PhD in Energetics

Research Title:
DATA-DRIVEN ENERGY MANAGEMENT STRATEGIES FOR ENERGY COMMUNITIES

Short Title:

Data-driven energy communities

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Supervisor	Supervisor: prof. Alfonso Capozzoli, Politecnico di Torino – alfonso.capozzoli@polito.it

Contact	www.baeda.polito.it

Context of the research activity	An energy community is a **collective organisation** characterized by **citizen-driven energy actions** that help pave the way for a clean and sustainable energy and digital transition, by informing and engaging end-users to become more aware and flexible consumers of energy. However, the benefits of an energy community can only be unlocked considering a sufficient number of buildings, focusing on district scale. The research effort on energy management in cluster of buildings has grown to address potential grid instability issues, related to the increasing penetration of renewable electricity resources (such as PV systems) and energy storages and to the influence of occupant behaviour. The spread of Information and Communication Technologies (ICT) and Internet of Things (IoT) devices make it possible to exploit **advanced metering infrastructures** to track energy demand and generation data in

near real-time, thereby paving the way for the **optimization of energy management, user engagement and peer-to-peer trading** strategies in such a new paradigm.

In this context, the scalability problem of control strategies at building community level can be faced by exploiting data-driven solutions which can help in reducing the energy consumption, costs and the carbon intensity while improving the penetration of renewable energy sources without jeopardizing grid reliability.

To this purpose, automated Energy Management and Information Systems (EMIS) based on the application of Artificial Intelligence (AI) can be employed. The application of such systems can lead to the development of effective and ready-to-implement energy management strategies for a fully data-driven energy community.

The focus of this proposal is on the specific segment of EMIS technologies in the context of data-driven energy communities. The proposed paradigm unfolds over two different levels: a control level based on automated system optimization (ASO), and an informative level based on energy information systems (EIS). The first one deals with the optimal centralized or distributed control of energy systems and exploits the exchange of energy and information between buildings and with the grid to manage the aggregated electrical load and achieve a more flexible use of energy. This approach involves the development of control strategies with adaptive and predictive capabilities based on Artificial Intelligence managing the operation of energy storage and HVAC systems, while exploiting the benefits of renewable energy systems. On the other hand, the informative level directly engages the community members leveraging advanced data-driven processes to extract useful knowledge from historical data and effective Key Performance Indicators (KPIs).

The research activity is aimed at demonstrating the added value of data-driven-oriented energy management strategies in the context of the energy communities, assessing their effectiveness in optimizing energy consumption and cost considering multiple objectives (e.g., energy flexibility, RES management, comfort conditions, ancillary services).

Bibliography

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Objectives	Nowadays, the building sector is facing a deep renovation, shifting the paradigm from energy consumers to prosumers. A key topic in this field is related to the concept of energy community, which puts emphasis on citizen engagement and allows energy consumers and prosumers to become more involved in how the energy is sourced or consumed. Furthermore, community members are encouraged to take on a more active role by, for instance, installing distributed renewable generation systems and energy flexible resources such as electrical batteries and thermal storage. Advanced metering infrastructure plays an important role in modern energy communities unlocking their full potential also by enabling the penetration data analytics technologies. In this context, the development of EIS and ASO systems is the core of this proposal. More in detail the PhD project has the following objectives: • Define the influencing variables and the hardware infrastructure that enable an effective data-driven energy management of energy communities, considering a trade-off between costs and benefits. • Define the objectives of data-driven energy management strategies, at both informative and control level. In this perspective, EIS systems are conceived for allowing an effective characterization, visualization and tracking of user energy performance, while at district scale, ASO systems should optimize energy flows among the members of the community and between the community and the grid. • Define new KPIs useful to analyze the energy behaviour of community members, from single building up to district scale. • Investigate advanced control strategies based on different frameworks (e.g., model-based, model-free) to optimize the operation of the energy community, evaluating pros and cons of both centralized and decentralized energy management approach. • Analyze the effects and opportunities of new peer-to-peer energy trading concepts that can be adopted in the context of a data-driven energy community.

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