Fostering "Energy Communities": An Ethnographic-SECI Approach to User-Centered Residential Micro-Smart Grid Adoption

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***Abstract*—This paper presents a user-centered approach to understanding the social context of smart residential microgrid adoption, with a focus on the SECI (Socialization, Externalization, Combination, and Internalization) model of knowledge creation. The objective is to identify the social characteristics that contribute to the social acceptance of smart residential microgrids, particularly from the perspective of prosumers interacting with AI. The study focuses on 12 Swiss smart grid stakeholders, including those who live in eco-neighborhoods, and own solar panels, plus three focus groups with experts. The study found that trust, community, and shared values are key social factors influencing the adoption of residential smart microgrids. Results also show how the SECI model could facilitate the creation and sharing of knowledge about energy management and sustainability practices, knowing that smart grids rely primarily on AI or explicit knowledge (Combination) and that successful implementation should as well, regarding this theory, focus on tacit knowledge (Socialization).**

Keywords— residential micro-smart grids, social context, user-centered approach, SECI model of knowledge creation

I. Context

The deployment of smart grids is seen as a promising solution to address the challenges of energy sustainability, reliability, and security. Smart grids can enable the integration of renewable energy sources, improve energy efficiency, and enhance grid stability and resilience. However, the adoption of smart grids by residential consumers, who are the end-users of the technology, has been slow and limited. Despite the technical and economic benefits of smart grids, the social factors that affect user acceptance and adoption have been largely overlooked. Therefore, this paper aims to investigate the social context of residential micro-smart grid adoption and to identify the social attributes that enable the social acceptance of the technology.

In the context of micro-smart grids, the notion of prosumers is important to consider. A prosumer is a hybrid actor whom both produces and consumes energy within the community. Prosumers can actively participate in the management of the microgrid, such as by adjusting their energy usage patterns or sharing their excess energy with others. This dynamic role challenges the traditional view of consumers as passive recipients of energy services and highlights the potential for community engagement and collaboration in the adoption of smart grid technologies.

The SECI model of knowledge creation provides rules for developing a coherent process of dynamic knowledge creation between each individual user and IT/AI processes embedded in a smart grid. According to [1], two kinds of knowledge can be conceptually distinguished along a continuum: (1) Tacit knowledge, which is non-verbalizable, intuitive, and unarticulated, involves nuanced comprehension, relies upon know-how and wisdom accumulated from collaborative experience, and is thus difficult to formalize; and (2) Explicit knowledge, which is predominantly codified.

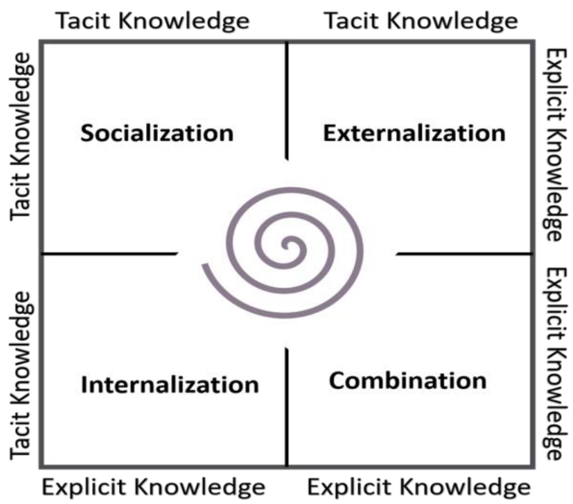

Fig. 1. Example The SECI model (Nonaka et al., 2000).

The SECI model (see Figure 1) is a framework for understanding the process of knowledge creation in organizations. It consists of four modes of knowledge conversion: Socialization, Externalization, Combination, and Internalization. In the case of a smart microgrid community (seen here as an organization), the SECI model can be applied to the process of creating and sharing knowledge about energy management and sustainability practices. The four dimensions of the SECI can be illustrated for the case of the smart microgrid community as follows. *Socialization:* Community members, particularly prosumers, can share their knowledge about energy use and conservation through direct interactions such as workshops, tours, and peer-to-peer learning. This helps to foster trust, community, and shared values, all of which are important social factors that contribute to the adoption of smart grid technology. *Externalization:* Community members are able to turn their knowledge into explicit knowledge, especially when they interact with smart meter sensors and real-time data about their energy consumption behaviors. This explicit knowledge is typically stored in databases using different digital architecture models. *Combination:* AI algorithms can produce solutions from the data provided by community members during the externalization phase. For example, the integration of renewable energy sources, the optimization of energy storage, and the management of demand response typically represent AI services produced during the combination and reconfiguration of explicit knowledge. *Internalization:* Community members, including prosumers, can absorb explicit knowledge provided by smart meters and convert it into tacit knowledge through repeated practice and application, such as monitoring energy consumption, adjusting behaviors and habits, and providing feedback to others. This ensures that the benefits of explicit knowledge are internalized and become part of the community's tacit knowledge, thereby improving the community's ability to understand and manage energy use and conservation.

The paper is organized as follows: Section 2 presents a brief literature review, including the new academic field of the energy community. Section 3 describes the methodology which is based on a classical ethnographic survey. Section 4 briefly presents the main survey findings, especially those related to the Socialization dimension of the SECI model, and related discussions, and Section 5 presents the conclusion and direction for further research.

II. Litterature Review

There has been some research and discussion on the importance of social cohesion and citizen engagement in energy communities, but the field is still relatively new and there is still much to be learned and developed in terms of best practices and effective strategies for incorporating these aspects into the design and implementation of residential micro smart grids. Citizens' engagement is crucial for sustainable urban development, including the transition to a fossil fuel-free future. However, research on smart cities tends to focus on technological innovation rather than public engagement [2]. While there is general acceptance of the benefits of rural electrification through mini-grids, there is a lack of empirical evidence of their impact on the general well-being or social development of the communities they serve [3]. This paper highlights the limited investment in mini-grids due to a lack of understanding of their social impacts. The existing knowledge base on social impacts is inadequate, and there is a need for better monitoring and evaluation methodologies. In [4], the authors propose an integrated framework for evaluating the sustainability of micro-grids, combining socio-technical transitions with socio-ecological resilience concepts and investigating the sustainability of micro-grids by analyzing their resilience, as micro-grids are becoming an appealing alternative to provide clean energy access to rural communities. Effective communication infrastructure is essential for managing distributed generation variability, security, and load-sharing issues. [5] reviews the features, characteristics, and challenges of microgrids and their associated communication techniques, with a focus on overcoming social barriers to implementation. [6] reviews the literature on community participation in private mini-grid projects and how it affects the project's sustainability. The authors find that community participation is essential for system sustainability and compiling best practices. They provide a framework and survey tool to gather information on community participation in mini-grid systems. The authors conclude that community participation should go beyond customer acquisition to accelerate universal electricity access and green economic recovery. [7] examines community energy initiatives and their potential to reshape the electrical system in a way that reduces emissions. The paper focuses on case studies that use a bottom-up approach, where an active and engaged citizenry is maximized, and also looks at recruiting and sustaining community participation as two key issues. The process of project development is important for realizing the catalytic and learning effects of meaningful and substantial local involvement. [8] discusses how "community" is often used to describe renewable energy projects in the UK, how different people interpret this term, and also argues that involving local communities in the development process is essential for the success of these projects. [9] introduces the concept of "community energy," which refers to the local production of renewable energy by citizens with the aim of contributing to a sustainable energy system. The article explores key issues and concepts related to community energy and suggests that science-based and practice-oriented policies could result from further research in this field. This notion of energy community is also becoming an extremely important issue for the European Community to support the development of the renewable energy mix [10]. [11] discusses the concept of energy communities and their potential to contribute to the decarbonization of the energy system. It explores the social arrangements and technical designs of energy communities and reviews the impacts of their formation.

III. Methodology

In our study of micro-smart grid communities, we used an ethnographic approach based on ethnomethodology. Ethnography is a method for conducting a detailed and systematic study of a specific human group or community, while ethnomethodology is an approach to analyzing social interaction that focuses on the practical methods and procedures that people use to make sense of their social world. Using this approach, we sought to identify the latent needs and expectations of the smart microgrid community, as well as detect the social trends and cultural factors that affect the adoption and use of microgrid technology. In this way, we are able to move beyond a priori theoretical frameworks and uncover the practical methods and procedures that underlie the social and cultural dimensions of the smart microgrid system, which is central to the socialization phase of the SECI model of knowledge creation. The survey included semi-direct interviews with 12 Swiss smart grid stakeholders, who were sampled to represent different profiles of potential micro-smart grid users or prosumers. For this qualitative research, we employed the purposeful sampling technique. The primary objective of this approach was not to achieve statistical representativeness, but rather to gain a deep and nuanced understanding of the social and cultural factors that shape the adoption and acceptance of residential micro-smart grids. In qualitative field research, the focus is on exploring and understanding complex social phenomena, rather than on testing predefined hypotheses or drawing statistical inferences. For this reason, qualitative methods are particularly well-suited to inductive and exploratory research, as they allow for hypothesis building and the development of explanatory frameworks.

The interviews were complemented by three focus groups with microgrid experts with different technical backgrounds, to ensure the social attributes derived from this research would be consistent with the more technical and logistical attributes of smart grids. The interviews were recorded, transcribed, and analyzed using the QDA Miner text analysis software. The analysis conducted in our study focused on identifying the social factors that influence user acceptance and adoption of residential micro-smart grids. We specifically examined elements related to tacit knowledge, as integrated with the SECI model. This research approach is based on the constructivist (or interpretivism) paradigm, which is particularly well-suited to understanding the complex social dynamics and perceptions surrounding smart grid technologies.

IV. Results and Discussions

Because this paper is short, we provide a limited number of significant results from our fieldwork. To simplify the presentation, after each key finding in the synthesis, we offer a research hypothesis and a brief discussion pertaining to the SECI Socialization phase like elements of interaction among prosumers in a smart grid community.

A. *Values/Ecofriendliness*

Key synthesis findings:

- Being more eco-friendly is a good motivation and gives people an incentive to take action in this direction.
- Eco-friendliness is not enough of an incentive to install solar panels.
- Learning more about the topics of electricity and microgrids raises awareness of the environmental issue.
- People living in a community need to have similar values, and to be committed to these values.
- People have different views and values regarding which energy sources are better.
- The topics of electricity and microgrids are linked to the environmental issue.

Research Hypothesis: *The level of motivation to install solar panels in a community is influenced by the individuals' awareness of the environmental impact of their energy consumption and their shared values and commitment to eco-friendliness.*

Discussion: Being eco-friendly and reducing the environmental impact of our actions is a growing concern for many people. However, it is not always enough of an incentive to install solar panels or take other actions that require time and resources. To motivate individuals in a community to install solar panels, they need to be aware of the impact of their energy consumption on the environment and be committed to reducing it. This awareness can be raised through education and information sharing about the topics of electricity and microgrids. Moreover, in a community, it is essential to have shared values and commitment to eco-friendliness. If individuals have different views and values regarding which energy sources are better, it may lead to a lack of cooperation and difficulty in implementing changes. Therefore, it is crucial to foster a shared sense of responsibility and commitment to eco-friendliness in a community.

B. *Elements Found in Ecodistricts*

Key synthesis findings:

- Influence on one another is stronger in a group where there is group cohesion.
- Group cohesion is deeply needed in a community.
- People need to actively participate so that group cohesion can be built.

Research Hypothesis: *The presence f group cohesion in a neighborhood positively influences the level of participation and engagement of individuals in community activities.*

Discussion: The findings suggest that group cohesion is a vital component in building a sense of community in a neighborhood. It is believed that a stronger sense of group cohesion can lead to a higher level of participation and engagement of individuals in community activities. This is because individuals feel a sense of belonging and attachment to the community when they are part of a cohesive group. The influence of others in the group is also stronger, which can lead to more social support, encouragement, and accountability for each other.

C. *Responsibility*

Key synthesis findings:

- The sense of responsibility is increased in a community where everyone is dependent on each other.
- In a community, each person needs to take their responsibilities seriously.
- The sense of responsibility is increased in a community where everyone is dependent on each other.

Research Hypothesis: *Communities that foster a sense of interdependence and responsibility among their members are more likely to successfully implement sustainable energy solutions.*

Discussion: The sense of responsibility is a crucial factor in the success of any sustainable energy initiative in a community. When every individual takes responsibility seriously, it leads to the development of a culture of accountability that is essential to achieving sustainability goals. This sense of responsibility can be further strengthened when members of the community depend on each other. When individuals realize that their actions directly affect their neighbors and the community as a whole, they are more likely to take their responsibilities seriously. One can hypothesize that fostering a sense of interdependence and responsibility among community members can lead to the successful implementation of sustainable energy solutions. This implies that involving and collaborating with the community are crucial factors for the success of sustainable energy initiatives.

D. Trust Elements

Key synthesis findings:

- There needs to be regular monitoring and maintenance so that members can feel safe.
- Having access to information regarding one's consumption is relevant to the people concerned.
- Risk and crisis management must be put in place so that members can feel safe.

Research hypothesis: *Regular monitoring, access to consumption information, and risk and crisis management are key factors in creating a safe and secure environment in a community.*

Discussion: The findings suggest that regular monitoring and maintenance of the community infrastructure is crucial in making community members feel safe. This includes having measures in place for risk and crisis management. Additionally, access to information regarding one's consumption is also relevant to community members, as it helps them make informed decisions about their energy usage and encourages more responsible behavior. Regular monitoring, access to consumption information, and risk and crisis management are likely to be key factors in creating a safe and secure environment in a community.

E. Living in a Community

Key synthesis findings:

- Community members need to make common decisions, rather than individual ones.
- Living in a community implies better relationships between neighbors.
- For a community to function well, members need to see that others are actively getting involved.
- Members of a community who are unmotivated to get involved must not penalize others' progress.

Research hypothesis: *In order for a community to successfully implement and maintain a microgrid, it is necessary for community members to make collective decisions, actively participate, and maintain good relationships.*

Discussion: The success of a microgrid in a community is heavily dependent on the level of participation and collaboration among community members. As such, the hypothesis that community members need to make common decisions, rather than individual ones, is crucial in ensuring that the microgrid is tailored to the specific needs and values of the community as a whole. Additionally, a strong sense of community and good relationships between neighbors can foster a culture of trust and cooperation, making it easier for members to work together towards a common goal. However, it is important to note that not all members of a community may be equally motivated to get involved in microgrid development and maintenance. To address this, it is necessary to implement strategies that incentivize and motivate community members to participate, while also ensuring that the progress of the project is not hindered by the lack of involvement of some members. In this sense, the hypothesis that members of a community who are unmotivated to get involved must not penalize others' progress is also critical for the success of a microgrid project in a community.

F. Knowledge/Information

Key synthesis findings:

- Getting involved in the process of installing solar panels teaches a lot about the topic, even if the process does not succeed.
- Information on how to get involved in the process of installing solar panels can be hard to find.
- Knowledge that everything is under control is important to feel safe.
- Communication is crucial in communities; it is better to give too much information than too little.
- It can be difficult to be aware of the amount of electricity one uses.
- Word of mouth has a strong influence on one's opinion of solar panels.

Research hypothesis: *Effective communication, information sharing, and knowledge transfer are crucial for promoting community participation in microgrid installation and maintenance, leading to a higher rate of successful adoption and long-term sustainability.*

Discussion: The findings suggest that community participation and engagement are critical factors for the success and sustainability of microgrid projects. Members of the community must be involved in the decision-making process and should have access to relevant information about the installation and maintenance of solar panels. The study shows that getting involved in the installation process can be an effective way to learn about solar panels and their benefits, even if the installation process does not succeed. However, the process of finding information on how to get involved in the installation process can be difficult and needs to be improved to increase community engagement. Moreover, the findings suggest that effective communication is crucial for building trust among community members and ensuring that everyone is aware of the progress and developments of the microgrid project. Members of the community need to feel that everything is under control and that they are being kept informed. Therefore, it is essential to provide regular updates and to give clear and comprehensive information about the installation and maintenance process. The study also found that word of mouth has a strong influence on one's opinion of solar panels. Therefore, community members who are actively involved in the installation and maintenance process should share their positive experiences with others to encourage more people to participate. Finally, the study highlights that a sense of responsibility and common decision-making are essential for building strong relationships between neighbors and creating a sense of community ownership and engagement in the microgrid project.

G. Resource Management

Key synthesis findings:

- In the process of implementing resource management, there may be trial and error, as well as grey areas.
- Resource management should not only be done on a small scale but also on a larger one.
- Combining technologies, for instance mixing photovoltaic and thermal panels, is a good solution to have better management of resources.
- The proportion of available roof area to be covered by solar panels must be well thought out.
- The management of resources must be organized and planned by the community, rather than improvised.
- The role of distribution network operators in regard to resource management seems unclear.

Research *Hypothesis: Effective resource management in microgrids requires careful planning, combining technologies, and the active involvement of the community.*

Discussion: The findings suggest that resource management in microgrids requires a well-organized and planned approach. The implementation of resource management may involve trial and error, and there may be grey areas that need to be addressed. However, combining technologies, such as mixing photovoltaic and thermal panels, can help achieve better resource management. The proportion of available roof area to be covered by solar panels is also a critical factor to be considered. In addition, the active involvement of the community in the planning and implementation of resource management is essential for success. Finally, the role of distribution network operators in the context of resource management in microgrids remains unclear and requires further investigation.

V. Conclusion

This study aimed to investigate the social context for residential micro-smart grid adoption from a user-centered perspective. Using a qualitative approach that combined semi-direct interviews and focus groups, we identified several key social factors that influence the adoption of micro-smart grids by residential users. This study used a qualitative approach to investigate the social context for residential micro-smart grid adoption from a user-centered perspective. The SECI model was utilized to examine the role of tacit knowledge in shaping user acceptance and adoption of micro-smart grid technologies. This model highlights the importance of both explicit and tacit knowledge in the adoption and effective use of smart grid technology. While AI-generated data provides crucial explicit knowledge, it is important to recognize the role of tacit knowledge in making sense of energy use and conservation at the community level. Our fieldwork synthesis revealed that community norms, values, and beliefs are critical in shaping the socialization of knowledge within the community. We also found that community members rely heavily on informal networks and personal relationships to share tacit knowledge and information about micro-smart grid technologies. Our research provides valuable insights for policymakers, energy companies, and researchers seeking to promote sustainable energy solutions and engage communities in the process. The study highlights several key factors that must be considered when implementing microgrids in communities, such as awareness of the environmental impact, shared values, group cohesion, effective communication, and resource management. Overall, the success of a microgrid project in a community is not only dependent on the technical aspects of the project but also on the social dynamics and relationships within the community. In the next step of the research presented here, we will evaluate how the attributes of social acceptability are combined with more technical attributes related to the physical laws of a power system [12], which for the latter are handled by AI/IT processes that correspond to the "Combination" phase. Thus, according to the SECI model, the 4 phases of knowledge creation must follow each other in an iterative way to be successful. Indeed, in a more classical relationship between multiple generators and often a single electric utility supplying electricity to many consumers, the logistical and managerial elements of the grid are provided by a single actor. Here we are dealing with a much more complex case, where numerous consumers also become producers (i.e., prosumers). Therefore, all the technical constraints associated with the grid must be considered, as well as the social acceptability characteristics that make them cooperate, otherwise, the project has no chance to succeed.

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