How renewables shape the future

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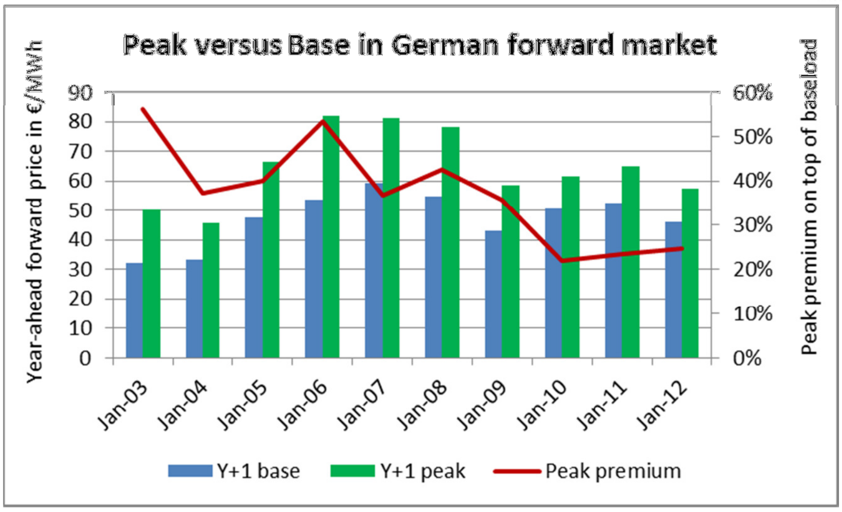
1 Introduction

In 2012, the German capacity of solar energy passed the 32 GW mark. The impact on the market prices are noticeable: summer prices go down, peak prices go down especially midday, and gas fired power generation plants have difficulty making money. In this article, we take a detailed look at how this is further going to shape future price levels. Whereas the market trades baseload and peakload products, we shift attention to the more detailed hourly price differences, reflected in hourly price forward curves (HPFCs). For example, we demonstrate that during day-time, an increase in the share of renewable production by 10 percentage points reduces power prices by 6.6%. During the night, the impact of renewables is even larger.

2 The fundamentals

Solar and wind are the primary renewable energy sources for Germany at the moment. They have zero or even negative marginal costs: whatever the power price level, the owners earn a guaranteed income (the feed-in tariff) and will always produce. This means that the flexibility to the system has to come from other elsewhere, the 'conventional' sources. That is mostly coal- and gas fired production. The easiest way to understand the impact of renewables on price levels, is to study a supply-demand curve. The supply curve, or merit order, is constructed by ranking the production plants from lowest to highest marginal costs. With increasing capacities of renewables, and depending on the weather conditions, the supply curves move to the right. This pushes the conventional sources out of the production and thereby lowers price levels.

For sure, market participants are factoring the renewable energy boom into their price levels. The forward spread between peakload and baseload used to be around 43% prior to 2009/2010, but has been around 20-25% in the past three years. This is quite a dramatic development for owners of gas-fired generation. And even for owners of pump hydro, who were expecting to benefit from unpredictable patterns in supply, times are difficult.



3 The impact of renewable production

Time-series graphs like the one shown in the previous chapter indicate that solar and wind generation have reduced power prices, and peak prices in particular. The market trades baseload and peakload, but what is more difficult to assess, is what future *hourly* price patterns will look like.

In order to incorporate the growing share of renewables in the hourly shaping of the forward curve, we need more precise methods than a graphical analysis. In fact, it is necessary to filter out the impact of other developments. For example, over the same time period of the German renewable boom, the economy has slowed down. And over the same time period, fuel prices have swung up and down. For this reason, a simple time-series analysis on the absolute price levels will not be very accurate. It is advisable to zoom in on small time intervals instead, such that the 'true' renewable effect can be filtered out from other general trends. In statistical terms: it is best to take first differences in order to make the time-series stationary.

We apply this logic to hourly price data for each hour h, consisting of:

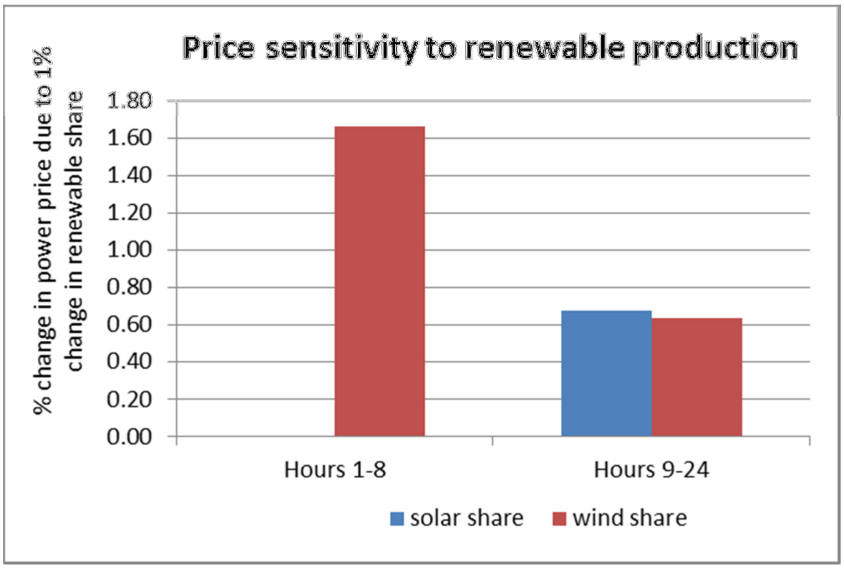
- P_h German hourly power prices, in €/MWh
- S_h German solar production, in GWh
- W_h German wind production, in GWh
- T_h German total production, in GWh

The power prices are from the daily auction at Epex, as quoted on EEX. The production data are from a couple of sources.

With these variables, it is possible to define various equations that capture a possible relationship between hourly power prices and renewable production. After some testing and common sense choices, a well-fitting equation is the following:

$$\Delta p_h = -\beta_1 \cdot p_{h-24} - \beta_2 \cdot \Delta s_h - \beta_3 \cdot \Delta w_h + \varepsilon_h$$

- We take 24 hourly time-steps, so look at the difference between hour 1 on day t to hour 1 on day t+1, from hour 2 on day t to hour 2 on day t+1, etc. This makes the analysis insensitive for the general intra-day (hourly) differences. The 24-hourly differences are denoted by the sign Δ.
- As primary dependent variable (left-hand side), the equation contains the change in the *natural logarithm* of the hourly power price. This is denoted by Δp_h. This price transformation corresponds with a merit order that has an exponential shape. It also gave better results than a regression on absolute price differences. Note that prices below 1 are set to 1, because otherwise the natural logarithm cannot be taken.
- As primary explanatory variables (right-hand side), the equation contains the change in the *share* of renewables in the total production mix (Δs_h and Δw_h). This normalizes the data and gave somewhat better results than taking the absolute production levels.
- An important control variable is the log price level from the previous day. This control variable captures the mean-reverting behavior of power prices: on a single day a price can be extraordinarily high, but generally trends to more moderate levels afterwards. It is part of almost any spot price analysis.
- As control variables, the equation furthermore contains dummies for Saturdays and Sundays (including public holidays). This is mainly because power prices tend to be lower on those days than on working days. For simplicity, the dummies are not shown in the equation.
- We perform this regression separately for the first 8 hours of the day, and the remaining 16 hours. This is because the impact of renewables appeared to be stronger during the night than day, most likely because then the demand is lower.
- Because the expected impact of all explanatory variables is negative, the regression contains minus signs.



All parameters of the equation are highly significantly different from zero, with t-values all above 20 (note 2 indicates significance at 95% level). The high R-squared of 20-23 % is another indicator that the data fits quite well to the specification. The parameters can be interpreted as follows:

- During the night, an increase in the share of wind production by 10 percentage points (e.g. from 15 to 25%), reduces power prices by 16.6% (e.g. from 30.00 to 25.40 €/MWh).
- During day-time and evening, an increase in the share of either wind or solar production by 10 percentage points reduces power prices by 6.4-6.8% (e.g. from 60.00 to 56.18 €/MWh).

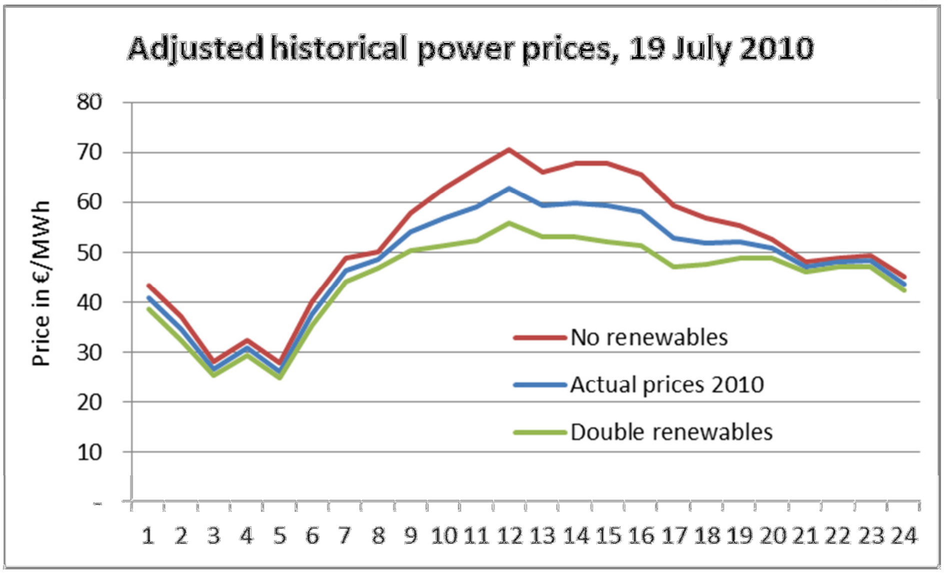
This information in itself is very interesting and can help traders to make better short-term price forecasts. In addition, we will take a more long-term view and assess how this price-renewable dependency affects the hourly price forward curve, HPFC.

4 Shaping the future

Forward curve building means that the available forward market prices are transformed into a continuous and accurate curve. For power, the end result typically has hourly granularity. The hourly shapes reflect likely differences between individual hourly power prices in the future. For example, between 0:00 and 4:00 in the night, prices tend to be lower than between 04:00 and 08:00, even though both blocks are offpeak. At the same time, the curves have to stay arbitrage-free relative to the current market quotes: the average of the HPFC over forward delivery periods are equal to the prices of the forward contracts.

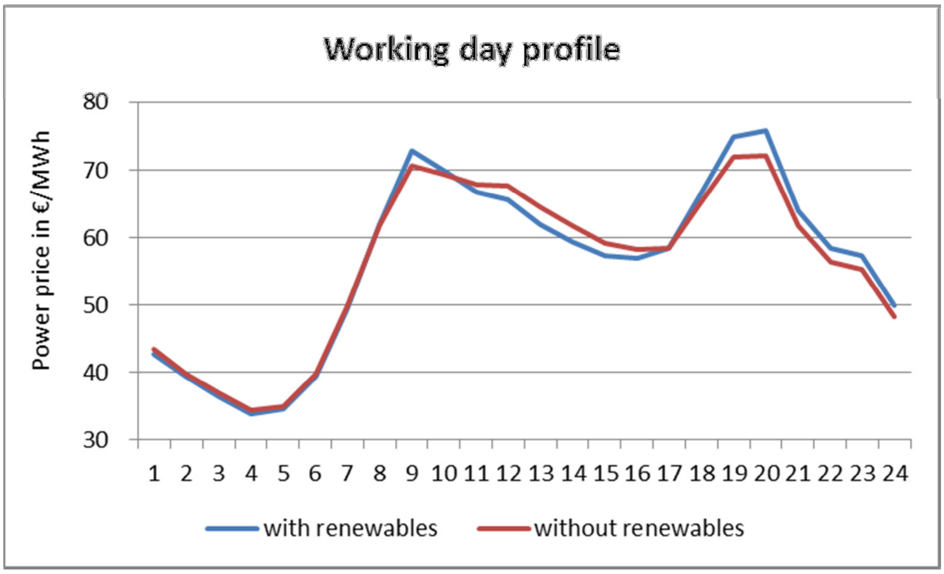
If renewable generation capacities were constant, past historical price patterns would be representative for the future. However, the share of renewables is growing, so typical hourly patterns in 2009 are already quite useless for predicting shapes in 2013. Using 2012 historical data would be better, but would not give us enough data and still be quite wrong for later years. As a solution, it is possible to generate 'new' histories of historical price data, consistent with future levels of renewables.

Market watchers expect renewable capacities in 2015 to be around twice as high as in 2010. It is possible to combine this information with the regression results: we create a hypothetical hourly spot price that would have been observed in 2010 if the renewable capacities of 2015 had already been in place. The new hypothetical prices are more spiky and can be used to shape the 2015 forward prices. Based on data from 19 July 2010, when there was quite a lot of solar production midday, the adjustment is shown in the next chart.



On a day with relatively a lot of solar production, prices during midday (11:00-17:00) are pushed down most. This leads to different patterns in the forward curve. In particular, it is realistic to assume that the general trend of renewable generation growth is incorporated in the peak and baseload forward prices in the market. A forward curve that is arbitrage-free will therefore especially exhibit lower prices during midday, but higher prices in the morning hours (8:00-11:00) and especially later in the afternoon (17:00-20:00) when demand is high and solar production low. Because wind is more evenly distributed over the day, more wind capacity has a relatively smaller influence on the hourly price forward curve.

How this eventually works out on the hourly price forward curve is visible in the next graph, showing an average working-day shape for 2018.



5 Conclusion

In this paper we presented a hybrid approach for shaping forward curves: our methodology combines fundamental information (about renewable production) with statistical analysis. The numbers shown have been estimated with around three years of German market data. We also tested with different time windows, but parameters were remarkably stable. Still, it is difficult to say whether the price response to renewables will generally decrease or increase. This will largely depend on policy decisions that try to keep enough flexibility in the power system, in addition to an increase in (non-flexible) renewable capacity.

Hourly price forward curves form the basis of pricing any non-standard profile. This can be a customer profile or e.g. the optimal production of a power station. With a consistent implementation of renewables in the forward curve building process, companies can price contracts and assets more accurately. Of course, inclusion of renewables in the forward curve building process is not the only important aspect. However, it is an important one, and we hope this paper is a practical contribution of how this can be achieved.