Modeling Economic Impacts of Renewable Energy Expansion – The Experience for Germany

Contribution to the special session: "Renewable energy policies – modeling challenges and economic results"

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1 Introduction

Given the increasing global awareness for the risks of climate change, many countries have endorsed long-term strategies for a transition to low carbon economies. A major decarbonisation strategy is to substitute fossil fuels with renewable energy sources (RES) as primary energy source (IPCC, 2011). Environmental and climate benefits like lower emissions of CO_2 and other air pollutants come along with such a strategy. Climate change mitigation is not the only rationale for renewable energy (RE) expansion, however. For most countries RE expansion means also a reduction of the dependence on energy imports by exploiting domestic energy potentials. Reduced dependency on fossil energy imports has not only a positive impact on energy security but may –in the long run - become also a major factor for international price competitiveness given the expectation of rising global prices for fossil fuels.

In recent years Germany has followed strategies to expand the share of renewable energy in the electricity market and to a lesser extent as well in the heating market. Looking at realized investments for new facilities, installed capacity and the dynamics of market penetration of RE technologies the country is in the position of a frontrunner in this policy field (REN21, 2011). Given the decision in 2011 to phase out nuclear energy it can be expected that Germany will stay in the lead with respect to RE expansion.

Having a strong home market is seen as a competitive advantage for domestic suppliers of RE technologies on export markets so that fostering the diffusion of RE has also elements of "green" industrial policy. The idea that climate change policies and other "green" measures create economic opportunities and have a potential to boost economic development within a green framework for long-term sustainable growth has been discussed in a broader concept such as the OECD "Green Growth Strategy" (OECD, 2009 and 2011) or UNEP "Towards a Green Economy" (UNEP, 2011).

Referring to the potential economic potentials and benefits of RE expansion is only one part of the story if we want to address the question if the overall balance of economic impacts of the German RE expansion strategy is positive or negative. Reshaping the energy system via RE expansion incurs additional upfront investments and may substitute income and jobs in the conventional (fossil and nuclear based) energy industry. At the same time the (private) costs of energy based on RE sources are for the moment higher than costs of energy based on conventional sources. The balance of economic benefits and costs, that is, the net economic impact, of renewable energy deployment is therefore an interesting research question. As an indicator of net economic impact we present the overall net employment effect of RE expansion. The answer to this question may also be of interest for political decision makers who want to foster RE expansion owing to the needs of climate policy and who want to get empirical advice concerning economic cost and benefits.

The remainder of this paper is structured as follows: The subsequent chapter addresses the method to represent the emerging RE industry in an appropriate analytical framework, namely in an input-output framework suitable to be included in the applied modeling exercises. Section 3 gives an overview of the economic activity related to actual RE deployment in Germany including gross employment for RE. Section 4 addresses question of net employment effects of RE expansion. Results will be presented based on modeling exercises applying econometric modeling and scenario-based analysis.

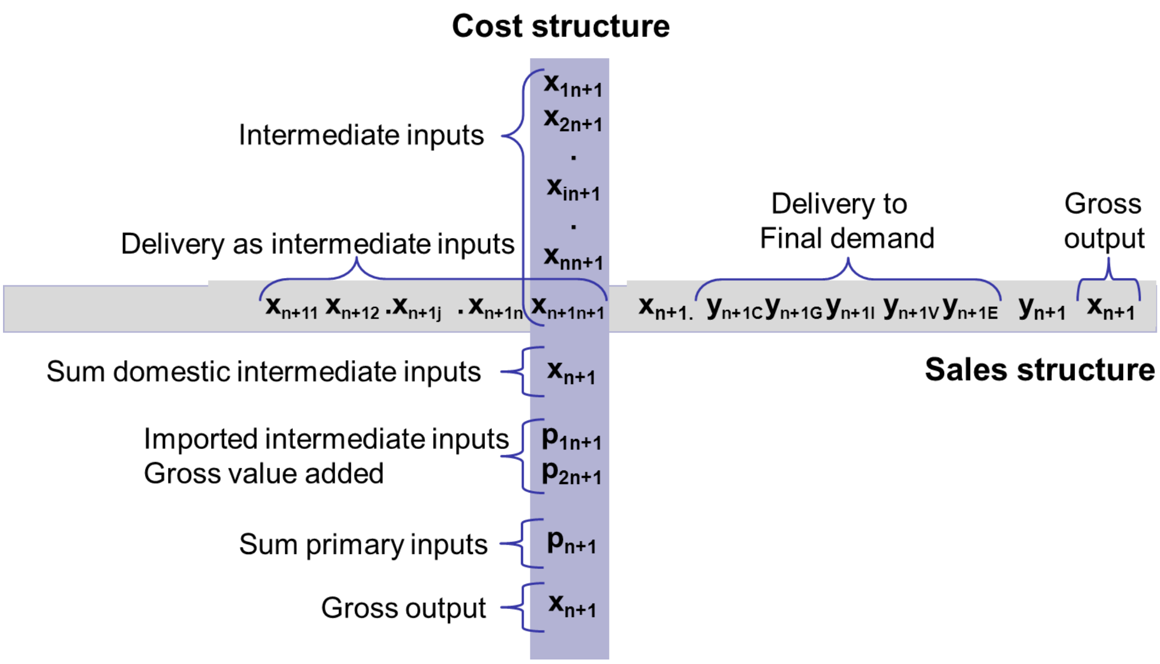
2 Representing RE in an empirical input-output framework

It is a well-known problem of empirical economic research that official statistics do not provide sufficient information for the analysis of upcoming new industries. As official statistical data have to be organized according to existing classification schemes which itself require standardization and unification at the international level it takes a long process of coordination and adaptation unless new industries show up in official data. The representation in official statistics may be even more difficult if the industry under investigation is cross-cutting through different sectors and technologies as it is the case with RE industry.

For disaggregated econometric models and applied general equilibrium models the sectoral modeling is usually based on the input-output accounting framework. Input-output tables provide detailed insights in the flows of goods and services between all sectors of the economy and the interdependence of the national economy with the rest of the world. For the benefit of a detailed and conceptually understandable analysis we decided to represent the new developing RE industries as additional sectors which supplement the existing official input-output-table for Germany. The latest available official table has 71 sectors and represents the year 2007 (DESTATIS, 2010). By adding new sectors for RE industries the number of sectors in the enlarged input-output-table is increased.

I-O tables are closed accounting schemes where the identity of the sum of inputs and the sum of outputs has to hold in each sector (Leontief, 1966). This consistency check of course has also to be fulfilled for newly created sectors. Each sector in an I-O table is defined in economic terms by its input and output structure, being represented by a new column and a new row in an existing table. The input or cost structure describes the amounts of goods and services required as intermediate inputs from all other domestic sectors, the amount of imported intermediate inputs and the value added in the sector itself. The output or sales structure describes the amounts of goods and services delivered to other sectors as intermediate goods or as final goods to final demand.

Figure 1: **Schematic representation of a new sector in the framework of an input-output table.**



We create two new sectors by defining the complete input and output structure according to the accounting rules of the input-output framework:

(i) 'Production of new RE facilities' and

(ii) 'Operation and maintenance of facilities for the use of RES'.

Sector (i) encompasses the production of new facilities ready for the use of RES, e.g. wind mills, photovoltaics installments or biomass-fired heating/power stations. Sector (ii) encompasses the operation and maintenance of facilities for RES use installed in Germany. The new sectors are fully integrated into the input-output framework, e.g. they suffice the accounting scheme that the sum of inputs equals the sum of outputs for each sector.

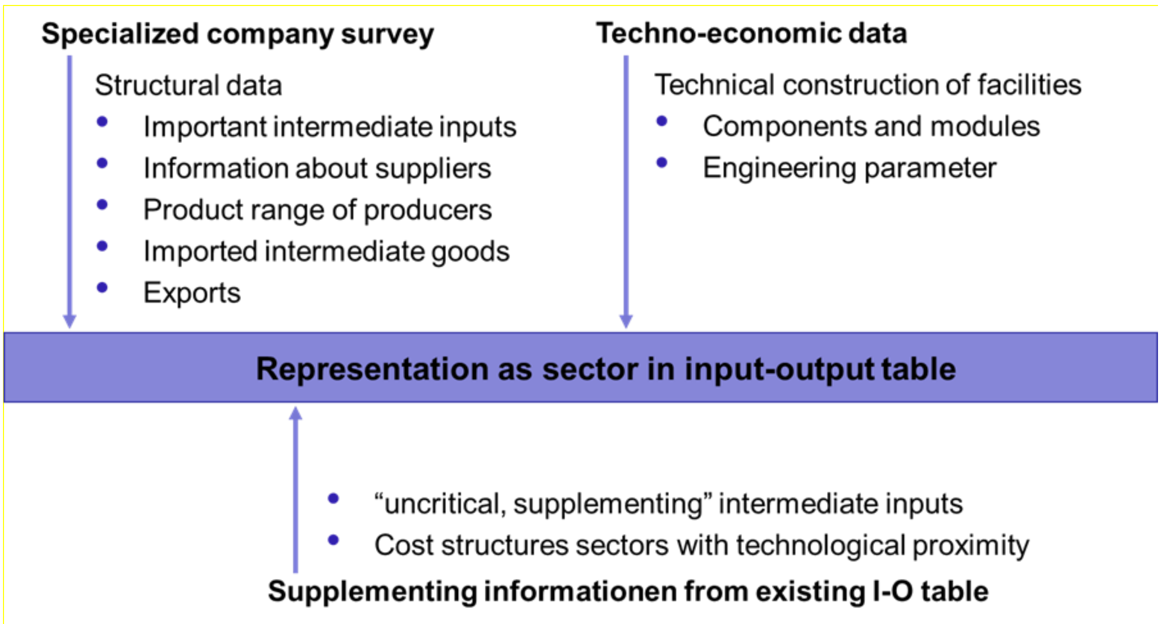
To account for the variety of technologies involved in RES use each of the two newly created sectors is build up in a bottom up process based on 12 subsectors each of which represents a defined RE technology. This follows the basic idea of input-analysis to represent economic sectors in a way that the sectors incorporate homogeneity of production processes to the largest possible extent. Internally we therefore distinguish the following 12 RE technologies:

(1) onshore wind,
(2) offshore wind
(3) photovoltaics,
(4) solar thermal heat,
(5) solar thermal power plants (CSP),
(6) hydropower,
(7) deep geothermal,
(8) near surface geothermal (heat pumps),
(9) biogas,
(10) stationary liquid biomass,
(11) small-scale biomass,
(12) biomass-fired heating/power stations.

Compared to a previous study (Lehr et al., 2008) the larger number of technologies distinguished improves the homogeneity of subsectors which is beneficial for empirical quality of representing technologies in an input-output framework.

The process of creating these new sectors involves different data sources and several working steps. The empirical data for generating the cost structure of production required in an input-output-framework are based on a specialized survey of companies active this economic cluster. Out of a sample of around 2,000 contacted companies 1,220 companies answered in 2008 in a telephone based survey. The information generated from the survey was supplemented with expert know-how mostly in the form of techno-economic data. To arrive at complete cost structures in the sense of input-output accounting additional information extracted from cost structures of established sectors in the existing I-O table were incorporated. For this purpose we especially looked at sectors which bear some "proximity" to specific RE industries from the perspective of deployed processes and production technologies. The methods for forming the new sector in the input-output framework are documented in detail in Lehr et a., 2011, chapter 2.

Figure 2: **Information flow and working steps for representation of additional RE sector in input-output framework.**



Using the input-output scheme as unifying analytical framework to establish the empirical economic data for RE as separate additional sectors in an enlarged input-output table allows to address different questions and to apply different models based on a identical data set.

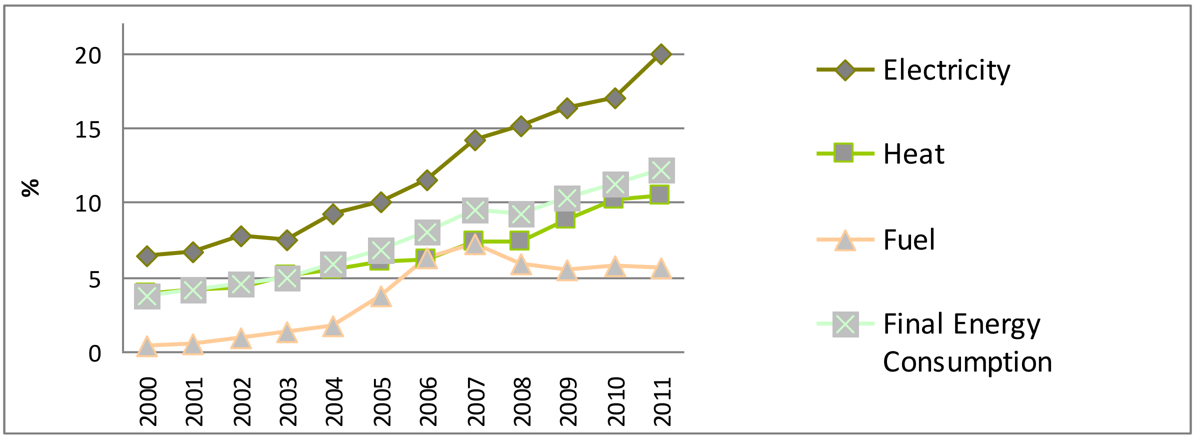
On the one hand we ask the question: (1) How many people do have a job in the economy as a whole due to existing economic activities in the field of RE use in Germany (gross employment from RE in a specific year)? We use (static) input-output analysis to measure overall economic activity and gross employment induced by the expansion of RE (see chapter 3).

On the other hand we ask the question: (2) What is the net impact on employment in the economy as a whole if a certain expansion strategy for RE is followed (net employment of RE expansion over a specific period of time)? We apply disaggregated econometric modeling and scenario analysis to evaluate the net economic impacts of RE expansion up to the year 2030 in Germany under different scenario assumptions and using different models (see chapter 4).

3 Gross Employment from RE in Germany: Deployment, economic Activity and induced employment

The use of RES in Germany increased substantially in the last years. Figure 3 shows the growing shares of renewable energy in final energy consumption between 2000 and 2011. The share in total final energy consumption increased from 3.8% in 2000 to 12.2% in 2011. The development in the power sector is most remarkable. The share of renewable energy in gross electricity consumption rose from 6.4% in 2000 to 20.0% in 2011. In the heating sector we see a steady increase to 10,4% in 2011, although the dynamic seems to level off in the last years compared to the dynamic development we see in electricity. The share of fuel from RES did not increase in the last years after reaching its peak in 2007.

Figure 3: **Share of renewable energy sources in final energy consumption in Germany between 2000 and 2011**



Electricity generated from renewable energy sources compared to total gross electricity consumption. **Heat** generated from renewable energy sources compared to total energy consumption for heat. **Fuel** created from renewable energy sources compared to total fuel consumption.

Sources: German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU): Erneuerbare Energien in Zahlen 2011. Preliminary Data as of March 8th 2012. Berlin 2012.

The growing utilization of RES in Germany comes along with increasing economic activity in the renewable energy sectors. Table 1 indicates some key figures. Substantial investments into new renewable energy facilities are required, the sum of investment increasing from €10.3 billion in 2005 to €22.9 billion in 2011 (after peaking so far in 2010 reaching €26.6 billion, the reduction being caused by heavy price cuts for photovoltaic products). Thus, the investment in renewable energy in current prices has grown by 122% in six years. RE facilities are therefore one of the fastest growing investment areas in the German economy. Investment in photovoltaic installations, in particular, has expanded strongly. PV investment makes up nearly two thirds of total investment in renewable energy in Germany in 2011. Over the same period of time total demand for facilities and components (including exports), operation and maintenance as well as biogenic fuels grew from €13.7 to €36.4 billion (increase of 167% in six years). Expenditure for operation and maintenance becomes more and more an important economic factor as the stock of operating RE facilities steadily increases. While sales in this area were €2.5 billion in 2005, the volume of demand more than doubled by 2011 to €5.9 billion (increase of 15% per annum in current prices).

Table 1: **Economic key figures for renewable energy sources in Germany 2005 - 2011.**

	2005	2006	2007	2008	2009	2010[1]	2011[1]
				In billion euros (current prices)			
Investments into RES facilities	**10.3**	**11.1**	**11.6**	**16.8**	**20.2**	**26.6**	**22.9**
Total domestic demand stimulus from RES	**13.7**	**17.6**	**24.8**	**30.1**	**31.7**	**35.5**	**36,4**
Sales[2] of complete facilities, including exports of complete facilities and components	8.6	11.4	15.2	19.7	21.4	25.3	24.9
Demand[3] for operation and maintenance of facilities	2.5	2.6	3.9	4.3	4.7	5.2	5,9
Demand[3] for biomass and biofuel	2.6	3.6	5.6	6.1	5.6	4.9	5,6
				in 1,000 persons			
Gross Employment	194	236	277	322	340	367	382

[1] Preliminary figure. [2] From manufacturers based in Germany. [3] Demand effective in Germany.

***Sources*: O'Sullivan et al. (2012), O'Sullivan et al. (2011) and Lehr et al. (2011).**

Companies in the RE sector in Germany have profited considerably over the last several years from investment in Germany and from the rising demand for renewable energy facilities worldwide. These companies are now established as an important economic sector. Sales (including the export of complete installments and of components) have rather steeply increased from €8.6 billion in 2005 to €24.9 billion in 2011, which puts the development in line with the growth seen for investment in renewable energy overall. Accounting for 43% of all sector sales in 2011, photovoltaic manufacturers were in the lead, followed by manufacturers of wind energy installations with 33% and those of biomass heat and power plants with 9%.

The strong rise of total economic activity has also resulted in considerable employment in the area of RE in Germany. We apply input-output analysis to estimate gross employment from RE expansion.[1] Applying the static open input-output model RE related expenditures are transformed into induced gross output, a method usually called imputation analysis in input-output literature. In a second step the employment requirements to produce this gross output are calculated using sectoral labour coefficients, which are defined as labor input per unit of gross output. It should be noted that by applying input-output techniques not on only the direct labor content for the production of RE goods is calculated but in addition also the indirect labor content of all products and services with enter the production process as intermediate goods (employment in supporting industries).

We include the following categories of expenditure:

(i) investment expenditure for new RE facilities (including exports)
(ii) operation and maintenance expenditure of existing RE facilities
(iii) expenditure for purchases of biomass and biofuel
(iv) expenditure for public funded research & development and administration.

It should be noted than only the part of expenditure is taken into account which is effective as domestic demand; this means imports for final demand use have to be excluded.

Estimation of gross employment from RE according to this method yields a total of 381,600 persons in 2011 (preliminary result). Out of this total 242,000 jobs are related to investment expenditure (including exports), 75,800 jobs are related to operation and maintenance and 54,200 jobs are related to fuel supply activities. Looking at the distinct RE technologies the largest number of jobs can be accounted to photovoltaics (110,900 jobs) followed by onshore wind (82,500) and biogas (33,800). Expenditure for public funded research&development and administration accounts for 9,600 jobs in 2011.

[1] Studies on the gross employment effects have been conducted for other countries, e.g. the UK (Esteban et al., 2011), the U.S. (Kammen et al., 2004; Wei et al., 2010) and the EU (Blanco and Rodrigues, 2009, Ragwitz et al. 2009). Except for Ragwitz et al. 2009 these studies do not use I-O methodology but other methods like surveys (e.g., Blanco and Rodrigues, 2009)or employment factors like the number of persons required to manufacture, install and operate a MW of a facility (Wei et al., 2010; Esteban et al. 2011).

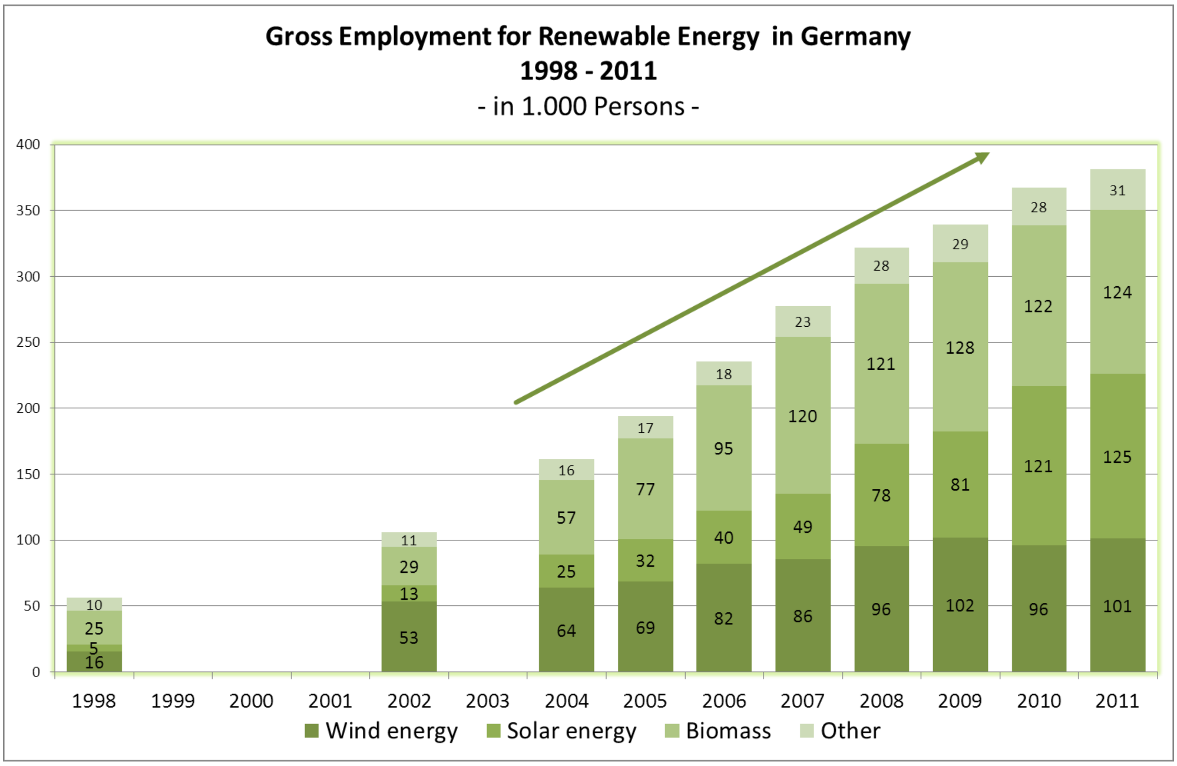
Table 2: **Employment from RE in Germany 2011.**

	Jobs provided by investment (incl. export)	Jobs provided by maintenance & operation	Jobs provided by fuel supply activities	Total no. of jobs in 2011	Total no. of jobs in 2010
Onshore wind	74,700	17,800		**92,500**	89,200
Offshore wind	7,900	700		**8,600**	6,900
Photovoltaics	103,300	7,600		**110,900**	107,800
Solar thermal	9,500	2,600		**12,100**	11,100
Solar thermal power plants	2,000			**2,000**	2,000
Hydropower	3,200	4,100		**7,300**	7,600
Deep geothermal	1,100	300		**1,400**	1,300
Near-surface geothermal	9,400	3,400		**12,800**	12,000
Biogas	21,900	14,100	14,600	**50,600**	35,100
Stationary liquid biomass	0	1,600	700	**2,300**	2,900
Small-scale biomass plants	7,300	15,000	11,500	**33,800**	36,400
Biomass-fired heating / power stations	1,700	8,600	4,200	**14,500**	24,500
Biofuels for transport			23,200	**23,200**	23,100
Subtotal	242,000	75,800	54,200	**372,000**	359,900
Publicly funded research/administration				**9,600**	7,500
Total				**381,600**	367,400

***Source*: O'Sullivan et al. (2012).**

Looking at the development of gross employment from RE in Germany over the last years (figure 4) a considerable and stable increase can be noted. Looking at broad RE categories like wind energy, solar energy and biomass have dominated the development of employment, while the other RES (e.g. hydropower and geothermal) play only a minor role. The share of biomass in RE employment is influenced by the fact that it is the only type RES for which fuel supply generates employment.

Figure 4: **Trends in gross employment from RE in Germany**.



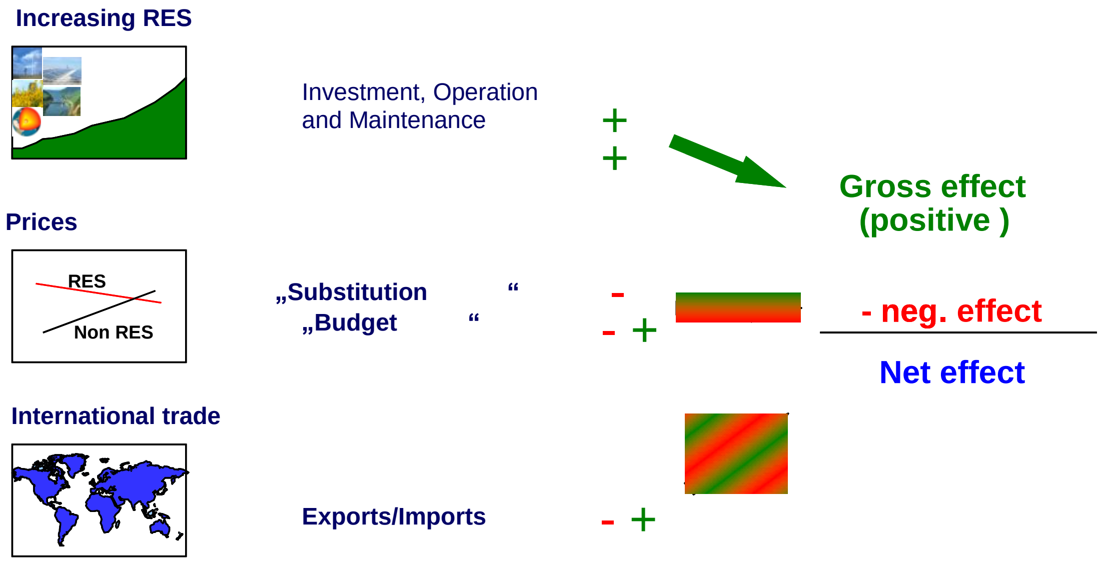
Sources: O'Sullivan et al. (2012), O'Sullivan et al. (2011) and Lehr et al. (2011); calculation of DIW

4 Net economic impact of RE expansion in Germany

The overall economic impact of increasing the contribution of RE to energy supply is the outcome of multiple interacting and counterbalancing mechanisms. To address the question of net economic effect we have to rely on disaggregated econometric modeling and scenario analysis. The basic approach is to compare the model outcomes of different runs of appropriate simulation models. The usual practice is to compare a policy driven simulation run (e.g. RE expansion driven by policy measures) to a simulation run representing a reference or base scenario (no policy scenario). The differences in model outcome between policy simulation and reference simulation are usually understood as the economic impact of the measures under investigation.

When discussing the economic impulses of RE expansion which have a likely impact on the overall economic outcome the following items and mechanisms are usually under investigation (see figure 5). Expenditures for new investment in RE facilities as well as the expenditure for operation and maintenance of RE facilities have a positive demand effect on the respective industries. These expenditures show also up when calculating the (positive) gross employment effect (see chapter 3).

Figure 5: **Economic impulses and potential effects of RE expansion on employment.**



Source: Lehr et al., 2011.

Potential negative impacts of RE expansion on the economy originate from two different sources: firstly, investment in renewable energy technologies displaces investment in fossil fuel technologies such as coal fired power plants or oil fired heating systems. This substitution effect leads ceteris paribus to a reduction in demand in the respective economic sectors. The second negative effect comes from additional costs of RE systems (compared to fossil or nuclear based systems). These additional costs add to the energy costs of households and firms. Germany supports RE electricity with a feed-in tariff, which leads to electricity price increases for households and firms according to a defined burden sharing process. This so-called budget effect reduces ceteris paribus the available budget for other expenditures having a negative demand effect in sectors which rely on private (household) demand. Due to learning curve effects for RE and increasing prices for fossil fuel the budget effect may reverse when RE expansion incurs even lower costs than conventional energy supply.

Importantly, these economic impulses will trigger second-order effects which affect employment and growth of the overall economy, but also the relative importance of various sectors, i.e. the sectoral structure of the economy. Due to different income elasticities of demand, for example, the budget effect will influence production differently by sector.

Likewise, increasing energy prices will primarily hurt energy intensive industries. Hence, in order to fully assess the impact of RE expansion strategies on the economy, the analysis needs to account for the interrelated and counterbalancing effects in an empirical model of the economy which also provides insights on sectoral effects in the economy.

This calls for the application of a disaggregated econometric model. For the investigation of the economic impacts of RE expansion the economy-energy-environment model PANTA RHEI (Lutz et al., 2005, Meyer et al. 2012) has been employed in several studies for Germany (Lehr et al., 2008, Lehr et al. 2011, Lehr et al. 2012.). PANTA RHEI is the environmentally extended version of the econometric simulation and forecasting model INFORGE (Ahlert et al., 2009). The model includes an input-output part according to accounting framework of national accounts (SNA). The input-output structures for RE sectors as described in chapter 2 are consistently integrated in PANTA RHEI.

A second disaggregated econometric model using the RE input-output sectors described in chapter 2 is the Sectoral Energy-Economic Econometric Model (SEEEM), also applied to evaluate the net economic impact of RE expansion in Germany (Blazejczak et al., 2011). SEEEM is based on the well-established macro-econometric multi-country model NiGEM (National Institute Global Econometric Model)[2]. Most OECD countries are represented with a full country model while smaller countries or blocks of countries such as OPEC are modeled in a more parsimonious manner. The country model for Germany in NiGEM has been substantially modified and expanded to suit the needs for investigation of RE expansion in Germany, in particular integrating a detailed sectoral module of the German economy following input-output approaches.

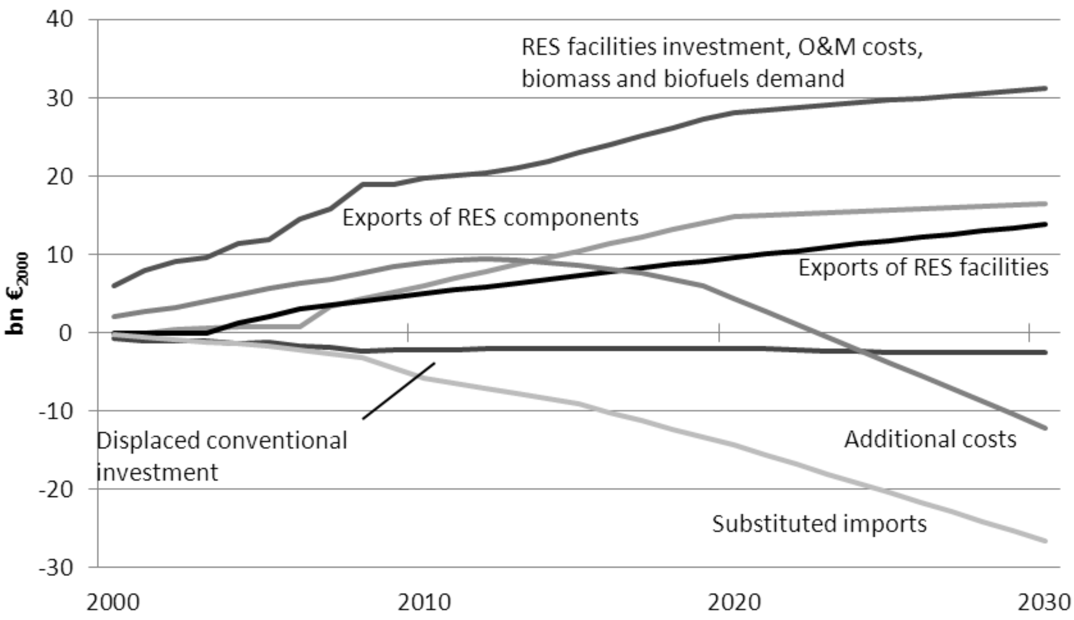
Figure 6 depicts – only as a generic example – the assumed paths of discussed economic impulses following the assumptions as depicted in *Leitstudie 2009* (BMU, 2009)[3] for the RE expansion scenario from 2000 to 2030. The impulses include investments, O&M costs, demand for biomass and biofuels, and exports of RES facilities and components. Only investments, O&M costs and exports from domestic production are included. Further

[2] http://nimodel.niesr.ac.uk/, accessed May 5th 2012..

[3] Leitstudie 2009, which we draw upon in this example, underestimates the strong deployment of photovoltaics that has taken place in the years 2009 to 2011. The economic impacts of faster deployment of PV are investigated by PANTHA REI simulations in Lehr et al. 2011.

impulses consist of displaced investments in conventional energy technologies, substituted imports of fossil fuels and additional costs.

Figure 6: **Generic example: Economic stimuli of the RE expansion scenario in billion euros** (constant prices of 2000)**.**



Sources: Calculations of DIW Berlin (Blazejczak et al. 2011) based on BMU (2009).

As mentioned before the net economic balance of the various effects associated with a RE expansion strategy is obtained by applying model-based scenario analyses. In both model applications (PANTA RHEI and SEEEM) the reference scenario is designed as a counterfactual scenario without any renewable deployment in Germany (therefore coined NULL scenario).

A variety of RE expansion scenarios under different assumptions has been simulated and analyzed in the last years for Germany (Lehr et al., 2008, 2011, 2012; Blazejczak et al. 2011). It is not possible to present results in all detail, so that the focus will be on giving some indications which assumptions are most sensible for the net employment effects. In general it can be stated that for the majority of scenarios simulated with PANTA RHEI the net employment effect tends to be positive, roughly speaking in an order up to 150,000 jobs in

2030.[4] In general the net effect becomes larger with time. Only under unrealistic pessimistic assumptions for exports (no increase at all for German RE exports from 2007 levels) the net employment effects becomes negative. Having different assumptions about the long term price path for fossil energy sources has some influence on the net employment effect. A higher price path for fossil energy sources correlates with higher net employment as under these conditions the additional cost burden of RE expansion is lower; vice versa a lower price path correlates with lower net employment due to the higher cost burden of RE expansion. Different PV diffusion scenarios have only slight impact on the net employment effect, although the highest net employment effect arriving at a little more than 250,000 jobs in 2030 is yield under the assumptions of high PV expansion, high exports and the high price path for fossil energy sources.

Simulations with SEEEM (Blazejczak et al. 2011) underpin the overall positive net economic effects of RE expansion in Germany. RE expansion corresponds with higher GDP growth and higher investments and private consumption compared to the NULL scenario. The impact on employment depends on assumptions about the flexibility of the labor market. Under assumptions of more flexible labor market conditions, namely assuming activation and retraining schemes to avoid mismatch of qualifications, the higher GDP growth translates in higher employment (up to 250,000 jobs in 2030). Under unchanged labor market conditions the higher GDP growth translates to a large extent in higher labor productivity so that net employment effect is positive but small.

5 Conclusions

As many other countries Germany follows a RE expansion strategy for climate change mitigation and other economic reasons. Looking at the dynamics of RE technology diffusion the country is in a frontrunner position.

We demonstrated that using the input-output scheme as unifying analytical framework to represent RE industries in a sectoral context allows to address different questions and to apply

[4] Some other studies like Frondel et al. 2010 doubt the existence of long-term positive net employment effects. In an older study Hildebrand et al., 2006 came to the conclusion of positive short-term but negative long-term net employment effects.

different models, namely to analyze the gross employment effect and the net employment based on a jointly used data set.

As RE activities already represent an important and growing economic factor in Germany, the gross employment for RE amounts to 380,000 jobs in 2011. A variety of simulations demonstrate that the long term net economic impacts of RE expansion tend to be positive. In the period until 2030 net employment is expected to be in the positive range up to around 150,000 jobs. The scope of positive effects depends strongly on different scenario assumptions. Important factors are the future growth of global RE markets, especially to what extent German companies can participate in these markets via exports, the future prices of fossil fuels (influencing the additional costs of RE) and some other economic parameter and institutional settings.

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