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Embracing complexity: Microgrids and community engagement in Australia

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A R T I C L E I N F O

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A B S T R A C T

In the context of the energy transition and a changing climate, microgrids have emerged as a promising solution for ensuring a resilient and reliable electricity supply for rural and remote areas. Beyond the technical and economic considerations, social acceptance will be immensely important if microgrids are to be widely adopted by the people who live in these communities. This requires complex community engagement strategies delivered by knowledgeable practitioners, encouraging collaborative participation and active community involvement in decision-making. This study investigated how community engagement was applied by nineteen organisations that received funding to undertake microgrid feasibility studies for ninety communities across Australia between 2020 and 2024. A Community-based Participatory research (CBPR) framework was employed to uncover the challenges encountered at each step of the engagement process and what was done to overcome them. The study revealed major community engagement challenges, including inadequate funding, low energy literacy levels, and engagement fatigue. The findings also suggest that due to the inherent complexity of microgrids, these projects need to take an iterative and flexible approach, planning for expansive and resource-intensive engagement with the community to be effective. The research findings provide valuable insights for community engagement practitioners, policymakers, and service providers involved in planning microgrids and developing related policies and programs for rural and remote communities.

1. Introduction

The energy transition represents a complex process, with multiple systems such as technical, social, institutional and cultural working in an overlapping manner [1–3]. Energy transitions do not only involve a substitution of technology but also include shifts in user practices, regulations, and public attitudes [4,5]. While assessing the techno-economic feasibility of different forms of emerging renewable energy technology is crucial, the role of social acceptance is equally significant for their widespread adoption [6]. Where local communities are involved and potentially impacted, lack of appropriate consultation can lead to conflicts, mistrust, and divisions forming opposition against any proposed projects [7]. Thus, deep community engagement and effective consultation can increase the chances for the social acceptance of renewable energy technologies [7].

Community engagement is considered a critical factor for the successful implementation of renewable energy projects, regardless of scale or type [8–10]. This is due to its ability to develop a sense of partnership between the different actors while building trust with the local community [11–13]. The inclusion of community-based approaches in energy projects can provide opportunities for the local communities to participate in the energy market beyond the role of purely a consumer [14,15]. Previous research has also revealed that those renewable energy projects where the community is more actively engaged tend to be more successful [8,9].

Renewable energy microgrids, a subset of renewable energy projects, have emerged in some countries as an attractive technological concept for delivering more resilient, reliable, secure, economic, and sustainable electricity to rural and remote communities [16–19]. While renewable microgrids for communities in Australia are still nascent, considerable government funding has been made available to accelerate their adoption [20,21]. A noteworthy example of one such initiative is the Australian Government's Regional and Remote Communities Reliability Fund - Microgrids (RRCRF) program. From 2020 to 2024, this program allocated $AUD50 million to finance thirty-six feasibility projects concerning a potential one-hundred-and-ten community microgrids.

This paper provides granular insights into the community engagement methods, approaches, and tools employed by twenty-five microgrid feasibility projects concerning ninety communities. The qualitative research presents empirical findings from nineteen semi-structured

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interviews with key project stakeholders, to gain insights into the community characteristics and challenges at each step along the engagement process. The research findings will help those involved in the planning of microgrid projects, as well as those designing related policy and programs.

This paper follows a structure outlined as follows: Section 2 presents a review of the literature on community engagement and social acceptance, identifying gaps related to the social aspects of microgrids in Australia. This is followed by the introduction of the Community Based Participatory Research framework, which was used to better understand how community engagement was being applied across the various microgrid projects. Section 3 outlines the methodology used to gain a deeper understanding of the community engagement strategies employed by the microgrid projects. Section 4 provides the results from the semi-structured interviews conducted, followed by Section 5 which discusses the findings in the context of the wider research topic. The research conclusions are provided in Section 6.

2. Literature review — The social dimensions of microgrids in the energy transition

The existing literature emphasises the significance of considering the social dimensions regarding how renewable energy technologies are deployed in the context of the energy transition [22]. In particular, a thorough understanding of community practices, thinking, and behaviour is vital in the overall process [23,24]. However, the absence of active community involvement in a renewable energy project can lead to diminished trust that the transition can deliver public benefits [25]. Thus, social acceptance plays a crucial role in the successful deployment of renewable energy projects [26]. Social acceptance requires comprehensive understanding of community concerns, preferences, and reservations [27,28]. Social acceptance can be achieved by engaging with the communities and understanding their perceptions of the technology [29].

Although there is no agreed definition of community engagement [30–32], it is generally defined as a process in which people work collaboratively, through inspired learning, to create and realise the visions of the future [33]. It can vary in each case as community energy projects exhibit substantial diversity depending on scale, technological variation, social organisation levels, and project purpose [34]. The subsequent level of community engagement can also range widely from passive consultation to active involvement and collaboration [35]. Projects may follow a top-down community engagement approach, commonly used in the traditional energy generation and transmission system, where the decision-making process is driven by politicians and energy experts [36,37]. However, such approaches have been criticised as being unable to capture the community's actual needs [31]. Conversely, other projects may follow a bottom-up community engagement approach [38,39], considering the project site as the source of grassroots innovation while devising strategies according to the community's desires and needs [40]. This approach is based on including local community members in the decision-making process and amplifying the views and expectations of the local community, while creating awareness and social acceptance around a project [41,42].

Various tools and techniques are utilised in community energy projects to achieve these objectives, including surveys, questionnaires, interviews, workshops, stakeholder meetings, network development, scenario generation, participatory mapping, and community liaison officers. Surveys and interviews were the most cited methods in the literature for data-gathering [43–47]. Interview techniques are varied and may be structured or semi-structured, conducted in person, or undertaken remotely by telephone or online [20,48]. Workshops and focus groups can increase community participation while providing a better understanding community attitudes, preferences, and vision [45]. The formation of a community group is also important, as bringing together like-minded people with similar interests has been found to strengthen the local decision-making process [49–51]. Interactive strategies, such as scenario generation [52] and the serious game approach [53], have also been effective at driving deeper engagement with communities.

Renewable microgrids have emerged as a promising concept to provide more resilient, reliable and sustainable power within a transitioning energy system [19,54]. This is due to their ability to operate independently of the main grid while integrating locally generated renewable energy resources [55]. They have also been cited as being able to provide other advantages such as energy security [56,57], energy reliability [58], remote power supply [59], and resiliency against natural disasters [60,61]. Microgrids have also been found to improve power quality, reduce frequency fluctuations and voltage imbalance, and improve power losses [62,63].

The literature reveals multiple definitions for the term 'microgrid' [64–67]. Nevertheless, one of the most cited describes it as *"a group of interconnected loads and distributed energy resources, which are operated in the particular electrical boundary as a single controllable entity. A microgrid can connect or disconnect from the grid and operate independently in the islanded mode"* [18,68,69].

The existing literature on microgrids predominantly focuses on its techno-economic aspects [65]. For instance, researchers have presented in-depth analysis of the economic aspects of microgrids [70–74]. Technical aspects of microgrids have also been discussed in detail. For instance, [75] have discussed the challenges and barriers of using converter-based microgrids, [76] have elaborated the protection scenarios in the microgrid operations, [77] have thoroughly reviewed technical aspects of DC and AC microgrids. [62,63,78] have reviewed dynamic frequency behaviour in microgrids. The role of energy storage in microgrids has been discussed by [79,80], while [81–83] have reviewed control strategies and control mechanisms. Microgrid design optimization and optimization of energy management systems have also been thoroughly evaluated [84–86]. Researchers have also highlighted the three major categories of microgrids: AC (alternating current) microgrids [87,88], DC (direct current) microgrids [89–91], and hybrid microgrid (which integrates both AC and DC power sources, storage, and loads) [91–94].

While there has been significant research previously undertaken on the techno-economic aspects of microgrids [91,95], some have highlighted that the social aspects of microgrids require more exploration [16,96,97]. This is despite their having been significant research on the social acceptance of renewable energy technologies more broadly. For instance, past research has highlighted the role social acceptance plays in solar projects [98], wind farms [99,100], community batteries [101], hydrogen production [102], and geothermal technology [103]. However, there has been limited research on the social acceptance of microgrids based on real-world projects. A review of the relevant international literature related to community participation and the social aspects of microgrids was undertaken, and a summary of these articles, along with the methods used in their research, has been presented in Table 1.

The literature revealed a notable disparity in the volume of research being undertaken between the techno-economic and community engagement/social aspects. While case study approaches are present in some of the selected papers, most articles focus on a small number of examples, and there remains a lack of consistent data on the social aspects, how the community engagement strategies were employed, the challenges, and how they were overcome.

Therefore, this research aims to address this gap by undertaking qualitative research that can provide a deeper understanding of how community engagement approaches are applied drawing on real world microgrid feasibility projects. This research can thus shed light on what lessons can be learned to support practitioners, policymakers, and industry in better engaging with rural and remote communities on microgrids.

Table 1
Summary of relevant articles.

#	Author	Details	Methods
1	[104]	Investigated public support for community microgrid installations in the US (Arizona, Colorado, New Mexico, and Utah) while determining willingness to pay.	Literature review, survey-based contingent valuation method
2	[70]	Examined the willingness of US consumers to pay for community microgrid services during power outages with a sample of 939 respondents.	Literature review, discrete choice experiment method
3	[18]	Identiffed, evaluated, and summarised trends relating to the social (as well as the technical) aspects of community-based microgrid deployments.	Systematic review
4	[97]	Explored community responses to four microgrid proposals in the US to examine differences between successful and unsuccessful. Interviews (n = 28) were undertaken with stakeholders.	Literature review, Advanced Preparatory Fieldwork approach, case study approach, semi-structured interviews
5	[105]	Undertook a review of microgrids, applying the STEEP (Social, Technical, Economic, Environmental and Policy) model to understand the challenges faced by remote communities with a focus on Nigeria.	Literature review, case study approach, STEEP framework.
6	[106]	Identiffed the success factors for microgrid implementation based on case studies from Germany, highlighting the signiffcance of success factors such as the active participation of stakeholders.	Literature review, case study approach, meta-study with thematic analysis
7	[107]	A desk-based review of community microgrids worldwide to examine the institutional reasons behind their growing adoption.	Literature review
8	[56]	Reviewed microgrids implementation in developing and developed countries while understanding the drivers and impacts of microgrid projects	Literature review, case study approach
9	[108]	Explored the role of stakeholders through interviews (n = 41) in inffuencing the development of community energy projects across Europe.	Literature review, structured interviews
10	[58]	A discussion article covering the key characteristics of community microgrids, the social beneffts, as well as the required technical solutions and methodologies.	Literature review
11	[109]	Desk-based research and use of the NIE (New Institutional Economics) framework to understand ownership, governance, and the role of customers.	Literature review, NIE framework
12	[110]	Used socio-ecological system theory to propose a community engagement methodology while seeking to validate it through a case study in rural Chile.	Literature review, case study approach, socio-ecological systems theory.
13	[61]	Investigated two cases of microgrid communities, how the communities were formed and the effects of microgrids on communities and stakeholders involved.	Literature review, case study approach
14	[111]	Undertakes a rapid review (industry and societal issue-based) to identify the case for microgrids in the context of multi-residential buildings and communities while summarising recommendations for government and industry.	Rapid review
15	[16]	Presents a transdisciplinary approach to community microgrid site selection for government-funded microgrid feasibility in Australia, based on survey data from other organisations, discussions with project partners, and semi-structured interviews (n = 40).	Literature review, surveys, interviews, case study approach
16	[112]	Undertakes a literature review on community microgrids, applying social capital theory to identify what factors can increase their social acceptance.	Literature review, social capital theory
17	[21]	Investigated four microgrid-related projects in Australia using a Multi-Level Perspective (MLP) framework to reveal commonalities and differences in relation to the drivers and challenges.	Literature review, case study approach, MLP framework
18	[20]	Explored the challenges and opportunities experienced by 25 microgrid feasibility projects (covering 90 communities) in Australia, using semi-structured interviews (n = 19) and the PESTEL (Political, Economic, Social, Technological, Environmental and Legal) framework.	Literature review, semi-structured interviews, PESTEL framework

3. Methodology

The methodology encompassed three nested components. The Community Based Participatory Research (CBPR) framework, which was used to frame the overall research as well as understand the specific methods, tools, and challenges that were encountered at each step of the engagement process. The semi-structured interviews captured the views and experiences from those involved in the microgrid feasibility projects. Thematic analysis was used to identify broader themes that emerged from the interviews. The following diagram summarises the methodology developed for this research (Fig. 1).

3.1. Theoretical framework — Community-based participatory research (CBPR)

A Community Based Participatory Research (CBPR) framework was selected as a holistic way of framing and evaluating community engagement as part of this research. As such, it would enable a deeper understanding of the community engagement processes used across such a varied number and types of microgrid feasibility projects.

Several other frameworks were also considered, including Arnstein's 'ladder of participation' method [113], the Public Engagement Onion model [114], Multi-Level Perspective (MLP) [4,115], the Behavioural Developmental Model (BDM) [116] and Social Capital Theory [112].

Despite the well-documented advantages associated with these other frameworks and models, the CBPR framework was deemed most suitable for this research because of its core principle, which focuses on the involvement of community stakeholders at every stage of the research process to develop action-oriented research [117,118]. CBPR has also been widely used within the health sector, where the framework has been noted as an effective tool for evaluating and shaping community engagement initiatives [119,120]. In addition, it is successful at achieving a common knowledge production process where multiple stakeholders are involved [121–123].

3.2. Semi-structured interviews

Building on the literature review and gap analysis described in Section 2, in-depth semi-structured interviews were conducted with key stakeholders representing nineteen of the thirty-six projects funded by the RRCRF program. Interviewees held diverse roles, including project managers, community liaison officers, senior engineers, energy specialists, and academic researchers. This qualitative research methodology enabled the extraction of detailed insights regarding the personal

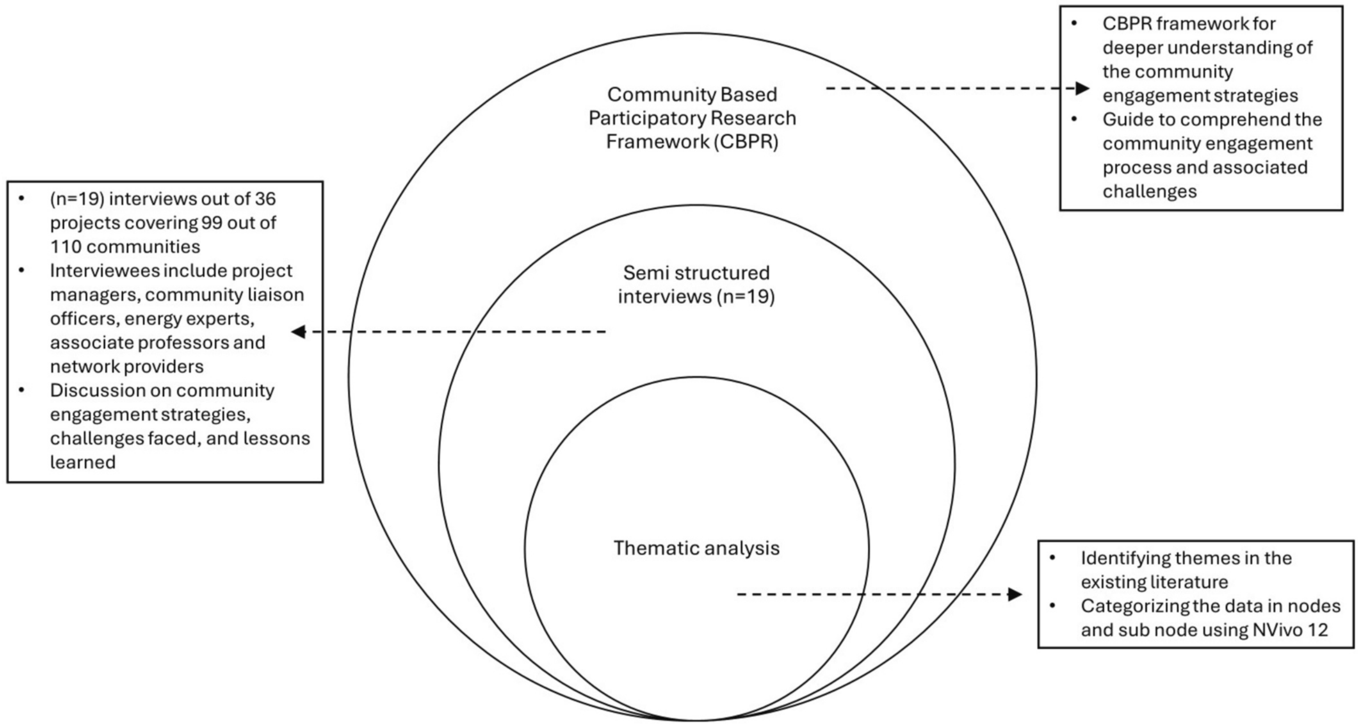

Fig. 1. A conceptual overview of the methodology.

perspectives and experiences of the participants involved in community engagement for these microgrid feasibility projects.

The initial step of the interview process involved identifying and recruiting participants from the projects that received government funding for their microgrid feasibility projects. Basic project details were sourced from the funding website, including the named project lead, the geographic location of the project's communities (where known), the funding amount, and short project descriptions. Potential interviewees were contacted directly where an existing professional connection existed, or through making a general inquiry with the lead project organisation named on the grant funding webpage. Requests for interviews were emailed and followed up with a limited number of additional emails and telephone calls until scheduled, declined, or no answer was received.

The interview guide was developed for data collection based on the identified research gaps in the literature. The interviewees' participation was purely on a volunteer basis, with no incentives provided for participating. The interviews were conducted online and ranged from 30 to 50 min. The questions sought to explore the community engagement strategies, the community response towards the project, challenges while engaging with the community, and how community engagement could be enhanced for future microgrid projects.

Of the thirty-six projects that received funding from the RRCRF program, nineteen accepted the invitation to be interviewed. Given that several of the funded projects encompassed feasibility assessments for more than one community, the successfully completed interviews allowed for investigation of the engagement approaches used in ninety of the one-hundred-and-ten communities (i.e., 81 %) where feasibilities were undertaken.

A major strength of the semi-structured approach was that it allowed flexibility in how questions could be asked and followed up, facilitating the discovery of more insightful answers to the interview questions given such a varied cohort of interviewees. However, it should be noted that a shortcoming of this approach is the risk of interviewer and social desirability focus bias [124]. Additionally, the limited number of interviews conducted ($n = 19$) poses the risk of yielding insufficient data, which can lead to conflicting narratives. While it would have been ideal to interview all participants involved, the process nonetheless provided detailed insights into the project. Another limitation is the exclusion of community members from each project in the interview process. Including local community leaders could have enriched the data; however, reaching individual community members requires significant resources and effort, which was beyond the scope of this research.

Insights from the semi-structured interviews were supplemented with additional information from material published by the different projects as part of their grant funding agreements. This included milestone reports, conference papers, news releases, articles, project websites, and other publicly accessible information. The details of the interviewees, their communities, roles in the project, and the number of projects covered are stated in Table 2.

3.3. Thematic analysis

A thematic analysis approach was used to analyse the qualitative data gathered from the interviews and supplementary resources. This involved the review of data, determining the coding unit, establishing a codebook, identifying themes, and checking for dependability. The interviews were recorded with the participant's permission and transcribed using software for speech-to-text conversion. The written transcripts were cross-checked again with the actual audio to address any data discrepancies. NVivo 12 was used to code the interview transcripts, and the data was categorised into nodes and sub-nodes. Emerging themes were also categorised and analysed to ensure duplicated themes are not recorded. The 'criteria of saturation' was used while analysing the data, meaning the data analysis continued until new themes stop emerging [125].

A thematic analysis of the interviews gives a high-level perspective of the community characteristics in the project, major challenges encountered, and general perceptions of the community towards the project. However, CBPR was adopted as the theoretical framework to dig deeper into understanding the engagement process and its various intricacies.

Table 2
Details of the interviewees.

Interviewee	Role	Organisation type	Community characteristics	No. of communities	Combined population of community served	State
1	Engineer	Network Provider	Residential, seasonal tourism	2	500–1000	NSW
2	Manager	Network Provider	Residential, commercial, seasonal tourism	35	500–5000	WA
3	Researcher	University	Residential, industrial	1	500–1000	NSW
4	Engineer	Community Group	Residential with seasonal tourism	1	<100	SA
5	Manager	Project facilitator	Residential, commercial, First Nations	1	500–1000	NT
6	Engineer	University	Residential with seasonal tourism	1	<100	Tas
7	Analyst	Electricity Retailer	Residential	1	1000–5000	Vic
8	Chief Executive Offfcer	Electricity Retailer	Residential, commercial	1	100–500	WA
9	Manager	Electricity Network Provider	Residential, commercial	3	1000–5000	NT
10	Project Manager	Industry Association	Farming	4	<100	QLD
11	Engineer	Electricity Network Provider	Residential, commercial	20	100–500	NT
12	Project Manager	University	Residential	6	1000–5000	Vic
13	Researcher	University	Residential, commercial	8	5000–10,000	NSW
14	Project Manager	Electricity Network Provider	Mining, First Nations	2	500–1000	QLD
15	Group Member	Community Group	Residential, commercial	1	5000–10,000	Vic
16	Project Manager	University	Residential, commercial	1	1000–5000	Vic
17	Chief Executive Offfcer	Electricity Network Provider	Residential, commercial	6	Some communities with <100 whereas one with 500–1000	WA
18	Researcher	University	Residential, seasonal tourism	2	500–1000	Vic
19	Manager	Electricity Network Provider	Residential, seasonal tourism	3	1000–5000	NT

4. Results

The results from this study have been presented in this section. The findings from the thematic analysis offer high-level insights into community characteristics, different community engagement approaches, the various challenges faced, and the ways they were overcome. Fig. 2 summarises the thematic analysis process, followed by the explanation in the following section.

4.1. Types of towns

The interview data revealed that most projects that received microgrid feasibility funding were for small communities with populations of between five-hundred and one-thousand people. However, this was

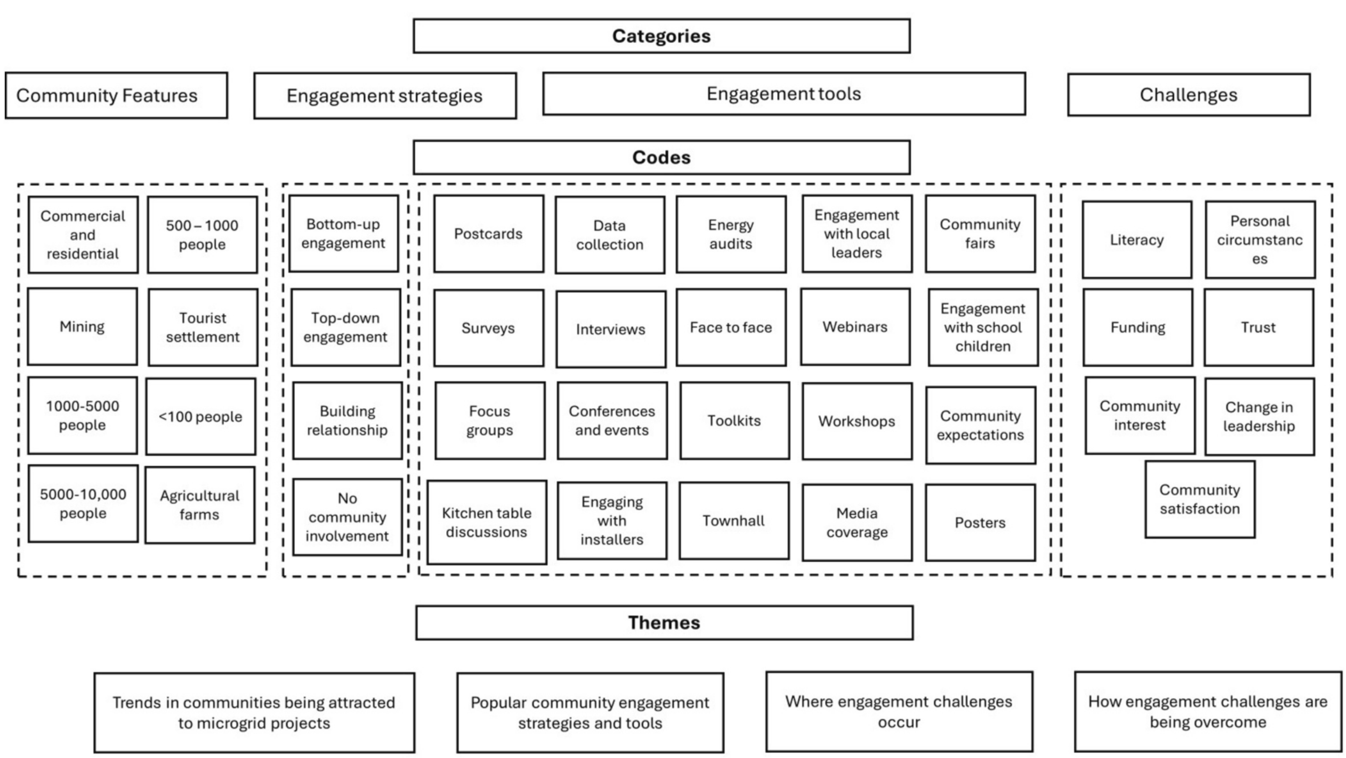

Fig. 2. Summary of the thematic analysis process.

followed closely by very small communities of less than one-hundred people and then those of between one-thousand and five-thousand people. Most of the feasibility studies were for residential towns with some commercial activities, followed by residential communities with seasonal tourism, residential First Nations, mining, and farming communities. Figs. 3 and 4 below show the community characteristics and population breakdown of those involved in the feasibility studies.

4.2. Community engagement approaches

The interviews revealed that both top-down and bottom-up engagement approaches were applied across the projects interviewed, although top-down was the slightly more popular strategy used for engaging communities. The bottom-up approach is characterised by a two-way communication process, sharing ideas and findings with the community, seeking feedback, and incorporating their inputs to devise solutions. Conversely, the top-down approach informs the community about project motives and processes without actively soliciting their views and ideas. It was found that the top-down approach was more likely to be employed in less energy-literate communities, or where there was perceived to be low community interest. Interestingly, just over a fifth of projects involved no formal community engagement (except some existing relations with the community leaders).

Fig. 5 shows the percentage of projects employing the different engagement approaches.

4.3. Community engagement challenges

4.3.1. Lack of funding on multiple fronts

A lack of funding for community groups and the level of engagement needed were highlighted by interviewees as posing challenges for their projects.

Community groups were noted to play a crucial role in providing resources and assistance to project teams. They would serve as important links between the project and the community, communicating the project objectives, its continuing progress, and judging community priorities, needs, and sentiments. However, interviewees emphasised the significant challenge of insufficient funding for community energy groups to provide the necessary resources to participate in projects as was desired.

Additionally, engagement initiatives were said to have been challenged by the same inadequate funding issue, particularly for running events, workshops, webinars, and even routine meetings. Additionally, the production and distribution of supplementary communication materials (such as posters and pamphlets) struggled due to limited resources. One reason provided by an interviewee for this was: "*During the project scoping, a substantial portion of the budget is typically allocated to techno-economic feasibility, with limited resources for community engagement and setting up community energy groups. We worked as a pure volunteer, advocating for the project*".

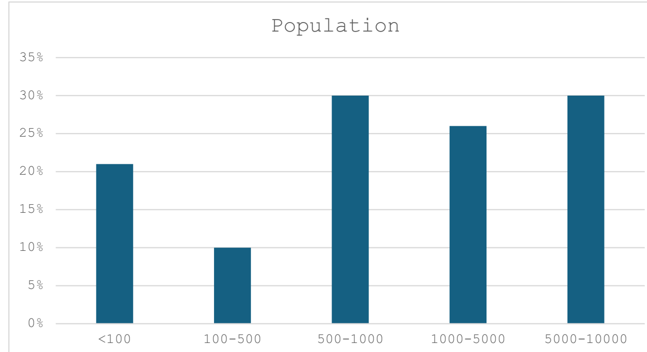

Fig. 4. Population of the communities involved in the microgrid feasibility studies.

4.3.2. Varying degrees of energy literacy increases engagement complexity

A lack of energy literacy within communities posed a fundamental challenge to many projects' engagement activities. The degree of energy literacy was found to vary between projects, within communities, and the community groups themselves.

The interviews revealed that limited knowledge existed regarding microgrids across all communities. However, in some cases, there was an absence of knowledge of the basic concepts surrounding electricity, energy bills, energy efficiency, and renewable energy. This made explaining a highly complex concept, such as a microgrid, even more difficult.

One explained that in their discussions with a community member on their understanding of basic energy concepts, "…*nobody knew what the term renewable energy meant, which I think is interesting because we use it all the time. And I didn't know that I would go into a community and that word would mean absolutely nothing to them.*"

Varying levels of energy literacy were also found within the community energy groups, which could lead to friction between members.

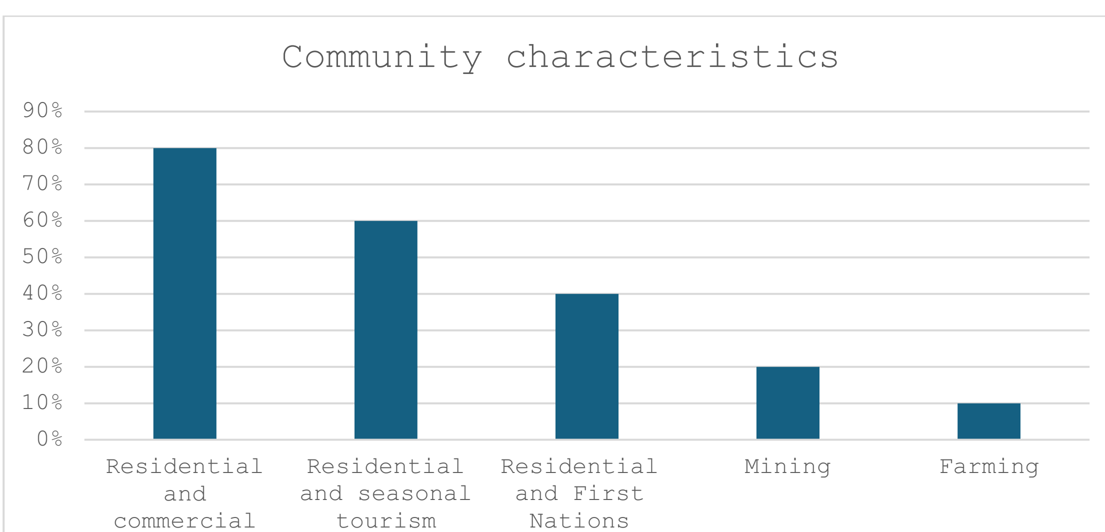

Fig. 3. Community characteristics of those involved in the microgrid feasibility studies.

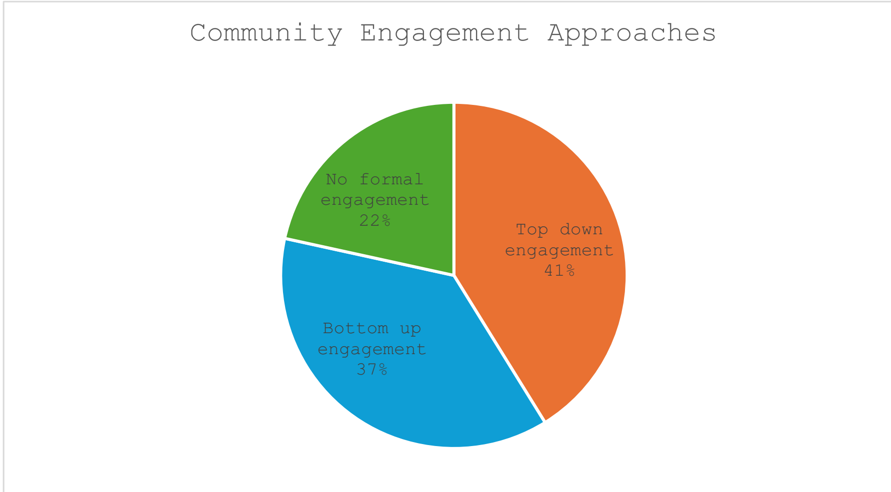

Fig. 5. Community engagement approaches used by the microgrid feasibility studies.

Some interviewees noted that a division would appear in the group where having too explain fundamental concepts repeatedly would generate frustration, with some of the more energy literate community members becoming disengaged. One of the interviewees stated, "*We wanted to engage the general community in the engagement process. However, we couldn't do it because of varying energy literacy and people's interests towards the project*".

4.3.3. *Community member attrition in multi-year projects*

Another challenge highly cited by the interviewees was community member attrition. It was observed that interest among community members and group participants would decline over the course of these complex projects, which would typically run for between two to four years. There was also natural attrition among members of the community groups, for reasons such as changes in living arrangements, relocation to other cities, and contrasting views with the other community members. Factors such as "consultation fatigue" and perceptions of "lack of tangible project outcomes" at the end of the feasibility studies were also given as reasons for the attrition. This posed significant challenges to the community engagement process. Project teams had to expend resources to build the new relationships and provide comprehensive explanations to onboard new community group members to the projects.

4.4. *Overcoming challenges*

The interviewees revealed multiple ways in which they countered these challenges. In what could be considered a 'fail fast approach' (this refers to trying different approaches early to quickly identify what works and what doesn't), adjustments to community engagement strategies and tactics were being made rapidly in response to their own observations and feedback from the community.

Regarding lack of funding, some projects were required to deliver community engagement activities on an in-kind basis.

To deal with the lack of energy literacy, some interviewees began to run short webinars to help increase the knowledge and understanding of community members without requiring a significant time commitment. Others ran engagement programs with schools, with one interviewee commenting on its approach: "*…we did go into schools. And so we gave them a bit of a lesson about clean energy and why diesel is not great. And then we all assembled some solar cars and little wind turbines and stuff like that, which they really enjoyed. And so I think that was probably their biggest exposure to learning about clean energy*".

One project introduced an incentive program to address attrition, stating, "*We included a $20 voucher for the community members participating in the event. We also incentivised community involvement by giving away free t-shirts and other merchandise to enhance community engagement*".

While the thematic analysis of the interview data could draw insights into the community engagement approaches at a general level, applying the CBPR framework would enable a deeper interrogation of the strategies, tools, and approaches used for community engagement over the course of the multiple microgrid feasibility studies. Specifically, it allowed insights to be drawn out for each step of the community engagement process. Each step in the CBPR process is explained before describing the relevant results from the interviews.

4.5. *Building partnerships*

This first step in the CBPR process requires establishing partnerships between researchers and local community members. This involves developing relationships based on trust, mutual respect, and shared decision-making [126,127]. Researchers and community members work together to define the research goals, objectives, and desired outcomes related to the projects.

The data collected from the interviews revealed that 63 % of the interviewees already had existing relationships with the local community, whereas 37 % had to establish contacts with local community leaders. The interviewees highlighted the significance of establishing and developing positive relations with the local community and other stakeholders. An interviewee stated: "*It's absolutely critical that you have good working relationships with all of the other government departments, local council, communities, it's all about relationships when you get out to the country. It is important to have the existing relationship with the communities*".

Interestingly, 57 % of the interviewees established a community energy group or a focus group in their respective communities as part of their project. Such groups were viewed by interviewees as a collective representation of the community, with them becoming the primary point of contact and acting as a bridge between the project team and all the community members. One interviewee stated: "*The community energy group included people from diverse backgrounds such as defence, consultancy, agriculture, and academic backgrounds. This diverse portfolio enhances the collaborative environment in the group, bringing different perspectives together*". Engagement through these groups was found to help the project teams develop trust among stakeholders, which is essential in community energy projects. Another interviewee stated that "*The establishment of a community energy group provides a progressive starting point for the project, and it was the big step in the engagement process. These* *community members essentially become the partners of the project, assisting with the communications and support throughout different phases of the project.*"

4.6. Identifying community expectations

This stage relates to identifying a community's expectations and drivers for any project or initiative [121]. Researchers collaborate with the community members to identify these drivers and ensure they align with the community's energy needs and priorities.

Most interviewees (57 %) used some form of initial engagement to understand their community's expectations at the beginning of their projects, including town hall meetings, workshops, pre-feasibility surveys, community reference groups, and engagement with key local stakeholders.

An interviewee commented: "*We conducted a vision workshop at the beginning of the project, understanding the community's vision for the project and their expectations. Subsequently, we formulated our research plan according to the expectations*".

Table 3 describes the different community engagement tools that were used in the microgrid feasibility studies to understand community expectations. Fig. 6 shows the percentage of projects that used those tools, with interviews and workshops the commonly employed.

Interviewees were also asked what expectations existed in their communities should a microgrid prove feasible and delivered. The bar graph (Fig. 7) below shows how from the thematic analysis of their answers, resilience and reliability were among the most held expectations, followed by decarbonisation and affordability.

A recurring issue raised in several interviews revolved around misconceptions regarding the scope of a feasibility study versus a demonstration or pilot project. This led to some community members expecting the delivery of a microgrid (or a component of it) by the end of the project. An interviewee stated: "*Sometimes, communities are unfamiliar with the project's scope and may hold misconceptions about the team's objectives. Hence, it is crucial to manage their expectations transparently through clear discussions about the project's scope.*"

4.7. Co-designing the study with the community

The co-design stage of the CBPR framework concerns incorporating community input and local knowledge into the project plan and other key elements to gain the highest quality outputs. As discussed previously, some projects adopted a bottom-up approach or two-way communication process, whereas others employed a top-down approach, informing the community about project motives and milestones without actively soliciting their views and ideas.

For bottom-up engagement in which co-design was central, community involvement was invited for input on many aspects, including the options around the microgrid's boundary, project ownership, and islanding characteristics. One interviewee stated "*The community was consulted with the boundary options for the feasibility of microgrids. The community members were presented with the four boundary options and asked to select the most appropriate one for the microgrids. The project team will then conduct the feasibility analysis on these two boundaries*". Another interviewee described their approach: "*The community members were asked about the ownership structure, and their inputs were considered in understanding the appropriate business models for the project.*"

Table 3
Community engagement tools used by the microgrid feasibility studies.

Type	Description
Interviews	One-to-one discussions with community members are conducted through a series of questions that can follow a formal and stricter set of questions (structured) or be a more open-ended and less formalised set of questions (semi-structured).
Focus groups	Brings community members and stakeholders together in a speciffc setting to discuss issues as a small group.
Workshops	Brings community members and stakeholders together in a speciffc setting to work intensively and interactively on issues as a small group.
Stakeholder engagement	Systematic identiffcation and communication with a key stakeholder group (e.g., Local Government, Installers) as a proxy for gaining an understanding of a community and their expectations.

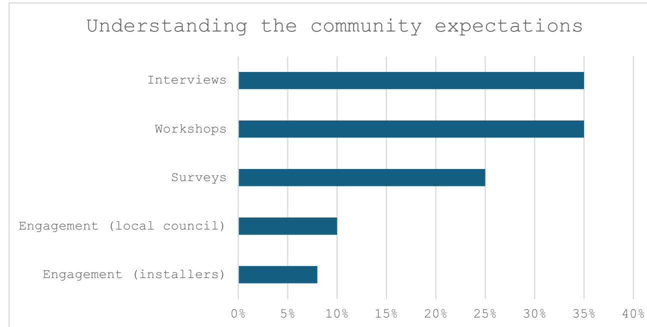

Fig. 6. Engagement tools used in the microgrid feasibility studies for understanding community expectations.

The engagement strategies used by the microgrid feasibility projects for codesigning the research are presented in Fig. 8. Focus groups and town hall events were found to be by far the most widely used strategy for eliciting input from community members for co-design.

The interview data showed that only 42 % of projects involved their communities in the co-creation process, whereas most interviewees didn't include communities in designing the research methodologies. This seems to be a missed opportunity for most projects to engage more deeply with their communities.

4.8. Collecting and analysing data in the feasibility studies

This step of the framework sheds light on the data collection strategies employed. It is considered a crucial aspect of any energy project, for example, aiding in characterising current and future energy loads and generation [124]. In the context of a microgrid feasibility study, data is needed for informed decision-making regarding such aspects as defining the optimal microgrid boundary, size, location, and available technical options. The interviewees mentioned that data collection efforts were extensive, and the data collection techniques varied depending on community dynamics and existing electrical infrastructure. Most projects relied on network data (80 %), followed by some form of energy monitoring device (50 %) and smart meter data (43 %). Slightly <10 % of the projects interviewed couldn't access any data, relying on power bill estimations instead.

Table 4 describes the different data sources that were used by the microgrid feasibility studies and Fig. 9 shows the percentage of those projects that relied on the different sources.

4.9. Analysis and interpretation of the data with the community

This step of the CBPR framework deals with collaboratively analysing and interpreting collected data, which can then enhance discussions with communities to validate the findings. The few interviewees who employed this considered it one of the most important steps in their respective projects. One interviewee stated, "*A major strength of their project was that they had designed the strategies with the community as they work closely with the local community. The significance of face-to-face meetings, community workshops, and lunch and kitchen table discussions lead to ideas that are later incorporated in the project*".

A moderate number of the projects (42 %) shared their findings and results from the data analysis with their communities, using it as a mode of engagement in face-to-face meetings and community workshops. One interviewee said, "*After analysing the data, we realised that a microgrid*

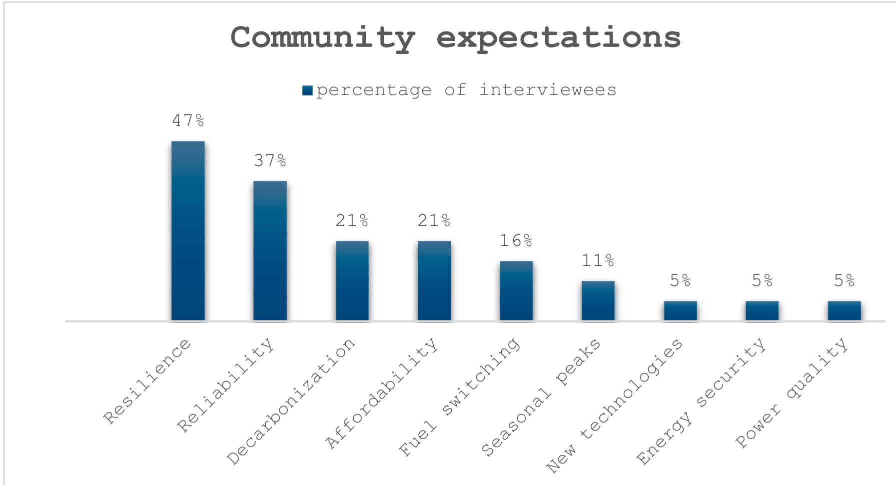

Fig. 7. Expectations of the communities involved in the microgrid feasibility studies.

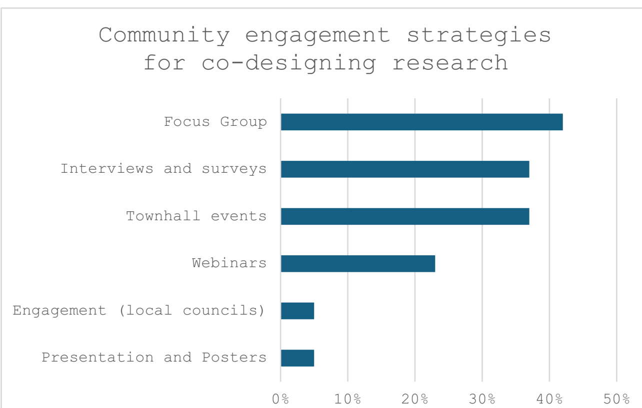

Fig. 8. Community engagement strategies for co-design used in the microgrid feasibility studies.

Table 4
Data sources used by the microgrid feasibility studies and their definitions.

Type	Description
Network data	Acquired directly or indirectly from electricity distribution network service providers, such as that relating to electricity distribution network topography and its capacity.
Smart meter data	Two-way communication metering device that measures how much electricity is consumed at deffned intervals.
Energy monitoring devices	Two-way communication monitoring device that measures how much electricity is consumed and generated at deffned intervals. Can offer more granular data than smart meters.
Interviews	One-to-one discussion with community members through a series of questions that can follow a formal and stricter set of questions (structured) or be a more open ended and less formalised set of questions (semi-structured).
Energy audits	An assessment using forms or digital devices that generate a report following an energy survey of a household or business. It can identify how energy is consumed and generated and potential areas for energy saving, onsite generation, reduced bills, and reduced emissions.
Inverter data	From solar PV inverters installed in households and businesses that record how much solar PV output is being generated and when.
SCADA data	From Supervisory Control and Data Acquisition (SCADA) systems of hardware and software that is used to remotely monitor, gather, and process real-time energy data at a speciffc location.
Energy bills	From documents issued periodically to households and businesses showing the amount of energy consumed, tariffs, and the costs incurred over a given period.

might not be the most feasible option for the community, which created frustration in the group. But this interpretation of the result allowed our team to look for other options to find optimal solutions for the community".

However, the interview data revealed that more than half (58 %) of the interviewees did not engage the community using the data they collected for analysis and interpretation.

4.10. Dissemination of results

This step of the CBPR framework places significance on the sharing of research findings with other communities while engaging in advocacy efforts to positively influence policy and practice. Most (84 %) of the interviewees emphasised the importance of collaboration between researchers and other research institutions to disseminate the research results. One interviewee stated: "*The knowledge sharing between the communities is significant, and resources should be shared as it will reduce the time for the new communities to begin their projects. The findings from the different studies will allow the new projects to learn from the lessons of the community and further enhance productivity*".

Many interviewees spoke of how their different projects developed their approaches to disseminate their findings. Eight different types of dissemination methods were found in these interviews. This included live webinars, microsites with project outputs and the latest news, community information dashboards, video recordings, face-to-face events, and conferences. Community dashboards and energy literacy toolkits were the least common, while webinars and media reports were the most common.

The different methods employed for informing, engaging, and disseminating information (and the target audiences) as part of the various projects are provided in Table 5. Fig. 10 shows the percentage of projects that relied on the different dissemination methods:

4.11. Action planning and continuous reflection

The last stage in the CBPR process places importance on developing an action plan and overall reflection on the process. This includes making recommendations for the future and seeking feedback from the communities.

Since most of the feasibility studies were still underway at the time of the interview, there was a lack of data regarding this final (but critical) step in the CBPR framework.

However, there were some examples of action planning and reflection on what had been learned. One interviewee referred to educational programs on energy efficiency that had been established in the community because of what was learnt from their feasibility study. They also

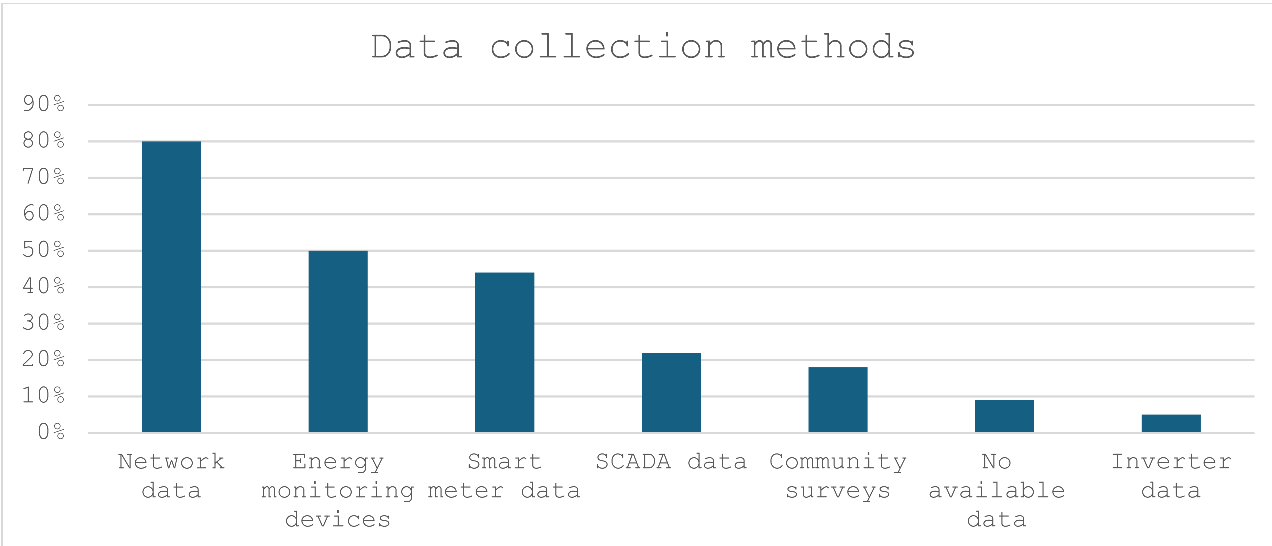

Fig. 9. Data collection methods used in the microgrid feasibility projects.

Table 5
Dissemination methods used in the microgrid feasibility projects and their target audience.

Dissemination method	Deffnition	Target audience
Townhall and community events	Open to the public events, held face-to-face in the community.	Community members and key stakeholders.
Webinars	A web-based seminar hosted online that allows participants to interact in real time. May be open to the public or restricted to the community.	Community members but can also be targeted at speciffc groups (e.g., from general public to other community groups)
Website or microsite	A primary or auxiliary website hosting information that can be accessed at any time.	Community members, other communities and community groups, the general public, the energy industry, practitioners, and researchers.
Community dashboards	A screen installed at strategic locations in a community which allows dynamic and static data on the project to be viewed at any time.	Community members and visitors.
Energy literacy toolkits	A set of resources to be used by individuals or groups for enhancing their energy literacy.	Community members, other communities and community groups.
Press releases and media	Disseminating information through traditional media channels (main and specialist media)	General public, energy industry, and practitioners.
Video	Professionally shot video recordings.	Community members, other communities and community groups, general public, energy industry, practitioners, and researchers.
Conferences and public events	Disseminating information through presenting at conferences and other industry and public events.	Community members, other communities and community groups, general public, energy industry, practitioners, and researchers.

initiated an appliance retrofit program to swap out older, inefficient equipment and replace it with newer, more efficient ones. Other interviewees referred to ongoing initiatives to help their communities apply for new funding to implement pilot projects based on the results from their feasibility study.

The bar graph summarises different community engagement strategies implemented by the interviewees in the microgrid feasibility studies (Fig. 11).

4.12. Summary of the results

Table 6 below summarises the results in the form of a heat map, which demonstrates how the interviewees and their projects engaged with each stage of the CBPR framework. The red colours depict where the interviewees' community engagement strategies touched on that part of the CPBR framework, the white depicts where it was absent. The dark red colour of the heat map depicts the projects which followed a bottom-up community engagement approach, whereas the light red colour reflects the top-down approach. As can be seen from the map, steps 1 (building partnerships) and 4 (data analysis and interpretation) of the CBPR were addressed by all the projects. Other steps, such as steps 2, 6, and 7, were addressed by the most but not all projects. Steps 3 (co-creation) and 5 (data analysis and interpretation) were the most neglected, with only a few interviewees in each case including these steps in their community engagement strategies.

For those projects that used bottom-up engagement strategies (shown in dark red), it was more likely that most (if not all) steps of the CBPR framework would be touched on. Top-down strategies (shown in light red) paid the most attention to steps 1 (building partnerships), 4 (collecting and analysing data), and 6 (dissemination of results).

5. Discussion

5.1. The social acceptance of microgrids

Our analysis uncovered that because of their inherent complexity, microgrid projects required expansive and resource-intensive community engagement strategies. A repeated explanation of the microgrid concept and its implications for the community was needed to enable informed decision-making by the community members. This demanded a wide variety of engagement methods, ranging from face-to-face meetings and townhall events to webinars and conducting outreach to schools.

Before investing in microgrid implementation, conducting feasibility studies is critical to determine the viability and desirability of a community microgrid solution. However, given the design of the funding program, the nascency of renewable microgrids, and the challenging nature of what the feasibilities had to achieve (especially during COVID restrictions that took place over the course of the funding period), the time taken to conduct a thorough engagement process posed a

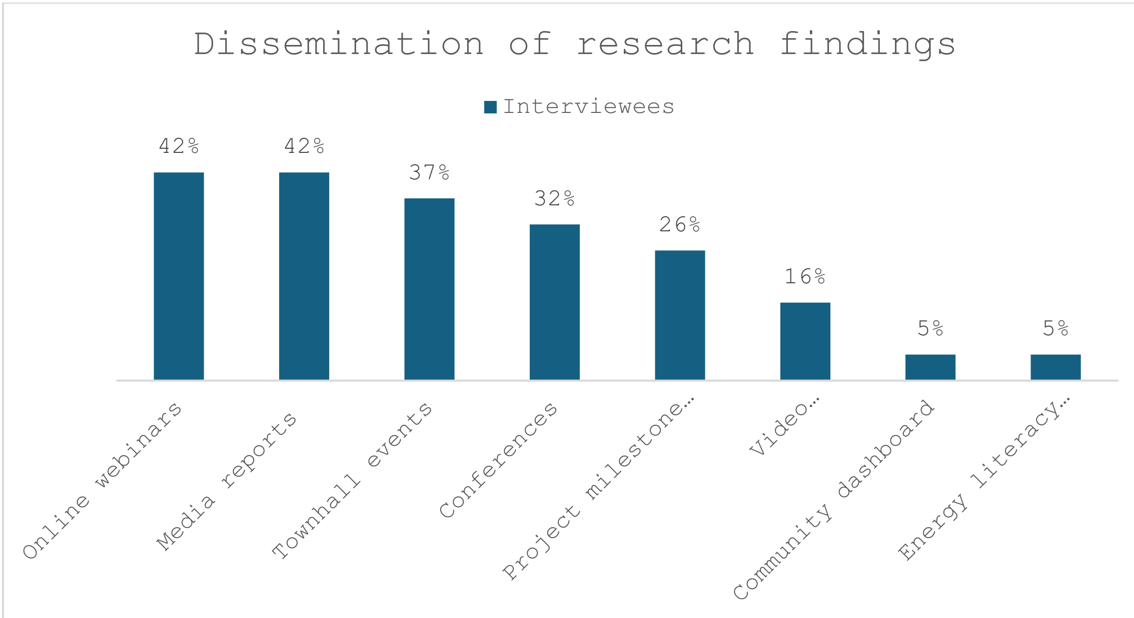

Fig. 10. Dissemination methods used in the microgrid feasibility projects.

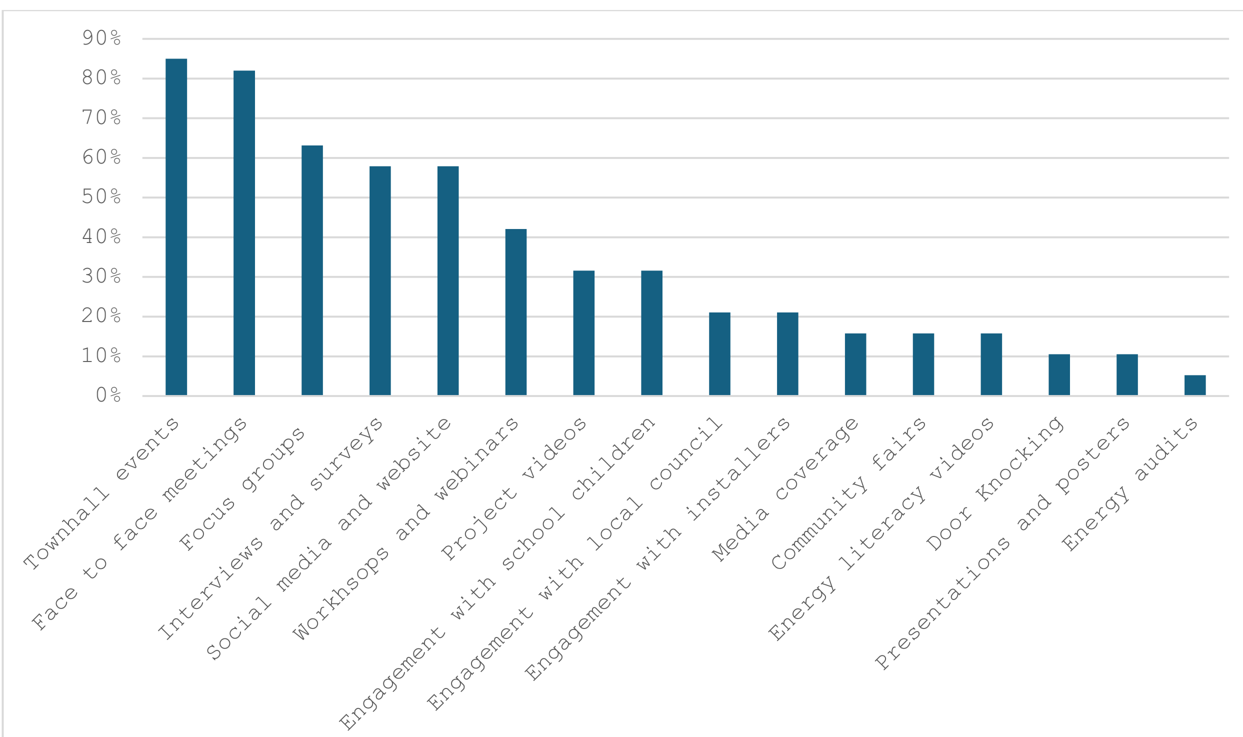

Fig. 11. Summary of community engagement strategies used in the feasibility studies.

challenge. The microgrid projects mostly spanned between two and three-years, with community members finding a degree of consultation fatigue, requiring motivation through introducing incentives and new activities. This emphasises the necessity of continuous community engagement to ensure that the local community feels supported throughout the project lifecycle (feasibility as well as implementation). It was also found from the research that most communities accepted the idea of renewable microgrids. However, their complexity and the shifting nature of communities means that the social acceptance of microgrids cannot be taken for granted, even if approved during the feasibility stages.

5.2. *Diverse approaches towards community engagement*

The results from the application of the CBPR framework revealed significant variations in the community engagement strategies being employed across the microgrid feasibility studies.

The findings suggest that communities with lower energy literacy mostly engaged with the top-down approach, with substantial resources directed towards educating them. These projects emphasised

Table 6
Heat map of the CBPR stages that were undertaken by each interviewee in their community engagement.

CBPR stage/ Interviewees [1]	1. Building partnerships	2. Identifying community expectations	3. Co-creation with community	4. Collecting and analysing data	5. Data analysis and interpretation	6. Dissemination of results	7. Action planning and reflection
1	Dark red	Dark red	Dark red	Dark red	Dark red	Dark red	Dark red
2	Light red	White	White	Light red	White	Light red	White
3	Dark red	Dark red	Dark red	Dark red	Dark red	Dark red	Dark red
4	Dark red	Dark red	Dark red	Dark red	White	Dark red	Dark red
5	Light red	Light red	White	Light red	White	Light red	Light red
6	Light red	White	White	Light red	White	White	White
7	Light red	White	White	Light red	White	Light red	Light red
8	Dark red	Dark red	White	Dark red	White	Dark red	White
9	Light red	White	White	Light red	White	Light red	White
10	Dark red	Dark red	Dark red	Dark red	Dark red	Dark red	Dark red
11	Light red	White	White	Light red	White	White	White
12	Dark red	Dark red	Dark red	Dark red	Dark red	Dark red	Dark red
13	Dark red	Dark red	Dark red	Dark red	Dark red	Dark red	Dark red
14	Light red	White	White	Light red	White	White	White
15	Dark red	Dark red	Dark red	Dark red	Dark red	Dark red	Dark red
16	Dark red	Dark red	Dark red	Dark red	Dark red	Dark red	Dark red
17	Light red	Light red	White	Light red	White	Light red	White
18	Light red	Light red	White	Light red	White	Light red	Light red
19	Light red	White	White	Light red	White	White	White

Legend: Dark red: Community engagement took place at this step (part of an overall strategy that was bottom-up). Light red: Community engagement took place at this step (part of an overall strategy that was top-down). White: No community engagement took place at this step.

community engagement strategies like workshops, webinars, face-to-face meetings, educational videos, and school-based programs to introduce communities to the concepts and benefits of renewable microgrids. Some project teams, however, took an alternate approach, basing feasibility studies on the existing data and merely sharing their findings with communities without deeper engagement.

In contrast, communities with higher energy literacy were found to be more likely to be engaged by those projects using the bottom-up approach. For gathering information and collaborative decision making, they employed face-to-face meetings, focus groups, webinars, workshops, interviews, surveys, and townhall events. In these projects, fewer resources were allocated towards educating the communities as these groups were already familiar with the basic concepts of energy efficiency and renewable energy, making it less of a challenge to try and understand the inherently more complex idea of a microgrid.

It is important to note that energy literacy is not the sole determinant that dictates the community engagement strategies in these projects. The results from the study reveal that factors such as project funding, milestone timelines, community characteristics, project scope, interpersonal resources, and community interests in the project were also responsible for how community engagement strategies were designed. Since RRCRF funding guidelines did not dictate any specific community engagement protocol, project teams could design their engagement strategies based on the above-mentioned factors.

Identifying and gauging these factors early on should help projects and practitioners tailor more appropriate strategies. Each community is different and presents unique characteristics and challenges, so a project's engagement strategy doesn't always yield the desired results. A 'fail fast' approach (iterating quickly if the feedback shows certain approaches are proving ineffective) was found to be utilised by many of the projects, allowing for a rapid pivoting to alternative tools and techniques until ones are found that are more effective.

5.3. Identifying community expectations

Our research indicates considerable variation in community expectations regarding the purpose and deliverables of microgrid projects. Understanding and identifying these is paramount for successfully planning these highly complex renewable energy projects. Each community possesses unique needs and desires that must be recognized and addressed to ensure acceptance and support. For instance, some communities may prioritize resilience against power outages, while others want to be able to share locally generated renewable energy within their community. Tailoring microgrid solutions to align with these specific expectations enables projects to meet the community's actual needs more effectively.

A key strategy for understanding community expectations involves conducting comprehensive surveys, interviews, vision workshops, and prefeasibility studies at the project's inception. These methods provide valuable insights into the community's priorities and concerns. The CBPR framework also emphasises the importance of dedicating time and resources to understanding community expectations. However, our findings reveal that only some of the microgrid projects invested sufficiently in this critical aspect. Implementing effective strategies to understand and integrate community expectations from the earliest of stages for microgrid feasibility studies is critical as it fundamentally shapes a project's trajectory and outcomes.

Research Limitations:

While this research offers valuable insights into the community engagement strategies used in real-world microgrid feasibility studies, there are certain limitations to consider. Although the research encompassed nineteen (of thirty-six) projects covering ninety (of one-hundred-and-ten) communities, there is still a limitation in that data could not be collected from all the projects. Furthermore, the research focussed on interviews only with project stakeholders who made themselves available. It did not include the perspective of the local communities and the energy groups involved in these projects. The study was also undertaken before most of the projects were completed, so it is unknown how many feasibility studies were successful and resulted in microgrid implementation. Further longitudinal research is required in this regard as it may take years to determine which feasibility studies resulted in the implementation of a microgrid or other related solution.

6. Conclusion

Microgrids are well researched in the literature, but much of the focus to date has been on the technical and economic considerations. Their inherent complexity presents a greater challenge to delivering effective community engagement compared with other types of renewable energy project. As such, community members' attitudes towards them must be understood appropriately if these types of complex local energy solutions are to be willingly adopted.

This research explored the community engagement strategies, related intricacies, and experiences of those involved in twenty-five government funded projects that undertook microgrid feasibilities for ninety remote and rural communities across Australia. Programs like this was found to play an important role in catalysing community action and forming new community energy groups. However, the number of microgrids that will result from the funding may not be known for many years.

A thematic analysis revealed a perception among interviewees of inadequate funding on multiple fronts for communities engaging with microgrid feasibility studies. It also found varying degrees of energy literacy that could challenge and slow progress of the projects while also causing friction within community groups. Attrition and fatigue for those community members engaging throughout these complex multi-year projects was also a common theme. In the face of such complexity, many project teams embraced the approach of rapid iteration, and as a result, several promising solutions to address these issues emerged.

Applying a CPBR framework helped expose the steps in the community engagement process that are most commonly being overlooked for all the projects interviewed. Specifically, these were during the 'co-creation with the community' and 'data analysis and interpretation' stages. These are both highly collaborative steps, found by the few interviewees who undertook them to be highly valuable in sensemaking while giving communities more agency over any proposed local energy solution.

CPBR can prove to be helpful in guiding community engagement strategies for complex microgrid projects characterised by a high degree of involvement and co-design, as well as for evaluating community engagement strategies. The findings also reveal that each community and microgrid feasibility varied considerably so no 'one-size-fits-all' community engagement approach is possible without room for adaptation. The combination of thematic analysis and CBPR framework has helped reveal broad themes while pinpointing issues at the various stages of the community engagement process.

Microgrid projects are a highly complex undertaking and those involved in delivering them need to plan for expansive and resource-intensive engagement with the community to be effective. With the social aspects of energy transitions (more generally) and microgrids (more specifically) often neglected, these findings on the community engagement approaches used in a range of microgrid projects can help advance collaborative efforts to ensure a resilient and reliable electricity supply for rural and remote communities. The research findings will be of use for community engagement practitioners, policymakers, and service providers involved in planning microgrids and developing related policies and programs for their adoption.

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CRediT authorship contribution statement

Farzan Tahir: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Scott Dwyer:** Writing - review & editing, Formal analysis, Supervision, Conceptualization. **Scott Kelly:** Writing – review & editing, Supervision, Formal analysis.

Declaration of competing interest

The authors declare that they have no competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

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