

DISSERTATION PROPOSAL

Managing Wind-based Electricity Generation and Storage

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This thesis focuses on the interface of Operations Management and renewable energy, especially wind-based electricity generation. Wind generation has grown rapidly worldwide in the past decade, and is likely to continue growing in the future. However, its growth faces myriad operational challenges (due to reasons such as the intermittence of wind energy), and thus raises many new and interesting research possibilities for Operations Management. I aim to explore these possibilities and to shed light on the operations of energy firms.

Essay 1: Managing Wind-based Electricity Generation with Storage and Transmission Capacity

One of the most immediate challenges is how to manage a wind farm that sells electricity to a market. Such a wind farm can be augmented by co-locating it with an electricity storage facility, such as an industrial battery. This enables: 1) storage of excess wind power that exceeds transmission capacity; 2) time-shifting wind power to periods of more favorable prices; and 3) taking advantage of arbitrage opportunities. To manage such a wind farm with an industrial battery, practitioners may use simple policies, such as the policy of selling whenever prices are positive, and otherwise storing as much as possible. However, this simple policy—based on our numerical results—could underperform the optimal policy by about 5%–7% for a typical setting. On the other hand, the dual-threshold policy that we develop could obtain the majority of the optimal value. We also numerically assess the value of including certain information (such as future information, and price and wind uncertainty) in designing heuristics, and quantify the added value of storage for a wind farm.

Essay 2: Is It More Valuable to Store or Destroy Electricity Surpluses?

In this essay, we investigate the best strategy to deal with electricity surpluses for a merchant who trades electricity in a market. Conventional wisdom suggests that the most valuable strategy is to store surpluses for future resale (buying low and selling high). Another potential strategy is to destroy electricity surpluses, due to a unique phenomenon of electricity markets: negative electricity prices. We model the problem of managing electricity surpluses in a market as a Markov decision process, and we show that the optimal policy structure subsumes the known optimal storage policy structure when commodity prices are strictly positive. We apply our optimal policy structure to real data, and find that the strategy of destroying surpluses is even more valuable than the storing strategy.

Essay 3: Which Parameters Matter for the Valuation of Electricity Storage?

In this essay, we will study how the market valuation of electricity storage technologies are affected by their operating characteristics such as cycle life, charging and discharging rates, and the relationships between them. We will compare the profits of three battery technologies in an electricity market over a finite horizon, and quantify the loss in profits if any characteristic is ignored, thus determining which characteristics are most valuable for each battery technology. We will also examine the sensitivity of our analysis to the decision frequency.