Fundamental shaping of Hourly Price Forward Curves (HPFCs) in the German Power Market

Industry contact person
Rikard Green,
Quantitative Analyst,
Energy Quant Solutions Sweden AB

Email: rikard.green73@gmail.com
Phone: +46 73-650 41 92

Appropriate student profile
The suitable candidate has a curious analytical mindset and a sound interest in quantitative methods/modelling and programming (Python (preferred) or R). It is an advantage if the candidate has an interest in the energy industry and the ongoing energy transition towards renewable generation technologies.

Project background and problem statement
EPEX SPOT is the German Day-Ahead (DA) power market where agents trade electricity for physical delivery for each hour of the coming day. By noon each day (t=0) the market participants submit their bids to buy or sell a given volume of electricity for each hour of the next day (t=1). The submitted buy and sell volumes are used (by EPEX SPOT) to construct hourly supply and demand curves, and (according to a complex optimization algorithm) the intersection of the curves determines the hourly DA-prices. See https://www.epexspot.com/en/basicspowermarket#day-ahead-and-intraday-the-backbone-of-the-european-spot-market for a pedagogical description of the prices calculations.

The DA-price profile typically follows a pattern over a 24-hour period and the pattern is intimately linked to the supply and demand for each hour. E.g., power demand is typically lower for the off-peak hours (night hours) and higher for the peak-hours (day hours), which leads to lower prices during the night and higher during the daytime. The same logic holds for the supply side, i.e., if supply is high (for example due to high wind speeds, leading to increased wind power production) the DA-prices will decrease.

Major Energy companies typically employ a so-called Hourly Price Forward Curve (HPFC) for pricing and valuation of deals and positions. The HPFC is of high importance since it handles significant economic values for the company. The HPFC is constructed in two distinct steps, where this Master thesis will focus on (parts of) step one.

1. Shaping: Estimation of an hourly future looking shape vector that accounts for all periodicities such as the hourly profiles (for different day types etc) and the yearly slowly evolving season (summer vs winter). Note: this thesis will focus entirely on the hourly profiles and hence exclude the yearly season from the analysis.

2. Calibration: The shaping vector (from step 1) is subsequently calibrated to current traded forward prices. This way we have a pricing model with historically estimated shapes,

calibrated to the latest traded future looking forward prices. Note: this thesis will not be concerned with the calibration step.

Solar and wind are important renewable energy sources for Germany now, and their intermittent nature makes it particularly interesting to analyse how they impact the hourly profiles in the German DA power market. This would be the initial core research question of the thesis. How do the renewable power technologies (wind/solar) impact the hourly profiles in the German DA-market?

Secondly, once the relation between the renewable production and hourly price profiles have been established, the student will develop a Machine Learning regression model to predict future hourly profiles in terms of renewable production forecasts. Hence, the model should use renewable production data as features (X) in order to predict the hourly DA target profile (y). There are no restrictions on the algorithmic choice, although XGBoost, ANN or SVM might be suitable alternatives.

Finally, if time allows, the project is not restricted to renewable production, but also conventional production (such as e.g., gas fired power plants) could be included in the analysis/model.

Literature and data

Paper 1:
The paper is gives an excellent first analysis of the German market with a view towards HPFC shaping.
Cyriel de Jong, Hans van Dijken and Emiliyan Enev (2013), KYOS Energy Consulting, "How Renewables Shape the Future"

Paper 2:
The paper develops a basic HPFC shaping regression model with renewables for the German power market.
Vivien Beolet, Cyriel de Jong, Emilian Enev (2014), "Improved hourly shaping using renewable production information"

Paper 3:
This paper develops a HPFC shaping model for the Nordic market that depends on hydrological information (related to hydro power production). Hence, the problem statement in the paper is very similar to this project, however for another market (Nordic instead of Germany) and other production data (hydro instead of renewables).
Green, Rikard (2014): "A Power Market Forward Curve with Hydrology Dependence - An Approach based on Artificial Neural Networks"

Data:
Production, consumption, and price data for the German power market
Data period: 20180101 - 20211231.
Data source: https://www.smard.de/en (data has been pre-downloaded by contact person)
File format: csv files
Pre-processing: No pre-processing has been done. Hence, data need to be cleaned and appropriately normalized.