Citizens empowerment in smart energy communities

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Abstract — **Nowadays, citizens have greater opportunities to join energy cooperatives, participate in co-owned renewable energy production and take on the role of energy prosumers. However, smart services are usually designed to fulfill a number of technological criteria and ensure the resilience of the energy systems, rarely taking into account end user input in the process. This paper introduces methods to empower citizens in the design and use of smart services and gives an example from a Swiss case study.**

Keywords—energy communities, living labs, citizen empowerment

I. Introduction

In accordance with the Paris Agreement [1], Europe is aiming for carbon neutrality by 2050. To carry out the energy transition set by this objective, it is required, among other things, to combine both reduction of energy consumption and massive development of production capacities from renewable energy sources (RES). Energy renovation, sustainable mobility, energy sobriety and societal acceptance of the transition are all powerful low-carbon transition levers that communities, businesses, and citizens can directly activate.

Aware of their role and eager to act, citizens, communities and local businesses are gradually making a place for themselves in the European energy landscape [2]. RES production projects with local and citizen governance are being established, new bonds of trust are being forged, new legal and partnership models are emerging, and new energy market designs are being explored [3].This paper presents an overview of existing methods and solutions for citizen empowerment in local energy communities.

In section II we present the emerging forms of local energy communities as well as their governance structures. We also give an overview of different smart solutions and services and the role of citizens in their design and use. Section III introduces the living lab methodology as a way for citizen empowerment in designing smart services while section IV shows results from a pilot site in Switzerland. Section V discusses the findings of the research.

II. Local energy communities

A. Concept and Governance

The European Union recognized local energy communities (LECs) for the first time in 2019 in the "Clean Energy" package which differentiates between "citizen energy communities" (CECs) and "renewable energy communities" (RECs) [4]. Both CECs and RECs refer to communities that generate, store and consume their own electricity, only renewable for RECs, renewable and conventional for CECs. CECs can also be involved in activities related to the electricity sector (aggregation, supply...). Their operation is based on a set of principles emphasizing voluntary and democratic participation.

Owned by their shareholders or members, LECs aim to generate economic, social and environmental gains for their members, not exclusively financial profits. With regard to their governance, decision-making power must be distributed equitably among the stakeholders involved. Effective control is vested in the members who are close to the renewable energy operations. In the case of CECs, recognized in the Electricity Market Directive, any entity or structure can be a member. However, the decision-making power is held by stakeholders who are not involved in commercial activities related to the primary energy sector.

B. Smart services in local energy communities

In order for local energy communities to exploit their potential in a holistic way, it is necessary to put in place measures, initiatives and services in the fields of electric mobility, leisure activities, smart home services, etc. The expansion of decentralized, non-dispatchable, renewable energy sources can give rise to congestion issues and power quality difficulties in local electricity networks [5]. In order to reduce the impact of these issues and to avoid the transmission of electricity over great distances, it is beneficial to match supply and demand locally. By enabling the end user to adapt their power consumption behavior and by setting incentives to consume the locally generated electricity simultaneously with its production, a communities' self-consumption can be increased. Rewarding final end use flexibility is one method of setting such incentives. This prerequires a high level of digitalization, smart-grid infrastructure, and the availability of smart services. Figure 1 illustrates the interlinkages between the different layers within an energy community.

Many different types of smart services can be offered in an energy context. Internet of things devices allow for more detailed data analysis concerning current states of operation and energy consumption over time, which can be used in their optimization. A complete smart-integration of electric vehicle charging [6] and heat pumps [7] leads to flexibility-business cases allowing users earn/save money. In addition to this, smart services are expected to increase the reliability of a network, reduce costs and minimize environmental impact [8].

Furthermore, the possibility of citizen involvement in flexibility and investment programs, smart solutions also allow for greater sector integration, further increasing an energy communities' self-consumption [5].

Information systems enable the emission of certificates of origin, giving users more power to choose the electricity mix of their preference. They also support the use of smart contracts, virtual energy trading and peer-to-peer trading [9]. In general, smart meter data can be used in demand prediction, as a first step toward demand side management in grids, and for the optimization of conventional power generation. An accurate demand prediction allows the DSO to inform users of flexibility costs, ahead of time. This, in turn, can lead to behavioral changes in end use customers [10]. Even regular information on personal energy usage can have an effect on consumption. Effectiveness of data driven information campaigns can be investigated in so called "Living Labs".

The use of smart services and web-based platforms can result in stronger community ties. They can help enhance the visibility of the energy community for a user. Energy communities in general are expected to aid social cohesion and give local control over financial resources and profit sharing [3].

Overall, smart services are key in developing functional, sustainable, decentralized energy communities which can empower the end user to change their consumption behavior, invest in renewables and reduce their environmental impact.

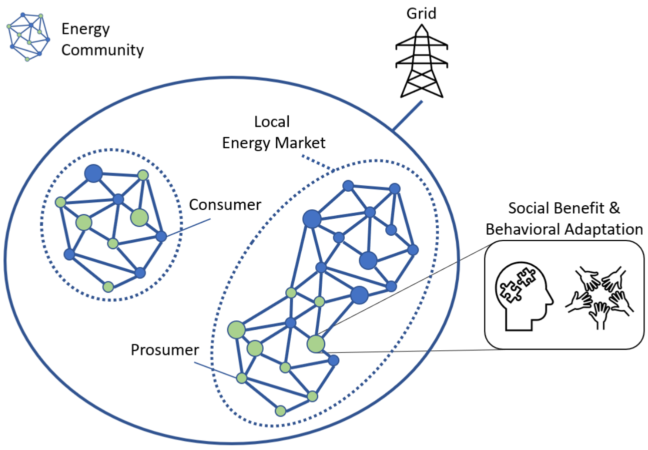

Figure 1: Illustration of energy communities, placed in a broader context of local energy markets and the centralized power grid.

III. CITIZEN EMPOWERMENT WITHIN ENERGY COMMUNITIES

A. Introducing the living lab approach

New approaches are required to encourage citizen engagement in Energy communities and smart energy services. Citizens are important prosumers in energy communities and can participate in projects due to a variety of values and concerns related to energy and ecological transitions, peak electricity, energy security and a desire for energy independence.

According to European Network of Living Labs (ENoLL) [11], Living Labs are defined as *"user-centered, open innovation ecosystems based on systematic user co-creation approach, integrating research and innovation processes in real life* communities and settings" [10]. In addition, Mastelic proposes the following definition: *"A living lab is an innovation intermediary, which orchestrates an ecosystem of actors in a specific region. Its goal is to co-design products and services, in an iterative way, with key stakeholders in a public private people partnership and in a real-life setting. One of the outcomes of this co-design process is the co-creation of social value (benefit). To achieve its objectives, the Living Lab mobilises existing innovation tools and methods or develop new ones*" [12].

A Living Lab can provide access to science and innovation services and tools such a research and innovation platform allowing enterprises and users/citizens participate in the energy transition either as entrepreneurs or communities. The main objectives are to explore new ideas and concepts, experiment with new products and services and evaluate breakthrough scenarios that could be turned into successful innovations" [13].

A Living Lab is composed of many stakeholders within a Quadruple Helix Model working together in a public-private-people-partnership (PPPP). [14]

The integration of key stakeholders and their empowerment through the innovation process is a key approach of Living Labs. Living Labs act as catalysts, as innovation intermediaries to orchestrate the co-design process in an ecosystem of actors. Living Labs help users to participate actively in the co-design of innovative products and services, the outcome of which is the co-creation of social value. The Living Lab Integrative Process (LLIP) [12] is used to understand social practices, integrate stakeholders, define barriers and then co-design, prototype and test solutions. The Living Lab Integrative process is a simplified innovation process at the project level which brings together the various elements of the Living Lab, into a structured set of stages where different tools can be used to achieve the objectives of the innovation process. The LLIP integrates the Quadruple Helix Model, and design thinking to give a practical way to implement projects using a variety of tools.

B. *Overview of applications in Switzerland and Europe*

The living lab integrative process was demonstrated in the use case of the project UserGap, which took place in Eikenott, a sustainable neighbourhood in Gland Switzerland, in which Living Lab methods and tools were applied. The aim was to better understand the components of the performance gap and how to reduce it. Transdisciplinary research was conducted at the MACRO (neighbourhood), MESO (buildings) and MICRO (households) levels. The empathise phase [15] of the process involved the analysis of the energy impact consumption in 300 apartments, typology of consumers and identification of main performance gaps. The tools used included a survey in the neighbourhood & load curve analysis, technical analysis, as well as a power/interest matrix to measure empowerment. The Power-Interest matrix as shown in Figure 2 allows to determine who are the “context setters” to engage, who are the “subjects” interested and to empower them and who are already the “players” with power and the “crowd” not interested nor empowered . [16]

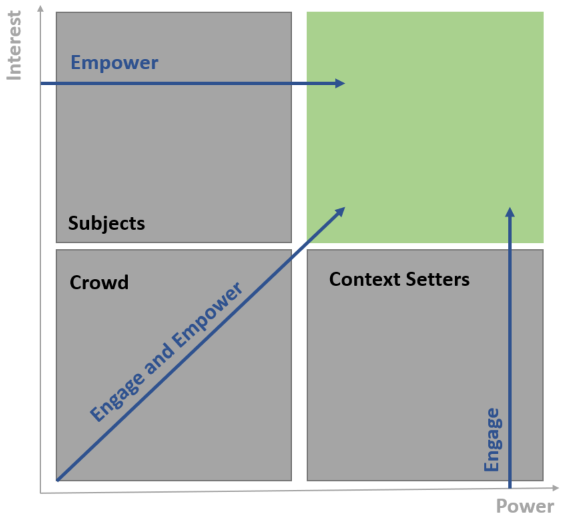

Figure 2: Power-Interest Matrix (Adapted from Eden and Ackermann, 1998). [16]

Community based social marketing was used to understand the barriers to energy performance. Qualitative Interviews with selected Stakeholders were undertaken and ethnography methods were applied. Co-design workshops with representative actors from the quadruple helix were carried out to develop a performance plan with inhabitants. A new serious game called Poker Design that allows citizens to co-design a plan for energy savings in their community was developed. The tool was designed and tested in the project. UserGap enabled the development of recommendations for construction policies and norms related to the design and use of energy products and services by inhabitants. For example, the "correct" use of blinds has a strong impact on thermic consumption in low consumption buildings. The Energy Performance Plan was prototyped and devices for energy efficiency were tested. TupperWatt evenings were carried out with the neighbours. An ex-post analysis of electrical, thermic and hot water consumption was undertaken to test performance. This approach is being tested in other neighbourhoods enabling scale up with the application of a sequential approach analysing economic, technical and social data. The empowerment of citizens in Eikenott demonstrated the potential for the application of the Living Lab Integrative Process in energy communities. Since 2021 the process is being applied in several EU H2020 projects including:

- the oPEN Project on Positive Energy Neighborhoods in establishing three Living Labs in Belgium, Estonia & Spain [17];
- the SCORE Project on Smart control of climate resilience in European coastal cities in establishing 11 Living Labs[18];
- the 2iSECAP project on Institutionalized Integrated Sustainable Energy and Climate Action Plans to engage civil society towards energy transition[19];
- DomOS Project on Operating System for Smart Services in Buildings [20].

IV. CASE STUDY IN SION, SWITZERLAND

The Living Lab Approach and Integrative Process is being applied since 2020 in the H2020 domOS Project in Sion Living Lab. Several different empowerment methodologies have been applied in the domOS Project at the three demonstration sites Sion, Switzerland, Alborg, Denmark and Paris, France to engage citizens in energy communities, including the co-design of services and gaining control over their own energy and comfort. The domOS demonstrators address a broad spectrum of services, building types, prosumers’ categories and energy sources. The Living Lab approach was applied in Sion, Switzerland in the engagement of prosumers in the development of Smart Energy Services. Mastelic recommends to include stakeholders in the co-design of low consumption buildings and energy conservation interventions [12]. If integrated into a co-design process, stakeholders have ideas that co-create societal and managerial value.

The citizens in the domOS project are referred to as Prosumers as they are supplying energy to the wider energy community of Sion through a variety of renewable energy and flexibility services. The prosumers in the Sion demonstrator are house owners with above average income mainly comprising families and business hotel owners. These prosumers are considered to have a common interest in the energy transition and have a common energy supplier and grid connection. These prosumers participated in a preceding EU project called GoFlex [21] where equipment was installed in their homes to enable energy consumption monitoring and the testing of energy flexibility solutions.

Living Lab methods and tools such as Integrating the Quadruple Helix of actors and a pre-analysis of stakeholders were undertaken initially to better understand the interest and influence of the various stakeholders in the domOS project to establish a strategy for their management. Residential customers were considered to have a medium level of interest and expectations regarding the project and measures to manage them closely were recommended due to their potential influence on the project. The business hotel owners have a lower level of interest but a higher level of influence and are therefore necessary to 'keep satisfied' during the project. There is a higher potential to empower the hotel owners to become players in the energy transition. Qualitative interviews were undertaken with house owners and the potential for engagement and thus empowerment was considered higher than originally estimated. A higher level of interest was noted than previously estimated. Approximately half of the prosumers interviewed participated in the co-design workshops which took place subsequently.

The collaborative workshops were applied in the domOS Project to allow co-designing of the services and products in a way that the value proposition is adapted to the clients' needs as much as possible.

The Living Lab Integrative Process was used to develop the domOS project Smart Energy services through:

- Identifying social practices and barriers in one-to-one qualitative interviews with prosumers and stakeholders including service providers;
- Analysing the emplowerment of stakeholders involved in the project, not only the citizens and prosumers;
- Co-designing of services (Heating, Relationship with energy, Flexibility and OK @Home SMART Home) using the pain/gain model to define the requirements for the future product/service in relation to the use case "relationship to energy" and an online platform for energy consumption;
- Testing and prototyping of the service 'Relation with Energy' a platform for presenting and engaging prosumers in their energy consumption.

The co-designing of the services used the Pain/Gain and Customer Job Model (Strategyzer) illustrated in Figure 3 as a tool to build the value proposition framework for each service (Heating, Relationship with energy, Flexibility and OK @Home SMART Home). The pains, gains & customer jobs' for each service were presented to the participants based on the results of the qualitative interviews.

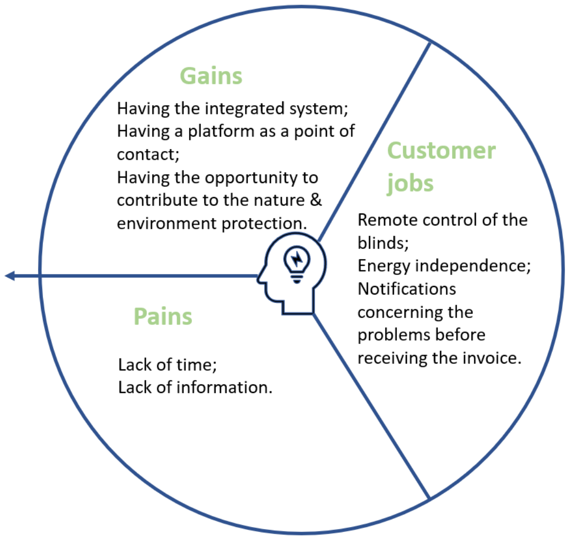

Figure 3: Showing the Pain Gain Model for the Energy Consumption Platform (Source Strategyser).

These results were then validated and explored more deeply using the World Café method [22]. Figure 4 shows the detail of the gain creators and pain relievers for the energy service 'relation with the client'.

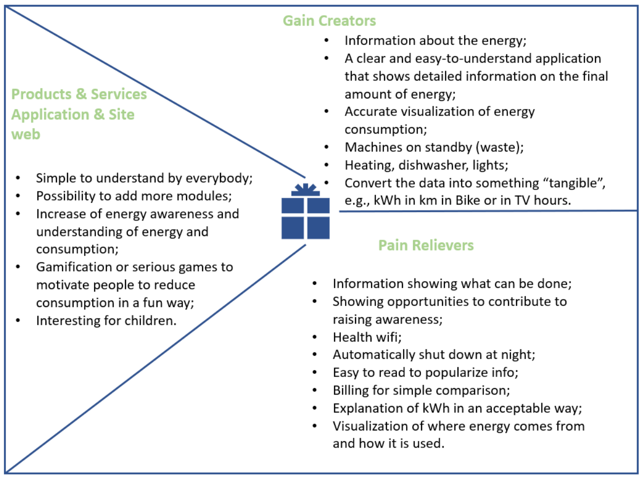

Figure 4: Showing the details of the gain creators and pain relievers for the energy service 'Relation with the client'.

The co-design workshop enabled the definition of the requirements for the future product/service in relation to the use case "relationship to energy" and helped to decide on the user stories for the future development. The workshop revealed a common value proposition for all services, namely simplicity, economy and peace of mind. The application of this methodology is ongoing in the Sion demonstrator as the process involves iteration where the prosumer is involved in

giving feedback about the products and services as they are developed.
Through the targeted interventions involving the co-design of the domOS products and services (the 'Subjects' the 'Crowd' and the 'Context setters') become empowered and will be mobilised in the Living Lab to become a "player" in the energy transition.
The Quadruple Helix Model of the Living Lab ensures the empowerment of the mix of actors needed to scale up solutions developed through the Living Labs and identified through the applied research [23]. The ongoing collaboration between OIKEN (Private), HES-SO (Research), Prosumers (Citizens) and the Grid Operators (Public) is important for the continued prosumer empowerment (Figure 5). This is an ongoing process at the Sion demonstrator site where several innovation projects are being developed consecutively with the same panel of prosumers.

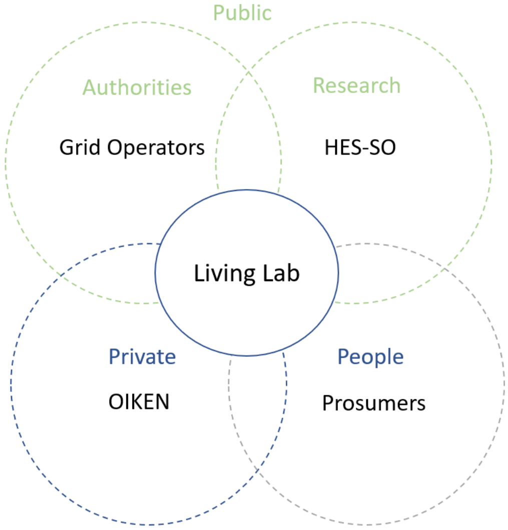

Figure 5: Quadruple Helix Model (Adapted from Carayannis and Campbell, 2012). [14]

The level of prosumer empowerment at the end of process is important and will be measured in coordination with other aspects of domOS Project such as the Smart Readiness Indicator, testing and implementation which will be undertaken with the same panel of prosumers.

V. Discussion

Both CECs and RECs must pursue the primary objective to provide environmental, economic or social benefits to its shareholders or members or to the local territories where it operates, rather than seeking profit. Thus, their development should bring different benefits at the environmental level: better integration of renewable electricity production via increased self-consumption and energy sharing on a local scale, in particular by changing consumption habits, should limit the mobilization of the network and allow greater penetration of decentralized generation. At the economic level, their impact should be favorable, whether on participants' bills or in terms of positive spin-offs on the local economy and jobs and the at the social level, these new possibilities of sharing are open to all citizens, including tenants and precarious households who do not have the possibility of investing alone in decentralized means of production.
The action in the UserGap research allowed to co-design an energy performance plan with key stakeholders. The analysis of the social performance proved to be very interesting for complementing the technical and economic analyses and thus the design of new neighbourhoods and retrofit projects. Challenges of multiple types of data collection, sequential approach and complexity of analysis of various sources were noted. The key lessons learned were that factors linked to energy and environment are not directly influencing the satisfaction to live in the neighbourhood. Automation could help users with default settings, but their regulation and maintenance are often neglected. Energy services and maintenance need leadership with an actor situated in the neighbourhood. There is a "social performance gap" measured with the importance/performance matrix applied to energy.
The research in the domOS Project enabled the application of Living Lab approaches and methodologies at the project level to explore citizen empowerment. Ongoing engagement and participation from stakeholders are needed to enable empowerment at a larger scale. Evaluation methods and tools are also needed to measure the outcomes and impact of Living Labs.
General tools such as Pain/Gain and Customer Job Model are helpful for the understanding of stakeholders' needs when co-designing products and services and contribute to the empowerment of citizens, however, a more ongoing engagement is needed throughout the prototyping and testing phases in order to sustain the motivation in the community. The co-design tools used for participatory activities should be adapted for the energy sector to include a broader group of stakeholders such as technology and energy services providers to help support and increase empowerment in energy communities and the energy sector.

VI. Conclusion

In this paper, we explored the living lab approach used as a tool for citizen empowerment in the design of new services related to the energy transition. Within this study, the framework of local energy communities was defined as the general set-up in which services are designed. We demonstrated that the Living Lab approach promotes social and technological innovations at different scales of the energy system and around various themes concerning the daily life of the LEC citizens. Thanks to realistic, iterative and longitudinal experiments, the actors of the LEC have the possibility of exchanging perspectives and knowledge around concrete activities that lead to solutions carried by users. As a research methodology, Living Labs also allow the coproduction of specific knowledge to innovation process and the discipline of design on the uses and their significance in the complexity of the energy systems context, the facilitation processes for the active participation of users and the integration of the analysis of uses at different times of the creative process. Our future experiments will therefore attempt to systematize and formalize further this methodology with the aim of carrying out innovative solution for energy communities.

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