ENERGY COMMUNITIES IN EUROPE: IDENTIFYING 4 ARCHETYPES OF ORGANISATION

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Overview

As Europe transitions towards a more decentralized and sustainable energy system, energy communities (ECs) have emerged as promising instruments to advance the energy transition. Recognized and promoted by European Commission directives[1], energy communities hold significant potential to mobilize private investment in renewable energy, enhance societal acceptance of innovative energy projects, and positively impact energy markets both in terms of liquidity and flexible capacities. However, energy communities exhibit considerable diversity in terms of participant composition, governance structures, business models (BMs), technical configurations, objectives, and geographical contexts. This variability implies that not all ECs align equally well with the European Commission's expectations. Moreover, the large-scale proliferation of off-market and inflexible energy communities may present challenges for system management by Distribution System Operators (DSO) and Transmission System Operators (TSO), and hinder market flexibility. A robust characterization of energy communities is therefore essential to evaluate their impact on the European electricity system.

Since the concept of energy communities was introduced in European directives only in 2018, its definition has remained ambiguous, with "local energy community" often encompassing a wide range of initiatives. This ambiguity complicates efforts to systematically register and monitor them. Recent efforts, such as the open database developed by Koltunov and al. (2023) and Wierling and al. (2023), have made significant strides in cataloging a broad spectrum of energy communities across Europe. These resources provide a foundation for comprehensive reviews of their development and integration into energy systems.

In this context, López and al. (2024) offer a detailed analysis of prevailing energy communities BMs in Europe, alongside their primary legal, technical, and organizational characteristics. Using this analytical framework, they examine various ECs across European countries, identifying regulatory advancements and persistent challenges to EC development within distinct national contexts.

As the adoption of energy communities grows, the implications for grid management have garnered increasing attention. Ilo and al. (2024) investigate the impact of widespread energy communities' deployment on grid operations, identifying both challenges and opportunities for System Operators. Their findings emphasize the importance of ECs evolving into reliable entities capable of providing flexibility and ancillary services to the grid. Similarly, Cruz-De-Jesús and al. (2024) underscore that while energy communities can engage in diverse activities beyond electricity supply, many communities tend to specialize in a single domain. Finally, Ponnaganti and al. (2023) evaluate the potential of local energy communities for integration into flexibility markets, highlighting critical enablers and advocating for the evolution of market design to accommodate EC participation.

Methods

This study evaluates the potential for deeper market integration of energy communities across multiple scales, including local flexibility markets, ancillary services, and European wholesale markets. The Business Model Canva approach was used to guide the construction of a descriptive database encompassing energy communities from nine European countries. The description is based on a comprehensive review of drivers motivating participation, types of participants, activities and technologies used within ECs, along with existing BMs.

Inspired from Braunholtz-Speight and al. (2020) energy communities clustering methodology, our study subsequently identifies distinct EC archetypes and assesses their compatibility with market integration and

[1] Renewable Energy Directive (2018) and Internal Electricity Market Directive (2019)

flexibility provision. The assessment is made by evaluating each group's specificity regarding seven indicators: Installed Power Generation, Inner Flexibility, Self-Consumption activity, Wholesale Market interest, Ancillary Services suitability, Local Flexibility Market suitability, and State of Development.

Results

The evaluation of clustering quality metrics, including the Silhouette Score, Calinski-Harabasz Index, and Davies-Bouldin Index, indicates that while certain archetypes of energy communities are well-defined and robustly clustered, others exhibit greater diffuseness and lower structural stability. Nevertheless, the four archetypes derived from the clustering process are interpretable in the context of our research objectives. Specifically, these archetypes have been identified as *'Flexible Communities,' 'Rural Self-Consumers,' 'Collective Generation' and 'Urban Collective Self-Consumers (CSC).'* Moreover, the characterization of these archetypes underscores the potential for enhanced market integration of specific EC types, aligned with their primary drivers and underlying BMs.

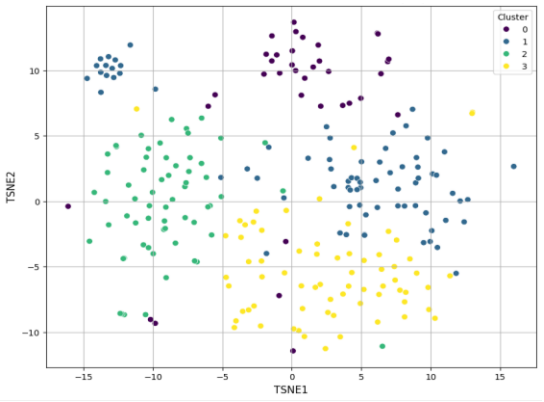

Figure 1 – tSNE data visualisation

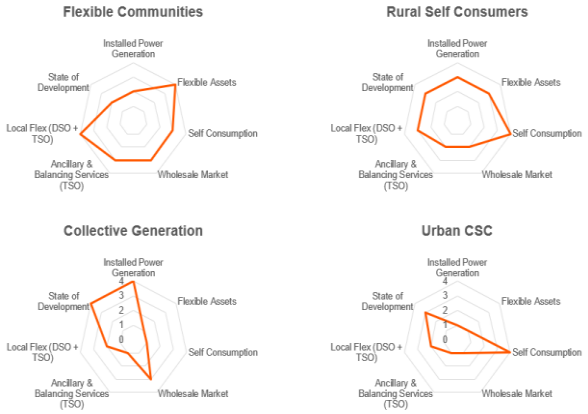

Figure 2 – Market Integration and Flexibility Assessment

Conclusions

This analysis contributes to the better understanding of the potential contributions of ECs to the energy transition by examining not only their technical and organizational characteristics, but also their core motivations and business models in relation to market integration. The findings suggest that while most archetypes demonstrate some degree of suitability for local flexibility markets, their potential for participation in wholesale markets and ancillary services varies significantly. This study paves the way for future research to quantify the impacts of ECs in such markets and to identify the key enablers and barriers for their sustainable development across Europe. As an extension of this work, the descriptive database will be made available for academic collaboration.

References

Braunholtz-Speight, T., Sharmina, M., Manderson, E., McLachlan, C., Hannon, M., Hardy, J., & Mander, S. (2020). Business models and financial characteristics of community energy in the UK. Nature Energy, 5(2), 169-177.

Cruz-De-Jesús, E.; Marano-Marcolini, A.; Martínez-Ramos, J.L. (2024) Participation of Energy Communities in Electricity Markets and Ancillary Services: An Overview of Successful Strategies. Energies 2024, 17, 4631.

Ilo, A. and al. (2024). Energy communities' impact on grids: Energy community embedment increasing grid flexibility and flourishing electricity markets. European Commission.

Koltunov, M. and al. (2023) Mapping of Energy Communities in Europe: Status Quo and Review of Existing Classifications. Sustainability 2023, 15, 8201.

López, I. and al. (2024). European energy communities: Characteristics, trends, business models and legal framework. Renewable and Sustainable Energy Reviews, 197, 114403.

Ponnaganti, P., Sinha, R., Pillai, J. R., & Bak-Jensen, B. (2023). Flexibility provisions through local energy communities: A review. Next Energy, 1(2), 100022.

Wierling, A. and al. (2023). A Europe-wide inventory of citizen-led energy action with data from 29 countries and over 10000 initiatives. Scientific Data, 10(1), 9.