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Measuring the cost of renewable energy in Germany

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ABSTRACT

Electricity generation from renewable energy is increasing globally. However, in most electricity systems this growth comes at a price in the form of increased costs. This paper quantifies the costs for renewable energy installations built in Germany between 2000 and 2011. Our analysis sheds light on the 'Energiewende' in Germany, which is a front runner in the worldwide renewables rollout. To evaluate cost, benefits and policy instruments, the methodology can also be applied to other countries.

1. Introduction

Electricity generation from renewable energy sources (RES) is increasing globally. Despite RES' benefits, it also increases electricity production costs, as RES technologies are not yet competitive in most electricity systems. RES plant operators in many countries receive payments above the wholesale electricity price to compensate for this cost disadvantage. The resulting cost increase can be quantified as an important step towards a cost-benefit analysis of RES. This paper presents a methodology to quantify these costs and applies it to the German electricity market.

Germany has seen – both in relative and absolute terms – one of the highest increases in RES generation worldwide. In 2011, Germany installed about 25 GW of photovoltaics (about 50% of total European capacity and three times the capacity installed in Asia) (IRENA, 2015). In the same year, the German wind capacity was about one-third of the total European wind capacity. The annual capacity increase of wind and photovoltaics in Germany between 2000 and 2011 was more than 4.000 MW per year. This is the highest per-capita value worldwide. As a consequence, the share of RES in German gross electricity consumption increased from 6.2% in 2000 to 20.3% in 2011 (FMEE, 2016).

However, this increase came at a cost. In 2011, more than 80% of RES generation received additional payments specified within the Renewable Energy Sources Act (RESA) (AGEE-Stat, 2016). The first version of this Act was implemented in 2000. Under RESA, RES plant operators receive a guaranteed payment for every produced MWh for 20 years (plus the remaining calendar year of installation).[1] Total payments to RES operators amounted to more than €16 bn. in that year.

In this context, many people ask how much the promotion of RES – in Germany and beyond – will cost. As the German so-called "Energiewende" ("energy transition") policy is globally observed and discussed, the German example is not only relevant to consumers in Germany but also to those in other countries. Increasing consensus on the necessity of additional measures to tackle climate change may accelerate worldwide growth in RES even further. Hence, many countries may follow the Energiewende in the coming years and may profit from thorough analyses of the German experience.

The paper is structured as follows: Chapter 2 gives a brief overview of recent international studies related to the economic effects of the promotion of RES. Furthermore, we give evidence of the substantial international debate, especially concerning the benefits flowing from RES, and describe different methodological approaches to monetize economic effects. Following our review, we develop our methodological approach. Chapter 3 gives information on the data used in our cost calculation, describes our assumptions and explains our methodological approach. Chapter 4 gives our monetized results, evaluating the costs of RES in Germany, while Chapter 5 discusses the results and brings the main findings into context.

2. Literature review

A large amount of literature discusses the benefits and costs of the promotion of RES on a regional, national, or even global level. However, the majority of these articles seem to analyze benefits in more detail than costs. Moreover, the numbers and even the composition of elements to consider differ significantly among the studies.

Most researchers agree that the mitigation of climate change is a key reason for the promotion of RES (see e.g. Arvizu et al. 2011,

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[1] This relatively long period is intended to correlate to the technical lifetime of the RES installations. This duration is also in line with the economic literature (see e. g. Fischer and Newell, 2008)

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Schmalensee, 2012, Fell and Linn, 2013, Edenhofer et al., 2013b, Murray et al., 2014, Figueres et al., 2017). Even to that end, economists specify that the underlying mechanism of replacing fossil fuels with CO_2-free solar or wind power does not always reduce emissions, in particular in the context of additional climate protection instruments: among several others, Schmalensee (2012) argues that RES promotion in the context of a CO_2 cap-and-trade system may "free" certificates to be used for additional coal generation (instead of gas). Other proposed benefits of RES expansion are even more controversial. Based on an extensive literature survey, it has to be concluded that there is no established methodology to quantify the costs and benefits of RES (or even what costs and benefits to include in the assessment). On the contrary, there is an ongoing, lively scientific debate on the subject. For example, Morris et al. (2012) discuss a RES-induced reduced energy dependency for the US market while Borenstein (2012) argues that non-environmental benefits are prominently used in public policy discussions, but "are generally much less persuasive." Edenhofer et al. (2013a) discuss the challenges of multiple "co-benefits" of RES in the context of overcoming climate externalities. They finally propose "[focusing] on climate change as the main argument for RE policy intervention." To make matters even more complicated, McCollum et al. (2013) argue that benefits of RES are interdependent and propose emphasizing research on "synergies between the multiple objectives for energy sustainability."

Within this challenging setting, several papers quantify both costs and benefits in different regions and countries. Ortega et al. (2013) conduct a cost-benefit calculation for the Spanish market concentrating on four main RES technologies. They quantify the benefits of a reduction of CO_2 emissions and also of decreased fossil-fuel imports for the Spanish energy sector. The costs considered are the feed-in tariff payments. The authors argue that they were not able to include additional components for costs and benefits because of a lack of data. The results show benefits exceeding costs for wind onshore, while costs are higher than benefits for photovoltaic systems. Overall, costs of RES support for the years 2002–2011 amount to €22 bn, whereas the calculated benefits are between €12.5 bn and €19.7 bn, depending on scenario assumptions. Likewise, Burgos-Payán et al. (2013) calculate for the Spanish case both the costs and benefits of RES integration, such as positive effects on the gross domestic product, the environment, human health and employment (in different units). They show that the premium for the renewable generators for the years 2008–2011 paid by the consumers amount to €18.4 bn. However, the authors reason that summing up over all four years, the savings for consumers, through price reductions due to RES and eventually other reasons, are greater than the costs that RES introduces. The assumed benefit by RES has a value of €2.1 bn. Zhao et al. (2014) use data of subsidies for Chinese renewable support instruments, calculating the costs of those policies. From the authors' perspective, benefits consist of environmental benefits, guaranteeing China's energy security by increasing renewable energy production, technological innovation, and economic development. However, the authors did not quantify the last three benefits. Krozer (2013) analyzed costs and benefits of RES for the case of the European Union for two different time periods (1998–2002 and 2003–2009) with respect to both high and low oil prices. He concludes a net benefit of renewable support because of assumed higher electricity prices in a case without RES support policies.

For the German case, Krewitt and Nitsch (2003) state in an early stage of the RESA that economic benefits and decreased environmental impacts outweigh the costs for the promotion of RES. The authors try to monetize effects wherever reasonable. Despite mentioning uncertainties and assumptions, the authors conclude that the avoided external costs by RES in the year 1999 was as high as €0.31 bn (year 2000: €0.52 bn), while the compensation for RES was €0.26 bn (year 2000: €0.49 bn). The authors further argue that the RESA "was not designed as an internalization instrument, but follows a range of different targets." Marcantonini and Ellerman (2015) quantify CO_2 abatement costs for the German market, focusing on wind and photovoltaics for the years 2006 to 2010. The authors calculate a renewable carbon surcharge, which consists of the net costs of the renewable technologies related to CO_2 emission reductions. Additionally, they quantify an implicit carbon price, simply adding historical annual average prices of EU ETS certificates. They conclude that German spending on the two renewable energy technologies was significantly greater than the observed prices for EUA certificates. They calculate that the average carbon surcharge for wind for the years 2006 to 2010 was 45 €/tCO_2 and the carbon surcharge for photovoltaics was 537 €/tCO_2. Furthermore, they do not value the reduction of wholesale electricity prices as a cost saving or benefit by RES partly because those savings are already included in fuel cost savings (cf. Burgos-Payán et al., 2013). Frondel et al. (2010) "critically review" costs and a selection of benefits, e.g. energy security, occurred with the implementation of the German *RESA*. The authors calculate costs for the period from 2000 to 2008 (estimating further costs for the years 2009 and 2010) for photovoltaics and wind. Cumulated real net costs will reach between $€_{2007}$ 11.2 bn and $€_{2007}$ 19.8 bn for wind, and $€_{2007}$ 34 bn for photovoltaics by 2008. Consequently, the authors argue, photovoltaics are cost-ineffective for climate protection. Furthermore, they doubt that there will be a net increase in employment in Germany because, for example, there will be increased electricity prices and job losses in specific industries. Contrary to that conclusion, Lehr et al. (2012) argue that almost all scenario results calculated by macroeconomic model show positive net employment effects in Germany for renewables in the energy sector. However, the results are highly sensitive to the assumptions made. Blazejczak et al. (2014) calculate macroeconomic and sectoral effects of the renewable energy expansion between 2000 and 2030 for Germany with the help of an econometric top-down model. The authors argue that the central goals of the energy transition are the reduction of environmental impacts and the improvement of long-term energy supply security. The model shows outcomes for gross output, gross added value, and employment. Results show that the German GDP will have increased by 3% by 2030 because of the deployment of renewable energies. This is due to lower fuel imports and increased export of renewable energy components. The model shows a positive but near zero net employment effect. With the help of German household micro data, Neuhoff et al. (2013) evaluated the impact of the renewable electricity support for the years 1998, 2003, 2008, and 2010. They further use this data for predicting the outcome for the year 2013. For the costs of RES promotion, the authors conclude that consumer spending for electricity will increase to 2.5% in 2013, of which 0.5% is due to the RESA surcharge. Furthermore, with respect to the distribution of costs, the economic burden placed on low-income households is significantly higher than on other income groups.

Given the issues in the published literature, the approach of this paper is to avoid controversial and hard-to-monetize elements of costs and benefits from the promotion of RES. We therefore use a less-controversial and more readily quantifiable approach for the costs of the promotion of RES in Germany. We argue that the costs from the promotion of RES are the difference between the subsidies paid within the framework of the feed-in tariff and the value of the electricity produced on the market.

3. Data, assumptions and methodology

The total RES cost obligation comprises both historical cost realizations (which are published) and estimated future payment obligations for existing plants. We estimate total aggregated additional costs of these RES power plants (*RESC*) with Eq. (1):

$$RESC = \sum_i \sum_j \sum_k c_{i,j,k} h_j \cdot (fit_{i,j,k} - p_k\, mvf_{j,k}) \frac{1}{(1+q_k)^n} \qquad (1)$$

In the equation, c denotes the installed capacity (in MW) of