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The influence of spatial effects on wind power revenues under direct marketing rules



ENERGY POLICY

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HIGHLIGHTS

- Germany couples feed-in tariff for renewable energies to hourly market prices.
- Analysis of position of wind turbines on relative revenues in EUR/MW.
- Quantification of locational effect for policy makers and investors.

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ABSTRACT

In many countries, investments in renewable technologies have been accelerated by fixed feed-in tariffs for electricity from renewable energy sources (RES). While fixed tariffs accomplish this purpose, they lack incentives to align the RES production with price signals. Today, the intermittency of most RES increases the volatility of electricity prices and makes balancing supply and demand more complicated. Therefore, support schemes for RES have to be modified. Recently, Germany launched a scheme which gives wind power operators the monthly choice to either receive a fixed tariff or to risk a – subsidized – access to the wholesale electricity market. This paper quantifies revenues of wind turbines under this new subsidy and analyzes whether, when and where producers may profit. We find that the position of the wind turbine within the country significantly influences revenues in terms of EUR/MWh. The results are important for wind farm operators deciding whether electricity should be sold in the fixed feed-in tariff or in the wholesale market. However, no location is persistently, i.e., in every calendar month of the year, above the average. This limits the effect of the new subsidy scheme on investment locations and long term improvements in the aggregated wind feed-in profile.

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1. Introduction

The promotion of electricity generation from renewable energy sources (RES) is a key element of the European energy policy. As of today, without additional subsidies electricity generation from RES cannot economically compete with generation from other sources (especially thermal power plants). Hence, politicians in many European countries, including Germany, decided to subsidize RES-generation with feed-in tariffs.

In this paper, we focus on the subsidization scheme of Germany and on German wind power generation. Wind power is one of the largest and most promising sources of renewable energy within the country. In Germany, feed-in tariffs are specified in the Renewable Energy Sources Act (RESA). These feed-in tariffs are the main incentive to build renewable energy plants as they guarantee a revenue for every unit of energy produced by renewable technologies. The act was established in 2000 and successfully increased the share of energy generation from wind and other RES in Germany. For example, at the end of 2011 a total of about 22 000 wind turbines was installed. Electricity generation from all RES amounted to 20% of the total electricity consumption in Germany in the first half of 2011. However, increasing shares of RES led to new challenges, especially in terms of integrating RESgeneration in the conventional wholesale electricity market. In a system with fixed feed-in tariffs, RES operators have no incentive to reduce output, although, e.g., wind plants are often able to do this at low costs. If an increasing share of supply – in addition to



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large parts of demand – is price inelastic, the remaining part of the market (i.e., mostly thermal generation capacity) has to balance supply and demand. Hence, price volatility increases. Without additional flexibility, the market may not even clear during certain hours as the inelastic available production from wind and other price inelastic sources may exceed desired demand. Furthermore, problems might also arise in the opposite case when price inelastic generation from RES and remaining thermal capacity is too low to cover demand.

Various possible solutions for these challenges are currently being discussed. One approach is an improved demand-side management (i.e., increasing the price elasticity of demand). In addition, available storage capacity could be increased. Furthermore, grid extensions could increase the market, thus allowing for more balanced supply and demand profiles. Another interesting idea, from an economic perspective, is to bring RES closer to the wholesale market, with the aim of increasing the price elasticity of supply. These challenges will become even more important in the future, when RES shares increase further. The current political goals for future shares of RES in the total electricity production are 35% in 2020, 50% in 2030 and 80% in 2050.¹

Consequently, the German parliament passed a new version of the Renewable Energy Sources Act (in the following called RESA₂₀₁₂) which addresses these aspects. The act became effective January 1st, 2012. One key aspect of $\ensuremath{\mathsf{RESA}}_{2012}$ is an improved direct marketing approach as an alternative to the feed-in tariff. The goal is to set incentives to sell electricity generation from RES directly in the wholesale electricity market in order to link the produced energy to price signals. The general idea of RESA₂₀₁₂ is that electricity generation from RES receives the wholesale electricity price. As this will not cover RES total costs (and is below current earnings in the feed-in tariff), an additional subsidy is paid to compensate for the difference between feed-in tariff and wholesale market prices. This subsidy is called 'market premium'. The market premium a wind turbine receives is calculated retrospectively for each month and depends on the hourly feed-in profile of the particular station in the particular month and on the profiles of all other stations as a reference.

The short-run effect on the dispatch of wind is probably limited due to generation costs close to zero. However, some effect can be expected for the case when generation from renewables exceeds demand because the incentive to reduce generation from wind power is higher in the market premium system than it is for fixed feed-in tariffs. Additional positive aspects are possible in the long run in the market premium system as a location's payoff profile will be included in the investment decision in addition to the total energy output. More detailed discussions of the general efficiency or the compatibility of the incentives set for investing in renewable energy may be found in a variety of papers, e.g., the recent papers of Faúndez (2008), Mulder (2008), Marques et al. (2011), Cansino et al. (2010), Desrochers (2008) and Lipp (2007). A historical overview of incentive schemes for renewable energy in Europe is given in, e.g., Haas et al. (2011).

In this paper, we take the subsidy scheme in RESA₂₀₁₂ as given and focus on the quantification of the effects it will have on wind turbines. We analyze onshore wind turbines only, since the proportion of offshore wind parks is still very small and there is no historical data regarding offshore installations. In particular, we analyze the effect which the location of a wind turbine has on its revenue. As direct marketing in RESA₂₀₁₂ subsidizes a turbine's energy in \notin /MWh based on the nationwide wind feed-in profile, the relation of the turbine's power profile to the nationwide wind

feed-in profile is a significant additional revenue component under the new scheme. If a turbine tends to produce energy in times where the nationwide wind energy production is relatively low, i.e., if its power production is anticorrelated to the total wind power production, revenues will be higher than for a production profile which is in line with the nationwide production. Electricity prices and wind generation are negatively correlated in systems with a high wind penetration because a high wind generation replaces thermal capacity thus setting the price at a lower level. In times of low wind generation, prices are high but wind profits under proportionally. The production profile of a wind turbine is determined by the wind speeds at its geographical position. Therefore, the position of a wind turbine is decisive for the revenue potential of wind energy in RESA₂₀₁₂. In the short term, information on this revenue potential is valuable for the operators of 22 000 wind turbines currently installed in Germany. In the long run, it can be used as an input to quantify the incentive to build future wind turbines in locations with more valuable pay-off profiles and thus increase efficiency in the system.

To our knowledge, no other publication has analyzed this effect so far. It has been studied for some time, however, that dependencies (e.g., correlations) of wind speeds at distant locations affect the accumulated wind power production of wind turbines. Kahn (1979) systematically analyzed these effects for arrays of Californian wind farms of different sizes. In a recent study based on copula functions, Grothe and Schnieders (2011) analyzed dependencies of wind power positions in Germany. In this study, we go a step further and analyze the effect of the position (and the unit specific production profile) on a wind turbine's revenue under the subsidized direct marketing of RESA₂₀₁₂.

In a first step, we use hourly wind speed data from different locations to calculate the hourly electricity production that a reference wind turbine would have produced in a particular place. Then, we calculate the relative performance for a representative unit at each location based on these electricity production estimates, the nationwide historical total feed-in of all wind turbines, and hourly electricity prices for the 12 months period from July 2010 to June 2011.

However, as we are interested in making recommendations for the future, the question remains whether a good performance during the analyzed year was achieved by chance or was rather the result of a statistically significant negative dependence of the unit's feed-in with nationwide feed-in. Hence, in a second step, we analyze an extended period of observation from 2001 to 2011. Since no consistent dataset for nationwide feed-in exists (the four German TSOs started reporting nationwide data on 2009-10-29), we use our set of hourly wind data for the different locations to estimate the nationwide feed-in for the extended period of observation. Then, again using electricity production estimates for the different locations, the estimated nationwide feed-in and historic hourly wholesale electricity prices, we calculate the relative performance for all locations in the extended time period. We are thus able to estimate at which location (and in which season and month) the new scheme leads to systematically higher or lower revenues when compared to the fixed feed-in tariff.

The remainder of the paper is organized as follows: In Section 2 we review the German Renewable Energy Sources Act with special focus on wind energy. In Section 3 we introduce the methodology and data used in the paper. Descriptive tables regarding the data are listed in the appendix. Our empirical analysis is presented in Section 4. Section 5 concludes.

2. RES promotion under RESA₂₀₁₂

In the RESA₂₀₁₂, RES units can choose freely between two subsidy options on a monthly basis: the fixed feed-in tariff (defined in

¹ BMU/BMWi (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety/Federal Ministry of Economics and Technology, ed.) (2010): Energy Concept for an Environmentally Sound, Reliable and Affordable Energy Supply, Berlin. p. 5.

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