ENERGY STORAGE IN ELECTRICITY MARKETS: EQUILIBRIUM MODELS AND LEARNING-ENABLED PARTICIPATION

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OVERVIEW

Energy storage resources—particularly batteries—are rapidly becoming essential sources of flexibility in modern power systems and active participants in electricity markets. By arbitraging price differences, they generate profit while reducing peak demand and mitigating renewable variability. Yet, their effective market participation requires accounting for future price opportunities and inherent uncertainties. As a result, storage operators may rationally withhold capacity for economic reasons, rather than offering strictly based on physical cost. These dynamics create challenges both for storage operators seeking to optimize returns and for regulators aiming to prevent market power abuse and ensure socially efficient outcomes.

This talk presents game-theoretic equilibrium frameworks alongside optimization and machine learning approaches for enabling efficient energy storage participation in electricity markets. I will demonstrate that strategic storage participation converges to efficient market outcomes under the existing two-settlement U.S. market design. Building on this foundation, I will examine the energy storage arbitrage problem in detail, framing it within a dynamic programming perspective, and present solution strategies ranging from classical stochastic optimization to decision-focused learning pipelines.

BIO

Dr. Bolun Xu is an Assistant Professor in Earth and Environmental Engineering at Columbia University, with an affiliated appointment in Electrical Engineering. He received his Ph.D. from the University of Washington, M.S. from ETH Zurich, both in Electrical Engineering. He also received dual bachelor degrees from Shanghai Jiaotong University and University of Michigan Ann Arbor in Electrical and Computer Engineering. Before joining Columbia, he was a Postdoctoral Fellow at the MIT Energy Initiative. His research focuses on the design and optimization of sustainable energy and power systems and the integration of emerging technologies. Dr. Xu is a recipient of the NSF CAREER Award, the Outstanding Young Investigator Award from the IISE Energy Systems Division, and the Early Career Award from the INFORMS Energy, Natural Resources, and Environment (ENRE) Section.