Renewable and Sustainable Energy Reviews 57 (2016) 7–15

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

The impact of renewables on electricity prices in Germany – An estimation based on historic spot prices in the years 2011–2013

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ARTICLE INFO

Article history:
Received 20 April 2015
Received in revised form
31 July 2015
Accepted 9 December 2015
Available online 1 January 2016

Keywords:
Energy economics
Renewable electricity
Merit order effect
Electricity market modeling
Generation capacity

ABSTRACT

Germany's public opinion and media usually attribute increasing electricity prices to the high share of renewables in the German power system. But average electricity prices at the European Energy Exchange dropped during the last years due to an excess of renewable energy. This study uses historic market data in order to quantify the effect of renewables on prices. Historic demand and supply curves from 2011 to 2013 have been used to reconstruct electricity prices under the assumption that no wind and PV would be available. The analysis reveals an astonishingly high increase of market prices up to 5.29 ct/kWh due to a lack of non-renewable power capacities. In 2013 the available conventional capacity would not have been able to cover the demand during 269 hours. The estimated maximum deficit of 5.6 GW is in good agreement to data published by the German grid operators. The discussion of the origin of this deficit leads to the conclusion that the current situation has not been caused by renewables. The liberalization of the European energy market established investment risks that hindered required investment a long time before the renewables boomed.

Contents

1. Introduction

The German Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz, EEG) initiated a widely unexpected rise of biomass, wind and photovoltaic installations. While its first version promoted primarily wind power and biomass CHP plants the first and second amendment in 2004 and 2009 encouraged additionally the installation of photovoltaics and biogas plants. The total installed capacity of wind power and photovoltaics increased from 35.7 to 76.6 GW between 2009 and 2014. The Renewable Energy Sources Act surcharge ('EEG-Umlage', i.e. 'EEG-surcharge') increased accordingly from 1.32 to 6.24 ct per kWh causing intense discussions that eventually reduced public acceptance of renewables [1,2].

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http://dx.doi.org/10.1016/j.rser.2015.12.003
1364-0321/

Different authors contributed the rising German electricity prices solely to renewables [3,4] and therefore propose new market models in order to promote the renewables market integration [5].

However, a direct link between high energy costs and renewables is not necessarily obvious and some authors consider the societal costs from Feed-in tariffs for renewables being "rather low" [6] or the financial burden being "overestimated" [7]. In fact, the levelized costs of electricity (LCOE) of renewable power generation dropped significantly during the last years and are meanwhile often comparable to electricity costs from conventional sources. The levelized costs of electricity (LCOE) from wind energy range already from 4 to 8 ct/kWh. Photovoltaic reached prices of 0.6–1.19 €/Wp for ground mounted systems [8]. Assuming 858 full load hours (German average for solar power in 2013) an interest rate of 5% and depreciation of 12 years provide an LCOE of 7.9 and 15.6 ct/kWh. Several German sites provide significantly more than 1000 full load hours and an LCOE below 7 ct/kWh therefore. Applying the same full load hours and interest rates to a combined cycle plant with natural gas prices of 3 ct/kWh, an efficiency of 60% and specific investment costs of 470 €/kW leads to electricity costs of 13.5 ct/kWh. Increasing the full load hours to 3000 h reduces these costs to 7 ct/kWh but this value still does not include maintenance and other operational costs. In the UK the construction of the new Hinkley Point C nuclear power station is planned to be subsidized with a 35 year inflation adjusted feed-in tariff of 92.5 GBP/MWh (2012 basis) representing 12.7 ct/kWh. Thus, renewables are meanwhile often competitive and no longer more costly than alternative sources. However, the Renewable energy sources (RES) support costs – the 'EEG-surcharge' – still has to pay for early renewable plants with much higher incentives.

By contrast, the impact of renewables on the electricity market process at the European Energy Exchange received low public awareness [7,9]. The last decade's price trend of the "Day Ahead" spot market changed and an excess of renewable energy caused decreasing mean electricity prices. Analysis of European Energy Exchange (EEX) spot market prices performed by [10] revealed savings of 7% average electricity prices for the period between July 2010 and July 2011 only from photovoltaics. In particular, the average daily maximum price dropped by 13%. The private households still have to pay significantly more for the EEG-surcharge (i.e. 22% in 2013) but the high ratio results from the fact that private households have to bear 35% of surcharge while the industrial sector only covers 30% in spite of a total consumption of almost 50% [7].

After Fukushima the German government decided to immediately shut down 8 of 17 nuclear power plants reducing the total installed capacity by 8.8 GW in 2011. Furthermore, the utilities did not commission enough conventional capacities such as coal and lignite fired power plants or combined cycles during this period to compensate this reduction. The total installed capacity of power plants >100 MW decreased from 74.590 GW in 2010 to 72.864 GW in 2013. Thus, shortages would have been likely without the substantial increase of wind and PV installations.

2. Literature review

A broad spectrum of literature exists on the influence of renewable energy generation on power markets. Electric power market, with its particularities due to the inherent properties of electricity, is the subject of an extensive theoretic model development to approach power system economics [11]. Fundamental models [12–15], financial mathematical models [16,17] as well as econometric time series models [18–21] are classes that are commonly used in short- and medium-term ex-ante modeling of electricity markets, while long-term modeling includes game theoretic approaches [22]. These modeling approaches are commonly combined in practice [23].

Since spot markets are widely accepted as reference price for electricity – in Germany approx. 40% of produced electricity is traded at day-ahead spot market of EPEX spot – the modeling of the determinant power plant fleet, the fuel prices and the load are key factors [21,24–26] for the predictive power of these models. Extensive work is also done on analyzing seasonal patterns, price spikes, volatilities and long-term behavior of spot markets [27,28].

Based on these models or empirically on historic data evaluations, several approaches exist to estimate the influence of renewable generation on electricity prices. The price reducing effect of a low marginal cost renewable electricity – commonly referred to as merit order effect – is widely accepted in its existence but the approaches for quantification are under discussion [29,30].

Hirth [31] provides an extensive survey on estimation of the market value of renewables. Main finding of his review are that market values of solar and wind power are reduced with penetration levels. This effect is more pronounced for solar than for wind market share and strongly depends on the evolution of the existing non-renewable capacity [32].

Assessing the German power market, a number of authors analyze price effects of renewables focusing on projections in order to predict ex ante future costs and electricity prices [33,34]. Naturally, significant assumptions, in particular regarding conventional and renewable generation portfolios, are required affecting the reliability of the forecast [35]. Considerable literature also apply historic market clearing price data (mainly based on EEX data) to estimate renewable influence ex post. Mainly, spot market settlement price and quantity are used to carry out linear regressions on significant influence parameters that e.g. represent marginal effect of additional renewable generation [36], but also the influence on EU-ETS (emission trading scheme) is quantified [37,38]. Some of these analyses restrict renewables to wind [39,40], others account for wind and PV or all renewables [41]. Sensfuss [42] includes in his analysis assumptions based on dynamic scenarios in order to account for changes in historic generation capacity.

The German market analysis shows wide spreading quantifications of the merit order effect, as shown in Table 1. Von Roon [43] for example estimated the price reducing effect of only wind feed-in to 1.08 ct/kWh already in 2008, summing up to a total wind induced merit-order effect of 5.3 billion euros. By contrast Sensfuss [42] develops a dynamic adaptation model of the generation portfolio, including decommissioning and conservation of capacities, resulting in an electricity price reduction of approx. 0.9 ct/kWh in 2012. Kopp [44] concludes, that due to the continuously increasing merit order effect, renewable energies are not able to refinance on spot markets in the future, even with generation costs that are competitive in comparison to fossil generation. Assuming a perfect prevision of all actors, Fürsch [45,46] simulates future merit order effects of up to 1 ct/ kWh in 2030. Without these idealizing assumption and realistic adaptability of generation portfolios, the authors estimate these effects to be far more pronounced. Paraschiv [47] concludes in her spot analysis based on a dynamic fundamental model, that market prices are reduced by increasing renewable generation, but that end-consumers still suffer a welfare decrease.

On the European level, numerous studies on market influence of renewables have also been published. Literature reporting an estimation of the merit order effect in ct/kWh is displayed in Table 1. O'Mahoney [48] estimates that price reduction due to wind generation in Ireland in 2009 sums up to 12% of the market dispatch and concludes an overall welfare increase, despite the subsidies. Huismann et al. [49] obtain clear evidence for