Renewable Energy and Employment in Germany

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Abstract: *The positive impacts of an increasing share of renewable energies on the mitigation of climate change as well as on the decrease of the dependency of energy imports are indisputable. However, one persistent problem for the German economy has been its high level of unemployment in the recent past. Therefore, any policy strategy will be measured also by its net-impact on the labor market. The paper describes the results of a study that models this impact and is novel within three respects: Firstly, an Input-Output-Vector for the renewable energy sector was developed based on the results of more than 1000 interviews with an extensive questionnaire, secondly gross and net effect of two different policy scenarios for Germany until 2030 were calculated and thirdly the approach varies from earlier studies by its explicit modeling of export and foreign trade effects.*

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

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1 Introduction

The discussion about the consequences of climate change following the 2007 publication of the fourth IPCC assessment report (AR4) has increased the attention towards renewable energy. The European Commission supports a leading role of Europe in climate gas mitigation and will set a goal of 30% renewable energy in the electricity sector if other countries join the effort. Though the overall benefits of the use of renewable energy in the electricity, heat and transport production in terms of environmental (climate change) benefits, as well as resource security and import independence currently seem to be undisputed, the overall economic costs of the support of renewable energy in these sectors continue to be an issue.

They become even more an issue if the economy's performance is slow. For instance in Germany, growth rates were very low at the beginning of the 2000s (1.2 in 2001, 0.0 in 2002, -0.3 in 2003). Unemployment rates around ten percent shifted the focus of the analysis of the economic effects of the German Renewable Resource Act (EEG) on labor market effects and several studies have analyzed these effects (cf. BEI03, HBBB06, IER05, ET06). These earlier studies either focused on the effects of electricity only, or modeled the end of the German feed-in tariff system and focus on the development until 2010.

Our analysis differs in three ways from previous work: Firstly, given the European reception of the German feed-in law as rather successful and the number of countries that modeled their legislation accordingly, we assume an ongoing political support of energy from renewable sources in Germany. Secondly, given the vast development of the industry in the last couple of years, the question has to be asked, if the analytical tools for the economic analysis of the sector should be improved. The data base and the empirical foundation should be strengthened for the sake of future analyses of an innovation oriented industry with a variety of highly developed technologies. For this purpose, the whole industry of systems for the use of renewable energy has to be examined, including heat systems and biofuels. Thirdly, as the industry becomes more and more oriented towards world markets, the role played by exports cannot be ignored as in previous work.

We share with the previous work the analysis of the major effects of the support of renewable energy on employment: High investment levels and large capacities installed directly exert a positive effect on the employment in the respective industries. These effects are supported by the import effect, i.e. money saved on imports of fossil fuels which are replaced by energy from renewable sources. Counterbalancing the positive effects are the reduced investments in fossil fuel systems and – most important – foregone investments and consumption from a lower available public and private budgets due to additional costs of RES. The balance of these effects compared across different development paths leads to the net economic effects, among which the net employment effects have our special attention.

The remainder is organized as follows: After these introductory remarks section 2 explains the modeling approach. Section 3 gives details of the survey and the data base. Section 4 contains a careful analysis of gross employment in the base year and until 2030. The net economic effects are discussed in section 5 and section 6 concludes.

2 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 developed. In short, a new vector is added to the systematic of the input-output table, based on detailed empirical data from a comprehensive survey. 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].

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.

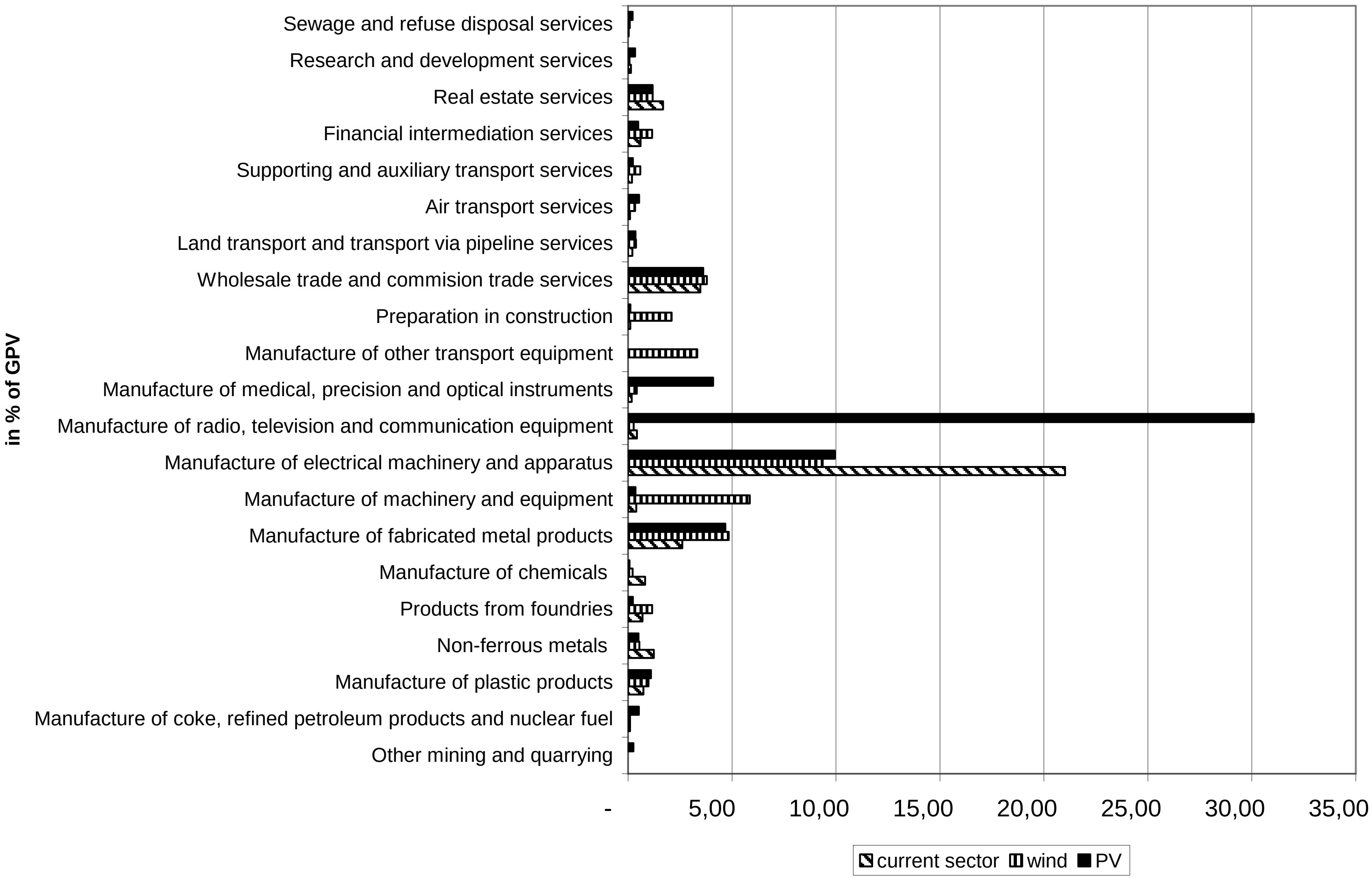
Input-output tables are closed accounting schemes where the identity of the sum of inputs and the sum of outputs has to hold in each sector. This consistency check has to also hold for the newly created sector “Production of systems for the use of RES”. If the original structure is expanded consistently 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.

[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.

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. For the analysis of the employment effects of the support of increasing use of renewable energy in Germany, the following set of scenarios is used:

- a German *reference scenario (REF)*, based on the energy economic reference forecast by EWI/Prognos (EWI/Prognos05)
- 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)
- international scenarios (*reference* and *dynamic current policy*) (IEA-REF04, EREC-DCP04)
- four scenarios for the development of market shares of the German industries for the analysis of exports

Energy consumption already declines in the *reference scenario* after 2010: in 2030 primary energy use is down to 85% and end energy consumption to 90% of their 2004 values. Electricity consumption increases until 2020 and decreases in the following decades back to its level today.

Table 1: Indicators in the reference scenario (REF) and the target oriented scenario (TOS)

	2004	2010	2030	2050	2010	2030	2050
		Reference			TOS		
Primary energy (PE) (PJ/a)	14,438	14,122	12,080	10,317	13,369	10,325	8,001
End use (END) (PJ/a)	9,243	9,187	8,403	7,309	8,925	7,688	5,917
-electricity (ELEC) (PJ/a)	1,810	1,854	1,854	1,782	1,742	1,537	1,415
CO_2-emissions(Mio t /a)	840	811	695	539	739	497	236
PE/GDP(GJ/1000 EUR)	6.875	6.124	3.961	2.866	5.797	3.385	2.223
END/GDP(GJ/1000 EUR)	4.401	3.984	2.755	2.030	3.870	2.521	1.644
ELEC/GDP(GJ/1000 EUR)	0.862	0.804	0.608	0.495	0.755	0.504	0.393
CO_2(1990=100, 987 Mio t)	85.1	82.2	70.4	54.6	74.9	50.4	23.9
Share RES PE (%)	3.6	5.7	10.7	16.0	6.9	21.5	42.0
Share RES END (%)	5.1	6.9	12.4	18.6	8.1	23.3	46.4
Share RES ELEC (%)	9.3	13.4	25.0	34.9	16.1	53.1	71.4
Source: BMU06							

Energy intensity decreases by 40% and renewable energy contributes 10% to primary energy use. The reference scenario assumes a continuation of current German policies, i. e. the German feed-in tariffs will be continued and nuclear energy will be phased out (BMU02). The reference scenario reaches a 30% (44%) CO_2 reduction by 2030 (2050) and misses the national targets.

The *target oriented scenario* is characterized by a faster decrease in energy intensity and a much more rapid increase of the share of renewables. The increase is after 2010 roughly twice as fast and by 2030 are 23% primary energy consumption and 53% of the electricity production from renewable energy. Table 1 compares the two scenarios for some decisive indicators. All other indicators such as population, GDP or households are identical across the scenarios.

The scenarios come with detailed information about the necessary investment into RES, the resulting development of additional costs based on technology specific databases of cost curves as well as a scenario for the development of fossil fuel prices and the CO_2-emission costs. 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 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. For the future market shares, we developed four technology specific scenarios. Currently, Germany shows some characteristics of a lead market for RES technologies, which may favor a strong future position on the international markets. 40% of the systems for the use of wind energy sold in the base year, 2004, 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 2 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 2: Global market shares of the German RES industry (in % of market based on EREC-DCP)

	2004			2010			2020			2030			
Electricity		a)	b)	c)	d)	a)	b)	c)	d)	a)	b)	c)	d)
Hydro	3.45	2.50	3.00	3.10	3.20	2.00	2.40	2.75	3.10	1.50	2.00	2.50	3.00
Wind	40.07	25.00	30.00	34.00	38.00	15.00	20.00	25.00	30.00	8.00	12.00	19.00	26.00
Photovoltaic	28.71	14.00	18.00	21.50	25.00	7.00	10.00	14.50	19.00	4.00	7.00	10.00	13.00
Geothermal	0.19	2.60	2.60	2.60	2.60	4.70	4.70	4.70	4.70	5.00	5.00	5.00	5.00
Biomass[1]	14.02	8.00	10.00	11.50	13.00	4.00	7.00	9.00	11.00	2.50	4.50	6.75	9.00
CSP	0.00	8.00	10.00	10.00	10.00	5.00	7.50	8.75	10.00	3.00	5.00	7.50	10.00
Average	20.30	10.70	13.08	14.90	16.72	7.28	10.00	12.79	15.59	4.15	6.46	9.63	12.80
Heat													
Solarthermal	5.97	5.10	5.20	5.40	5.60	5.10	5.15	5.33	5.50	3.00	4.70	5.05	5.40
Geothermal	7.90	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	9.00	9.00	9.00	9.00
Biomass	14.77	8.00	11.00	12.00	13.00	5.00	8.00	9.50	11.00	3.00	6.00	8.00	10.00
Average	9.36	6.90	8.62	9.26	9.89	5.24	6.93	7.83	8.73	3.21	5.45	6.54	7.64
Total Average	17.04	9.74	11.95	13.47	14.99	6.88	9.39	11.81	14.23	3.94	6.24	8.95	11.66

[1] Including Biogas, Scenario a) – d): from heavily dropping shares to only slightly decreasing shares

Source: BMU06

Each of these developments 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.

The novelty of the combined modeling approach lies in the combination of very detailed analyses on each level and the provision of a strong empirical foundation.

3 Data from the survey

For this purpose the most comprehensive survey to date of more than 1,100 companies in this subject area was performed in the summer of 2005 in cooperation with the German Renewable Energy Federation (BEE) and the Institut für Sozialforschung und Kommunikation[3]. There are other detailed surveys on this matter, but they either focus on a certain region (cf. IWR04-06) or on certain technologies only.

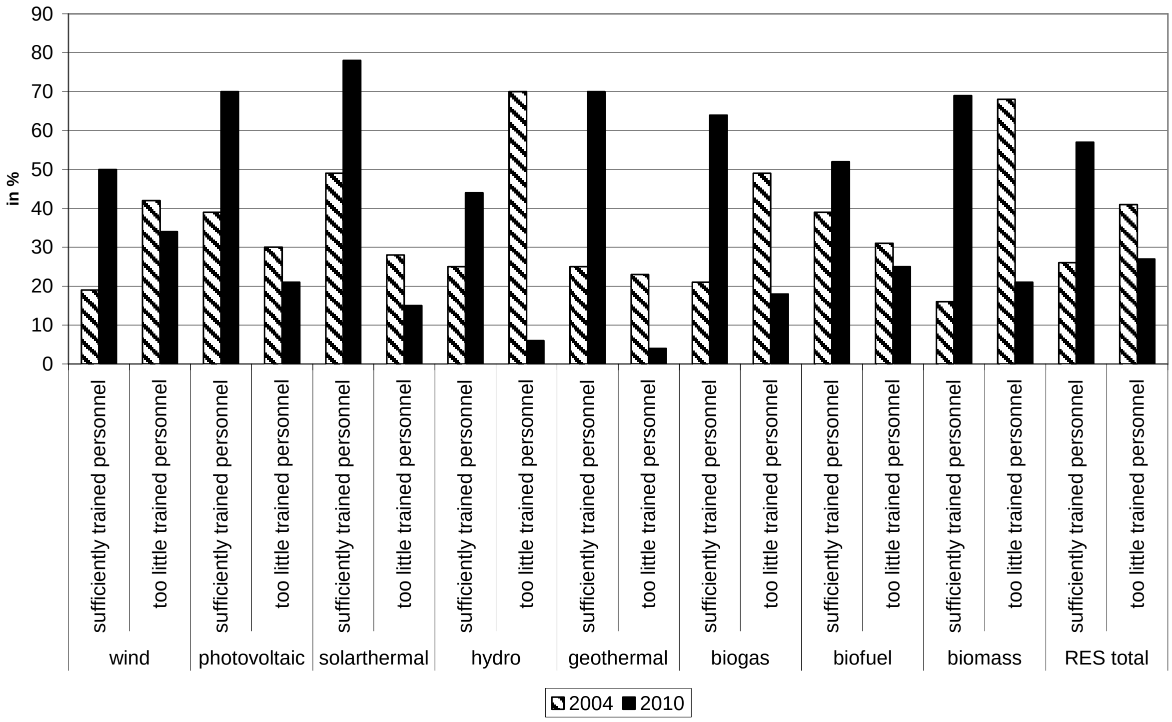
Addressees of the questionnaire included system manufacturers, suppliers, developers and planners, system operators, financers, insurers, and retailers. They represent a total of 26,400 jobs. The industry is dominated by SMEs: 84% of the companies employ less than 250 people.

One goal of the survey was to obtain data to amend the input-output tables. For this purpose, detailed information about the inputs in the different production processes was obtained. The questionnaire included a comprehensive component list of the important inputs and intermediary goods for the respective production. The input structure was specified to different categories, such as imported inputs, domestic inputs by region, by production and service sector. Information has been obtained following the entire value chain.

Furthermore, questions about the type and extent of employment, the composition of the staff according to education, sex, and job location, but also about the company’s demands on the job market, the success hiring qualified personnel and their expectations for the future development have been included in the questionnaire. The answers provide a more detailed picture of the employment situation in the industry. Figure 2 shows the current situation and the expected development for skilled labor availability in the different RES sectors. Almost all sectors lack skilled personnel, the largest shortage in hydro energy, biogas and biomass. All sectors expect the situation to improve by 2010.

[3] A more comprehensive account of the survey results can be found in the appendix in BMU06.

Figure 2: Skilled labor availability by RES sector – 2004 and expectation 2010



The vast majority of the respondents have an optimistic outlook to the future. On average, the expected increase of employment until 2010 is 54%. These expectations are based on positive German market trends and increasing international trade. The majority of respondents rate their international competitive position as good to very good. The export ratio in the trade sector, defined as the ratio between the export of systems and preliminary products (e.g. components) and turnover including services was on average 28% in 2004. Various other publications exclude the service area when calculating the export ratio. The corresponding export ratio for 2004 then amounts to 35% for the entire sector, with significant differences between the individual lines of business: it is nearly 50 % for wind power, and almost 80% for hydropower. By contrast, exports are still of little significance in the area of biomass use with less than 10%, and in photovoltaics with 20%. Approximately two thirds of the export revenues in 2004 were earned in the EU countries (EU-25), another 15% in Asia, and 10% in North and Central America**.** The European market will presumably continue to play an important role for exports from Germany in the future. Therefore, support policies in Europe are most important in the medium range for the development of this sector.

Germany is still considered an attractive location for the production of systems for the use of renewable energy. A number of political and structural conditions make Germany attractive. Important, but not the only reason, is the domestic market, which is supported by political instruments like the Renewable Energy Sources Act or the Federal Market Stimulation Programme. Further important aspects are the availability of qualified personnel, a good infrastructure, and excellent technology development which is linked to the strong research activities in the area of renewable energy.

The data from the survey are combined with technical data to amend the input-output tables and to derive the direct and indirect employment of the new sector. Using the scenarios for the development of technological parameters, costs and capacities installed, leads to estimates for the development of employment until 2030.

4 Employment – gross and regional effects

The relevant factors for the calculation of gross employment for the base year (2004) 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 biofuels. 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.

Table 3: Domestic production of systems for the use of RES (2004)

	Investment in Germany in Mill. €	Imports in Mill. €	Investment fulfilled by domestic production in Mill. €	Exports in Mill. €	Total demand for domestic production in Mill. €
Wind	2,363	0	2,363	784	3,147
Photovoltaic	2,250	1,072	1,178	97	1,275
Solarthermal	530	166	364	42	406
Hydro	70	0	70	263	333
Biomass	1,425	377	1,048	32	1,080
Biogas	201	86	116	3	119
Geothermal	193	114	79	37	116
Total RES	7,033	1,814	5,219	1,258	6,477
Source: BMU 2006.					

Table 3 gives the total domestic production for national and international installation of capacities as 6.477 billion Euro. From the survey, the additional amount of exports of components and parts can be estimated as 733 million Euro. Therefore, gross employment is derived from a total investment in new systems and components of 7.2 billion Euro. The operation and maintenance can be derived from detailed data about the capacities installed in the past. Total operation and maintenance costs amount to 2.3 billion Euro. 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. A very careful estimate leads to investments of 660 million Euro in 2004. The data on biofuels are better and the demand for biofuels can be given as 892 million Euro (EE05).

The largest impact in terms of employment comes from the investment into new systems. This impact leads to a total (gross) employment of 97,000 people. Almost 50,000 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.

Almost 27,000 people work for the production of exported parts and systems; this is more than one quarter (27%). Especially in the wind energy sector, exports play a very important role. Here, 18,000 people work for the production of exports. Operation and maintenance leads to the employment of 47,000 people. For the base year, this impact is only half as much as the production of systems, but with increasing capacities installed the number of employees will rise in the future in this sector. Almost 50% of total employment in O&M goes into the use and production of biomass.

Table 4: Gross Employment from RES in Germany 2004

	Employees	in %
Wind	63,944	40.7
Photovoltaic	17,397	11.1
Solarthermal	7,666	4.9
Hydro	9,515	6.1
Biomass	51,745	32.9
Biogas	5,035	3.2
Geothermal	1,773	1.1
Total RES	157,075	100.0

[1)] Including the demand for biomass and biofuels.

Source: Input-Output-Analysis of DIW Berlin.

A regional analysis shows that total employment from RES is almost equally distributed over Germany. We consider for 4 regions – North, East, West and South[4] – the distribution of total employment and of the production of intermediary goods. Total employment has the highest shares in the North (29%) and the South (28%), followed by the East (25%) and the West (18%). The distribution of the input flows shows more regional differences: In the North almost half of all inputs come from the North and in the South, still more than one third of all domestic inputs come from production in the South. But only 19% of the inputs for production in the East come from the Eastern region – 32% come from the South and 27% from the North. Therefore, the production in the Eastern region induces employment in all other regions to a high degree. Since the region East still is characterized by high levels of unemployment, the development of certain technology clusters that produce along the value chain could be supported in the future.

[4] **North =** Schleswig-Holstein, Lower Saxony, Hamburg and Bremen; **South=** Baden-Wuerttemberg und Bavaria and Hesse, **East=** Mecklenburg-Western-Pomerania, Brandenburg, Thuringia Saxony-Anhalt, Saxony and Berlin; **West =** North-Rhine-Westphalia, Rhineland-Palatinate and Saarland;

For the calculation of future gross employment the development of the productivity in the various industries has to be estimated. When output is measured in monetary units, productivities are affected by technological progress, capital input and price fluctuations. Labor intensive production is characterized by large labor coefficients or small productivities – examples include the early stage of agriculture and service sectors. In these sectors increases of productivity can result in large decreases of employment. Typically, productivities increase over time due to capacity increases, technological progress and scale effects. In the young industries for the production of RES systems we observe two effects: firstly, the production facilities are state of the art, since they are relatively new and large increases in productivity might not occur, but secondly, the market grows tremendously and new innovative products will be demanded which lead to innovative processes and increased productivity (e. g. in the photovoltaic sector). The survey results show that the industry itself expects large increases in productivity depending on the technology.

Table 5: Development of the labor coefficients until 2030 (2004=100)

	2004	2010	2020	2030
Wind	100.0	86.7	62.4	47.1
Photovoltaic	100.0	74.5	44.3	33.6
Collector	100.0	80.7	60.8	46.0
Hydro	100.0	94.3	81.2	69.2
Biomass	100.0	84.5	59.5	45.7
Biogas	100.0	83.2	54.2	39.8
Geothermal	100.0	85.9	65.0	50.5
CSP	100.0	78.2	60.1	49.1

Source: BMU06

From the comparison with the historical development of other sectors and the learning curves of the various technologies, the development of the productivity has been derived. For solar collectors, hydro energy and biomass the learning factors are 0.9 or higher, therefore the expected increase in productivity is rather small. Wind energy also is a mature technology, though off-shore wind energy has a lower learning factor and is expected to show larger productivity increases once the installed capacities increase. Table 5 shows the development for all technologies. The largest increases in productivity (decrease in labor coefficients) are expected from the photovoltaic industry and from the production of biogas.

From the development of total (=national + international) investment in RES from domestic production as described in section 2, the projection of the labor coefficients and the ratio of direct and indirect employment, different scenarios for the development of total domestic employment are derived. Table 6 shows the spectrum of the possible developments.

Table 6: Employment until 2030 in different scenarios (rounded to the next 100)

	2004	**2010**	**2020**	**2030**
Cautious (DCP)+ TOS	157,074	244,000	306,700	332,800
Cautious optimistic (DCP)+ TOS	157,074	263,000	353,500	415,000
Cautious (REF) + REF	157,074	161,300	170,00	180,000
Cautious optimistic (REF) + REF	157,074	170,800	181,800	197,400
TOS: Target oriented scenario, REF,: reference scenario, BMU06				

The export scenarios are matched with the respective scenarios for the national development. The target oriented scenario for the national development in combination with the cautious optimistic scenario for the export development leads to the highest level of employment with more than 400,000 employees. The reference scenario leads in combination with the cautious scenario for the export to a situation where the exports can barely make up for the decreasing domestic development. Total employment will be smaller than today (2005: 190,000; 2006: 214,000).

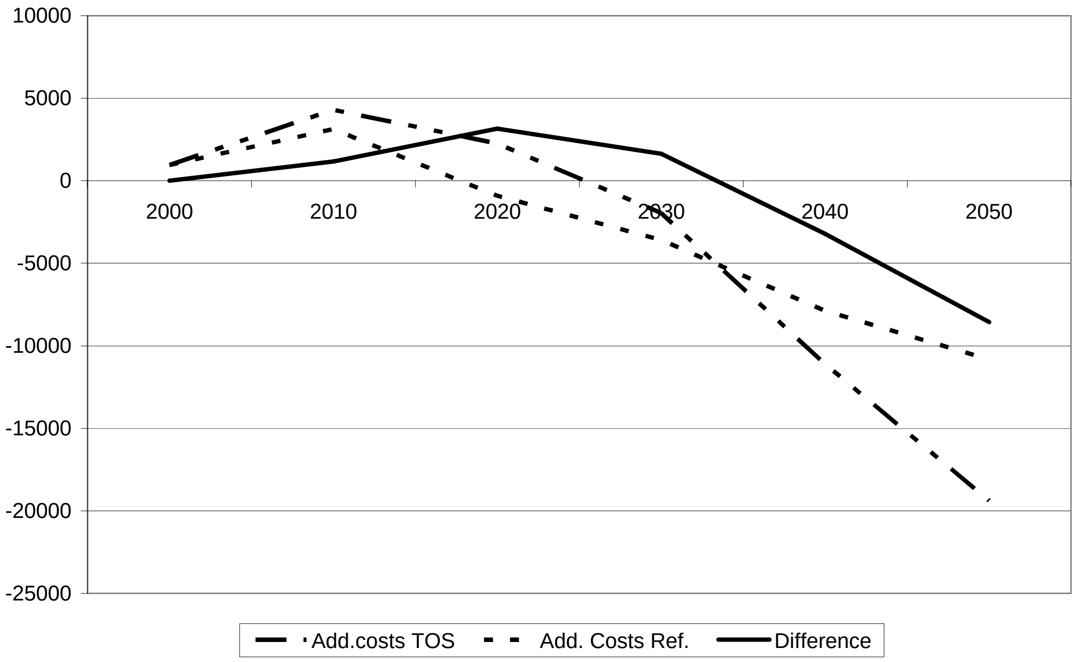
5 Net effects

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.

Figure 3 shows the development of the additional costs for the TOS and the REF scenario. The difference of the additional costs reaches its peak around 2020. In the reference scenario, renewable energy becomes competitive at an earlier time, because the more innovative – and more expensive – technologies are used to a lesser extend. The TOS reaches competitiveness around 2025 and becomes advantageous in terms of costs compared to the reference scenario after 2030.

Figure 3: Development of additional costs in the TOS and the REF Scenario



Net exports as difference between exports and imports in each scenario grow faster in the TOS than in the reference 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.

The different investments in renewable energy systems and their operation and maintenance, the reduced imports of fossil fuels, the additional costs and the different 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 7 gives the changes of some important economic indicators in absolute values. The analysis uses the cautious scenario for the export development. The effects for the other scenarios of export development are given in the text below.

Gross production, GDP, consumption, investment and exports are higher in the TOS in all decades[5]. 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.

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

Table 7: Changes of some important economic indicators in the TOS – absolute values from REF

	2010	2015	2020	2030
CO_2-emissions million t	-5.72	-9.74	-15.64	-73.99
GDP billion €95	9.88	13.01	17.04	20.93
Gross production billion €95	22.76	31.43	42.15	52.88
Private consumption billion €95	4.95	6.39	8.25	11.07
Government billion €95	1.02	1.22	1.56	2.01
Investment construction billion €95	0.60	0.78	1.05	1.12
Investment equipment billion €95	2.09	2.33	3.27	2.90
Export billion €95	4.72	7.45	9.96	13.60
Import billion €95	3.67	5.37	7.33	10.13
Public debt billion €	-8.94	-24.19	-50.91	-143.43
Average wage €	0.06	0.09	0.14	0.16
Consumer price index 1995=100	0.04	0.12	0.21	0.08
Labor 1000	55.23	64.21	73.60	84.41
Source: BMU06				

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. This result also holds through several sensitivity analyses:

- variation of the exports
- higher fossil fuel prices resulting in lower additional costs
- higher domestic investment in RES
- Low energy prices, no exports

The results of the sensitivity analysis show that increasing exports drive the model more significantly than energy price assumptions. A mere increase of domestic investment leads to a positive labor effect, but it is rather small: A time dependent investment increase of on average 2 billion €/a with a peak investment of 3.5 billion €/a in 2020 leads to additional employment of 8-12,000 people. Without the expansion of the international market, the renewable energy industry cannot contribute a large employment benefit to the German economy. To validate the model against previous work, a scenario with low energy prices (30$/b) and without exports has been run. It leads to negative employment effects just as previous work has shown.

6 Summary and Conclusions

The increasing awareness of climate change and its consequences leads to a new assessment of the different routes to CO2-mitigation. Among other options, the possible contributions of renewable energy and its costs are under scrutiny. Our analysis contributes to the discussion with the following insights from the German market and the German experience.

The additional costs of renewable energy in a target oriented scenario will increase over the next 10 years if we assume a moderate estimate of future energy prices. For an oil price of 60 US $/b and a CO2-price from tradable permits around 15 €/t the maximum of the additional costs will be 5 billion Euro in 2015. With these prices, competitiveness will be reached around 2020. Obviously, it will be reached the earlier, the more rapidly fossil fuel prices rise. The analysis described above is oriented towards a rather conservative approach in terms of framework conditions, but target oriented in terms of capacities installed; the national targets will be reached.

International markets play a very important role for the development of the domestic industry. Currently, 16% of the world markets are installed in Germany. Future world markets will grow faster than the German market, as current installation plans and targets in several countries show. By 2020 domestic installation will only contribute 4% to the international market. Therefore, the employment in the industry crucially depends on the development of exports. If the role of Germany as a lead market can be retained, employment in the RES sector could reach more than 400,000 by 2030 and net employment effects will be positive.

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