Politecnico di Torino

ENERGETICS

ABB S.p.A. - Data-driven strategies for coordinated energy management in cluster of buildings: towards real-life implementation

Funded By	ABB S.P.A. [P.iva/CF:11988960156]
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Context of the research activity	This research focuses on the challenges posed by decentralized energy systems for the management of energy communities. It proposes a framework integrating scalable co-simulation tools, advanced control architectures, and user-centric energy information systems. Key areas include optimizing energy performance and flexibility across different building typologies, deriving surrogate controllers, enhancing user engagement, and defining KPIs to streamline monitoring and operation.
	The energy and digital transition within the building sector demands innovative strategies to address the increasing complexity of decentralized energy generation systems. Energy communities (ECs) have emerged as a pivotal concept in this transformation, fostering collaborative energy management and empowering end-users to actively participate in energy-related decision-making. Despite their potential, ECs face several operational challenges, including the heterogeneous nature of building typologies, the integration and use of different external data sources, and the scalability of advanced energy management strategies. In this context, this research proposes the development of a comprehensive framework that incorporates co-simulation tools, advanced control architectures, and energy information systems (EIS) to enhance the operational performance and efficiency of renewable energy communities (RECs). A primary objective of this study is to advance scalable co-simulation environments capable of not only simulating the behavior of energy communities but also emulating the real-world operations of existing ECs across a range of building categories. The research seeks to address the critical challenge of achieving an optimal balance between simulation detail and computational efficiency, ensuring that the proposed framework remains both practical and accessible. The co-simulation environment shall integrate extensive datasets, including information from Energy Performance Certificates (EPCs), utility bills, electric meters, smart thermostats, and weather services, to provide a comprehensive and dynamic representation of the system across varying configurations and scenarios.

Objectives	Another key focus of this proposal lies in the development of advanced control architectures and algorithms designed to streamline the practical implementation of energy management strategies. A significant component of this effort involves the derivation of surrogate controllers—simplified rule-based systems extracted from complex control policies. These controllers are designed to adapt dynamically to user behavior and grid conditions, ensuring operational efficiency and demand flexibility. The study further explores advanced control methods that exploit model-based and model-free approaches, critically evaluating the trade-offs between centralized and decentralized energy management strategies from both technical and economic perspectives. Eventually, the design of user-centric energy information systems aimed at fostering greater engagement and participation within energy communities will by subject of investigation. These systems will prioritize the development of intuitive, user-friendly interfaces that translate the results of complex optimization processes and predictive analytics into actionable insights. By increasing user awareness of potential benefits, such as cost reductions and incentive mechanisms, these systems aim to facilitate informed energy-saving decisions. Furthermore, the research will explore the potential of LLMs as tools to assist non-expert users in understanding and handling technical outputs. In addition to these goals, the research will focus on identifying a strong set of Key Performance Indicators (KPIs) to monitor, evaluate, and improve the performance of energy communities. These KPIs will provide a clear view of energy consumption, efficiency, and flexibility at different levels, from single buildings to entire districts. Using these metrics, the study will help pinpoint the key factors that impact energy management and demand flexibility in a REC and determine the minimum number of monitored and control variables needed for effective operation. The research proposal combines advanced simulation tools, real-world data integration, and state-of-the-art machine learning techniques to address the multifaceted challenges associated with renewable energy community management. Through the development of a scalable co-simulation framework, adaptable control architectures, and user-centered interfaces, this research will demonstrate the added value of data-driven methodologies in optimizing energy consumption, reducing operational costs, and mitigating environmental impacts. The expected outcomes will provide actionable insights into the design, implementation, and management of real-world energy communities, aligning with broader goals of sustainability and digital transformation within the energy sector.

Skills and competencies for the development of the activity	• Data-driven building energy management; • Energy data analytics technologies; • Building physics and HVAC systems; • Physics-based and data-driven based modeling of digital twins for the built environment and building energy systems; • Programming skills (Python and R environment are considered preferential); • Knowledge of state of the art of machine learning algorithms; • Knowledge of simulation environment for the assessment of predictive building energy management strategies.