

Conceptual Modeling of Local Energy Markets in the Japan Electric Power Exchange (JEPX)

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論 文 名	Conceptual Modeling of Local Energy Markets in the Japan Electric Power Exchange (JEPX) (日本卸電力取引所 (JEPX) における地域エネルギー市場の概念モデル化)			
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論 文 審 査 の 結 果 の 要 旨

The accelerating integration of distributed energy resources (DERs), coupled with rising prosumer-driven demand, is reshaping electricity markets. In response to these evolving energy challenges, Local Energy Markets (LEMs) have emerged as a promising solution to strengthen energy autonomy, improve operational flexibility, and facilitate the integration of renewable energy sources. This thesis proposes a comprehensive decentralized hybrid LEM modeling framework that integrates peer-to-peer (P2P) and community-based markets (CBM) structures within a scalable, privacy-preserving architecture. The developed modeling framework consists of four main sub-models. The first model considers joint energy and reserve trading through a consensus-based Alternating Direction Method of Multipliers (ADMM) approach, preserving data privacy, capturing participant preferences, and distributing computational effort. To enhance behavioral realism, the second model includes peer-specific utility functions incorporating demand elasticity and risk preferences, while physical grid constraints are addressed via a Linearized Power Flow for Distribution (LPF-D) formulation. The third model utilizes a region-wise approach to assess the implementation of LEM across nine Japanese regions, each representing communities with surplus, balanced, or deficient energy profiles. The fourth model is developed based on a bi-level optimization model in order to integrate demand response programs (DRPs) into the LEM, capturing dynamic temporal flexibility over a 24-hour horizon.

The findings from this research validate the proposed modeling framework's ability to demonstrate the potential implementation of the decentralized LEM in the future smart electricity market and its key role in improving economic efficiency, increasing market fairness, and supporting the integration of renewable energy in JEPX.

The candidate adequately answered all questions of the examiners and external observers related to the details of the developed models and validation of the results. In the public defense, the candidate answers several questions from participants satisfactorily. Therefore, the examination committee approved that the candidate had passed the examination.