Approach to Energy System Modelling for Supporting Decarbonization Scenarios in Energy Communities

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Abstract. This research paper proposes an approach to energy system modelling for supporting decarbonization scenarios in energy communities and transition towards a sustainable energy future. Energy communities, comprising small-scale distributed energy systems, are increasingly being considered as a viable solution to achieve decarbonization goals. The process of designing and implementing energy communities faces technical challenges such as integration of data and services from different assets and technology providers. Preliminary results from a case study from Serbia are also presented.

Keywords: Energy system modelling, Decarbonization, Energy Communities, Renewable Energy, Energy Efficiency, PUPIN R&D Campus.

1 Motivation

The global community is currently faced with a critical challenge of reducing greenhouse gas emissionsto combat climate change. The energy sector, which is responsible for a significant percentage of global emissions, has to be transformed to achieve this objective. Decarbonization of the energy sector is a complex and challenging process, requiring a fundamental shift in the way energy is produced, distributed, and consumed.

This research paper explores the approach to energy system modelling for supporting decarbonization scenarios in energy communities. An energy community [1] is a localized system that produces, distributes, and consumes energy within a defined geographical area. Energy communities are characterized by small-scale distributed energy systems, such as photovoltaic (PV) panels, wind turbines, electrical vehicle (EV) chargers and energy storage systems. The energy produced within such community is consumed locally, and the surplus energy can be sold back to the grid. The concept of energy communities is gaining popularity as a solution for reducing carbon emissions and promoting energy independence [2]. However, designing and implementing energy communities require a thorough understanding of the energy system's complexities, the impact such infrastructure would have to the electrical grid and the impacts of different scenarios on the community's sustainability and viability.

This paper presents the work conducted in the first year of the EU funded OMEGA-X project (**O**rchestrating an interoperable sovereign federated **M**ulti-vector **E**nergy Data Space built on open standards and ready for **GA**ia-**X,** 2022-2025)[1]. The OMEGA-X high-level objective is to implement a data space (based on European common standards), including federated infrastructure, data marketplace and service marketplace, involving data sharing between different stakeholders and demonstrating its value for real and concrete energy use cases and needs, while guaranteeing scalability and interoperability with other data space initiatives, not just for energy but also cross-sector. The Research &Development (R&D) campus of Institute Mihajlo Pupin (PUPIN) [3] has been used to demonstrate the feasibility of the approach for the Local Energy Communities (LEC) Use Case family of pilots [4].

2 Methodology

Decarbonization is the process of reducing the carbon footprint of the energy sector by reducing greenhouse gas emissions. Decarbonization in LEC framework requires a comprehensive and integrated approach that considers the specific characteristics and needs of the community members. Thus, the energy system modelling is considered a valuable tool for analysing the feasibility and performance of different decarbonization scenarios in LEC context, helping decision-makers to identify the most suitable strategies and assess their potential impacts on economic, environmental, and social factors.

The approach proposed herein consists of several steps including (1) business analysis for the decarbonization process; (2) data collection, model development and scenario analysis; (3) infrastructure upgrade and ICT services deployment.

- The business analysis for the decarbonization process usually takes into consideration the overall activities related to the energy flows within the community, including energy generation, distribution, and consumption, see an example of Business Use Case (BUC *Planning services*) in Figure 1 illustrated with the Sparx Enterprise Architect tool[2].
- Data collection involves gathering data on energy demand, supply, and infrastructure within the energy community. Model development involves constructing a mathematical model of the studied aspect (e.g. energy demand forecasting, PV production forecasting). Scenario analysis, e.g. BUC *Collective self-consumption* involves simulating different scenarios to evaluate the impact of different policies and technologies on greenhouse gas emissions and other Key Performance Indicators (KPIs) [5].
- Once the legal requirements are fulfilled, the LEC operator signs a contract with the Distribution System Operator and implements the needed infrastructure changes. The deployment include installation of a ICT platform and services for LEC monitoring and control, see for instance the System Use Case (SUC) *Implementation of integration solutions, APIs*.

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[1] https://omega-x.eu/pilots/
[2] https://sparxsystems.com/products/ea/

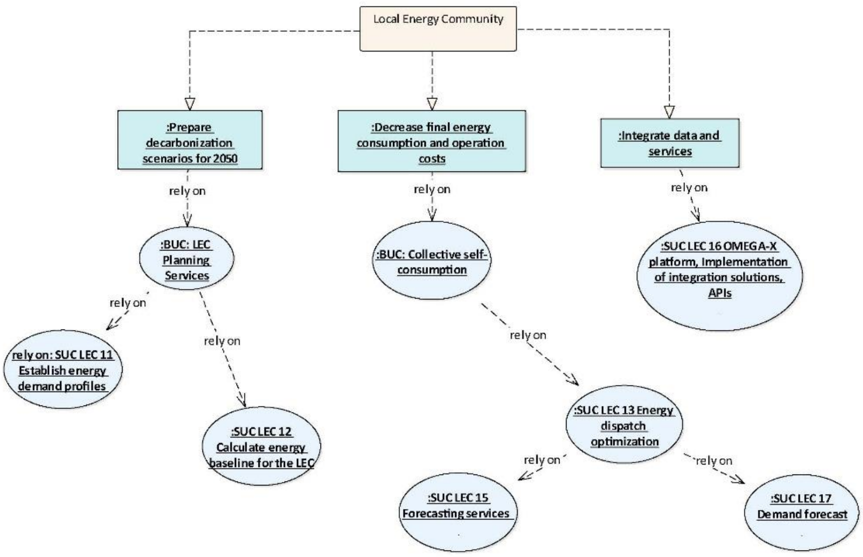

Fig. 1. LEC Business and System Use Case Analysis.

3 Results and Discussion

Case Study Context: The objective of the case study is to explore a variety of strategic options for becoming Zero Emissions LEC by 2050. For this purpose, the PUPIN R&D campus is considered. The campus represents an energy community comprising separate legal entities within the Institute Mihajlo Pupin as well as external legal entities, which share common energy supply (both conventional and renewable), storage and dispatch infrastructure. The R&D campus consists of several buildings. The common energy supply infrastructure comprises a thermal plant running on fuel oil (mazut) and a local PV power plant (50kWp). The campus is also connected to the public power grid via low-voltage power station (0.4kV/220V). The overall supervision and control of energy flows is based on the deployed SCADA system (View4, IMP’s proprietary solution) which communicates with several remote terminal units (pAtlas RTUs) and PLCs (ATLAS MAX).

Scenarios: With more than 25 years to go until 2050, in order to achieve 2050 Climate Targets, short, medium and long term actions are needed to be implemented by the LEC Operator, see examples in Table 1.

Challenges: In OMEGA-X framework, the extension of existing PUPIN services, integration of existing services with OMEGA-X services and integration with operational proprietary SCADA system for self-consumption have been studied. Challenges identified so far are:

- Automatic collection and processing of data needed for preparing the energy transition scenarios. Namely, the techno-economic assessment for energy transition scenarios have shown that more detailed data on current and future energy needs for the district is needed;
- Interoperability of PUPIN SCADA data and OMEGA-X services. Standardized data connectors are needed for more efficient integration of OMEGA-X services with PUPIN infrastructure, see Figure 2;
- Legal aspects related to formalizing the energy community and compliance with national regulations.

Table 1. PUPIN Decarbonization Scenarios

Scenario name	Scenario description	Output
Short-term energy community planning	This scenario involves the short-term planning of the energy community, including the optimization of energy consumption and production to meet the energy demand of the occupants and reduce energy costs and Greenhouse Gas (GHG) emissions.	An optimized energy production and consumption plan for the next year, which maximizes the use of renewable energy sources, reduces energy costs and GHG emissions, and meets the energy demand of the occupants.
Mid-term energy community planning	This scenario involves the mid-term planning of the energy community, including the integration of new services and equipment, such as the OMEGA-X, to improve energy efficiency and increase the share of renewable energy sources.	A mid-term energy production and consumption plan that integrates new services and equipment, maximizes the use of renewable energy sources, reduces energy costs and GHG emissions, and meets the energy demand of the occupants.
Long-term energy community planning	This scenario involves the long-term planning of the energy community, including the development of a roadmap for achieving the decarbonization target.	A long-term energy production and consumption plan that provides a roadmap for achieving the decarbonization target, maximizes the use of renewable energy sources, reduces energy costs and GHG emissions, and meets the energy demand of the occupants.

Results (PUPIN Energy Services Integration for Collective Self-Consumption): The research infrastructure needed for testing the integration of energy services for the future energy self-consumption has been established. The objective is to ensure that all necessary software components (data models and services), as well as connectors for data exchange with service providers in the OMEGA-X energy data space are deployed. The long-term energy community success, scalability of the installed solutions and sustainability depend on collaboration and coordination among various stakeholders. Hence, the PUPIN team proposed an integration platform [6] composed of different services that communicate with each-other or with service providers in the OMEGA-X energy data space. Interoperability is ensured by the adoption of the OMEGA-X semantic models [7].

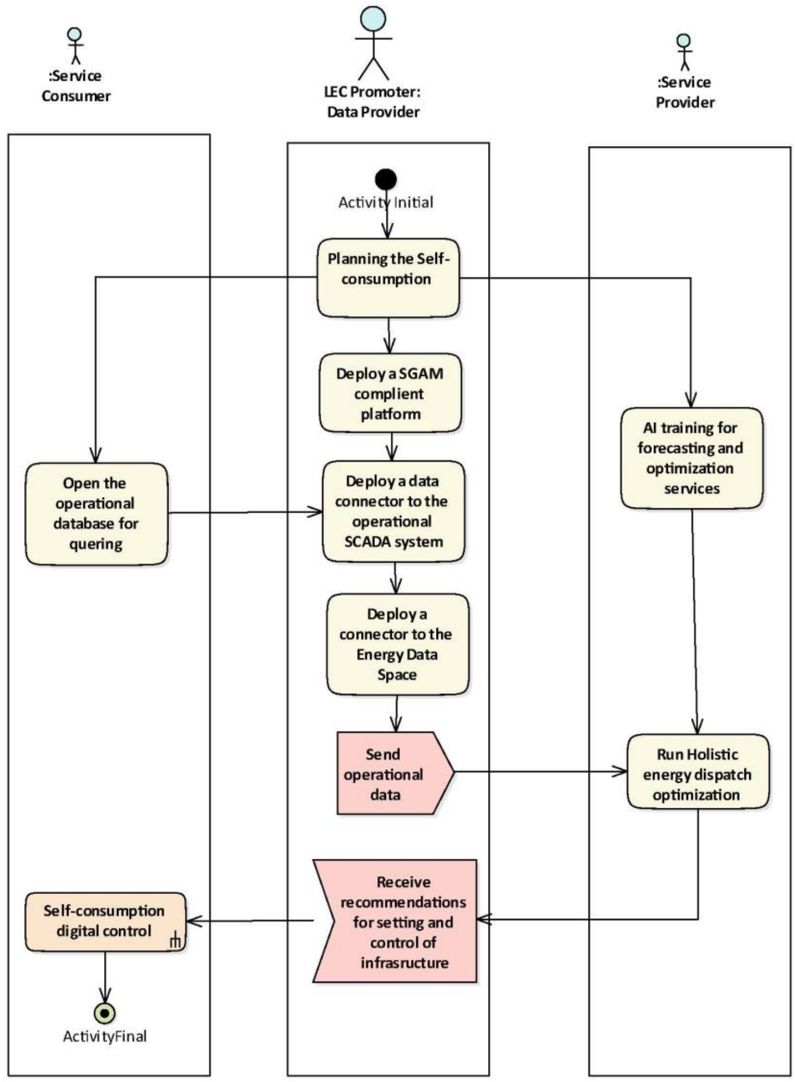

Fig. 2. Example of an Activity Diagram.

4 Conclusion

This paper proposed an approach to energy system modelling for supporting decarbonization scenarios in energy communities. The presented approach involves different steps from business use case modelling; via data collection, model development, scenario analysis; to software platform and services deployment. The approach provides insights into the energy potential of the community, the feasibility of developing an energy community, and the impacts of different scenarios on the community's sustainability and viability. A well-designed energy community can lead to reduced carbon emissions, lower energy costs, and improved energy security, making it a critical element in the transition towards a sustainable energy future.

In the presented case study, besides providing insights into the potential for decarbonisation, it support decision-making processes related to investments in the energy management infrastructure and ways of upgrading the PUPIN proprietary SCADA system that currently monitors the PUPIN R&D campus.

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