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Barriers to Community Microgrids in Fragmented Communities: Insights from a Case Study

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***Abstract*— This paper discusses the challenges of implementing microgrids in fragmented communities and highlights the significance of community identity and active involvement of residents. Community identity fosters inclusiveness and support for social relationships. However, the impact of cooperative and conflictual relationships on governance arrangements and social and environmental outcomes has received limited attention in studies. To illustrate the importance of community involvement in the development of a microgrid, we consider a remote community in Australia with frequent power outages and poor internet connectivity. The study involved a survey and interviews to understand the community's perspectives on the implementation of a microgrid, including their willingness to invest financially in purchasing and selling local renewable energy, their electricity usage patterns, their interest in hosting renewable energy sources, and their willingness to collaborate.**

***Keywords*— community microgrids, community energy, socio-technical systems**

I. Introduction

The global energy landscape is evolving at a rapid pace, with renewable energy sources gaining increasing importance in mitigating climate change [1]. Community microgrids have emerged as a promising option for energy distribution and management, presenting an alternative to the traditional centralised power grid [2]. These microgrids are small energy networks designed to offer reliable, sustainable, and resilient energy supply to specific communities. Capable of operating independently or in parallel with the main grid, they can serve a wide range of geographical areas, load types, and community sizes [3]. Community microgrids can significantly reduce the carbon footprint of energy consumption and allow communities to produce and manage their electricity, offering a chance for economic development and resilience [4].

The implementation of microgrids in different communities presents complex challenges that are not just limited to technical and financial considerations, but also extend to social dimensions [5]. Communities that become both energy producers and suppliers experience a transformative and self-organised approach that is expected to lead to a shift in energy technology implementation and outcomes [6]. Each community has unique characteristics, which can make it difficult for project stakeholders to adapt its technical standards and practices [7]. Hence, the successful implementation of community microgrids hinges on a comprehensive understanding of the social factors that influence their adoption and operation [8]. Various success factors for community microgrid projects have been identified in previous research [9], including stakeholder engagement [10], technical feasibility [11], regulatory support [3], financing [12], and community identity [13]. For example, the study on the successful community energy project on Samsø Island [14] highlights the importance of entrepreneurial individuals who were part of a strong network on the island and could build new relationships outside it. The island's community is known for having many formal and informal local networks that promote community spirit and inclusiveness, which leads to a commitment to social relations that supports the island's search for new opportunities. The study also emphasises the importance of strong relations between local organisations and the community as an essential background condition [14].

While studies have examined social factors in community microgrids, the majority have focused on the successful parameters in cooperative communities [9], [15], [16]. Few studies have explored conflictual relationships in physical community microgrid projects and how they affect governance arrangements and social and environmental outcomes [17]. This highlights a gap in the literature

emphasising the need for further research into the challenges associated with implementing community microgrids in fragmented communities where social divisions may complicate the process [18]. In fragmented communities, social divisions can create significant obstacles for community microgrid projects [19]. These challenges can range from a lack of trust and cooperation [20] to disputes over the distribution of benefits and the technical feasibility of the project [21]. These issues may impede the development and adoption of community microgrids [22], leading to a loss of opportunities for energy resilience and economic development in these communities.

II. Community Engagement and Participation

Effective community microgrid projects require a high level of participation and engagement from community members at all stages of the project [23]. Community members' contribution is essential for achieving the project's objectives, ensuring the project aligns with their needs and values, and ultimately, ensuring the project's long-term success [24]. A key factor in achieving success is the ability of community members to act collectively towards a shared purpose, which helps to build a sense of ownership and commitment to the project [25]. To address these social dimensions, it is essential to engage citizens through community training and capacity building, thereby facilitating the transition towards a more decentralised energy system [26]. By actively involving community members in each phase of the project, community microgrids can effectively address the specific energy needs and requirements of the community while promoting energy self-sufficiency, reducing carbon emissions, and creating a more sustainable energy future. Furthermore, community involvement in these projects can build trust, foster collaboration, and encourage ownership and accountability, leading to stronger, more resilient communities [27].

However, achieving success in community microgrid projects is context-dependent and may face unique challenges in different communities [14]. For example, the use of common pool resources such as energy can provide opportunities for cooperation and collective action among community members [22], but it can also lead to free-rider behaviour and barriers to participation and fair benefit distribution [28]. Additionally, the motivations of community members to participate in the project, as well as their physical limitations, can also affect the project's success [22]. Therefore, it is crucial to take a community-specific approach that considers the unique challenges and motivations of community members to ensure the success of community microgrid projects [12].

To further understand the social success parameters of community microgrids, this paper draws inspiration from the recommendation to examine the specific internal context of the community, as suggested by previous research [18]. This involves considering:

- Community Spirit
- Cooperative Tradition
- Locality and Responsibility

III. Community Microgrid Case Study

The case study was carried out in a remote community with less than 20 inhabitants, located in a mountainous region of Australia, which serves as a popular tourist destination due to its location on a major highway between two popular destinations. Tourism in the area is generated by passers-by as well as by nearby attractions with a focus on the community's natural capital. residential member of the community. This community is therefore especially interesting as each participant in this study is both a business owner and a residential member of the community.

In the past decade, except for a couple of years, there have been occasions when the System Average Interruption Duration Index (SAIDI) limits were exceeded. During one incident, the town experienced a power outage that lasted for more than two days due to suspected lightning, while another outage lasted over two days due to wires being down. The community also suffers from poor internet connectivity, and in the event of a power outage, all telecommunications services become unavailable after approximately four hours. The limited backup battery storage of the telecommunication tower, which relies on the town's power supply, is the primary cause of this issue. To ensure the town can withstand such extended outages, the solution must have significant capacity. Additionally, the town experiences severe weather conditions in winter and high fire danger in summer.

A. Initial Survey

As a first step, an initial survey was conducted to gather information about the community's views and motivations regarding the implementation of a microgrid. The purpose of the survey was to collect data on each community member's current energy status quo and their vision for a possible microgrid. The survey also aimed to assess the community's willingness to invest financially in purchasing and selling local renewable energy. It included questions designed to inform the community about microgrids and gather input on how they would like to use and generate electricity. Additionally, the survey collected information on electricity usage patterns, interest in hosting renewable energy sources, and views on the current electricity quality and stability. Other aspects covered by the survey included community members' willingness to pay more for greater reliability, interest in being active in a community microgrid, and engagement in the development process.

B. Interviews

The primary focus and the second step of the case study involved conducting in-depth interviews to explore the community's social factors in greater detail, with the aim of understanding the feasibility of a community microgrid. The interviews were designed to investigate the social structure of the community, which included examining factors such as trust, identity, norms, attitudes, and willingness to collaborate. To facilitate the interview process, a framework was developed to ensure consistency and comparability across interviews. This framework consists of various indicators to identify successful social factors in the community. Figure 1 illustrates the relationship between these indicators and the recommendations presented in [18].

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To ensure that the interviews were as informative as possible, the insights gathered from the survey were used to inform the interview questions. The interviews were structured as individual 30-minute in-person sessions for each community member, allowing for personalised attention and deeper exploration of their views and opinion. Prior to collecting data, the university's research ethics committee approved the human ethics protocols and data privacy protection measures under approval number ETH22-7777.

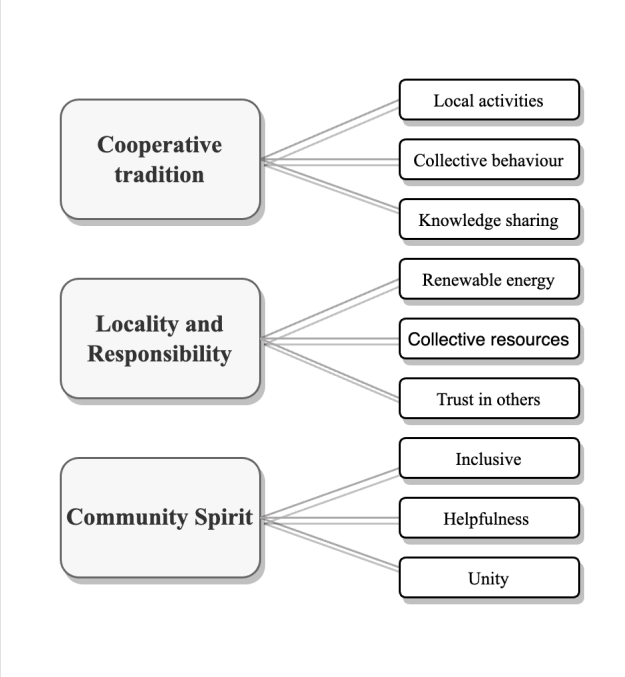

Fig. 1. Interview framework showing the relationships between indicators (on the right) and themes (on the left).

IV. Results

For both the survey and interviews, 6 out of 8 community members participated, representing approximately 20 people from their households. The insights from the survey and interviews reveal possible barriers to the implementation of a community microgrid. The results are summarised in Table 1 and discussed further in the sections below.

TABLE I. Overview of Community-Related Features

Institutional Features of Community	From Case Study
Community Spirit	Everyone for themselves. Lack of influence in decision-making.
Cooperative Tradition	Minimal cooperation Varying levels of trust and willingness to contribute to the community. Some expressing self-interest as a priority.
Locality and Responsibility	Tourism, many businesses rely on consistent power for their guests. Positive attitude towards renewable energy.

A. Community Spirit

The prevailing attitude among community members is one of self-preservation, with a focus on individual businesses rather than the community as a whole. Most of the community members described that helpfulness exists when there is a business interest or gain for each member. Helpfulness for the sake of it seems to be lacking and previous conflicts between community members have been identified. This may affect the perspective of fairness between community members. For example, one community member's willingness to participate was identified to be directly related to the concern of not receiving the same physical installations as their neighbours. Similarly, the community state that they often feel a lack of influence in decision-making in relation to community matters.

There appears to be a general belief within the community that full agreement on solutions to community problems will not occur. The results from the interviews specifically indicate that the community spirit is such that if something needs to be done, you do it yourself.

B. Community Tradition

While community members are willing to assist each other with business-related matters connected to tourism, there is not much collaboration outside of this context. The only cooperative tradition that can be identified is when businesses collaborate within the community. Community members also share varying opinions on knowledge and information sharing with each other. However, the majority seem to state that important information and communication tend to occur after significant events have taken place.

Continuing, the geographical structure of the community may impact the cohesiveness and possibility of cooperation. As seen in Figure 1, this community has a scattered structure and long distances between some of its community members. As stated by the community, local activities or local groups are non-existing. Interactions between community members are therefore separated to mostly be one-to-one communication when needed. This further seems to cause fewer physical meetings and communication between the community, increasing the fragmentation that is already there.

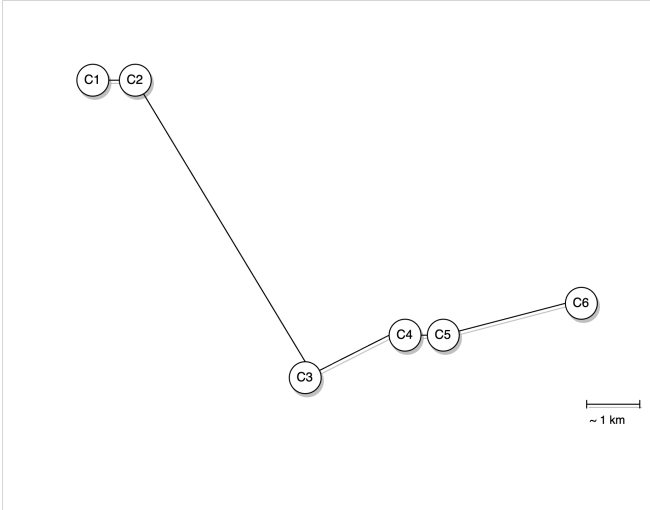

Fig. 2. The representation shows the geographical distance between participants in the community, with C1 to C6 representing community member 1 through community member 6.

C. Locality and Responsibility

We further identify that the willingness to participate in a possible community microgrid is highly dependent on the norms and relationships in the community as previously identified in studies such as [20], [29]. When it comes to attitudes connected to collective resources, the majority of the community does not believe in sharing resources without some sort of monetised solution. There is a great belief in the community that others would benefit more from sharing resources than themselves. The uncertainty of others can be related to the trust in the community, which is found to be divided, with some individuals placing trust in specific community members while others lack trust towards the whole community. Only two community members explicitly shared that they trust each other and share the same view and helpfulness towards each other. However, the community as a whole appears to have a strong level of trust in the network and service provider and suggests that they should take a leading role in the project.

Managing shared power resources is complex, and some community members may need to be convinced of the benefits of a microgrid solution. For example, all respondents agree that resilience against power outages is important, but only half are willing to pay more for greater reliability. None of the respondents believes that they will become more independent from the main grid through a microgrid solution, but all agree that they would want to host renewable energy sources. Half of the respondents are unsure about investing in local renewable energy, and mixed thoughts were expressed about how much they would be willing to pay for it in the future. Additionally, the lack of belief in the community's ability to run the microgrid, concerns about maintenance and resource allocation, and a lack of collaboration outside of business contexts pose significant obstacles to the project's success

D. Understanding Fragmented Communities and Identifying Steps Forward

The perception of the community towards the microgrid project can vary depending on the questions we ask and the approach we take, as demonstrated by the case study. Initially, the information about the community seemed promising. The community had positive attitudes towards renewable energy and community microgrid solutions. They also expressed a need for resilience and showed a willingness to host distributed energy resources and participate in the project. However, when the survey and interviews were conducted, multiple barriers to the project became apparent. The community's structure and dynamics posed challenges to the project's success, and some community members were not showing up to local community information sessions. Additionally, some members were interested in the outcome but generally lacked the time to commit to the project

Further, an interesting finding from the case study was that, in the survey, resilience against outages was identified as the community's number one priority. However, the results also indicated that the community was not willing to pay more for this to happen. On the other hand, the interviews identified that the community might be more positive towards a community microgrid if it removed the dependency on having individual backup diesel generators to protect each business during possible outages. Questions regarding the investment and time needed for these separate backup generators showed that willingness to pay more for resilience was already there. However, a lack of knowledge about the community microgrid restrained the answers due to not fully understanding the possibilities of such as system.

When it comes to community engagement, we also identified technical and physical barriers to possible participation. Given the limited internet connectivity in the town, online webinars were not a viable option for engaging with the community. Therefore, the most effective approach was identified to be in-person meetings with the residents, supplemented with occasional phone calls and email updates to keep them informed. The community also showed a lack of time to participate or engage in a possible microgrid which also affects the ability to participate. Hence, compared to the microgrid project initiated by the community itself or a cooperative community, a project similar to this one might have to find alternative ways to community engagement and participation. We summarise some of the suggestions on how to continue a community microgrid project in a fragmented community

- Design the microgrid based on the community's feasibility of participation and engagement.
- Ask specific questions about community members' attitudes towards resource sharing and trust in others.
- Customise capacity-building programs for individuals who are hesitant to participate, rather than focusing solely on group activities.

V. Conclusion

The success of a community microgrid project depends on the community's perception of the project and their engagement and participation in it. This paper emphasises the significance of comprehending the social factors and community dynamics to identify social barriers and their underlying causes in community microgrids. We especially find that identifying the community's attitudes towards collaboration, trust, and self-interest are crucial impediments to the feasibility of the potential implementation of community microgrids. The case study showed that the community's attitudes and priorities towards the project can change depending on the questions asked and the specific approach. Technical and physical barriers were also found to hinder possible community engagement and participation. Hence, identifying the most effective approach to engaging with the community is also critical. Lastly, insights from this case study can provide valuable guidance for future community microgrid projects in fragmented and divided communities.

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