“Data-driven models for electricity spot markets: monitoring, forecasting and strategic bidding”

Electricity markets are becoming increasingly complex due to the transition towards decarbonized power systems, characterized by high penetration of variable renewable energy. In this context, this PhD thesis develops data-driven electricity spot market models, applied to the Italian case. It addresses three critical steps of a market actor’s decision-making pipeline: monitoring market fundamentals, predicting participant behaviors to forecast market results, and defining optimal bidding strategies to maximize revenues and foster competition. The proposed approaches rely on statistical and machine learning methods for binary, time series and functional data, with a particular emphasis on uncertainty quantification and model interpretability. Specifically, the first contribution is a blind source separation framework based on a constrained variant of non-negative matrix factorization, which enables the high-frequency monitoring of unobserved sectoral power demand from aggregate grid load measurements. The second contribution introduces a general functional data analysis framework for predicting supply and demand merit-order curves in auction-based markets, from which both point and probabilistic electricity price forecasts can be derived. The third contribution proposes a probabilistic classification pipeline to model pay-as-bid power reserve markets, allowing participants to estimate price-dependent bid acceptance probabilities and optimally price their flexibility.