118	111	101
-lignite	139,5	136,2	141,0	143	133	132	120	110
-oil	2,0	3,0	4,0	3	2	2	2	1
-gas	17,5	23,1	23,0	23	65	49	35	36
-nuclear	153,5	161,6	169,6	127	31	0	0	0
CHP (TWh/a)	**69,0**	**72,0**	**74,5**	**106**	**144**	**172**	**182**	**181**
-hard coal	34,1	30,9	26,0	29	37	39	38	37
-lignite	8,0	10,0	12,0	12	12	8	5	5
-oil	7,0	6,0	4,0	6	7	7	7	7
-gas	16,4	21,6	29,0	56	85	115	130	130
-waste	3,0	3,0	3,0	3	3	3	3	3
-biomass	0,5	0,5	0,5	0,5	0,3	0	0	0
RES (w/o biomass)	**19,7**	**19,7**	**19,7**	**20**	**19**	**19**	**19**	**19**
-hydro	19,0	19,0	19,0	19	19	19	19	19
-wind	0,7	0,7	0,7	0,5	0,3	0	0	0
-photovoltaic	0,0	0,0	0,0	0	0	0	0	0
-geothermal	0,0	0,0	0,0	0	0	0	0	0
-import SOT	0,0	0,0	0,0	0	0	0	0	0
-import other RES	0,0	0,0	0,0	0	0	0	0	0
Total	**524,9**	**550,4**	**571,2**	**560**	**520**	**492**	**468**	**447**

To ensure comparability to earlier studies the target oriented scenario (TOS) of BMU 2006 is used for comparison. A problem is the most recent development in 2006 and 2007, which is underestimated in TOS. Instead of implementing a new TOS scenario, the underestimation until 2010 is accepted and the original scenario is used. Table 2 shows a comparison of the two developments.

Table 2: Differences of primary energy consumption and CO_2-emissions between the ZERO and the TOS scenario

in PJ/a	2000	2010	2020	2030	2040	2050
RES	-136	-774	-1401	-2120	-2713	-3180
Fossil	223	1022	1804	2900	3602	3912
- Oil	88	304	449	675	994	1304
- Coal	92	535	830	1555	1963	1963
- Gas	43	183	525	670	645	645
CO_2-Emissions Mio. t CO_2/a	23	87	148	246	307	332

The table gives the central structural data for primary energy consumption in the two scenarios. Due to the statistical method used for RES that calculates RES without transfer losses the amount of fossil primary energy is higher in the ZERO scenario than the mere replacement. The structure is given by the age structure of the power plants and bio fuels are replaced by oil. The additional CO_2-emissions are lower than the CO2 reductions published by the German ministry of the environment since hydro and a base supply of biomass are also included in the ZERO scenario. The total development of emissions stays with 780 Mio. t/a in 2020 and 570 Mio. t/a in 2050 a lot higher than the necessary reductions for a sustainable climate protection strategy.

The ZERO scenario includes the necessary investment in new fossil power plants (table 3). The ZERO scenario makes investment of 70 billion € necessary until 2030, approx. 30 billion more than in the TOS. The investment in RES is replaced predominantly by investment into fossil electricity generating plants, mainly using coal.

Table 3: Total investment for ZERO and comparison to TOS

Period	PP	CHP	Total	Add. Comp. TOS.
1995 – 2000	2.478	557	3.034	3.034
2001 – 2010	9.336	7.513	16.849	8.298
2011 – 2020	15.042	16.078	31.120	9.718
2021 – 2030	9.716	9.942	19.658	9.019
Total 1995 – 2030	**36.572**	**34.090**	**70.662**	**30.069**

Globally, the primary energy consumption in 2030 will be between 690 EJ (IEA-REF) and 651 EJ (EREC-DCP). With a 13.5% share of RES in the reference scenario there and a 22%

share in the dynamic current policy scenario, the absolute amount of RES is 1.5 times higher in the DCP scenario. The increases in electricity production from RES after 2010 largely base on wind, solarthermal and photovoltaic power generation and to a lesser extend on power from biomass and waste. The largest increases in the heat generation are due to biomass and solarthermal applications.

The German industry currently holds large market shares in several of the technologies needed for this increase. This is partly due to the circumstance that the German market makes for a large part of the international market for systems for the use of RES. With a worldwide increasing demand for these systems, the German market will relatively loose importance for the domestic producers and exports will gain importance. Currently, Germany shows some characteristics of a lead market for RES technologies, which may favor a strong future position on the international markets. 60% of the systems for the use of wind energy sold in 2006, were "made in Germany" as well as almost 30% of the photovoltaic systems and 14% of systems for the use of biomass. Generally, we assume the shares in the electricity production to be higher than in the heat sector. Since hydro energy does not expand greatly in the scenarios considered, the situation of the German industry in this segment also is not expected to change a lot and will stay around 3% of the world market. Wind energy systems will decrease in share on the heavily expanding market but still increase in volume. The production for the domestic market and for the export market, however, will be different, low tech products or products that take a lot of transportation effort will be produced close to the installation of a wind park, whereas Germany can try to maintain its competitive advantages with high-tech components. Table shows the range of export developments which are used in the modeling experiments. The different development paths enable us to test for the sensitivity of the model towards the respective export development and test our results.

Table 4: Global market shares of the German RES industry (in % of market based on EREC-DCP)

	2004	2010	2020	
Electricity				
Hydro	3.45	3.00	2.40	2.00
Wind	40.07	30.00	20.00	12.00
Photovoltaic	28.71	18.00	10.00	7.00
Geothermal	0.19	2.60	4.70	5.00
Biomass[1]	14.02	10.00	7.00	4.50
CSP	0.00	10.00	7.50	5.00
Average	**20.30**	**13.08**	**10.00**	**6.46**
Heat				
Solarthermal	5.97	5.20	5.15	4.70
Geothermal	7.90	8.00	8.00	9.00
Biomass	14.77	11.00	8.00	6.00
Average	**9.36**	**8.62**	**6.93**	**5.45**
Total Average	**17.04**	**11.95**	**9.39**	**6.24**

This development leads to revenues in the respective industries, foregone consumption in other sectors, investment in input sectors and impacts on the labor market. To quantify these effects the **econometric model** PANTA RHEI is used. PANTA RHEI is an ecologically extended version (cf. BMOS00) of the 58 sector econometric simulation and forecasting model INFORGE (ME98). The extension comprises of a deeply disaggregated energy and pollution model, including 30 fuels which are used in households and the production sectors. From the modeling aspects, PANTA RHEI belongs to the class of econometric input-output models. Its advantages are the ability to model bounded rationality decisions and the wide empirical database. PANTA RHEI is built fully integrated and bottom up, leading to each sector of the economy being modeled in great detail. The macroeconomic aggregates are calculated by explicit aggregation. The model consists of more than 40,000 equations describing the inter-industry flows between the 58 sectors, their deliveries to personal consumption, government, equipment, investment, construction, changes in stocks, exports, as well as prices, wages, output, imports, employment, labor compensation, profits, taxes etc. and describes income redistribution in full detail. One further strength of the model is its high level of interdependence, for instance between prices and wages or between prices and volumes.

Final demand is determined from the disposable income of private households, the interest rates and profits, the world trade variables and the relative prices for all components and product groups of final demand. For all intermediary inputs, imports and domestic origins are distinguished. Givens final and intermediary demand, final production and imports are derived. Employment is determined from the production volume and the real wage rate in each sector, which in return depends on labor productivities and prices.

The new detailed structure of the renewable energy sector has been integrated in the model and the future energy scenarios provide information on investment in the sector and the financial burden on the economy by way of additional costs of renewable energy (budget effects). The effects of a certain policy measure are calculated by comparing different runs of the model, one run using a reference development without the measure and one – or several - that includes a policy measure. The comparison of the effects on the macroeconomic indicators then shows the net economic effects, e. g. on the labor market, on GDP etc.

Employment – gross effects

In the following gross employment is calculated on three different levels. Firstly we consider the production of facilities for the use of RES. The relevant factors in this first step of the calculation of gross employment are the demands caused by investment in systems for the use of RES and fulfilled from domestic production, the respective demands from operation and maintenance and from the production of biomass and bio fuels. The first and the last demand may stem from domestic installation of capacities or from international demands, the second one only stems from domestic demands.

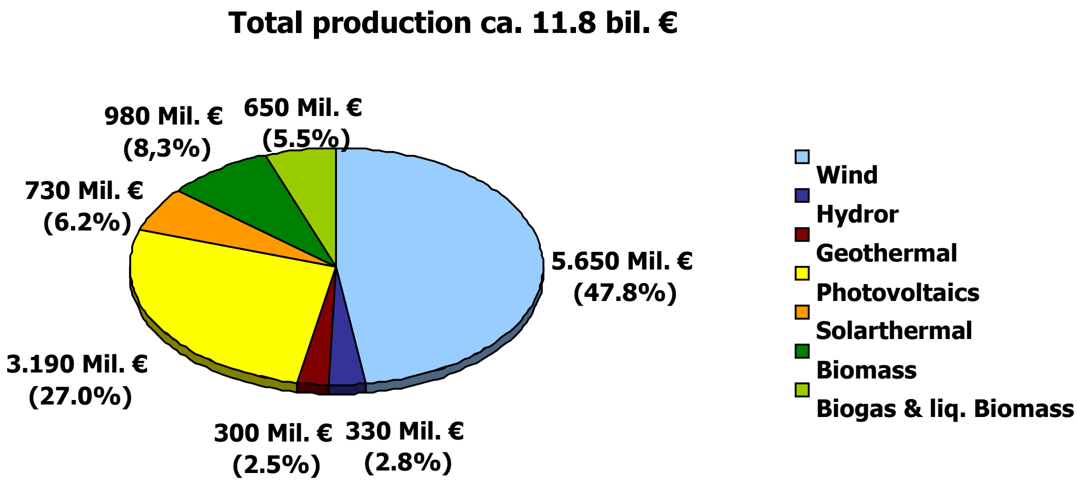


Figure 2: Total turnover from production 2007.

Source: BMU2008

Figure 2 gives the total domestic production for national and international installation of capacities as 11.8 billion Euro. The operation and maintenance can be derived from detailed data about the capacities installed in the past. A large percentage of these costs goes into the operation and maintenance of wind parks (42.5%) followed by biomass (32%). Finally, the cost for the provision of biomass and biofuels has to be taken into account. Since a large share of the total amount of wood used is not traded on markets and not part of any official statistic, estimates in this sector are prone to errors.

The largest impact in terms of employment comes from the investment into new systems. This impact leads to a total (gross) employment of **146,300** people (cf. table 5). Almost 67,500 jobs are connected with wind energy, directly in the wind industry and in industries producing intermediary inputs and services. The share of the directly employed differs across the different technologies. For wind energy, 43% of the total induced employment is directly in the wind system producing industry.

Secondly, we analyze the impact of the growing importance of renewable energy on employment in the research and development sector. R&D is financed by private and public budgets. The investment into R&D from the RES industry itself and employment in the R&D departments of the firms in this sector are already included in the above analysis. Our focus here is on R&D that is publicly financed and takes place predominantly in research institutes (private and public) and universities. Research institutes can be funded institutionally or by project. The latter funding stems from public tenders and is acquired competitively. Total project funding from the European Union, the federal government and the state governments amounted to almost 680 million € between 2004 and 2006, with 190 million € in 2004, and almost 250 million € in 2005 and 2006. From the federal government a constant amount of close to 32 million € went into institutional funding. The highest entry in the support balance was R&D on photovoltaics with 24 – 42 million € and geothermal power and heat generation with 6-14 million €. To support the exports of the RES industry, which play an increasing role as we have pointed out earlier, the German government spent nearly 15 million per year on public relation and export facilitating information campaigns (journeys, workshops etc.).

Gross employment in the R&D sector follows from the productivity of the sector (direct employment) and the input structure of the sector for indirect employment. Public relation, export support and information campaigns have been considered and entered into the calculation as "Services to production" with the respective indicators.

Thirdly, increasing domestic production in the RES sector requires increasing capacities and therefore yields increasing demand for production equipment. However, here the data are very poor. Though the annual business reports of the industry reflect the capacity increases in physical units, investment into new machinery is not published. This sector was also neglected in the 2004 survey mentioned earlier, but will be included in an update of that survey in 2008. From a small sample of telephone interviews and an evaluation of published data (cf. Kratzat, et al. 2007) investment can be estimated as 2.7 billion € between 2004 and 2006. This leads for instance for 2006 to additional employment of 23.500.

Table 5 shows the different components of gross employment in the RES sector.

Table 5: Gross Employment from RES in Germany 2007

	Investment including export	O&M	Biomass production	Total	Total 2006
Wind	67.500	16.800		84.300	82.100
Photovoltaic	36.700	1.900		38.600	26.900
Solarthermal	10.200	1.900		12.100	13.300
Hydort	5.000	4.400		9.400	9.400
Geothermal	4.200	300		4.500	4.200
Biomass	13.900	17.400		31.300	33.800
Biogas, liq. Biomass	8.800	4.700		13.500	11.400
Biomass solide			22.800	22.800	18.200
Biofuel			28.500	28.500	32.000
Total	**146.300**	**47.400**	**51.300**	**245.000**	**231.300**
R&D					**4.030**
Production systems					23.500
Sum				**249.300**	

Source: Input-Output-Analysis of DIW Berlin.

Net effects

While domestic investment and exports have a positive effect on employment in the respective industries, the overall economic impact of the support of renewable energy crucially depends on the additional costs, which are borne by all consumers. The additional expenditure on RES leads to foregone expenditure in other sectors and to less employment in these sectors. This so-called budget effect is the most important negative impact on the economy.

To quantify the budget effect, the differences in the additional costs for the respective scenarios are calculated. The additional cost result from the scenarios on capacities installed and energy produced from renewable sources, assumptions on the price development of fossil fuels and of CO_2-emissions (i.e. of tradable permits) as well as assumptions about newly installed fossil capacities. The cost differential between the use of renewable and fossil energy leads to the so-called additional costs. If these are zero, renewable energy is competitive and does not need the monetary support any more. The difference of the impacts of the two scenarios depends on the difference of the additional costs.

Net exports as difference between exports and imports in each scenario grow in the TOS scenario and they do not occur in the ZERO scenario. Before 2020, this growth is mainly due to the development of the wind industry; later (post 2020) the solar industry (PV and thermal) are the drivers of the export growth.

Investments in renewable energy systems and their operation and maintenance, the reduced imports of fossil fuels, the additional costs and the net exports give rise to a variety of effects in a very interdependent model such as PANTA RHEI. Dynamic effects of a changing economic structure and of technological change in reaction to these effects are modeled in PANTA RHEI. Increasing productivity due to technological change leads to increasing output with the same level of employment. This development is paralleled by increasing energy efficiency and, therefore, a decreasing impact of energy prices on the economy. Budget effects from lower household incomes or lower imports of fossil fuels and other goods are taken into account.

Table 6 gives the changes of some important economic indicators in absolute values. The analysis uses the cautious scenario for the export development. Gross production, GDP, consumption, investment and exports are higher in the TOS in all decades[3]. However, a higher production does not result in an equally high amount of value added, but partly results in an increase in imports or imported inputs. The positive impacts mainly stem from the higher investment in equipment and from exports. This already shows the high importance of strong export activities. The pessimistic export scenario leads to exports approximately at the same level as the production for the domestic market, therefore, the successful participation on the world markets has failed in this scenario.

[3] PANTA RHEI produces results for each year; the values are presented for selected years.

Table 6: Changes of some important economic indicators in the TOS – absolute values from ZERO

	2010	2015	2020	2030
GDP billion €95	15,30	18,95	26,36	34,58
Gross production billion €95	38,58	48,32	63,34	80,27
Private consumption billion €95	6,70	9,96	13,36	19,65
Government billion €95	1,45	1,67	2,55	3,54
Investment construction billion €95	0,75	1,02	1,54	1,59
Investment equipment billion €95	5,66	4,47	5,91	7,84
Export billion €95	7,08	10,02	13,26	16,67
Import billion €95	6,59	8,49	10,70	15,33
Public debt billion €	-33,39	-64,67	-115,05	-283,98
Average wage €	0,14	0,17	0,19	0,21
Consumer price index 1995=100	0,35	0,37	0,17	-0,20
Labor 1000				
Source: BMU07				

In all export scenarios wind energy is the dominant industry, followed by biomass and photovoltaics. The export effect increases over time due to expanding world markets, while domestic investment only slightly increases. Investment in construction and governmental consumption contribute below average to the positive development. This can be explained by the modeling assumption that government revenues are rather used to lower public debts. If this had been modeled differently, employment effects could be even higher. The additional costs of RES are reflected in the increase of the price index.

The development of wages reflects the general price development as well as the increases in productivity. The increase in real wages limits the labor market and the increase in employment. Overall net employment is positive even at the maximum of the (negative) budget effect.

Summary and Conclusions

The increasing awareness of climate change and its consequences leads to a new assessment of the different routes to CO2-mitigation. The discussion at least in Germany has shifted from general criticism of the costs connected with a structural change in the energy supply system to a more detailed analysis of the underlying processes and the industries involved. Though the grounds for such an analysis have been laid by developing an input-output-vector of the industry in 2004 the rapid changes in this industry can only be recovered by frequent empirical updates. This contribution is still based upon the 2004 data and analyses the overall economic effects of an increase in RES compared to a ZERO scenario, where RES have not been supported at all. A new survey in the industry that includes the equipment producing sector is carried out in 2008 and the results will be used to update the existing input-output vector. With increasing economic relevance, however, there is increasing interest in regional analysis which also will be a topic of future work.

Most of the research that went into this subject has been funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety in several studies and projects.

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