

HOW NUCLEAR POWER PLANTS IN SPAIN HAVE REACTED TO THE INTRODUCTION OF RENEWABLE ENERGY

Margaret Armstrong, Mines-Paristech, +33 140519313, margaret.armstrong@mines-paristech.fr
Asana Sasaki, Ecole des Ponts Paristech, +81 9035300295, asana.sasaki@gmail.com
Frederic Novel-Cattin, Renault, +33 176876426 frederic.novel-cattin@renault.com
Alain Galli, Mines-Paristech, +33 140519314, alain.galli@mines-paristech.fr

Overview

The introduction of renewable energy (notably wind and solar power) into the energy mix in Europe is causing massive problems for traditional power companies. According to a recent issue of *The Economist* [1], the market capitalization of the top 20 European utilities has dropped by \$1.3 trillion since 2008, with German companies being the most severely effected. E.ON's income from conventional power generation (fossil fuels and nuclear) has fallen by more than 30% since 2010 [1]. In this paper we investigate what companies are doing to become more profitable. Our hypothesis is that traditional power producers have subtly changed their bidding strategies for selling electricity on the day-ahead and intraday markets. We test this hypothesis using the bids by nuclear power-plants to sell electricity on the Spanish day-ahead market over the period from 2002 to 2012. The Spanish market was chosen because the individual bids made by each producer are available to the public, making it possible to track the evolution in each power plant's bidding strategy. Secondly, renewable energy accounts for 35% of the power generated in Spain, with windpower providing more than 18% [2]. We chose to focus on nuclear plants because even though there are only 9 of them in Spain, they contribute about 20% of the electricity production.

Just after the Spanish market was liberalized, nuclear power plants offered their production at a zero marginal cost. As more windpower came online, they started offering 5% of production at more than 90 euro per MWh. The solid line in Figure 1 shows the total amount offered by a typical plant in 2011 while the dotted line corresponds to the amount offered at zero cost. The difference was offered at 91.01 euro per MWh. We demonstrate that this apparently minor change has pushed the average day-ahead price up by about 1 euro per MWh, leading to an increase

of about 200M euro per year in the cost of electricity to consumers. These results have important implications for policy-makers and energy sector regulators, as well as for consumers.

Methods

In 2004, the Portugal and Spain created the Iberian electricity market. The day-ahead market is the main wholesale market. After receiving the offers to buy and sell power for each 1-hour time period, the power exchange aggregates them. The intersection of the two curves gives the market-clearing price and the associated volume. In addition to simple bids, sellers are allowed to submit complex bids with four types of constraints: indivisibility; load gradients; minimum daily income and scheduled stops. As can be seen from Figure 2, these have a marked effect on the market clearing price and volume. The fine grey and blue lines are the aggregate curves submitted by the sellers and the buyers. The thick red line corresponds to the bids to sell that were accepted (*casada*, in Spanish); the thick aqua line shows the purchase orders that were accepted. It is superimposed on the fine blue line. The market closing price (red circle) is much higher than it would have been without these constraints (blue circle). We use the term "theoretical price" to denote the intersection of the aggregate curves without taking account of the complex bids.

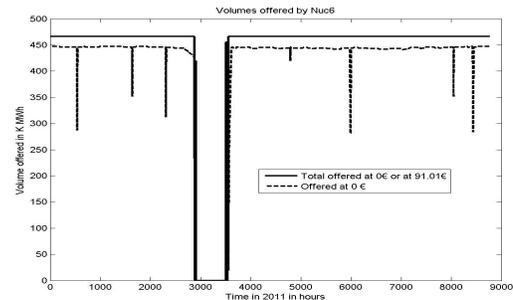


Fig 1: Volumes offered by typical nuclear producer in 2011, including 5% at 91.01€

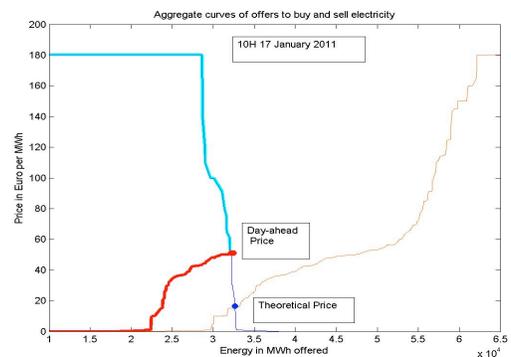


Figure 2: Aggregate curves of offers to buy & sell power on the Spanish day-ahead market at 10H on 17 January 2011. Note how much higher the market closing price is (red dot) compared to the theoretical price (blue dot)

Source: www.omie.es

The day-ahead price and volume are available from the exchange's website; the theoretical price is found by computing the intersection of the aggregate curves obtained using all the bids and offers which are also available on OMIE's data download section.

To assess the impact of offering 100% of the expected production at zero cost rather than 95%, we need to be able to estimate what the day-ahead price would have been. Having all the individual bids together with the bidders names, it is easy to determine what the aggregate selling curve would have been if the 5% offered at above 90 euros had been offered at the usual price, and hence determine the new theoretical price. The difficulty lies in working out what effect the four types of constraints would have had because while the bids are available on the internet, the constraints are not. Our first idea was to plot the day-ahead price versus the theoretical price and fit a regression line, and hence deduce what day-ahead price would correspond to the new theoretical price. Unfortunately there is too much dispersion for this to be effective. So we made the simplifying assumption that the ratio of the day-ahead price to the theoretical price would have remained the same as it is at present for that hour.

Results

This approach was applied to the data for the years 2010, 2011 and 2012; that is, for all 8760 hours in each year. Table 1 gives the average day-ahead price (top line) and the average of the estimated day-ahead price (second line). Knowing the volume of electricity sold during each hour, we computed the total cost of electric powersold via they day-ahead market, and likewise what the total cost would have been if the top 5% of the nuclear power had been offered at zero cost. The first amount corresponds to the revenue actually obtained by electricity producers in Spain whereas the second is our estimate of what it would have been. The difference between the two corresponds to the additional revenue generated by this bidding strategy. The amounts were about 200M euros per year for the three years considered. So this very simple and apparently innocuous strategy significantly increased the producers revenue.

Table 1 : Additional Revenue Generated by this Bidding Strategy

	2010	2011	2012
Average Day Price	37.0098 €	49.9198 €	47.2379 €
Estimated Day-Ahead Price If nuclear plants offered all Their production at 0€	36.0041 €	48.9930 €	46.0705 €
Total Cost of Electric Power	8805 M€	11053 M€	11190 M€
New Estimated Total Cost	8605 M€	10881 M€	10968 M€
Difference	200.2 M€	172.2 M€	221.6 M€

Conclusions

Ten years ago nuclear power producers in Spain offered all their production at zero cost. Now they offer 95% at 0€ per MWh and the remaining 5% at more than 90 € per MWh. So except for 2 hours in 2011 when the market price actually reached 91€, the plants produce at only 95% capacity but as they are available to produce if needed they are eligible for the capacity payment for the full 100%. As 5% of the production at zero cost is effectively removed, other traditional generators with higher marginal costs are brought online. We estimate that this adds 200M € (\$ 270 M) to the wholesale electricity cost in a perfectly legal way. Follow-up studies that are currently in progress on other types of traditional power-plants in Spain indicate that they have also developed strategies for enhancing profitability. We chose to focus on Spain merely because detailed data is available there. We believe that electricity producers in other countries have also developed bidding strategies for optimizing profits. In the absence of detailed data, it is much more difficult to demonstrate that it is occurring, and to estimate its effect on wholesale prices.

What view should we take on such practices? On the one hand, as McRae and Wolak [3] noted: *A firm's management has a fiduciary responsibility to its shareholders to take all legal actions to maximize the profits it earns from participating in the wholesale market.* On the other hand consumers have to pay the additional cost, which has an impact on the country's competitiveness. But whatever view one takes on the practices, regulators and policy makers, and the community in general should be aware of what is going on.

References

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