

Data Science Challenge: Predicting Energy Prices

Estimating future electricity prices is a critical economic success factor for energy market participants. In this project a modular Day-Ahead electricity price forecasting approach is proposed.

Phase 1: Gathering Domain Knowledge & Data Sources

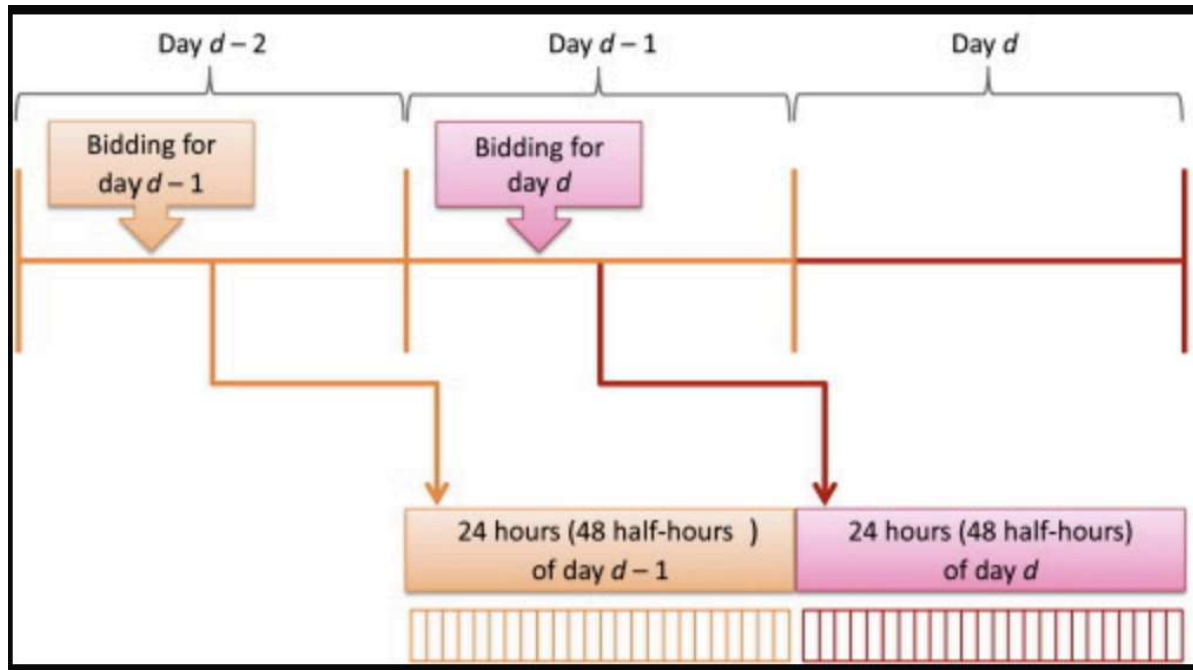
In Germany's liberalized energy market, electricity is traded on specialized exchanges, with the main trading platform being the Day-Ahead market. Here, participants commit to buying or selling a specific quantity of electricity for one-hour blocks on the following day. These trades are organized through an anonymous auction, where buyers and sellers submit bids until 12:00 noon on the day before delivery. Each bid specifies the amount of energy, the maximum (or minimum) price they're willing to pay (or accept), and the hour of delivery. Once bidding closes, the Market Clearing Price (MCP), also known as the uniform price, is determined. This price is set using the Merit Order Model, which prioritizes energy sources based on their marginal generation costs — with cheaper sources used first to meet demand. Producing energy at prices below marginal generation costs for a long period causes economic harm, as power producers cannot cover their production costs. For this reason, selling prices are usually set at the marginal costs of each technology. The Market Clearing Price (MCP) is determined by the marginal generation cost of the last power plant needed to meet the current demand. Once set, this market clearing price applies to all accepted orders in the Merit Order, regardless of the quantity offered or the original bid price. Lower-priced bids are accepted, while higher-priced bids are rejected. Since renewable energy sources operate with almost zero marginal generation costs, the amount of renewable energy produced impacts how many other generation technologies make it into the Merit Order. When renewable generation is high, it generally leads to lower prices because more expensive generation sources are "pushed out" of the merit order.

Since the bidding procedure is anonymous, Day-Ahead pricing are not known before the market closes, and other market participants' orders are kept unrevealed until the auction is over and all accepted orders are legally binding. Market participants are interested in estimating the market clearing price for each of the following day's 24 hourly blocks in order to maximize their bidding strategy. Accurate understanding of Day-Ahead prices is essential for a market actor's financial success.

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In [1]: from IPython.display import Image
Image(filename=r'C:\Users\Preethi\Desktop\RCS\Papers or Articles\DayAheadImage.png', width=600, height=600)

# Figure 1: Day-Ahead energy market bidding
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Out[1]:



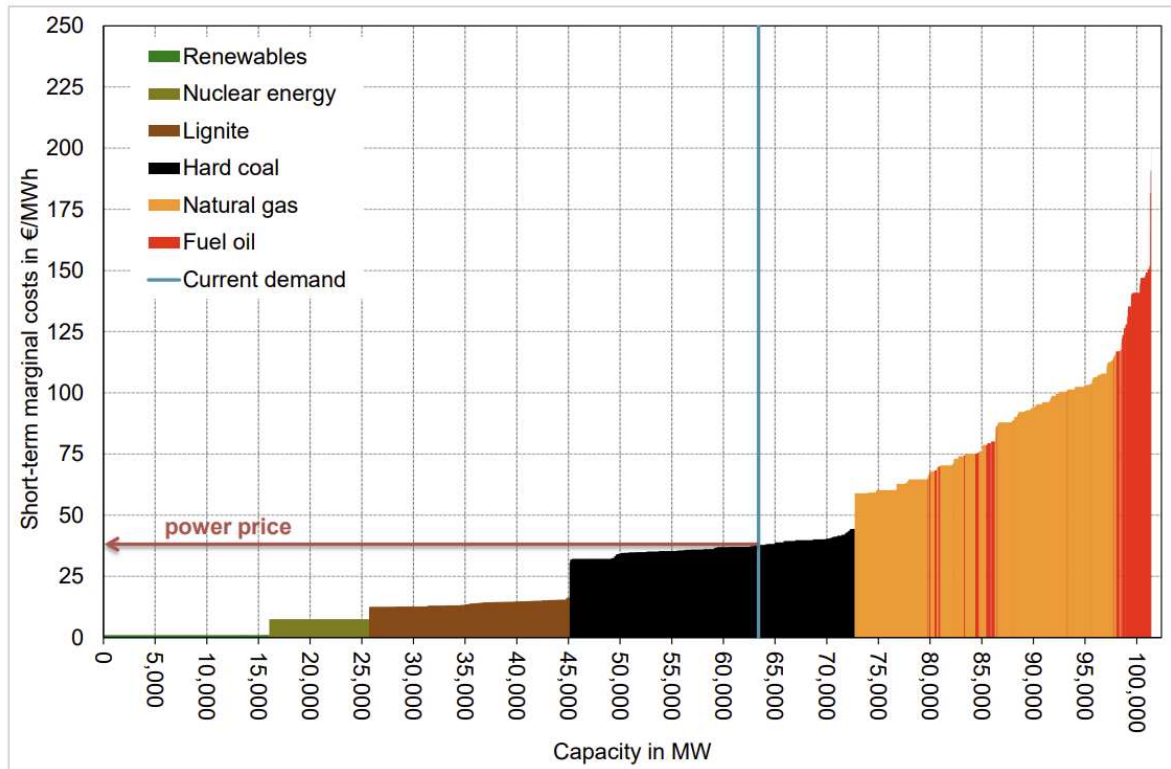
This diagram illustrates Day-Ahead energy market bidding and scheduling process:

- Each day, market participants bid for electricity delivery on the following day.
- For example, on Day $d-2$, participants place bids for energy to be delivered on Day $d-1$, and on Day $d-1$, bids are submitted for delivery on Day d .
- Once bidding closes, energy schedules are set for 24 hour of the target delivery day.
- Lower bids are accepted first, ensuring that the scheduled energy meets the forecasted demand at the lowest possible cost.

This cycle of bidding and scheduling helps maintain a balanced and cost-effective energy supply each day.

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In [9]: Image(filename=r'C:\Users\Preethi\Desktop\RCS\Papers or Articles\MeritOrderGraph.png', width=600, height=600)
# Figure 2: Merit order curve
#Source: Johanna Cludius, Hauke Hermann, Felix Chr. Matthes, and Verena Graichen. The merit order effect of wind and
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Out[9]:



This graph illustrates the merit order curve for the German electricity market. The merit order arranges energy sources by their short-term marginal costs (€/MWh) from lowest to highest.

- Renewable energy sources like wind and solar are shown on the left with nearly zero marginal costs, meaning they are prioritized in the market.
- Nuclear, lignite, hard coal, natural gas, and fuel oil follow, each with progressively higher marginal costs. These fossil fuel-based and nuclear sources become part of the supply only as needed to meet demand.
- The current demand level is represented by the red vertical line, indicating the point at which the market meets electricity needs.
- The spot market price (or market clearing price) is determined by the marginal cost of the most expensive source needed to fulfill demand. In this graph, it is set by a high-cost fossil fuel source.

As more renewable energy enters the grid, the demand line shifts to the left, reducing reliance on expensive sources and lowering overall market prices. This shift emphasizes the cost-effectiveness of renewables in the energy mix.

